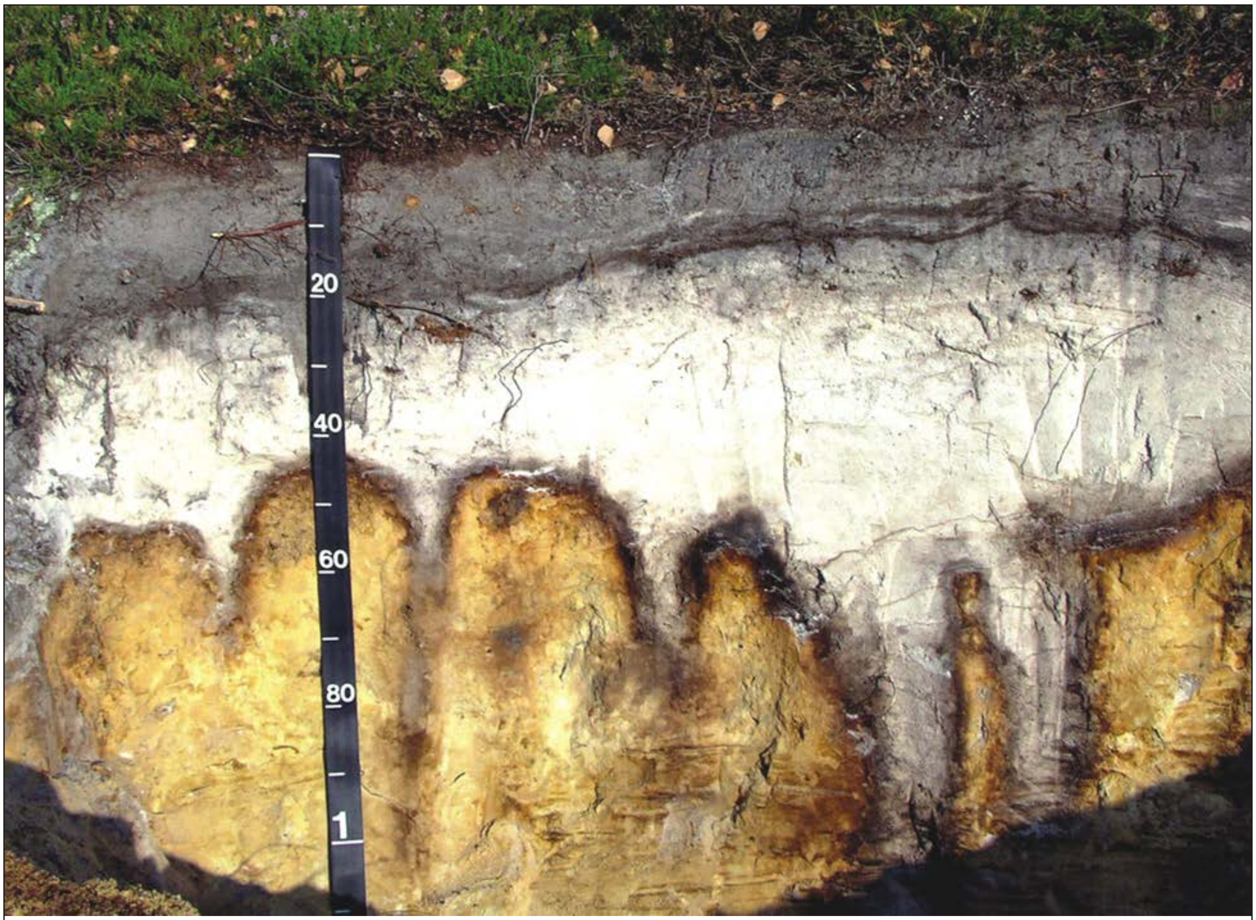

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Effect of Soil Moisture Regime and Rice Cultivation on Mineralogical Characteristics of Paddy Soils of Mazandaran Province, Northern Iran, Amol

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Abstract: The clay mineralogy of paddy soils with different water table depth and drainage of Northern Iran were investigated to determine their origin and factors controlling their distribution pattern in soils. In this study sand, silt and clay fractions were separated by centrifuge after the removal of organic matter, carbonates and sesquioxides. For identification of clay minerals, clay suspensions were saturated by Mg and K and then 10 mg of clays were placed on glass slides for XRD analysis. In all of the soils studied, smectite, illite, chlorite, kaolinite and quartz were identified. Clay mineralogy is probably more affected by parent materials and less influenced by aquic and anthraquic conditions. However, there are some indications that aquic and anthraquic condition may affect on quantity of clay minerals, as shown by higher smectite in poorly drained soils.

Key words: Paddy soils, aquic and anthraquic conditions, smectite, illite, chlorite

INTRODUCTION

Clay is the result of the aqueous solutions interaction with rocks. The dissolution and decrystalization is the process by which they are formed and transformed (Velde, 1995). Mineral compositions of the paddy soil with permanent reduce condition in Gilan Provinces, Northern Iran were investigated by Gelsefidi *et al*. (2001). In all of the soil studied smectite, illite and chlorite were identified. Khormali and Abtahi (2003) suggested smectite formation in poorly drained soil with low water table depth of soils. Therefore, the main objectives of this study (1) Semi-quantitative and qualitative determination, the origin and distribution patterns, (2) effect of aquic and anthraquic condition on clay minerals.

MATERIALS AND METHODS

Study Area

The study area (at the East of Amol city) is located in Mazandaran Province, Northern Iran, in the southern coast of the Caspian Sea (Fig. 1), with different water table depth (Fig. 2). Studied area has general slope from south to east. Its physiographic unit is alluvium plain. A humid climate with moderate temperature characterizes the area. The mean annual temperature is approximately 16.0°C. This area has an average annual rainfall of 848.4 mm (1988-1998). The soil moisture and temperature regimes are Wet Ustic and Thermic, respectively. The parent materials are derived from sediments weathered from primary rocks content Calcite, Dolomite and loess moved to this plain.

Field Work

This study was accomplished from September 2005 to September 2006. Seven pedons (35 paddy soil samples) and 1 pedon (4 soil samples) as a blank (soil under cultivation of citrus fruit) were

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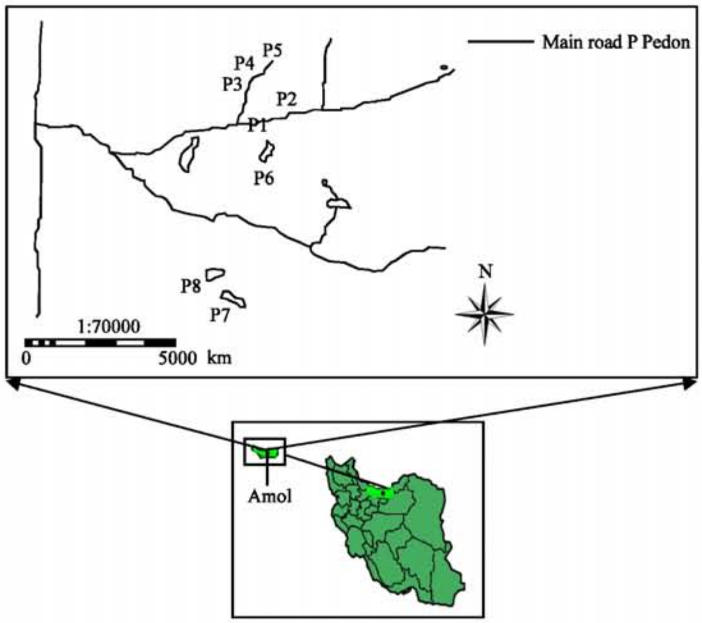

Fig. 1: The location of Mazandaran Province and Amol area

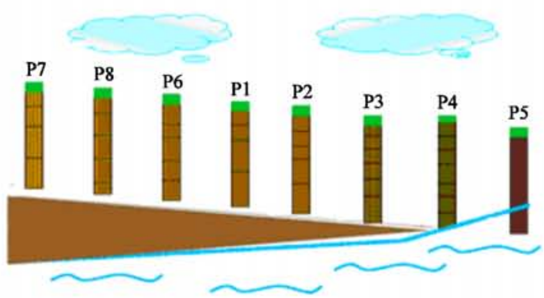

Fig. 2: The location of pedons according to water table depth

selected. Soil samples described and classified, according to keys to soil taxonomy (Soil Survey Staff, 2006). Four representative pedons (16 samples) were considered for further mineralogical study.

Physiochemical Analysis

Air-dried soil samples were crushed and passed through a 2 mm sieve. Samples were dispersed using sodium hexametaphosphate for determination of sand, silt and clay fraction by the hydrometric method (Bouyoucos, 1962). Organic matter was measured by wet oxidation (Nelson and Sommers, 1982). Alkaline-earth carbonate (lime) was measured by acid neutralization (Ehyaee and Behbahanizade, 1993). Soil pH was determined with a glass electrode in saturated paste (Ritvo *et al*., 2003). Electrical conductivity (total soluble salt) was measured in the saturation extract (Ehyaee and Behbahanizade, 1993). Cation Exchange Capacity (CEC) was determined using sodium acetate (NaOAc) at a pH of 2.8 (Bower and Hatchea, 1966).

Mineralogical Analysis

Removal of chemical cementing agents and separation of clay fractions was carried out according to Kittrick and Hope (1963) and Jackson (1975). The carbonates were removed using 1 N sodium acetate buffered at pH = 5. The addition of 1 N sodium acetate was continued until no effervescence was observed with 1 N HCl (Jackson, 1975). The reaction was performed in a water bath at 80°C. Organic matter was oxidized by treating the carbonate-free soils with 30% H_2O_2 and digestion in a water bath. Iron oxides were removed from the samples by the dithionate citrate bicarbonate method. The iron oxide-free samples were centrifuged and clay separates were removed. Additionally, for removal of the fine clay (particles <2/0 μm), clay separates were centrifuged according to Kittrick and Hope (1963). The (001) reflections were obtain following Mg saturation, ethylene glycol salvation and K saturation. The K saturated samples were studied after drying and heating at 550°C for 4 h. A total number of 16 clay samples from soils and parent rocks were studied using XRD.

RESULTS AND DISCUSSION

Soil profile description and some physical and chemical properties are shown in Table 1. In studied area pedon 5 is located Northern and lowland part of this region. The water table was at (or close to) the surface through out the year. Only some years in harvesting time and 2-3 weeks after harvesting is not flooded, but the soil surface is mostly wet because of arrival deposition from top land. Soil development of this pedon is the last, which has undergone little soil formation. The other pedons were not saturated all of the year and the water table fluctuation was influenced by cropping and flooding of the rice-growing and rainfall. Pedon 7 and 8 were at southern of studied area that have the height water table depth and locate in top land. Pedons 1, 2, 3 and 4 were located between pedons 5 and 7. Rice soils are mostly found in the alluvial lowland in humid regions. This implies that in the genesis of rice soils the soil material factor is one primary importance. Several processes may account for formation variety soils in this region, such as physical properties of parent material, organic matter repletion, clay mineral formation and their translocation by flooding and cropping and oxidation and reduction processes. The parent material of this area is mainly from lime and most of the soils are

Table 1: Selected physical and chemical properties of soils

Horizon	Depth (cm)	Moisture matrix color	Sand (%)	Silt (%)	Clay (%)	Texture	$CaCO_3$ (%)	OM (%)	ECe	pH	CEC
Pedon 1 (Paddy soil)											
Fine, mixed, (calcareous), superactive, thermic, fluvaquentic endoaquolls											
Ap_g	0-15	2.5Y3/2	9.7	46.8	43.5	Si.c	11.0	2.9	1.1	7.5	25.5
B_{g1}	15-23	2.5Y4/2	17.6	43.0	39.4	Si.cl.l	6.5	2.6	0.5	7.8	23.9
B_{g2}	23-80	2.5Y4/2	20.0	42.9	37.1	Si.c	10.0	1.7	0.4	7.6	30.4
C_g	>80	2.5Y4/3	13.0	50.1	36.9	Si.cl.l	15.0	1.6	0.4	7.8	32.6
Pedon 2 (Paddy soil)											
Fine loamy, mixed, (calcareous), superactive, thermic, fluvaquentic endoaquolls											
Ap_g	0-17	2.5Y3/3	16.7	49.9	33.9	Si.cl.l	16.0	2.4	2.1	7.6	34.8
Ab_g	17-22	2.5Y4/2	12.7	50.3	37.0	Si.cl.l	16.0	2.6	2.2	7.4	39.1
B_g	22-27	2.5Y4/2	39.7	47.6	12.7	l	19.0	1.6	0.5	7.7	13.0
C_{g1}	27-80	2.5Y4/2	23.3	42.8	33.9	Cl.l	12.0	1.6	0.5	7.7	32.1
C_{g2}	>80	2.5Y4/2	23.0	56.8	20.2	Si.l	10.0	1.6	0.6	7.7	32.1
Pedon 3 (Paddy soil)											
Fine loamy, mixed, (calcareous), superactive, thermic, fluvaquentic endoaquolls											
Ap_g	0-15	2.5Y3/2	29.8	46.8	23.4	l	16.0	1.8	1.4	7.4	31.1
Ab_g	15-27	2.5Y3/2	26.2	46.8	27.0	Cl.l	17.0	1.9	3.5	8.0	31.1
Bg_1	27-40	2.5Y3/3	23.7	45.7	30.6	Cl.l	12.5	1.4	0.4	8.0	30.4
Bg_2	40-46	2.5Y3/3	23.6	46.8	29.6	Cl.l	13.0	1.4	0.4	7.7	30.9
C_{g1}	46-80	2.5Y4/3	16.2	50.3	33.5	Si.cl.l	9.5	1.6	0.4	7.9	32.0
C_{g2}	>80	2.5Y4/3	16.7	48.7	34.6	Si.cl.l	11.0	1.4	0.4	7.7	30.5
Pedon 4 (Paddy soil)											
Fine, mixed, (calcareous), superactive, thermic, fluvaquentic endoaquolls											
Ap_g	0-17	2.5Y3/2	23.6	52.6	23.8	Si.l	15.5	3.3	1.8	7.4	16.3
Ab_g	17-22	2.5Y4/2	7.0	55.8	37.2	Si.cl.l	13.5	3.1	0.9	7.5	19.4
C_{g1}	22-26	2.5Y4/2	10.4	55.8	33.8	Si.cl.l	18.5	1.3	0.4	7.8	17.6
C_{g2}	6-40	2.5Y4/2	6.8	52.8	40.4	Si.cl	15.0	1.3	0.4	7.7	33.7
C_{g3}	40-45	2.5Y4/3	9.4	56.9	43.7	Si.cl	14.5	1.6	0.5	7.8	14.7
Ab	45-60	2.5Y4/3	7.0	49.2	43.8	Si.c.l	16.5	3.9	0.6	7.5	23.9
B_{gh}	>60	2.5Y3/2	12.9	37.0	50.1	cl	15.0	7.9	2.0	7.4	28.6

Table 1: Continued

Horizon	Depth (cm)	Moisture matrix color	Sand (%)	Silt (%)	Clay (%)	Texture	$CaCO_3$ (%)	OM (%)	ECe	pH	CEC
Pedon 5 (Paddy soil)											
Fine loamy, mixed, (calcareous), active, thermic, mollic fluvaquents											
Ap_g	0-15	2.5Y3/1	17.4	45.4	37.2	Si.cl.l	16.5	8.1	1.6	7.4	21.7
A_g	15-60	2.5Y2/1	13.7	49.2	37.1	Si.cl.l	15.0	7.8	0.8	7.5	17.4
C_g	>60	2.5Y3/2	69.6	16.7	13.7	Sa.l	11.0	1.2	2.3	7.6	13.3
Pedon 6 (Paddy soil)											
Fine loamy, mixed, (calcareous), superactive, thermic fluvaquentic endoaquolls											
Ap_g	0-19	2.5Y3/2	23.4	39.9	36.7	Cl.l	9.0	2.7	1.1	7.6	27.2
A_g	19-25	2.5Y3/2	26.7	36.2	37.1	Cl.l	12.0	2.3	0.4	7.8	35.9
B_{g1}	25-70	2.5Y4/2	19.2	42.5	38.3	Si.cl.l	10.0	2.1	0.4	7.6	21.4
B_{g2}	70-10	2.5Y3/2	43.0	36.9	20.1	l	9.0	2.4	0.5	7.7	17.6
C	>100	2.5Y4/3	43.8	35.1	21.1	l	9.0	2.1	0.4	7.6	17.5
Pedon 7 (Fruit garden sample)											
Fine, mixed, (calcareous), superactive, thermic, fluventic haplustepts											
A	0-15	2.5Y4/2	10.0	46.2	43.8	Si.cl	10.5	4.9	3.1	7.3	36.9
B_{w1}	15-53	2.5Y3/2	6.7	49.5	43.8	Si.cl	11.0	3.5	0.5	7.5	32.1
B_{w2}	53-100	2.5Y3/2	9.7	43.5	46.8	Si.cl	11.0	2.1	0.3	7.5	30.6
C_g	>100	2.5Y4/3	11.8	45.1	43.1	Si.cl	8.5	1.3	0.5	7.4	31.1
Pedon 8 (Paddy soil)											
Fine, mixed, (calcareous), superactive, thermic, fluvaquentic endoaquolls											
Ap_g	0-16	2.5Y3/2	13.3	50.0	36.7	Si.cl.l	12.5	2.1	1.7	7.4	23.5
Ab_g	16-25	2.5Y4/2	14.5	51.3	34.2	Si.cl.l	13.0	1.5	0.7	7.7	16.6
B_{g1}	25-50	2.5Y4/2	16.7	49.5	33.8	Si.cl.l	16.0	1.3	0.3	7.8	16.5
B_{g2}	50-80	2.5Y3/3	7.0	52.7	40.3	Si.c.l	10.5	2.0	0.4	7.5	32.5
C	>80	2.5Y3/3	17.4	42.6	40.0	Si.c.l	9.5	2.1	0.4	7.7	33.2

Table 2: Relative abundance of clay minerals of studied soils and parent rock

Horizon	Depth (cm)	Illite	Chlorite	Vermiculite	Kaolinite	Smectite	Quartz
Pedon 1 (Paddy soil)							
A_{pg}	15-0	+++	+	ND	+	+++++	+
B_{g1}	24-15	++++	+++	ND	++	+++	+
B_{g2}	80-24	++++	+++	ND	+	++	+
C_g	80<	+++++	++	ND	++	++	+
Pedon 5 (Paddy soil)							
A_{pg}	15-0	+++	+	ND	+	+++++	+
A_g	60-15	++	+++	ND	++	+++++	+
C_g	60<	+++++	+++	ND	++	+	+
Pedon 7 (Fruit garden sample)							
A	15-0	+++++	++	ND	+++	++	+
B_{w1}	54-15	+++++	++	ND	++	+++	+
B_{w2}	100-54	+++	+++	ND	+	+++++	+
C	100<	+++++	+++	ND	++	++	+
Pedon 8 (Paddy soil)							
A_{pg}	16-0	++++	++++	ND	+	+++	+
AB_g	25-16	+++	+++	ND	++	++++	+
B_{g1}	50-25	+++	++	ND	+	+++++	ND
B_{g2}	80-50	+++	++	ND	+	+++++	ND
C_g	80<	+++++	+++	ND	+	++	ND

+: 0-10, ++: 10-20, +++: 20-30, ++++: 30-40, +++++: >40, ND: No Define

calcareous throughout. The electrical conductivities (EC) of all soil are less than 4 ds m^{-1}. Organic matter content in all surface horizons are more than 1%, especially pedon 5. This increasing maybe related to weak oxidation and low activity of microorganisms because of flooding and reduces condition. The pH range in the studied pedons is 7-8. The CEC of the soils which is dependent on the amount and the type of clay minerals, ranges from 10-40 $cmol^{(+)}$ kg^{-1} (Table 1).

Clay Mineralogy of Soils

The semi-quantitative analysis of clay minerals and XRD patterns of clay in the studied area are shown in Table 2 and Fig. 3-6. Smectite, illite, chlorite and kaolinite are the major clay minerals of both

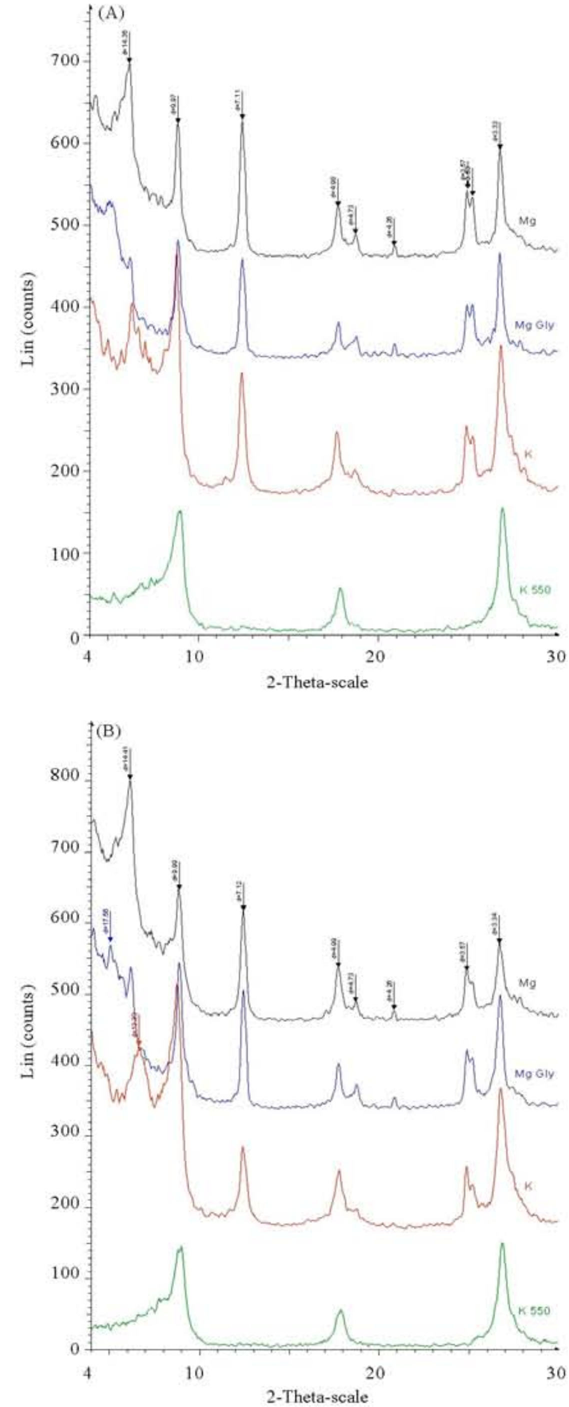

Fig. 3: XRD patterns of clay in parent rock (A) and in A_{Pg} horizon (B) of pedon 1, respectively

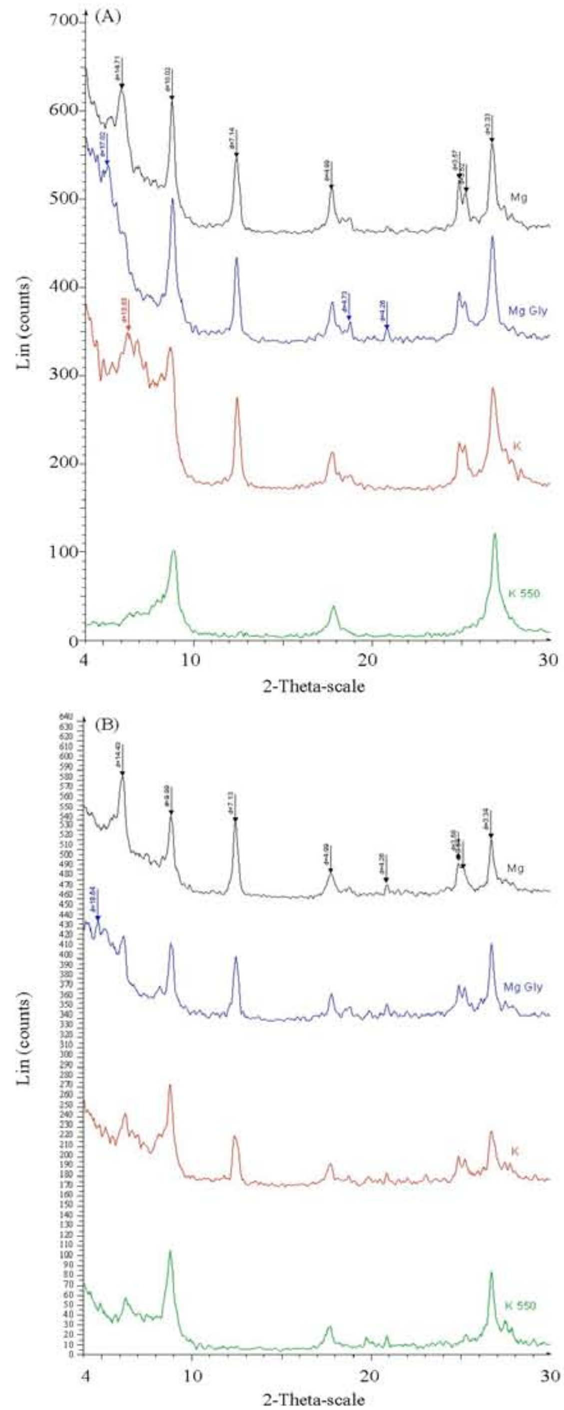

Fig. 4: XRD patterns of clay in A_{Pg} horizon (A) and in parent rock (B) of pedon 5, respectively

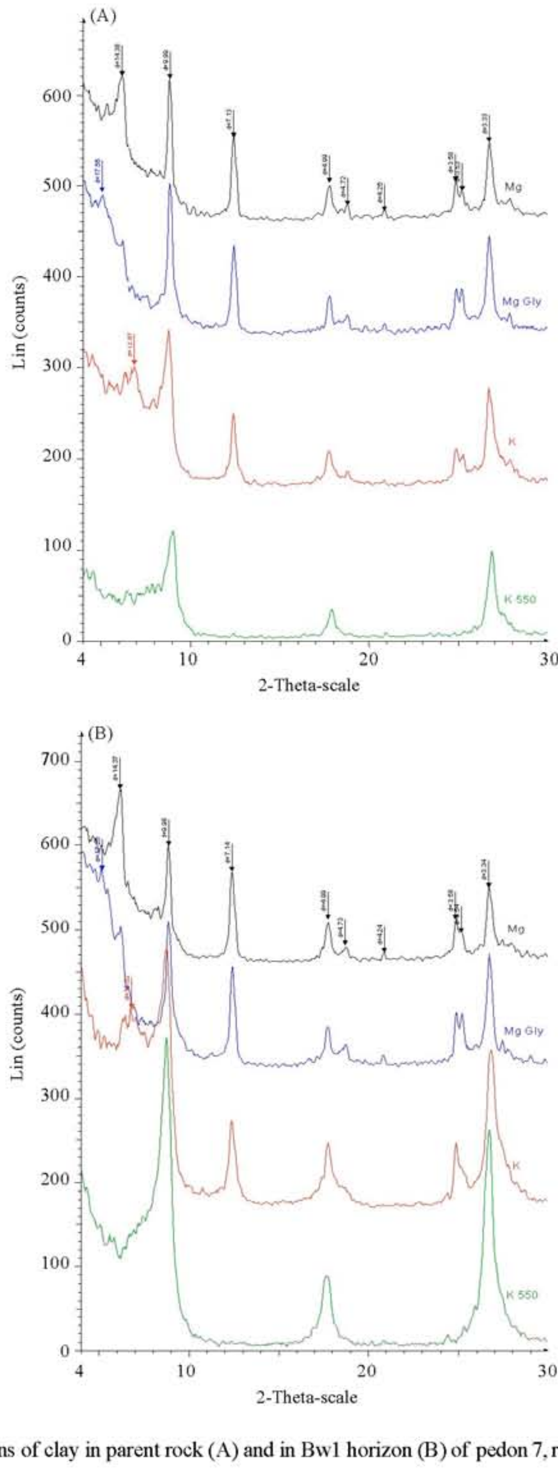

Fig. 5: XRD patterns of clay in parent rock (A) and in Bw1 horizon (B) of pedon 7, respectively

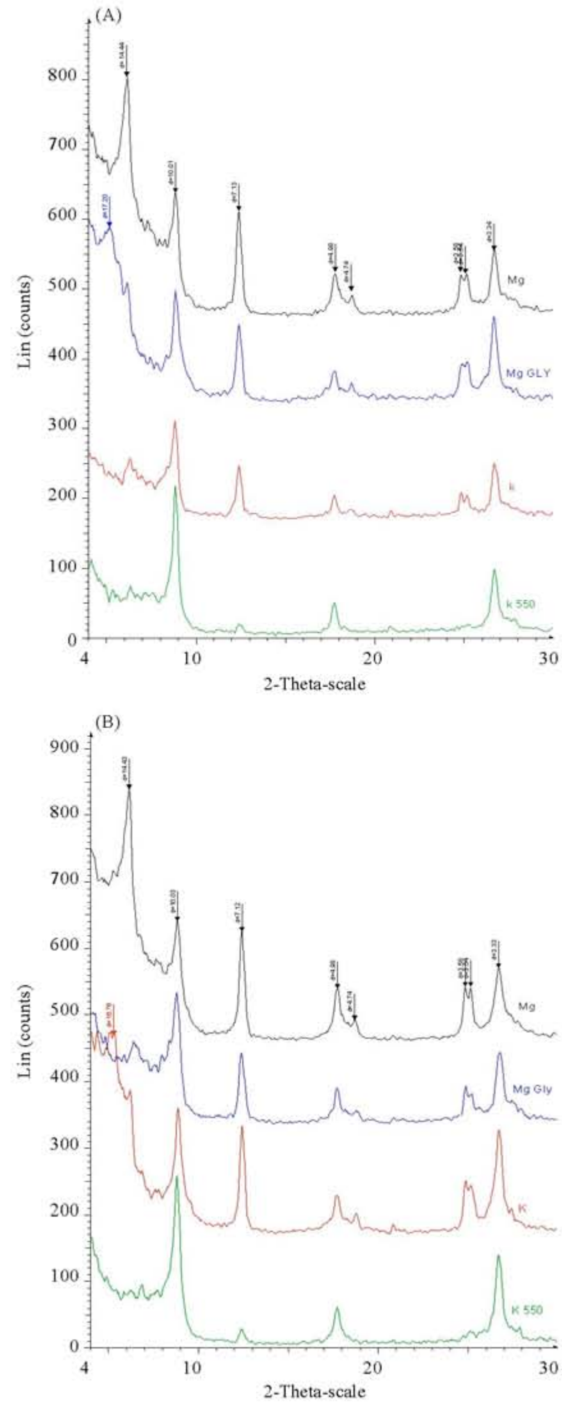

Fig. 6: XRD patterns of clay in parent rock (A) and in B_{g1} horizon (B) of pedon 8, respectively

paddy soils and the blank pedon. Studies by XRD revealed that illite is a commonly observed clay mineral in well drained pedons, which their abundance in soils is largely due to their presence in parent rock.

Illite

It is formed in pedogenic and sedimentary environment and also is commonly believed to be inherited largely from parent rock. Wilson (1999), Bronger *et al*. (1998) and Sanguesa *et al*. (2000) had the same result from their study too. A few studies have documented illite formation in soil by weathering of feldspars, increasing of soil leaching make a condition that K release from mica and are weathered and transform to 2:1 clay minerals (Dixon and Weed, 1989; Nanzyo *et al*., 1999; Lee *et al*., 2003; Kitagawa and Itami, 1996). One of the primary reasons for decreasing illite in surface is simple transformation to the other clay minerals especially smectite, because of the relative leaching environment for the release of K from micaceous minerals and mainly illite. The alteration of this mineral is due to the decrease of iron content, the decrease of layer charge and the degradation of crystal structure, through the pedogenesis under the seasonally reductive condition.

Smectite

It is the main clay mineral in surface and near surface and near surface reduced horizons of weakly drained pedons. The presence of large amounts of this mineral in poorly drained pedons with low water table depth is reported by Abtahi and Khormali (2001) and Aoudjit *et al*. (1995). They discussed there are 3 main sources of smectite in soils: (1) neoformation from soil solution, (2) detritial origin or inheritance, (3) transformation of other clay minerals. Low-lying topography, poor drainage and base-rich parent material, favorable chemical conditions characterized by high pH, high silica activity and an abundance of basic cations are the factors strongly influenced the origin and distribution of smectite in soils. Neoformation of Smectite was also reported, but illite transformation to smectite is a major source of this mineral in studied soil. When illite is exposed to weathering, K exit from illite layers and this condition is suitable to form smectite. Many researcher reported illite transformation to smectite as a main source of this mineral. Khormali and Abtahi (2003) found smectite in soils with poorly-drainage soils relate to well drained soils, like in pedon 5 with this condition we have high percent smectite, but in pedons 1, 7 and 8 smectite decreases with depth, because of high water table depth, well drained condition and also high leaching of basic cations, made unstable environment for smectite forming chemically. In pedon 5 with anthraquic condition, high enough base cation content can effects on pedogenic forming of this clay mineral.

Chlorite

It is also an inheritance clay mineral in the studied area as well as illite, but it does not show any regular pattern with increasing depth (Table 2). The dehydroxilation and oxidation of Fe^{+2} cause chlorite to transform to the other clay minerals. One of the important reasons of chlorite stability in reduced studied soil is consistency of Fe^{+2} exist in this clay mineral. In developed weathering, chlorite transform to kaolinite and free Fe oxides.

Vermiculite

It is not seen in studied soil samples. Vermiculite role as a halfway product, forming from mica (Nanzyo *et al*., 1999; Lee *et al*., 2003) and transform to smectite in poor drained condition. The same is reported by Kittrick and Hope (1963) too.

CONCLUSION

Soil mineralogy is one of the most important determinants of the inherent capability of rice soils considered on a regional scale, differentiation of soil quality according to mineralogy is relatively clear when rice is grown with little or no added plant nutrition, or at a low level of management and also, clay minerals recognition, have important implications for agricultural and environmental purposes because of adsorption, fixation and release of nutrition elements in clay part. Clay mineralogy is probably more affected by parent materials and less influenced by aquic and anthraquic condition, in most cases the materials deposited as alluvial sediments have been barely altered by the natural and artificial processes inherent in rice cultivation. Accordingly, the mineralogy of rice soils is almost the same as that of their parent materials. However, there are some indications that aquic and anthraquic condition may affect on quantity of clay minerals, as shown by higher smectite in poorly drained soils. There are two factors to consider in evaluating the mineral composition of rice soils; one factor is that rice soils in this area occur in alluvial lowlands and their parent materials have been sorted by the sedimentation process. In low land sediments are brought in by floodwater from rivers and by irrigation. The improving action of the floodwater sediments depends, of course, on the source of the floodwater. The other factor is that the rice soils are distributed in more or less humid, warm to hot regions, that implies that soil materials had generally been strongly weathered and leached even before rice cultivation started. These two factors would suggest generally low importance of sand-size grains in paddy soils as the source of plant nutrients, in terms of both quantity and quality.

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