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STUDIES ON MAJOR SOILS OF THE FORSAYTH GRANITE

1. MORPHOLOGICAL AND CHEMICAL PROPERTIES

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SUMMARY

A catenary sequence of soils derived from Forsayth Granite in the Georgetown area of north Queensland was identified. Four groups of soils are described. They are lithosol-earthy sand intergrades; earthy sands; podzolic, soloth and solodic soil intergrades; and solodic and solodized solonetz soils.

Soil chemical data indicate that all the soils are of low fertility. They are critically deficient in phosphorus and may be deficient in potassium.

I. INTRODUCTION

Near Georgetown in north Queensland, there is an extensive area of soils developed on the Forsayth Granite (White 1962). These soils were described by Sleeman (1964) and also later classified and mapped by Isbell, Webb and Murtha (1968) in a broad reconnaisance soil survey.

Extensive grazing of native pastures is the main form of land utilization. Some attempts to introduce improved pasture species, notably Townsville stylo (*Stylosanthes humilis*), have been made with limited success. The major limitation to pasture production appears to be low soil fertility. In this paper the morphological and chemical properties of the soils developed on the Forsayth Granite are presented.

II. ENVIRONMENT

CLIMATE. The area studied has a dry tropical climate with a marked summer rainfall dominance. Mean annual rainfall for Georgetown is 813 mm but variability is high (44%). Of the annual rainfall, 93% occurs from November to April inclusive and some high intensity falls are common.

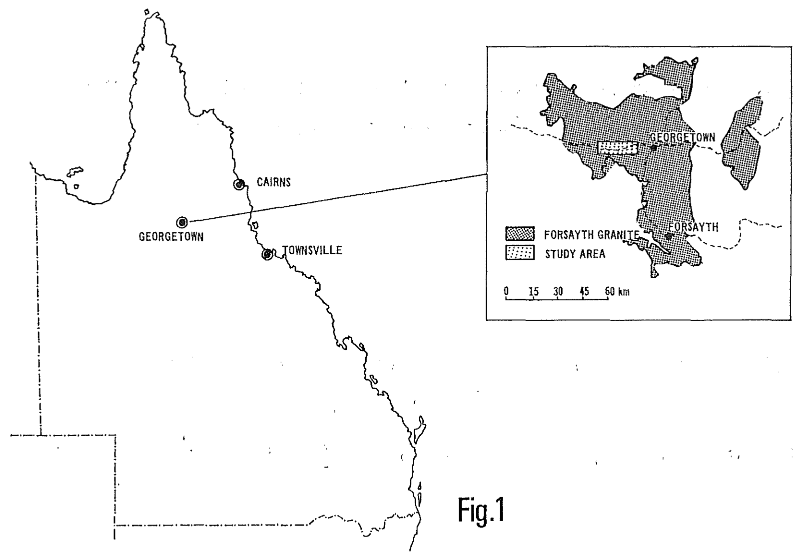

Fig.1

Mean daily maximum temperatures for Georgetown for the hottest months of October to March inclusive range from 33° to 35·5°C. The mean daily maximum temperatures for the cooler months are high and range from 28° to 32°C. Frosts are very uncommon.

VEGETATION. The vegetation has been described in detail by Perry and Lazarides (1964) as characteristically an open woodland of Georgetown box (*Eucalyptus microneura*) with a low tree layer of *Petalostigma banksii, Bauhinia cunninghamii* and *Terminalia platyptera.* A shrub, konkerberry (*Carissa lanceolata*), is common. The grass community is a 'three awn' community dominated by *Aristida* spp., chiefly *A. armata and A. pruinosa.* Less commonly found are *Chrysopogon fallax, Bothriochloa ewartiana, Themeda australis* and *Heteropogon contortus.*

GEOLOGY AND GEOMORPHOLOGY. Soils in the Georgetown area are derived from the Forsayth Granite, a grey, coarse-grained, massive to porphyritic biotite-granite (White 1962) which covers an area of approximately 260 000 hectares. Topography is moderately undulating with broad crests and long slopes, although in the south-west, near Forsayth, strongly undulating land with occasional low hills predominates. Granite tor outcrop is common on crests and upper slopes.

III. METHODS

A sample area was selected for study. It covers approximately 1 300 hectares (0·5%) of the Forsayth Granite and lies between Georgetown and a point approximately 16 km west on the Georgetown-Croydon road. For ease of access, the main road was used as the central traverse line. Soil classification was carried out at all slope positions on each side of the road and up to 0·8 km from the road. In addition, soils on slopes 1·6 km south, 4·3 km south, and 3·2 km east of Georgetown were checked to confirm their similarity to those in the study area.

Composite surface soil samples were collected from 40 different sites while soil profile samples were collected from seven sites. At four of these sites, bulk surface samples were collected for use in nutrient pot studies in the glasshouse. The results of the nutrient experiments are reported in part 2 of this series (Webb, 1975).

Soil samples were analysed for electrical conductivity, pH, chloride, exchangeable cations, cation exchange capacity, total nitrogen, organic carbon and available phosphorus.

Electrical conductivity and pH were determined on a 1:5 soil-water suspension at 25°C. Chloride was determined on this suspension by electrometric titration using silver nitrate (Piper 1950). Total nitrogen was determined on a Kjeldahl digest and organic carbon by the Walkley-Black method (Piper 1950). The organic carbon values were not 'corrected' by a factor. Exchangeable cations were extracted with normal ammonium chloride at pH 7·0 and cation exchange capacity obtained by determining the exchanged ammonium from the ammonium-saturated sample. Available phosphorus was measured by the method of Kerr and Von Stieglitz (1938) using 0·01 N sulphuric acid.

IV. RESULTS

(a) Soil morphology

A catenary sequence of soils was identified from detailed soil classification at all slope positions within the study area. The sequence consists of shallow immature earthy sands on crests, grading through sandy podzolic and podzolic-soloth-solodic intergrades to solodics and solodized solonetz in the drainage lines. Four groups of soils are listed below. Detailed profile descriptions are shown in Appendix 1.

(i) LITHOSOL–EARTHY SAND INTERGRADES. On crests and upper slopes, shallow loamy sands are the dominant soils. These vary in depth (20 to 50 cm) to the underlying weathering granite. A_1 horizons are 15 to 20 cm thick, brown to dark brown, with a loamy sand texture. Structure is massive and the surface is hard-setting. Consistence is slightly hard or hard when dry. There is usually a clear change to an A_2 horizon. The A_2 horizon is yellowish brown to brown loamy sand which is massive, earthy and has a hard to very hard consistence (dry). Small angular quartzitic gravel less than 1·5 cm wide may occur. There is a clear change to C horizon which contains partly weathered granite.

Principal profile forms (Northcote 1971) recognized were UC4.11, Uc4.12, Uc4.2.

(ii) EARTHY SANDS. On upper to mid-slope positions and on broad crests which are slightly lower than the dominant crests in the landscape, moderately deep earthy sands are the dominant soils. These are 50 to 110 cm thick. They exhibit changes down the profile. The A_1 horizon is usually 15 to 20 cm thick and is a dark greyish brown loamy sand. It is hard and massive. There is a clear to gradual change to a B horizon.

The B horizon is yellowish brown to brown loamy sand often with clearly defined yellowish-brown to yellowish-red mottles. The soil is massive, earthy and hard. Angular quartzitic gravel less than 1·5 cm wide commonly occurs. There is a clear change to a C horizon of weathered granite. Occasionally some soils have an A_2 horizon.

Principal profile forms recognized were Uc5.23, Uc5.22, and Uc4.22.

(iii) Podzolics, soloths and solodic soil intergrades. Weakly developed sandy surfaced podzolics, soloths and solodic soil intergrades occupy the mid and lower-slope positions. Very occasionally, they are found in upper slope positions. They are hard setting, texture-contrast soils ranging in thickness from 30 cm to 120 cm but generally from 65 cm to 90 cm.

The A_1 horizon is 15 to 20 cm thick and is a dark greyish brown to brown loamy sand. It is massive and hard. There is a clear boundary to the A_2 horizon. The A_2 horizon ranges from 15 to 50 cm but is generally about 40 cm. It is yellowish-brown to brown loamy sand or occasionally loamy coarse sand. Weak reddish-brown or yellowish-brown mottles may occur. The soil is massive, has an earthy fabric and is hard when dry. Small angular quartzitic gravel less than 1·5 cm wide may be present. The boundary to the B horizon is abrupt.

The B horizon is dark greyish-brown to greyish-brown sandy clay loam or sandy clay. Small flecks and mottles are common and may be red, yellowish-brown, yellowish-red or reddish-brown. Structure is usually blocky, though massive B horizons do occur. Consistence when dry is very hard to extremely hard. Occasionally calcium carbonate concretions (<1 cm) occur in the lower B horizon. This grades to a BC horizon which is usually less than 10 cm thick. In this, small pieces of soft weathered granite with a speckled appearance are mixed with some clay material giving a texture of a gritty clay or coarse sandy clay which is massive. This overlies granite.

Principal profile forms recognized were Dy33.21, Dy3.22, Dy3.23, Dy2.21, Dy2.22, Dy2.23, Dy2.11, Dy2.12, and Dy2.51.

(iv) Solodic and solodized solonetz soils. In the lowest positions in the landscape are solodic and solodized solonetz soils. These are hard-setting texture-contrast soils with a bleached A_2 horizon overlying a clayey B horizon. They are generally 80 to 95 cm thick but range from 50 to 140 cm.

The A_1 horizon is 10 to 15 cm thick but may range up to 30 cm. It is dark grey to dark brown loamy sand or sandy loam which is massive and hard. Small angular quartzitic gravel and small ironstone concretions up to 3 cm diameter are common. A clear to abrupt change occurs to the A_2 horizon. The conspicuously bleached A_2 horizon varies in thickness from 2·5 cm to 15 cm but the thin horizon is more common. It is pale brown to light grey loamy sand or sandy loam which is massive and hard. Small quartzitic gravel and concretions found in the A_1 horizon are present also in the A_2. The boundary with the B horizon is abrupt.

The B horizon ranges from 20 to 120 cm in thickness, but is commonly about 60 cm. The upper B horizon is a dark greyish-brown to greyish-brown sandy clay loam to sandy medium clay. It has yellowish-brown and lesser yellowish-red and reddish-brown mottles which are small and reticulate. The soil is extremely hard when dry. Structure is generally coarse prismatic but columnar structure was observed at a few sites—the diameter of the structural units varying from 5 to 25 cm. With depth a gradual change occurs to brown or greyish-brown mottled sandy loam to sandy clay. Consistence is very hard or extremely hard when dry. Structure is coarser than in the upper B and may be massive. Calcium carbonate concretions usually occur. A thin BC horizon (10 cm) with soft weathered granite and clayey material grades to the underlying rock.

Principal profile forms recognized were Dy3·43, Dy3·33, and Dy2·43.

The granite influence is evident in all soils by the presence of the coarse sand particles throughout and by the weathered granite lower in the soil profiles.

TABLE 1

ANALYTICAL DATA FOR SOILS REPRESENTATIVE OF THE MAJOR SOILS DEVELOPED ON THE FORSAYTH GRANITE

Great Soil Groups	Principal Profile Form	Horizon	Depth (cm)	pH	Available Phosphorus (p.p.m.)	Exchangeable Cations (m-equiv./100g)					Total N %	Org. C† %	Cl %	E.C.[2] (μ mhos/cm^{-1})
						Ca++	Mg++	Na+	K+	C.E.C.[1]				
Lithosol earthy sand intergrade	Uc 4·11	A_2	0–15	5·9	< 5	1·3	0·3	< 0·1	0·10	6	0·03	0·03	< 0·001	22
		A_1	15–35	5·8	< 5	1·3	0·2	< 0·1	0·11	8			< 0·001	12
Earthy sand ..	Uc 5·23	A	0–15	5·8	< 5	1·2	0·3	< 0·1	0·16	3	0·02	0·24	< 0·001	13
			15–35	5·0	< 5	0·7	0·3	< 0·1	0·14	6			0·002	35
		B	35–55	5·7	< 5	0·4	0·4	0·1	0·11	4			< 0·001	10
		BC	55–90	5·7	< 5	1·1	0·85	0·2	0·11	7			< 0·001	10
			90–110	5·9	< 5	2·5	1·6	0·8	0·08	9			0·001	12
Soloth-podzolic intergrade	Dy 3·21	A_1	0–15	5·6	8	1·4	0·4	< 0·1	0·14	4	0·03	0·27	< 0·001	14
		A_2	20–50	5·6	< 5	1·2	0·2	0·75	0·10	4			< 0·001	12
		B	60–80	6·0	< 5	2·0	1·6	0·75	0·09	8			< 0·001	18
		BC	80–90	6·1	9	2·1	2·1	0·6	0·13	10			0·001	17
Soloth	Dy 3·21	A	0–20	6·0	< 5	1·3	0·5	0·2	0·10	3	0·02	0·18	< 0·001	12
			20–55	5·3	< 5	0·5	0·7	0·2	0·10	3			< 0·001	14
		B	55–70	5·4	< 5	0·7	2·5	1·3	0·05	9			< 0·001	23
			70–85	5·4	< 5	2·2	6·0	2·5	0·17	14			0·005	21
		C	85–120	5·9	< 5	1·8	6·0	1·9	0·11	16			0·002	21
Solodic and solodized solonetz soils	Dy 3·43	A_1	0–19	5·5	< 5 (2)*	0·7	0·4	0·1	0·09	4	0·02	0·21	< 0·001	14
		B	19–32	7·8	< 5 (2)	1·4	1·1	3·4	0·09	9			< 0·001	60
			32–60	9·2	14 (6)	3·8	2·1	5·4	0·15	13			0·01	230
			60–90	9·3	20 (16)	5·4	2·9	4·0	0·19	16			0·01	200
		BC	90–120	9·1	100 (2)	6·3	1·7	6·0	0·18	15			0·01	230
		C	120–135	9·1	60 (6)	6·1	2·7	4·2	0·13	13			0·01	230

[1] C.E.C. Cation Exchange Capacity. [2] E.C. Electrical Conductivity, of 1:5 Soil:Water Suspension. † Walkley-Black Values Uncorrected.
* Extracted with $NaHCO_3$. m-equiv./100g = milli-equivalents per 100g soil

(b) Chemical properties of the soils

Analytical data for representative profiles are shown in table 1 while chemical characteristics of a larger number of surface soils are listed in table 2.

TABLE 2

CHEMICAL CHARACTERISTICS, WITH STANDARD DEVIATIONS (SD) AND COEFFICIENTS OF VARIATION (CV) FOR THE SURFACE (0–15CM) OF MAJOR SOILS

Determination	No.	Mean	Range of Site Values	Among SD	Sites CV
Phosphorus (p.p.m.)					
Lithosols	11	5	3–9	2·1	42
Earthy sands	7	4	3–5	1·1	28
Podzolics—soloths and solodic soil intergrades	12	7	5–14	2·6	37
Solodics	10	6	5–14	2·9	47
Nitrogen (%)					
Lithosols	11	0·03	0·03–0·05	0·01	20
Earthy sands	7	0·03	0·02–0·04	0·01	29
Podzolics—soloths and solodic soil intergrades	12	0·04	0·02–0·05	0·01	25
Solodics	10	0·04	0·01–0·05	0·01	39
Organic carbon (%)					
Lithosols	11	0·31	0·18–0·51	0·11	35
Earthy sands	7	0·24	0·18–0·33	0·05	22
Podzolics—soloths and solodic soil intergrades	12	0·27	0·12–0·47	0·11	39
Solodics	9	0·27	0·05–0·42	0·13	46
C : N ratio					
Lithosols	11	10	4–16	3·9	41
Earthy sands	7	8	5–12	3·0	35
Podzolics—soloths and solodic soil intergrades	12	8	3–14	2·9	37
Solodics	9	8	2–14	3·6	46
C.E.C. m-equiv./100g.					
Lithosols	11	1·7	1–2	0·5	27
Earthy sands	7	2·4	2–3	0·5	22
Podzolics—soloths and solodic soil intergrades	12	2·3	1–4	1·0	42
Solodics	8	1·8	1–3	0·9	51

(i) pH AND EXCHANGEABLE CATIONS. All soils are acid in the surface. Median values (and range) for pH of surface soils for the four soil groups are: lithosol-earthy sand intergrades 5·5 (5·1–5·9); earthy sands 5·8 (5·2–6·0); podzolics, soloths and solodic soil intergrades 5·5 (5·1–6·0); and solodic and solodized-solonetz soils 5·6 (5·4–6·0). The four groups appear to be similar in soil pH at the surface. The lithosol-earthy sand intergrades and the earthy sands are acid throughout with little change in pH with depth. The podzolics and soloths are similar but other soils associated with that group do have alkaline and neutral reaction trends. The solodic and solodized-solonetz soils are all alkaline in the B horizon.

The data for surface soils of the profiles (table 1) show low values for all cations and cation exchange capacity is also very low. The exchangeable potassium levels for all the soils are below 0·2 m-equiv./100 g which is widely accepted as a threshold value (Williams and Lipsett 1960; Piper and de Vries 1960). Exchangeable sodium percentages of the B horizon of the Dy3·43 soil are extremely high while those for the Dy3·21 soil (table 1) are high. Exchangeable sodium in subsoils is low for the lithosols and earthy sands.

(ii) PHOSPHORUS, NITROGEN AND ORGANIC CARBON. Available phosphorus levels in all surface soils are very low at all sites (tables 1 and 2). High values for weak acid extractable phosphorus are shown for the lower B, BC, and C horizon of the solodized-solonetz (table 1). However, sodium bicarbonate extractable phosphorus of these alkaline samples is low suggesting a low level of plant available phosphorus in subsoils.

Organic carbon and total nitrogen levels are very low for all surface soils.

V. DISCUSSION

Profile descriptions demonstrate the morphological differences in the major soils which were found in the catena. The most complex are the podzolic-soloth and solodic soil intergrades which occur on the mid and lower slope positions.

The analytical data in tables 1 and 2 indicate that, in the surface, all soils of the four groups have very similar values in pH, available phosphorus, total nitrogen, organic carbon, and exchangeable cations. All of the attributes are uniformly low. The soil groups differ markedly in some characters only at depth. The solodic soil (table 1) and the soloth and soloth-podzolic intergrade have higher exchangeable cation values than occur in the sands. The soluble salt levels in the solodic soil are also markedly higher than those in the other soils. However, they are not of the order where plant growth would be restricted.

Although variability in phosphorus is high, all values are in the low range and an overall deficiency is indicated. Variability in organic carbon values is moderately high while that for nitrogen is moderately low. Nitrogen values are similar to those quoted by Isbell and Gillman (1973) for deep sandy soils in Cape York Peninsula. C:N ratios are not high and even after allowing for a factor of 1·3 are much lower than those listed by Isbell and Gillman (1973).

The soils have several adverse physical properties. Surface soils are massive and light textured and are not well suited to moisture penetration and storage. The solodic soils have a very hard setting surface and a dense clay B horizon which would cause low infiltration rates, impedance of downward water movement and possibly restricted root penetration. The lithosol-earthy sand intergrades and the earthy sands are coarse textured throughout and have poor moisture storage. The sandy surfaced texture-contrast soils are able to store slightly more moisture in the weakly developed or thin B horizons, but suffer from some of the adverse physical properties of both the earthy sands and the solodic soils.

VI. CONCLUSIONS

All the attributes described above indicate that the four major soils developed on the Forsayth Granite have a low level of fertility.

Analytical data suggest that all soils are critically deficient in phosphorus and may be deficient in potassium.

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APPENDIX 1

PROFILE DESCRIPTIONS OF FOUR MAJOR SOILS

Principal profile form ..	Uc4.11
Soil Group	Lithosol—earthy sand
0–15 cm	Brown loamy sand (10YR 5/2·5 dry, 4/3 moist)—massive, slightly hard, with some small angular quartzitic gravel. A clear change occurs to—
15–42 cm	brown loamy coarse sand (10YR 6/4d, 5/4m)—massive, hard, with some small angular quartzitic gravel. A clear change to—
42–65 cm	dark yellowish brown loamy sand (10YR 5/3·5d, 4/3·5m)—massive, very hard, with decomposing granite

Principal profile form ..	Uc5.23
Soil Group	Earthy sand
0–15 cm	Brown loamy sand (10YR 5/3d, 4/3m)—massive, slightly hard. A clear change occurs to—
15–55 cm	yellowish brown loamy coarse sand (10YR 6/5d, 5/5m)—massive, hard, with some quartzitic gravel (12mm). A gradual change occurs to—
55–90 cm	yellowish brown loamy coarse sand (10YR 6/3·5d, 5/3·5m) with small yellowish red mottle (5YR 4/6m)—massive, very hard, with some quartzitic gravel (< 12mm). A clear change occurs to—
90–110 cm	yellowish brown loamy sand (10YR 5/3·5m)—massive, very hard, with decomposing granite

Principal profile form ..	Dy3.21
Soil Group	Podzolic
Hard setting surface	
0–20 cm	Brown loamy sand (10YR 5/3d, 4/3m)—massive, slightly hard. A clear change occurs to—
20–55 cm	yellowish brown loamy coarse sand (10YR 6/4d, 5/5m)—massive, hard, with some small ironstone concretions (6mm) and angular quartzitic gravel (12mm). An abrupt change occurs to—
55–85 cm	pale brown sandy clay loam (10YR 5/3m) with a red mottle (2·5YR 4/6m), weak blocky, hard to very hard. A clear change occurs to—
85–120 cm	yellowish brown sandy clay loam (10YR 5/6m) with small red mottle (2·5YR 4/6m)—structured, very hard, with some decomposed granite
	pH at 90 cm. 6·0

Principal profile form ..	Dy3.43
Soil Group	Solodic and solodized-solonetz soils
Hard setting surface	
0–10 cm	Dark greyish brown loamy sand (10YR 5/2·5d, 4/2m)—massive, slightly hard; a few small ironstone concretions in the lower part. An abrupt change occurs to—
10–20 cm	pale brown coarse sand (10YR 7/2d, 6/3m)—massive, very hard. An abrupt change occurs to—
20–60 cm	dark greyish brown sandy clay (10YR 5/2d, 4·5/2m) with small yellowish brown mottle (10YR 5/6m), prismatic, breaking into blocky, extremely hard, gradual change to—
60–120 cm	dark brown sandy clay (10YR 5/2·5m) with dark yellowish brown mottle (10YR 4/5m), coarse blocky to massive, extremely hard, with some angular quartzitic gravel and soft carbonate. A gradual change occurs to—
120–135 cm	greyish brown sandy loam (10YR 4·5/2m)—massive, very hard, with decomposed granite.
	pH at 120 cm 8·7.

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