[Jour. Indian Chem. Soc., Vol. 46, No. 9, 1969]

Effect of Weathering and Parent Materials on Clay Mineralization Part—II.

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The clays from the arid zone, *e.g.*, Churu and Ludhiana having been formed in an alkaline earths ionic environment contain illite and chlorite. Kaolinite is likely to have been derived from *K*-feldspars. Under insufficient leaching condition in the semi-arid zone and under suitable calcium-magnesium environment montmorillonite is the dominant clay mineral in Annegeri soil. The small amount of kaolinite present in this clay seems to come from *K*-feldspar. The clays of both Machkund and Padwa soils contain mainly kaolinite with traces of illite, caused by pronounced leaching of weatherable feldspar in the semi-arid to humid climatic conditions. The humid condition of Pasighat under alkaline and alkaline earths ionic environment favours illite as well as vermiculite formation. Kaolinite is the result of intense weathering. The highly acidic soils of Cherrapunji is kaolinitic but under favourable potassium equilibrium condition contains illite as well.

The paper deals with the chemical, X-ray and d.t. analyses of clays isolated from some soils. From these data the mineralogical make-up of the clay can be ascertained.

According to Jackson[1] the distribution of free iron oxide associated with clay in the profile sometimes reveals the intensity of weathering. Hence the contents of free oxide of iron in the clays were determined.

EXPERIMENTAL

A short description of the soils used is given in table 1. The isolation of clays from soils and the method of their purification are similar to those reported earlier[2]. The $<2\mu$ fraction was subjected to X-ray analysis using Ni filtered CuK_α radiation and Philips 11.483 Powder Camera. The results of analysis are given in table 3. Differential thermal diagrams (Figs. I and II) of organic matter free clay fraction in H-form were obtained with the help of a manually operated d.t.a. apparatus set up in the laboratory (Adhikari and Ray[3]). The results are summarised in table 4. The chemical analysis carried out using standard procedure is given in table 2. The contents of free oxide of iron determined by extraction with dithionate citrate as proposed by Aguilera and Jackson[4] are shown in table 2 (last column)

1. M. L. Jackson, Soil Chemical Analysis—'Mineral fraction for and 'Differential thermal analysis of soil minerals'. Adv. course, Wisconsin Univ. Madison, 1956, **101**, 260.
2. B. Datta and M. Adhikari, *Indian J. Appl. Chem.* 1968, **31**, 143.
3. M. Adhikari and S. Roy, *Sci. & Cult.*, 1957, **23**, 258.
4. N. H. Aguilera and M. L. Jackson, *Soil Sci. Soc. Amer. Proc.*— 1953, **17**, 359.

TABLE 1

Description of Soils

Soils Location	Climatic Zone	Profiles	Depth in cm.
Churu, Rajasthan	Arid desert	1	0–12.5
		2	52.5–113
Ludhiana, Punjab	Arid	1	0– 15
		2	30– 60
		3	120–180
Annegeri, Mysore	Semi arid	1	0– 15
		2	30– 60
		3	120–180
Machkund Orissa,	Humid	1	0– 15
		2	15– 60
		3	60–120
Padwa		1	0– 15
		2	30–120
Pasighat, N.E.F.A.	Humid	1	0– 18
		2	18– 75
		3	75–125
		4	125 and below
Cherrapunji, Assam	Highly perhumid	1	0– 15
		2	30– 60
		3	120–180

RESULTS AND DISCUSSION

Chemical Analysis : High silica content and SiO_2/Al_2O_3 ratio of Churu, Ludhiana and Annegeri clays (Table 2) suggest the presence of 2:1 lattice type clay minerals in them. High K_2O content along with fairly high Mg content of Churu and Ludhiana clays suggest that besides illitic clays some magnesium bearing silicate mineral might be present. Annegeri clay contains fairly good amount of MgO and CaO but very low K_2O suggesting the presence of montomorillonite type clay mineral as the major constituent.

Both silica and SiO_2/Al_2O_3 ratios of Machkund and Padwa clays indicate the presence of 1:1 type clay minerals in them; K_2O content of Machkund clay points to the presence of illite as well. Pashighat clays are likely to contain 2:1 lattice layer clay mineral as is judged from SiO_2/Al_2O_3 ratio and contents of K_2O and MgO. The Cherrapunji clay probably contains 1:1 type clay along with some illite as is evident from SiO_2/Al_2O_3 ratio and K_2O content.

TABLE 2

Chemical analyses of Soil clays (oven dry basis)

Soil	Profile No.	SiO_2 %	Al_2O_3 %	Total Fe, Fe_2O_3 %	TiO_2 %	CaO %	MgO %	K_2O %	Loss on ignition %	Molar ratio of $\frac{SiO_2}{Al_2O_3}$	Free Oxide of Fe, Fe_2O %
Churu	1	45.45	23.39	10.77	0.44	0.82	1.19	6.50	10.96	3.3	1.75
	2	43.58	24.11	9.07	0.45	0.86	2.23	6.62	13.13	3.1	0.60
Ludhiana	1	40.89	27.22	12.27	0.40	0.84	1.07	8.09	9.96	2.5	0.98
	2	42.44	33.60	4.43	0.86	0.96	2.21	5.65	9.85	2.1	1.18
	3	43.50	26.57	12.55	0.69	0.76	0.90	5.80	9.23	2.8	0.96
Annegeri	1	51.87	24.48	11.94	0.68	1.48	1.38	0.81	10.15	3.6	0.23
	2	53.23	15.50	12.96	0.72	0.92	1.00	0.85	13.02	5.9	0.97
	3	55.27	16.17	11.67	0.91	0.80	1.81	0.65	12.72	5.8	0.69
Machkund	1	38.59	26.82	14.80	3.73	0.54	0.62	3.49	11.19	2.4	2.05
	2	36.35	32.15	11.93	0.49	0.23	0.44	4.50	13.00	1.9	6.26
	3	40.01	31.36	14.17	0.30	0.26	0.38	2.31	11.97	2.2	1.17
Padwa	1	36.66	32.72	13.74	0.54	0.37	0.71	2.11	12.35	1.9	3.97
	2	39.60	33.46	12.49	0.50	0.40	0.79	1.54	12.47	2.0	4.66
Pasighat	1	38.16	30.17	14.09	0.47	0.62	0.55	3.52	13.42	2.1	0.89
	2	41.64	31.02	10.22	1.46	0.26	1.48	4.91	10.90	2.3	1.55
	3	45.10	26.60	8.73	0.83	0.76	2.18	4.09	11.71	2.9	2.12
	4	43.81	27.92	9.49	0.48	0.11	1.96	5.36	10.87	2.7	1.06
Cherrapunji	1	34.39	25.55	21.59	1.04	0.65	0.55	3.12	13.31	2.3	1.52
	2	30.87	33.85	13.85	1.17	0.70	0.60	5.40	12.94	1.5	1.63
	3	31.62	43.88	5.33	0.48	0.62	0.70	4.45	12.81	1.2	2.00

From the high content of free oxide of iron it appears that clays from the humid regions are highly weathered. Similarly low values of free iron oxide in clays from the arid zones suggest that weathering is less favourable (Datta and Adhikari, loc. cit.)

X-ray diffraction study : X-ray analysis of Churu clay shows (Table 3) diffuse reflection at 10°A, weak reflection at 7°A and 14.02°A besides others. On heat treatment to 600° the 10°A line is fixed at 9.8°A, 7°A line disappears and 14.02°A line becomes stable even on glycerol treatment. These results suggest that the clay is mainly illitic but contains small amounts of chlorite and kaolinite. Th Ludhiana clay behaves similar to Churu clay.

TABLE 3

Lattice spacings in A and their intensities in powder diagrams of H-clays

	Lattice spacings				Comparable with					
	Illite		Kaolinite		Chlorite		Montmorillonite		Vermiculite	
	d_{hkl}	I*	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I	d_{hkl}	I
Churu	9.99 (9.8 on heating)	(diffused)	7.21	1/2	14.02 (stable on heating & glycerol treatment)	1/2				
	4.4622	8								
	3.3310	10								
	2.5786	7								
	1.5065	6								
Ludhiana	10.0	(diffuse)	7.075	1/2	14.4	2				
	4.445	5								
	3.33	10								
	2.5714	4								
	1.5029	3								
Annegeri	9.9	(very diffuse)	7.00	2			14.062 (Shifts to 17.0 A on glycerol treatment and 9.54 A° on heating)	6		
	3.33	3	2.57	5						
	2.5786	5								
							4.4633	10		
							1.5007	7		
Machkund	10.0	(diffuse)								
	4.3879	5	7.11	7						
	3.5503	4	3.5503	3						
	2.6742	1/2	2.5743	1						
	1 4955	1/2	1.4955	1/2						
Padwa	10.0	(very diffuse)	7.1205	10						
	4.5997	3	4.48	5						
	3.3507	1	4.1295	3						
	1.4955	6	3.5785	8						
			2.40	5						
			2.4926	4						
			2.2989	2						
			2.0112	2						
			1.4955	6						
Pasighat	10.2	(very diffuse)								
	4.445	4	7.008	3					13.67 (profile 1)	3½
	3.3285	10	3.54	5						
	1.4986	1/2	2.57	4					14.02 (profile 2)	3½
			1.49	1					1 54	
Cherrapunji	9.9	(diffuse intensity very strong)	7.03	2						
	4.84	4								
	4.5253	5								
	4.45	4								
	4.1181	½								
	3.3383	10	2.57	4½						
	2.57	9½								
	2.4896	1/2								
	1.50	2								

*I = Intensity of lines

Annegeri clay shows (Table 3) that montmorillonite is the dominant clay mineral in it. This is confirmed by well-defined band spacing at 14.06°A which shifts to 9.54°A on heating and expands to 17°A on glycerol treatment. Besides this the clay contains small amount of kaolinite and illite, these being confirmed by the weak reflection in the region of 7°A and diffuse reflection at 9.9°A. The 7°A line is eliminated on heating the clay to 600°.

The strong basal reflection at 7.11°A and other lines, the line intensity and sharpness indicate that well-crystallised kaolinite is the major clay meneral in Machkund soil clay. The diffuse and weak reflection at 10°A indicates the presence of degraded illite in it. Similar is the case with Padwa clay. The diffuse band spacing at 10°A which sharpns on heating and collapses to some extent on KCl treatment confirms the presence of degraded illite in Pasighat soils. The well-defined line at 7.0°A which disappears on heating to 600° confirms the presence of kaolinite. Besides these, the diffraction pattern of this clay shows (both profiles 1 and 2) a reflection at 13.67°A (profile 1) and 14.02°A (profile 2). The spacings which are glycerol stable indicating absence of motmorillonite, they collapse to 9.6-10.2°A on heating to 600°, showing absence of chlorite. The 14.02A°/13.67°A lines are due to vermiculite. The Pasighat soil clay, therefore, consists mainly of degraded illite along with some kaolinite and vermiculite. The X-ray diffraction analysis of Cherrapunji soil clay shows that degraded illite is the major constituent, together with a small amount of kaolinite which is confirmed by the diffuse 9.9°A line and 7°A line.

TABLE 4

	Endothermic peaks at °C	Exothermic peaks at °C
Churu	575°	
Ludhiana	95°, 525, 625°	
Annegeri	130°—150° 640°—650° 500°—550° (weak) 860°	960° (weak)
Machkund and Padwa	500°—600°	
Pasighat	100° (absent in profile 2), 275°, 550°, 640°.	
Cherrapunji	580°—590° (absent in profile 2)	950°

Differential thermal analysis (Fig. I-II) : The d.t.a. curves for Churu soil clays (Fig. Ia, table 4) show endothermic reaction from 350° finally giving a sharp peak at 575°. Such well-defined endothermic peaks in d.t.a. curves at this temperature and absence of endothermic reactions in the range 100-150° indicate that the clays contain well-crystallised kaolinite mixed with some illite (Adhikari[5]). The d.t.a. curve for Ludhiana clay (profile No. 2) shows (table 4) first dehydration peak at about 95° the second and the third at about 525° and 625° respectively.

The features in the d.t.a. curve are characteristic of a mixture of kaolinite with illite clays (Adhikari, loc. cit.). Those of the clays in the other profiles of this soil clays are more or less similar to that of Profile No. 2.

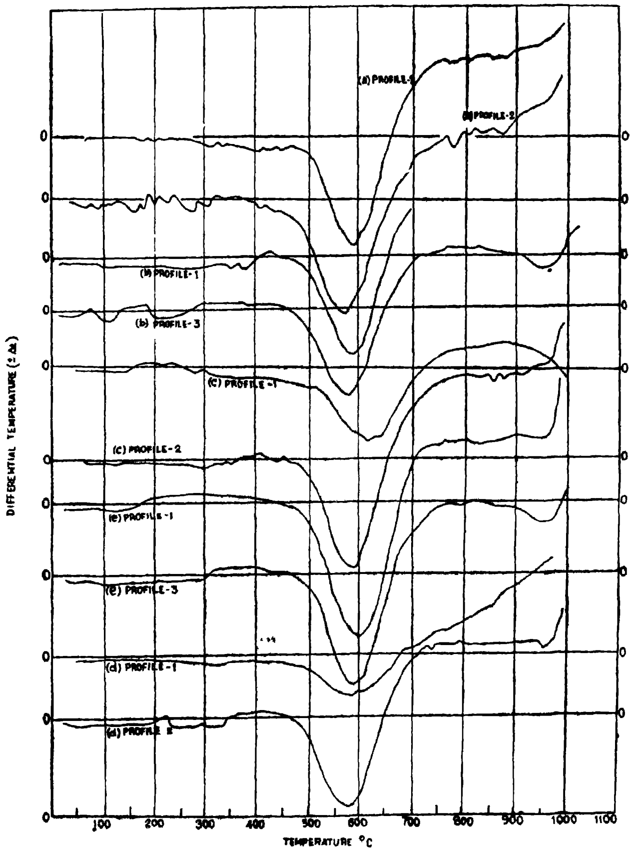

FIG. I

The d.t.a. curves for Annegeri clays in all profile samples (Fig. IIa) shows a vigorous endothermic reaction in the range 130-150° followed by a sharp endothermic peak at 640-650°, a small high temperature endothermic peak at about 860° and finally an exothermic reaction. All these are characteristic of montomorillonite clays which agrees with the X-ray data. The weak endothermic peak at about 500°-550° may be caused by traces of kaolinite.

The d.t.a. curves for Machkund and Padwa (Profile No. 1) show (Fig. 1c, d, table 4) very weak low temperature endothermic reactions. This feature together with broad and

5. M. Adhikari, *J. Indian Soc. Soil. Sci.*, 1958, **6**, 147.

hump like appearance due to dehydroxylation, endothermic reaction sharp in the range 500-625° and intense like well-crystallised kaolinite and absence of high temperature exothermic peak suggest illite in predominantly kaolinite clay (Grim[6] Adhikari, loc. cit). The d.t.a. curves of other Machkund and Padwa soil clays, (table 4) also reveal that kaolinite constitutes the major clay mineral with small amount of illite.

The clays from Pasighat soils show in their d.t.a. diagrams, (Fig. IIb, table 4) such common features as water loss below 100° and graded but continuous endothermic reactions up to 900°.

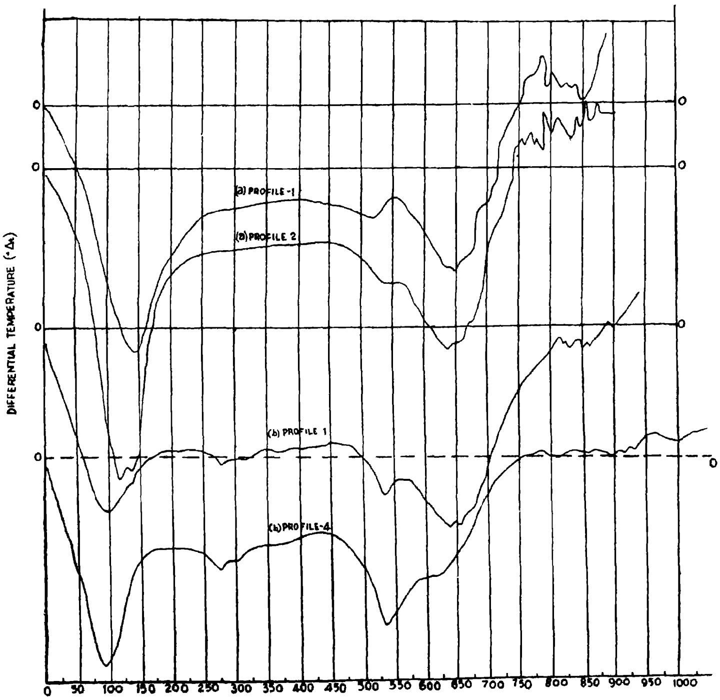

FIG II

Some of the curves (Profiles 1 and 4) show sharp thermal reactions in the vicinity of 100° but all show endothermic reactions at 275°, 550° and 640°. The reactions at 275° and gradual dehydration reaction from about 500° to 800°may be due to vermiculite (Walker[7], Barshad[8]). The presence of endothermic peaks at 550 and 640° may be due to kaolinite and illite. The d.t.a. results of clays from Profile No. 2 (tables 4) are slightly different in having no low temperature (i.e. at 100°) endothermic peak but show broad and shallow endothermic reactions. These are due to either degraded illite (Adhikari[9]) or interstratified

6. R. E. Grim, *Am. Min.*, 1947, **32**, 43.
7. F. G. Walker, Min. Soc. Great Britain, monograph, London, 1951, 199.
8. I. Barshad, *Am. Min.*, 1950, **35**, 225.
9. M. Adhikari, *J. Indian Soc. Soil. Sci.*, 1957, **5**, 199.

illite-vermiculite (Cole and Hosking[10]). In general, from the results of d.t.a. of these clays it is possible to infer that degraded illite along with kaolinite and some vermiculite are the minerals present in them, the relative abundance of each constituent being, however, different in the different horizons. In the case of Cherrapunji clays, the d.t.a. curves manifest (Fig. Ie, table 4)) deep and sharp dehydroxylation endothermic reactions at 580-590° and small endothermic reactions at about 950°, followed by exothermic reactions which are characteristic of mica-like clay minerals (Jackson, loc. cit.). They clays from Profile No. 2 (table 4) are slightly different. They do not show sharp endothermic reaction peak at 590° and exothermic reaction at higher temperatures, which are characteristic of degraded illite. The highly acidic soil of Cherrapunji contains illite along with kaolinite. The potassium equilibrium may explain the formation and stabilization of illite in the soil, whereas kaolinite is the result of drastic acidic weathering of feldspar (Datta and Adhikari, loc. cit.

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Received January 3, 1968.

10. W. F. Cole and J. S. Hosking. The differential thermal investigation of clays. "Clay mineral mixtures and interstratified minerals", Min. Soc. Clay Min. Group., London, 1957, 248.