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THE TITANIUM CONTENT IN REPRESENTATIVE SOILS OF A PLEISTOCENE TERRACE IN EAST PAKISTAN AND ITS PEDOGENIC SIGNIFICANCE

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Titanium in soil, silt and clay fractions of a number of soils from the Barind tract was determined. The mean TiO_2 content in the soils ranged from 0.6 to 1.2 per cent with a mean value of 0.8%. The per cent TiO_2 in the clay fraction was higher than that in the silt fraction. These soils showed signs of the development of argillic horizons.

In the crust of the earth titanium is thought to be the most abundant of all the trace elements. Goldschmidt[1] estimated the average titanium content in the igneous rocks to be 0.44%. Rankama and Sahama[2] collected data on the content of titanium in the sedimentary rocks. Their results showed that most of the sedimentary formations contained an average of 0.5% titanium. These authors further reported that the Quaternary clays of Norway had only 0.47% titanium. From the above information it appears that in most igneous and sedimentary formations the titanium content ranges from 0.4 to 0.5%. In latosols and latosolic soils, however, the amount of titanium is much higher. Rankama and Sahama[2] reported a laterite having a titanium content of 3.25%. Jackson[3] indicated that not all laterites contain high titanium in them. In a study of the Hawaiian soils Sherman[4] reported that titanium in these soils ranged from 2.5 to 25%. In this study the above author was dealing mostly with latosols developed on freely drained highlands. In a recent study of the gray hydromorphic soils of the Hawaiian Islands it has been reported by Hussain[5] that these imperfectly drained soils in Hawaii have as low as 0.6% titanium.

Titanium is present in all soils but their amount depends on the quantity of this element in the parent materials and parent rocks.

A number of authors have worked on the movement and subsequent accumulation of titanium during the pedochemical weathering of soil parent materials. Joffe and Pugh[5] reported that titanium tends to accumulate in the surface horizon of laterite and podzol soils and indicated that titanium was possibly present as the mineral ilmenite. Hough and Byers[7] also reported that titanium in soils was present as the minerals ilmenite and rutile and assumed that these were primary minerals and were resistant to chemical weathering. Later studies by Sherman[4] have shown that the titanium mineral in the soils which were studied by Hough and Byers[7] was present as anatase, a secondary titanium oxide mineral.

Sherman[4] investigated the genesis of titanium-rich soils of the Hawaiian Islands and reported that titanium content was higher in the surface horizons of soils which developed under a humid tropical climate having an alternating wet and dry season. He further indicated that titanium easily dehydrated near the surface to form concretions and coated the surfaces of soil aggregates and peds. Katsura *et al.*[8] worked with the titanium bearing iron oxides in some Hawaiian latosols which they designated as titanomaghemite formed by the direct oxidation of titanomagnetite without any subtraction of iron from the system or addition of titanium into the system.

Karim[8] made a study of the pedological significance of titanium in some soils of South Australia and concluded that under lateric process of soil formation titanium content is lower in the A horizon clay than that in the B horizon clay and under podzolic process the titanium in the A horizon clay is higher than that in the B horizon clay. Robinson and Holmes[10] pointed out that in the soils of the United States the titanium in the colloid fraction showed an opposite distributional trend to that of the soils.

First work on the titanium distribution of some soils in East Pakistan was reported by Karim and Khan.[11] Their results showed an enrichment of this element in the colloid fraction of B horizons in the soils of the Madhupur tract, a Pleistocene terrace in East Pakistan. Their results further indicated that the distribution of TiO_2 in the soils followed the same trend as that of the clay fraction.

The Pleistocene terraces in East Pakistan are regarded as the relatively stable and older geologic formations of this province.[12] Since pedogenic processes have been operative there for a considerable length of time the soils in these terraces have developed well-defined profile characteristics and the minerals have in some cases been segregated. The objective of the present study was to examine the profile distribution of titanium in the soils developed on a Pleistocene terrace in East Pakistan and to look into their pedogenic significance. In this report only the soils of the Barind tract, the largest of the Pleistocene terraces in East Pakistan have been considered.

Materials and Methods

Thirtyone soil samples representing six typical soil profiles from the Barind tract were collected on natural horizon basis to use in this study. The six soil series were Belabo, moderately well-drained; Chandra, moderately well-drained; Amnura, poorly drained, seasonally flooded; Jhikra, moderately well-drained; Lauta, poorly drained; Nijhuri, imperfectly drained.

The soils of the Barind tract are never flooded but during the rainy season rain-water sometimes accumulates on them temporarily and cannot easily pass through the soils because of the impervious nature of lower horizons of some of these soils. Annual precipitation in this area is around 50 in and the mean annual temperature is 77°F with a Meyer's NS quotient of 203.[13] Detailed morphological description of these soils was presented by Islam.[14]

The materials of the Barind tract are clayey in nature and were probably rich in calcareous materials at one time. In the light of the findings of Pendleton and Sharasuvanna[15] it may be safely said that the parent materials of these soils were of mixed origin. This conclusion was drawn from the SiO_2/R_2O_3 ratio of the soils (Table 1). During the late Pliocene period the parent materials were deposited in an inland lake and were subsequently uplifted during the Pleistocene time.[16]

Titanium in total soil, silt and clay fractions was determined by the Na_2CO_3 fusion method of Piper.[17] Titanium was estimated colorimetrically by developing a yellow colour after treating an aliquot with H_2SO_4 according to the method of Sherman and Kanehiro.[18] Silica-sesquioxide ratio of soils was determined following the Na_2CO_3 fusion method as described by Piper.[17]

Silt(0.02–0.002 mm) and clay (<0.002 mm) fractions were seperated after pretreating the soils. In this the soils were first treated with H_2O_2 to remove organic matter. They were then deferrated according to the method of Aguilera and Jackson[19] to remove free iron oxides. Free alumina and silica were removed by boiling the soils with 2% Na_2CO_3 for five minutes. The soils were then dispersed with dilute Na_2CO_3 and the silt and clay fractions were separated by centrifugation method.[20]

Results and Discussion

The average titanium oxide content of the soils from the Barind tract was 0.8% and the range in TiO_2 values was from 0.5 to 1.2% (Table 1). The high average titanium oxide content relative to that for sedimentary rocks (Rankama and Sahama[2]) is due probably to the nature of the parent material.

Karim and Khan[11] determined the TiO_2 content of some representative soils from the Madhupur tract. Their results showed the average TiO_2 content in these soils to be 1.2%. A group comparison between the titanium content of the soils of the Barind tract and that of the Madhupur tract showed a 't' value which was significant at one per cent level. This result, therefore, indicates that the soils of the Barind tract contain a significantly smaller amount of titanium than that of the Madhupur tract. This may lead one to suggest that although the materials of the above two tracts were deposited during the Pleistocene time, their composition and also the provenance was different.

In most of the soils there is a tendency of accumulation of titanium near the surface. To explain this trend of distribution it probably is essential to look into the environmental conditions under which these soils have developed.[4] Barind tract has two pronounced seasons, dry and wet. Dry season starts from early November and continues up to June, while wet season starts from July and ends in October. Because of this seasonal changes the minerals present in these soils undergo hydration and dehydration alternately every year. Intense chemical weathering takes place during the wet season as a result of which the titanium minerals are hydrated. During the dry season because of high evaporation, hydrated titanium minerals may be transported towards the surface where evaporation is maximum. When the dehydrated titanium minerals come near the surface they are easily dehydrated and may permanently be accumulated there.

The accumulation of titanium in the soil profiles may also be linked with the type of soil forming process. In the present soils TiO_2 shows a surface enrichment which gradually decreases down with depth. This type of accumulation is usually observed under podzolization process of soil formation.[6]

Another reason for the higher concentration of TiO_2 in these soils may be the properties of the titanium-bearing minerals. Titanium oxides are regarded as resistant minerals during chemical weathering. The surface enrichment might be due to the fact that titanium-bearing minerals being stable in nature are preferentially accumulated while other easily weatherable minerals are decomposed. It is natural that the accumulation of TiO_2 will be higher where the intensity of weathering is maximum and gradually decreases down with the lowering of weathering intensity.[12]

Titanium Oxide in Silt Fraction.—The TiO_2 in the silt fraction of the soils from the Barind tract varies from 0.3 to 0.7%. The mean TiO_2 in this fraction is only 0.4%. It is interesting to note that TiO_2 in the silt fractions is much lower than that in the total soil or in clay fraction (Table 1). This may be due to the fact that smaller amount of titanium-bearing minerals is present in this size fraction. It may be pointed out that the primary minerals in soils become more susceptible to pedochemical weathering as they are gradually diminished in size and consequently become more unstable.[21]

In the silt fraction of Jhikra and Lauta series there is a slight decrease of TiO_2 content down the profiles. The vertical distribution pattern of TiO_2 in the silts of Belabo, Amnura and Nijhuri, however, is irregular in nature which may indicate that it is parent material and not weathering that controls the distribution of this element (Table 1).

Titanium Oxide in Clay Fraction.—Steinkeoning[22] worked on the distribution of titanium in various fractions of a number of soils and showed that TiO_2 concentration is higher in the clay fraction compared to that in the coarser fractions. It is apparent that in the soils of the Barind tract with the exception of Amnura and Jhikra series TiO_2 in the clay fraction is higher than that in the soil or in the silt fraction (Table 1). This result is, therefore, in agreement with that reported by Steinkeoning.[22] Karim and Hussain[23]

TABLE 1.—DISTRIBUTION OF TITANIUM OXIDE IN THE SOILS, SILT AND CLAY FRACTIONS FROM THE BARIND TRACT.

Soil series	Horizon	Depth (in)	TiO_2			(SiO_2/R_2O_3)*
			in oil (%)	in silt (%)	in Clay (%)	in soil
Belabo	Ap	0–3	0.7	0.3	1.3	11.0
	B1	3–11	0.8	0.4	0.9	9.2
	B21	11–19	0.7	0.4	0.9	9.5
	B22	19–35	0.6	0.5	0.8	8.0
	C	35–50	0.6	0.4	0.7	7.5
Chandra	Apg	0–5	1.2	0.4	1.3	11.1
	B21g	5–15	0.9	0.6	1.0	9.2
	B22g	15–26	0.8	0.7	1.2	7.4
	C	26–45	0.7	0.3	0.8	7.3
Amnura	Apg1	0–6	1.0	0.5	0.9	10.1
	Apg2	6–17	0.9	0.4	0.9	11.8
	B21g	17–26	0.8	0.4	0.9	9.0
	B22g	26–40	0.8	0.5	0.6	8.6
	B23g	40–55	0.7	0.3	0.5	7.9
Jhikra	Ap	0–5	0.9	0.6	0.7	12.7
	B	5–14	0.9	0.5	0.6	9.9
	Cl	14–25	0.9	0.5	0.8	10.5
	C2ca	25–40	0.6	0.4	0.8	9.6
	C3ca	40–50	0.6	0.4	0.7	9.2
Lauta	Apg1	0–5	0.7	0.5	1.2	13.4
	Apg2	5–17	0.7	0.4	0.8	10.5
	Ab1g	17–26	0.9	0.4	1.0	10.9
	B21g	26–37	0.5	0.4	0.8	10.5
	B22g	37–52	0.6	0.3	0.8	9.6
	B23g	52–65	0.6	0.3	0.7	10.0
Nijhuri	Apg	0–4	1.0	0.3	1.0	13.8
	B1g	4–8	0.9	0.3	1.0	14.0
	B21g	8–12	0.7	0.3	0.8	12.3
	B22g	12–20	0.8	0.4	0.7	9.6
	B3g	32–54	0.7	0.3	0.6	9.5
	B3g	20–30	0.7	0.3	1.0	9.0
	Mean	—	0.8	0.4	0.9	9.8

*Molar ratio on ignited soil basis.

TABLE 2.—RESULTS OF MECHANICAL AND CHEMICAL ANALYSIS OF SOILS OF THE BARIND TRACT.

Soil Series	Horizon	Depth (in)	Mechanical separates			Organic matter %	pH
			Sand %	Silt %	Clay %		
Belabo	Ap	0–3	50	29	21	3.1	6.4
	B1	3–11	50	28	22	1.0	5.5
	B21	11–19	37	22	41	0.7	5.3
	B22	19–35	36	21	43	0.5	5.4
	C	35–50	33	21	46	0.4	5.8
Chandra	Apg	0–5	43	37	20	1.9	5.5
	B21g	5–15	28	26	46	1.0	5.6
	B22g	15–26	26	23	51	0.7	5.8
	C	26–45	25	23	52	0.4	5.8
Amnura	Apg1	0–6	45	35	20	0.9	5.5
	Apg2	6–17	42	32	26	0.4	6.9
	B21g	17–26	32	25	43	0.3	6.6
	B22g	26–40	32	25	43	0.2	6.5
	B23g	40–55	29	26	45	0.2	6.4
Jhikra	Ap	0–5	26	27	45	1.6	7.4
	B	5–14	23	21	56	1.6	7.9
	Cl	14–25	26	27	47	0.4	7.6
	C2ca	25–40	26	27	47	0.4	7.9
	C3ca	40–50	27	26	47	0.2	7.9
Lauta	Apg1	0–5	43	29	28	0.4	5.2
	Apg2	5–17	39	31	30	0.2	5.9
	AB1g	17–26	51	22	27	0.2	6.1
	B21g	26–37	38	22	40	0.2	6.2
	B22g	37–52	35	19	46	0.1	6.1
	B23g	52–65	25	24	51	0.1	6.2
Nijhuri	Apg	0–4	53	27	20	1.3	5.3
	B1g	4–8	45	17	38	0.4	6.1
	B21g	8–12	44	19	37	0.4	6.0
	B22g	12–20	40	18	42	0.3	6.0
	B23g	20–32	41	17	42	0.2	6.0
	B3g	32–54	39	17	44	0.2	6.2
	Mean	—	37	24	39	0.65	—

studied the titania content in some soils from Sylhet foothills and reported that titania in the clay fraction was much higher than that in the soils. They also reported a surface concentration of titania in the clay fractions of their soils. According to them titanium in the clay was possibly present as small-sized, discrete titanium oxide minerals.

TiO_2 in the clay fraction of all the soils except the Jhikra series shows a decrease with depth. This means that there is a preferential accumulation of titanium in the colloid fractions of surface horizons. Karim[9] regarded this as a characteristic feature of podzol soils. The distribution pattern of TiO_2 in the clay fraction of the present soils is in agreement with the findings of Karim and Khan.[11] The concentration of titanium near the surface may be explained by the fact that since titanium minerals are resistant they tend to accumulate as the pedochemical weathering advances.

The mean titanium contents in the soil, silt and clay fractions are 0.8, 0.4 and 0.9% respectively (Table 1). The fact that the mean TiO_2 in the soils is higher than that of the silt fraction indicates that titanium content in the sand fraction is also higher. This conclusion has been drawn from the fact that in the mechanical composition of soils the mean percentages of sand, silt and clay are 37, 24 and 39 respectively (Table 2).

In the clay fraction TiO_2 may occur in different forms. It may be present as fine-grained discrete oxides such as leucoxene, anatase and rutile. Of these three minerals rutile is primary whereas anatase and leucoxene are secondary in origin.[4] In the absence of X-ray diffraction analysis it was not possible to determine as to which of the above minerals are present in the clay fractions of the present soils. But microscopic analysis has shown that the titanium minerals in the sand fraction was mostly rutile.[14] Jackson[3] and Sherman[4] have, however, reported that in the tropics the titanium oxide minerals in soils are more often anatase formed during pedochemical weathering.

In the clay fraction, titanium may occur in another form such as in the octahedral layer of clay minerals, because this element can isomorphously substitute aluminium in the octahedral layer of clay crystal lattice.[20] Such occurrence of titanium in the octahedral layer of a nontronite mineral has been reported in some imperfectly-drained tropical soils.[5]

Again, if the TiO_2 content in the clay fractions of the Barind tract soils is compared statistically with that in the clay fractions of the Madhupur tract soils (Karim and Khan[11]) the result shows a highly significant difference between them. This indicates, therefore, that the parent materials of these two major Pleistocene terraces were different and probably did not come from a single source but from different sources. But the materials of both these terraces in East Pakistan were deposited during the same geologic time.

Particle Size Distribution.—The clay content in these soils varies from 30 to 56% with a mean value of 39% and the texture of most of the soils ranges from loamy clay to clay (Table 2). In all the soils there was an increase of clay content from the surface downwards while the percentage of sand decreases in that direction. The increase in clay content with depth may be due to the movement of this fraction from the surface downwards. If this is so, then these soils may be said to contain 'argillic horizons' in the illuvial zone.[24] But before designating them as argillic horizons the orientation of translocated clay particles and the identification of 'illuviation cutans' are essential. The amount of clay films may have to be measured. And for this there is need for further study in this direction.

Organic Matter.—The organic matter content in the Barind tract soils ranges from 0.1 to 3.4% with a mean value of 0.65% (Table 2). This shows that the amount of organic matter in these soils is quite low. This is probably because of the fact that these soils are located in the humid tropics to subtropics zone and as a result the rate of decomposition of organic matter is rapid. The soils of the Barind tract seem to contain even less organic matter than the average organic matter content of East Pakistan soils which is around 1.0%.

Results on pH shows that the soils of the Barind tract are moderately acidic except the Jhikra series which looks like slightly alkaline. This result, therefore, removes the wrong impression that all the soils of the Barind tract are calcareous in nature.

Summary

Titanium oxide in a number of soils from the Barind tract has been determined to see how far the soil-forming processes have influenced the distribution of this element. It was observed that in the soils there was a preferential accumulation of titanium near the surface. This type of distribution might be due to the existence of alternate wet and dry seasons in this area. Another reason for this surface accumulation might be that the titanium-bearing minerals are relatively stable in soils. During pedochemical weathering these minerals would tend to accumulate while there would be a relative impoverishment of weatherable minerals. A group comparision between the titanium content of the Barind tract and the Madhupur tract soils showed that the parent materials on these two Pleistocene terraces were different. It was further concluded that the provenance of the materials of these two tracts might not be the same.

Titanium in the clay fraction of the Barind tract soils was high but it could not be ascertained whether it occurred as discrete oxide minerals such as anatase, leucoxene and rutile or it occurred in the octahedral layer of clay crystal lattice. The vertical distribution of TiO_2 in the soils and clays indicated that probably podzolization was the major pedogenic process in these soils. The higher concentration of clay down the profiles might indicate the presence of argillic horizons.

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