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Paleoclimate Evidences in Alluvial Plains of Karoon River, South Khuzestan, Iran

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ABSTRACT

Micromorphological properties, particularly pedofeatures in soils, aid in the determining of past conditions, especially the paleoclimate of a region. In order to obtain evidence regarding the paleo climate in the alluvial plains to the South of the Khuzestan province in Iran, 3pedons were dug and analysed .The Southern region of Khuzestan has an arid climate with less than 250 mm annual precipitation and more than 25°C mean annual temperature and an Aridic-hyperthermic soil moisture and temperature regimes. Based on the morphological descriptions obtained through field studies, physicochemical analysis results and micromorphological observations, the symptoms of Argillic and Gypsic diagnostic horizons have been distinguished in these soils within three soil series. The Studied thin sections showed illuviated form of clays includedinfillings and coatings on channel voids at deeper horizons. Whatsmore; in some cases, clay coatings occurred on gypsum crystal infillings on voids, or stratified pedofeatures of clay coatings and gypsum accumulations existed. According to the depth and forms of these pedofeatures, researchers concluded that, the observed illuviated clays must be due to a moister paleoclimate in the past. The existence of any specified difference in clay coatings of irrigated pedons and non-irrigated ones, also strengthened this hypothesis. On the other hand the formation of polygenetic pedofeaturesemphasizes subsequent different pedogenic processes.

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INTRODUCTION

The fact that the present is the key to the past, has aided scientists to use paleosols properties as indicators of historical ecological characteristics, particularly the paleoclimate of a region. [29] Aridisols occupy more than 18% of the earth's land surface and are the most common soils in the world [5]. Aridisol is the dominant soil order in the Middle East, While 65% of Iran has an aridic soil moisture regime [25]. Occurrence of illuvialpedofeatures, particularly illuvial clay in arid regions seems to be the indicator of paleoclimate conditions. Micromorphological observations help researchers discover historical conditions and pedogenic origins of the observed phenomena's. Ayoubi *et al*., [3] stated that recognition of these microscopic properties plays an important role in the identification and classification of paleosols. Many pedologists have carried out research in theidentification and classification of paleosols up to now [8,14,1,15,17,20,6,12,13].

Nettleton *et al*. [20] attributed the formation of Argids suborder to the humid conditions of Pleistocene after their investigations on the soils of the Southwestin the United States. They reported that the formation of this suborder does not commensurate with the present dry conditions. TaghizadehMehrjardi *et al*., [29] considered the depth and forms of illuviated clay pedofeatures in aridisols of Yazd. They concluded that observed illuviated clays at lower depth must be the result ofa more humid climate in the past. Khademi and Mermut [13] performed a study on micromorphology and classification of Argids in gypsiferousAridisols of central Iran, agree with other soil scientists about the past moister climate and further state that the coexistence of argillic, calcic, and gypsic horizons in colluvial soils is a peculiar combination and suggested a multistage pedogenesis

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in the researched landscape. Due to thearidic moisture regime in the studied region, the existence of clay coatings in these soils was completely unlikely. During previous soil survey investigations in the abovementioned area, no evidence of illuvial clay horizons was reported. So the occurrence of clay coatings in the studied profiles inspired us to first investigate the origin of these pedofeatures and secondly to find the chronosequence of existing pedofeatures in alluvial soils of the Karoon River.

MATERIALS AND METHODS

2.1. Study area:

The study area was theAmir Kabirsugarcane agro industrial unit, located between longitudes 31°15′N and 31°40′S, latitudes 48°30′E and 48° 12′W, in the Southof the Khuzestan province in Iran. The mean annual temperature and mean annual precipitation of this area are 25 °C and 252 mm. The physiographic unit is a River alluvial plain of the Karoon river. Soil Moisture-Temprature regime is categorized as Aridic-Thermic, Soil survey staff, [27].

2.2. Sampling:

3 pedons were selected from the three soil series of the land. 2 profiles in sugarcane cultivated lands and 1 profile in adjacent non-cultivated land. The pedons were dug. Morphological features of each horizon were described according to the Soil survey staff [27]. General information of representative pedons is presented in table1.

Table 1: Information of studied soil profiles in Haft tappe series.

Region	Soil Series	Profile No.	Field No.	Coordinate South West	Years under drainage (till now)	Classification (Subgroup)
Amir Kabir	Karoon	1	2-18	244631E 3442758N	Blank (non-drained)	TypicHaplosalids
	Amir Kabir	2	4-4	243991 E 3440114 N	16	TypicAnthracambids
	Ahoo	3	15-4	237815 E 3430376 N	13	TypicAnthracambids

Undisturbed soil samples of all diagnostic horizons were collected viaKubiena boxes. In order to measure the soil bulk density, a core sampler was used. Soil samples of all horizons were obtained in plastic bags and then the samples were air-dried and carefully passed through a 2 mm sieve to remove stones, roots and large organic residues before conducting laboratory analysis.

2.3. Laboratory analysis:

Physical characteristics included bulk density and particle size distribution. Particle size was determined using the hydrometer method [7], Bulk density was determined using a Core method [9].

Soil particles (≤ 2mm) were subjected to the following chemical characterization: Soil pH was measured in saturated soil using a glass electrode [16]. Electrical conductivity was measured in saturated paste using a conductivity meter [24]. Soluble cations included Na and K was measured via flame photometry and EDTA titration was used for measuring soluble Ca^{2+} and Mg^{2+}. SOM was determined by using Walkley and Black procedure [11]. CCE was measured by digestion in HCl [18]. CEC was determined using Sodium Acetate (NaOAc) at pH 8.2 [4]. Gypsum (CaSO4. 2H2O) was determined by precipitation in Acetone [26].

In order to have representative samples of different horizons for observing soil features under polarized light, undisturbed soil blocks were taken in Qubiena boxes. All samples were impregnated with polyester resin after replacing water with acetone to avoid structural modification. After air-drying, oriented thin sections with a thickness of about 30 micro meters were prepared.Finally, the thin sections were observed under a petrographic microscope (Motic BA300 POL). The micro morphological features were captured using a digital camera (Motic cam pro 252A). Finally the soils were classified into subgroup levels.

Result:

Abbreviated field description results and laboratory data of 3 representative soil profiles from all studied pedons are presented in tables 2 and 3. All studied pedons had a 2-8 cm black organic buried horizon which lies at varying depths between 150-180 cm in this region (fig.1).

This might relate to the historical native vegetation. These areas belong to the alluvial plains of the Karoon River, which according to their geomorphology unit andthe parent materials of this landscape are defined as river sediments. All pedons showed 30-40 % Calcium Carbonate equivalent in all horizons. Since The South of Iran is covered by limestone formations, the parent materials of all soils are strongly calcareous [12].

Advances in Environmental Biology, 8(12) July 2014, Pages: 1399-1405

Fig. 1: Buried organic horizon at depth of 110-140 cm, lies beneath the soils of study region.

3.1. Profile 1:

The main vegetative cover of these areas is halophilic plants. No signs of carbonate calcium accumulation and illviated clay occur in the field description. Instead large amount of salty crystals were observed at all horizons from top to bottom of the prdon. The structure of all pedons was massive. Common amount of hair roots in surface horizon was noticeable and this amount decreases to only a few strands towards the bottom of the pedon.

Table 2: Morphological characteristics of studied soil profiles.

Profile &field No.	Horizon	Depth(cm)	Matrix color	Mottles	Texture	Structure	Clay coating
1(2-18)	A	0-34	10YR5/4,7.5YR5/4	-	Cl[1]	M[6]	-
	Cg1	34-70	7.5YR 4/4	F 2 f, 5YR 5/8	Sic[2]	M	-
	Cg2	70-98	10YR4/4,7.5YR4/4	C 3 d,5YR 5/8	Sic	M	-
	Cyg	98-150	5Y5/2,10YR 3/1	M 3 p ,5YR 5/8	Cl	M	-
2(4-4)	Ap	0-20	10YR 3/3	-	Scl[3]	P[7]	-
	Bk1	20-55	10YR 4/4	-	Cl	M	-
	Bk2	55-85	10YR 4.5/4	-	Cl	M	-
	Bkg1	85-125	10YR 4/4	C 2 f,10R5/1	Sicl[4]	M	-
	Bkg2	125-145	10YR 5/4	M2d,2.5Y7/8,10Y7/8	Sicl	M	-
	Cg	145-170	10YR 2/1,5Y 5/3	C 2 d ,10YR7/8	Cl	M	-
3(15-4)	Ap	0-20	10YR 5/4	-	Cl	P	-
	Bwd	20-47	7.5YR 4/4	-	Cl	M	-
	Bw1	47-74	7.5YR 4/4	-	Cl	M	-
	Bw2	74-101	5YR 4/4,7.5YR 4/4	-	Sicl	M	-
	Bwg	101-150	10YR4/3,10YR 6/2	C 2 d ,7.5YR 6/2	C[5]	M	-

[1] Clay loam; [2]Silty clay; [3] Sandy clay loam; [4]Silty clay loam; [5] Clay; [6] Massive; [7]Plow

Table 3: Laboratory datas of studied soil pedons.

Profile &field No.	Horizon	Depth(cm)	%Sand	%Silt	%Clay	Bulk density (gr/Cm^3)	EC(ds/m)	pH	ESP	%CaSo^4.2H$_2$O	%CaCO3	%OC
1(2-18)	A	0-34	26.4	36.5	37.6	2.7	16.6	7.7	29.1	0.151	38.8	0.23
	Cg1	34-70	4.4	52.4	43.6	1.7	26.2	7.8	30.5	0.151	39.1	0.18
	Cg2	70-98	4.4	54.5	41.6	1.8	25.2	8.0	35.5	0.027	39.4	0.23
	Cyg	98-150	30.4	40.0	29.6	1.7	24.3	7.9	31.6	0.071	37.5	0.49
2(4-4)	Ap	0-20	53.9	20.4	25.6	1.8	3.7	7.0	4.8	0.013	37.2	0.23
	Bk1	20-55	37.9	30.4	31.6	1.7	1.6	7.7	8.1	0.004	37.3	0.02
	Bk2	55-85	27.9	38.4	33.6	1.6	1.5	8.0	3.1	0.004	38.8	0.12
	Bkg1	85-125	15.9	50.4	33.6	1.6	1.2	7.9	6.4	0.003	39.0	0.06
	Bkg2	125-145	11.9	54.4	33.6	1.5	1.2	7.9	7.5	0.003	39.4	0.08
	Cg	145-170	23.9	36.4	39.6	-	2.1	8.0	11.6	0.003	38.5	0.08
3(15-4)	Ap	0-20	41.8	28.6	29.5	1.9	5.7	7.5	9.6	0.041	39.1	0.62
	Bwd	20-47	27.9	32.7	39.4	2.1	1.9	7.8	8.1	0.007	38.6	0.43
	Bw1	47-74	30.0	34.8	35.2	1.9	2.1	7.8	8.8	0.004	38.5	0.18
	Bw2	74-101	18.4	42.5	39.0	1.7	2.0	7.9	8.0	0.003	38.3	0.21
	Bwg	101-150	6.5	36.7	56.8	1.4	1.9	7.9	6.8	0.003	38.1	0.14

The subsurface diagnostic horizons in this pedon were Salic at a depth of 34-98 cm and also, Ochric horizon in the surface diagnostic horizon to a depth of 34 cm. Based on the key to soil taxonomy this soil was classified as being a subgroup as TypicHaplosalids. Some of the morphological and physico-chemical properties of this profile are presented in tables 2 and 3. Soil salinity is high all over the soil profile. The surface horizon showed the lowest level, 16.66 dS/m and the subsurface horizon had an average value of 25 dS/m. The high salinity of the soils with shallow groundwater is due to the capillary movement of water, which is loaded with soluble salts to the surface, where the water evaporates and the salt concentrates [13]. The EC of ground water was 44.2 dS/m at depth of 150 cm from the surface. The maximum level of organic carbon was measured at the fourth depth of 0.49% because of the buried organic horizon, as it is about 0.26% more than the surface layer.

3.1.1. Micromorphological observations (depth 0-34 cm):

The apedal spongy microstructure occurs in this horizon. The type of pores in this horizon is generally vughs and smaller amounts of vesicles. The dominant minerals are Calcite, Quartz, and minor amounts of opaque minerals. The coarse fraction consists predominantly of limestone along with igneous rocks and sandstone. The fine fraction consists of clay and calcite with few gypsiccrystalithicb-fabric. Also, distributed humified organic matters in the micromass can be identified. The most characteristic pedofeatures in the thin sections were plenty of gypsum crystals, frequently as void infillings and some distributed in the micromass.

3.1.2. Micromorphological observation (74 - 98 cm):

The massive microstructure occurs in this horizon. The type of pores in this horizon is generally planar voids and in some parts a few vughs and vesicles were observed too. The dominant minerals are the same as above. The coarse fragments are dominantly limestone and silt stone. The fine mass consists of clay and micritic calcite with some gypsiccristalithic b-fabric. The most characteristic pedofeatures in this horizon was plenty of clay coatings frequently around the void surfaces, also there was plenty of big gypsum crystals usually as void infillings and some lenticular gypsum crystals was observed, distributed in the micromass. Redoximorphic features was seen as fine and coarse Fenodules in this horizon, fig. 3, a.

3.2. Profile 2:

The profile has been under sugarcane cultivation for about 16 years. No signs of Calcium carbonate accumulation were seen in the field. No particular structure was seen in this pedon because of deep plowing and the low water table. The sugarcane roots were distributed through the subsurface horizon at depth of 55 cm.The subsurface diagnostic horizons in this pedon were Cambic to a depth of 20-55 cm and also, Anthropic horizon in

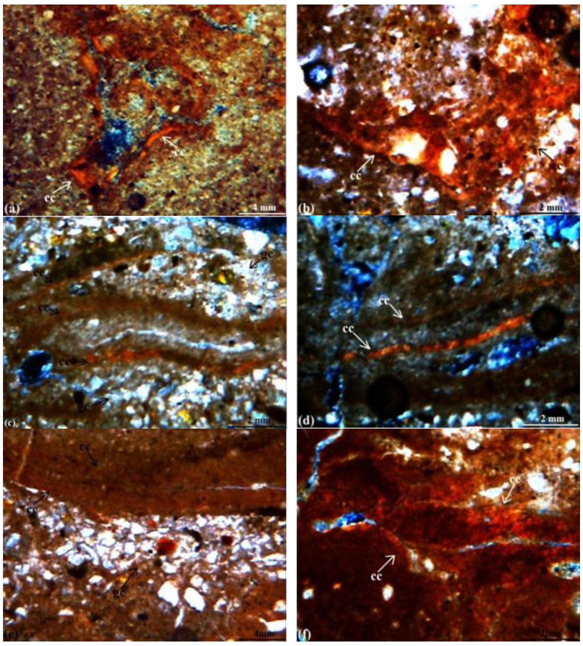

Fig. 2: Micrograph related to cc(abbreviated for clay coating), on void surfaces in profile 1, 70-98 cm,(a)., crescent cc in profile 2, 55-85 cm,(b)., profile 3, 74-101 cm,(c and d)., profile 3, clay coatings on gc (abbreviated for gypsum crystals) infillings in a void, 74-101 cm,occurred., thick cc in profile 3, 74-101 cm (f).

The surface diagnostic horizon, to a depth of 20 cm. Based on the key to soil taxonomy (2010), this soil was classified as a subgroup known as asTypicAnthracambids. Some morphological and physico-chemical characteristics of this profile are presented in tables 2 and 3.

3.2.1. Micromorphological observations (depth, 55-85 cm):

The microstructure occurs is massive. The type of pores in this horizon is generally planar voids with some vesicles. The dominant minerals in this horizon are Calcite, Quartz, and some opaque minerals. Coarse fragments are dominantly limestone, silt stone and sand stone.

Advances in Environmental Biology, 8(12) July 2014, Pages: 1399-1405

The fine mass consists of clay and micritic calcite. Some humified organic matters in the micromass were seen. The most characteristic pedofeatures in thin sections was clay coatings frequently around the void surfaces, fig. 3, b.

3.3. Profile 3:

The study profile had been under sugarcane cultivation for about 13 years. No signs of Calcium carbonate accumulation had occured in the field description. Surface horizon was plowed so, no structure were described but the subsurface horizons showed subangular blocky structure. The sugarcane roots spread into the subsurface horizons to a depth of 74 cm. The subsurface diagnostic horizons in this pedon were Cambic at a depth of 20-47 cm and also Anthropic horizon is the surface diagnostic horizon at a depth of 20 cm were observed. Based on the key to soil taxonomy (2010), this soil was classified at subgroup level as TypicAnthracambids.Some of the morphological and physico-chemical characteristics of this profile are presented in tables 2 and 3.

3.3.1. Micromorphological observations, depth (20-47 cm):

Subangular blocky microstructure occurs in this horizon. The types of pores in this horizon are channel and vughs. The dominant minerals in this horizon are Calcite, Quartz, Biotite and opaque minerals. The coarse fragments are limestone and sand stone and fine mass consists of clay and micritic calcite with locally gypsiccristalithic b-fabric. Organic matter residues as partially to completely decomposed root residues were seen in channels and the micro mass. The most characteristic pedofeatures in the thin sections were clay coatings frequently around the void surfaces; also there were plenty of big lenticular gypsum crystals usually as void infillings.

3.3.2. Micromorphological observations, depth (74-101 cm):

Microstructure and types of pores and the dominant minerals in this horizon are the same as above. The fine mass is dominantly clay. Organic matter and fine fragments are small humified organic matters. The most characteristic pedofeatures in this part were predominantly oriented clay coatings, frequently around the void surfaces and lenticular gypsum crystals, as infillings in voids fig. 2, c, d, e and f.

3.3.3. Micromorphological observations, depth (110-150 cm):

All characteristics are the same as above. In addition to the abovementioned pedofeatures some redoximorphic Fe nodules also were seen in the micromass.

Discussion:

In the thin sections prepared for the horizons of the non-cultivated pedon and for subsurface horizons of cultivated pedons, plenty of gypsum crystals as void infillings or embedded in the matrix were observed. Similar results were reported by Khademi for surface horizons of some alluvial studied soils which were rich in gypsum [13]. Voids and channels partially filled with gypsum crystals coexisting with other voids and channels totally filled indicate a gradual process of secondary gypsum enrichment [10]. In the thin sections prepared from subsurface horizons of studied pedons, the accumulations of illuvial clay as clay coating on void surfaces were observed. The majority of the electrical conductivity in these pedons belongs to Sodium Chloride, specifically in pedon No.1 related to non-cultivated lands..On the one hand, with due regard to the flocculation effect of salts like Sodium Chloride on clay particles, the displacing of clay particles which causes clay coatings is impossible. One the other hand,clay coatings occur in all subsurface horizons of studied pedons in 3 different soil series.While there is an existence of similar clay coatings in all studied pedons of different soil series, it is note that 2 other pedons have been under irrigation for years , while the blank one has never been irrigated. This indicates that a far moister paleoclimate existed than what existstoday.Based on geological and biological evidence, Moatamed [17] has suggested that a more humid climate existed in Iran in the early to middle Holocene. Mahmudi [15] believes that, during the period of glaciation, the central and southern parts of Iran experienced a climate with more rainfall than today, whereas in the interglaciation periods the climatic conditions were rather the same as today. Krinsley [14] believes that during the previous moister periods in Iran, the situation was suitable for leaching and translocation of clay particles. He also believes that this situation was probably because of a low temperature in this region and the level of precipitations during these times. Many pedologists agree with this hypothesis that the existence of such clay coatings in Aridisols was formed in a climate moister than today's environment [8,20,13]. TaghizadehMehrjardi [29] stated that the illuviation process in arid regions are due to the absence of sufficient moisture, and the calcareous property of the majority of soils, and other preventing factors occur slowly over time and are discontinuous or never occur. He also suggests that for reaching a sufficient confidence, more experiments such as dating of deposits using CO2 method is necessary.

In observed thin sections despite the existence of clay coatings in the illuvial horizons as compared with the overlying eluvial horizons, the clay content did not have the necessary value to be qualified as an Argillic, table

3. This result is in agreement with Taghizadeh *et al*., [29] studies. This might be due to the lithological discontinuity which commonly occurs in alluvial sediments and which eliminates the requirement of clay increasing for the diagnosing of an Argillic horizon.

The occurrence of clay coatings on void surfaces infilled with gypsum crystals, (fig.3f) ,shows that gypsification progresses from surface horizons towards the depth was and had occurred before the formation of clay coatings. In some cases (fig. 3 c), it was also seen that regypsification and gypsum crystal infillings above the clay coatings exist. This example probably show that in a climate that was moister than today, primary gypsification occurred and was followed by translocation of clay and once more in the subsequent drier climate ,the gypsification process ,led to gypsum crystals accumulation in voids. In general, it seems that the studied soils have undergone several genetic cycles and also, the processes of gypsification, clay illuviation, and regypsification were the effective major processes in these soils. These evidences are similar to the findings of Ayoubi [3] &Khademi [13]. Ayoubi [3] believed that the existence of different stratifications relates to the occurance of different pedogenic processes back to back. He reported the formation of two oriented clay layers between two pedogenicCalcim carbonate layers in the Btky horizon, which had been later covered by a gypsum rich layer. He emphasis that such a trend might form due to the lessivage of clay particles after the translocation of Calcium Carbonate, followed thereinafter by recalcification and then gypsification which he considered as a polygenetic pedofeatures [3].

Thin section observations showed no disruption in established clay coatings. Nettleton *et al*. [20] reported that, in some clay argillic horizons, clay coatings probably have been destroyed by a combination of root and animal activities,crystallization of calcium carbonate, and shrink–swell pressure brought on by wetting and drying. Reynders [23] believed that micro-churning and swelling and shrinking have obliterated the evidence of clay illuviation in the B horizons in some Aridisols in Morocco. When illuviation occurs sufficiently deep to escape present-day wetting and drying and physical turbations, clay coatings may be preserved [2]. For example, clay coatings existed in deeper horizon thin sections in the present study were more consistent than shallower horizons. Allen [2] stated that argillic horizons in buried soils were shown to be well preserved and consist of strongly oriented channel clay coatings.

Conclusion:

In the thin section prepared from the subsurface parts of the studied profiles, the accumulations of illuvial clay in the form of clay coating on voids faces and as infillings inside the voids were observed. Also, the occurrence of clay coatings above the gypsum infillings in voids illustrates degypsification process from the upper horizons and downward movement of gypsum before the formation of clay coatings. In addition, the occurrence of gypsum crystals that were superimposed on the clay coatings shows the regypsification process and gypsum retranslocation and reaccumulation. With due attention to the existing examples of clay coatings in irrigated and non-irrigated pedons, it seems that the formation of these pedofeatures is in related to prior moister climates. Indeed, in this region with the present aridic moisture regime, these features are very unlikely to form, therefore the presence of a more humid paleoclimate is probable. The coexistence of clay coatings and gypsicpedofeatures in described horizons in these alluvial soils together, suggest a multistage pedogenesis in this landscape.

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