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Road Research Laboratory

A LABORATORY INVESTIGATION OF 158 SAMPLES

OF SUBSOIL FROM NORTHERN BORNEO

by

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SUMMARY

This note describes a laboratory examination of 158 samples of subsoil which were taken during a reconnaissance survey of Northern Borneo.

The soil samples represented many of the principal soil groups of Northern Borneo and the aims of the investigation were to determine the soil classification properties of the groups and the differences in properties within the groups. Soil profile samples were also examined to determine variations in physical properties with depth.

The classification tests comprised particle-size analyses and liquid and plastic limit tests. The results showed that:-

(i) The soil classification properties of the different groups studied confirmed the grouping of the soils based on information obtained during the survey.

(ii) The soil samples from the east coast of North Borneo generally had higher clay contents than those from the west coast.

(iii) The chocolate coloured "Cocoa" soils of the Tawau area in North Borneo, which were formed from basaltic lavas, had liquid and plastic limits and activity values similar to those of the volcanic red clays of Kenya. X-ray analysis showed that the predominant clay mineral was halloysite, which was also present in the Kenya red clays.

(iv) For the soil profiles examined the clay contents generally increased to a depth of 5 feet. This was probably caused by the high rainfall in Borneo which results in water carrying the clay particles down into the subsoil. The increase in clay content with depth was particularly marked for the humus podzol profiles. Below 5 feet the clay content generally decreased.



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Introduction

In September 1960 Messrs. Clare and Beaven of the Road Research Laboratory visited North Borneo, Sarawak and Brunei to make a reconnaissance survey of soils and roadmaking materials. During the survey 158 samples of soil and aggregate were taken for detailed examination at the Road Research Laboratory; 62 of the samples were from North Borneo, 84 from Sarawak and 12 from Brunei. The samples were representative of some of the principal soil groups of northern Borneo, the groups being tentatively divided on a morphological basis.

The aims of the laboratory investigation were:-

- (i) to determine the soil classification properties of the soils.
- (ii) to discover as far as possible the mode of formation of the soils.
- (iii) to determine the suitability of the soils for use in bases for roads, including stabilization with cement.

This report deals with the first part of the investigation, and describes the classification tests carried out on the soils. The tests comprised particle-size analyses and the liquid and plastic limit tests, and from the results it was also possible to obtain an indication of the variation of properties within the soil groups.

The locations of the soil samples

The locations from which the soil samples were taken are given in Tables 1-5; and are shown on the maps of North Borneo, Sarawak and Brunei in Figs 1 and 2. In a number of instances the samples were taken in a vertical sequence in cuttings, and represent soil profiles.

The classification of the soils

The soil samples belonged to the following groups of soils which have been recognised during and subsequent to the field survey work:-

- (i) Yellow or yellow-red sandy clays or silty clays developed from sandstone and shale. (Yellow/red latosols or yellow podsollic soils).
- (ii) Residual soils formed from igneous rocks. This group includes soils from the Tawau area of North Borneo formed from basaltic lavas and volcanic ashes and tuffs. Also included are soils from Sarawak with granite and andesite as the parent rocks.
- (iii) Detrital soils ("lithosols") formed by the break-up of shales and sandstones.
- (iv) Humus podzols, which are white sands known locally as "Kerangas"* soils.
- (v) Beach sands, alluvial soils and hydromorphic soils.

/Laboratory tests

* "Kerangas" is an Iban word referring to heavily leached gravels, sands or light soils on which rice can not be grown.

Laboratory tests

The laboratory tests carried out to classify the soils were:-

- (a) Particle-size analyses.
- (b) Liquid and plastic limit tests.

Rainfall in Borneo is high and leaching is known to occur and as a result the physical characteristics of soils would be expected to vary with depth in the profile. To identify variations in these physical characteristics particle-size analyses of 60 of the profile samples were made. Coarse analyses of the samples were carried out by the method described in test 6B and fine analyses by test 6C B.S.1377:1961.⁽¹⁾

118 of the 158 samples were noticeably cohesive and the liquid limit and plastic limit tests were made to discover variations in texture with geographical distribution and to confirm any textural variations in the soil profiles. To determine the liquid limit the 'one-point' method was used as described in test 2B, B.S.1377:1961.⁽¹⁾

The results of the classification tests are given in Tables I-V.

Activities were calculated for samples where both clay content and plasticity index were determined to provide some indication of the mineralogy of the clay fraction. The activity values are given in Tables I-V.

The activity of a soil is defined as the plasticity index divided by the clay content expressed as a percentage of the soil fraction passing the B.S. No. 36 sieve.

Discussion of the results of the soil classification tests

The results of the particle-size analyses of the soil profile samples showed that generally the clay content increased with depth down to approximately 5 feet and that below this depth the clay content decreased. The clay contents and in some cases the plasticity indices of the soil profiles were plotted against depth and are shown in Fig. 3.

The results were consistent with the occurrence of two soil-forming processes; they were:-

(i) Weathering at the exposed surface which gives rise to a greater proportion of clay in the upper layers. The intensity of weathering decreases with depth and therefore the clay content would be expected to decrease. This is shown in the soil profile at Muara Tutong Road (2 ft-19ft) where the parent rock is known to be shale.

(ii) Leaching of clay downwards into the subsoil as a result of the high rainfall in northern Borneo. The increase in clay content with depth is most noticeable in the humus podzol profiles as would be expected in fairly well-drained soils. (see Table IV).

Amongst the humus podzol profiles the profile from mile 24, Brunei-Seria Road consisted of very uniform medium-fine sands with no clay present. (Fig. 4 and Table IV). The gradings of the sands were similar to those reported for this deposit by Wilford⁽²⁾ who noted that they were suitable for the manufacture of high-grade colourless glass.

The profile samples from Port Access Road, Kuching (2ft to 12 ft) showed a deposit of gravel at a depth of 4 feet (see Fig. 5).

/TABLE I

TABLE I

The results of classification tests on the sandy clays and silty clays
(Yellow/red latosols and yellow podsollic soils)

Sample No.	Location and depth		Colour	Texture	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification
					Gravel per cent	Sand per cent	Silt per cent	Clay per cent					
1374	Serian-Simanggang Road. Mile 4.5 Cutting		yellow-brown	clay	4	13	35	48	74	33	41	0.8	CH
1378	Serian-Simanggang Road. Mile 24 Cutting	5 ft	yellow	sandy clay					71	34	37		MH
1379	" "	9 ft	red-yellow	sandy clay					76	43	33		MH
1380	" "	13 ft	red-yellow	sandy clay					60	38	22		MH
1381	" "	17 ft	red-yellow	sandy clay					56	37	19		MH
1382	" "	21 ft	red-yellow	sandy clay					53	35	18		MH
1385	Bukit Lima, Sib. Borrow Pit		red	clay					79	36	43		MH
1389	Sarikei-Repok Road. Mile 4. Borrow Pit		brown	sandy clay					60	29	31		CH
1390	" " " "		red-white	sandy clay					45	29	16		MI
1391	Sarikei-Repok Road. Mile 2. Cutting.	3 ft	brown	sandy clay		39	35	26	34	22	12	0.4	CL
1392	" " " "	10 ft	red-white	silty clay		29	36	35	48	26	22	0.6	CI
1393	" " " "	15 ft	red-white	sandy clay	1	47	31	20	39	24	15	0.6	CI
1394	" " " "	20 ft	pint-white	sandy clay		34	40	26	38	24	14	0.5	CI
1395	" " " "	23 ft	brown	silty clay		39	45	16	35	23	12	0.8	CI
1397	Sarikei-Bulat Road. 3 miles from Repok junction. Cutting	3 ft	brown	clay					69	33	36		MH
1398	" " " "	8 ft	red-white-yellow	clay		4	41	55	101	42	59	1.0	CH
1401	Sarikei-Binatang Road. Kelupe		yellow	sandy clay		40	← 60 →						
1403	" " " "		orange-white	clay			62	38	72	41	31	0.8	MH
1404	" " " "		yellow-white	silty clay		11	54	35	45	33	12	0.3	MI
1407	Sibu-Ulu Oya Road. Mile 11		yellow	clayey sand					30	18	12		CL
1408	" " " " Mile 3		red-white	sandy clay					42	24	18		CI
1419	Miri-Berop Road. Mile 10.5	1 ft	yellow	sandy clay					37	21	16		CI
1420	" " " "	2 ft	yellow	sandy clay					44	21	23		CI
1421	" " " "	3 ft	yellow	sandy clay					49	23	26		CI
1422	" " " "	4 ft	yellow	sandy clay					49	23	26		CI
1424	Miri. Borrow Pit.	1 ft	orange	silty sand					non-plastic				
1425	" " " "	2 ft	orange	clayey sand					26	22	4		ML
1426	" " " "	3 ft	orange	clayey sand					27	24	3		ML
1427	" " " "	4 ft	yellow	clayey sand					24	23	1		ML
1428	" " " "	5 ft	yellow-white	clayey sand					24	21	3		ML
1429	Lubok-Nibong Puyut Road. Mile 10	2 ft	yellow	sandy clay					35	21	14		CI
1430	" " " "	4 ft	yellow	sandy clay					51	25	26		CH
1431	" " " "	5 ft	red-brown	sandy clay					49	26	23		CI
1457	Ranau Track. Mile 4		brown	clayey sand					62	28	34		CH
1458	" " Mile 6		red-yellow	clayey sand					41	26	15		MI
1459	" " Mile 6		yellow	clayey sand					50	27	23		CI
1460	" " Mile 6		light-brown	clayey sand					42	22	20		CI
1461	" " Mile 6		light-brown	clayey sand					38	20	18		CI
1462	Tuaran Waterworks		red-white	clayey sand					59	28	31		CH
1463	Sungei-Manilla Road	2 ft	yellow	silty clay					79	37	42		MH

/TABLE I (contd)

TABLE I (contd)

Sample No.	Location and depth	Colour	Texture	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification	
				Gravel per cent	Sand per cent	Silt per cent	Clay per cent						
1464	Sungei-Manilla Road	9 ft	North Borneo	brown-yellow					54	24	30		CH
1465	Labuk Road. Mile 30												
1466	Top of hill	1 ft	" "	yellow-orange		14	47	39	67	34	33	0.8	MH
1467	" " " "	2 ft	" "	brown		13	43	44	74	30	44	1.0	CH
1468	" " " "	3 ft	" "	brown		4	46	50	80	34	46	0.9	CH
1469	Labuk Road. Mile 30												
1469	Bottom of valley	1 ft	" "	brown-yellow		15	45	40	71	29	42	1.0	CH
1470	" " " "	2 ft	" "	brown-yellow		15	49	36	68	29	39	1.0	CH
1471	" " " "	3 ft	" "	brown-yellow		2	48	40	64	29	35	0.9	CH
1472	Labuk Road. Mile 30												
1472	Ridge crossing valley	1 ft	" "	brown-yellow		5	52	43	61	28	33	0.8	CH
1473	" " " "	2 ft	" "	brown-yellow		5	51	44	60	25	35	0.8	CH
1474	" " " "	3 ft	" "	brown-yellow		3	55	42	54	22	32	0.8	CH
1475	Labuk Road. Mile 27												
1475	Top of rise	9 in.	" "	brown-yellow					71	30	41		CH
1506	Labuk Road. Mile 27												
1506	Half way up hill		" "	brown-yellow					48	26	22		CI
1507	Lahad Datu		" "	red					86	39	47		MH
1508	Papar. Mile 9.25												
1508	Kimanis Road		" "	orange		40	← 60 →						
1512	Papar Quarry. Mile 5		" "	red-yellow-grey					65	29	36		CH
1513	Tenom Keningau Road, Baiaya series	<18 in.	" "	yellow-white					41	24	17		CI
1514	Tenom Keningau Road, Kapayan series. Mile 40	1 ft	" "	orange		27	← 73 →		39	20	19		CI
1515	" " " "	4 ft	" "	orange		30	← 70 →		41	20	21		CI
1516	Tenom Keningau Road, Settlement scheme feeder road. Mile 34		" "	light brown					23	19	4		CL
1517	" " " "		" "	orange					41	20	21		CI
1518	Koto Belud		" "	orange					47	23	24		CI
1445	" " " "		" "	yellow					44	24	20		CI
1445	Muara Tutong Road. Cutting	2 ft	Brunei	red					74	29	45		CH
1446	" " " "	5 ft	" "	red-grey					74	28	46		CH
1450	Sungei-Liangon-Seria Tutong Borrow Pit.		" "	yellow		63	20	17	33	19	14	0.8	CL
1375	Serian-Simanggang Road												
1375	Mile 36.5. Cutting	3 ft	Sarawak	white		30	50	20	50	29	21	1.0	MI
1376	" " " "	8 ft	" "	white		30	62	8	53	38	15	1.9	MH
1377	" " " "	12 ft	" "	white		32	60	8	56	40	16	2.0	MH

/TABLE II

TABLE II

The results of classification tests on the group of soils developed from igneous rocks

Sample No.	Location and depth	Country	Colour	Texture	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification
					Gravel per cent	Sand per cent	Silt per cent	Clay per cent					
1372	Serian-Simanggang Road. Mile 36.5. Cutting	Sarawak	yellow-red-white	silty clay	3	6	76	15	47	37	10	0.7	MI
1383	Sebuyau Quarry	"	brown-white	sandy clay	12	54	12	22	70	36	34	0.8	MH
1366	Kuching-Serian Road, Stebun Quarry	"	red-yellow	sandy clay	16	34	24	26	69	43	26	0.7	MH
1368	Cutting near Serian	"	brown-yellow	silty clay	5	21	56	18	66	46	20	1.0	MH
1491	Apas Road. Mile 21	North Borneo	yellow-white	clay					117	41	76		CH
1492	Apas Road. Cutting. 1ft 6in.	"	orange-yellow	clay					117	43	74		CH
1493	Apas Road. Cutting 3ft	"	orange-yellow	clay					121	45	76		CH
1501	Borneo Abaca Estate. Main pit	"	brown	sand	31	52	←17→		Non-plastic				
1486	Apas Road. Mile 21.5 3ft	"	brown	clay					86	34	52		CH
1487	" " " " 4ft 6in.	"	brown-yellow	clay					117	45	72		CH
1488	" " " " 6ft	"	orange-red	clay					121	49	72		MH
1489	Apas Road. Mile 21.5 + 50 yd.	"	yellow-red	clay					118	43	75		CH
1490	Apas Road. Mile 21	"	red	clay					129	49	80		CH
1495	Apas Road. Mile 8.5 Cutting 1ft 6in.	"	orange	clay					64	26	38		CH
1496	" " " " 2ft 6in.	"	red-yellow	clay					91	35	56		CH
1497	" " " " 4ft	"	grey-red	clay					97	38	59		CH
1498	" " " " 5ft 6in.	"	grey-red	clay					62	29	33		CH
1499	" " " " 6ft	"	grey-red	clay					104	40	66		CH
1500	" " " " 11ft	"	grey-red	clay					104	39	65		CH
1502	Merutai Estate. Near Tawau.	"	red	clay					136	48	88		CH
1482	Quoin Hill, Apas Road Mile 25 5ft	"	chocolate	clay					117	68	49		MH
1483	Quoin Hill, Apas Road Mile 25 7ft	"	chocolate	clay					106	70	36		MH
1484	Quoin Hill, Apas Road Mile 25 9ft	"	chocolate	clay					103	66	37		MH
1485	Apas Road 4ft	"	chocolate	clay					101	66	37		MH
1503	Tiger Estate, Tawau	"	chocolate	clay					112	53	59		MH
1504	Tiger Estate, Tawau	"	chocolate	clay					104	47	57		MH

/TABLE III

TABLE III

The results of classification tests on the lithosols (weathered shales and weathered sandstones)

Sample No.	Location and depth	Country	Colour	Texture	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification
					Gravel per cent	Sand per cent	Silt per cent	Clay per cent					
1476	Labuk Road. Mile 23 Cutting	North Borneo	light brown	weathered sandstone	2	38	← 60 →						
1399	Sarikei-Bulat Road, 5 miles from Repok junction	Sarawak	grey	weathered shale					35	23	12		CI
1400	Sarikei-Binatang Road. Kelupe	"	red	weathered ⁺ shale	(i)	24	55	21	61	42	19		MH
					(ii)	3	74	23					
1477	Labuk Road	North Borneo	black	weathered shale					51	19	32		CH
1478	" "	" "	black	" "					61	20	41		CH
1479	" "	" "	black	" "					60	25	35		CH
1480	" "	" "	black	" "									
1481	Batu Sapi track	" "	black	" "									
1447*	Muara-Tutong Road. Cutting	Brunei	black	" "					64	21	43		CH
1448	" " " 8ft	"	black	" "					50	20	30		CI
1449	" " " 14ft	"	black	" "					47	18	29		CI
1402	Sarikei-Binatang Road Kelupe	Sarawak	grey	weathered shale ⁺	(i)	18	67	15	43	18	15		MI
					(ii)	1	79	20					
1386	Bukit Lima, Sib. Borrow pit	"	grey	weathered shale					59	30	29		CH
1388	Sibu Waterworks, Borrow pit.	"	grey	" "					47	28	19		MI
1396	Sarikei-Bulat Road, Borrow pit. 1/4 mile from Repok junction	"	red	" "					50	34	16		MI

* Sample Nos 1445 and 1446 (see latosols) are part of this soil profile.

⁺ (i) Standard treatment.

(ii) Dispersion process repeated.

/TABLE IV

TABLE IV

The results of classification tests on the Humus podsol ("Kerangas") soils

Sample No.	Location and Depth	Country	Colour	Texture	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification
					Gravel per cent	Sand per cent	Silt per cent	Clay per cent					
1409	Sibu Airfield. Borrow pit 2ft	Sarawak	brown	sand	1	66	25	9					
1410	" " " " 4ft	"	brown	sand		61	24	14					
1411	" " " " 6ft	"	brown	sand		58	25	17					
1412	" " " " 8ft	"	white	sand		58	27	15					
1413	" " " " 10ft	"	white	sand		57	30	13					
1414	" " " " 12ft	"	white	sand	65	26	9						
1360	Port Access Road, Kuching 2ft	"	white	sand	60	← 40 →							
1361	" " " " 4ft	"	white	gravel sand	48	38	← 14 →						
1362	" " " " 6ft	"	white	sand	42	← 58 →							
1363	" " " " 8ft	"	white	sand	2	44	← 54 →						
1452	Brunei-Seria Road. Mile 34 2ft	Brunei	white	sand	1	98	← 1 →						
1453	" " " " 4ft	"	white	sand		97	← 3 →						
1454	" " " " 6ft	"	white	sand		99	← 1 →						
1455	" " " " 8ft	"	white	sand	2	97	← 1 →						
1456	" " " " 10ft	"	white	sand		99	← 1 →						
1510	Tenom-Keningau Road. Baiayo Series 0-8in.	North Borneo	white	sand		32	← 68 →	18	16	2	0.2	SF	
1511	" " " " 8in.-18in.	"	white	sand		36	52						12
1405	Sarikei-Binatang Road, Kelupe	Sarawak	brown	sand	4	74	← 22 →						

** Sample No. 1512 (yellow podsol soil) is part of this soil profile.

TABLE V

The results of classification tests on the group of soils including beach sands, alluvial soils and hydromorphic soils

Sample No.	Location	Country	Description	Particle-size distribution				Liquid limit per cent	Plastic limit per cent	Plasticity index per cent	Activity	Casagrande group classification
				Gravel per cent	Sand per cent	Silt per cent	Clay per cent					
1359	Sarawak River, Kuching	Sarawak	Brown sand - alluvial soil	4	93	← 3 →	60	29	31		CH	
1435	Sungei Bari, Sungei Bakong Marudi Mile 1	"	Light grey podsolized Lighomorhic soil									
1436	Miri-Kuala Baram Road	"	Beach sand									
1437	" " " " Mile 3	"	" " 1 ft									
1438	" " " " Mile 5	"	" " 1 ft									
1439	" " " " Mile 7	"	" " 1 ft	5	95	← 5 →						
1440	" " " " Mile 9	"	" " 1 ft									
1505	Lahad Datu	North Borneo	Brown sand - alluvial soil									

/The

The particle-size distributions of the beach sands from the surface of the Miri-Kuala Baram Road between miles 1 and 9 were all similar (see Fig. 6) and showed that the sands were single-sized fine sands. Even though the samples were taken several miles apart the uniformity in composition was extremely marked.

The particle-size distributions of the other soil profile samples are shown in Figs 7-11.

During the sedimentation tests a streaming effect which usually lasted between 10 and 15 seconds was observed for all the soils tested when the soil suspensions were disturbed. The effect was most noticeable in the soil suspensions of the weathered shales which contain a high proportion of flat or flaky particles.

The liquid and plastic limit tests were carried out to determine variations in texture of the soils with respect to their geographical distribution to show textural differences between the soil groups and also to show variations within the soil groups.

The results showed that:-

(i) In the group of yellow/red latosols the soils from the east coast of North Borneo were more clayey than those from the west coast. The liquid limits of the samples from the west coast ranged from 23 per cent to 66 per cent and were approximately of the same order as those obtained for this region by the Public Works Department (22 per cent to 50 per cent). Texturally the soils varied from light to heavy clays. The liquid limit values of the east coast samples varied from 48 per cent to 86 per cent and were predominantly heavy clays.

Grouped with the yellow podsollic soils were the samples from the Serian-Simanggang Road. The profile samples (5 ft to 21 ft) at mile 24 were below the A-line (Fig. 13) and were known to have been formed from older sedimentary strata than the other soils in the group. The three profile samples (3 ft-12 ft) at mile 36.5 were atypical of the group, they were white in colour and plotted below the A-line (Fig. 13); they had high silt contents which probably accounted for their poor performance as roadmaking materials.

(ii) The residual soils developed from igneous rocks were divided into three groups on the basis of the Casagrande classification (see Fig. 14). These corresponded to:-

(a) The overburden clays from Sarawak with the group symbols MI and MH. They were formed from granite or andesite.

(b) The soils from the Tawau area of North Borneo which were formed by the weathering of intermediate ashes and tuffs. They were denoted by the group symbol CH and generally had high liquid limit values (>86 per cent).

(c) The soils from the Tawau area which were developed from basaltic lavas had high liquid limit values (>100 per cent) and plotted below the A-line. X-ray analysis of one of these samples showed the predominant clay mineral was the hydrated form of halloysite; hydrated halloysite was present in some of the volcanic red clays of Kenya. The liquid and plastic limit values were also similar to the values obtained for Kenya clays containing hydrated halloysite⁽³⁾ which suggests that their engineering properties are probably similar.

In the shale group (shales are defined as argillaceous rocks) the hardness of the lumps of rock varied considerably from soft in the case of the cohesive black shale samples to relatively hard in the case of the red shale samples. During the soil classification tests the samples, particularly the red shales were found to be considerably altered by the work involved during the tests. This was shown by the particle-size distribution tests on sample Nos 1400 and 1402 (see Table III) where higher silt and clay contents were obtained when the time of dispersion was increased. The change in structure during the tests may give an indication of the mechanical breakdown of shales during construction operations. Liquid and plastic limits were determined for a number of shale samples to discover whether any relation existed between the values obtained and the colours of the samples. When the values for liquid limit and plasticity index were plotted on the Casagrande classification chart (Fig. 15) the two red shale samples were below the A-line, the grey shales were close to the A-line and the black shales were above the A-line. This may indicate either variation in the degree of weathering or changes in mineral composition.

The activities were calculated for 28 of the samples and the values obtained ranged from 0.2 to 2.0. 16 of the samples had values between 0.8 and 1.0 which according to Skempton⁽⁴⁾ suggests that the majority of the samples were in the group of normally active clays with illite as the predominant clay mineral.

Chemical tests

To compare some of the humus podzols of northern Borneo with the somewhat similar podzol soils that occur in the United Kingdom, organic matter contents were determined for a soil profile from the Tenom-Keningau Road (sample Nos 1510, 1511 and 1512) and for a brown sand from the Sarikei-Binatang Road (sample No. 1405). The free iron oxide content of sample No. 1405 was also determined.

The organic contents and chloride contents of the beach sands (sample Nos 1436 to 1440) used in the construction of the sand road from Miri to Kuala Baram were also determined. Tests for chloride were carried out because it was thought that the good performance of the sand surface might be due to the binding effect of brine in the soil moisture derived from the sea adjacent to the road. (Sodium chloride is a hygroscopic salt and is used in some parts of the world to bind earth roads and lay dust).

The organic contents were determined by the dichromate-oxidation method described in test 7 1377:1961,⁽¹⁾ the chloride contents by the gravimetric method of precipitation by silver nitrate, and the 'free' iron oxide by the method of Mackenzie.⁽⁵⁾

TABLE VI

The results of the chemical tests

Sample No.	Depth	Organic matter content per cent	Other tests
1510	0- 8in.	0.1	
1511	8in.-18in.	0.5	
1512	below 18in.	0.5	
1405		3.2	0.6 per cent 'free' iron oxide
1436	1ft	0.3	No chloride present
1437	1ft	0.8	" " "
1438	1ft	0.3	" " "
1439	1ft	1.4	" " "
1440	1ft	0.8	" " "

/The

The results showed that:-

(i) The organic contents of the beach sands from the Miri-Kuala Baram Road ranged from 0.3 per cent to 1.4 per cent. No chlorides were present which showed that no stabilizing effect could be attributed to brine.

(ii) The soil profile from the Tenom-Keningau Road (Baiaya series, sample Nos 1510, 1511 and 1512) did not contain any significant amounts of organic matter. There was, however, a slight increase in organic matter with depth which correlated with the increase in clay content with depth.

(iii) Sample No. 1405, in the group of humus podzols, was a brown sand with an organic matter content 3.2 per cent and an iron oxide content of 0.6 per cent. These values were typical of those found in the B horizon, the zone of accumulation of a humus podzol profile.

Conclusions

The 150 subsoil samples from northern Borneo were classified in the field into seven different soil types based on their mode of formation. The results of the particle-size analyses and plasticity tests showed that the four major groups were essentially different. Within these groups a variation occurred which could in part be correlated with changes in the parent material.

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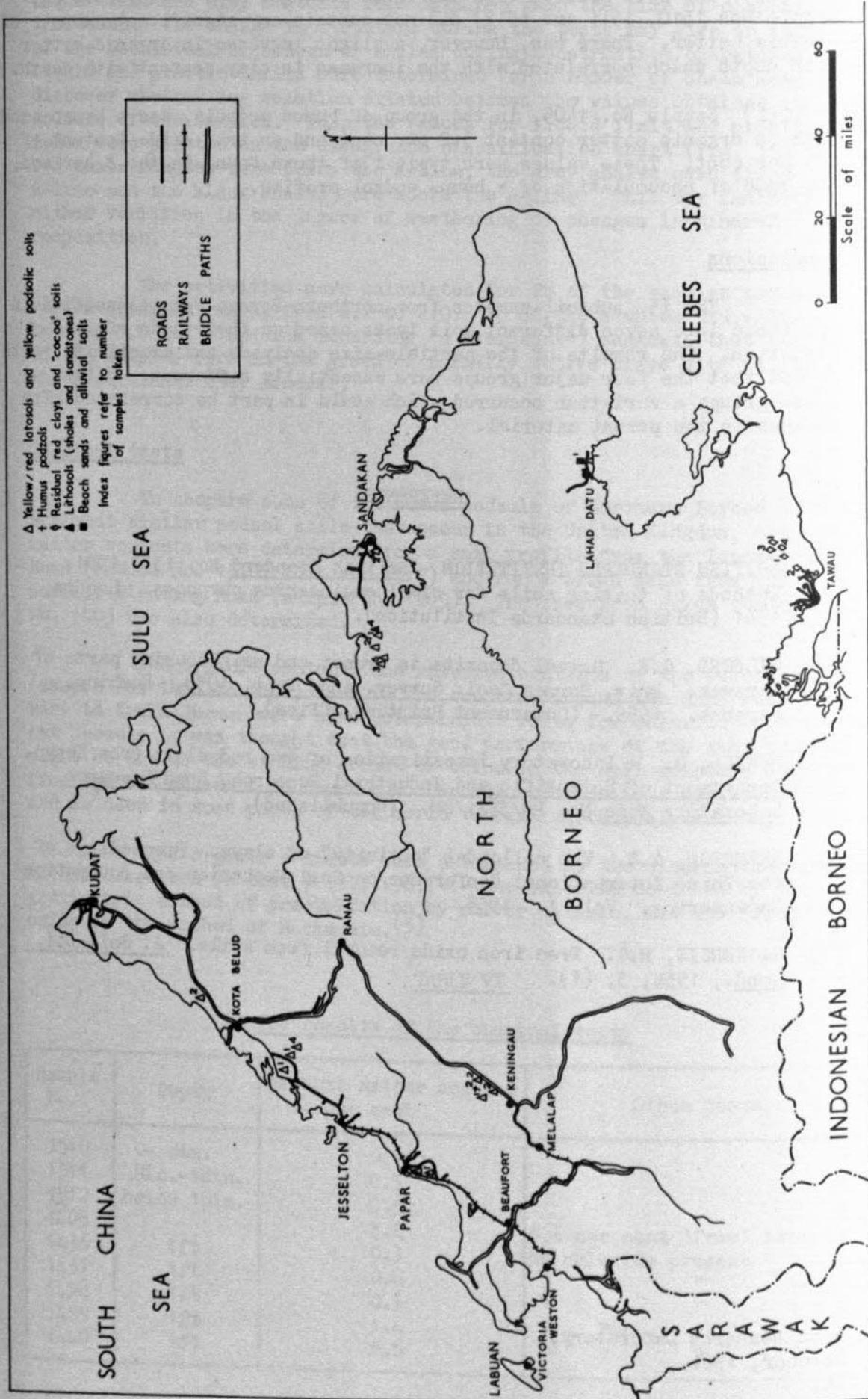


Fig. 1. THE LOCATION OF THE SAMPLES FROM NORTH BORNEO

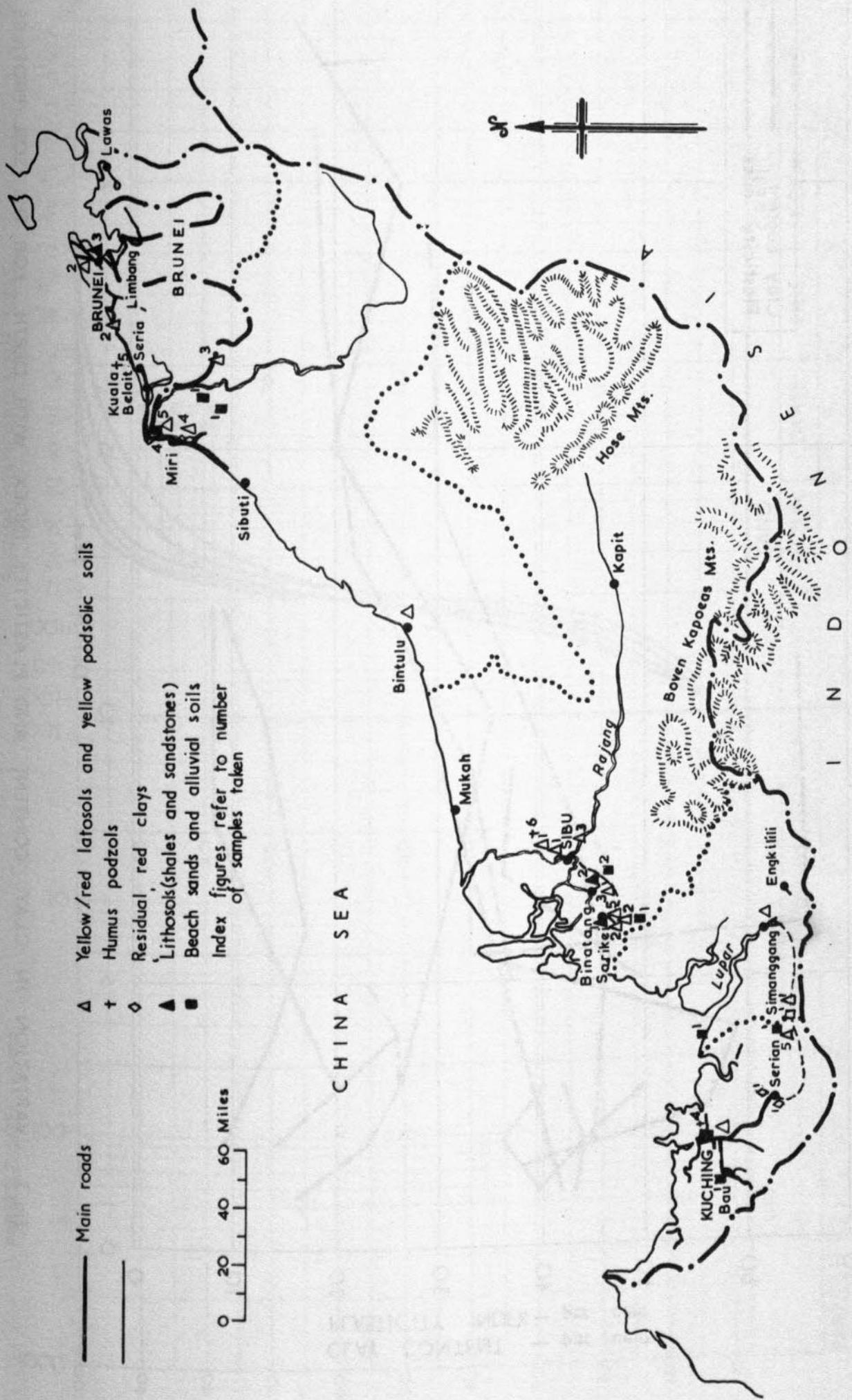


Fig.2 LOCATIONS OF SAMPLES FROM SARAWAK AND BRUNEI

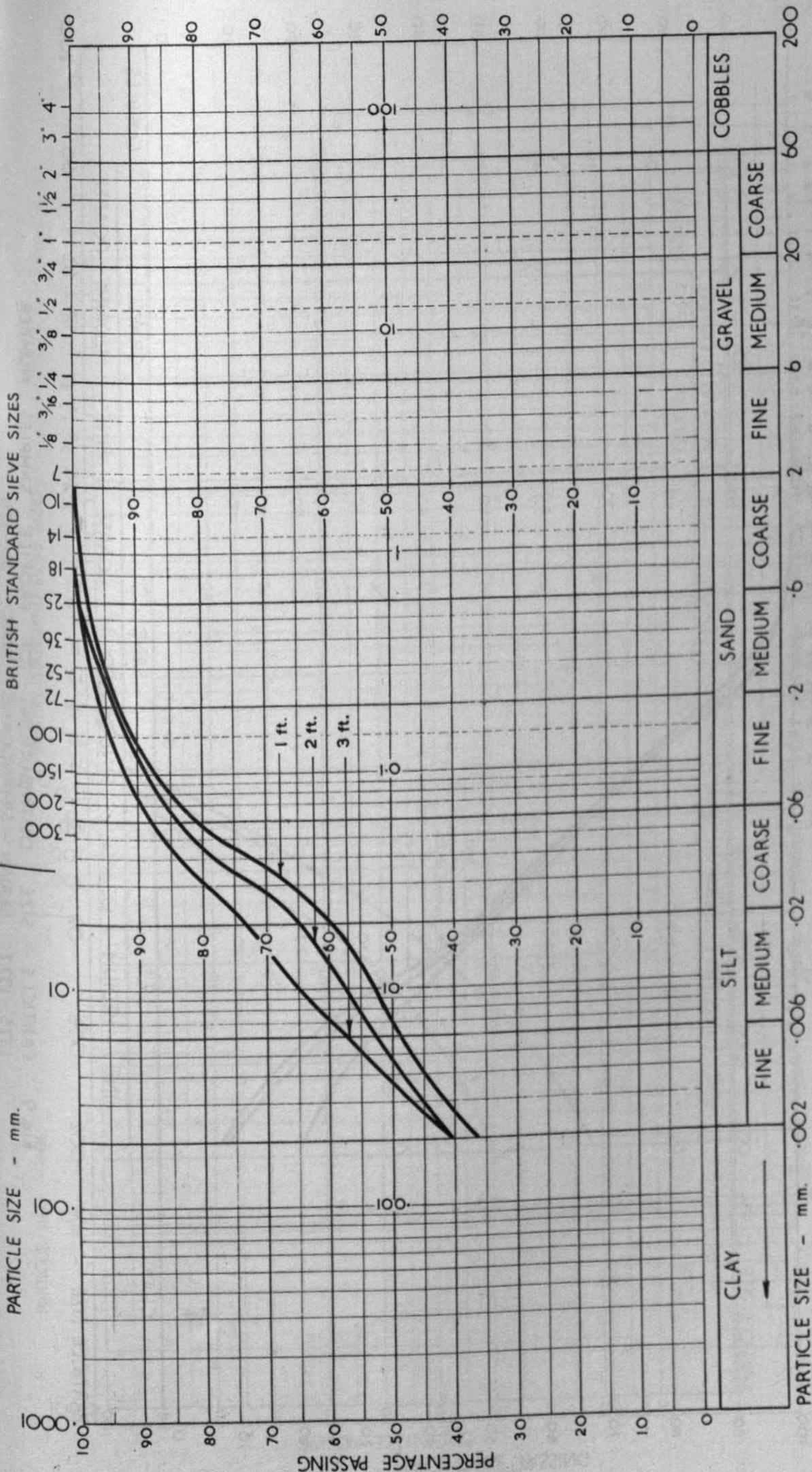
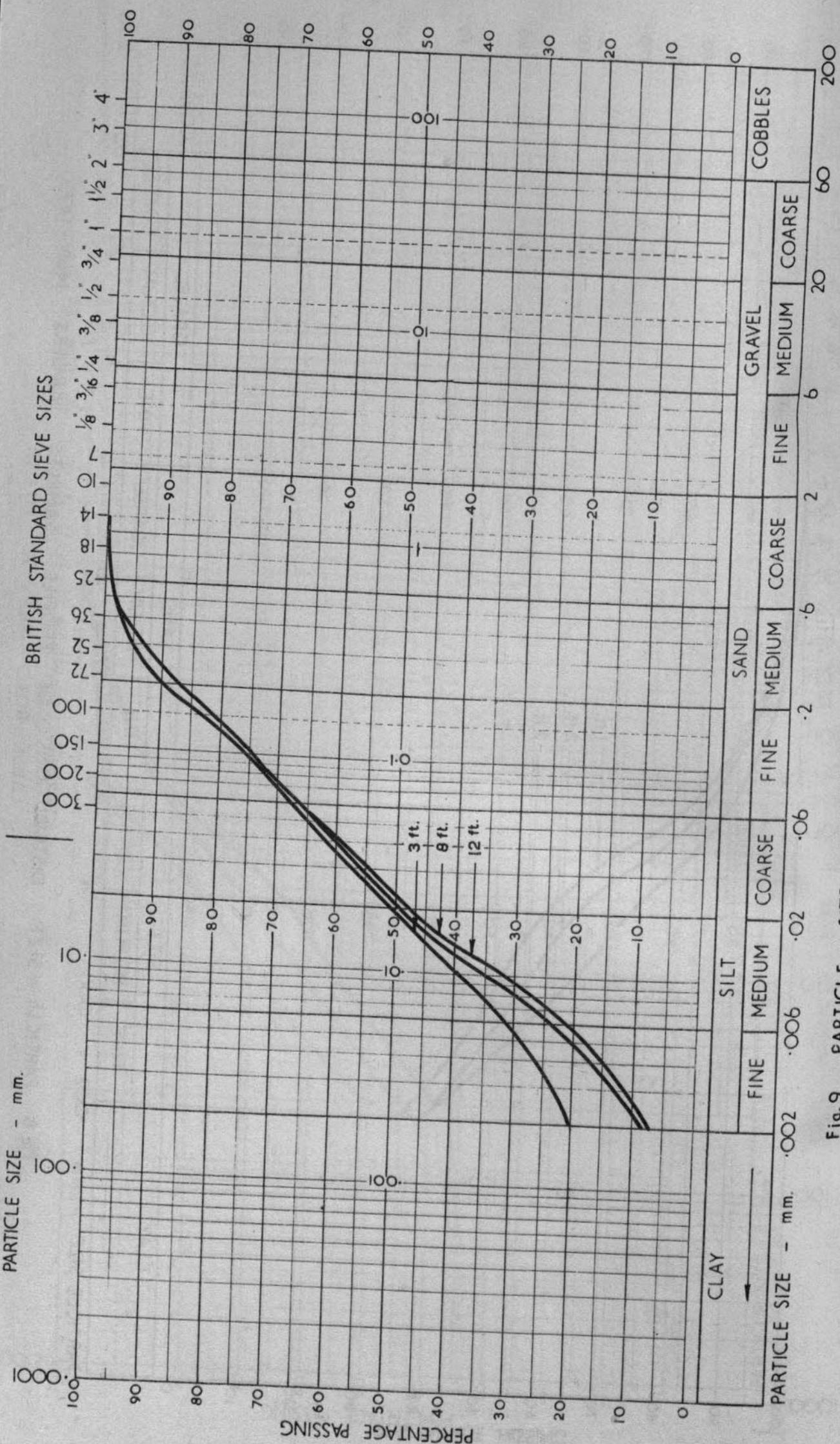


Fig. 8 PARTICLE - SIZE DISTRIBUTIONS OF PROFILE SAMPLES NUMBERS 1468 - 1470, LABUK ROAD MILE 30 1ft - 3ft.



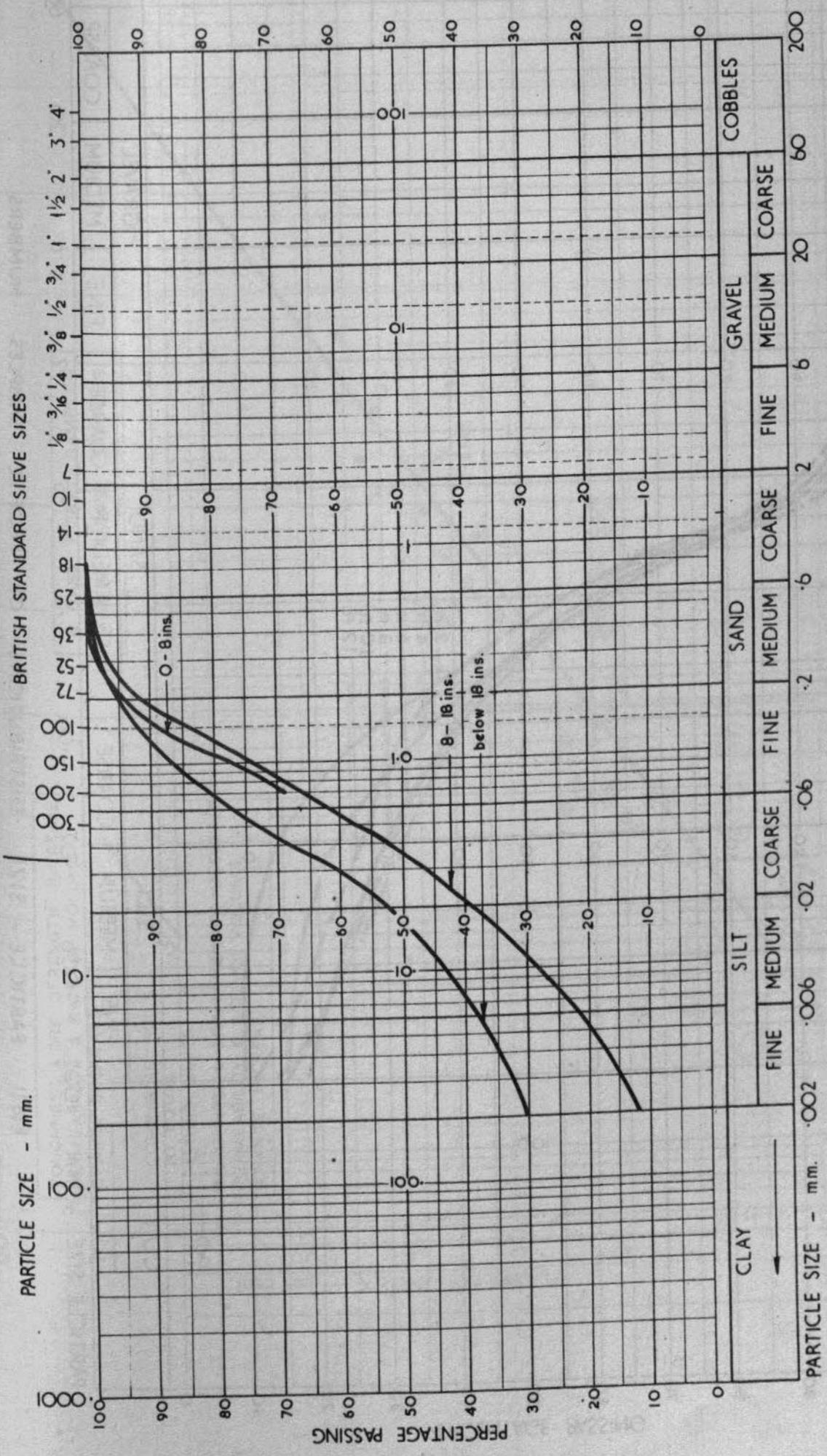


Fig. 10 PARTICLE - SIZE DISTRIBUTIONS OF PROFILE SAMPLES NUMBERS 1510 - 1512, TENOM - KENINGAU ROAD, SURFACE TO BELOW 18 ins

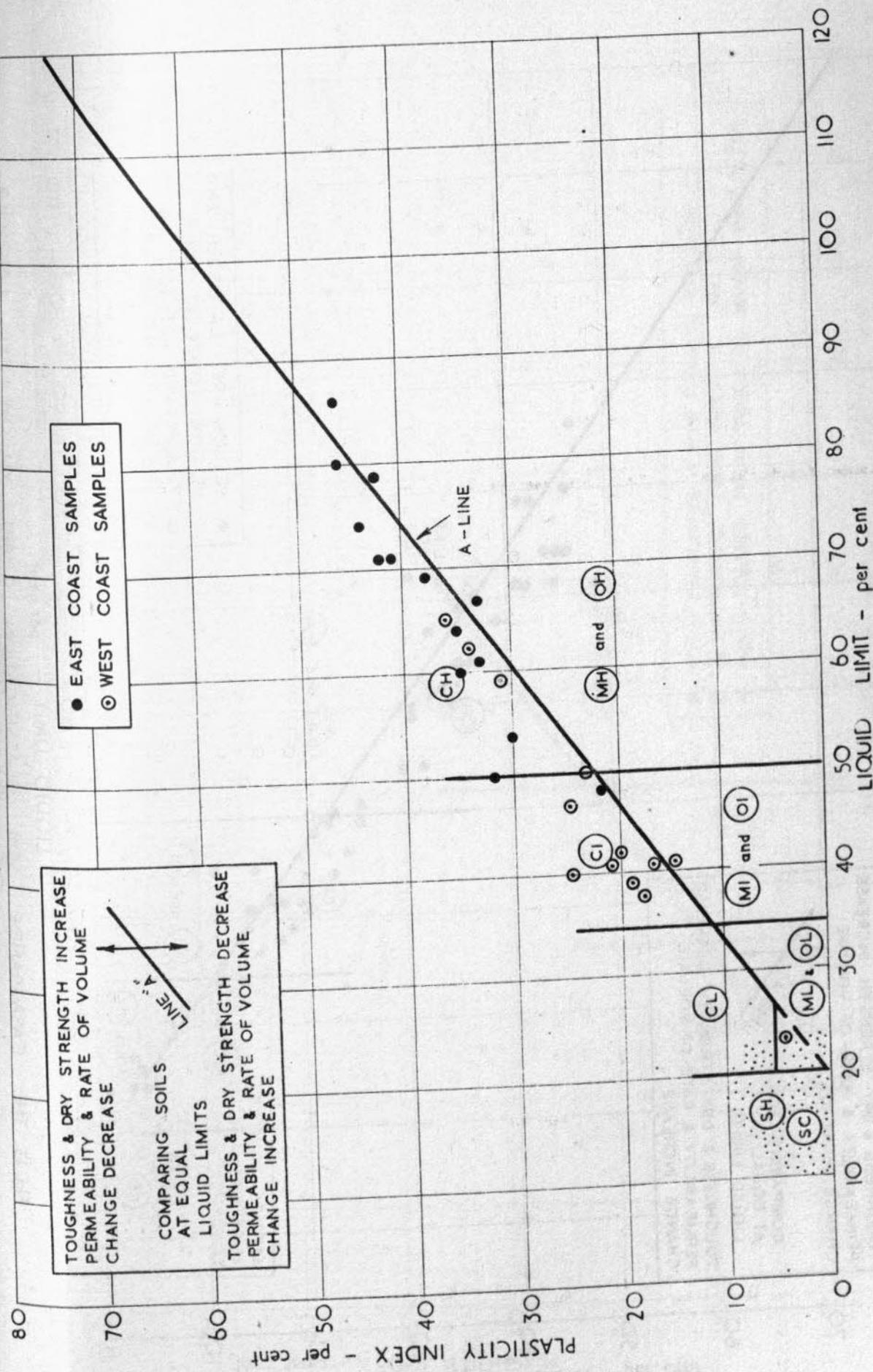


Fig.12 THE CASAGRANDE SOIL CLASSIFICATION CHART
THE YELLOW / RED LATOSOL AND YELLOW PODSOLIC SOIL SAMPLES FROM NORTH BORNEO

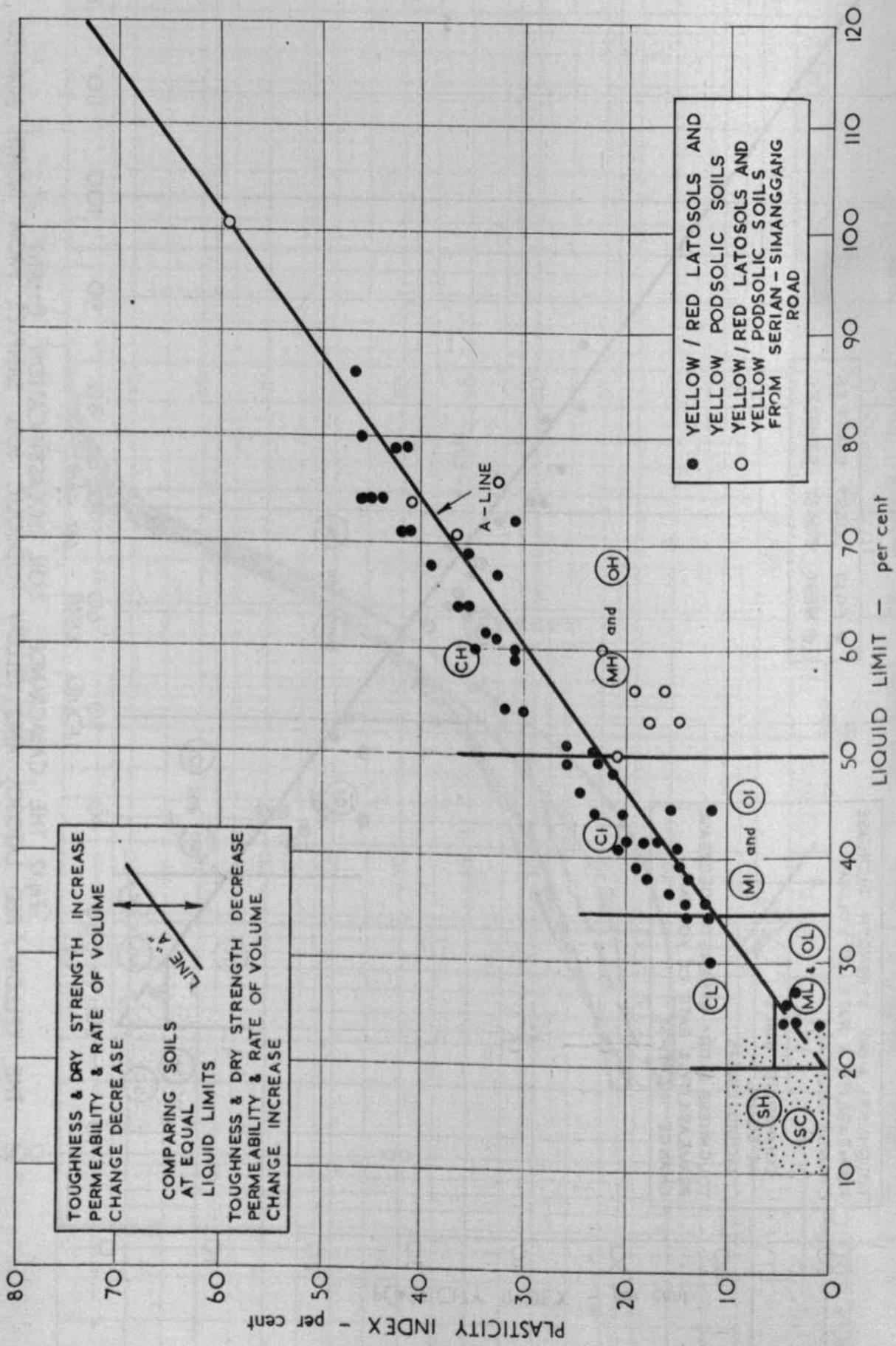


Fig. 13 THE CASAGRANDE SOIL CLASSIFICATION CHART YELLOW / RED LATOSOLS AND YELLOW PODSOLIC SOILS

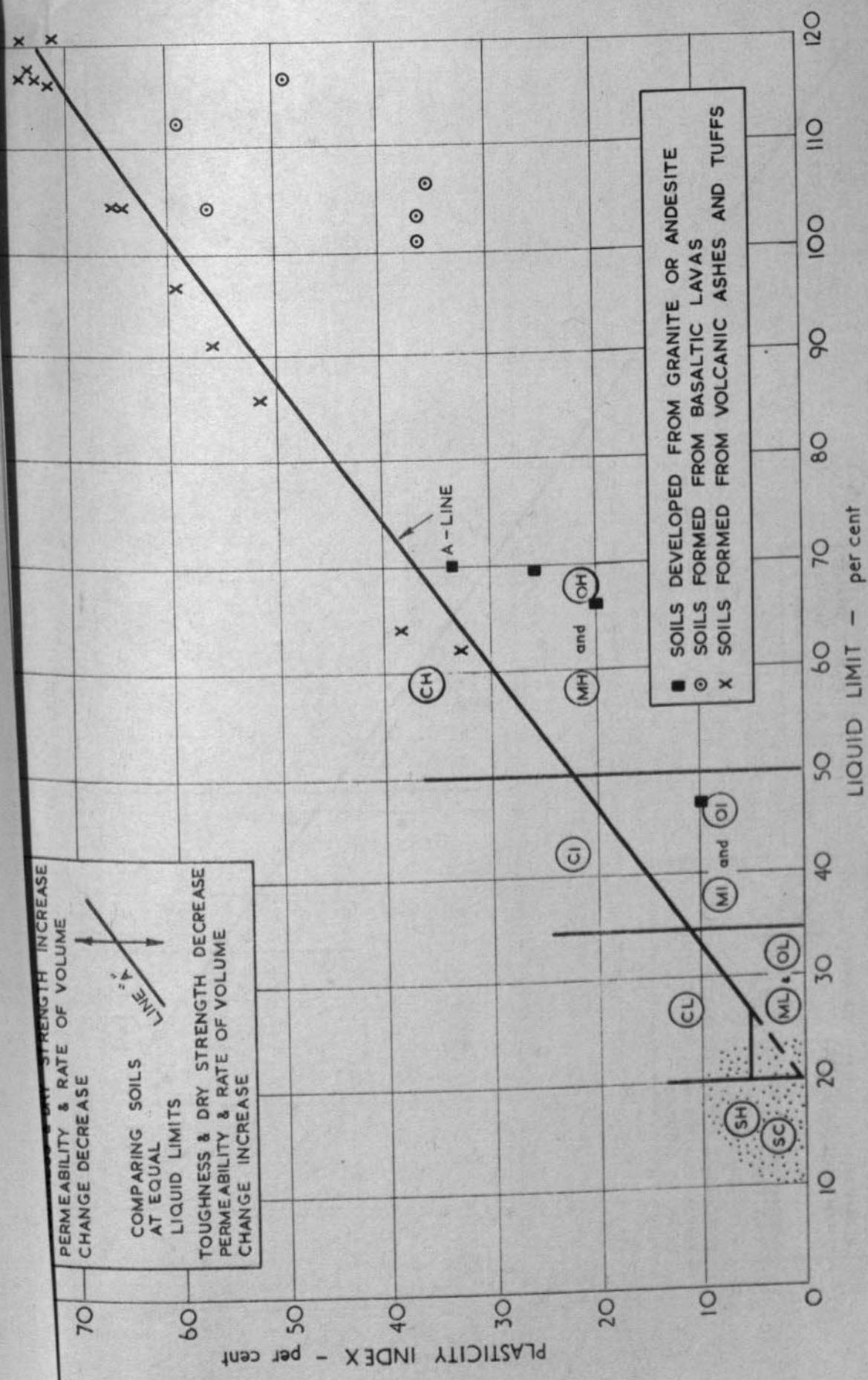


Fig. 14. THE RESIDUAL SOILS DEVELOPED FROM IGNEOUS ROCKS

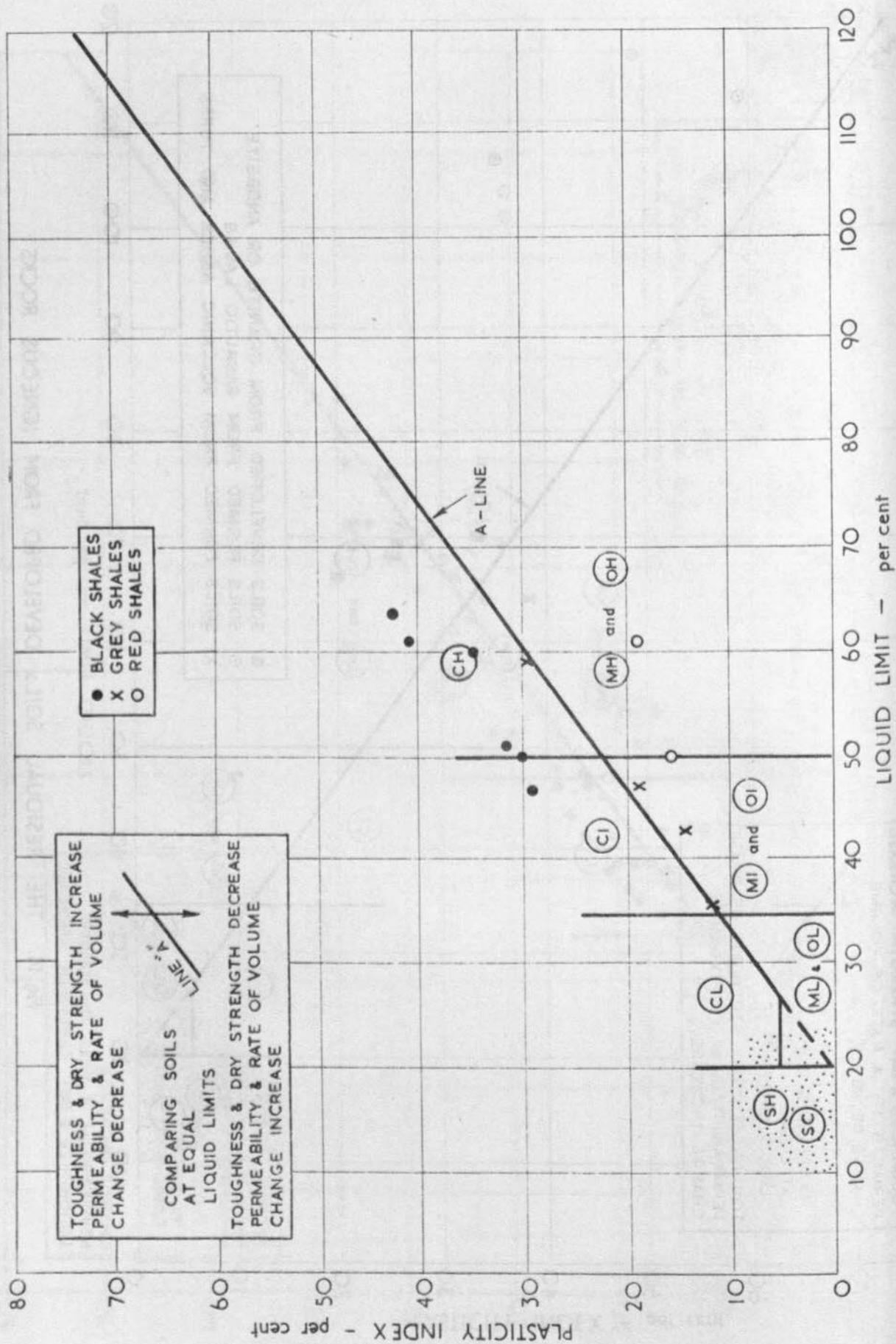


Fig. 15. THE WEATHERED SHALES

