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NOTES ON THE SOILS OF COASTAL QUEENSLAND AND PORTIONS OF THE HINTERLAND WITH SPECIAL REFERENCE TO THE TROPICAL LATITUDES †

By L. J. H. TEAKLE*

In the winter of 1947, officers of the C.S.I.R. (now C.S.I.R.O.) and Queensland State Department of Agriculture and Stock, together with lecturers from the Universities of Melbourne, Sydney and Queensland, undertook a trip to North Queensland to search for and investigate plants which may exhibit therapeutic properties. Arrangements were made for the soil factor to be examined as far as possible as a collateral investigation by the writer.

The observations on the soils were necessarily very general over much of the traverse. However, in order to systematise the information gathered, an endeavour was made to classify into groups the main profiles observed. Sampling of the soils was confined to the tropical latitudes where some 200 samples from 40 sites were collected to represent the major groups of soils recognised. Morphological and environmental features were studied in the field and the samples have been examined in the laboratories of the C.S.I.R.O., Division of Soils, Waite Institute, Adelaide. The laboratory work was undertaken primarily to provide information for the Conference on tropical soils held at Rothamsted, England, in June, 1948.

In view of the urgent need for information regarding the soils of Australia, particularly in the tropical areas, it is considered that the field observations made and the results of the laboratory examinations, incomplete though the work may be, should be recorded and discussed for the use of colleagues, particularly those in Australia. Some of the ideas may provoke thought and criticism.

GEOGRAPHY

The area examined extends from Brisbane (latitude $27\frac{1}{2}$°S) to Mossman (latitude $16\frac{1}{2}$°S). Over half of the area traversed lies within the tropics. The topography is very varied. Topographical features include flat, low-lying coastal plains, undulating to hilly country of the coastal ranges, undulating plains and tablelands in the hinterland areas and steep mountain ranges. Elevations along the traverse range from a little above sea-level to approximately 3,000 feet.

CLIMATE

The traverse includes a wide range of rainfall. The country between Emerald and Charters Towers, representing the inland portion of the traverse, receives on the average only 25 inches per annum. In the neighbourhood of Tully, on the north coast, the average annual rainfall approximates 180 inches. The bulk of the sites where detailed examinations were made would be in the rainfall range of

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† The field work was carried out as part of Project 91. "Investigation of the characteristics of the soils of the Soil Regions of Queensland" which is financed by the Commonwealth Research Fund.

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TABLE I

Meteorological data for representative Queensland centres

(Data from " Results of Rainfall Observations in Queensland," published by the Bureau of Meteorology, 1940, and C.S.I.R. Pamphlet No. 42, 1933).

Note.—The " normal " rainfall is the centre of a fairly broad modal group of rainfall values and does not coincide with the average. J. F. McConnell, " Discussion of Rainfall " Bur. of Meteor. Rainfall Observations made in Queensland Districts 314, 32 P. 33. 1940.

CENTRE	RAINFALL			TEMPERATURE			RELATIVE HUMIDITY	
	Average annual inches	Summer Normal (October-March) inches	Winter Normal (April-September) inches	Mean Maximum °F.	Mean Minimum °F.	Mean °F	9 a.m. %	3 p.m. %
Brisbane	44.9	25	13	78.0	59.8	68.9	67	55
Rockhampton	39.3	24	9	83.2	62.9	73.1	68	49
Emerald	24.5	16	6½	85.6*	58.2*	71.9*	61*	—
Capella	22.1	15	5½	—	—	—	—	—
Clermont	26.7	16	5½	85.1*	57.7*	71.4*	62*	—
Charters Towers	24.6	18	5½	86.2*	62.0*	74.1*	62*	—
Townsville	45.7	35	7	82.3	68.7	75.5	67	64
Cardwell	82.7	65	16	83.1*	64.8*	74.0*	77*	—
Tully	178.1	110	53	—	—	—	—	—
Innisfail	143.5	92	50	82.2*	65.5*	73.8*	81*	—
Cairns	88.6	62	23	84.6	68.3	76.4	73	65
Atherton	52.8	40	10	78.6*	57.2*	67.9*	74*	—
Mareeba	35.2	30	4	—	—	—	—	—

* Data from C.S.I.R. (Aust.), Pamphlet 42, **1933.**

40 to 80 inches per annum. On the average, more than two-thirds of the rainfall is registered in the summer months. Quite a considerable portion falls in heavy downpours which cause floods and lead to soil erosion on cleared areas. Rapid and heavy run-off reduces the leaching efficiency of rainfall on many types of country and accentuates the effects of long, dry spells on the vegetation.

Little of the country would be liable to long periods of excessive temperatures. The S.E. Trade Winds, together with the summer rainfall, moderate the temperatures but lead to high humidities. The mean annual temperature ranges from under 70°F at Brisbane and on the Atherton Tableland to slightly over 76°F at Cairns. The difference between mean annual maximum and minimum temperatures is generally less than 20°F in the coastal areas but rises to as much as 27°F in the inland portions of the traverse.

The area generally escapes the excessive desiccation experienced over much of Australia. The mean annual saturation deficit of water vapour ranges from just under 0.20 inches to slightly over 0.25 inches of mercury while the mean annual relative humidity approximates 70% on the coast and 60 % in the inland parts of the traverse. (9 a.m. readings.)

Table I summarises important climatic data for representative centres in the traverse.

In many instances it is found difficult to interpret the complete soil pattern in terms of the present climatic and topographical features. In fact, certain characteristics of some of the important soil groups examined are considered to be the result of conditions vastly different from the present day. The possibility of polygenesis and the time factor must be kept in mind in classifying and correlating the soils.

GEOLOGY

The geology of the traverse is very complex and will not be discussed in any detail. With minor exceptions the area forms part of the huge Tasman geosyncline of the Silurian-Permian period, uplift of which has led to the formation of the coastal ranges of Queensland.

Sedimentary rocks from Tertiary to Palaeozoic in age cover a considerable area. Granite is exposed in many localities including Ingham, Kirrama Range, Mareeba and part of the Atherton Tableland, while basalt flows range from small areas to quite large expanses such as occur at Childers, Emerald, Innisfail and on the Atherton Tableland. The underlying rock formation profoundly affects the nature of the soil profile by influencing the depth of weathering, permeability, soil texture, character of the clay, content of calcium, magnesium, iron, etc. and, indirectly the vegetation. It profoundly affects the quality of the soil for agricultural, pastoral and forestry purposes.

VEGETATION

Four main and five minor groups of vegetation formations are observed.

1. *Eucalyptus woodland.*

These formations are commonly called open forest. They include a variety of *Eucalyptus* spp.: *Angophora* spp., *Tristania* spp., *Casuarina* spp., *Acacia* spp., *Grevillea* spp., *Callitris* sp., etc. and many species of shrubs and a number of grasses. The grasses include species of *Themeda, Aristida, Bothriochloa, Dichanthium, Heteropogon, Chloris,* and *Triodia.* Grass trees (*Xanthorrhoea* sp.) and Cycads occur on the poorer soils.

The species dominating in the various associations of this group vary with the rainfall, geological and soil features.

2. *Rain Forest*

The rain forest is popularly referred to as "scrub"—sometimes as "vine scrub." This is unfortunate as the term "scrub" is applied also to mulga and brigalow country, where the trees may also be closely spaced.

There is a great wealth of plant species in the rain forest including trees of many families, epiphytes such as orchids, ferns, tree ferns, mosses, lichens and vines. Occasional eucalypts, limited to one or two particular species, may be observed. Grasses and ground herbage are uncommon.

Rain forest is an important feature of the country where the rainfall exceeds about 50 inches per annum. This form of vegetation is usually associated with the deep weathering of the underlying rocks. if not with a deep soil. Where the rainfall is moderate, it develops most usually in patches on deeply dissected range country, or where there is a favorable geological formation, for example, basalt. In high rainfall areas, however, it is a general feature irrespective of geological substratum except where poor drainage or other factors may constitute an unsatisfactory environment.

As compared with contiguous open eucalyptus forest or cleared land, it would seem that the rain forest effects considerable modification of the soil moisture regime and of the microclimate, particularly the moisture content of the atmosphere and the temperature of both soil and air. It is expected that there would be a considerable reduction in the amplitude of the important climatic factors within the rain forest.

A feature of the rain forest is a leaf litter usually 2-3 inches deep. A heavy leaf-fall coupled with rapid decomposition of the organic matter results in rapid circulation of the constituents absorbed from the soil by the vegetation. This circulation will be interrupted when the rain forest is destroyed.

In the virgin state the rain forest has little attraction for the pastoralist.

3. *Acacia scrub.*

In the drier parts of the traverse, scrubs, in which the *Acacia* spp. are locally dominant, constitute an important vegetation cover. The scrub is often dense, but is usually open enough for at least a light grass cover to develop. The dominant species in the different scrub associations are brigalow, (*Acacia harpophylla*), lancewood (*A. shirleyi*), and gidgea (*A. cambagei*). Belah (*Casuarina lepidophloia*) and yellow wood (*Terminalia oblongata*) frequently occur with brigalow.

4. *Grassland.*

Commonly where the rainfall is not more than 25 inches to 30 inches per annum but sometimes where it is as high as 40 inches, patches of open grassland or savannah are observed. These are referred to as "Downs". Most important are the Mitchell grass (*Astrebla* spp.) associations which, in the region traversed, are confined to "black" clay soils. This is the most valuable grazing country of the hinterland. Furthermore, it offers prospect for the production of grain sorghum in some districts. In fact, the Queensland British Food Corporation has selected an area of this class of country near Capella as a grain sorghum project and planted 30,000 acres in 1949.

A low value type of grassland or savannah is an association of spinifex (*Triodia pungens*) with a sprinkling of stunted *Eucalyptus melanophloia, E. erythrophloia, E. setosa* and *E. papuana.*

Minor groups of vegetation associations not included in the above groups are:

1. (a) Teatree (*Melaleuca cunninghamii*), grass tree (*Xanthorrhoea*), *Banksia, Casuarina,* etc. on poorly drained areas with a clay subsoil.

   (b) (*Melaleuca viridiflora*) on similar areas.

2. Wet heath areas in "wallum" country. Important families in this association are shrubby *Myrtaceae* (including *Leptospermum spp.*) *Epacridaceae, Cyperaceae,* and *Restionaceae.*

3. "Dry monsoon forest" or "dry rain forest"—stunted members of the rain forest species in areas of moderate rainfall.

4. Heath and scattered trees, (e.g. *Eucalyptus drepanophylla*) on poor gravelly country.

5. Coolabah. (*Eucalyptus coolabah*) on areas liable to flooding in the Mitchell grass Downs.

SOILS

Under such a wide range of environmental conditions, a great variety of soils may be expected and, indeed, is encountered. Owing to the high rainfall, and, in some cases, to other factors, most of the soils are of the leached class and acidic in reaction. Exceptions are certain types characteristic of portions of the Emerald—Charters Towers section of the traverse which are either calcareous in the subsoil or sufficiently alkaline to point to a high metallic cation status in the exchangeable fraction. In this section the rainfall approximates only 25 inches per annum. The grassland and acacia scrub soils also are alkaline.

An important group of the soils of the leached class exhibit ferruginous gravel and other features characteristic of the material known as laterite. These soils are observed on many parts of the traverse and appear to reflect the effects of conditions vastly different from the present climate. It is easy to accept the theory that these are soils which commenced formation a very long time ago, probably in the Pliocene period, and retain many characters inherited from a period or periods when the climate was vastly different from the present time.

The chief soils observed are classified into 12 groups.

SUMMARY OF SOIL GROUPS

Group A. Greyish to grey brown acidic soils with clay accumulation in the subsoil—podzolic soils.

Group B. Grey soils of poorly drained areas where the topography is usually flat. This group includes "wallum" country.

Group C. Brown to red brown soils with clay accumulation in the subsoil; apparently acidic in reaction.

Group D. Red and grey or yellow brown soils with ironstone and bauxitic gravel—soils with laterite.

Group E. Red brown to brownish red soils which are acidic in reaction, without substantial profile differentiation, and with no obvious zone of sesquioxide accumulation—red loams.

Group F. "Black" clay soils.

Group G. Greyish to brown heavy soils with melonholes or gilgais.

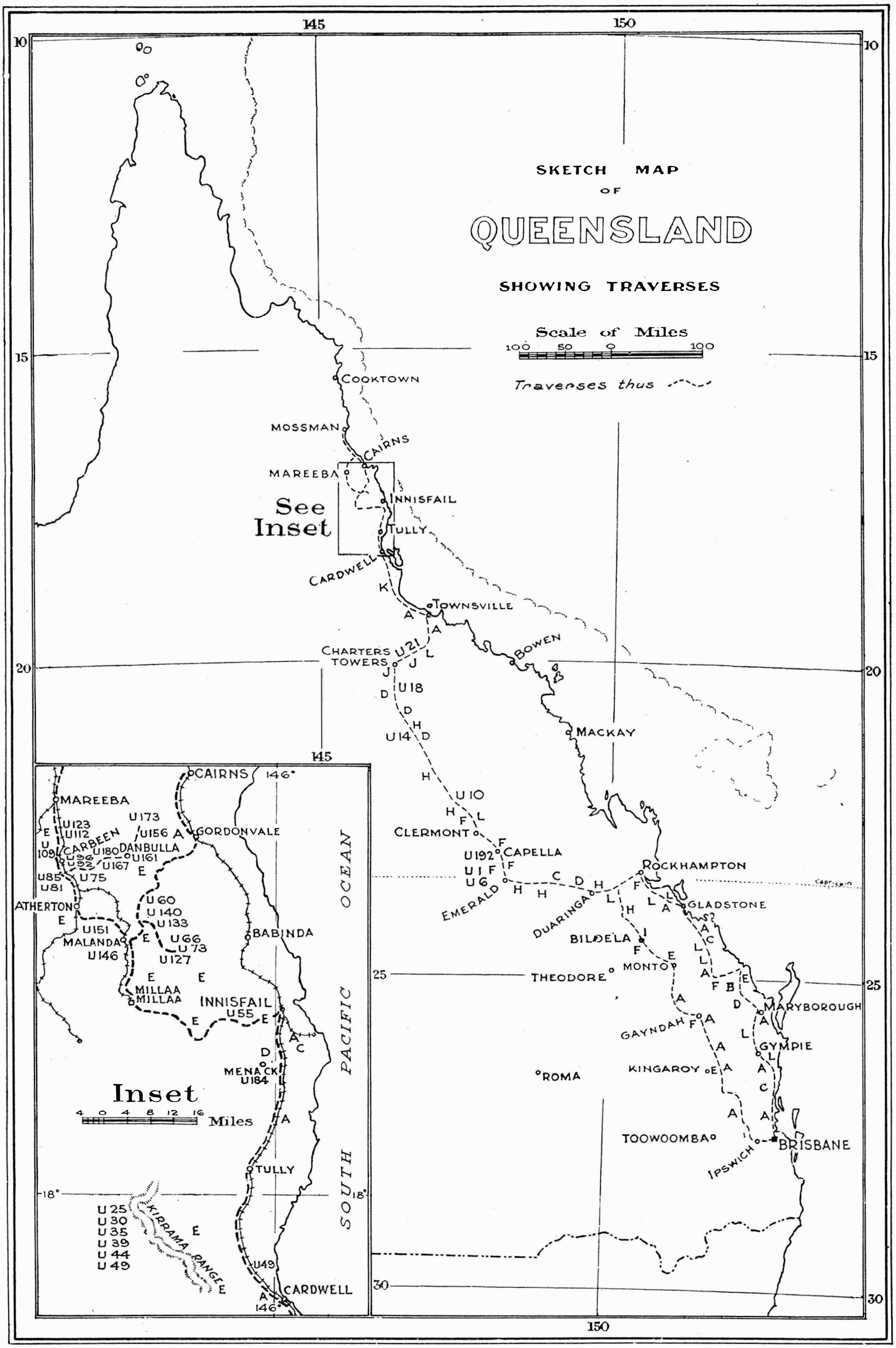

FIG. 1.—Sketch Map of Queensland showing the route traversed. The letters, e.g. A, indicate the dominant group observed. The numerals, e.g. U192 indicate the approximate location of the sites sampled.

Group H. Brown to red brown soils, generally calcareous in the subsoil and probably neutral to alkaline in reaction.

Group I. Greyish to grey brown soils with neutral or alkaline subsoil, generally calcareous.

Group J. Brown to red brown soils with profile differentiation but no obvious calcium carbonate; formed on granite—red brown earths.

Group K. Greyish to brown soils of alluvial flats and deltas.

Group L. Shallow and stony soils, skeletal soils and range country.

In popular parlance, groups F, G, and I are commonly classed as "black" soils.

DESCRIPTION OF THE SOIL GROUPS

GROUP A.

Greyish to grey brown soils with clay accumulation in the subsoil and acidic in reaction throughout—These soils show evidence of leaching and segregation of the clay and sesquioxide in the subsoil. They are generally classified as *podzolic.* In fact, in spite of the differences from the well-known podzols of the coniferous forests of the Northern Hemisphere, in Australia these soils are sometimes regarded as podzols.

The most important features of these soils are :

A Horizon or surface soil.

Little or no leaf litter; grey to grey brown in colour and with humus accumulation in the upper part of the layer; sometimes somewhat lighter in colour or bleached in the lower part to form a distinct A_2 horizon. The texture is usually a sandy loam or loam but may be clay in some instances.

B Horizon or subsoil.

Well differentiated from the surface with clay accumulation and in some instances obvious segregation of sesquioxides. A number of colour types is observed including yellow, brown, red brown and red. Mottling is common, particularly of red and yellow shades. Rusty mottling occurs where drainage is restricted. It is thought that the main colour variations in the subsoil are related in large measure to the nature of the parent material, but some colours such as the rusty and red mottlings are the result of conditions of impeded drainage.

At least two subgroups are observed.

1. Grey surface soils with definite bleaching in the subsurface layers.

2. Brownish grey to greyish brown surface soils with little or no bleaching in the subsurface.

Soils of subgroup 1 are the more common in the southern parts of the traverse and form most readily on the more acidic rock types; those of subgroup 2 appear to be dominant on the traverse from about 100 miles north of Brisbane. Formation is favoured by parent material such as calcareous sandstones and granodiorites. As the basicity of the parent material increases the soils become darker and develop features which approach those of the "black" clay types (Group F) under lower rainfall or brown types (Group C) in the wetter areas.

On the flat areas, such as alluvial terraces, clay accumulation in the subsoil is marked and results in impeded drainage. Such soils would be recognised as a third subgroup and classified as "planosols" in the present American system. Such a differentiation is not attempted in this study as soils with apparently similar profiles are observed on moderate slopes in undulating country.

Only one of the sites examined can be considered as a possible representative of this group. Even this is doubtful in the absence of more data. This is the open forest soil U180—183 from Danbulla in the Atherton Tableland region. (For analytical data see Table 1 of the Appendix, page 33.) This soil is slightly acidic (pH 6.18) and contains only 0.038 per cent. P_2O_5 in the surface soil. Organic matter is low. There is definite differentiation in the profile with the subsoil clay content being more than double that of the surface. But the exchangeable metal cations are exceedingly low (1.25 milli-equivalents per 100 grams of soil or 3.5 per 100 grams of clay in the subsoil 14-20 inches deep) and with respect to this characteristic the soil closely resembles the soils of Group E, the so-called red loams. Magnesium is the dominant exchangeable metal cation in the subsoil.

Vallance (1938) (1939) and Vallance and Wood (1940) have described in detail soils of the Beerburrum, Glasshouse and Nambour districts some 50 to 60 miles north of Brisbane which exhibit similar chemical features to U180-183. These soils are of the "red earth residual" group of Bryan (1939) and it is doubtful if they should be included with group A. The obvious affinity is with Group D—soils with laterite.

Vallance has suggested that these soils are pseudo-podzols. The writer agrees with this viewpoint if not the name. There are no really characteristic podzol features. A new soil group name is required.

The soils of group A are characteristic of the undulating to hilly coastal country and the hinterland of Queensland where the rainfall exceeds 30 inches per annum. In the virgin state, this country generally carries a eucalyptus woodland with an undergrowth of grass and some shrubs. In the wetter areas, the shrub undergrowth may become dominant under some conditions.

These soils are relatively undeveloped for agriculture except for sugar cane in some coastal districts. Generally the country is devoted to stock-raising, with or without ringbarking. By encouraging the growth of grass, ringbarking is said to double the carrying capacity. Summer maize and winter cereals are grown in restricted areas, especially on those soils in the valleys where the fertility level and moisture status are most favourable.

It is recognised that these soils are of low fertility in comparison with black clay soils, red soils of the rain forests, and the alluvial soils. First, many types lack the capacity to store large quantities of moisture, a very important characteristic owing to the dry periods, which, unfortunately, are only too common in parts of Queensland. Second, it is probable that they need generous fertiliser treatment for satisfactory growth of many agricultural crops. Favoured as these soils are with a generous, if somewhat uncertain, rainfall, their large extent renders them worthy of consideration for much greater agricultural development where the slopes are satisfactory. It seems that they should play an important part in the extension and stabilisation of agriculture in Queensland. Obviously, there is need for research to determine fertiliser requirements and suitable crop rotations, involving renovating crops and pastures as well as main crops.

GROUP B.

Grey soils of poorly drained areas, usually flat country often subject to seasonal inundation. This group includes "wallum" country.—A wide variety of profiles and soil associations are included in this group but few examinations were made on account of the minor agricultural importance.

1. *Wallum country.*

The term "wallum country" is applied to low fertility coastal areas which are characterised by bottle brush (*Banksia* spp.) and associated plants. This class of country includes a number of different soil associations and soil types some of which have been described by Young (1946). Prominent among these are grey sandy flats which carry a "wet heath" vegetation association in some instances and, in others, *Melaleuca viridiflora.* These very sandy soils of the poorly drained flats appear to resemble the Plantagenet series of Western Australia described by Hosking and Burvill (1938) and the Thorpe and Tomahawk series of northern Tasmania described by Hubble (1946). Such soils may be classified as ground-water podzols. They are characterised by a dark surface layer due to enrichment with organic matter which rests on a bleached sandy A_2 horizon. At some depth is a blackish or brownish humus accumulation which constitutes a B_1 horizon. This often cements the sand to form a hard pan. In some cases the hard pan may be more or less ferruginous.

Other types of wallum country carry more or less stunted eucalypts, Banksia and grass tree (*Xanthorrhoea* sp.), etc. These soils, though poor in important nutritional factors, are superior to the very sandy types in that there is a clayey subsoil below the sandy surface. Such soils are extensive between Maryborough and Bundaberg. In some districts they alternate with sandy types.

2. *Teatree flat country.*

A soil included in this group was examined 10 miles north of Cardwell. (See U49-54 in Table 1 of the Appendix, page 33.) This area consists of a flat, low-lying coastal plain abutting a steep, granitic range on the west. It carries a vegetation association of which prominent species are *Melaleuca cunninghamii,* grass tree (*Xanthorrhoea* sp.), *Casuarina* sp., and wattles (*Acacia* sp.). The profile exhibits a dark grey to brownish grey sand to sandy loam on the surface and a greyish yellow subsoil characterised by rusty mottling. Furthermore, in the subsoil, at a depth of more than two feet, there is a bleached grey clay with yellowish and reddish mottlings which appears to be a glei horizon. The dispersible clay observed in some pools in this vicinity suggest solonisation, a deduction supported by the chemical analyses reported in Table 1 of the Appendix (page 33).

The chemical analyses reported show that the content of exchangeable metal cations is exceedingly low, amounting to only 0.78 milli-equivalents per 100 gms. of soil in the surface and 2.5 milli-equivalents in the subsoil. Furthermore, the exchangeable metal cations are chiefly magnesium (83%) in the second foot, while calcium is very low indeed, amounting to only 3% of the total in the surface and 2% in the second foot. Sodium is not high either in the surface or subsoil. The soil may be described as a magnesium soloth.

It is evident that this soil is exceedingly low in natural fertility. Acidity is not excessive (pH 5.5 in the surface) but the surface contains only 0.011% P_2O_5 and the low content of exchangeable calcium in relation to the magnesium may induce physiological disturbances in ordinary field crops.

GROUP C.

Brown to red brown soils with clay accumulation in the subsoil and apparently acidic in reaction—These soils, together with those of Group A, occur as part of the pattern where the rainfall exceeds 30 inches per annum. The profile consists typically of a brown to reddish brown surface on a yellow brown, red brown to brownish red subsoil with clay enrichment. They appear to develop where the parent material is of more basic constitution such as greenstones, calcic sediments and basalt.

These soils appear to be good agricultural land where of good depth and the topography is favourable. In the virgin state they generally carry eucalyptus woodland and grass. Frequently they have been developed for fodder crops, pineapples, bananas, beans, etc.

No sites were examined or sampled to represent this group.

GROUP D.

Red and yellow brown soils with ironstone or bauxitic gravel—The ironstone or bauxitic gravel is considered to be representative of the material laterite. These soils are permeable to water. The clay is non-plastic and very low in capacity to absorb exchangeable metal cations; the profile differentiation is poorly developed but is more evident in the yellow types than in the red. The red coloured types exhibit a very well developed and stable crumb structure particularly in the surface.

The complete profile of a lateritic soil is presumed to exhibit the following features :

(i) a surface of reddish, brownish, or greyish soil;

(ii) a layer of accumulation of sesquioxide, chiefly iron and aluminium oxides. The sesquioxides may be pisolitic, or concentrated in a vesicular mass. It may be fragmental or cemented to form boulders and, occasionally, hard pan. This is laterite. It is noteworthy that laterite is never massive but is vesicular and vermiform in structure; the vesicles are filled with clay suggesting deposition of the sesquioxides according to an intricate pattern in a clay matrix. This layer ranges in thickness from several feet to over 100 feet and varies in colour from yellow brown to dark red. The ironstone fragments are frequently stained black. When freshly exposed this material is soft and cheesy to cut but it hardens in contact with the air. There is no doubt that it is similar to the laterite described by Buchanan in 1807;

(iii) a whitish clay underlying the layer characterised by the accumulation of sesquioxides or laterite. The upper part of the whitish clay is heavily mottled with patches of iron oxides (mottled zones) and becomes less mottled with depth to form the "pallid" zone;

(iv) decomposing rock of various types including basalt, sandstones, etc.

Whitehouse (1940) reports "billy," a siliceous infiltration or accumulation, in layers (iii) or (iv) in some profiles, but none is observed at the sites examined on this investigation.

Group D is sub-divided into two major sub-groups on the basis of colour and structure differences.

Subgroup D1—*red types.*

In this investigation, these soils were observed more generally on the more basic rocks or derivatives rich in ferro-magnesian minerals. Features of the soil profile are brownish red and red colours and sesquioxidic aggregations in the lower layers. These aggregates are frequently stained "black" by manganese dioxide. Below the zone of sesquioxide accumulations, there is generally clay with whitish and reddish colours prominent. Physically, the soils are open and permeable and there is usually considerable depth of unconsolidated material or regolith.

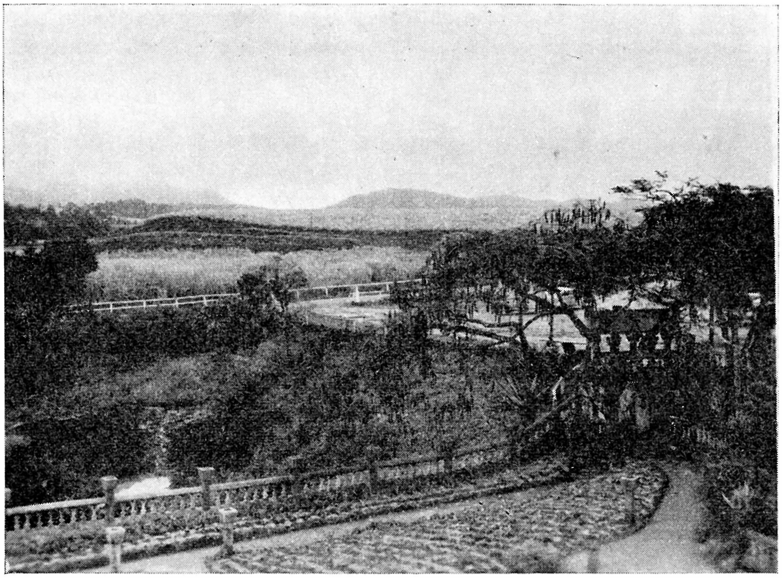

PHOTO 7—View of undulating red, lateritic country at Mena Creek 12 miles south of Innisfail. This country originally carried rain forest and is now under sugar cane. The rock at Mena Creek is basalt.

Subgroup D2—*yellow types*

Yellow brown subsoil colours are characteristic of the soils of this group which appear to be confined to the more acidic rocks or derivatives. These soils show more evidence of differentiation in the profiles suggesting greater migration of clay than in the red group. The profiles observed on this expedition exhibit a greyish or yellowish grey sandy surface with a yellow brown sandy subsoil showing clay enrichment and laterite in pisolitic form or as boulders.

In all cases the weathering of minerals has been very active in the soils exhibiting laterite. Much of the calcium, magnesium, potassium, etc. — elements important in plant and animal nutrition—has been lost and reserves of primary rock minerals, further weathering of which would release these elements, are thought to be low or non-existent.

In general, the red types, subgroup D1, are superior to the yellow for agricultural purposes. Where of good physical condition and of good depth, these soils, with generous fertiliser treatment and suitable farming methods, have proved suitable for horticulture, maize, peanuts, sugar cane, pasture and other types of farming.

Being more sandy and gravelly the yellow types usually lack moisture holding capacity and other factors important in nutrition and are seldom used for agriculture in Queensland.

Analysis of the soils of group D are given in Table 1 of the Appendix (pages 33 and 34).

The only site sampled deemed to represent the red subgroup (D1) is U 184-191. This site is south of Innisfail and the profile was sampled in a deep tramway cutting near Mena Creek, where the parent material is basalt. Apart from the appearance of laterite structure in the lower part of the cutting, there is little evidence of profile differentiation. The laterite structure is not well developed but is characteristic in many features including vesicular segregations of sesquioxide and some development of whitish mottling at the bottom of the profile. It is thought to be a very immature laterite.

Disregarding the surface soil which has most likely been disturbed and, perhaps, modified during the construction of the cutting, the analyses of the samples reported in Table 1 of the Appendix (page 33) show the soil to be strongly acidic pH 5 or less). The clay content exceeds 60 per cent. although the soil is not obviously of a clayey texture and the content of the exchangeable metal cations is only 0.5 milli-equivalents per 100 gms. of soil. It is of interest that each of the four principal cations is in about the same proportion.

Three sites represent the yellow soils—subgroup D2. These are U14—17 and U18—20 which were sampled south of Charters Towers and U 112—118 which was sampled about nine miles south of Mareeba on the Atherton Tableland. Each of these soils appears to be forming on a sandstone and under a relatively low rainfall which would be about 25 inches per annum south of Charters Towers and about 40 inches south of Mareeba. These soils contain varying amounts of ferruginous concretions and, south of Charters Towers, surface boulders of vesicular, ferruginous material, undoubtedly fragmental laterite, may be observed at many points.

The clay content shows quite marked increase with depth but the differentiation, while more marked than in the red types, is not so obvious as would be expected in the usual podzolic soils. The reaction of these soils is slightly acidic or neutral. Phosphorus and total nitrogen are both very low (less than 0.1% P_2O_5 and N respectively).

In the samples analysed the metal cations are relatively low in one profile and low in the other. Magnesium appears to be particularly high in both of the subsoils examined, amounting to over 60% of the total exchangeable metal cations.

GROUP E.

Red brown to brownish red soils, acidic in reaction, without substantial profile differentiation and with no zone of sesquioxide accumulation.—In Australia, soils of GROUP E are generally classed as red loams and are observed from Tasmania to North Queensland particularly where basalt is the parent rock. In Queensland, these soils have been observed under rainfall ranging from about 30 inches per annum, as at Mareeba, Gayndah, Kingaroy, etc., to 150 inches per annum as at Innisfail. While certain of their profile properties correlate with the amount of rainfall, the general features of these soils over this range are similar. Profile differentiation is poorly developed as the migration and segregation of clay and other constituents under the influence of leaching rain water has been of minor proportions; the soils are highly coloured, permeable and well structured particularly in areas of more generous rainfall; all examples examined are acidic in reaction, those under the higher rainfall being more acidic. The reaction approximates pH 5 where the rainfall is high while those under the lower rainfall conditions the soils are but slightly acidic, the pH generally exceeding 6.

An interesting structural feature of some of the profiles when examined (during the dry period of the year) was the crunchy feeling of the subsoil when being bored. In these instances the subsoil material appears somewhat lumpy and some of the fragments break with a biscuity snap. The significance of this property is not understood.

Although there are many examples under high rainfall conditions of many feet of red soil-like material, evidence of decomposing rock is often encountered at a depth of three or four feet. In the higher rainfall areas the underlying rock is frequently soft and weathered sometimes to a reddish colour to considerable depths. On portions of the Atherton Tableland where the rainfall is low, the rock is usually hard immediately below the soil, suggesting less advanced weathering.

It is considered that the true soil or solum of these types is not abnormally deep as is often claimed.

These red soils appear to form most readily on basalt and are observed over a very wide range of rainfall and latitudes. However, where the rainfall is adequate and the temperature apparently favourable these soils are observed on granite, as in the Kirrama Range near Cardwell and at Danbulla on the Atherton Tableland, and on schists, etc. All red soils are not basaltic as is often popularly believed.

On the basis of colour these soils are subdivided into sub-groups E_1 and E_2. Those with prominent red and brown shades are classified as subgroup E_1; those with yellow shades, E_2. Subgroup E_1, the typical "red loam", is most widespread but subgroup E_2 was observed on certain types of schists on the Atherton Tableland. In this soil, the surface is a dark yellow brown and the subsoil yellow brown to orange in colour. An example is site U127—132 sampled near Topaz in the southern part of the Atherton Tableland. On the granites at Kirrama Range certain of the soils exhibited similar features and may be included in subgroup E_2.

The degree of redness appears to be related to the nature of the parent rock. Thus basalt and less acidic granites commonly develop the redder types of soils while the more acidic granites are associated with browner types. However, on some parts of the Atherton Tableland the soils derived from basalt are distinctly brown rather than red in colour. Similar observations of northern New South Wales have been made on the basaltic tableland in the Lismore district. No explanation of this colour variation is known.

Two sub-divisions of the red subgroup, E_1, the boundary between which is not particularly distinct, may be noted on the Atherton Tableland:

(1) the high rainfall types where the rainfall exceeeds 50 inches and rain forest is the characteristic cover;

(2) the lower rainfall types represented by the eucalyptus woodland area on basalt country between Atherton and Mareeba.

(1) *High rainfall types.* (E_1 (h))

These soils usually develop under rain forest but are observed under eucalyptus forest in a number of cases, for instance, in the Kirrama Range. The profile is generally deep—at least four feet—and the underlying rock is frequently weathered to considerable depths. Where the weathered material is red the soils are popularly described as very deep. The surface soil is characteristically very crumbly and dark red brown in colour—often blackish. Under rain forest in the Kirrama Range, these soils on granite contain a little over 3 per cent organic carbon in the surface layer while on the Atherton Tableland, on basalt, the organic carbon content of the surface soil approximates 6 to 8 per cent. on most sites. It is significant that, on the Atherton Tableland, rain forest soils of this type which have been under grass for many years appear to contain about half this quantity of organic carbon. One sample from a maize field contained only about 2 per cent. organic carbon.

Table II shows the organic carbon, total nitrogen contents and carbon nitrogen ratio of surface soils of subgroup E_1.

1. from the high rainfall rain forest areas which are now
   (a) under rain forest, or
   (b) under pasture or cultivation after clearing the rain forest.
2. from sites under lower rainfall conditions in eucalyptus woodland.

TABLE II

The organic matter of Group E—subgroup E1 (Red Loams).
Organic carbon by Walkley and Black method.

Serial No.	District	Approx. rainfall	Depth ins.	Condition	Parent rock	Org. C %	Total N %	C/N ratio
(1) High rainfall and rain-forest country (subgroup E1(h))								
U25	Kirrama Range	over 80	0—3	rain forest	granite	3.48	0.284	12.3
U 30	,,	,,	0—3	,,	granite or diorite	3.59	0.322	11.2
U 44	,,	,,	0—4	,,	granite	3.26	0.296	11.0
U156	Danbulla ..	75	0—6	,,	,,	3.33	0.343	9.7
U173	,, ..	75	0—8	,,	,,	4.19	0.294	14.3
U 55	Palmerston ..	150	0—6	cleared roadside under lantana	basalt	3.30	0.306	10.8
U 60	Yungaburra ..	55	0—6	cleared and under wild tobacco and regrowth	,,	6.59	0.559	11.8
U 66	Butcher Ck. ..	100	0—3	rain forest	,,	8.41	0.790	10.6
U133	,,	100	0—6	paspalum	,,	4.80	0.469	10.2
U140	,,	80	0—6	,,	,,	3.60	0.390	9.2
U146	Malanda ..	70	0—6	rain forest	,,	6.42	0.602	10.7
U151	Atherton (Sth)	52	0—7	maize	,,	2.21	0.235	9.4
U 81	Atherton (Nth)	50	0—6	rain forest	,,	5.97	0.613	9.7
(2) Lower rainfall with Eucalyptus woodland between Atherton and Mareeba. (subgroup E1(l)).								
U 85	South Mapee ..	<50	0—6	Euc. woodland	basalt	3.51	0.257	13.7
U 92	Mapee ..	<50	0—6	,, ,,	,,	2.73	0.202	13.5
U 96	South Carbeen	40	0—3	,, ,,	,,	2.10	0.155	13.5
U104	Carbeen ..	40	0—2	,, ,,	,,	2.65	0.194	13.6
U109	North Carbeen	40	0—3	,, ,,	,,	1.59	0.113	14.1
U123	North Carbeen	40	0—6	,, ,,	,,	1.62	0.114	14.2

The carbon : nitrogen ratio suggests that the organic matter of the surface layers sampled is reasonably well decomposed or humified.

The exchangeable metal cation content of these soils is characteristically low particularly when it is remembered that the clay content is exceedingly high in most instances. As would be expected in view of the high organic matter content, the surface is much richer in these cations than the subsoil. In the subsoil there is usually less than 1 milli-equivalent of total metal cations per 100 gms. of soil.

Table III gives the information regarding the exchangeable metal cation status of surface and subsoils of the soils of Group E (red loams) and other soils for which information is available.

TABLE III

Exchangeable cation capacity of soils examined, degree of unsaturation as measured by the proportion of exchangeable hydrogen and the cation exchange capacity per 100 grams of clay. See Table 1 of Appendix for further details,

(Exchangeable hydrogen determined by the metanitrophenol method to pH 8.4).

Nearest Centre	Approx. annual rainfall inches	Parent material	Soil Group	Surface Soil: Serial No.	Surface Soil: pH	Surface Soil: milli. eq. per 100 gm. soil: cation exch. capac.	Surface Soil: milli. eq. per 100 gm. soil: Exch. met. cations	Surface Soil: milli. eq. per 100 gm. soil: Exch. H	Surface Soil: Exch. H as % cat. exchange capacity	Surface Soil: Exch. cations m. eq. per 100 gm. clay*: Metal	Surface Soil: Exch. cations m. eq. per 100 gm. clay*: Total (capac)	Subsoil: Serial No.	Subsoil: pH	Subsoil: Milli. eq. per 100 gm. soil: cation exch. capac.	Subsoil: Milli. eq. per 100 gm. soil: Exch. met. cations	Subsoil: Milli. eq. per 100 gm. soil: Exch. H	Subsoil: Exch. H as % cat. exchange capacity	Subsoil: Exch. cations m. eq. per 100 gm. clay: Metal	Subsoil: Exch. cations m. eq. per 100 gm. clay: Total (capac)
Danbulla.. .	75	granite	A	U180	6.18	—	4.2	—	—	28	—	U182	5.69	—	1.25	—	—	3.5	—
Cardwell .	80	,,	B	U 49	5.53	—	0.78	—	—	5.2	—	U 51	5.83	—	2.56	—	—	8.0	—
Innisfail .. .	150	basalt	D1	U184	5.60	17.4	2.39	15.0	86	4.2	31	U186	5.00	12.4	0.53	11.9	96	0.8	19
Between Emerald and Charters Towers	20 to 25	sand-stone	D2	U 14	5.85	—	1.55	—	—	11	—	U 16	6.56	—	4.51	—	—	13	—
Mareeba	40	? sand-	D2	U112	6.61	—	9.06	—	—	30	—	U114	6.91	—	7.66	—	—	16	—
		stone										U117	7.19	—	7.60	—	—	15	—
		granite	E1(h)	U 25	6.47	—	18.78	—	—	188	—	U 27	5.12	—	0.55	—	—	2.0	—
Kirrama Range	80	basic granite	,,	U 30	5.17	23.1	6.9	16.2	70	38	128	U 32	5.49	8.1	0.8	7.3	90	2.6	26
		granite	,,	U 39	6.11	—	8.13	—	—	45	—	—	—	—	—	—	—	—	—
		granite	,,	U 44	5.22	—	4.60	—	—	27	—	U 46	5.16	—	0.78	—	—	2	—
Innisfail	over 100	basalt	,,	U 55	5.30	27.3	4.18	23.1	85	9.3	61	U 57	5.18	13.8	0.72	13.1	95	1.4	28
Yungaburra ..	55	basalt	,,	U 60	5.08	—	3.57	—	—	8.7	—	U 62	4.85	—	0.48	—	—	0.9	—
	100	basalt	,,	U 66	4.97	—	7.83	—	—	29	—	U 69	5.14	—	0.73	—	—	1.3	—
Butcher Creek	100	basalt	,,	U133	5.62	—	4.65	—	—	23	—	U136	5.44	—	0.40	—	—	0.9	—
	80	basalt	,,	U140	5.93	27.1	6.63	20.5	76	16	66	U142	5.76	13.0	2.5	10.5	81	3.6	19
Malanda	70	basalt	,,	U146	5.64	—	6.75	—	—	22	—	U148	5.43	—	0.94	—	—	1.4	—
	55	basalt	,,	U151	6.34	—	10.4	—	—	23	—	U153	5.32	—	1.76	—	—	2.4	—
Atherton	50	basalt	,,	U 75	7.10	45.4	36.8	8.6	19	97	120	U 78	7.07	10.6	5.4	5.2	49	7.6	15
	50	basalt	,,	U 81	6.62	—	40.8	—	—	136	—	U 83	7.04	—	10.3	—	—	22	—
	75	granite	,,	U156	5.05	25.9	3.8	22.1	85	14.4	100	U158	5.09	11.4	0.55	10.9	96	1.7	36
Danbulla..	75	granite	,,	U167	5.36	—	1.69	—	—	7.4	—	U169	5.76	—	1.65	—	—	4.1	—
	75	granite	,,	U173	4.86	—	1.46	—	—	5.0	—	U175	5.02	—	0.26	—	—	0.93	—
Mapee ..	< 50	basalt	E1(l)	U 85	6.53	—	19.2	—	—	69	—	U 87	6.25	—	9.9	—	—	17	—
	< 50	basalt	,,	U 92	6.09	—	12.0	—	—	32	—	U 94	6.41	—	—	—	—	—	—
	40	basalt	,,	U 96	6.21	—	12.9	—	—	34	—	U 98	6.29	—	5.5	—	—	8	—
Carbeen ..	40	basalt	,,	U109	6.86	24.6	15.3	9.3	38	41	67	U111	6.90	12.2	5.8	6.4	52	12	25
	40	basalt	,,	U104	6.53	—	20.2	—	—	63	—	U106	6.70	—	11.3	—	—	19	—
Carbeen .. .	40	basalt ?	E2	U100	6.80	—	23.3	—	—	80	—	U102	6.48	—	10.0	—	—	15.4	—
Kirrama Range	80	granite	,,	U 35	5.72	—	4.15	—	—	42	—	U 37	5.41	—	0.61	—	—	1.9	—
Topaz	150	schist	,,	U127	4.32	—	1.01	—	—	3.9	—	U130	4.79	—	0.33	—	—	1.3	—
Emerald	25	basalt	F	U 1	7.91	—	67.2	—	—	129	—	—	—	—	—	—	—	—	—
Emerald- Ch. Towers ..	25	?	H	U 10	7.06	—	14.5	—	—	40	—	—	—	—	—	—	—	—	—
Charters Towers	25	granite	J	U 21	6.89	—	8.8	—	—	52	—	U 23	7.16	—	14.3	—	—	31	—

* Includes exch. cations held by organic matter (see text).

The very low status of these soils with respect to exchangeable metal cations as well as the high content of magnesium in relation to calcium in some of the surface samples and in many of the subsoil samples can well be important factors in the nutrition of crops.

Of particular importance in the fertility of these soils is, undoubtedly, the cation exchange status of the surface soils. The details presented in Table 1 of the Appendix show that calcium is characteristically, but by no means invariably, the dominant exchangeable metal cation. Furthermore, the cation exchange capacity of the surface soil in most instances is from two to four times that of the subsoil. The ratio between the content of exchangeable metal cations of the surface and subsoil samples is even greater. If it be accepted that the clay minerals are similar in both surface and subsoil these differences can reasonably be attributed to the differences in organic matter content. Thus, the obviously aberrant figures given in Table III for exchangeable cations per 100 grams of clay in the surface soil serve to emphasise the paramount importance of organic matter in these soils. They point to the need to conserve the organic matter to maintain fertility in such soils where the mineral colloids are so impoverished in exchangeable metal cations.

(2) *The lower rainfall types.* (E_1 (1))

The lower rainfall types studied in this investigation occur under a eucalyptus woodland between Atherton and Mareeba where the average annual rainfall would range from about 35 inches to about 50 inches. The soils are formed on basalt apparently similar to that of the main Atherton Tableland area. Like the high rainfall soils, these show a highly coloured profile with little differentiation. They differ from the high rainfall types in showing less development of structure in the top 6 or 12 inches and appear more compact when being dug. Analyses show them to be lower in clay content and much lower in organic matter. The soils are also less acid, the reaction range being generally pH 6 to 7. The content of exchangeable metal cations is low but very much higher than in most of the higher rainfall rain-forest types except that sampled just north of Atherton. See site U81—84, Table III.

In the samples examined, exchangeable magnesium appears to be of normal proportions. Furthermore, these soils are generally shallow and rest on relatively hard rock. Boulders of basalt are common. The ground cover is quite different from the rain forest as about 50% of the surface is bare between the grass tussocks under a very open eucalyptus woodland. This condition of the surface will profoundly affect the temperature regime of the soil. The higher soil temperatures which undoubtedly develop would be expected to reduce the accumulation of organic matter as compared with the rain forest soils. This is the case in the samples analysed (Table II).

Speaking generally of the soils representative of Group E it may be pointed out that the phosphorus content is closely correlated with the parent material. Soils on basalt are rich (0.22 to 0.46% P_2O_5) and those on granite low (0.04 to 0.08% P_2O_5) in phosphorus.

GROUP F.

"Black" clay soils.—Black clay loam to clay soils are observed on the traverse from Brisbane to a point well north of Clermont under rainfall ranging from 20 to 45 inches per annum. These were once thought to belong to the chernosem great soil group but both Dr. C. E. Kellogg and Professor G. W. Robinson are emphatic that this is not the case owing to their heaviness, structural characteristics and restricted internal drainage.

PHOTO 1—Rain forest of the Kirrama Range, near Cardwell, N.Q. The large tree on the left is kauri pine (*Agathis palmerstoni*).

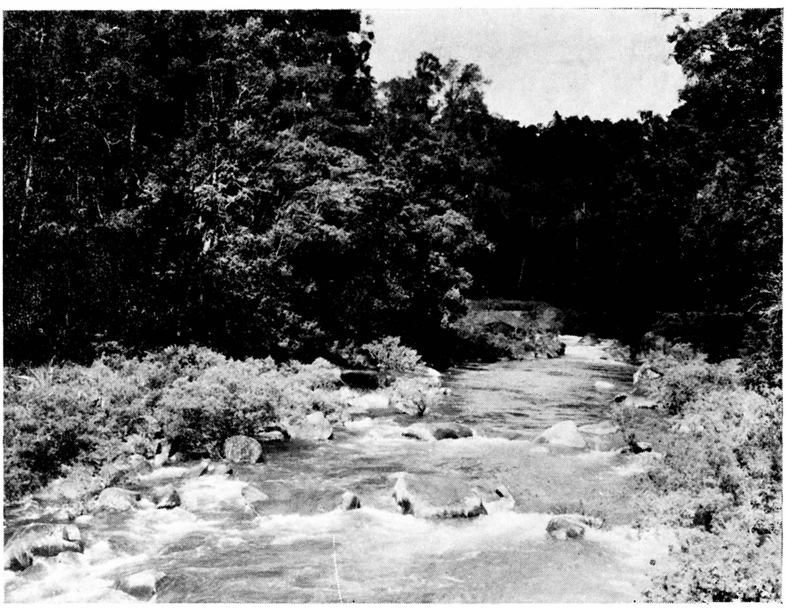

PHOTO 2—The Beatrice River in dense rain forest on the Palmerston Highway, about 36 miles from Innisfail. The river is a tributary of the North Johnstone River.

PHOTO 3—A patch of open eucalyptus forest in rain forest in the Kirrama Range, near Cardwell, N.Q. The chief trees are *Eucalyptus grandis* and *E. tereticornis*. Kangaroo grass (*Themeda australis*) is the chief grass in the open forest at this site.

PHOTO 4—The leaf litter above a mealy " red loam " soil (U25) under rain forest in the Kirrama Range, near Cardwell, N.Q.

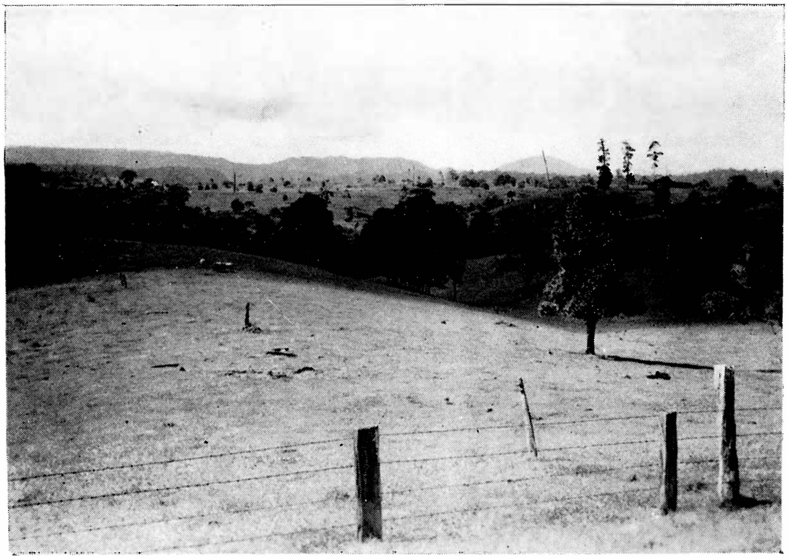

PHOTO 5—Well managed kikuyu grass (*Pennisetum clandestinum*) on undulating to hilly tableland country near Millaa Millaa, N.Q. This country was under rain forest until cleared during the 1912-1914 period.

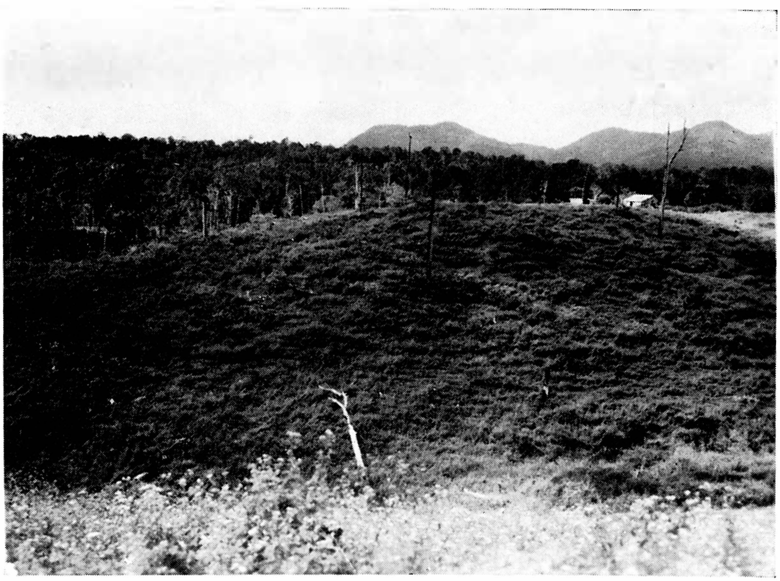

PHOTO 6—Dairy country on the Palmerston Highway about 17 miles from Innisfail. This country was under rain forest until cleared in 1935. Lantana (*Lantana camara*) and *Ageratum conyzoides* have invaded the pastures and are very serious weeds. It will take some years of careful management to control the weeds and produce a pasture as in Photo 5.

The characteristic features are:

(a) Dark grey, dark grey brown, dark reddish brown to black colour.

(b) Granular surface when dry (self-mulching).

(c) Great capacity to shrink on drying and swell on wetting. Extensive cracks develop on drying.

(d) Montmorillonite clay.

(e) Macro-structure more or less unstable in water.

(f) Low organic matter content—generally less than 4 per cent.

These black clay soils may be subdivided into a number of groups some of which at least are considered to be of great soil group status. Most important are:

(a) Shallow black soils with little development of brownish B horizon which merges into fragmental, weathering rock at depths ranging from 1 to 3 feet. These soils are observed on basalt, on limestones and travertine, on calcareous sandstones, on greywacke rich in ferro-magnesians and on serpentine but are most common on basalt. In the lower rainfall areas the reaction is neutral to alkaline but is usually acidic in the higher rainfall areas. Lime is usually observed at depth—in very shallow types it may be found in the joints of the underlying rocks.

(b) Soils of considerable depth forming both directly on the above-mentioned rocks as well as on colluvial or alluvial accumulations derived at least in part from these rocks. These are the only soils examined chemically on this traverse. The general features of the profile as observed north of Emerald are:

(i) A few inches of dark grey brown to dark grey fine, granular clay. Fine pellets of calcium carbonate commonly occur. A red brown tinge may be observed where limestone (travertine usually) constitutes the parent material.

(ii) From 8 to 12 inches of dark grey brown clay of cloddy structure, and usually containing fine pellets of calcium carbonate.

(iii) About two feet of massive dark grey brown clay, usually with fine pellets of calcium carbonate. When dry the soil cracks into blocks which may be broken with pressure into fragments with a shiny fracture and rounded edges.

(iv) Below three to four feet the dark grey brown clay becomes progressively browner in colour and diffuse as well as nodular calcium carbonate is usually observed. With the increase in the amount of calcium carbonate the soil becomes less massive and less tough to bore and the colour may change to a brown or to a mottled horizon with such colours as brown, grey brown, and dark grey brown being prominent.

It may be noted that similar soils occur on the Darling Downs, at Theodore and on the Ord River plains in Western Australia.

This soil is very hard to bore and, on drying, cracks extensively to a depth of about two feet; some cracks are much deeper. The plastic clay, with a swelling capacity of over 25% in many cases, makes a very poor foundation for roads and buildings.

There are three main vegetation associations on this group of soils.

(i) Grassland—undulating to flattish plain country carrying Mitchell grass (*Astrebla* spp.), blue grasses (*Dichanthium* spp. and *Bothriochloa* spp.), other grasses and associated herbs.

(ii) Scrub—a fairly thick stand of brigalow (*Acacia harpophylla*), yellow wood (*Terminalia oblongata*) and *Casuarina lepidophloia* covers some areas. The soil is less uniform than that under grassland, being commonly pock marked with small brown or red brown patches a few feet, or even a few yards across. It may exhibit gilgais or melonholes. The brown patches are rich in limestone pellets on the surface and resemble in some respects the subsoil normally found under the "black" surface at a depth of two to four feet. These brown patches are thought to represent an ititial stage in gilgai formation and to be due to convectional movements in the soil.

(iii) Woodland—flattish areas, liable to flooding, carry coolabah (*Eucalyptus coolabah*) and grass.

The main areas of "black" clay soils observed in this study are in the Emerald district. Here they are formed extensively on basalt. Also, "black" clay soils are common in valleys where, apparently, the alluvium is of a suitable composition. Such occurrences are usually of limited extent but there are important examples of huge flood plains, such as the Condamine River plains in the Western Darling Downs, where these soils extend for many miles.

Three sites were examined to represent this group. Two were taken in brigalow scrub 23 miles north of Emerald and the other about 5 miles farther north in the grassland near Chirnside.

One of the sites in the brigalow scrub (U1) was a dark grey brown clay; the other (U6), about 10 yards away, was in a brown patch. The profile in the grassland near Chirnside (U192) closely resembled that of the dark grey brown clay in the brigalow scrub (U1).

Analysis of the samples from these profiles are unfortunately incomplete (See Table III, page 17 and Table 1 of the Appendix, page 43). The data available show that the profiles are quite alkaline throughout and the clay content is high. Organic carbon is unexpectedly low being less than 1% in the brigalow soils and only 1.4% in the grassland type. Nitrogen is only about 0.1%. Surprisingly for a basaltic soil, phosphate is exceedingly low, ranging from 0.032 to 0.042% P_2O_5—figures to be expected in a granitic soil. It will be recalled that red soils on basalt generally contained ten times as much phosphate.

Calcium carbonate is observed throughout the black soil profile. In the surface, it occurs in small amounts as pellets but increases with depth. It does not reach large proportions in the samples analysed but may be concentrated in certain parts of the subsoil in some sites. The surface of the brown soil patch is characterised by large pellets of calcium carbonate as well as fine, earthy, calcareous material equal to over 5% of the soil—similar to the amount of calcium carbonate in the subsoil of the adjacent "black" soil. This development is considered to be due to soil "convection" which results in the subsoil coming to the surface in patches. Gilgais or crabholes form under some conditions.

GROUP G.

Greyish to brown heavy soils with melonholes or gilgais.—None of these soils was examined or sampled. The micro-relief is thought to be due to the soil "convection" mentioned above. These soils are most common under brigalow scrub.

GROUP H.

Brown to red brown soils, generally calcareous in the subsoil and neutral to alkaline in reaction.—These brown to red brown soils of the drier areas generally carry scrub (brigalow and gidgea, etc.) or eucalyptus woodland. Judged from the single profile sampled, (U10—12 of Table 1 of the Appendix, page 43) the chief features are a brown surface soil with a soft, lumpy or crumb structure, resting on a brown to dark brown calcareous clay. Obvious lime accumulation commences at a depth of about 18 inches. Texture and colour differentiation in the profile is not marked. This is a typical brown pedocal and on the traverse was generally observed in the 20—30 inches rainfall belt.

There is generally little development of this class of country except in the provision of fences and water supplies for grazing purposes. Reports indicate that the carrying capacity may be greatly increased—at least doubled—by ring-barking. This appears to constitute no hazard provided the country is carefully managed to avoid soil deterioration and erosion.

GROUP I.

Greyish to grey brown soils with neutral or alkaline subsoil generally calcareous.—None of these soils was examined or sampled. They occur in the same zone as soils of Group H and may be closely related. *Note*: Since this paper went to press a profile of this type was examined at Biloela and observed to show solonetzic features.

GROUP J.

Brown to red brown soils, formed on granite, which show profile differentiation, an alkaline subsoil but no obvious calcium carbonate.—These soils are observed in the Charters Towers district and were classified as *red brown earths* by Prescott in 1933 (unpublished report). There are two main subgroups—(a) A brown sandy surface with a yellow brown clayey subsoil. (b) A red brown sandy loam surface with a brownish red clay subsoil. The analyses of samples from a site representing the second subgroup (U21—24) are reported in Appendix Table 1, page 43. As may be expected this soil is low in organic matter (about 1%) and in phosphate (0.037% P_2O_5).

This class of country carries a eucalyptus woodland and is used for cattle grazing.

GROUP K.

Greyish to brown soils of alluvial flats and deltas.—This group includes a variety of soils. In the undulating and hilly country there are numerous valleys, large and small, with accumulations of alluvium. In many cases the soils are immature—little evidence of profile development is observed—and the texture ranges from sandy to clayey. In some areas profile differentiation has occurred and the soils are of the Group A type. Differentiation has progressed to the extent of developing a tight clay subsoil in many instances; these are usually indicated by box (*Eucalyptus populifolia*). Drainage is poor. In some cases black, deltaic soils are observed, for example, north east of Bundaberg and southwest of Rockhampton. No samples were taken.

GROUP L.

Shallow and stony soils, skeletal soils and range country.—The soils of much of the range country are shallow and stony, but very variable. Within a few feet the profile may change from a foot of sandy loam on weathering rock to a similar surface with a clay subsoil which may exhibit a variety of colours including grey and yellow.

This country is used for grazing and timber purposes.

DISCUSSION.

These observations on certain of the soils of Queensland may be discussed from a number of angles. The ideas presented are based on limited observations and data but it is hoped that they will promote interest in soils and add to an understanding of the soils of Queensland. Many of the ideas have been developed in the course of talks with many colleagues.

1. *Soils associated with laterite—GROUP D.*

The so-called laterite soils of Australia have presented an interesting problem for many years. It was once thought that they were an efflorescence due to the rise of sesquioxides by capillarity, Simpson (1912). Clarification of the position was greatly advanced by Prescott (1931) who represented the soils as fossil—the product of a past age—and now being truncated and dissected. Whitehouse (1940) and Teakle (1938) have pointed to the progress of soil formation on the layers exposed by truncation and dissection and recently Stephens (1946) has given details of recognised soil series associated with the various exposed portions of laterite profiles in southern Australia.

Prescott has referred to certain occurrences of laterite as "residual podzols" and is supported in his concept by Stephens. There seems little justification for the term "residual podzol" as two assumptions are necessary—

(1) That the soils are the residuals from a previous period.

(2) That these soils were once podzols.

There may be, in fact there is, strong evidence in favour of these soils being residuals; that they have persisted for a very long time, perhaps since Pliocene times. Their characters will reflect in some degree the varying pedogenic conditions of bygone ages, but there is little to support the theory that they were once podzols. These soils exhibit the definite features enumerated above. Morphologically, they have little in common with true podzols except for acidity and the accumulation of sesquioxides in the B horizon which is unlikely to be due to podzolisation at all.

The source of the sesquioxides has been discussed by many workers. The Mohr hypothesis for the formation of laterite envisages an initial stage involving the loss from the profile of potassium, sodium, calcium and magnesium by hydrolysis and leaching. This is followed by a second stage in which silica is eluviated to be precipitated above the parent material. Then follow two further stages in which iron oxide and aluminium oxide respectively are deposited by *upward* movement *from* the mottled and pallid zones, which are water-logged owing to restricted drainage induced by the precipitation of silica.

Is there any reason to postulate substantial upward movement from the pallid zone? Upward movement would have to be by diffusion which is known to be exceedingly slow.

It is well known that ground waters are frequently heavily charged with soluble iron, probably ferrous bicarbonate, and exposure to air leads to the deposition of yellow hydrated iron oxide, Hester and Shelton (1947). The ferrous bicarbonate in the ground water could be 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 pallid and mottled zone, where reducing conditions will prevail.

Iron and aluminium in solution would be leached downward through the soil to enrich the ground water, the height of which will fluctuate according to the seasonal rainfall. Deposition from the ground water would naturally occur most readily at or near the fluctuating capillary fringe where intermittent aeration would promote oxidation of the ferrous carbonate to ferric oxide. Iron oxide deposits in a characteristic pattern largely in the upper part and, by some process but imperfectly understood, alumina separates out more freely in the lower portion of the horizon.

It is interesting to speculate on the conditions under which laterite forms. Most will agree that slightly undulating to flattish topography is necessary such as that resulting from severe land planation. Rainfall must be heavy and, probably, seasonal. Warm to high temperatures would seem favourable. Drainage would be restricted and dependent largely on the lateral movement of a water table which fluctuated in height seasonally.

Laterite represents the final stage in soil senility. Weathering has resulted in the decomposition of many of the original mineral species and the bulk of the important and more labile elements such as calcium, magnesium, potassium, sodium and sulphur have been removed. Quartz, sesquioxide and kaolin constitute the bulk of the residue. It is possible, however, that some primary minerals are preserved by inclusion in the mass of deposited sesquioxides.

The question arises as to whether laterite is forming today. Dr. Kellogg considers that laterite is now in the process of formation in Central Africa. Mr. G. A. Stewart, of the C.S.I.R.O., interprets certain formations in the Northern Territory of Australia as concurrently forming laterite. A section in alluvial country near Lismore in Northern New South Wales exposes material with some morphological characters similar to laterite.

But the great bulk of the laterite in Australia is ancient. There can be no doubt that laterite formation commenced a long time ago, probably in Pliocene time, and there is evidence that it once covered a large proportion of Australia, constituting a "duricrust" over much, if not all, of the "old" or "Great" Plateau —to extend Jutson's (1934) physiographic division of Western Australia to other parts of the continent. It is now in the course of truncation, dissection and denudation. The exposed surfaces and the drift material are being modified, as far as such inert materials will respond, by current pedogenic factors. In some districts these factors normally lead to the formation of podzolic soils. It is doubtful, however, whether even in such districts, the soils containing laterite which is still virtually intact should be classed as "lateritic podzols" or, worse, "residual podzols" where they are of a grey colour. Rather, consideration should be given to classing such soils as a new member of the Great Soil Groups. There seems no reason to introduce the concept of the podzol.

The significance of the laterite is a most important question in the classification of these soils. Dr. C. E. Kellogg regards the laterite as an adventitious feature and not a differentiating characteristic at the great soil group level. This opinion is based on observations in other continents, particularly in equatorial Africa. It is difficult to accept for the Australian laterites as represented in these Queensland soils, and, indeed, in similar soils in other parts of Australia. It is felt that here the laterite is of great pedological significance—that it is the result of pedogenic factors which once operated in Australia over a large proportion of the landscape but are now inoperative. There is no recorded evidence in Australia that the laterite is merely adventitious. It seems worthy of recognition as a differentiating characteristic at the great soil group level.

The distribution of laterite on the Atherton Tableland is interesting. In no case was laterite observed on the Atherton basalts. Of course, this does not mean that further search may not discover laterite on basalt. Where examined, these soils were invariably "red loams" (GROUP E). Near Carbeen, laterite was observed, the soil being of the class referred to above as "yellow types"—subgroup D_2. It appeared that the laterite was formed on sandstone country over which the basalt flow had not extended.

The occurence of ferruginous gravel, apparently lateritic, in the marginal basalt in the vicinity leads to the opinion that the laterite formation preceded this basalt flow and conditions in this area have not subsequently been favourable for laterite formation—certainly not general laterite formation.

Red lateritic types (subgroup D_1) are observed on basalt at many places in coastal Queensland—for instance, Tamborine, Toowoomba, Kingaroy, Gayndah, and Childers. Some profiles on basalt in the Innisfail area suggest incipient laterite formation. In fact, the site sampled at Mena Creek (U184-191) has features which could well be immature laterite. This site has been included in Group D—soils associated with laterite.

The Innisfail, Palmerston, Atherton Districts, with large areas of basalt country, offer a splendid opportunity for the study of laterite formation and distribution, and the relationship between red lateritic soils (Group D) and red loams (Group E).

2. *The relationship between red lateritic soils of Group D and red soils without laterite, or "red loams", of Group E.*—These soils have many features in common but the outstanding difference is in the occurrence of the material laterite. Comparisons derived from the data in the Appendix, Table 1, pp. 33-42, show that both soils are low to exceedingly low in exchangeable metal cations and have been subjected to considerable leaching—probably over a long period of time. The presence of laterite residuals in some areas (Tamborine, Toowoomba, Gayndah, Childers and Kingaroy) where "red loams" soils (Group E) are general, suggests that the "red loams" commenced to form at a period subsequent to the formation of the laterite sheet.

This hypothesis is supported by evidence from the Atherton Tableland where, as stated above, the edge of the basalt flow overlying sandstones is observed near Carbeen. Here laterite occurs on the older sandstones but the normal red soils without laterite appear characteristic of the younger basalt. Apparently the basalt flow was subsequent to the period of laterite formation and the red loams likewise, are younger than the laterite.

In a valuable publication on the soil groups in the Belgian Congo, Kellogg and Davol (1949) discuss the soils which appear closely related to certain of the groups described in this paper. A system of nomenclature for tropical soils, based largely on Congo experience, is proposed but is not adopted in this paper pending further consideration of the matter.

It is suggested that the Queensland soils included in:—

(i) Group E_1 may be correlated with "red latosols";

(ii) Group E_2 may be correlated with "yellow latosols";

(iii) Group J are related to, or may be correlated with, the "reddish prairie soils"—of Kellogg and Davol.

With the possible exception of U184-191, Group D_1, none of the soils described appears to be equivalent to the "earthy red latosols" of the Belgian Congo. It is likely, however, that the "earthy red latosols" are closely related to some of the red soils associated with laterite in other parts of Queensland, particularly where there has been an accumulation of colluvial material. If this is so, a correlation with Group D_1 may be established.

3. *The age of the "red loams" of Group E.*

It is thought that red loam soils are of considerable age, that is, they started to form in a previous era, an era earlier than the arid period of a few thousand years ago. Conditions of high rainfall would seem necessary. This idea arises out of the observation of a soil with a yellow brown clay subsoil on basalt exposed by Rocky Creek, a few miles north of Atherton. The soil is undoubtedly of recent origin, due to the removal of the "red loam" soil by the creek. It is in sharp contrast with the adjacent "red loams" away from the influence of the creek. Supporting evidence is reported by Forbes (1948) who states that, near Bacchus Marsh in Victoria, soils on the *older* basalt exhibit the features of the "red loam" profile while, on the *younger* basalt, the soils show clay segregation in the subsoil like that of Rocky Creek. The soils on younger basalt at Bacchus Marsh are classed as red brown earths. Supporting evidence is obtained from the soils on the younger basalt at Gayndah, Queensland.

Red loams occur very generally under rain forest but there are also considerable areas under eucalyptus forest or woodland. The place of the vegetation factor in the formation of these soils is not well understood. While these soils appear to form most readily on basalt, they are also observed on granite and schist, but apparently only where the vegetation and climate are suitable. Perhaps the time factor may also be important. Research is needed to clarify many questions.

4. *Black clay soils—Group F.*

It seems that, for the formation of these black clay soils, two conditions are favourable.

(a) A moderate rainfall, of the order of magnitude of 20—30 inches per annum in the Queensland latitudes, with marked summer incidence. (See Table I, p. 4).

(b) Parent material rich in clay forming minerals, and in calcium and/or magnesium. In view of this, basalt, calcareous sandstones or shales and limestone, even serpentine, provide suitable parent materials either *in situ* or transported.

Where the parent material is conducive, e.g. basaltic, black clay soils are observed in the wetter areas under a rainfall up to 40 inches per annum—sometimes higher. These soils are structurally similar to those of lower rainfall areas but the aggregates are more stable in water, they show evidence of more leaching and of the effects of restricted drainage. Calcium carbonate pellets are rare or absent in the surface but there are often many small rounded pellets of iron oxide stained with manganese oxide. It is suggested that these black clay soils developed their characteristics in the arid period which is thought to have ended about 4,000 years ago. In spite of the subsequent increase in rainfall the main features of a black clay soil have been retained but there is evidence of leaching of calcium carbonate and some structural modifications.

Professor G. W. Robinson compares the black clay soils (Group F) with the "tropical black clay" soils of the Transvaal of South Africa. Evidence from India indicates that the general features of the black cotton soils or "regur" are very similar to those of the Queensland black clay soils.

In 1939 and 1942, two important Bulletins were published by the Indian Society of Soil Science. The first, Bulletin No. 2, gives the results of a symposium on the black and red soils of Southern India; the second, Bulletin No. 4, discusses the Base Exchange Properties of Indian Soils. Contributors included J. N. Mukherjee, A. Sen, R. P. Mitra, S. P. Raychaudhuri and B. V. Nath. As in Queensland, the contrasting black and red soils occur in the same districts and on the same rock types in India. Generally, the black soils are on the lower levels. The evidence suggests that there is a close similarity between the Indian and Queensland soils and the opinions of the Indian workers are of considerable value.

The Indian workers appear to believe that the black soils of lower levels are formed by the transportation of finer materials and infiltration of soluble products of weathering from the higher levels. The lime moving in solution deposits as kankar in the black soils. However, B. V. Nath suggests that where the two soils occur side by side on the same parent material, transformations occur as a result of climatic changes. Beginning with a red soil, transformation into a black soil occurs under intermittent conditions of aridity and heat; into a laterite by extremes of humidity and heat.

The first explanation may be useful in some cases but fails as a generalisation. Nath has suggested the important and neglected factor of time, which may prove the key. Transformations from one soil to the other—from the kaolinitic clay or the mixture of kaolinite and colloidal alumina of a red soil to the montmorillonite of a black soil—is hard to believe. The picture becomes much more clear if it is assumed that exposure of the parent material by surface denudation at different periods permits the initiation of soil formation under different pedogenic conditions. That exposed under one set of conditions will form a red soil; that under another will form a black soil, and so on. Once started the direction of soil formation is not readily changed and the pattern persists.

The black clay soils are among the most valuable soils of Queensland for crops and pastures and it is unfortunate they are not more extensive. Those of the Darling Downs, once highly prized grazing country, now produce the bulk of Queensland's winter cereal crops, carry a very important section of the dairy industry, and are becoming increasingly important for grain sorghums, millets, linseed and sunflower. Lucerne and certain introduced grasses, such as *Paspalum scrobiculatum* and Rhodes grass, offer promise as pasture species.

The black clay soils of the Darling Downs and the Lockyer Valley are rich in phosphate, most samples containing over 0.1% P_2O_5. The low P_2O_5 content of the samples from near Emerald (U1, U6 and U192) is quite unexpected and hard to explain as these soils are formed on basalt. On the Darling Downs and in the Lockyer Valley crops have been grown on the black clays for decades without the use of superphosphate—just how long the Emerald soils will carry crops without the use of superphosphate is an unsolved question.

Under cultivation black clay soils are subject to water erosion, even on slopes as low as one per cent. The ravages of erosion are particularly insidious as the effects are often not observed until gullying develops. Soil conservation measures should be incorporated in any developmental program on these rich soils to preserve their fertility.

In other parts of the State, where the rainfall is now regarded as too risky for agriculture, black clay soils are highly valued for their natural grazing pastures.

Where water is available the black clay soils are used for irrigated crops and fodders. It is likely that many small and some large irrigation projects may be developed in the future on these soils. These heavy soils require careful handling under irrigation.

5. *Effect of clearing and agricultural development of the red loam soils of Group E.*

Analyses of the surface layer of a number of the red soils from the Atherton Tableland are given in Table II p. 16. It is recognised that there are insufficient data to be absolutely conclusive but the substantially lower organic carbon contents under paspalum and maize culture appear significant. It seems that, after removing the rain forest, the organic carbon content may be about halved after 20 or 30 years under a paspalum sward. Under maize the loss is much greater. Examination of the soil indicates that under paspalum or cultivation the crumb structure is greatly reduced and there is some subsurface compaction. What factors effect these changes?

Dr Kellogg emphasised the changed temperature conditions after removal of the rain forest. Under the rain-forest canopy and with a fair leaf litter the soils would probably never exceed the maximum air temperature. Accumulation of organic matter would be favoured. Under grass and cultivation much higher soil temperatures would be attained and thus would profoundly affect the accumulation of organic matter, the degree and kind of microbiological activity and the maintenance of soil structure. This is a very challenging soil problem. Under clean cultivation erosion removes the surface soil and accelerates the loss of organic matter.

6. *Agricultural development prospects.*

Confining attention to the black clay soils (Group F) and the brown alkaline soils (Group H), the opinion is expressed that there are great opportunities for agricultural development by the use of drought resistant and quick growing summer cereals such as grain sorghum. It is recognised that droughts will occur but where the rainfall exceeds about 20 inches per annum the summer rainfall will generally be adequate to grow a crop. Early frosts are liable to cause damage in some years. The success of the Peak Downs project of the Queensland British Food Corporation promises to establish the place of agriculture in the great pastoral industry of the area. At present most of this country is under grazing. Both sheep and cattle are used. There is generally little development except in the provision of fences and water supplies. Reports indicate that the carrying capacity may be greatly increased, at least doubled, by ring-barking.

The production of summer cereals will provide supplementary feeds on the properties and thus avoid heavy freight and purchase of high priced fodder on a sellers' market in drought periods. The grain and the stubble will be available in the normal routine of stock feeding and enable more economical use of the rough grazing to be made. Where water is available, small irrigation projects may be organised on suitable soil types. People point to the failure of wheat culture in these areas some decades ago. With the drought resistant, summer-growing grain sorghum and other millets, modern mechanical methods and new means for the control of pests and diseases, the risk of failure is minimised and there is every promise of success.

NOTES ON ANALYTICAL METHODS

The methods used to obtain the analytical data set out in Table 1 of the Appendix were essentially those described by Piper (1942). In the rapid method used for the determination of particle size the soil was dispersed with sodium hexametaphosphate, pre-treatments with hydrogen peroxide and dilute acid being omitted. The amounts of the finer particles were obtained by determinations of the density of the suspensions. Organic carbon was determined by the Walkley and Black wet oxidation method and comparison of eight results so obtained with dry combustion determinations on the same soils indicated an average recovery factor of 76.6%.

	Walkley & Black value	Dry Combustion
U10	0.68	0.948
U14	0.38	0.499
U49	1.22	1.47
U55	3.30	4.32
U60	6.59	8.41
U75	4.50	5.88
U85	3.51	4.72
U140	3.60	4.63

The figures quoted are the uncorrected Walkley and Black values except where indicated. The cations in the ammonium chloride leachate for estimation of exchangeable cations were determined by a modification of the Lundegardh flame technique and exchangeable hydrogen by meta-nitro-phenol buffer method to pH 8.4.

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APPENDIX—TABLE 1

ANALYSES OF SOILS OF TROPICAL QUEENSLAND

Soil Group	GROUP A—Podzolic soils			GROUP B—Grey soils of poorly drained areas. (a solonised soil with glei features—a magnesium soloth)					GROUP D--Soils with laterite. Subgroup D1—Red types.			
Location	Danbulla—Kairi Rd., near Robson Creek.			10 miles north of Cardwell					Tram cutting just north of Mena Creek, South Innisfail.			
Virgin vegetation	Eucalyptus woodland.			Melaleuca scrub on flat					Probably rain forest—cleared			
Geology	? granitic			alluvium					basalt			
Rainfall—inches	about 75			about 80					about 150			
Serial No.	U180	U182	U183	U49	U50	U51	U52	U54	U184	U186	U188	U190
Depth—inches	0—5	14—20	20—28	0—4	4—12	12—24	24—32	51—70	0—9	24—42	54—78	114—132
Colour	G	YB, RB	BR&YB	DG	GY	GY, rusty	G,YB,RB	G, YB	BR	BR	B	GB, R
Texture	Grt† L	Grt C	Grt C	Grt SL	Grt SCL	Grt SC	Grt SC	Grt SCL	Lt C	CL	CL	Lt C
Reaction—pH	6.18	5.69	5.76	5.53	5.53	5.83	6.03	5.92	5.60	5.00	4.92	4.86
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	45	35		33	35	23	34	—	8	6	3	—
Fine sand—per cent.	21	11	—	29	29	25	20	—	12	10	10	—
Silt—per cent.	16	15	—	20	15	16	15	—	21	18	18	—
Clay—per cent.	15	36		15	17	32	28	—	57	66	67	—
Loss on ignition—per cent.	6.0	7.2	8.6	5.4	4.0	5.8	5.6	5.1	16.4	12.9	13.0	12.1
Organic carbon—per cent.	1.14	—	—	1.47**	—	—	—	—	1.85	—	—	—
Nitrogen—per cent.	0.088	—	—	0.081	—	—	—	—	0.166	—	—	—
P_2O_5—per cent.	0.038	—	—	0.011	—	—	—	—	0.202	—	—	—
Exchangeable ions—milliequivalents per 100 grams soil												
Ca	2.48 (59)	0.15 (12)	—	0.02 (3)	0.03 (3)	0.05 (2)	—	—	1.52 (64)	0.17 (32)	0.01 (3)	—
Mg	1.22 (29)	0.66 (53)	—	0.51 (65)	0.74 (73)	2.13 (83)	—	—	0.62 (26)	0.12 (23)	0.10 (26)	—
K	0.38 (9)	0.31 (25)	—	0.15 (19)	0.15 (15)	0.23 (9)	—	—	0.15 (6)	0.14 (26)	0.18 (47)	—
Na	0.12 (3)	0.13 (10)		0.10 (13)	0.10 (9)	0.15 (6)	—	—	0.10 (4)	0.10 (19)	0.09 (24)	—
Total Met. ions	4.20	1.25	—	0.78	1.02	2.56	—	—	2.39	0.53	0.38	—
Exch. hydrogen*	—	—	—	—	—	—	—	—	15.0	11.9	—	—
Cation exch. capacity	—	—	—	—	—	—	—	—	17.4	12.4	—	—
Exch. H as % cation Exch. capacity	—	—	—	—	—	—	—	—	86	96	—	—
Cation Exch. capac. per 100 gm. clay	—	—	—	—	—	—	—	—	—	—	—	—

* Metanitrophenol method for pH 8.4. ** Dry combustion figure. Walkley and Black value 1.22. † Grt—gritty.

Soil Group	GROUP D—Soils with laterite. Subgroup D2—Yellow types of soil with laterite.								
Location	214 miles north of Emerald			266 miles nth. of Emerald		Junction of Mareeba and Chewko Roads			
Virgin vegetation	spinifex and scattered Eucalypts			open Eucalyptus woodland		Eucalyptus woodland			
Geology	? sandstone			? sandstone		? sandstone			
Rainfall—inches	20—25			20—25		about 40			
Serial No.	U14	U15	U16	U18	U20	U112	U114	U117	U118
Depth—inches	0—6	6—22	22—33	0—10	below 36	0—5	14—36	48—66	66—72
Colour	GB	Y	Y, Lt Y, R	GB	YB	GY	GY	GY,RB,G,B	G, YB, RB
Texture	SL	SCL	SCL	Gr LS	V Gr†SC	Gr SCL	V Gr SC	Gr SC	tight C
Reaction—pH	5.85	5.50	6.56	6.55	6.97	6.61	6.91	7.19	6.26
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	34	28	23	—	—	29	22	22	—
Fine sand—per cent.	41	35	32	—	—	21	10	13	—
Silt—per cent.	10	7	9	—	—	18	16	12	—
Clay—per cent.	14	28	35	—	—	30	48	50	—
Loss on ignition—per cent.	2.9	4.0	5.7	2.4	4.6	8.9	10.3	10.7	10.0
Organic carbon—per cent.	0.499**	—	—	—	—	0.96	—	—	—
Nitrogen—per cent.	0.032	—	—	—	—	0.077	—	—	—
P_2O_5—per cent.	0.005	—	—	—	—	0.099	—	—	—
Exchangeable ions—milliequivalents per 100 grams soil									
Ca	0.79 (51)	—	2.02 (45)	—	—	5.36 (59)	2.63 (34)	1.29 (17)	—
Mg	0.47 (30)	—	2.11 (47)	—	—	3.38 (37)	4.64 (61)	5.76 (76)	—
K	0.19 (12)	—	0.10 (2)	—	—	0.22 (3)	0.10 (1)	0.10 (1)	—
Na	0.10 (7)	—	0.28 (6)	—	—	0.10 (1)	0.29 (4)	0.45 (6)	—
Total Met. ions	1.55	—	4.51	—	—	9.06	7.66	7.60	—
Exch. hydrogen	—	—	—	—	—	—	—	—	—
Cation exch. capacity	—	—	—	—	—	—	—	—	—
Exch. H as % cation Exch. capacity	—	—	—	—	—	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	—	—

** Dry combustion figure. Walkley and Black value 0.38. † Gr—gravelly.

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1 (h)—high rainfall—red soils.									
Location	Society Flat, Kirrama Range			Society Flat, Kirrama Range, Cardwell (see U35)				Depot, Kirrama Range, Cardwell		
Virgin vegetation	rain forest			rain forest				Eucalyptus forest		
Geology	granite			basic segregation in granite				granite		
Rainfall—inches	about 80			about 80				about 80		
Serial No.	U25	U27	U29	U30	U31	U32	U34	U39	U40	U42
Depth—inches	0—3	12—39	54—70	0—3	3—6	6—27	48—70	0—4	4—11	24—60
Colour	DGB	Brt B	DB	DRB	RB	BR	LR	DGB	DB to B	BR & YB
Texture	L	SCL	CS & grit	CL	SCL	SC	Grt C & dec. rock	Grt SCL	Grt C	C
Reaction—pH	6.47	5.12	5.60	5.17	5.64	5.49	5.38	6.11	5.63	5.69
$CaCO_3$ —per cent.	—	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	38	28	—	40	40	37	—	46	38	20
Fine sand—per cent.	29	31	—	19	19	15	—	13	11	10
Silt—per cent.	20	12	—	19	15	15	—	21	20	18
Clay—per cent.	10	27	—	18	24	31	—	18	31	41
Loss on ignition—per cent.	12.0	6.8	4.5	16.9	11.1	12.1	8.1	10.6	11.8	9.7
Organic carbon—per cent.	3.48	—	—	3.59	—	—	—	2.42	—	—
Nitrogen—per cent.	0.284	0.048	—	0.322	0.141	—	—	0.156	—	—
P_2O_5 —per cent.	0.063	—	—	0.070	—	—	—	0.039	—	—
Exchangeable ions—milliequivalents per 100 grams soil										
Ca	13.88 (74)	0.02 (3)	—	4.35 (63)	—	0.10 (12)	—	4.90 (60)	—	—
Mg	4.19 (22)	0.29 (53)	—	2.05 (30)	—	0.51 (63)	—	2.62 (32)	—	—
K	0.56 (3)	0.17 (31)	—	0.29 (4)	—	0.10 (12)	—	0.42 (5)	—	—
Na	0.15 (1)	0.07 (13)	—	0.21 (3)	—	0.10 (13)	—	0.19 (3)	—	—
Total Met. ions	18.78	0.55	—	6.90	—	0.81	—	8.13	—	—
Exch. hydrogen	—	—	—	16.2	—	7.3	—	—	—	—
Cation exch. capacity	—	—	—	23.1	—	8.1	—	—	—	—
Exch. H as % cation Exch. capacity	—	—	—	70	—	90	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	26	—	—	—	—

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(h)—High rainfall—red soils.								
Location	1 mile east of Depot, Kirrama Range			Palmerston Road, 15 miles from Innisfail			10 chains from Toll Gate—Gillies Highway		
Virgin vegetation	Rain forest			Rain forest—in lantana on roadside			Rain forest—cleared—now under wild tobacco and Ageratum		
Geology	? granite			probably basalt			probably basalt—granite near by		
Rainfall—inches	about 80			over 100			55		
Serial No.	U44	U46	U48	U55	U57	U59	U60	U62	U64
Depth—inches	0—4	11—27	45—66	0—6	15—48	64—87	0—6	16—36	54—75
Colour	GB	RB—BR	BR & Y	RB	RB	B to DGB	rich RB	BR	BR
Texture	Grt SCL	Grt C	Grt C—dec. rock	CL	CL	CL	C	CL	CL
Reaction—pH	5.22	5.16	5.28	5.30	5.18	5.02	5.08	4.85	5.01
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	42	18	—	2	2	—	4	3	1
Fine sand—per cent.	13	10	—	14	18	—	15	17	10
Silt—per cent.	22	22	—	36	28	—	36	24	16
Clay—per cent.	17	46	—	45	50	—	41	56	71
Loss on ignition—per cent.	11.9	10.6	7.7	21.4	17.4	13.7	24.8	13.8	12.4
Organic carbon—per cent.	3.26	—	—	4.32**	—	—	8.41**	—	—
Nitrogen—per cent.	0.296	—	—	0.306	—	—	0.559	—	—
P_2O_5—per cent.	0.041	—	—	—	—	—	0.225	—	—
Exchangeable ions—milliequivalents per 100 grams soil									
Ca	1.53 (33)	0.01 (1)	—	2.34 (56)	0.23 (32)	—	1.50 (42)	0.01 (2)	—
Mg	2.45 (53)	0.45 (58)	—	1.41 (34)	0.21 (29)	—	1.40 (39)	0.26 (54)	—
K	0.44 (10)	0.22 (28)	—	0.33 (8)	0.10 (14)	—	0.44 (12)	0.10 (21)	—
Na	0.18 (4)	0.10 (13)	—	0.10 (2)	0.18 (25)	—	0.23 (7)	0.11 (23)	—
Total Met. ions	4.60	0.78	—	4.18	0.72	—	3.57	0.48	—
Exch. hydrogen	—	—	—	23.1	13.1	—	—	—	—
Cation exch. capacity	—	—	—	27.3	13.8	—	—	—	—
Exch. H as % cation Exch. Capacity	—	—	—	85	95	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	28	—	—	—	—

** Dry combustion figure. Walkley and Black values 3.30 and 6.59.

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(h)—High rainfall—red soils								
Location	Topaz Road, Boonjee			J. R. Soley—Butcher Creek			near Gardner Ck. on Butcher Ck. Rd.		
Virgin vegetation	Rain forest			Rain forest—cleared—paspalum			Rain forest—cleared—paspalum		
Geology	basalt			basalt			basalt		
Rainfall—inches	100			100			about 80		
Serial No.	U66	U69	U70	U133	U136	U139	U140	U142	U145
Depth—inches	0—3	20—28	28—50	0—6	33—54	100+	0—6	19—36	86—96
Colour	B	B	B	RB	DRB	B	RB	LBR	B
Texture	CL	Lt C or CL	CL	CL	CL to C	LC	Hy CL	Hy CL	Hy CL
Reaction—pH	4.97	5.14	5.05	5.62	5.44	5.10	5.93	5.76	5.14
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	15	1	—	15	1	—	5	3	—
Fine sand—per cent.	21	10	—	28	10	—	20	10	—
Silt—per cent.	32	31	—	32	43	—	30	15	—
Clay—per cent.	27	56	—	20	45	—	41	70	—
Loss on ignition—per cent.	32.0	15.9	13.6	24.8	22.8	17.4	17.2	15.7	15.7
Organic carbon—per cent.	8.40	—	—	4.80	—	—	4.63**	—	—
Nitrogen—per cent.	0.790	—	—	0.469	—	—	0.390	—	—
P_2O_5—per cent.	—	—	—	0.331	—	—	0.314	—	—
Exchangeable ions—milliequivalents per 100 grams soil									
Ca	4.43 (57)	0.12 (16)		2.51 (54)	0.15 (38)	—	3.48 (53)	1.64 (66)	—
Mg	2.56 (33)	0.27 (37)	—	1.69 (36)	0.05 (12)	—	2.22 (33)	0.51 (20)	—
K	0.64 (8)	0.11 (15)	—	0.26 (6)	0.05 (12)	—	0.83 (13)	0.25 (10)	—
Na	0.20 (2)	0.23 (32)	—	0.19 (4)	0.15 (38)	—	0.10 (1)	0.10 (4)	—
Total Met. ions	7.83	0.73	—	4.65	0.40	—	6.63	2.50	—
Exch. hydrogen	—	—	—	—	—	—	20.5	10.5	—
Cation exch. capacity	—	—	—	—	—	—	27.1	13.0	—
Exch. H as % cation Exch. capacity	—	—	—	—	—	—	76	81	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	19	—

** Dry combustion figure. Walkley and Black value 3.60.

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(h)—High rainfall								
Location	2 miles south Malanda			5 miles south of Atherton			Danbulla—near Emerald Creek Fork		
Virgin vegetation	Rain forest			Rain Forest—cleared—maize			Rain Forest		
Geology	basalt			basalt			granite		
Rainfall—inches	about 70			about 55			about 75		
Serial No.	U146	U148	U150	U151	U153	U155	U156	U158	U160
Depth—inches	0—6	12—30	57—66	0—7	30—54	92—100	0—6	16—30	72—96
Colour	RB	BR	BR	DRB	BR	B	DB	RB	pinkish YR
Texture	CL	Lt C	Lt C— dec. rock	CL	CL	CL	SL	SCL	SC
Reaction—pH	5.64	5.43	5.08	6.34	5.32	4.62	5.05	5.09	5.44
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	12	1	—	7	1	—	32	32	—
Fine sand—per cent.	28	11	—	18	8	—	19	20	—
Silt—per cent.	26	17	—	26	16	—	18	14	—
Clay—per cent.	31	69	—	46	74	—	26	32	—
Loss on ignition—per cent.	26.9	16.2	5.3	15.9	11.8	5.3	14.8	10.0	14.3
Organic carbon—per cent.	6.42	—	—	2.21	—	—	3.33	—	—
Nitrogen—per cent.	0.602	—	—	0.235	—	—	0.343	—	—
P_2O_5—per cent.	0.450	—	—	0.419	—	—	0.079	—	—
Exchangeable ions—milliequivalents per 100 grams soil									
Ca	3.84 (57)	0.38 (41)	—	6.32 (61)	0.83 (47)	—	2.35 (62)	0.25 (46)	—
Mg	2.03 (30)	0.35 (37)	—	2.37 (23)	0.44 (25)	—	1.06 (28)	0.10 (18)	—
K	0.65 (10)	0.05 (5)	—	1.49 (14)	0.33 (19)	—	0.25 (7)	0.10 (18)	—
Na	0.23 (3)	0.16 (17)	—	0.22 (2)	0.16 (9)	—	0.10 (3)	0.10 (18)	—
Total Met. ions	6.75	0.94	—	10.40	1.76	—	3.76	0.55	—
Exch. hydrogen	—	—	—	—	—	—	22.1	10.9	—
Cation exch. capacity	—	—	—	—	—	—	25.9	11.4	—
Exch. H as % cation Exch. Capacity	—	—	—	—	—	—	85	96	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	36	—

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(h)—High. rainfall											
Location	Danbulla—Robson Creek Camp (classification provisional)			Danbulla—on Emerald Creek Road				1.8 miles north Atherton			2.2 mls. nth. Atherton	
Virgin vegetation	Eucalyptus woodland			Rain forest—sample from road cutting				Rain forest			Rain forest	
Geology	granite			granite ?				basalt			basalt	
Rainfall—inches	75			about 75				about 50			about 50	
Serial No.	U167	U169	U172	U173	U174	U175	U178	U75	U78	U80	U81	U83
Depth—inches	0—5	12—30	72—90	0—8	8—14	14—24	76—94	0—6	27—48	84—144	0—6	14—28
Colour	DGB	DBR	Orange	GYB	YB	YB & B	R,Y,Pink	DRB	DRB	BR	DRB	DRB
Texture	SL—SCL	SCL	SL	Grt Gr SL	Grt Gr CL	Grt Gr C	Grt C	CL	C	C	CL	C
Reaction—pH	5.36	5.76	5.63	4.86	4.98	5.02	4.99	7.10	7.07	6.96	6.62	7.04
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	37	30	—	43	36	39	—	3	3	—	6	4
Fine sand—per cent.	23	23	—	13	14	12	—	15	9	—	24	18
Silt—per cent.	14	7	—	9	18	17	—	40	16	—	40	30
Clay—per cent.	23	40	—	29	28	28	—	38	71	—	30	44
Loss on ignition—per cent.	10.9	6.4	5.7	21.5	17.6	17.2	10.2	20.2	11.5	11.6	23.2	12.3
Organic carbon—per cent.	2.77	—	—	4.19	—	—	—	5.88**	—	—	5.97	—
Nitrogen—per cent.	0.183	—	—	0.294	—	—	—	0.536	—	—	0.613	—
P_2O_5—per cent.	0.060	—	—	0.059	—	—	—	—	—	—	0.437	—
Exchangeable ions—milliequivalents per 100 grams soil												
Ca	0.65 (38)	0.10 (6)	—	0.54 (37)	—	0.03 (12)	—	28.45 (77)	3.69 (68)	—	34.36 (84)	7.85 (76)
Mg	0.79 (47)	1.35 (82)	—	0.62 (42)	—	0.05 (19)	—	6.74 (18)	1.02 (19)	—	4.89 (12)	1.66 (16)
K	0.15 (9)	0.10 (6)		0.20 (14)	—	0.05 (19)	—	1.42 (4)	0.59 (11)	—	1.41 (2½)	0.72 (7)
Na	0.10 (6)	0.10 (6)	—	0.10 (7)	—	0.13 (50)	—	0.16 (1)	0.13 (2)	—	0.15 (½)	0.10 (1)
Total Met. ions	1.69	1.65	—	1.46	—	0.26	—	36.77	5.43	—	40.81	10.33
Exch. hydrogen	—	—	—	—	—	—	—	8.6	5.2	—	—	—
Cation exch. capacity	—	—	—	—	—	—	—	45.4	10.6	—	—	—
Exch. H as % cation Exch. Capacity	—	—	—	—	—	—	—	19	49	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	—	15	—	—	—

** Dry combustion figure. Walkley and Black value 4.50.

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(1)—Low rainfall						
Location	1 mile south Mapee			Mapee		1.1 miles south Carbeen	
Virgin vegetation	Eucalyptus woodland			Eucalyptus woodland		Eucalyptus woodland	
Geology	basalt			basalt		basalt	
Rainfall—inches	less than 50			less than 50		about 40	
Serial No.	U85	U87	U89	U92	U94	U96	U98
Depth—inches	0—6	9—23	60—102	0—6	20—36	0—6	19—33
Colour	DRB	DRB	RB	DRB	BR	DRB	BR
Texture	L	C	C	L	C	L	C
Reaction—pH	6.53	6.25	5.77	6.09	6.41	6.21	6.29
$CaCO_3$—per cent.	—	—	—	—	—	—	—
Coarse sand—per cent.	9	3	—	2	4	4	2
Fine sand—per cent.	22	9	—	23	14	24	12
Silt—per cent.	42	27	—	34	26	32	21
Clay—per cent.	28	58	—	38	54	38	65
Loss on ignition—per cent.	17.2	13.3	6.6	15.1	11.4	13.4	11.4
Organic carbon—per cent.	4.72**	—	—	2.73	—	2.10	—
Nitrogen—per cent.	0.257	—	—	0.202	—	0.155	—
P_2O_5—per cent.	0.456	—	—	0.327	—	0.324	—
Exchangeable ions—milliequivalents per 100 grams soil							
Ca	11.81 (61)	7.09 (72)	—	7.79 (65)	—	7.84 (61)	2.72 (49)
Mg	4.43 (23)	2.19 (22)	—	3.15 (26)	—	3.58 (28)	2.17 (39)
K	2.85 (15)	0.47 (5)	—	0.95 (8)	—	1.32 (10)	0.50 (9)
Na	0.11 (1)	0.15 (1)	—	0. 15(1)	—	0.15 (1)	0. 13(3)
Total Met. ions	19.20	9.90	—	12.04	—	12.89	5.52
Exch. hydrogen	—	—	—	—	—	—	—
Cation exch. capacity	—	—	—	—	—	—	—
Exch. H as % cation Exch. Capacity	—	—	—	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—

** Dry combustion figure. Walkley and Black value 3.51

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E1(l)—Low rainfall								GROUP E—" Red loams " and related soils. Subgroup E2—Yellowish soils		
Location	1 mile west of Chewko X Road north of Carbeen		8.4 miles south Mareeba—just south of Jump-up			3 ch. east of Carbeen Siding evidence of laterite			Society Flat, Kirrama Ra., Cardwell classification provisional		
Virgin vegetation	Eucalyptus woodland		Eucalyptus woodland			Eucalyptus woodland			Eucalyptus woodland or forest		
Geology	basalt		basalt			basalt			alluvium in granite country		
Rainfall—inches	about 40		about 40			about 40			over 80		
Serial No.	U109	U111	U123	U124	U126	U104	U106	U108	U35	U37	U38
Depth—inches	0—6	19—30	0—6	6—18	30—41	0—2	6—16	over 30	0—6	16—36	42—60
Colour	DGB	Brt BR	DRB	DRB	R	DGB	RB	BR	BG	GYB&rusty	DYB to G
Texture	CL	C	CL	C	CL	CL	C	C	Gr SCL	Gr SC	clayey grit
Reaction—pH	6.86	6.90	6.74	6.43	6.27	6.53	6.70	6.51	5.72	5.41	5.40
$CaCO_3$	—	—	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	17	10	11	8	—	15	11	—	46	24	—
Fine sand—per cent.	18	14	15	8	—	20	12	—	24	26	—
Silt—per cent.	26	24	27	16	—	29	16	—	17	17	—
Clay—per cent.	37	49	46	66	—	32	60	—	10	32	—
Loss on ignition—per cent.	10.9	10.1	11.2	10.7	10.7	13.2	10.5	10.7	7.0	6.8	4.4
Organic carbon—per cent.	1.59	—	1.62	—	—	2.65	—	—	1.89	—	—
Nitrogen—per cent.	0.113	—	0.114	—	—	0.194	—	—	0.119	—	—
P_2O_5—per cent.	0.353	—	0.249	—	—	0.534	—	—	0.038	—	—
Exchangeable ions—milliequivalents per 100 grams soil											
Ca	10.61 (69)	3.45 (59)	9.21 (62)	3.94 [55)	—	12.5 (62)	5.86 (52)	—	2.21 (53)	0.01 (2)	—
Mg	3.54 (23)	1.65 (28)	3.92 (26)	2.17 (30)	—	5.63 (28)	4.19 (37)	—	1.50 (36)	0.31 (51)	—
K	1.03 (7)	0.58 (10)	1.39 (9)	0.92 (13)	—	1.75 (9)	1.08 (9)	—	0.34 (9)	0.19 (31)	—
Na	0.10 (1)	0.16 (3)	0.39 (3)	0.19 (2)	—	0.28 (1)	0.20 (2)	—	0.10 (2)	0.10 (16)	—
Total Met. ions	15.28	5.84	14.91	7.22	—	20.2	11.33	—	4.15	0.61	—
Exch, hydrogen	9.3	6.4	—	—	—	—	—	—	—	—	—
Cation exch. capacity	24.6	12.2	—	—	—	—	—	—	—	—	—
Exch. H as % cation Exch. Capacity	38	52	—	—	—	—	—	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	25	—	—	—	—	—	—	—	—	—

ANALYSIS OF SOILS OF TROPICAL QUEENSLAND—Continued

Soil Group	GROUP E—" Red loams " and related soils. Subgroup E2—Yellowish soils.								
Location	8 ch. west of Carbeen Siding evidence of laterite		south-west of Topaz				Danbulla—2½ miles south Emerald Ck. Fork		
Virgin vegetation	Eucalyptus woodland		Rain forest				Eucalyptus woodland—cleared—paspalum		
Geology	basalt?		schist				? granitic		
Rainfall—inches	about 40		about 150				about 75		
Serial No.	U100	U102	U127	U128	U130	U131	U161	U163	U165
Depth—inches	0—5	13—27	0—4	4—14	24—36	36—54	0—6	16—26	59—96
Colour	DGB	YB	DYB	YB to B	BR & Or B	BR, Or B, Y	G	YB to Lt Y	Purp. R
Texture	CL fine Gr	C fine Gr	FSL	FSL	FSCL	FSCL	SCL	SCL	C
Reaction—pH	6.80	6.48	4.32	4.64	4.79	4.86	5.90	5.94	5.09
$CaCO_3$—per cent.	—	—	—	—	—	—	—	—	—
Coarse sand—per cent.	18	8	17	14	12	—	48	42	—
Fine sand—per cent.	18	8	46	46	39	—	11	13	—
Silt—per cent.	31	16	6	15	22	—	16	18	—
Clay—per cent.	29	65	26	23	25	—	22	26	—
Loss on ignition—per cent.	12.9	12.3	12.2	7.1	5.3	4.5	10.5	6.6	6.3
Organic carbon—per cent.	2.29	—	4.37	—	—	—	2.49	—	—
Nitrogen—per cent.	0.177	—	0.347	—	—	—	0.228	—	—
P_2O_5—per cent.	0.305	—	0.079	—	—	—	0.043	—	—
Exchangeable ions—milliequivalents per 100 grams soil									
Ca	15.0 (64)	4.61 (46)	0.02 (2)	—	0.01 (3)	—	3.52 (69)	1.10 (53)	—
Mg	6.84 (30)	4.99 (50)	0.58 (57)	—	0.05 (15)	—	1.27 (25)	0.68 (33)	—
K	1.25 (5)	0.21 (2)	0.27 (27)	—	0.10 (30)	—	0.22 (4)	0.16 (8)	—
Na	0.23 (1)	0.21 (2)	0.14 (14)	—	0.17 (52)	—	0.13 (2)	0.12 (6)	—
Total Met. ions	23.3	10.02	1.01	—	0.33	—	5.14	2.06	—
Exch. hydrogen	—	—	—	—	—	—	—	—	—
Cation exch. capacity	—	—	—	—	—	—	—	—	—
Exch. H as % cation Exch. Capacity	—	—	—	—	—	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	—	—

Soil Group	GROUP F—Black clay soils								GROUP H—Brown heavy soils			GROUP J—Red brown earths		
Location	23 miles north Emerald			23 miles north Emerald		Chirnside—28 miles north Emerald			130 miles north Emerald			20 miles north-east Charters Towers		
Virgin vegetation	Brigalow scrub			Brigalow scrub		grassland			brigalow scrub			Eucalyptus woodland		
Geology	basalt			basalt		basalt			? alluvial or drift			granite		
Rainfall—inches	25			25		25			20—25			25		
Serial No.	U1	U3	U5	U6	U8	U192	U194	U197	U10	U11	U12	U21	U23	U24
Depth—inches	0—3	12—43	62—87	0—3	15—39	0—4	14—36	66—78	0—7	7—18	18—48	0—3	13—19	24—33
Colour	DGB	DGB	B	DB	DB	DGB	DGB	LB-B-Olive	B	B	DB	B	BR	RB
Texture	C	C	C	C	C	C	C	C	Grt C	Grt C	Grt C	SL	SC	SC
Reaction—pH	7.91	8.62	8.45	8.74	8.70	8.53	8.88	8.78	7.06	8.31	8.77	6.89	7.16	8.03
$CaCO_3$—per cent.	0.17	1.20	4.77	5.17	5.31	0.49	1.03	10.4	—	—	4.61	—	.02	—
Coarse sand—per cent.	16	12	—	17	—	—	—	—	29	24	—	30	20	—
Fine sand—per cent.	19	14	—	22	—	—	—	—	28	26	—	41	19	—
Silt—per cent.	12	12	—	16	—	—	—	—	8	12	—	11	14	—
Clay—per cent.	52	59	—	44	—	—	—	—	36	38	—	17	46	—
Loss on ignition—per cent.	7.2	8.2	9.0	9.4	9.2	10.4	8.9	11.6	4.8	5.7	6.7	4.1	8.5	4.5
Organic carbon—per cent.	0.72	—	—	0.80	—	1.44	—	—	0.95**	—	—	0.61	—	—
Nitrogen—per cent.	0.080	—	—	0.100	—	0.103	—	—	0.080	—	—	0.057	—	—
P_2O_5—per cent.	0.032	0.023	—	0.038	—	0.042	—	—	—	—	—	0.037	—	—
Exchangeable ions—milliequivalents per 100 grams soil														
Ca	45.1 (67)	—	—	—	—	—	—	—	9.28 (64)	—	—	5.52 (63)	8.58 (60)	—
Mg	21.6 (32)	—	—	—	—	—	—	—	3.86 (27)	—	—	2.47 (28)	5.05 (35)	—
K	0.39 (1)	—	—	—	—	—	—	—	1.21 (8)	—	—	0.73 (8)	0.33 (2)	—
Na	0.16 (—)	—	—	—	—	—	—	—	0.16 (1)	—	—	0.10 (1)	0.38 (3)	—
Total Met. ions	67.2	—	—	—	—	—	—	—	14.51	—	—	8.82	14.34	—
Exch. hydrogen	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cation exch. capacity	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exch. H as % cation Exch. Capacity	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cation Exch. Capac. per 100 gm. clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—

** Dry combustion figure. Walkley and Black value 0.68.

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