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SOIL PROPERTIES AND TOPOGRAPHIC RELATIONSHIPS OF SOME REPRESENTATIVE ENTISOLS AND INCEPTISOLS IN WESTERN IRAN

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ABSTRACT

Properties, genesis and classification of five soils were investigated in western Iran. Each soil was located on different topographic positions. These soils were: pedon 1, Jafar-Abad series on the old plateau; pedons 2 and 3, Chaghagolan series and Deh-Pahn series, respectively, both on the piedmont alluvial plains; pedon 4, Nukan series on the alluvial-colluvial fans; and pedon 5, Ghare'-Sue series on the river alluvial plain. The soils are weakly developed and calcareous throughout with carbonate nodules, concentrations, and powdery pockets. On a catenary sequence, Entisols of the upper parts, i.e. the alluvial-colluvial fans, showed no profile differentiations, whereas Inceptisols of the lower parts, i.e. the piedmont alluvial plains, revealed deeper solum with cambic and calcic horizons. Topography was the main soil forming factor affecting soil properties, namely, color, organic matter, cation exchange capacity, clay-sized particles, and calcium carbonate accumulation. Calcification was the main pedological process occurring in soils. Some pedogenic transformations of illite and chlorite produced smectite and palygorskite minerals. Provisionally, pedon 1 is classified as a Petrocalcic Calcixerept; pedons 2 and 3 Typic Calcixerepts; pedon 4 a Typic Xerorthent; and pedon 5 a Vertic Endoaquept.

Key words: Calcihication, Entisols, Inceptisois, Topography.

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تحقیقات کشاورزی ایران

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رابطه پستی و بلندی با خصوصیات برخـــی خاکهـای انتـی سـولز (Entisols) و اینسپتی سولز (Inceptisols) غرب ایران

مجید باقر نژاد و علی اشرف امیری نژاد

بـه ترتیب اسـتادیار و دانشـجوی سـابق کارشناسـی ارشـد بخـش خاکشناســی دانشـکده کشاورزی دانشگاه شیراز، شیراز، جمهوری اسلامی ایران.

چکیده

ویژگی های تکوین و رده بندی پنج خاک در غرب ایران بررسی شد. خاکها در موقعیت هـای توپوگرافی مختلف واقع شده بودند. خاک های مورد مطالعه عبارت بودند از: بدون شـماره ۱ بـه نـام سری جعفر آباد واقع در واحد فیزیوگرافی فلات (پلاتو) ، پدونهای شماره ۲و ۳ به ترتیب به نام هـای سری چغاگلان و ده پهن هر دو واقع در دشت های آبرفتی دامنه ای، پدون شـماره ۴ بـه نـام سـری نوکان واقع در مخروط افکنه های آبرفتی-واریزه ای ، و پدون شماره ۵ به نام سری قـره سـو واقـع در دشتهای آبرفتی رودخانه ای. این خاک ها همگی آهکـی و دارای تکـامل ضعیـف بـوده و آهـک در آن ها به صورت گره ، سخت دانه و پاکت پودری بود. تفکیک افق در پروفیل خـاک هـای انتـی سـولز نقاط مرتفع (مخروط افکنه های آبرفتی-واریزه ای) ردیف پستی و بلندی مشاهده نشـد. درحـالی کـه خاک های اینسپتی سولز نقاط پایین (دشت های آبرفتی) دارای سولوم عمیق تر، همراه با افق هـای کمبیک و کلسیک، بودند. پسـتی و بلنـدی ، مهمـترین عـامل تشـکیل و تکـامل خـاک در منطقـه مـورد مطالعه، بر ویژگی های خاک از جمله رنگ، مقدار مواد آلی، ظرفیت تبادل کاتیونی، ذرات رس و تجمـع

کربنات کلسیم تأثیر گذاشته است. کلسیم دار شدن مهمترین فرآیند پدولوژیکی خاک های منطقه بـود. احتمال وقوع تغییر پدوژنیکی ایلیت و کلریت و تبدیل آنها به اسمکتیت و پالی گورسکیت در این خاکها تشـخیص داده شـد. بـا توجـه بـه نتـایج ، پـدون شـماره ۱ پتروکلسـیک کلسـی زرپـت (Petrocalcic Calcixerepts) ، پدون های شماره ۲ و ۳ تیپیک کلسی زرپت (Typic Calcixerepts) ، پدون شماره ۴ تیپیک زراورتنت (Typic Xerorthents) و پدون شماره ۵ ورتیک اندواکوپت (Vertic Endoaquepts)) رده بندی شدند.

INTRODUCTION

Catenary relationships between soils were recognized independently by Milne (20) in East Africa and by Ellis (8) in Canada. However, the role of topography as an independent soil forming factor is best known through the factors of soil formation expounded by Jenny (13). Relationships of topography to soil properties and genesis have been studied in Iran by Abtahi (1) and by Gharaee and Mahjoory (10). Soils formed on similar parent materials with the same age, show different profile development due to different topographic positions. Some soil properties, including depth of solum, amount and thickness of organic matter in A horizon, amount of soluble salts, and horizon differentiation often have close relationships with topography. In particular, there are clear relationships between soil processes and the geomorphic position in the landscape (6). Abtahi (1) stated that genesis, morphology, physico-chemical properties and mineralogy of soils in his study were all affected by topographic position. In semi-arid conditions, as the slope decreases the amount of calcium carbonate increases (24) and some specific pedogenic transformations of soil minerals have been reported (10).

In Iran, young and weakly developed soils make up almost all of the arable lands on different topographic positions. The main objective of this investigation was to determine relationships between soil characteristics and geomorphic positions of some representative Entisols and Inceptisols developed on a catena in Kermanshah semiarid region, western Iran (Fig. 1).

MATERIALS AND METHODS

Kermanshah, the study area, extends between the latitudes 47° 6' and 47° 10' and longitudes 35° 18' and 35° 23' (Fig. 1). The mean annual precipitation is 550 mm mostly occurring from November through April.

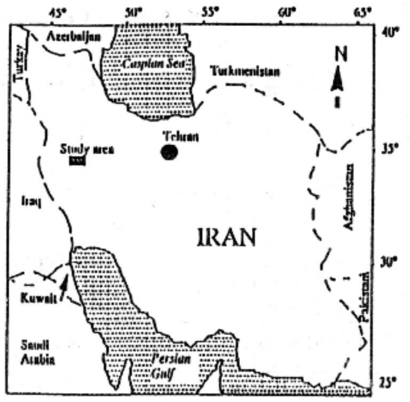

Fig. 1. Location map of Kermanshah.

The average annual air temperature is 14.5°C (16). The study area covers about 5000 ha of a catena, the upper parts of which are developed on limestone of upper Triassic to lower Cretaceous age, and the lower parts on sediments derived from Quaternary limestones (9). Dryland farming, irrigated agriculture, orchard, and pasture are four common land uses of the region.

Four main geomorphic surfaces were defined: old plateau; piedmont alluvial plain; river alluvial plain; and alluvial-colluvial fans (Fig. 2). Mixed slopewash materials constituted the parent materials of the soils. The old plateau (O, Fig. 2) is located on the southern part of the study area. A thick subsurface petrocalcic horizon is covered by a shallow ochric epipedon. The calcrete pan prevents root penetration and deep percolation of water. The piedmont alluvial plains (P, Fig. 2)occupy some 68% of the area. The calcareous, fine-textured slopewash materials are deposited on the surface of the plains. The alluvial-colluvial fan (A, Fig. 2) is located on the northern parts of the study area. The surface is covered by coarse gravel;

the soils are undeveloped and well drained. The river alluvial plain (R, Fig. 2) is a product of deposition of calcareous, fine-textured Ghare'-Sue River alluvium and exhibits some black manganiferous mottles in the sub-surface horizons.

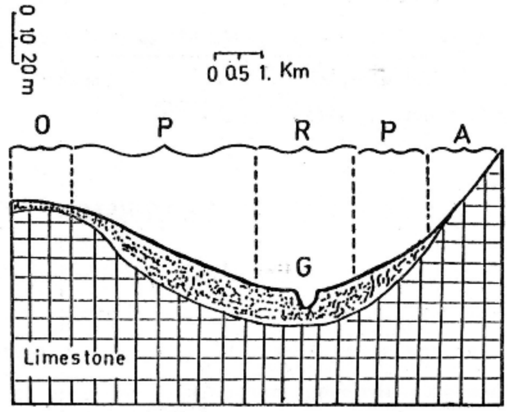

Fig. 2. Four main geomorphic positions and the Ghare'-Sue River; O=Old plateau; P=Piedmont alluvial plain; R=River alluvial plain; A=Alluvial-colluvial fan; G=Ghare'-Sue River.

Soil samples were collected from the profiles dug in each topographic site. Analyses were carried out of particle size using sedimentation and sieving (7); exchangeable Ca, Mg, K, and Na by displacement with NH_4OAc (5); and calcium carbonate equivalent was determined by HCl (21). Soil profiles were described and classified according to Keys to Soil Taxonomy (23).

Soil samples were prepared for clay separation and X-ray analysis by removing soluble salts and carbonates by Na OAc treatment, oxidizing the organic matter with H_2O_2 (12) and removing free iron oxides by the method of Mehra and Jackson (19). The Na-saturated samples were then dispersed in distilled water in 1000 cm^3 sedimentation cylinders. The <2 μm fractions were obtained by repeated siphoning (17). Then, mineralogy was determined by X-ray diffraction with a Philips X-ray diffractometer and Fe-filtered copper K_α radiation. Scans were made at a speed of $1°2\theta\ min^{-1}$ from $2°2\theta$ to

30°2θ. The (*001*) reflections were obtained following Mg^{+2} saturation, Mg^{+2} saturation and glycerol solvation, K^{+} saturation, and consecutive heat treatment at 550°C. Palygorskite was distinguished on electron micrographs obtained by a SM 300 Transmission Electron Microscope, 80 KW. Estimation of clay mineral proportions was semi-quantitatively obtained using the (*00l*) peak intensities of the Mg-saturated and glycerol solvated samples (15). Vermiculite was detected by laboratory determinations as proposed by Alexiades and Jackson (2).

RESULTS AND DISCUSSION

Field and laboratory studies of soils (Tables 1 and 2) suggested that topographic position is a principal soil forming factor affecting soil development in the study area. The effects of topography have been revealed through differing morphology, physico-chemical properties, genesis, and mineralogy of soils (Tables 1, 2 and 3, respectively) that were located on different positions of the catena. The soils on the steep slopes (15-20% , pedon 4) are without profile differentiation and classify as Entisols; uplands showed no horizon other than ochric epipedon. As the slope decreases (pedons 2 and 3) the depth of solum increases leading to the formation of cambic and calcic horizons in soil profiles of the lower parts of the study catena, which classify as Inceptisols.

The data presented in Table 2 show that the clay-sized particles increase as the slope decreases (pedons 2 and 3). As Jenny (14) described, this could be a result of surface water movement and subsequently, translocation and redeposition of soil particles on the slope. Pedon 5, the lowest part of the catena, should have received washed-down clay-sized particles and, some vertic features, namely slickensides and large cracks, were distinguished in these profiles.

The color of soils on various positions of the catena was related to topography (Table 1). The soil color was changed from 10YR 5/4 (dark yellow) in surface horizons of the uplands (pedon 3) to 5YR 2/2 (dark gray) in corresponding horizons of the lowlands (pedon 5). These results are in agreement with more and longer periods of soil moisture, and accumulation

Table 1. Classification and morphological characteristics of soils.

Pedon No	Horizon	Depth (cm)	Color	Texture	Structure	Consistency	Boundary	Remarks
			Fine, mixed (calcareous), thermic, Petrocalcic Calcixerepts					
1	A_p	0-10	10YR 4/4	sic	m	mfr	c	few fine roots
	C_m	10-45	10YR 5/4	sic	m	mfi	-	highly calcareous cemented horizon
			Fine, Carbonatic, thermic, Calcixerepts					
2	A_p	0-25	10.0YR 6/4	sic	m	dh	c	
	B1	25-50	7.5YR 6/4	c	3pr	dh	c	cracks to 90 cm depth
	B_k1	50-90	7.5YR 5/4	sicl	2pr	dh	c	Secondary $CaCO_3$ appears
	B_k2	90-140	7.5YR 5/4	sil	1,2bk	dh	-	Powdery pockets and Concretion of $CaCO_3$ (about 40%)
			Fine, mixed (calcareous), thermic, Typic Calcixerepts					
3	A_p	0-24	10YR 5/4	c	m	mvfr	c	
	B1	24-50	10YR 5/4	c	abk	mvfr	g	
	B_k1	50-83	10YR 5/4	c	2pr	mvfr	c	few accumulations of $CaCO_3$ in forms of concretions and powdery pockets
	B_k2	83-128	10YR 5/4	sic	0,1pr	mfr	g	accumulation of secondary $CaCO_3$
	C	128-150	10YR 5/4	sic	m	mfi	-	gravel (about 10%)
			Loamy skeletal, mixed (Calcareous), thermic, Typic Xerorthents					
4	Ap	0-17	10YR 5/4	sicl	m	mfr	c	very few fine roots
	C	17-50	10YR 5/4	gsicl	m	-	-	gravel (>70%)
			Very fine, mixed (calcareous), thermic, Vertic Endoaguepts					
5	A_p	0-20	2.5YR 4/2	c	m	dh	c	-
	B_g1	20-45	2.5YR 5/2	c	3pr	dh	c	cracks and Mn mottling many color mottling, few accumulations of secondary $CaCO_3$
	B_g2	45-140	2.5YR 5/2	c	3pr	dh	-	

sic, sicl, c, gsicl= silty clay, silty clay loam, clay and gravelly silty clay loam texture, respectively, m, pr, bk, abk= massive, prismatic, blocky, and angular blocky structure type, respectively, 0, 1, 2, 3= structureless, weak, moderate, and strong structure grade, respectively, mfr, mfi, dh, mvfr= moist friable, moist firm, dry hard and moist very friable consistency, respectively, c, g= clear, and gradual boundary, respectively.

Table 2. Physico-chemical properties of soils.

Pedon No.	Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC_e dSm^{-1}	sp%	CCE%	OM %	CEC $cmol\ kg^{-1}$
1	A_p	0-10	7	48	45	sic	7.6	0.34	52.2	21.2	1.2	28.0
	C_m	10-45	4	68	28	sicl	7.9	0.27	46.9	58.8	0.3	18.2
2	A_p	0-25	6	46	48	sic	7.7	0.59	54	31.2	0.77	27.4
	B1	25-50	3	34	63	c	7.7	0.55	49	32.5	0.44	24.0
	B_k1	50.90	3	67	30	sicl	7.7	0.49	51	40	0.29	20.5
	B_k2	90-140	3	72	26	sil	7.8	0.48	52	46	0.23	16.0
3	A_p	0-24	6	34	60	c	7.7	0.30	51	7.5	0.75	30.8
	B1	24-50	5	36	59	c	7.8	0.27	52.7	9.8	0.43	29.7
	B_k1	50-83	3	37	60	c	7.9	0.24	55.3	14.5	0.24	29.7
	B_k2	83-128	5	45	50	sic	7.9	0.25	50.8	18.5	0.20	23.9
	C	128-150	5	53	42	sic	7.9	0.24	48	15.5	0.15	15.0
4	A_p	0-17	8	59	33	sicl	7.7	1.45	42.3	22.8	0.49	22.8
	C	17-50	10	60	30	gsocl	7.7	1.00	47.2	21.0	0.24	21.7
5	A_p	0.20	8	36	56	c	7.7	0.74	56	25.6	1.3	28.5
	B_g1	20-45	4	35	61	c	7.8	0.55	58	25.0	0.75	29.7
	B_g2	45-140	5	33	62	c	7.9	0.58	61	25.6	0.49	29.7

of soil organic matter as slope angle decreases. This result can be extended to the soil cation exchange capacity as well.

Table 3. Relative abundance of clay minerals in soils.

Pedon	Horizon	Illite	Chlorite	Vermiculite	Smectite	Palygorskite
1	C_m	++	++	*	+	++
2	A_p	++	++	**	++	++
	B_k1	++	++	**	++	+++
3	A_p	++	++	**	++	++
	B_k1	++	++	**	++	++
4	C	+++	+++	*	+	+
5	A_p	++	++	**	++	++
	B_g2	++	++	**	+++	++

* = 1-3% ; **=3-6%; +=10-20% ; ++ = 10-20%; +++= 20-40%.

Soil pH and electrical conductivity showed very little, if any, relationship with topography which might be due to the highly calcareous parent material (10).

Mineralogical analyses (Table 3) showed similar mineralogical compositions among the studied soils but their relative abundance was different. The 10 Å peaks in various horizons of all pedons (Fig. 3) suggest the presence of mica (illite). These peaks remained unchanged in all treatments that were carried out for mineral identification. The 14 Å peaks (Fig. 3) indicate both chlorite and smectite in various horizons of all pedons. But these two clay minerals were distinguished from each other by using glycerol solvation and heating treatments. After these two treatments, the 14Å peaks of chlorite were remained intact, but the peaks of smectite expanded to 18 Å when glycerol solvation was used, and collapsed to less than 10 Å after being heated to 550° C (Fig. 3). Pedogenic transformations of illite and chlorite result in formation of smectite and palygorskite (4, 3, 18). These changes are evident in the greater amount of smectite and palygorskite occurring in the soils of the lower parts (pedons 2, 3 and 5, respectively) of the studied catena.

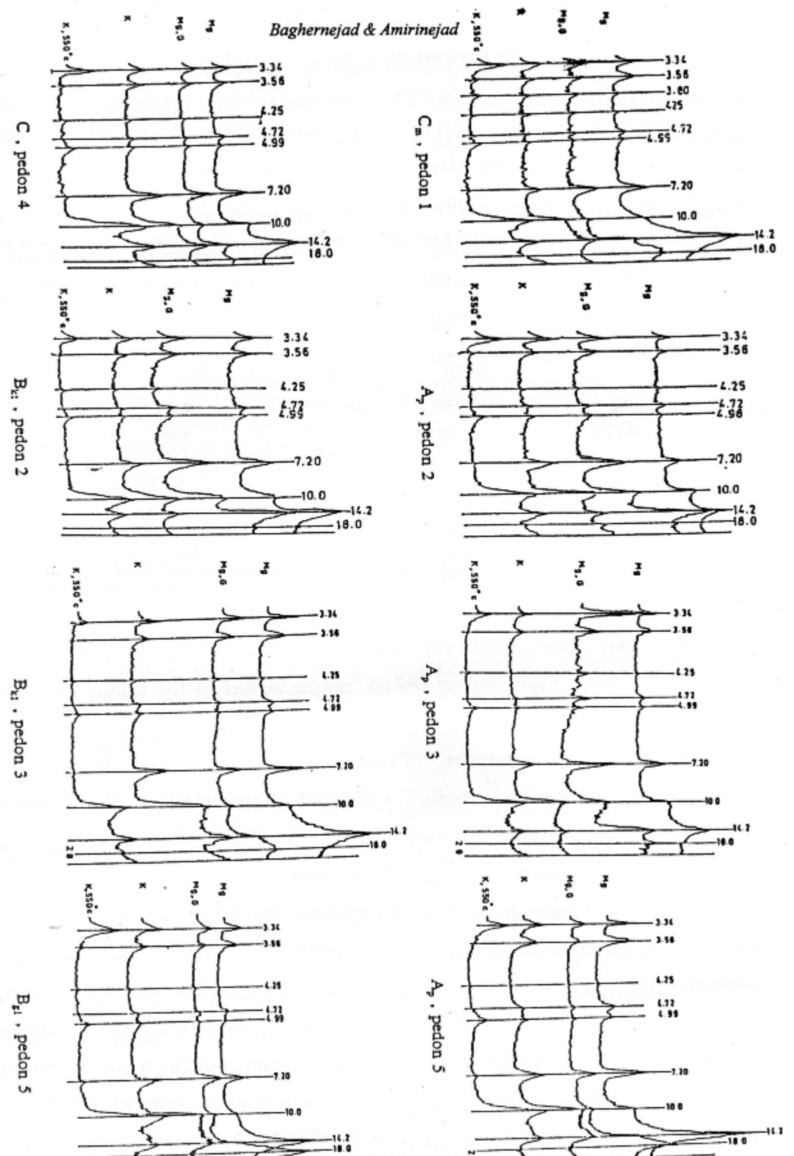

Fig. 3. X-ray diffractograms of <2 μm clay fraction of the indicated horizons of soils.Treatments: Mg=Mg-saturated; Mg, G=Mg saturated and glycerol solvated: K=K saturated; K, 550° C=K saturated and heated to 550° C.

The 10.6 Å and 6.4 Å peaks in soils of pedons 1, 2, 3, and 5 suggest the presence of palygorskite (1). The presence of fibrous clays (palygorskite) in soils was also verified by TEM (Fig. 4). The occurrence of palygorskite in the calcareous alkaline environment of arid and semiarid soils has been reported by several workers (1, 4). The regularly interstratified smectite-vermiculite and/or chlorite clays of all pedons are indicated by 31.1 Å peaks (22).

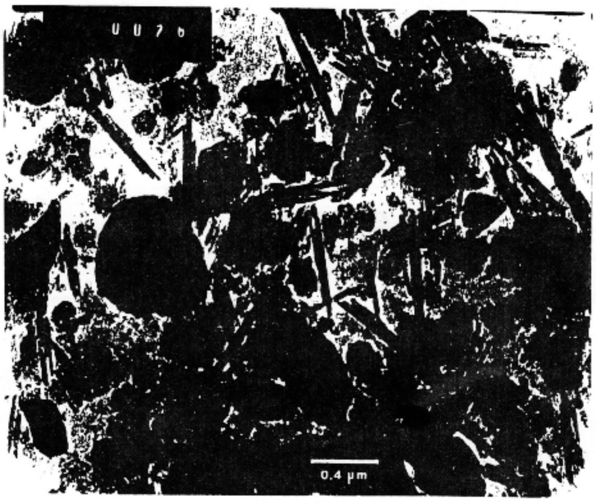

Fig. 4. Transmission-electron micrograph of palygorskite from <2 μm clay fraction of B_ki horizon at pedon 2.

Calcification is the principal process occurring in the soils. From field observations, the steep slopes showed more primary carbonates (fine and coarse particles) than that of the lowlands. The latter area showed evidences of secondary carbonates similar to those reported by Abtahi (1) and Harper (11). Pedon 1 had an ochric epipedon and a petrocalcic subsurface horizon which suggest the age of the old plateau site of pedon 1.

Pedons 2 and 3 had ochric epipedons and cambic and calcic subsurface horizons, again indicating soil evolution due to calcification. Pedon 4 showed no horizon differentiation because of steep slope (i.e., about 20%). Soils in this pedon did not have enough time for evolution due to intensive surface erosion. Pedon 5 in lowland area had cambic horizon with evidences of vertic features. Soils in this pedon were affected by river water and aquic soil moisture regime was, therefore, identified in soil control section.

Tentatively, with the data available, pedon 1 on the old plateau is classified as a fine, mixed (calcareous), thermic, Petrocalcic Calcixerept; pedons 2 and 3 on the piedmont alluvial plains are classified as Fine, mixed (calcareous), thermic, Typic Calcixerepts; pedon 4 on the alluvial-colluvial fans is classified as a Loamy skeletal, mixed (calcareous), thermic, Typic Xerorthent; and pedon 5 on the river alluvial plain as a Very fine, mixed (calcareous), thermic, Vertic Endoaquept.

CONCLUSIONS

Differences in soil properties, genesis and classification were found to be related to the various topographic positions. Dynamic interaction between soil properties and landforms, i.e. pedogeomorphology (6), were defined. The catenary hydrological conditions were reflected by variation in water retention and transmission. Such differences were manifested in catenary variations of individual mechanisms as well as in kind, amount and balance of pedological processes. Impacts of topographic position were greater on Inceptisols than that on Entisols of the region. Soil properties such as color, organic matter, cation exchange capacity, clay-sized particles, and calcium carbonate accumulation were affected by topography. Pedogenic transformations of illite and chlorite might have resulted in genesis of smectite and palygorskite.

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