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Origin and Distribution of Clay Minerals in Calcareous, Gypsiferous, Saline Soils and Sediments of Bakhtegan Lake Bank, Southern Iran

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ABSTRACT- Pedogenesis and clay mineralogy of soils and rock samples were studied in a transect of calcareous, gypsiferous, saline soils and sediments of Bakhtegan lake bank in southern Iran. The main objectives of study were to determine the occurrence of clay minerals and factors controlling their distribution pattern and relative abundance in soils and parent materials. The soil parent material is highly calcareous in all regions. However, gypsiferous and saline soils mainly occur near the Bakhtegan Lake with much evaporitic sediments (gypsum and halite) and where there is a saline and alkaline ground water table. XRD, TEM, SEM and EDX analyses indicated that chlorite, illite, palygorskite, smectite and interstratified minerals are the dominant clay minerals in both soil and rock samples. The presence of illite, chlorite abundance could be attributed to the parent rock samples and inherited origin. Interstratified minerals of chlorite-smectite or illite-smectite are observed in clay fraction of soils situated in plains and down slope due to further weathering and transportation from upslope to down slope. Studies indicated the presence of neoformed, transformed and inherited forms of palygorskite in all soils. Studies have showed that arid soils in southern Iran were affected by post-Tethyan sediments and some minerals have evolved from the weathering of these sediments.

Keywords: Clay Mineralogy, Smectite, Palygorskite, Arid Climate, Bakhtegan Lake

INTRODUCTION

It has been recognized that the minerals in the clay (< 2 μm) fraction of soils play a crucial role in determining their major physical and chemical properties, and inevitably, questions concerning the origin and formation of these minerals have assumed prominence in soil research (40). Palygorskite, smectite, chlorite, illite, kaolinite and vermiculite are the main clay minerals in arid and semi-arid regions (2, 16, 22 and 30). Millot (28) distinguished three principal processes to account for the genesis of clay minerals: (1) Inheritance from parent materials, (2) transformation of other clay minerals, and (3) neoformation from soil solution.

Illite and chlorite are two commonly observed clay minerals occurring in steep areas and are believed to be inherited largely from parent rocks (40). Interstratified

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minerals primarily represent intermediate transformation products, mainly involving mica, chlorite and an expansible phase, either smectite or vermiculite (34), although there are many examples of interstratified minerals in soils originating by inheritance. Environmental conditions are suggested to lead to smectite formation in Aridisols (6 and 14). Neoformation of smectite was reported by Gharaee and Mahjoory (16) and Givi and Abtahi (17) under saline and alkaline conditions with high concentrations of Si, Mg and Al in southern Iran.

Henderson and Roberson (18) and Burnett et al. (10) were the first to report traces of palygorskite in sediments and soils from Iran. Several researchers indicated both inherited and pedogenic sources of palygorskite in Iran (2, 16, 21, 22, 26 and 30). Khormali and Abtahi (22) concluded that the percentage of palygorskite in soils is related to the gypsum content and the ratio of mean annual precipitation to mean annual reference crop evapotranspiration (P/ET°).

Gypsum ($CaSO_4.2H_2O$) is an abundant soil mineral in arid climates and occurs in significant quantities due to low rainfall which does not allow the leaching of weakly soluble gypsum where the parent material of soil is derived from evaporates and other geological materials of marine origin such as Cretaceous clay duet. In strong arid climates, the ascending process is dominant and gypsum accumulation occurs in the epipedon.

Fars province including part of the Zagros orogenic area has been the site of more or less continuous sedimentation from the Triassic to Plio-Pleistocence time period. Carbonate deposition controlled by epiorogenic movements dominated until the late Cretaceous period when movements within Zagros areas began to influence sedimentation. Therefore, with calcareous parent material, calcification and movement of carbonate within the soil profile is the most important pedogenic process in arid and semi arid regions. Moreover, the adjacent limestone formations enrich soils with carbonate.

Being part of the post Tethyan sea environment rich in evaporates, Bakhtegan lake marginal soils with gypsiferous, calcareous and saline materials and an arid climate provides a suitable area to study the origin and distribution pattern of clay minerals. Also, few studies have been carried out about clay mineralogy of arid soils. Therefore, the main objectives of this study were; (1) to investigate the occurrence, origin and distribution of clay minerals in an arid region of southern Iran, and (2) to determine the relation between gypsiferous, calcareous and saline materials and the formation of clay minerals.

MATERIALS AND METHODS

Description of the Study Area

The study area is located between Bakhtegan salt-lake and Sadegh Abad Mountain (part of Zagros Mountains), north-east of Shiraz city (29° 17′ 12′′ N, 57° 53′ E, Fars Province, Iran) (Fig. 1). The elevation of the study area is 1565m above sea level with16°C and ~ 240mm mean annual temperature and precipitation, respectively. According to Banaei (5), the soil moisture and temperature regime of the study area are “dry xeric" and "thermic", respectively. Seven representative pedon sites from a transect of mountain to lowlands of the study area were selected. Soils were described and classified according to the Soil Survey Manual (38) and Keys to Soil Taxonomy (37), respectively (Table 1).

Table1. Classification and selected morphological characteristics of the studied pedons

Horizon	Depth (cm)	Color (moist)	Boundary	Structure	Consistence moist	Consistence wet	Other components
			Xerorthents - Colluvial fan (pedon 1)				
A	0-25	10YR4.5/3	cl	m	fi	SS/SP	Very few fine roots, 50-70% gravel
C_1	25-80	10YR4.5/4	gr	m	fi	NS/SP	30-50% coarse gravel
C_2	80-120	10YR5/4		m	fi	NS/SP	30-50% coarse gravel
			Calcixerepts-Colluvial-alluvial fan (Pedon 2)				
A	0-30	10YR4/3	cs	m	fi	SS/SP	Few fine roots, 10-20% gravel
B_{k1}	30-80	10YR4/4	cs	m	fi	SS/SP	Few fine roots, 20-30% gravel
C	80-125	10YR4/4		m	fi	SS/SP	30-50% coarse gravel
			Calcixerepts –Piedmont plains (Pedon 3)				
A_p	0-25	10YR4/3	cl	c1abk	fi	SS/SP	Few to common fine roots, 0-5% medium gravel
B_{w1}	25-50	10YR4/4	gr	m1abk±c1 abk	fi	SS/SP	Few fine roots, few lime concretions
B_{k1}	50-90	10YR4/4	gr	c1abk±m1 abk	fi	SS/SP	Few lime concretions
C	90-130	10YR4/4		m±c1abk	fi	SS/SP	-
			Haploxeralfs-Plateaux (Pedon 4)				
A_p	0-25	10YR4/3.5	cl	c1abk	fi	S/P	Few to common fine roots
B_{t1}	25-65	7.5-10YR4/4	gr	c1abk±m2 abk	vfi	S/P	Few fine roots, clay skin
Bt_2	65-125	7.5-10YR4/4		c1abk±m2 abk	fi	S/P	Few clay skin
			Haploxererts-Flood plains (Pedon 5)				
A	0-30	10YR4/3	gr	c1abk	fi	S/P	Few fine roots, cracks 1-2 cm wide
B_{w1ss}	30-50	10YR3.5/3	cl	c1abk	vfi	VS/VP	Few fine roots, with cracks and slickenside
B_{w2}	50-90	10YR4/3.5	gr	c1abk±m2 abk	vfi	VS/VP	Few fine roots, few irregular lime powdery pocket
B_{w3ss}	90-130	10YR4/3.5		c1abk±m2 abk	vfi	VS/VP	Slickenside is clear, mottling and gleying
			Haploxerepts-Flood plains (Pedon 6)				
A	0-15	10YR5/2	cl	m	fi	SS/SP	Few to common fine roots
B_{y1}	15-40	10YR5/3	w	m	vfi	SS/SP	Few fine roots, many gypsum mycelium and crystal
B_{y2}	40-55	10YR7/3.5	w	m	-	-	Hard and compact, with salt and many gypsum crystals
B_{y3}	55-90	10YR7/3.5	cl	m	vfi	SS/SP	Very pale brown, many gypsum crystals
C	90-135	10YR7/3.5		m	vfi	SS/SP	pale brown, many gypsum crystals

Fig 1. Location of the area under study in Southern Iran

Geology

The Iranian plateau is located in the ancient Tethys seaway (25). According to Zahedi (41), the Zagros area underwent a relatively moderate orogenic phase (attenuatd Laramian phase) near the end of Cretaceous and the beginning of Eocene, characterized by folding, emergence and erosion. The laramian movements were succeeded by a shallow marine transgression. A later regression of the sea eastward resulted in the formation of intermontane lakes in the Middle Tertiary, which may have produced an environment conducive for the formation of fibrous clay minerals.

Chronological order starts from Albian to Quaternary of Mesozoic-Cenozoic time in the region. Mid and Upper Cretaceous rock units, Tertiary rock units and Quaternary alluvial deposits are the three main rock units. The surface of the soils are now covered with Quaternary deposits known as physiography (Fig. 2).

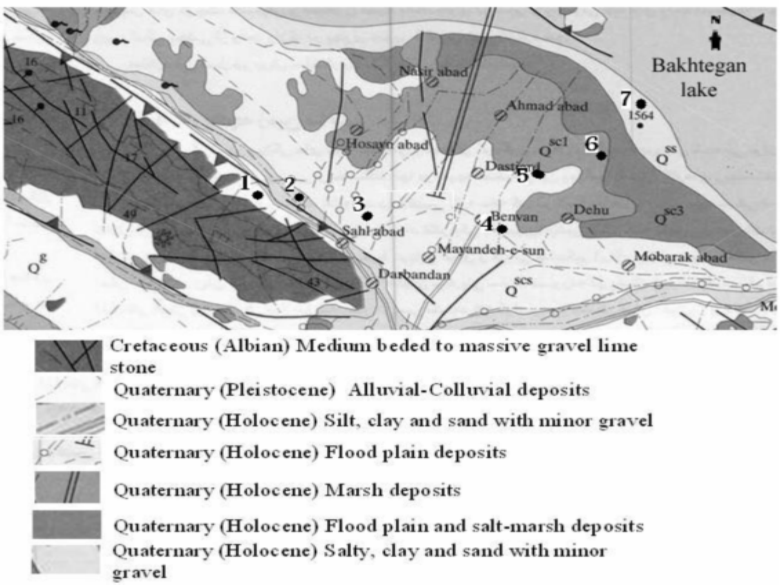

Fig 2. Geology map of the area under study and location of pedons

Laboratory Analyses

Physical and Chemical Analyses

Air-dried soil samples were grounded and passed through a 2mm sieve. Particle size distribution was determined by hydrometer method (8). Calcium carbonate equivalent (CCE) was measured by acid neutralization approach (33). Gypsum ($CaSO_4.2H_2O$) was determined by precipitation with acetone (33). Organic carbon was measured by dichromate oxidation according to Nelson (29). Soil pH was measured in a saturation paste and electrical conductivity (total soluble salts) was determined in saturation extract (33). Cation exchange capacity (CEC) was determined using sodium acetate (NaOAc) at pH 8.2 (11).

Mineralogical Analyses

Prior to mineralogical analyses, soil samples were washed to remove gypsum and soluble salts. Carbonates were removed using 1N sodium acetate and continued until no effervescence was observed with 1N HCl (19). 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. Free iron oxides were removed from the samples by citrate dithionate method (27). Separation of clay fractions were carried out according to Kittrick and Hope (24). The clay fractions of soil and parent rocks were treated to prepare the following oriented slides: Mg-saturated and glycerol-solvated, K-saturated, K-saturated and heated at 550°C. These slides were scanned using a D8 Advance X-ray diffractometer. Quantification of clay minerals was done according to Johns et al (20).

Electron Microscopy Studies

Small soil aggregates (~ $1cm^3$) were studied by scanning electron microscopy (SEM). Dried samples were mounted on Al stubs by carbon glue, then coated with Au and examined using a Cambridge SEM. Identification of the chemical composition of clay minerals was carried out using an Oxford ISIS EDX system. For transmission electron microscope (TEM) studies, 150µL of homogenous diluted clay suspensions were dried on 200-mesh Formvar-coated Cu grids by placing them under a heat lamp for 20 minutes and studied by a Philips EM 300 TEM.

RESULTS AND DISCUSSION

Soil morphological, physical and chemical characteristics

Tables 1 and 2 present some main morphological and physico-chemical properties of the studied pedons. Soils of the study area have a weak or moderately fine to medium subangular blocky or massive structure. Munsell color of the well-developed to undeveloped soils with a high water table varies from 10YR4/4 to 2.5Y5/2.

Table 2. Selected physical and chemical properties of pedons in the studied region.

Horizon	Depth	Particle size			pH(paste)	OC	CCE	Gypsum	CEC	EC	SAR
		Clay	Silt	Sand		%			Cmol$_c$Kg^{-1}	dS m^{-1}	
		%									
						Pedon 1					
A	0-25	11	48	41	7.84	0.585	61.25	tr	8.87	1.49	3.44
C_1	25-80	21	24	55	7.56	0.214	67.5	tr	9.13	7.92	1.2
C_2	80-125	19	26	55	7.54	0.253	68.76	tr	9.15	6.36	0.8
						Pedon 2					
A	0-30	21	38	41	7.72	0.58	61.3	tr	8.7	1.49	3.44
B_{k1}	30-80	27	32	41	7.48	0.25	67.5	tr	7.8	4.92	1.2
C	80-125	33	30	37	7.67	0.27	68.8	tr	8.40	3.36	0.8
						Pedon 3					
A_p	0-25	27	46	27	7.73	0.8	55	tr	11.8	2.654	2.34
B_{w1}	25-50	39	48	13	7.86	0.59	55	tr	12	6.150	1.24
B_{k1}	50-90	30	56	14	7.65	0.5	56.3	tr	11	3.627	1.28
C	90-130	29	52	19	7.54	03	57.05	tr	9	7.640	1.82
						Pedon 4					
A_p	0-25	46	42	12	7.55	1.3	36.25	tr	19	3.45	2.3
B_{t1}	25-65	55	37	8	7.45	0.5	38.8	tr	21	3.37	2.35
Bt_2	65-125	57	34	9	7.97	0.4	41.5	tr	21	4.93	1.5
						Pedon 5					
A	0-30	47	42	11	7.67	1.17	43.7	tr	22.7	7.761	4.8
B_{w1ss}	30-50	53	37	10	7.699	1.14	36.3	0.25	23	7.297	14.2
B_{w2}	50-90	51	38	11	7.52	0.6	45	0.2	14	6.833	1
B_{w3ss}	90-130	47	39	14	7.39	0.42	48.8	tr	11.8	6.411	0.97
						Pedon 6					
A	0-15	13	53	34	7.85	0.9	14.1	27	21	15.3	12
B_{y1}	15-40	16	52	32	7.91	0.95	12.8	41	16	15.3	30
B_{y2}	40-55	16	42	42	7.88	0.5	6.6	25	16	23.7	37
B_{y3}	55-90	14	42	44	7.82	0.25	10.6	46	12	27.3	31
C	90-135	12	65	23	7.51	0.25	46	30	12	28	35
						Pedon 7					
A_z	0-10	36	36	28	7.51	2.5	36.6	0.5	16	24	46.7
B_z	10-25	24	42	34	7.75	2	40.6	1	16	64.2	37
C_{z1}	25-50	22	51	27	7.15	0.9	40.7	1.5	15	36	37.8
C_{z2}	50-100	20	56	24	7.48	1.3	42.8	1	13	38.5	37.8

Almost all soils are highly calcareous throughout with an average $CaCO_3$ content > 40%, increasing with depth, except for pedon 6 which is a gypsiferous pedon. Most soils with argillic horizons and vertic properties are heavy-textured. Soils setting on fan deposits and plateau range from coarse textures to medium ones. Soils with high amount of salt and gypsum (pedons 6, 7) are medium –textured. Soils from the colluvial and alluvial fans (pedons 1, 2 and 7) exhibited CEC of less than 10cmol$_c$ Kg^{-1}, while CEC of the others ranged up to 23cmol$_c$ Kg^{-1}, mostly dependent upon the amount and type of clay minerals, ranges from 12% to 27% in coarse and medium textures to as high as 57% in the B_{t2} horizon of pedon 4. Electrical conductivity increases with decreasing slope and drainage weakness and reaches the vicinity of the lake. The pH ranges from 7.15 to 7.91, in the studied pedons, with greater values in the lower horizons.

Soil genesis of the studied pedons

The site lies in a transect of mountains (part of Zagros Mountains) to the southern bank of Bakhtegan salt-lake. The study area physiographically consists of alluvial-colluvial fans, piedmont plains, plateau, flood plain and low lands. Bakhtegan lake shores have been commonly covered with white-color gypsum and salt evaporitic sediments. Moreover, the adjacent limestone formations cause the enrichment of soils with carbonate. Therefore, the soils of fans, plateau and floodplain are calcareous. Calcic features are the main morphological features in pedon 2 and 3, and were observed in the field as powdery pockets or concretions in B_{tk} or B_k horizons that have been formed in plateau, piedmont and flood plains. Clay skins were noted in the field on ped surfaces. In general, pedons with argillic horizons are associated with calcic horizons. According to Abtahi (1), the formation of argillic horizons in arid saline and alkaline environments is possibly related to the dispersive effect of high sodium concentrations, even in the presence of calcium carbonate. These soils have undergone the following processes:

Salinization ⟶ Alkalization ⟶ Desalinization ⟶ Solonetzation ⟶ Dealkalization

Another group of soil is Vertisols that occur in flood plains with distinct vertic characteristics. The areas with gypsiferous or saline soils are mainly bare and occur near lakes and where there is saline-alkaline ground water and are classified as Gypsic Haploxerepts and Typic Aquisalids, respectively.

Clay mineralogy of soils and sedimentary rocks

X-ray diffractograms and relative abundance of clay fractions in the studied soils and rocks are shown in Fig. 3 and Table 3, respectively. Chlorite, illite, palygorskite, interstratified minerals and smectite are the major clay minerals present in both parent rock and clay samples.

Table 3. Relative abundance of clay minerals, of the clay fraction of the studied soils and parent rocks.

Pedon	Horizon	Ch* %	Ill* %	Pl* %	Sm* %	In* %
R*	-	52	38	10	-	-
1	A	54	27	19	-	-
2	B_{k1}	24	41	26	-	9
3	B_{tk1}	17	25	20	25	13
4	Bt_2	10	17	20	45	8
5	A	52	10	20	11	7
5	B_{w1ss}	40	16	10	30	14
6	A	38	28	30	-	4
7	A_z	36	18	10	14	22
7	C_{z1}	36	21	14	8	21

*** Ch: chlorite, Ill: Illite, Pl: Palygorskite, Sm: Smectite, In: Interstratified minerals, R: parent rock**

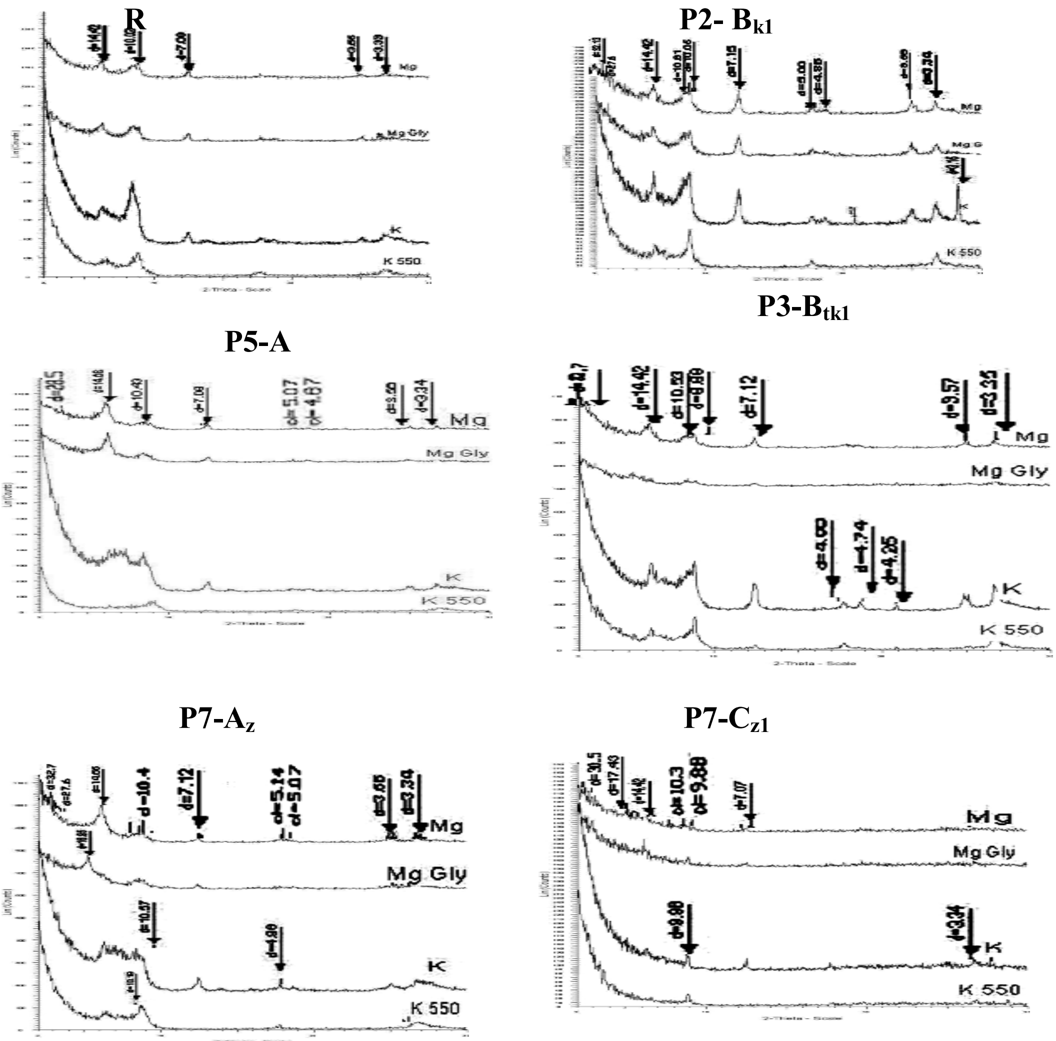

Fig. 3. XRD patterns of carbonate-free oriented clay fraction (<2mm) of the selected studied soil and rock samples

Illite and chlorite are two commonly observed clay minerals in arid environments and their abundance in the soils is largely due to their presence in parent rocks. These minerals are dominant in the clay fraction (Table 3). Chlorite is also inherited in the studied soils. Also, illite and its presence in soils is mainly of detrital origin (Fig. 3). These clay minerals are considered as the precursors for the pedogenic formation of other clay minerals in arid and semi arid regions (21). In the present study simple transformation of other clay , smectite and interstratified minerals is important, for it shows a relative decrease with slope in soils with B_t horizon (pedon 4). Transformation of illite into smectite at the soil surface and the subsequent translocation of highly crystallized smectite to B_t horizon might have also resulted in the accumulation of higher smectite in B_t horizon (Table 3), as mentioned by Khormali (3 and 23). As shown in Table 3, the presence of smectite is observed as a portion of the clay minerals in

Alfisols (pedon 4), weakly drained Vertisols (pedon 5) and in soil with saline and alkaline ground water table (pedon 7). 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 influencing the origin and distribution of smectite in soils (7 and 4). In conclusion, the presence of large amounts of this mineral in poorly drained pedon 7 is evident. As discussed by Abtahi (1), the presence of smectite in pedon 7 suggests the neofrmation origin for this mineral under favorable soil solution environment. Neoformtion of smectite was also reported by Gharaee and Mahjoory (16) and Givi and Abtahi (17) under saline and alkaline conditions with high concentrations of Si, Mg and Al in southern Iran. However neoformation cannot solely explain the general increase of this mineral with decreasing slope (pedon 4, 5 and 7). Increasing soil available moisture in the calcareous environment with high Mg^{++} and high Si mobility might provide favorable conditions for the formation of smectite through transformation. As discussed earlier, illite and chlorite content with decreasing slope are different from smectite which shows a relative increase. In addition, the detrital origin of smectite and interstratified illite-smectite in low-lying topography is considerable.

Moreover, the presence of interstratified minerals in pedons occuring in plains and downslopes (pedon 4, 5 and 6) can be considered as an intermediate stage of this transformation. Interstratified minerals of chlorite-smectite or illite-smectite are observed in clay fraction of soils occurring in plains and down slope positions due to further weathering and transportation from upslope to down slope.

The occurrence and stability of vermiculite in calcareous and silica rich soils have not been well-documented (6). According to Wilson (40) with regard to the transformation of clay minerals, a general example would be:

illite $\longrightarrow$ vermicullite $\longrightarrow$ smectite

At about pH > 6 (as in case of the studied soils), Al is not soluble. In contrast Si is highly soluble especially in the common pH of around 8 (as in calcareous soils of southern Iran). Therefore, high Mg present in calcareous materials can substitute Al in the lattice and form smectite. However vermiculite is not stable and there is no evidence showing the existence of this mineral in the studied soils.

X-ray diffractograms and TEM micrographs indicate a considerable amount of palygorskie in all soils (Fig. 3 and 4). The presence of palygorskite in rock units belongs to Tertiary calcareous sedimentary rocks (R) and in alluvial-colluvial fans (e.g. pedon 1 and 2) it could also be related to inheritance and detrial origin. So inheritance of palygorskite is possible and has a fairly wide distribution in the studied soils and soils of Iran.

Pedogenic palygorskite can be the result of either in situ transformation of another mineral or authigenic formation from solution (neoformation origin). The result of clay mineralogy of most soil samples showed that the relative amount of palygorskite is much more than that of parent rock samples and soils occurring in fans (table 3). It may indicate that the pedogenic path for palygorskite formation is more important than inheritance (also mentioned by Owliaie et al. (30).The transformation of 2:1 clay minerals, mainly illite or smectite, to palygorskite in solutions high in Si and Mg and low in Al and K is a possible mechanism as reported by many researchers (13, 36 and 39).

According to Paquet and Millot (31), palygorskite weathers into smectite when the mean annual rainfall exceeds 300mm. Khormali and Abtahi (22) also showed that when the P/ET$^{\circ}$ (ratio of mean annual precipitation to mean annual response crop evapotranspiration) is < ~ 0.4, palygorskite forms the dominant clay minerals in arid soils. As it has been shown in table 4, in this region the P/ET$^{\circ}$ is ~ 0.1 and the mean annual rainfall is 240.5 mm. Therefore, the presence of palygorskite is a common mineral. .

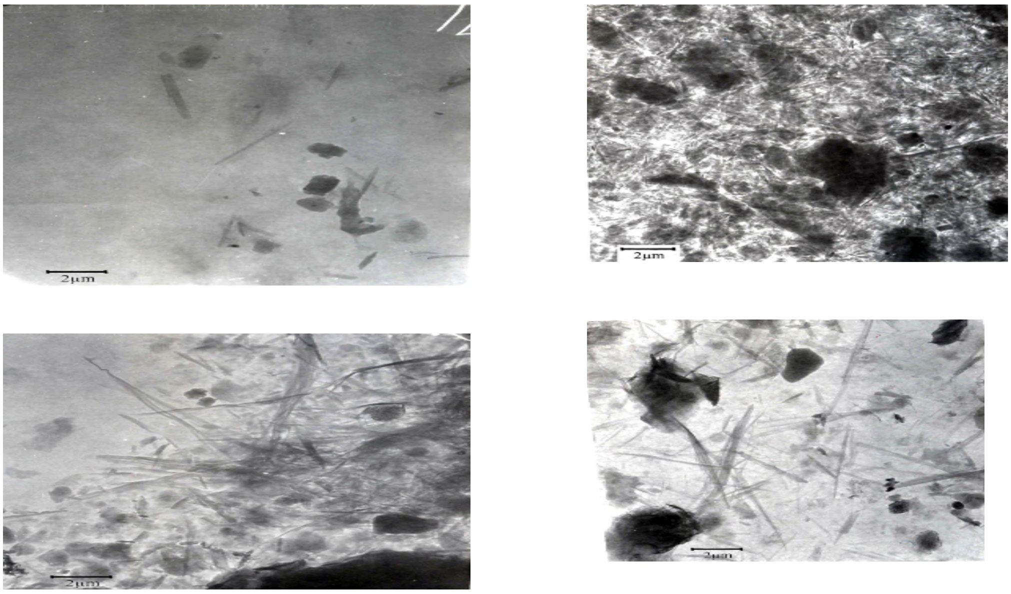

Fig. 4. TEM image of the A horizon of pedon 2 (a), B_{tk1} horizon of pedon 3 (b), A_y horizon of pedon 6 (c) and C_{z2} horizon of pedon 7 (d), respectively

It is commonly agreed that the presence of gypsum (15, 21 and 30), calcrete or caliche (9, 22, 32 and 35), saline and alkaline ground water lake (1 and 22), would favor the in situ formation of palygorskie from soil solution.

Distribution of palygorskite, however, is not solely related to the sedimentary parent rocks and, as discussed earlier, there are also other factors influencing its pedogenic formation, such as the presence of gypsum, calcite and saline and alkaline shallow water table. The presence of shallow saline and alkaline ground water, (pedon 7), could also favor the neoformation of palygorskite from soil solution (Fig. 4c and 4d). Under such conditions palygorskite may also form from smectite due to proximity in their stability field (34). Palygorskite, an Mg-rich fibrous clay mineral, is often considered to be easily destroyed by transportation or high shrinkage and swelling in down slope (Fig. 4b) (28).

The coexistance of pedogenic carbonate nodules with palygorskite and coatings in the Aridislos of central Iran suggests that palygorskite was trapped by pedogenic carbonate (21). The relationship of palygorskie with gypsum can be observed in SEM images. Eswaran and Barzanji (15) showed that neoformed palygorskite fibres coated gypsum and hornblende crystals. They concluded that palygorskite in some alluvial and colluvial soils of Iraq formed after the crystallization of gypsum. As viewed with a SEM image, palygorskite enmeshed with calcic and gypsum crystals, suggest that this mineral has formed authigenically (Fig. 5).

Fig. 6 presents the major pathway for the formation of clay minerals in the studied soils. The origin of chlorite and illite in soils is considered to be mainly inherited from parent rocks. As discussed earlier, vermiculite is considered to be unstable under the present conditions of the studied area and also there were no evidences of kaolinte due to unfavorable conditions of formation. Neoformation is the main mechanism for the occurrence of palygorskite and the formation of smectite could be mainly related to the transformation of illite and/or palygorskite. This was also indicated by Khormali and Abtahi (22).

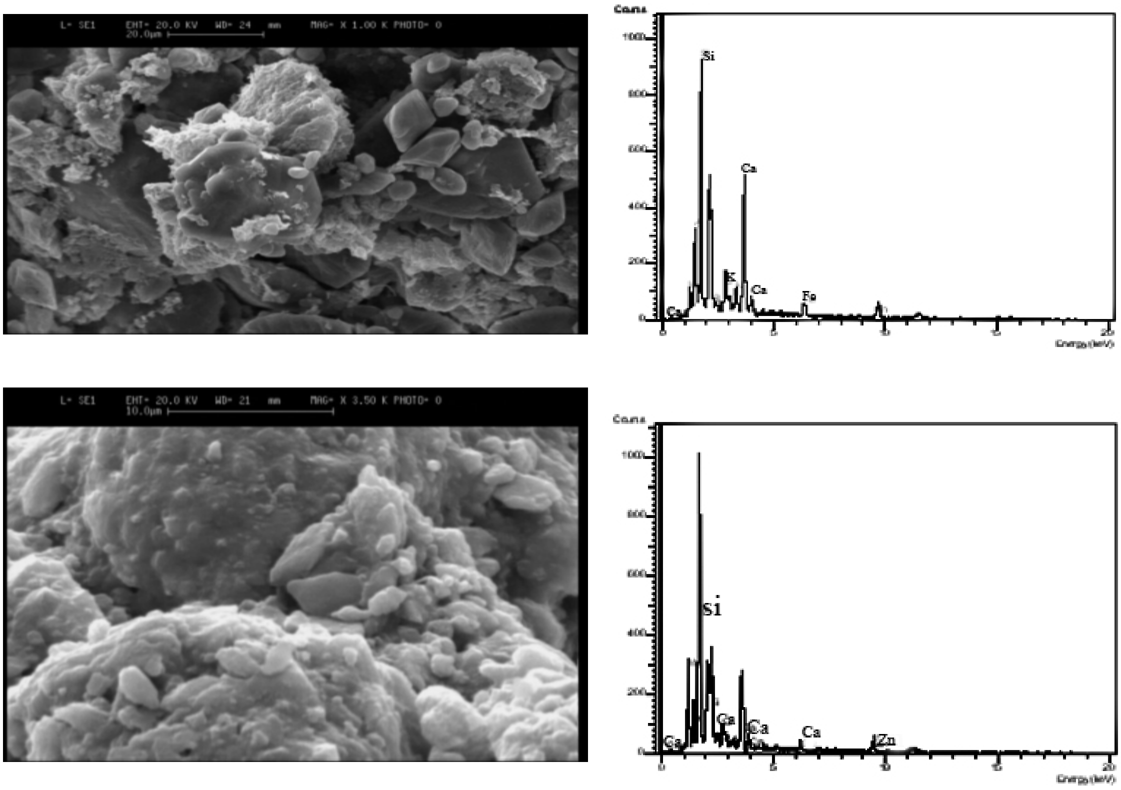

Fig. 5. SEM image of pedogenic carbonates coated with palygorskite (pedon 2, B_{k1}) (a) and gypsum (pedon 6, B_{y2}) (b) elemental analysis of palygorskite fibres on calcium carbonate nodules and gypsum crystals (SEM-EDX) (c) and (d), respectively

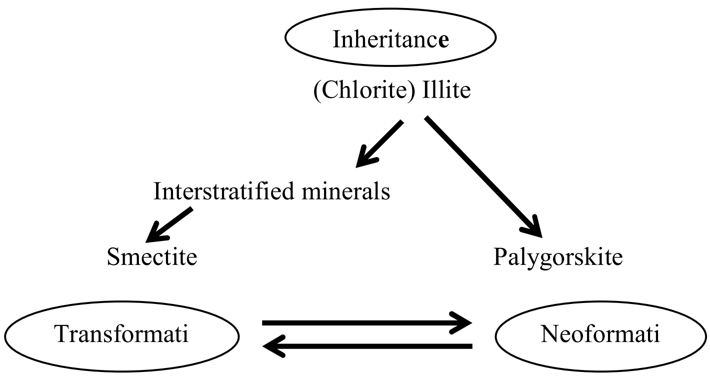

Fig 6. Pathways for the formation of clay minerals in the studied soils. The thickness of the arrows indicates the importance of the pathway. The parentheses indicate lesser importance.

CONCLUSIONS

In the studied soils, palygorskite, chlorite, illite, smectite and interstratified minerals were the dominant clay minerals. The abundance of illite and chlorite can be related to the parent rocks and inherited origin. Illite and chlorite are generally considered to be weatherable and could be changed because of transformation reactions into interstratified expansible minerals and smectite.

The results showed that smectite constitutes a high portion of clay minerals in well drained Alfisols, relatively poorly drained Vertisols and soils with alkaline and saline ground water. Therefore, it can be concluded that, in well drained soils, smectite increases due to the transformation of interstratified minerals and illite and it can increase in low-lying topography as a result of transformation, transportation of upslope to downslope (detrital origin) and neoformation.

There were no evidences of kaolinte and vermiculite in the studied soils due to unfavorable and unstable conditions of their formation.

The study area is a part of the post-Tethyan sea environment rich in the evaporitic (salt and gypsum) and it has been affected by the saline and alkaline Bakhtegan lake, which could produce an environment conducive for the formation of fibrous clay minerals.

SEM images show the authigenic origin of palygorskite in the gypsiferous soils and soils with pedogenic calcic.

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توزیع و منشاء کانی‌های رسی در مواد آهکی، گچی، شور و رسوبات حاشیه دریاچه بختگان، جنوب ایران

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چکیده– در این تحقیق پیدایش و کانی شناسی نمونه‌های سنگ و خاک در یک مقطع عرضی از مواد آهکی، گچی، شور و رسوبات حاشیه دریاچه بختگان در جنوب ایران بررسی شد. اهداف اصلی مطالعه تعیین حضورکانی‌های رسی، فاکتورهای کنترل کننده، الگوی توزیع و فراوانی نسبی آنها در مواد مادری و خاک‌ها ی منطقه می‌باشند. مواد مادری خاکها در کل منطقه آهکی می‌باشند. با این وجود، خاک‌های گچی و شور در نزدیک دریاچه بختگان با میزان بالایی از رسوبات تبخیری و سطح آب زیرزمینی شور و قلیا رخ می‌دهند.

آنالیزهای تفرق اشعه ایکس، میکروسکوپ الکترونی و میکروسکوپ الکترونی روبشی کلرایت، ایلایت، اسمکتیت و کانی‌های مخلوط را به عنوان کانی‌های رسی غالب، در نمونه‌های خاک و سنگ نشان دادند. حضور کلرایت و ایلایت موروثی و وابسته به سنگ مادر می‌باشند. کانی‌های حدواسط اسمکتیت ـ کلرایت یا اسمکتیت ـ ایلایت در جزء رس خاک‌هایی که در دشت‌ها و شیب‌های کم قرار گرفته‌اند، به علت هوادیدگی بیشتر و انتقال از شیب‌های بالا به شیب پایین مشاهده می‌شوند. مطالعات پالیگورسکایت به فرم های موروثی، تبدیل‌یافته و نو تشکیل در همه خاک‌ها نشان داد. این مطالعه نشان داده است که خاک‌های خشک در جنوب ایران بوسیله رسوبات پالئوـ تتیس تحت تاثیر قرار گرفته و بعضی کانی‌ها از هوادیدگی این رسوبات نشات گرفته‌اند

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واژه های کلیدی: کانی شناسی، اسمکتیت، پالیگورسکایت، اقلیم خشک، دریاچه بختگان

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