ALTERATIONS IN CHEMICAL COMPOSITION DURING THE PROGRESSIVE WEATHERING OF DWYKA TILLITE AND DOLERITE IN NATAL

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Description of Materials

Soil profiles developed from Dwyka tillite consist of a fine sandy loam overlying a gravel and rubble layer and succeeded by a zone of clay illuviation. Below this, the disintergrating tillite may proceed to depths of two hundred feet under favourable circumstances. This material in its most weathered aspect consists of a "soapy" orangy yellow fine silty clay of the following textural composition: Coarse sand 10 per cent, fine sand 30 per cent, silt 20 per cent and clay 40 per cent. Where conditions for weathering are not favourable, that is, the absence of *pre-weathering*, a phenomenon which is particularly noticeable under the overburden of the Recent Sands, the tillite may weather to as little as 20 feet from the surface. It would thus appear that the local availability of effective groundwater is a dominant factor in progressive weathering. Where planation of the earlier products of weathering has been incomplete in past cycles, as for example on late Cainozoic surfaces, there will remain a reservoir of effective moisture to accelerate further weathering.

Such circumstances may largely be responsible for the well known differential decomposition of dolerites, which result in the production of red and black soils from a parent rock of uniform composition and structure. In this paper, the study of dolerite decomposition embraces both those circumstances leading to black and red soils. Red soils are associated with very deep weathering, the profile commonly consisting of some ten to thirty feet of reddish or chocolate clay loam, followed by well weathered also rather "soapy" yellowish material which may extend a further 20 feet in extreme cases. Rather brittle partly weathered rock thereafter proceeds to depths of up to 60 feet. In the case of the production of black soils at the surface, however, rather brittle decomposing rock commences a little way below the soil.

In this study, samples have not been taken of the soil, but only of the *in situ* weathering material. Material was taken from the entire sections of the profiles tabulated in Tables I and II.

Laboratory Procedures

Samples were dried, broken up and finally pulverised in an agate mortar to pass through a 70 I.M.M. grade sieve. Fusion with sodium carbonate was resorted to for the determination of silica, titanium, aluminium, iron, manganese, magnesium, calcium and phosphate, while fusion with a mixture of calcium carbonate and barium chloride was used for sodium and potassium flame determinations. A separate procedure with hydrofluoric acid was employed for the determination of ferrous iron.

Analytical Results

Decomposition of Dwyka Tillite

Silica. There has been little alteration in the quantity of silica in the profile, except in the case of Site E, which is an instance of extreme weathering, with the replacement of silica by alumina. The general tendency is for a very slight decrease towards the surface.

Titanium. There is little variation in the titanium content of the profile, increases towards the surface being attributed to the possible residual effects of a former overburden of ilmenite-rich Recent Sands.

Aluminium. In all cases there appears to be an immediate slight increase in alumina on weathering of the rock. Under normal conditions this initial increase is fairly static.

Iron. The percentage of iron is rather static throughout the profile. Most of the ferrous iron of the original rock has been oxidised down to great depths.

Manganese. There is a tendency for manganese to become depleted towards the surface. This may be due to precipitation as nodules or in seams, and not reflected in the sampling. There is certainly a major accumulation in the gravel or "ouklip" layer of the derived soil, which was not included in this study.

Magnesium. Variations occur according to the site, accumulating in some instances but not in others. Site E, extreme weathering, shows strong depletion, however.

Calcium. There is a high loss of calcium immediately on weathering, the residual calcium remaining fairly constant throughout the entire depths of the profiles sampled. Extreme weathering has not materially altered the status by further loss.

Sodium. With the exception of Site B, there is a marked tendency for sodium to be removed progressively with weathering. With extreme weathering it is reduced considerably.

Potassium. The case of potassium is of interest as there is very little removal throughout the profile. The clay was found to be dominantly kaolinite, with illite only weakly accessory and in the light of this, the retention of potassium is difficult to explain, though of interest.

Phosphorus. In all cases there is a moderate depletion of phosphorus towards the surface.

Decomposition of Dolerite

Silica. Only in cases of advanced weathering (Site H) is there a very noticeable reduction in silica content with weathering of the rock. The phenomenon is one of alteration rather than removal.

Titanium. The variation in titanium content is negligible. Accumulation in Site H, would once again appear to result from the overburden of Recent Sands, which occur in the immediate vicinity of the quarry.

Aluminium. The pattern followed is much the same as for tillite, though occasional variable results cannot be accounted for. The process of alumina increase and silica decrease is normal in advanced weathering.

Iron. As distinct from tillite, there is a marked accumulation of iron in the weathering material, particularly emphasised in extreme weathering (Site H). This accumulation of iron is passed on to the derived soil, which contains 15 per cent and more of Fe_2O_3, as opposed to 5 per cent in tillite-derived soils. In these latter soils, iron appears to be lodged in the gravel layer, which may contain up to 60 per cent Fe_2O_3. This migration of iron is not by any means so noticeable in dolerite-derived soils. As distinct from tillite weathering, also, ferrous iron is only partly oxidised in the weathering complex of dolerite.

Manganese. Manganese is rather static, the loss being only noticeable in cases of very advanced weathering.

Magnesium. in the initial stages of weathering there is no appreciable loss of magnesium from the weathering complex. In the highly weathered material, however, its removal is fairly drastic.

Calcium. As distinct from tillite, there is a more gradual loss of calcium with weathering, but once again extremely noticeable with advanced weathering.

Sodium. Sodium is more or less static, except on extreme weathering, when it is largely removed.

Potassium. Once again it is of great interest to observe the retention of potassium in the weathering profile. Analyses are on record in which the potassium content of samples of the highly weathered dolerite crust are actually higher than in the parent rock.

Phosphorus. The moderate depletion which takes place in the case of tillite weathering is not observed here.

General Remarks

This paper is intended primarily as a chemical study of the composition of the products of weathering of two common rock types on the Natal Coast. It does not take into account the complex alterations in the mineralogy of the weathering mass resulting from the alteration of primary to secondary minerals. Such a study could, for example, undoubtedly throw some light on the mechanism of potassium retention subsequent to the breakdown of potash feldspars such as orthoclase and microcline and some ferromagnesian minerals such as biotite.

Allied would also be a study of the availability of altered potash to plant roots foraging amongst the numerous cleavage planes of the weathering parent material. The unusually high amount of potash in weathering tillite and its retention even in the soil has always been of interest and is once again reflected in the analyses of Table I.

The paper illustrates the role of weathering on the depletion (or accumulation) of the various elements existing in the parent rock. Without this knowledge one would not be so well acquanited with the reserves of the original elements which are available in soil formation. In other words, we are presented with a chemical balance sheet of what transpires between parent rock and the early stages of "soil" development. What happens after that could be a function of how we care for the soil.

Summary

Samples have been taken from several weathering faces of two rock types, Dwyka tillite and dolerite, for chemical analyses. In all, 36 samples were analysed, together with six samples of fresh rock for purposes of comparison.

The results indicate a fairly static chemical composition during the initial stages of progressive weathering, but in cases of advanced weathering there is a rapid loss of sodium and magnesium in the case of tillite and of both alkaline earths and sodium in the case of dolerite. Aluminium and iron accumulation is associated with silica loss. The retention of potassium through all stages of weathering of both rock types is an interesting feature of the study.

Mr. du Toit (in the chair): I think we will ask the authors to present their second paper "The weathering of granite on the South Coast of Natal", and hold a joint discussion on both papers. The subject matter treated is largely similar.

TABLE I

ANALYSIS OF PROFILES OF WEATHERING DWYKA TILLITE
(RESULTS EXPRESSED ON OVEN-DRY BASIS)

SITE	A Umhlatuzana		B Umhlatuzana				C Umhlatuzana				D Umhlatuzana		E West-ridge	F Westville				Fresh Dwyka Tillite	
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
Depth from Surface in Feet	0–9	20–25	0–30	30–45	45–60	65–75	0–12	12–30	30–62	62–70	0–10	10–20	12–14	5–8	10–14	18–22	26–27	I	II
Description of Sample	Extremely well weathered orangy yellow soft clayey material	Hard and brittle greyish yellow only partly weathered	First part well weathered passing into partly weathered	Hard and brittle greyish yellow. Breaks along cleavages	Recurrence of soft well weathered tillite	Very hard and brittle greyish yellow slightly weathered	Orangy yellow soft clayey material	Medium hard to brittle yellowish grey	Hard brittle yellowish grey	Medium hard and brittle greyish yellow	Soft yellowish material almost a clay	Becoming hard and brittle yellowish grey	Very soft highly weathered material with "soapy" feel	Orangy and well weathered	Greyish yellow brittle	Greyish yellow very brittle	Greyish yellow very brittle	Umgeni quarries rotary quarter inch screen	Phoenix. Chips taken from selected rock samples
SiO_2 %	65.30	66.93	67.05	67.41	68.27	67.04	65.20	66.99	67.60	67.73	72.12	67.51	62.87	65.18	64.14	65.81	65.83	65.34	68.44
TiO_2	0.85	0.69	0.78	0.68	0.52	0.64	0.85	0.63	0.58	0.61	0.59	0.78	0.97	0.62	0.66	0.65	0.65	0.67	0.64
Al_2O_3	14.68	13.48	13.07	14.48	14.28	13.97	14.78	13.78	13.80	13.79	11.15	12.15	15.23	14.83	13.64	12.72	13.54	12.59	10.94
Fe_2O_3	4.99	4 84	5.08	4.78	4.09	4.50	5.89	6.10	6.55	6.32	6.11	6.75	8.89	6.24	7.77	8.74	6.73	4.63	2.66
FeO	0.23	0.32	0.16	0.11	0.19	0.23	0.39	0.33	0.29	0.21	0.25	0.30	0.12	0.28	0.34	0.27	0.26	3.34	3.35
MnO	0.06	0 03	0.08	0.10	0.11	0.15	0.01	0.04	0.08	0.08	0.08	0.06	0.01	0.05	0.08	0.09	0.09	0.13	0.09
MgO	1.84	1.74	3.96	3.03	2.62	2.93	1.20	1.52	1.20	1.20	1.28	1.42	0.42	1.02	1.12	1.23	1.23	1.29	1.79
CaO	0.47	1.05	0.32	0.16	0.12	0.57	0.25	0.36	0.25	0.33	0.25	0.37	0.44	0.36	0.34	0.61	0.86	2.72	2.95
Na_2O	1.70	2.77	2.18	2.45	2.15	1.78	1.38	2.07	1.63	1.80	1.37	1.83	0.47	1.53	2.58	2.65	2.65	3.37	3.31
K_2O	2.66	2 84	3.43	3.26	2.97	3.16	2.69	2.81	2.73	3.20	2.79	2.92	2.59	2.49	2.70	2.50	2.29	3.42	2.45
P_2O_5	0.06	0.22	0.08	0.10	0.11	0.15	0 04	0.06	0.06	0.07	0.09	0.15	0.10	0.11	0.11	0.12	0.13	0.19	0.14
Loss on Ignition	4.68	2.73	2.67	2.36	2.61	2.48	3.97	2.97	3.31	3.23	2.78	3.14	6.84	5.07	4 24	3.41	3.37	2.44	2.53
Moisture	2.28	1.75	1.26	1.11	1.28	1.41	2.59	2.49	2.65	2.28	1.85	2.88	1.51	1.64	1.79	1.86	1.95	0.60	0.14
Total	99.80	99.39	100.12	100.03	99.32	99.01	99.24	100.15	100.73	100.85	100.71	100.26	100.46	99.42	99.51	100.66	99.58	100.73	99.43

TABLE II

ANALYSIS OF PROFILES OF WEATHERING DOLERITE

(RESULTS EXPRESSED ON OVEN-DRY BASIS)

SITE	G MOUNT EDGECOMBE (Westbrook Estate)			H MOUNT EDGECOMBE (Cornubia Estate)				I MOUNT EDGECOMBE (Waterloo Estate)				J MANDINI				K GINGINDHLOVU				FRESH DOLERITE			
SAMPLE No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
DEPTH FROM SURFACE IN FEET	3–5	10–14	20–30	13–17	18–26	28–36	40–50	3–9	10–19	20–30	50–60	1–3	3–8	8–14	14–20	2–5	5–10	12–25	25–35	I	II	III	IV
Description of Sample	Soft yellowish weathering material	Rather hard and brittle yellowish grey	Very hard and brittle and only just weathered	Very soft orangy yellow and highly weathered material	Soft yellowish fairly well weathered	Hard and brittle greyish yellow partly weathered	Hard and brittle slightly weathered	Rather soft yellowish well weathered material	Fairly hard and brittle greyish yellow partly weathered	Hard and brittle partly weathered	Very hard and brittle and slightly weathered	Soft well weathered material	Slightly brittle partly weathered	Brittle and partly weathered	Very hard and brittle slightly weathered	Slightly brittle greyish yellow	Very brittle and partly weathered	Very hard and brittle slightly weathered	Very hard and brittle slightly weathered	Mt. Edgecombe. Sample chipped from rocks	Westbrook Estate. Sample chipped from rocks	Tongaat. Sample chipped from rocks	Mt. Edgecombe (Waterloo). Sample chipped from rocks
SiO_2 %	50.83	51.26	51.79	41.91	42.89	50.35	50.69	51.63	51.99	50.35	51.45	49.16	49.93	49.36	50.05	48.61	49.80	49.86	50.06	50.43	51.12	50.68	51.03
TiO_2	1.25	1.17	1.28	2.60	3.06	2.25	1.87	1.18	1.07	1.14	1.36	0.90	0.97	0.96	0.89	1.37	1.44	1.32	1.29	1.02	1.00	1.06	0.97
Al_2O_3	13.33	12.97	11.52	16.73	14.81	11.66	11.68	13.51	11.06	13.24	14.43	9.07	10.05	9.64	11.02	13.16	11.59	12.78	10.27	14.58	14.75	17.01	15.40
Fe_2O_3	8.73	9.32	11.91	21.76	19.45	14.00	13.68	12.38	11.00	10.26	7.80	12.90	11.33	11.33	8.97	10.22	11.02	11.24	11.63	3.78	3.89	3.26	3.73
FeO	3.58	3.57	3.39	1.53	1.27	3.17	4.87	1.26	2.70	3.59	4.25	4.22	4.32	4.17	4.35	4.38	5.13	5.09	5.02	9.58	9.68	9.45	9.09
MnO	0.14	0.12	0.11	0.11	0.12	0.15	0.20	0.10	0.15	0.16	0.21	0.16	0.16	0.15	0.15	0.16	0.19	0.20	0.16	0.17	0.23	0.18	0.16
MgO	4.10	3.04	2.88	0.60	0.72	1.61	3.63	4.24	5.33	5.59	4.82	6.09	7.41	6.46	7.20	2.26	2.54	2.60	3.10	6.89	3.77	4.04	4.50
CaO	8.24	8.14	8.06	0.73	0.91	5.83	6.56	6.30	7.69	8.25	8.75	7.64	7.96	7.74	8.51	6.39	6.98	7.28	6.95	11.31	11.25	10.66	10.85
Na_2O	2.88	3.57	2.02	0.35	0.66	2.36	1.73	1.83	1.83	2.03	1.60	1.42	1.47	1.49	1.44	1.72	2.25	1.90	2.60	1.78	2.10	1.62	2.43
K_2O	0.78	0.98	0.56	0.60	1.00	0.82	0.68	0.40	0.51	0.40	0.33	0.31	0.32	0.34	0.30	0.60	0.66	0.59	0.61	0.66	0.75	0.50	0.70
P_2O_5	0.16	0.17	0.18	0.15	0.19	0.08	0.14	0.11	0.14	0.12	0.14	0.13	0.10	0.10	0.09	0.15	0.16	0.14	0.15	0.18	0.15	0.08	0.07
Loss on Ignition	2.95	2.76	2.72	10.08	9.71	3.37	2.66	4.16	3.13	2.73	2.17	3.54	3.16	3.05	2.97	5.11	3.50	3.23	5.10	0.21	0.28	0.47	0.03
Moisture	2.77	2.96	3.11	4.04	4.29	3.36	2.60	4.35	3.78	3.36	2.89	5.14	4.57	4.92	4.65	5.92	4.23	4.58	3.56	0.07	0.21	0.09	0.29
TOTAL	99.74	100.03	99.53	101.19	99.08	99.01	100.99	101.45	100.38	101.22	100.20	100.68	101.75	99.71	100.59	100 05	99.49	100.81	100.50	100.66	99.18	99.10	99.25