© Proc. Indian natn. Sci. Acad., 48, A, No. 2, 1982, pp. 209-217.
Printed in India.

Soil Mineralogy

MINERALOGY OF CLAY, SILT AND SAND FRACTIONS OF A PEDON FROM DARJEELING HIMALAYAN REGION

S. S. SAHU[1] *and* SUDHANSU K. GHOSH

Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi-110 012, India

(*Received 10 September 1981*)

Clay mineralogy has been elucidated on the basis of X-ray diffraction, electrometric titration, viscometric study and C. E. C. of clays. Mineralogy of silt and sand fractions has, however, been determined by X-ray diffraction analysis only. Mica was found to be the dominant mineral in both clay and fine silt (2–5μ) fractions. The presence of a mica-vermiculite regularly interstratified mineral with (002) spacing at 12Å is the characteristic feature of the mineralogy of this pedon. Small amount of vermiculite, chlorite and kaolinite are the other associated minerals in the clay fraction. The presence of chlorite and mica are traceable to the sand fraction also. In the coarse sand fraction flakes of biotite mica are visible. Chlorite and mica in the clay appears to have been inherited from the parent material whereas the interstratified mica-vermiculite and vermiculite are the product of weathering of biotite mica. The weathering mean of the layers indicated decreasing weathering intensity down the profile depth.

Keywords: Soil Mineralogy; Clay Mineral Genesis; Mica-Vermiculite Mixed Layer Mineral

INTRODUCTION

SOILS of Kalimpong and its surrounding areas have been included under brown forest soil group in the soil map of India (Govinda Rajan, 1970). Soils of this region has not yet been classified according to new taxonomic system. Information on the fertility level, chemical and physico-chemical properties of the soils are available from the work of the State Department of Agriculture, Government of West Bengal. Some knowledge on the clay mineralogy of Kalimpong soil and soils of terai region can be obtained from the investigations of Ghosh (1964), Ghosh and Dutta (1974) and Sahu *et al.* (1977). But little is known about the mineralogy of the coarser fraction and its relation to clay mineralogy in the soils of this mountain tract. In view of this, the present study has been planned to elucidate the clay mineralogy in relation to silt and sand fraction of a representative pedon from Kalimpong region and to trace the genesis of minerals in the clay fraction.

[1]Department of Agricultural Chemistry and Soil Science, Faculty of Agriculture, B.C.K.V.V., Kalyani, Nadia (West Bengal), India.

Materials and Methods

Soil samples from three different depths viz., 0–15, 15–30 and 30–45cm of a A-C pedon, from the State Govt. farm at Kalimpong, have been collected for the present study. Organic carbon, *p*H and nitrogen contents of the samples have been determined by the method described by Piper (1950). Particle size fractions have been separated after removal of organic matter and free iron oxides following the method of Jackson (1965). Mg- and K-saturated clays were used for X-ray diffraction analysis in a Philips X-ray diffractometer using CuK_α radiation obtained at 35 KV and 15mA and a scanning speed of 1 degree 2θ per minute and a time constant of 4. Parallel oriented specimens were used for X-ray diffraction studies. Semiquantitative estimation of clay minerals was carried out based on the method of Gjems (1967) but modified to correct intensities of the peaks appearing at 2θ angles lower than 8° so that the integrated intensities of the low angle peaks are comparable to the peak at 10Å. 7Å etc. The *p*H titration curves and viscosity buffer curves were obtained with the addition of bases to H-clays as per method used by Mukherjee *et al.* (1942). Mineralogy of sand ($> 50\mu$) and fine silt fraction (2–5μ) were studied by X-ray diffraction analysis. Weathering mean has been calculated following the method of Jackson and Sherman (1953).

Results and Discussion

Some properties of the soils are presented in Table I. The *p*H of the soil is around 6.0 and remains the same down the depth of the profile. Soils of the surrounding area are much more acidic but due to adequate liming, the soils of the State Farm are of higher *p*H. Organic matter content is moderate, varying from 4.03 to 3.90 per cent and C:N ratio varied from 12.8 to 12.1. Relatively high C:N ratio is indicative of less humified organic matter in the soil.

Table I

Some characteristics of the soil

Depth cm.	*p*H	% O.M.	% O.C.	% Total N	C : N Ratio
0–15	6.05	4.03	2.37	0.19	12.7
15–30	6.00	3.90	1.88	0.16	12.1
30–45	6.05	3.90	2.30	0.18	12.8

Electrometric and Viscometric Studies

Pronounced monobasic acid character has been observed in the nature of the titration curves of soil clays (Fig. 1*a* & *b*) isolated from the surface (0–15cm) and subsurface (15–30cm) soils and converted to acid clays. There is very little buffering in the run of the curve and it shows inflexion at *p*H 8.80 for both the soil clays against the addition of 28.50 and 30.0me of base per 100g clay. Nature of the titration curve and the base required at inflexion point indicated the dominance of 2:1 lattice minerals in the clays (Mukherjee & Mitra, 1944; and Sahu & Das, 1974). The viscosity buffer curves (Fig. 1*c* & 1*d*) show no hump in the run of the curves suggesting absence of appreciable amount of smectite type of clay minerals in these clays. The curves resemble those of mixtures of 2:1 non expanding clay minerals. Thus the presence of large amount of 2:1 lattice non-expanding minerals in the soil clays is indicated by the *p*H and viscosity curves. But the individual group of the mineral could not be identified. The X-ray diffraction studies has brought out this information in detail.

X-ray Diffraction Analysis of Soil Clay Fraction

X-ray diffractograms of the clay minerals isolated from three different layers are almost similar. They differ only in the relative intensity of the peaks (Figs. 2, 3 & 4). The presence of a strong peak at 14.14Å alongwith its higher order at 7.08, 4.69 and 3.54Å in the diffractograms of Mg clay of surface soil which does not change its

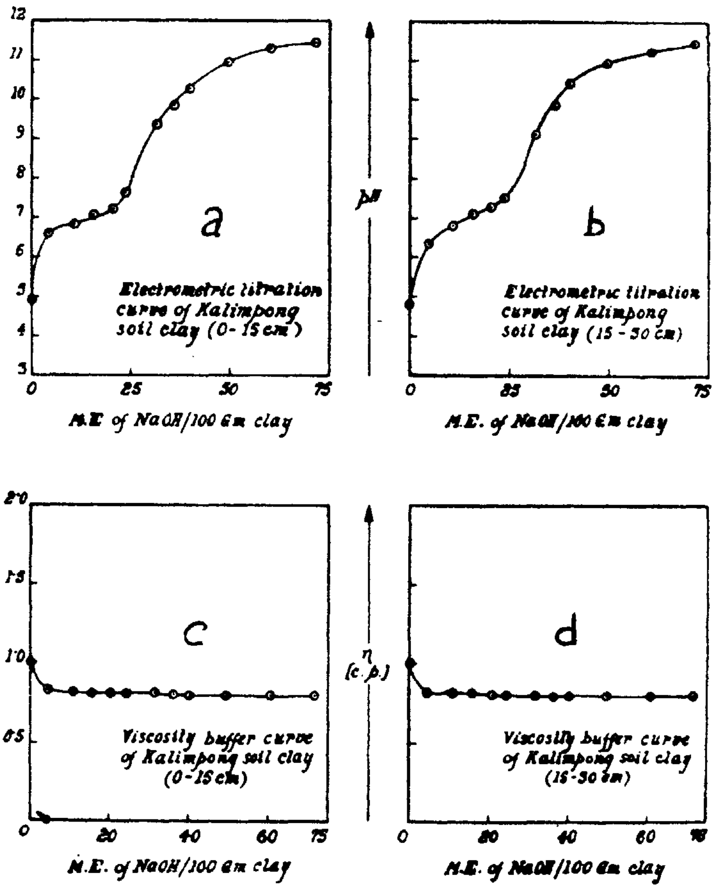

FIG. 1 Electrometric titration and viscosity buffer curves of soil clays.

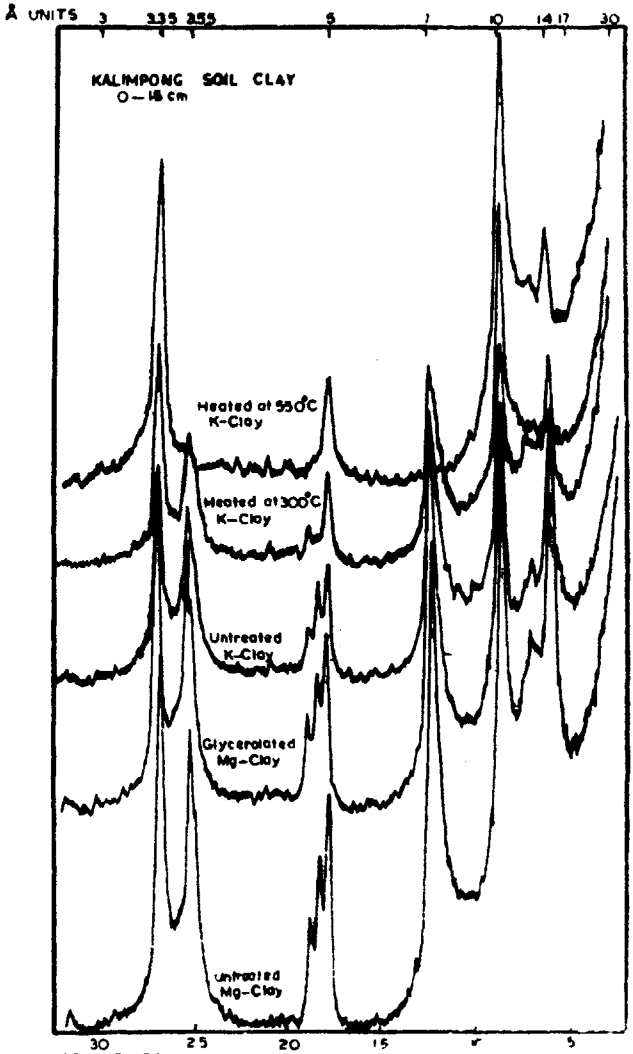

FIG. 2. X-ray diffractograms of Kalimpong soil clay (0–15cm).

position and/or intensity on glycerol solvation, may be due to chlorite and vermiculite in the clay fraction. Heating of K-clay to 300 °C leads to partial collapse of part of the mineral giving 14.14Å spacing and on further heating to 550 °C for 2hrs. it has collapsed to 10Å. This behaviour confirms that a part of the 14Å mineral is vermuculite. The same diffractograms of clays, subjected to 550 °C heating, also shows the presence of a peak with reduced intensity at 14.14Å, providing sufficient evidence for the presence of chlorite in the soil clay.

A small peak at 12.09Å and higher order peaks at 4.86 and 3.53Å can be seen in the diffractograms. With glycrol solvation of Mg-clays or K-saturation these peaks do not change their position, suggesting the presence of interstratified mineral

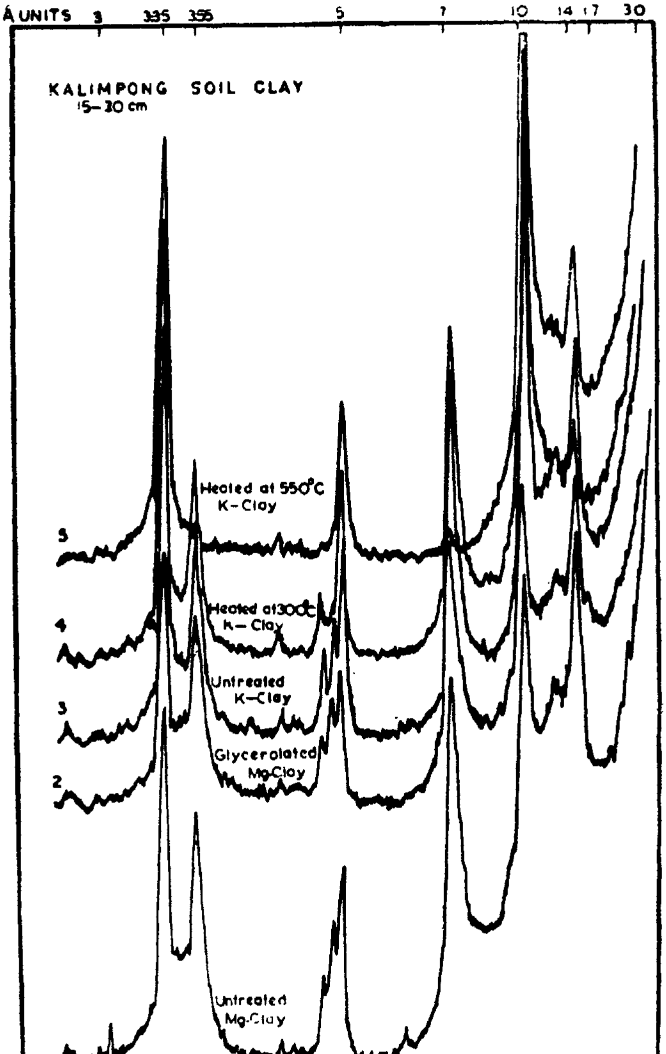

FIG. 3. X-ray diffractograms of Kalimpong soil clay (15-30cm).

in the clay fraction. These are indicative of alternate interlayering of a 10Å and 14Å minerals. The (001) peak, to be expected at 24Å, has not, however, been detected due to poor resolution at the low angles in the diffractograms. The 12.09Å peak however shifted to 11.1Å and gradually merged with 10Å component on heating the K-saturated clay to 300 °C and to 550 °C respectively. The 14Å component in the interstratified mineral was thus nonswelling type but revealed characteristics of collapsing as heated to higher temperature.

This behaviour to thermal treatment coupled with its non-collapsibility on K-saturation strongly indicate that the 14Å component is a low charged vermiculite or partially chloritised vermiculite. The regularly interstratified mineral may, therefore. be considered as a mica-vermiculite one.

The presence of a large amount of mica in the clay fraction can be well established from the presence of very strong peaks at 10.03Å, 4.98Å and 3.32Å. The presence of good amount of kaolinite in the clays is evident from the well resolved (002) peak of kaolinite at 3.56Å as distinct from the (004) peak of chlorite at 3.54Å.

The diffractograms of the clays from 2nd layer (15–30cm) of the pedon also depict the presence of similar types of mineralogical composition with difference in their relative abundance. Moreover, in this diffractogram a very small peak at 4.26 and 3.18Å indicate the definite presence of traces of quartz and feldspar respectively.

The similar mineralogical composition of the clay fraction of the 3rd layer of the pedon is also indicated by the diffractograms in Fig. 4. It only shows the difference in the relative intensity of the different peaks.

As mentioned earlier, semiquantitative clay mineralogical composition has been calculated from the peak area measurement. This is presented in Table II. Mica is the dominant mineral varying from 53 to 60 per cent and increases down the depth in this pedon. Mica-vermiculite mixed layer mineral is 9 percent on the surface and it increases to as high as 15 per cent in the next layer. The 3rd layer contain only 11 per cent in its clay fraction. Kaolinite varies from 10–17 per cent in this pedon and there is a decreasing trend down the depth. Chlorite and vermiculite varies from 3 to 7 per cent and 8 to 13 per cent respectively. Feldspar and quartz is absent in the surface layer and only 2 to 3 per cent is present in the clays of subsurface soils.

TABLE II

Mineralogical composition and weathering mean of soil clays

Depth cm	Feldspar	Quartz	Mica	Mixed layer	Vermiculite	Chlorite	Kaolinite	Weathering mean of soil
	% of clay							
0–15	—	—	53	9	13	7	17	7.71
15–30	2	2	55	15	12	3	11	7.51
30–45	3	2	60	11	8	5	10	7.30

Weathering mean has been estimated on the basis of quantitative mineralogical composition of the clay fractions. The weathering mean of the surface soil is 7.71 which decreases to 7.51 and 7.30 down the depth. This indicates that the surface soil i.e. Ap horizon is more weathered than the subsurface soils i.e. (C horizon).

The mineralogy of coarse fraction is revealed from the diffractogram in Figs. 5 and 6. The diffractograms of the silt fraction indicate the presence of mica, chlorite,

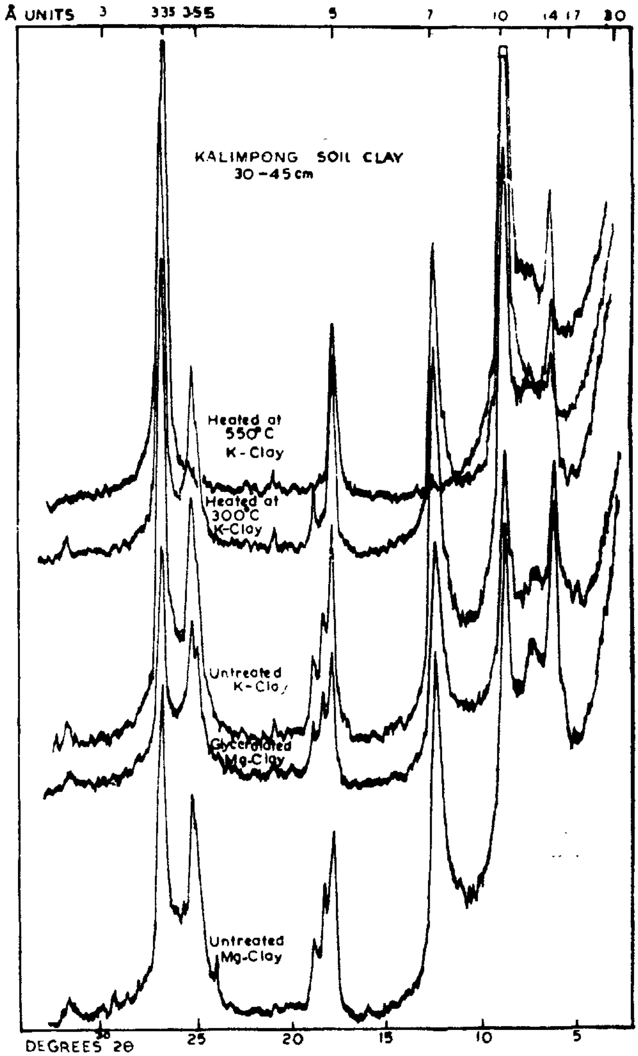

FIG. 4. X-ray diffractograms of Kalimpong soil clay (30–45cm).

mica-vermiculite interstratified mineral, quartz, kaolinite and feldspar in order of dominance. The sand fraction contains quartz, mica, chlorite and feldspar as identified from the diffractograms of the sand fraction of the three layers of the pedons as presented in Fig. 6.

The parent material of the pedon has been derived from rock formations of a part of the Darjeeling Himalayan region, which are rich in schists, gneisses and slates. These rocks are rich in mica, chlorites and quartz. Therefore, the occurrence of mica and chlorite in all the three fractions is in good agreement with the mineralogy of source material and indicates that their occurrence is by inheritance from the parent material. Small amount of quartz and feldspar in the clay fractions

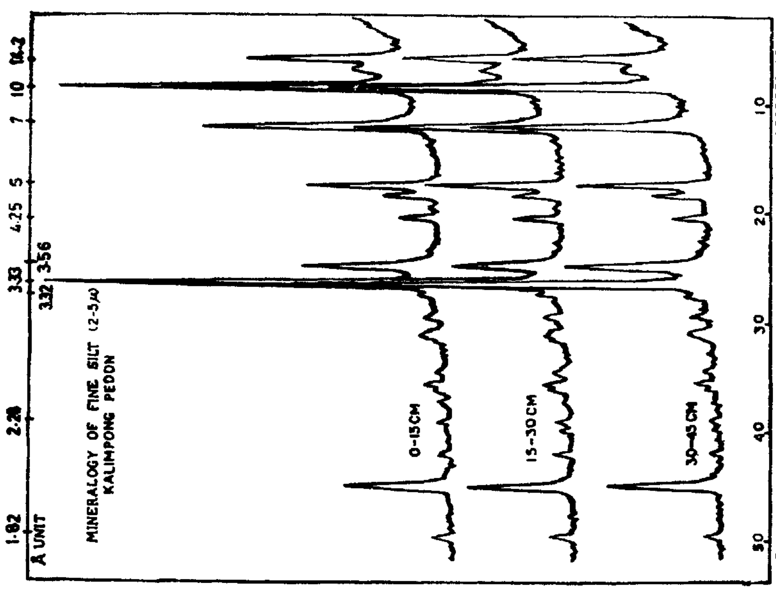

FIG. 5. X-ray diffractograms of silt fractions (2–5μ) of Kalimpong soil.

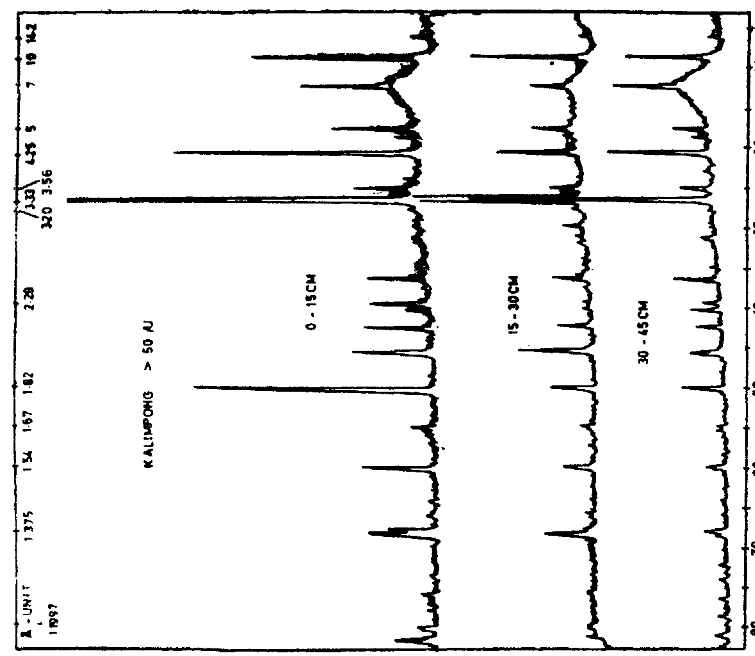

FIG. 6. X-ray diffractograms of sand fractions (> 50) of Kalimpong soil.

which could be traced back to the coarser fractions have also been similarly inherited. Flakes of biotite mica is easily observed in the sand fractions of this pedon even with unaided eye. This biotite mica appear to have weathered to mica-vermiculite interstratified mineral and also vermiculite. The mica-vermiculite interstratified mineral is traceable to silt and clay fractions. The weathering sequence of biotite mica in the pedon can be considered to have followed the following course :

Biotite ——→ Mica-vermiculite ——→ Vermiculite
(Sand) (silt and clay) (clay)

Kaolinite in the clay fraction seems to have originated from the weathering of feldspar.

REFERENCES

Ghosh, S. K. (1964) Mineralogy of clay, silt and sand fraction of soils in relation to genesis and potassium supplying power. *Ph.D thesis*, Post Graduate School, IARI, New Delhi.

Ghosh, S. K., and Datta, N. P. (1974) X-ray investigation of clay minerals in the soils of West Bengal. *Proc. Indian natn. Sci. Acad.*, **40B**, 138–150.

Gjems, O. (1967) Studies on clay minerals and clay mineral formation in soil profiles in Scandinavia. *Meddeleser fra Det Norske Skogforsoks-vensen*, No. **81**, Bind-21, Vollebekk, Norway.

Govinda Rajan, S. V. (1970) *Soil Map of India*, published by All India Soil and Land Use Survey, I. A.R.I,, New Delhi.

Jackson, M. L. (1965) *Soil Chemical Analysis–Advanced Course*. Published by the author, Dept. of Soil Science, University of Wisconsin, Madison, Wisconsin.

Jockson, M. L., and Sherman, G. D. (1953) Chemical weathering of minerals in Soils. *Adv. Agron.*, **5**, 221–319.

Mukherjee, J. N., Mitra, R. P., Chatterjee, B., and Mukherjee, S. K. (1942) On the nature of the reaction responsible for soil acidity. VIII. The acid character of hydrogen clay in relation to some problem in soil science. *Indian J. agric. Sci.*, **12**, 86–96.

Mukherjee, J. N., and Mitra, R. P. (1944) Differentiation of hydrogen clays and identification of their mineral constituents by electrochemical and viscous methods *Nature*, **154**, 824.

Piper, C. S. (1950) *Soil and Plant Analysis*. Academic Press, New York.

Sahu, S. S., and Das, S. C. (1974) Study of electrochemical and physico-chemical properties of clay mineral and their mixtures and of some soil clays to characterise their clay mineralogy. *Proc. Indian natn. Sci. Acad.*, **40B**, 235–248.

Sahu, S. S., Roy, S., and Ghosh, S. K. (1977) Clay mineralogy of a terai soil profile from Mohitnagar, Jalpaiguri, district, West Bengal. *Indian Agric.*, **21**, 187–194.