Pedogenic Development of Fe-Mn Glaebules in Two Monadnock Soils of Assam

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Abstract: *Iron-manganese glaebules from two monadnock soils of Assam representing Typic Hapludult and Ultic Hapludalf was studied for their characterization and genesis. The glaebules are round to subrounded form, dark reddish brown (5YR 3/2) to brownish yellow (10 YR 6/6) in colour and occurs in the Bt and BC horizons of the soils. The glaebules contain higher amount of Fe_2O_3, MnO_2, Zn and Cu than the surrounding soil matrix. The free Fe_2O_3 constitutes 60 to 70 per cent of the total Fe_2O_3 in the glaebules. DTA analysis shows that they have goethite, illite and kaolinite minerals. The Fe-Mn glaebules are thought to be formed through continued segregation and concentration of Fe and Mn oxides by alternate oxidizing and reducing conditions.* (**Key words:** *glaebules, monadnocks, oxidizing/ reducing state).*

The Brahmaputra valley of Assam consists of alluvial plains interpersed with numerous monadnocks or isolated hillocks which are presumed to be detached from the Meghalaya plateau by degradational work of the Brahmaputra river (Pofali & Shankaranarayana 1982) and are formed from granites and gneisses (Gowsami 1960). Chakravarty *et al.* (1982) studied the Fe-Mn glaebules in some alluvium derived soils of Assam. But such information is not available on monadnock soils of Assam. The present paper is aimed to study the chemical and mineralogical composition as well as genesis of Fe-Mn glaebules in two monadnock soils of Assam.

MATERIAL AND METHODS

Two soil samples developed on monadnocks were collected from Alamganj (26°07'18" N, 89°58'45" E) and Fulbari (26°48'18" N, 92°43'45" E), representing Typic Hapludult (P_1) and Ultic Hapludalf (P_2). The mean annual rainfall of these areas is 2733 and 1756 mm and that of temperature is 24.6°C and 26°C respectively. The tempera-

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ture regime is hyperthermic.

The Fe-Mn glaebules from the Bt horizons of both the pedons as well as from BC horizon of P_2 were separated by wet sieving, dried at 60°C and their percentage determined. The composite samples were ground to pass through 300 mesh sieve. The sieved samples (glaebules and surrounding soils) were analysed for organic carbon (Jackson 1973) and free iron and aluminium oxides (Mehra & Jackson 1960). Ignited samples were used for total elemental analysis (Jackson 1973). Total sodium, potassium, calcium and magnesium iron, manganese, zinc and copper were determined by atomic absorption spectrophotometer. Mg saturated samples were used for DTA in Stanton Redcroft simultaneous thermal analysis using Pt-Rh-Pt thermocouple by heating upto 1350°C at the rate of 10°C per minute.

RESULTS AND DISCUSSION

Characterization: The general characteristics (Table 1) show that the glaebules are dark reddish brown (5YR 3/2) in Typic Hapludult (P_1) and brownish yellow (10YR 6/6) in Ultic Hapludalf (P_2). They occur as rounded to subrounded concretion-sand nodules having sharp boundaries with the surrounding soils. The glaebules of lower horizons contain more organic carbon than the surrounding soils. This may be due to illuviation of humified materials alone or in combination with Fe into lower horizons and their subsequent accretion into glaebules. Karmakar (1985) observed significant correlation between pyrophosphate extractable Fe and humus in soil matrix of these pedons. Loss on ignition and free oxides of Fe and Al are higher in glaebules than in the surrounding soil matrix.

The elemental analysis (Table 2) shows that the glaebules contain lower SiO_2 and higher Al_2O_3 (except in Bt2 horizon of P_1), higher Fe_2O_3, MnO_2, Zn and Cu than the surrounding soil matrix of the corresponding horizon. Sidhu *et al.* (1978) and Chakravarty *et al.* (1982) reported that Fe-Mn glaebules contained greater concentration of Fe, Mn and Zn than the surrounding soil materials. In general, the glaebules of Typic Hapludult (P_1) have higher amount of all these elements except SiO_2 as compared to the glaebules of the Ultic Hapludalf (P_2). The SiO_2 content in the glaebules and surrounding soils of P_2 is higher than

TABLE 1. General characteristics of glaebules and surrounding soil matrix

Horizon with depth (cm)	Glaebules (%)	Glaebules size (mm)	Colour (dry)	O.C. (%)	Loss on ignition (%)	Free oxides Fe_2O_3 <----(%)--->	Free oxides Al_2O_3	Sand 2-0.05 mm	Silt 0.05-0.002 mm	Clay <0.002 mm	pH
								<---------(%)------>			
Pedon-1 (Typic Hapludult)											
A_p (0-14)	-	-	7.5YR 5/4	1.22	5.7	3.3	0.9	43.5	25.9	30.6	5.2
BA (14-31)	-	-	7.5YR 6/6	0.87	5.8	4.1	1.0	38.3	25.4	36.3	4.8
Bt1 (31-53)	-	-	7.5YR 6/6	0.56	6.6	4.2	1.4	23.0	25.5	51.5	4.9
Glaebules	5.4	1-5	5YR 3/2	0.15	7.3	11.8	7.2	-	-		--
Bt2 (53-130)	-	-	7.5YR 6/8	0.36	6.0	5.4	1.7	25.8	26.7	47.5	5.0
Glaebules	6.3	1-7	5YR 3/2	0.45	8.8	13.6	6.4	-	-	-	-
Pedon-2 (Ultic Hapludalf)											
A1 (0-3)	-	-	7.5YR 5/4	1.16	5.7	2.3	0.6	56.5	18.7	24.8	5.0
A2 (3-25)	-	-	7.5YR 5/4	0.58	4.3	1.9	1.0	55.4	19.4	25.1	5.2
Bt1 (25-105)	-	-	7.5YR 5/6	0.39	4.2	2.6	0.3	49.9	19.8	31.3	4.6
Bt2 (105-128)	-	-	10YR 7/6	0.09	3.3	2.2	0.7	51.1	14.4	34.5	5.1
Glaebules	5.6	1-8	10YR 6/6	0.06	3.4	4.6	1.3	-	-	-	-
BC (128-162)	-	-	10YR 8/6	0.03	2.7	1.4	0.6	59.4	14.9	25.7	5.3
Glaebules	6.6	3-16	10YR 6/6	0.09	3.9	5.0	1.3	-	-	-	-
C (162-220)	-	-	10YR 8/1	-	2.4	1.0	0.4	68.0	21.3	10.7	5.0

that of P_1. This may be due to more desilication in P_1 as a result of advance soil development under more humid climatic condition. The contents of CaO, MgO, K_2O and Na_2O in the glaebules and surrounding soil materials are almost same. The Fe_2O_3 content in the glaebules is 1.6 to 2.0 times as that in the surrounding soil. The free Fe_2O_3 constitutes major part (60 to 70 %) of the total Fe_2O_3 in the glaebules. The MnO_2 content in the glaebules is very high (7 to 143 times) as compared to that in the surrounding soils. From the morphological and elemental analysis, the glaebules can be characterized as Fe-Mn glaebules.

The DTA (Fig.1.)curve exhibiting a strong endothermic peak with maxima at 290°C inboth the samples indicates the presence of goethite. Although, the endothermic peak temperature for goethite is in the 300-400°C region, it may be 293°C or still lower for more poorly crystalized samples (Mackenzie 1957). Two

TABLE 2. Total elemental analysis of glaebules and surrounding soil matrix

Horizon with depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO_2	Zn	Cu	Molar $\frac{SiO_2}{R_2O_3}$
	<				(%)			>	< ppm	>	
Pedon-1 (Typic Hapludult)											
A_p (0-14)	73.7	15.6	6.6	0.6	0.6	1.1	0.20	0.11	260	270	6.3
BA (14-31)	74.5	14.2	7.2	0.6	0.5	0.9	0.20	0.11	250	270	6.7
Bt1 (31-53)	65.7	18.0	10.0	0.5	0.6	1.1	0.10	0.05	280	280	4.6
Glaebules	54.1	18.7	16.9	0.6	0.5	0.9	0.10	2.60	310	390	3.1
Bt2 (53-130)	65.0	21.2	10.8	0.6	0.6	1.3	0.10	0.03	280	300	3.9
Glaebules	55.6	19.2	17.3	0.6	0.6	1.0	0.10	4.30	310	400	3.1
Pedon-2 (Ultic Hapludalf)											
A1 (0-3)	81.4	10.7	4.9	0.7	0.5	0.8	0.10	0.04	250	220	10.0
A2 (3-25)	81.8	10.8	4.2	0.7	0.5	0.7	0.10	0.05	250	230	10.3
Bt1 (25-105)	82.6	11.0	4.3	0.7	0.5	0.5	0.03	0.03	210	240	10.2
Bt2 (105-128)	82.5	10.0	4.7	0.7	0.5	0.8	0.10	0.06	250	280	10.8
Glaebules	72.8	16.5	7.5	0.6	0.5	0.8	0.10	0.43	290	350	5.8
BC (128-162)	82.1	10.8	4.0	0.6	0.4	0.8	0.10	0.02	250	240	10.4
Glaebules	73.3	15.8	8.2	0.6	0.6	0.8	0.10	0.49	300	380	5.9
C (162-220)	83.5	9.5	3.1	0.6	0.4	1.1	0.20	0.01	240	260	12.3

endothermic peaks with maxima at 494°C and 584°C in Typic Hapludult (P_1) and at 575°C in Ultic Hapludalf (P_2) followed by exothermic peaks at 915 to 931°C suggest the presence of illite and kaolinite. The DTG curves show two peaks, one at 290°C and another around 500°C with corresponding weight losses of 7 to 11 per cent in Typic Hapludult (P_1) and 2 and 4 per cent in Ultic Hapludalf (P_2) as exhibited by the TG curves. The weight losses at these temperatures may bedue to loss of sorbed water and dehydration of the lattice, respectively. The low temperature exothermic peak with maxima at 248°C observed in the Typic Hapludult (P_1) may be due to crystallization of amorphous ferric oxides to hematite (Mackenzie 1949).

Genesis: The horizons have developed on relatively homogenous parent materials of granite and gneiss (Goswami 1960) which is also evident from the fine sand mineralogy. The fine sand fraction of P_1 consists of 49.1 per cent quartz, 36.7 per cent orthoclase and 17.6 per cent muscovite and that of P_2 consists of 51.1 per cent quartz, 25.3 per cent orthoclase, 9.3 per cent plagioclase, 13.9 per cent muscovite with traces of heavy minerals like zircon, chlorite, biotite and garnet in both the pedons

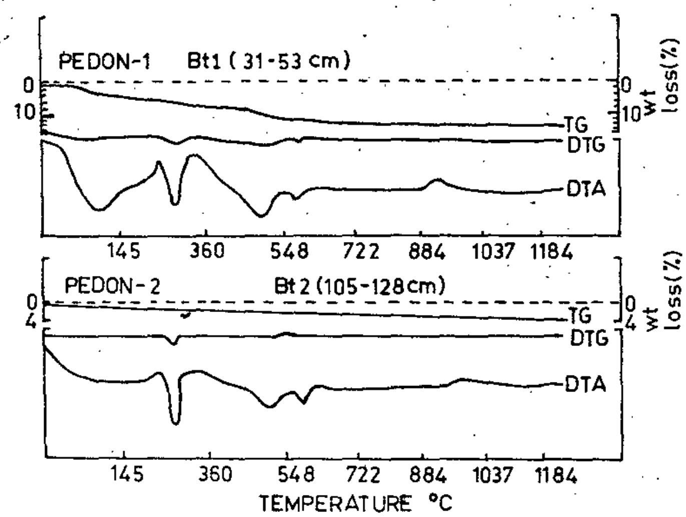

Fig. 1. Thermographs of glaebules

(Karmakar 1985). The landscape position does not indicate the transportation of glaebules. All these suggested that the Fe-Mn gleabules have been formed *in situ*.

Gallahar *et al.* (1974) postulated that laterization is probably involved in the formation of glaebules. In the present study, molar SiO_2 : R_2O_3 ratios (Table 2) indicate more desilication in Typic Hapludult (P_1) than Ultic Hapludalf (P_2). Although the Fe_2O_3 content in the glaebules of P_1 is more than that of P_2, the ratio of total Fe_2O_3 in the glaebules to the surrounding soils in both the profiles is similar. This suggests that intense desilication has considerably contributed to the Fe_2O_3 content of the glaebules of Typic Hapludult (P_1). The study region is characterized by alternate wet and dry seasons receiving about 80 per cent rainfall during March to September. The behaviour of Fe and Mn in oxidizing and reducing environment is analogous. The reducing environment facilitates the solubility of Fe and Mn compounds in the upper horizon and subsequently translocation to lower horizons by leaching. On oxidation during dry seasons, these compounds

are likely to coprecipitate to form Fe-Mn glaebules through accretion of soil plasma in the S-matrix. In the process, organic matter, Zn and Cu are likely to be coprecipitated and/or occluded. This is supported by glaebules of lower horizons having higher amount of total Fe_2O_3 and MnO_2. The Fe-Mn glaebules occur at higher depth in the Ultic Hapludalf (P2). The coarser texture of P2 facilitates reductive illuviation of Fe and Mn to a greater depth. Desilication resulted in accumulation of Fe in these soils. Fe-Mn glaebules were formed through continued segregation and concentration of Fe and Mn oxides by alternate oxidation and reduction conditions.

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