

STUDIES ON CEYLON SOILS

V.—SOILS ASSOCIATED WITH LIMESTONE

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C EYLON soils associated with limestones are of two classes: those derived from Miocene limestone deposits, such as are to be found in the Jaffna Peninsula, and those which overlie the crystalline limestones, mainly dolomitic, as in the Nalanda district. Both groups of soils have however, several features in common, the characteristic brick red to brown colour of the majority of them and their high exchangeable base contents compared with those of other Ceylon soil groups, being the most marked. The red soils bear a close resemblance to the *terra rosa* of the Mediterranean and other limestone regions of the world. The soils vary in texture from loams to clay loams. Despite their heavy nature, they are free-working and well-drained. This is because of their high available lime contents which tend towards the development of a fine granular structure in the soils. The soils are deep and are neutral to alkaline in reaction. Free carbonate of lime is often absent or present only in small quantities. Organic matter is generally low in these soils and is their main requirement. The soils are suitable for the cultivation of a variety of crops, both arable and wet land. Thus in the Jaffna Peninsula where topographic conditions are favourable, the heavier loams are cropped with wet-land paddy during the rainy season and with arable crops during the rest of the year. These soils have a rather different profile to that of the solely arable soils, but their chemical characteristics are similar. The nearest approach to the *rendzina* group of limestone soils are the grey soils of the Island of Kayts, containing a reserve of free calcium carbonate in the shape of limestone concretions and other marine deposits. These soils are mainly cultivated with paddy.

The crops found most suitable for cultivation on the red soils are tobacco, grains and pulses, vegetables and fruits. The quality of the food products grown on these soils is very good.

Rainfall and elevation conditions of the sedimentary limestone soil areas are very different to those obtaining in the crystalline limestone districts. In the Jaffna Peninsula and the adjoining mainland the average annual precipitation is only about 50 inches, the greater part falling in the North-East monsoon. In the Matale and Nalanda districts, the rainfall is much higher — from 80 to 90 inches — and the distribution is more even. The elevation of the latter districts is also much higher. The average annual temperature of Jaffna is 81°F. while that of the Matale-Nalanda area is about 78°F. The Matale and Nalanda districts, particularly the former, are therefore suited for the growing of crops like cacao, rubber and coconuts.

In this paper six typical limestone soil profiles will be discussed, four being of the Jaffna group and two of the Nalanda class. The former comprise purely arable or paddy land, and arable — wet-land profiles. For the sake of convenience the analytical data are shown in two tables, table I for the Jaffna group and table II for the Nalanda group.

1. THE RED LOAMS (JAFFNA GROUP)

Location	...	Tinnevely Farm, about 3 miles from Jaffna.
Elevation	...	11 ft. (approx.)
Climate	...	Rainfall about 50 in.; temperature 81°F.
Geological origin	...	Miocene sedimentary limestone.
Mode of formation	...	Transported: alluvial.
Topographic position	...	Level.
Drainage	...	Very good.
Vegetation	...	Tobacco and garden crops.

PROFILE

- A1. 0-1 ft. Brick red uniform loam; fine granular; hard when dry but friable; fairly compact; no concretionary material or gravel; roots abundant; alkaline; horizon boundary indistinct.

C. 1 ft.-4 ft. Same as A1 only soil more compact and roots not so abundant. Small percentage of limestone concretionary material.

TABLE 1
THE JAFFNA GROUP
Mechanical Analysis

	<i>Tinnevely</i>		<i>Chunnakam</i>		<i>Pandatarippu</i>		<i>Kayts</i>
	A	AC	AC	A	C1	C2	A
	%	%	%	%	%	%	%
Stones and gravel	—	1.9	—	—	5.3	6.4	4.6
Coarse sand	35.4	22.9	17.7	14.3	15.4	13.3	18.2
Fine sand	31.2	21.8	27.6	25.3	23.9	20.1	45.4
Silt	3.4	4.3	6.4	5.7	5.5	6.4	4.3
Clay	26.2	41.7	39.7	44.8	43.8	47.7	26.5
Loss by solution	0.9	2.0	2.2	2.4	1.5	1.7	1.4
Moisture	2.9	7.3	6.4	7.5	9.9	10.8	4.2
Sticky point moisture	15.3	24.4	22.7	29.9	32.4	34.7	22.9
Texture index number	24.2	38.2	36.6	41.1	40.2	43.9	24.7
Soil type	Loam	Heavy Loam	Heavy Loam	Clay Loam	Clay Loam	Clay Loam	Loam

Chemical Analysis

Loss on ignition	5.22	12.80	13.2	15.10	16.25	17.32	8.16
Organic matter	0.77	0.57	2.44	2.03	0.61	0.34	1.52
Combined water	4.45	12.23	11.58	13.07	15.64	16.98	6.04
Carbon	0.45	0.33	0.84	1.18	0.44	0.20	0.88
Nitrogen	0.057	0.052	0.102	0.125	0.051	0.025	0.085
Carbon/nitrogen ratio	7.8	6.4	8.82	9.5	8.6	8.1	10.3
Calcium carbonate	—	—	0.07	—	—	—	0.10
Reaction	8.0	7.8	8.3	7.8	8.2	8.4	8.3
Total exchangeable bases (m.e. per 100 gm soil)	9.88	11.16	16.64	25.01	22.57	21.05	19.62
Exchangeable calcium	7.92	9.02	13.29	20.09	17.16	16.96	15.00
Total lime	0.251	0.311	0.528	0.676	0.507	—	0.595
„ potash	0.310	0.433	0.321	0.557	0.533	—	0.605
„ phosphoric acid	0.115	0.153	0.154	0.107	0.146	—	0.119

Clay Analysis

Loss on ignition	17.21	—	17.81	19.31	—	—	18.31
Silica (SiO ₂)	44.10	—	43.94	47.56	—	—	49.78
Sesquioxides (R ₂ O ₃)	53.18	—	52.78	44.34	—	—	40.16
Alumina (Al ₂ O ₃)	38.90	—	35.03	32.38	—	—	28.77
Iron oxides (Fe ₂ O ₃)	14.28	—	17.75	11.96	—	—	11.39
SiO ₂ /Al ₂ O ₃ (molecular)	1.93	—	2.13	2.49	—	—	2.93
SiO ₂ /R ₂ O ₃ „	1.56	—	1.61	2.01	—	—	2.34
Soil type	Non-lateritic to lateritic	—	Non-lateritic	Non-lateritic	—	—	Non-lateritic

ANALYTICAL DATA AND DISCUSSION

An examination of table I will indicate that these soils are heavy loams, the lower horizon being distinctly heavier in texture than the upper soil layer. The structure of the soil is however fine granular and gives the soil an appearance of being lighter than what it actually is. The sticky point moisture contents for soils of this texture are low, and there is a marked divergence between the texture index number as determined by the mechanical composition ⁽³⁾ and Hardy's texture index. The organic matter contents of the soils are very low and so are the nitrogen contents. Organic matter is essential for good crop yields on these soils and this is well realised by the Jaffna cultivator. The soils are devoid of free calcium carbonate but contain fairly high exchangeable base contents. Calcium constitutes about 80 per cent. of the bases. In reaction they are alkaline. Total lime, phosphoric acid and potash contents are very light, the lower horizon being higher in these constituents than the upper. The clay analysis of the A horizon shows that the soil is on the borderline between the non-lateritic and lateritic types. For all practical purposes the soil may however be considered to be non-lateritic. The iron content is fairly high when compared with those of the grey and brown soils.

2. THE RED HEAVY LOAMS (JAFFNA GROUP)

Location	...	Chunnakam, 6 miles from Jaffna.
Elevation	...	11 ft. (approx.)
Climate	...	Rainfall about 50 in.; temperature 81°F.
Geological origin	...	Miocene sedimentary limestone.
Mode of formation	...	Transported: alluvial.
Topographic position	...	Level.
Drainage	...	Very good.
Vegetation	...	Tobacco and garden crops.

PROFILE

AC. 0-4 ft. Deep brick red heavy loam; small clod to granular structure; hard but friable; compact; alkaline; root growth good; no horizon boundaries distinguishable.

ANALYTICAL DATA AND DISCUSSION

The soil is a uniform textured and coloured clay loam very similar in texture and physical characteristics to the C horizon

of the Tinnevely soil. The organic matter and nitrogen contents of this soil are however about twice as much as those of the latter soils. Like these soils, the heavy loam soils is alkaline in reaction, but it contains in addition a small reserve of free calcuim carbonate. Its total exchangeable base content is high (16.6 mgm. equivalents), calcium forming again about 80 per cent. of the total. The soil is particularly rich in lime, but its phosphoric acid and potash contents are also quite high. The clay analysis reveals an alumina content of 35 per cent., an iron oxide content of 17.7 per cent. (the deeper red colour of this soil being apparently due to this fact) and a silica percentage of 44. On the basis of the silica/alumina molecular ratio, the soil is distinctly of the non-lateritic type. The Chunnakam soil and the Tinnevely soil are good examples of soil types belonging to the same soil series — the Tinnevely soil being a loam and the other a heavy loam.

3. THE BROWN CLAY LOAMS (JAFFNA GROUP)

Location	... Pandatarippu, about 8 miles from Jaffna.
Elevation	... About sea level.
Climate	... Rainfall 50 in.; temperature 81°F.
Geological origin	... Miocene sedimentary limestone.
Mode of formation	... Alluvial.
Topographic position	... Flat, the level of the soil being about 4 feet below that of the road.
Drainage	... Imperfect during wet weather.
Vegetation	... Paddy alternating with tobacco and other rotation crops.

PROFILE

- A. 0-8 in. Dark-grey brown clay loam; irregular clod to columnar; compact; hard but fairly friable; root growth good; horizon boundary distinct.
- C1. 8-15 in. Yellowish-brown clay loam; nodular to small clod; occasional nodules of ferruginous limestone concretions present; hard and compact; roots absent; alkaline; horizon boundary fairly distinct.
- C2. 15 in.-3 ft. Brownish-yellow clay loam; nodules of blackish brown ferruginous limestone concretions fairly abundant; small clod; compact and hard; roots absent; alkaline.

ANALYTICAL DATA AND DISCUSSION

The mechanical analyses show that these soils are clay loams, ideally suited for paddy. The different horizons are of the same textural class, but the C1 and C2 horizons are slightly heavier. The combined water contents are fairly high. The organic matter and nitrogen contents of the A horizon are fairly high when compared with those of most Jaffna soils, but the C1 and C2 horizons are very poor in these constituents. The soils are alkaline in reaction, the alkalinity increasing slightly with depth. The exchangeable base contents are very high, being about the highest so far found in local soils. Calcium forms about 80 per cent. of these bases, as is to be expected. The soils are very rich in mineral plant nutrients, particularly potash and lime. The clay analysis reveals an iron oxide content of only 12 per cent. an alumina content of 32.4 per cent. and silica of 47.6 per cent. The soil is therefore, on the silica/alumina molecular ratio, which in this instance is 2.5, non-lateritic in nature. The brown and yellow colours of this soil are probably associated with its comparatively low iron oxide content and periodical imperfect drainage.

4. THE GREY CALCAREOUS LOAMS (JAFFNA GROUP)

Location	...	The Island of Kayts.
Elevation	...	Slightly above sea level.
Climate	...	Rainfall 45 in.; temperature 81°F.
Geological origin	...	Miocene sedimentary limestone.
Mode of formation	...	Alluvial.
Topographic position	...	Flat.
Drainage	...	Poor.
Vegetation	...	Paddy.

PROFILE

- A. 0-8 in. Grey heavy loam; blackish scum on surface; fair quantities of limestone concretions; crumb to fine granular structure; hard but friable; root growth good; horizon layer distinct.
- C. Conglomerate of lime and concretionary material.

ANALYTICAL DATA AND DISCUSSION

The table would indicate that the soil is a loam, with fairly low organic matter and nitrogen contents. Free calcium carbonate is present as nodular concretions of diameter larger than

1 cm. The latter are separated from the soil proper in the process of sieving. Calcium carbonate existing in intimate combination with the soil occurs only to an extent of 0.1 per cent. The soil is alkaline in reaction, well supplied with exchangeable bases, mainly calcium, and very rich in total lime and potash, particularly the latter. Its phosphoric acid content is also high. The clay fraction on analysis shows 50 per cent. silica, 28.8 per cent. alumina and only 11.4 per cent. iron. The silica/alumina molecular ratio is as high as 2.9, which places the soil definitely in the non-lateritic class. This type of soil is in the closest approach locally to the *rendzinas* of other limestone areas of the world.

5. THE RED LOAMS (NALANDA GROUP)

Location	...	Nalanda Experiment Station.
Elevation	...	About 850 ft.
Climate	...	Rainfall: 85 in. (approx.); temperature 78°F.
Geological origin	...	Crystalline limestone; largely dolomitic.
Mode of formation	...	Residual.
Topographic position	...	Hilly to flat; sample taken from a level field.
Drainage	...	Good.
Vegetation	...	Tobacco, citrus, etc.

PROFILE

- A1. 0-15 in. Chocolate-brown loam; few small ferruginous concretions and stones; coarse granular to small irregular columnar; hard but friable; compact; good root growth; neutral; horizon boundary indistinct.
- A2. 15-30 in. Similar to A1 but colour deeper chocolate red and concretions and gravel in slightly higher proportions.
- C. 30-54 in. Red clay loam; low columnar to lenticular; hard and fairly friable; very compact; no root growth observed; neutral.

TABLE II
THE NALANDA GROUP

Mechanical Analysis

	<i>Nalanda</i>		<i>Nalanda-Dambulla</i>	
	A1	A2	C	AC
Stones and gravel	%	%	%	%
	2.2	4.2	—	—
Coarse sand	32.9	29.8	21.5	25.2
Fine sand	33.6	28.9	27.7	21.7
Silt	5.1	4.8	4.2	4.8
Clay	25.0	32.8	43.9	42.4
Loss by solution	1.5	1.4	0.5	1.8
Moisture	1.9	2.3	2.2	4.1
Sticky point moisture	19.0	20.1	21.7	28.2
Texture index number	23.3	29.5	40.1	38.7
Soil type	Loam	Loam	Clay Loam	Heavy Loam

Chemical Analysis

Loss on ignition	4.65	5.31	5.27	8.73
Organic matter	2.07	1.14	.87	3.33
Combined water	2.58	4.17	4.40	5.40
Carbon	1.20	.66	.51	1.93
Nitrogen	0.123	0.076	.073	.235
Carbon/nitrogen ratio	9.7	8.6	7.0	8.2
Calcium carbonate	—	—	—	.163
Reaction	7.0	6.9	6.9	7.2
Total exchangeable bases (m.e. per 100 gm. soil)	10.56	9.12	8.40	25.92
Exchangeable calcium	6.53	5.68	4.98	15.84
Total lime	.352	.258	—	.582
„ potash	.187	.198	—	.269
„ phosphoric acid	.087	.086	—	.166

Clay Analysis

Loss on ignition	20.50	—	—	21.56
Silica (SiO ₂)	44.14	—	—	44.42
Sesquioxides (R ₂ O ₃)	51.26	—	—	50.48
Alumina (Al ₂ O ₃)	31.97	—	—	31.77
Iron oxides (Fe ₂ O ₃)	19.29	—	—	18.71
SiO ₂ /Al ₂ O ₃ (molecular)	2.34	—	—	2.37
SiO ₂ /R ₂ O ₃ „	1.69	—	—	1.72
Soil type	Non-lateritic	—	—	Non-lateritic

ANALYTICAL DATA AND DISCUSSION

The soils of this profile are chocolate red to terra cotta red loamy to clay loam soils, with no apparent horizon boundaries. Ferruginous concretions occur in the A1 and A2 horizons only to the extent of 2 to 4 per cent. In hilly areas the soils contain a very high percentage of ferruginous nodules and boulders. These soils overlie the limestone rock, which is often several feet below the surface. The analyses reveal a wide divergence between the texture index number and Hardy's texture index in this group of soils as well. The combined water content for soils of this textural class are exceptionally low. The organic matter and nitrogen contents are fair in the A1 horizon but poor in the others. The soils contain no free calcium carbonate, are neutral in reaction and fairly rich in replaceable bases. Calcium constitutes only about 60 per cent. of these bases. This is as is to be expected considering that the limestone rock from which the soil is derived is largely dolomitic. The total lime and potash contents are high, but not as high as those of the Jaffna group of limestone soils. The silica/alumina molecular ratio of the clay fraction is 2.3, indicating that the soil is definitely non-lateritic in nature.

6. THE CHOCOLATE RED HEAVY LOAMS (NALANDA GROUP)

Location	... 3 miles from Nalanda on the Nalanda-Dambulla road.
Elevation	... About 700 ft.
Climate	... 75 in. (approx.); temperature 78°F.
Geological origin	... Crystalline limestone, largely dolomitic.
Mode of formation	... Residual.
Topographic position	... Undulating; sample from crest of a low hillock.
Drainage	... Very good.
Vegetation	... Grasses and shrubs.

PROFILE

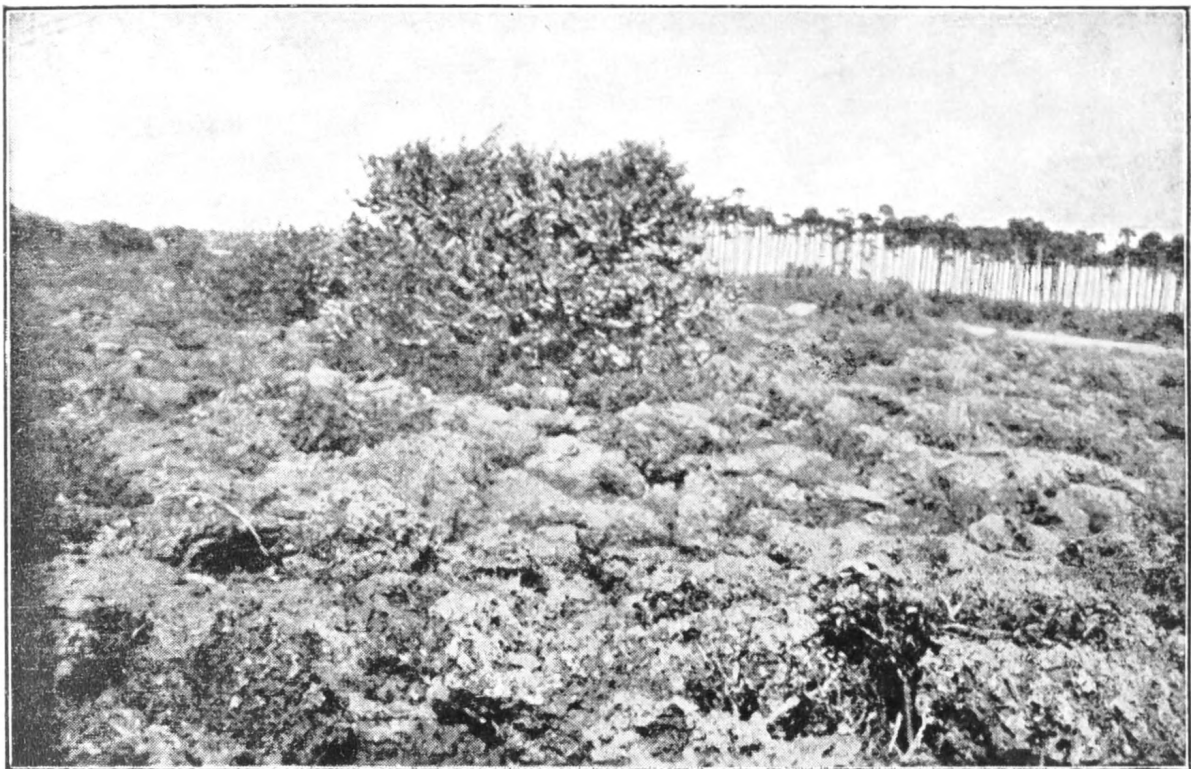
- A. 0-2 ft. Uniform chocolate-red heavy loam; columnar to prismatic; hard but friable; porous; alkaline; root growth good.
- C. > 2 ft. White crystalline limestone.

ANALYTICAL DATA AND DISCUSSION

This soil is a heavy loam but with a low combined water content. Similar soils of uniform colour and structure showing no horizon delimitations and extending to several feet in depth, occur largely over the area. The soil directly overlies the parent rock. It has a good reserve of organic matter and is rich in nitrogen. The carbon/nitrogen ratio is 8.2 and varies from about 7 to 10 in soils of this group. In reaction the soil is on the alkaline side of neutral. Its replaceable base content is very high (25.9 mgm. equivalents). Calcium comprises only about 60 per cent. of these bases for the reason already explained. Replaceable magnesium will doubtless constitute a comparatively high percentage of the total. The soil is rich in total lime and potash and also in phosphoric acid. The analysis of the clay fraction shows an iron oxide content of 18.7 per cent., alumina of 31.8 per cent. and silica of 44.4 per cent. The silica/alumina molecular ratio is 2.37 indicating that the soil is definitely non-lateritic in type.

GENERAL DISCUSSION AND CONCLUSION

An examination of the analytical and profile data of these soils as a whole indicate that, except for the Kayts grey loam and Pandatarippu grey brown loam, they are of a similar nature to the red limestone soils of Barbados described by Saint ⁽¹⁾ and others referred to by Robinson ⁽²⁾ as *terra rossa*. The clay fractions of the red soils have lower silica/alumina molecular ratios and higher iron oxide contents than those of the grey soils. The red soils generally occur where the soils are at a higher level and well-drained; the grey soils at lower levels and under imperfectly drained conditions. Local soils have however, for some reason yet to be discovered, low sticky point and combined moisture contents. The index of texture, as calculated from Hardy's formula, shows therefore a wide divergence from the texture index number as determined by calculation from the mechanical composition. On the former basis the soils would be considered to be much lighter textured than on the latter. The textural type is therefore designated according to Charlton's texture index number ⁽³⁾ modified to conform to the present international scale of soil particle size. The grey and brown grey loams of Kayts and Pandatarippu, especially the former, may be considered to be the local *rendzinas*. The red soils of the



Photo

W. R. C. Paul

Showing the nature of the vegetation on an outcrop of sedimentary limestone at Puttur, Jaffna Peninsula

Nalanda district overlying crystalline limestone are generally similar to the Jaffna red limestone soils, except in regard to their higher organic matter contents and silica/alumina ratios of the clay fraction, and lower percentages of exchangeable calcium. The illustration accompanying this paper will give an idea of the nature of the vegetation and the topography of an outcrop of sedimentary limestone in the Jaffna Peninsula.

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