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Application of the WRB (FAO) and US Taxonomy Systems to Gypsiferous Soils in Northwest Isfahan, Iran

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ABSTRACT

Gypsiferous soils occur in the arid and semi-arid regions of Iran and are found in different geomorphic units. Few studies are available on the genesis and classification of these soils. In the present study, fifteen pedons from an area extending from Jaafarabad Mountain to the central piedmont plain are studied. The objective is to classify the gypsiferous soils studied according to the USDA Soil Taxonomy (1990, 1994, 1996, 1998, and 1999) and WRB (FAO, 1974, 1988- FAO, ISSS, ISRIC 1994, 1998) systems. For this purpose, the designation, amount of gypsum, depth and the thickness of gypsic horizons will be taken into account. The study area includes different geomorphic units such as gravelly fan, quaternary gravelly alluviums and piedmont plain. The 1994 version of the USDA Soil Taxonomy allows for more characteristics of the soils under study to be defined as compared with the previous versions, while the more recent versions (1996, 1998, and 1999) have remained unchanged in this regard. FAO (1974, 1988) and its successor WRB (1994, 1998) show continual and immense progress allowing for greater differentiation of various soils. It will be shown that the WRB 1998 version offers greater possibilities for more detailed characteristics to be included in the classification system; hence, its higher efficiency in comparison to the USDA system.

Keywords: Aridisols, Gypsiferous soils, Classification, USDA, WRB.

INTRODUCTION

Gypsum is a common mineral occurring in semi-arid and arid regions (Watson, 1983 and 1988; Porta and Herrero, 1988; Doner and Warren, 1989; and Herrero *et al*., 1992). The presence of this mineral in soils is closely associated with climatic and topographic conditions (Nelson, 1982; Porta and Herrero, 1988). Gypsic soils are reported in xeric, ustic, and aridic moisture regimes (Watson, 1983; FAO, 1990). Gypsic horizons are formed in regions with less than 400 mm rainfall (Porta and Herrero, 1988; FAO, 1990) while gypsic crusts are normally found in desert areas with less than 250mm rainfall (Watson, 1983). Gypsum crystals occur individually or as masses in soil groundmass and pores (Porta and Herrero, 1988; Eswaran and Zi-Tong, 1991). When the amount of gypsum increases, it invades the total space of the soil horizon. Ggypsiferous soils have recently received more attention, but a better understanding of their genesis requires more information. Soil Taxonomy (Soil Survey Staff, 1999) designates the gypsiferous soils in different sublevels of Aridisols, Gelisols, Inceptisols, Mollisols, and Vertisols. The world Reference Base for Soil Resources (1998) recognizes a larger category as Gypsisols.

Diagnostic horizons in the two above mentioned classification systems are defined as “Gypsic”, for soft and unindurated gypsic layers and “Petrogypsic”, for cemented and indurated ones. Eswaran and Zi-Tong (1991) have suggested a hypergypsic horizon with>

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60% secondary gypsum. As a consequence, a great hypergypsic group had to be added to Aridisols. In an international workshop on WCMDS in China in 1993, the committee accepted "Petro, Haplo and Hyper" formative elements to differentiate indurated soils containing <60%, and soils containing> 60% gypsum (Ilaiwi and Eswaran 1993). Recently, WRB has established a third diagnostic horizon named "Hypergypsic" to define intensive crystallization of secondary gypsum in soils. A master horizon (Y) has been proposed for designating and distinguishing hypergypsic horizons (Herrero *et al*. 1992).

Gypsiferous soils are widespread in most provinces of Iran (especially in central Iran), exceptions being the northern Iranian provinces (Table 1). Estimates of the area under these soils in Iran are varied. FAO (1991), Mashali (1992), and Mahmudi (1998) have reported these soils to be distributed over 420 km^2, 9.8 million ha and 27-28 million ha, respectively. The results from a new study (ISWRI, in press) show that the area may be over 30 million ha (Table 2). Given their proper geological resources (Khademi *et al*., 1997; Toomanian *et al*., 1999), carbonates, sulfates and evaporate minerals play a major role in the genesis and evolution of the soils in central Iran. According to Khademi *et al*. (1997) and Toomanian *et al*. (1999), the main resources for gypsum in our study area are the different Cretaceous sediments. Toomanian *et al*. (1999), studying the origin of gypsum in the same area, found a relationship between gypsum accumulation and the adjacent mountains. They also showed that gypsum had been released from these sediments through weathering processes and then accumulated in nearby soils after translocation.

Table 1. The extent of gypsiferous areas in different provinces of Iran, according to Mahmudi (1998).

G[a]	C[b]	Provinces
2319000	162000	Sistan
1618430	350190	Hormozgan
1490860	112020	Khoozestan
924980		Semnan
563500	5350	Zanjan
356510		Kohgiluieh
237590	110070	Kermanshah
138420		Lorestan
70810		Markazi
24890		Hamadan
10990	120350	W.Azrbayejan
416435		Yazd
5390370		Khorasan
39589450		Isfahan
2043500	124500	Kerman
1604060		Fars
1045660	3560	Booshehr
629960	14600	Ilam
480640	79540	Azrbayejan
229960	65240	Tehran
168740		Mazandaran
101090		Kordstan
27880		Gilan
15505		Chaharmahal
28781145		Total

[a] Homogeneous gypsic areas
[b] Heterogeneous gypsic areas

The mineral gypsum can be readily found in all geomorphic surfaces in the Isfahan region. Toomanian *et al*. (2001) reported on the genesis and evolution of gypsiferous soils extending on fans, dissected old alluviums, and piedmont plains of this area. Amit and Yaalon (1996) have done a useful work on the micromorphologic aspects of different gypsum crystals in gravelly soils. As its main objective, the present paper will apply the WRB (FAO) and US Soil Taxonomy systems to classify the gypsiferous soils in northwest Isfahan.

MATERIALS AND METHODS

The Study Area

The study area, located on the southern slopes of Jaafarabad Mountain, is the best representative of gypsiferous soils within the northern Zayandeh Roud sub-basin (Figure 1). It has a dry and hot climate with dry summers (Karimi, 1987). The annual evapotranspiration rate, mean temperature, and precipitation are 1571mm, 14.1ºC and 122mm, respectively. The climatic data for the study area are presented in Table 3. Cross sections of the study area are shown in

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Table 2. The extent of gypsiferous areas with their associations in Iran.

Soil Associations in Mapping Units	Area (ha)
(Typic, Xeric, Ustic) Haplogypsids + (Typic, Xeric, Ustic) Torriorthents + Typic Calcigypsids	10557051
(Typic, Xeric, Ustic) Torriorthents + (Typic, Xeric, Ustic) Haplogypsids + Typic Calcigypsids	24669068
Gypsic Haplosalids + Gypsic Aquisalids	7300336
Petrogypsic Haplosalids + Gypsic Haplosalids	3052610
Typic Petrogypsic + Typic Haplogypsids	997281
Typic Haplogypsids + Gypsic Haplosalids	4119476
TOTAL	50695822

Figure 2. The soils in this area have been formed through the weathering of calcareous sediments and shale. Soil temperatures and moisture regimes are thermic and aridic, respectively (Banaii, 1998).

Geomorphologic and paleoclimatologic studies by Krinsley (1970), Bobek (1961), and Wright (1961) show that central Iran had a much colder and wetter climate in the late Pleistocene and early Holocene eras. Several sedimentation processes contributed to the formation of the present landforms. These included the following 1) Removal of materials in the direction of mountain slopes by colluvial and alluvial processes to form taluses, fans and/or pediments. Through this process, mountain sediments underwent weathering and gypsum was released and spread (Toomanian *et al*., 1999). 2) The transportation of large quantities of materials along the longest slope of the catchment through catastrophic flooding processes during the late Pleistocene and early Holocene periods. Coarse materials and gypsum mineral were translocated along this path away from the central parts to the area around the outlet of the catchment. Old alluvial terraces were thus formed (Krinsley, 1970) and later dissections caused them to form a rolling surface. It is supposed that the movement of fine material with gypsum transversely from gravelly and extremely gypsiferous hills resulted in the formation of non-gravelly surfaces. 3) Existing piedmont plains were formed beside the old alluviums by subsequent minor erosion and sedimentation processes.

The piedmont plain is the only cultivated

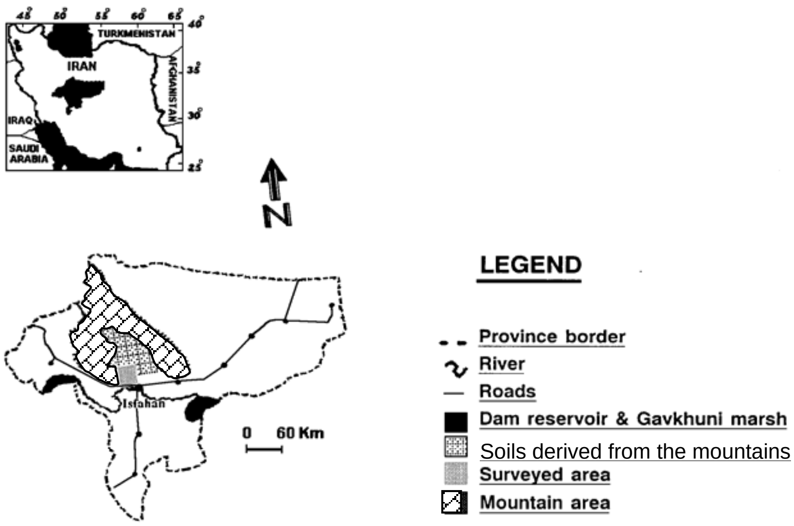

Figure 1. Study area in Isfahan province, central Iran.

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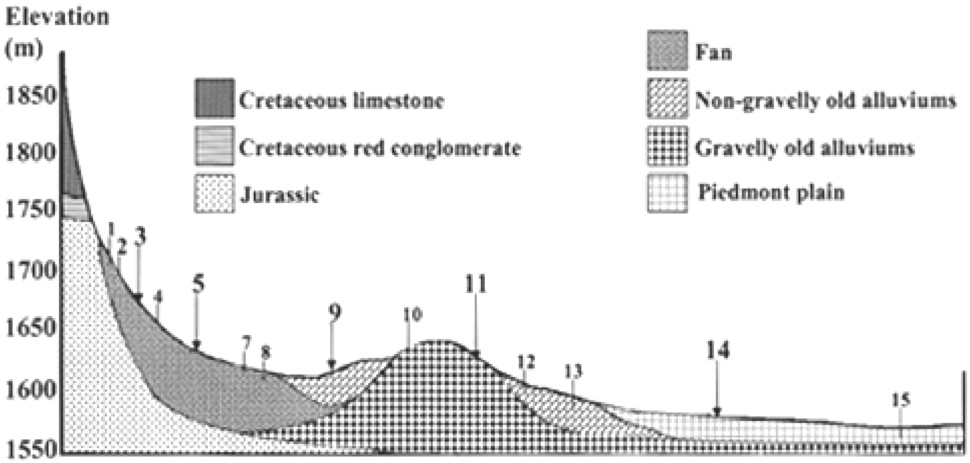

Figure 2. Cross-section showing the geology and landforms in study area.

(wheat and barley) part of the area while the rest is used for low productive ranges. The sparse green cover consists of *Euphorbia sp*. *Alhaji camelorum*, *Artemizia herba*, and *Peganum harmal*.

Fieldwork

A transect of soil with fifteen pedones (from mountain to piedmont plain) was studied (Figure 2). Using the Field Book for Description and Sampling Soils (NSSC-NRCS, 1998), soil pedons were described and soil samples were taken from genetic horizons. In order to distinguish, define and designate the genetic horizons, the Soil Taxonomy (1990, 1994, 1996, 1998, and 1999), FAO (1974, 1988), and FAO, ISSS, ISRIC (WRB 1994, 1998,) systems were considered. The suggestions of Eswaran and Zi-Tong (1991) and Herrero *et al*. (1992) were also taken into account to identify the hypergypsic horizons. Five representative profiles, (each within a geomorphic unit), were selected to show the diversity of soil characteristics and to establish the relationship between gypsum accumulations and geomorphic units.

Methods

Chemical properties and gypsum amount were determined using the Soil Chemical Methods of Analysis (1986) and hydration water was calculated according to Lagerwerf *et al*. (1965) and Nelson *et al*. (1978). The revision included a) changing the soil/water ratio from 1/5 to 1/500, b) increasing the first shaking period from 0.5 to 48 hours, and c) increasing the sedimentation period after adding acetone from 0.5 to 2 hours. The method described by Polemio and Rhoades (1977) was used to measure the CEC of the samples.

Considering the pre-treatment described by Hess (1976), textures of samples were measured using the pipette method. Silica jell was used to dry samples. All oven-dried base data were corrected for two water molecules of dried gypsum (Nelson *et al*., 1978).

Thin soil sections were prepared according to Murphy (1986). The cannus resin with somewhat different mixing rates was used to impregnate the undisturbed samples. The thin sections were described according to Bullock *et al*. (1985).

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Table 3. Climatic data for the study area (1987-1996).

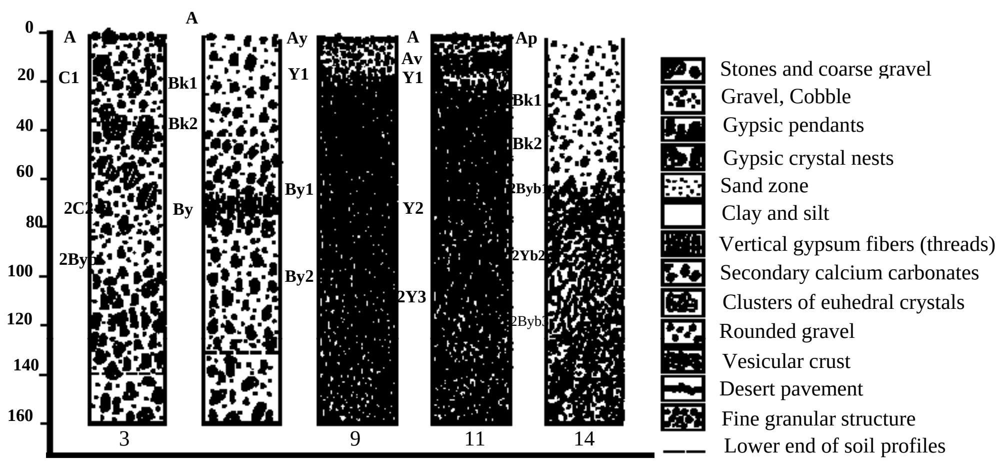
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Mean Max. Temp.	8.7	11.9	16.7	22.2	28	34	36.3	35.2	31.2	24.3	17.7	10.9
Mean Min. Temp	-1.9	-0.3	4.4	9.4	14.3	19.2	21.6	19.9	15.2	9.3	3.7	-0.8
Mean Temp	3.4	4.4	8.6	12.4	17.4	22.4	24.1	22.7	19.2	16.7	10.4	5.1
Rainfall (mm)	23.1	15.1	20.5	15.4	9.8	0.7	0.9	0.1	0	4.3	10.1	22.4
Pot. Evapo-Transpiration (mm)	46.8	58.9	110	139.5	186.7	313.3	228.5	208	155.1	115.9	65.1	4.4
Freezing period (day)	24.6	15.9	6.6	0.1	0	0	0	0	0	0	5.2	20.8
Relative Humidity (%)	60.9	53.8	46.9	40.1	33.6	23.6	25	25.8	28.3	38.6	49.7	58.7

RESULTS

The morphologic and physico-chemical characteristics of representative profiles are presented in Tables 4 to 6. The morphologic characteristics and horizon schematic sketches of profiles are shown in Figure 3. Each profile represents a geomorphic unit.

The coarse gravelly upper fan with a slope of 8-15% contains a coarse textured and weakly developed soil formed from limestone and shale. Because this landform had been permanently receiving coarse materials from the adjacent mountain, it would not have been expected to show any development, thus remaining young through time. In the gypsic horizon, gypsum occurs as clusters of crystals and pendants. It was not clear whether the gypsic (2Byb) horizon in this soil had formed from a different parent material or if coarse textured soil had allowed percolating water to translocate the gypsum to that depth.

The lower fan, with a slope of 5-8%, contains gypsic and calcic horizons in its soil profile. The upper boundary of the gypsic horizon has diagonal fibers of gypsum crystals, abruptly separated from the calcic horizon. At higher depths, the crystals change to clusters and pendants. A few gypsum crystals are found within the calcic horizon. More gypsum crystals are concentrated in soil pores but few in soil groundmass. Micromorphological features formed in the subsoil horizons include channel or chamber internal gypsic coatings, infillings, and grain



Representative profiles of each geomorphic surface

Figure 3. Schematic sequences of features seen in soil profiles.

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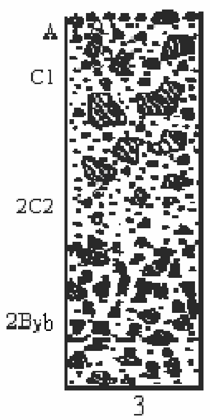
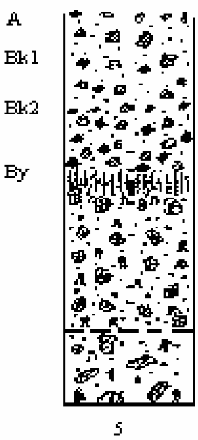


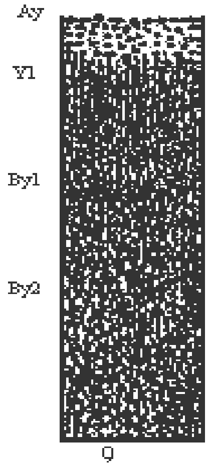
Soil Taxonomy:
1990, 1994, 1996, 1998, 1999- Typic Torriorthents
WRB (FAO):
1974- Calcaric Regosols
1988- Skeli-Haplic Gypsisols
1994- Haplic Gypsisols
1998- Skeli-Calcaric Regosols

external coatings (Figure 4).

Old dissected non-gravelly alluvial surfaces are composed of soils with gypsum crystals and fine earth only. These materials have formed a granular structure in the topsoil. Arrangements of gypsum crystals have formed vertical gypsic fibers (vertical bands of elongated crystals, Figure 5) along subsoil horizons. Vertical gypsic fibers are in some way connected laterally to form a firm,



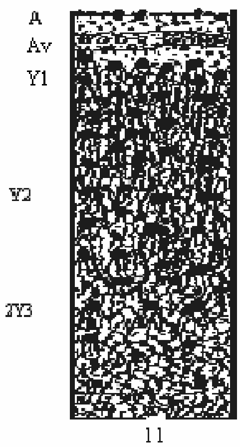
Soil Taxonomy:
1990-Calcic Gypsiorthids
1994, 1996, 1998, 1999- Typic Calcigypsids
WRB (FAO):
1974-Calcic and/or Gypsic Yermosols
1988-Hapli-Calcic Gypsisols
1994-Calcic Gypsisols
1998-Calcic, Endo Hypogypsic Gypsisols



Soil Taxonomy:
1990-typic Gypsorthids
1994, 1996, 1998, 1999-Leptic Haplogypsids
WRB (FAO):
1974-Gypsic Yermosols
1988-Epi-Haplic Gypsisols
1994-Haplic Gypsisols
1998-Epi- Cumuli, Hypergypsic Gypsisols

densely-packed three-dimensional continuous porous media in the Y1 (Herrero *et al*., 1992) and By1 horizons. The length of these fibers (threads) decreases with depth. The amount of silt and gravel increases in the horizon but soil porosity decreases.

Old dissected gravelly alluvial surfaces are composed of a thin surface layer of fine loose soil material below a desert pavement.



Soil Taxonomy:
1990-Typic Gypsorthids
1994, 1996, 1998, 1999-Leptic Haplogypsids
WRB (FAO):
1974- Gypsic Yermosols
1998-Epi-Haplic Gypsisols
1994-Haplic Gypsisols
1998-Skeletic, Epi-Cumuli Hypergypsic Gypsisols

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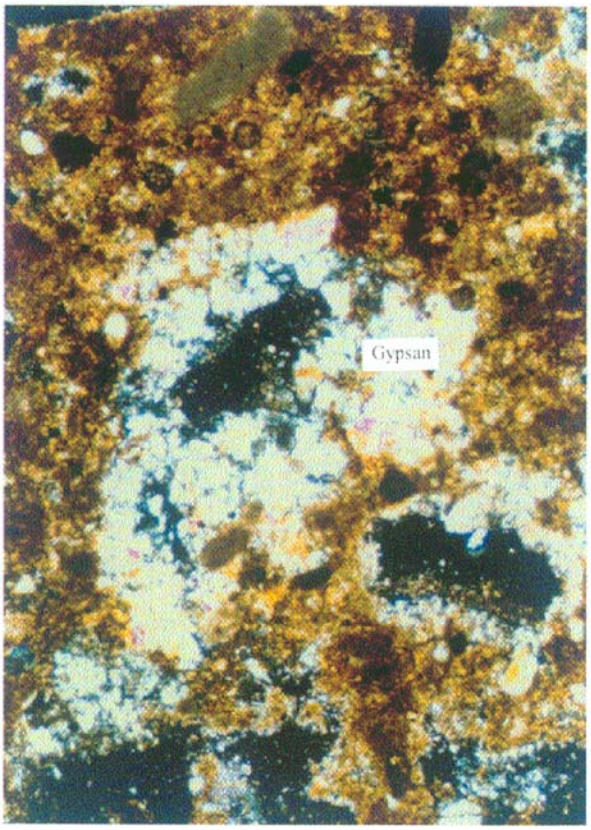
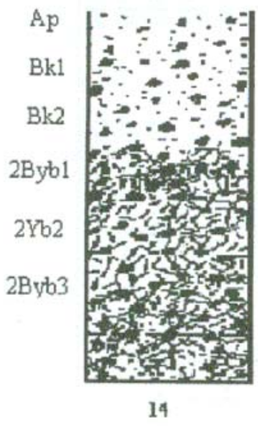


Figure 4. Crystalline infillings inside Voughs of By horizon in profile No. Five (Cross polarized, 40X).

Under this layer, a vesicular crust about 10cm thick has been formed (Figure 6). The whole soil below this crust is composed of gravel and gypsic pendants. Elongated groupings of fibrous crystals (WRB, 1994; Stoops and Ilaiwi, 1981) connect laterally to make a strong network throughout the profile (Boyadgiev and Sayegh 1992). Non-gypsic fine soil materials remain like isles inside the continuous crystalline gypsic pedofeatures. Below a depth of 115cm, gravel is lacking and the arrangement of gypsum crystals changes (Figure 7).



Soil Taxonomy:
1990-Calcic Gypsiorthids
1994, 1996, 1998, 1999- Typic Calcigypsids
WRB (FAO):
1974-Calcic and/or Gypsic Yermosols
1988-Endo-Calcic Gypsisols
1994-Calcic Gypsisols
1998-Calcic, Endo Hypogypsic Gypsisols

Piedmont plain, as the lowest geomorphic surface studied, contains medium texture soils. The upper soil with a clear and abrupt discontinuity lies over a remnant coarse alluvium. Calcic horizon has formed in the upper soil and gypsic horizon in the buried soil. There is a transitional zone in which carbonates and gypsum accumulations are formed together. The groundmass of gypsic horizon consists mainly of isolated lenticular euhedral gypsum crystals (Figure 8). Table 7 presents the classification of the soils studied.

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Table 4. Morphologic characteristics of representative soil profiles.

Hor.	Depth	Color	Texture	Structure	Consistency	Border	Carbonate	Gypsum	Reac	Gravel	Other
Prof. 3, upper fan											
A	0-15	7.5YR4/4	SL	SG	So	Dir	-	-	ev	60%	All primary carbonate
C1	15-70	7.5YR5/4	SL	SG	Sh	Dw	-	-	ev	60%	All primary carbonate
2C2	70-100	10YR5/4	LS	SG	Sh	Cw	-	-	ev	30%	All primary carbonate
2Byb	100-140	10YR4/4	L	SG	Sh		-	2mcs	ev	20%	All primary carbonate
Prof. 5, Lower fun											
A	0-15	10YR4/4	SL	Gr2vf	Sh	Cs	Fd	1fcs	ev	20%	
Bk1	15-38	7.5YR4/4	SCL	Sbk1f	H	Aw	C2ism-sc	1fcs	ev	15%	
Bk2	38-65	10YR4/4	SCL	Massive	H	Aw	M2rsm-sc	1fcs	ev	40%	
By	65-130	10YR5/6	SCL	Massive	H		C2rsm-sc	2mcs	ev	15%	
Prof. 9, Non- gravelly alluvium											
Ay	0-17	10YR6/4	SL	Gr1vf	So	Cs	Fd	3ccs	ev	10%	
Y1	17-54	10YR6/4	SL	Massive	Sh	Gir	Fd	3mcs	ev	5%	10% Orange mottles
By1	54-98	10YR7/3	SL	Massive	Sh	Dir	Fd	3mcs	ev	15%	10% Orange mottles
By2	98-150	10YR6/4	SL	Massive	Sh		Fd	3mcs	ev	20%	10% Orange mottles
Prof. 11, Gravelly alluvium											
A1	0-8	10YR5/6	SL	Massive	So	Aw	Fd	1fcs	ev	30%	
Av	8-15	10YR5/6	SL	Massive	Sh	Aw	Fd	1fcs	ev	15%	
Y1	15-73	10YR7/3	SL	Massive	Sh	Grir	Fd	3mcs	ev	45%	
Y2	73-115	10YR7/3	SL	Massive	Sh	Grw	Fd	3mcs	ev	40%	
2Y3	115-150	10YR7/3	SL	Massive	Sh		Fd	3mcs	ev	5%	
Prof. 14, Piedmont plain											
Ap	0-25	10YR4/6	SCL	Gr1vf	So	As	Fd	1fcs	ev	15%	
Bk1	25-45	7.5YR4/6	CL	Massive	Sh	As	C2isf-sc	1fcs	ev	15%	
Bk2	45-60	7.5YR5/4	L	Massive	Sh	Cw	C2isf-sc	1fcs	ev	5%	
2Byb1	60-90	7.5YR4/6	SL	Massive	Sh	Grs	Fd	3ccs	ev	40%	
2Yb2	90-117	10YR5/6	SL	Massive	Sh	Grw	Fd	3ccs	ev	35%	
2Byb3	117-140	10YR5/6	SL	Massive	Sh		Fd	2mcs	ev	45%	

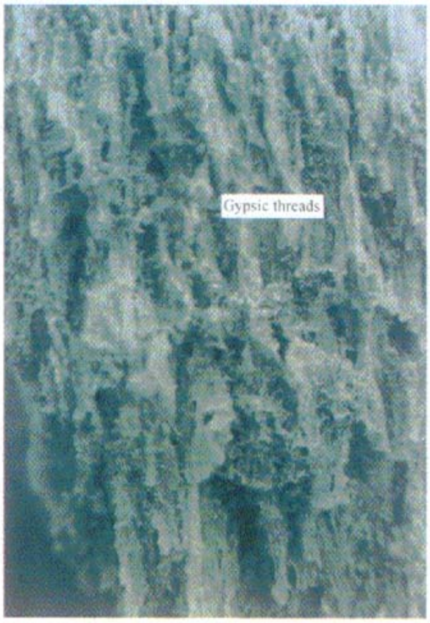

Figure 5. Vertical bands of gypsum fibers formed in Y1 horizon of profile No. Nine (Hand specimen).

DISCUSSION

The genesis and evolution of gypsic horizons in the study area is defined in detail by Toomanian *et al*. (2001). They had accomplished the development of gypsic horizons based on field visibility, degree of complexity of crystal arrangements, and percentage of groundmass captured with crystallin pedofeatures in four stages. 1) Formation of sparsely distributed nonvisible microscopic secondary gypsum crystals in the pores and groundmass of coarse gravelly soils. Excluding the 2Byb horizon, soils in the upper fan remain at this stage. 2) Formation of colonies and nests of gypsum crystals in gypsiric layers of the middle fan. These individual multicrystalline pedofeatures are visible in the field. The soil at this stage does not meet the gypsic horizon criteria yet. 3) Formation

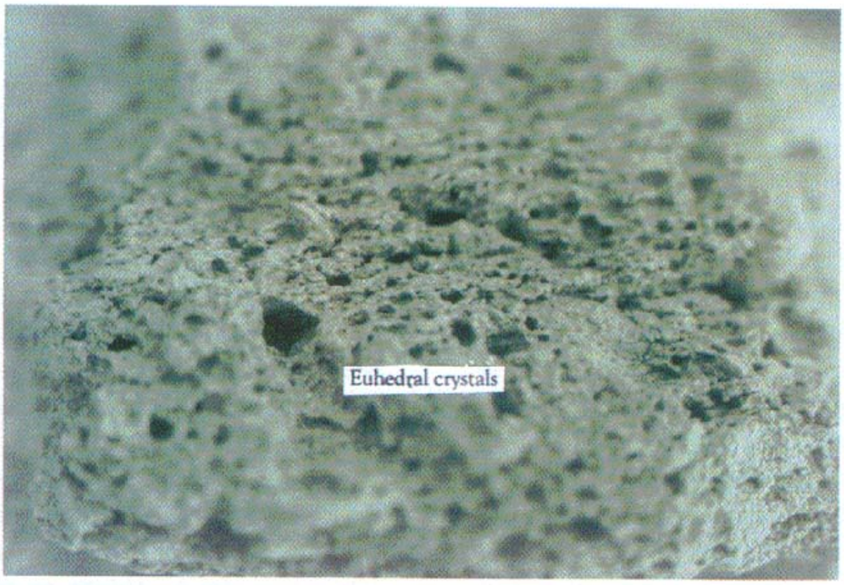

Figure 6. Vesicular soil crust, formed under desert pavement on surface of profile No. Elevent (Hand specimen).

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Table 5. Physical characteristics of representative soil profiles.

Horizones	Depth	Sand %	Silt %	Clay %	%Saturation Percentage	Very Fine Sand %
Prof. 3, Upper fan						
A	0-15	53	30	17	23.05	11.5
C1	15-70	68	21	11	27.66	13.7
2C2	70-100	81.4	13.6	6	30.2	11.1
2Byb	100-140	31.5	44.5	24	44.03	10
Prof. 5, Lower fan						
A	0-15	69.5	17.5	13	18.36	5.2
Bk1	15-38	59.5	16.5	24	32.2	7
Bk2	38-65	63.5	14.5	22	25.7	4.9
By	65-130	57	13	30	42.6	5
Prof. 9, Non-gravelly alluvium						
Ay	0-17	60	30.5	9.5	18.7	12.6
Y1	17-54	64	33.5	2.5	21.4	11.8
By1	54-98	53	41	6	21.9	7
By2	98-1150	52	45.5	2.5	25.1	5.2
Prof. 11, gravelly alluvium						
A1	0-8	55.3	33	11.7	18.7	11.2
Av	8-15	50	35	15	20.5	15.6
Y1	15-73	72	22	6	15.84	11.5
Y2	73-115	65	27	8	20.62	8.1
2Y3	115-150	70	24	6	25.36	7.3
Prof. 14, Piedmont plain						
Ap	0-25	55	20	25	27.45	10.2
Bk1	25-45	43.5	28	28.5	35.16	9.3
Bk2	45-60	35.5	41.5	23	39.6	11.2
2Byb1	60-90	60	31	9	23.9	7
2Yb2	90-117	67	18.5	14.5	19.6	6.3
2Byb3	117-140	71	18	11	21.13	4.1

of the compound gypsic pedofeatures took place at this stage, and the gypsic horizon criteria are met. This stage was found mainly in finer textured soils of the lower fan. 4) Evolution of gypsic horizons reached its maximum and soils met the hypergypsic criteria. Under the circumstances, the super-enriched gypsic soils (Stage four) are divided into three categories: i) a wall of crystalline gypsic vertical fibers (threads) formed in non-gravelly old alluviums (Figure 5); ii) a wall of pendants or bearded gravel with their interconnections formed in gravelly old alluviums; and iii) euhedral gypsum clusters (Figure 8).

Classification of these soils using the latest versions of the two systems is presented in Table 7. We consider FAO and WRB as one system because WRB plays a complementary role to that of FAO and tries to provide scientific depth and background to the revised 1988 legend. As we know, international taxonomic systems are intended to continually “incorporate the latest knowledge related to global soil resources and their interrelationships, to include some of the recent pedological studies and expand the use of the systems from an agricultural base to broader environmental ones”.(FAO. ISSS. ISRIC. 1998).

From an agricultural viewpoint, soil classification is to differentiate soils according to their morphologic and/or genetic characteristics in order to obtain as complete as possible uniform soil. Every attempt aimed at including more detailed soil genetic or mor-

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Table 6. Chemical characteristics of representative profiles.

Horizons	Depth	Organic Matter (%)	CEC C mole/Kg soil	PH Paste	EC dS/m	Gypsum %	Carbonate %
Prof. 3, Upper fan							
A	0-15	0.066	5.7	8	1.1	1.2	55.5
C1	15-70	0.054	2.8	8	1.06	1.1	59.7
2C2	70-100	0.03	2.1	8.15	0.84	1	59.3
2Byb	100-140	0.04	4.75	7.8	2.9	13.2	33.7
Prof. 5, Lower fan							
A	0-15	0.6	8.2	7.85	3.1	1.43	59.5
Bk1	15-38	0.37	8.4	8.15	0.8	1.22	52.76
Bk2	38-65	0.66	5	8	1.1	0.8	56.3
By	65-130	0.64	2.63	7.70	4.7	20.2	37.8
Prof. 9, Non-gravelly alluvium							
Ay	0-17	0.49	5	7.7	2.7	39.3	31
Y1	17-54	0.13	1	7.5	2.6	67.4	19.8
By1	54-98	0.13	3.3	7.75	2.75	50.7	25.6
By2	98-1150	0.29	5.7	7.75	2.7	50	21.8
Prof. 11, Gravelly alluvium							
A1	0-8	0.25	6.1	7.7	3.21	2.6	44.3
Av	8-15	0.16	6.7	7.75	3.15	3.2	42.7
Y1	15-73	0.14	5.1	7.9	4.3	78	10.23
Y2	73-115	0.16	4.9	7.8	4.43	68	18.1
2Y3	115-150	0.32	3.2	7.7	3.7	64.7	24.2
Prof. 14, Piedmont plain							
Ap	0-25	0.34	20	7.9	5.7	1	50
Bk1	25-45	0.25	7.22	7.8	7.34	1.57	41.6
Bk2	45-60	0.38	9.56	7.75	9	1.05	38.9
2Byb1	60-90	0.1	0.4	7.6	6.4	34.33	30.33
2Yb2[a]	90-117	0.1	6.45	7.75	4.4	56.53	30.45
2Byb3	117-140	0.2	5.4	7.8	4.6	14.3	48.9

[a] According to field observation.

phologic properties will lead to the improvement of taxonomic systems. The application of efficient systems helps to show the potential of each polypedon. In order words, each system aims to highlight the use and management aspects of soils. In order designate gypsic horizons and classification there is, therefore, a need for understanding complete pathways of gypsification processes. Also we should consider the amount, thickness, and depth of gypsic horizons in soil profiles, beside other genetic horizons and non-genetic characteristics.

Classification of the soils studied in this study using different versions of the USDA and WRB systems revealed that skeletal and high reaction classes of undeveloped soils of the upper fan could only be considered if the latest version of WRB (1998) were applied.

All versions of soil taxonomy and the latest versions of WRB indicate that calcic and gypsic horizons are formed in soils developed on the lower fan. However, the depth of gypsic horizons and range of their accumulation are incorporated only in the 1998 version of WRB.

In soils developed on alluviums (non-gravelly and gravelly) and piedmont plain, the US system indicated the depth of gypsic horizons but no mention is made of the range of accumulated gypsum and the thickness of the horizons. However, WRB (1998), with its flexible structure, was able to account for both of the properties mentioned as well as the skeletal property of gravelly alluviums.

In dry regions and in processes of carbonate parent materials, gypsic horizons are found together with calcic and with or without salic horizons. The presence of considerable amounts of secondary carbonates in the form of concentrations or pockets in gypsic

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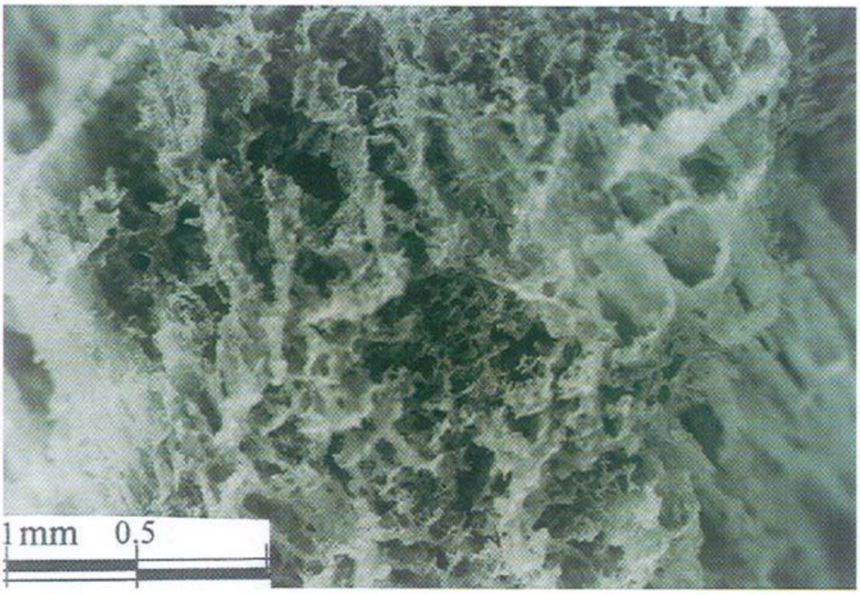

Figure 7. Changing the arrangement of gypsum crystals in 2Y3 horizon of profile No. Eleven (Hand specimen).

horizons confirms Boyadgiev's (1993) view about the formation and the common occurrence of both minerals in the same horizon.

CONCLUSIONS

The most recent version of WRB (1998) seems to be the most appropriate system for the classification of gypsiferous soils. It defines the characteristics of these soils because of the wide possibilities that it offers at the subunit levels. Despite its efforts to overcome the shortcomings at family level (Table 7), the USDA system is not able to compete with WRB in classifying all the soils studied in this research.

Excessive contents of gypsum in the root zone are an important factor, which restrict the growth of plants and curb root distribu-

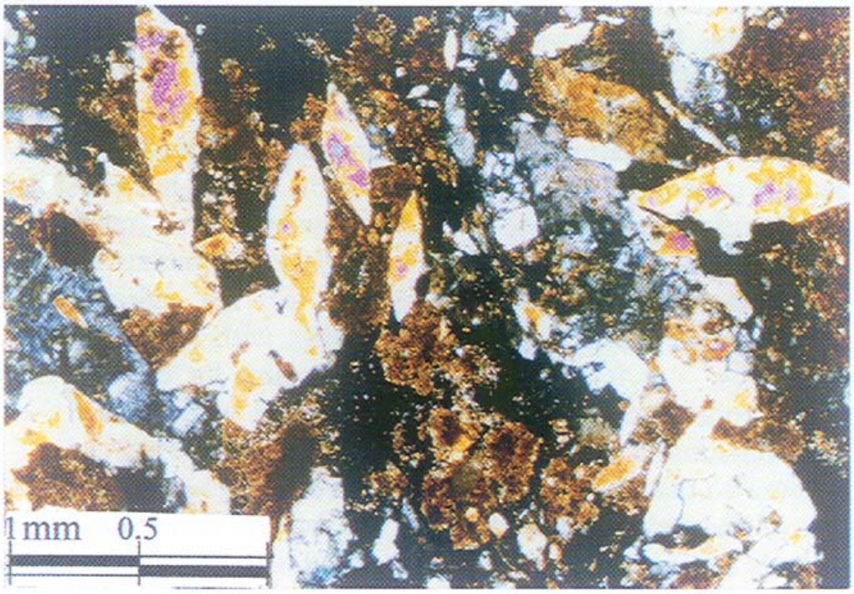

Figure 8. Isolated euhedral lenticular gypsum crystals formed in 2Byb1, 2Yb2 and 2Byb3 horizons of profile No, Fourteen (Cross Polarized).

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Table 7.Classification of soils studied in the WRB (FAO) and Soil Taxonomy systems.

Rep. Profiles	WRB, 1998	Soil Taxonomy 1999	US Family classification
3	Skeli-Calcaric Regosols[a]	Typic Torriorthents	Loamy- skeletal over sandy, mixed (calcareous), thermic, Typic Torriorthents.
5	Calci-Endo Hypogypsic Gypsisols[a]	Typic Calcigypsids Haplc Calcigypsids[b]	Fine loamy, carbonatic, thermic, Typic Calcigypsids.
9	Epi- Cumuli, Hypergypsic Gypsisols[a]	Leptic Haplogypsids Leptic Hypergypsids[b]	Coarse loamy, gypsic, thermic, Leptic Haplogypids.
11	Skeletic- Epi-Cumuli, Hypergypsic Gypsisols[a]	Leptic Haplogypsids Leptic Hypergypsids[b]	Loamy-skeletal, gypsic, thermic, Leptic Haplogypsids.
14	Calci- Haplogypsic Gypsisols [a]	Typic Calcigypsids Haplic Calcigypsids[b]	Coarse loamy over loamy-skeletal, gypsic, thermic, Typic Calcigypsids.

[a] Proposal for WRB, 1998.
[b]Proposal for Soil Taxonomy, 1999.

tion. Therefore, it is advisable to define gypsic horizons according to their effects on soil productivity levels. We suggest the use of 5%, 25% and 40% minimal gypsum quantities in soil taxonomy to define the following.

1. Hypogypsic – containing 5- 25% gypsum, which in the primary percentages does not affect plants growth but, as the amount of gypsum increases, reduces the increase in plant growth.
2. Haplogypsic – containing 25-40% gypsum, substantially reducing plants yield.
3. Hypergypsic - containing >40%, in which the roots of no agricultural plants may grow.

Furthemore, we suggest that: 1) In case of consecutive gypsic horizons, the definition of "5% more than the underlying layer" should be omitted from the criteria of gypsic horizons in each system; and 2) all oriented gypsum crystals, regardless of their size, shape and type of orientation, be recognized as secondary (pedogenic) features.

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بکارگیری روشهای WRB (FAO) و رده بندی آمریکائی در طبقه‌بندی خاکهای گچی شمال غربی اصفهان

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چکیده

خاکهای گچی در مناطق خشک و نیمه خشک ایران دیده می‌شوند. مطالعات کمی در ارتباط با ژنـز و رده‌بنـدی اینگونـه خاکهـا انجـام شـده اسـت. خاکهـای گچـی در اراضـی اسـتان اصـفهان در واحـدهای ژئومرفولوژی متفاوتی تشکیل شده اند. منـشاء گـچ درایـن اراضـی بـه انحـاء مختلـف بـه مـواد مـادری بـر می‌گردد و ژنز خاکهای گچی منطقه نیز توسط پروسه های مختلف گچی شـدن انجـام مـی‌شـود. بحثهـای منشاء گچ و چگونگی تکوین و تکامل خاکهای گچی منطقه توسط نگارنده قبلا ارائه گشته اسـت. هـدف از مطالعه حاضر طبقه‌بندی کردن خاکهای گچی تشکیل شده در واحدهای ژئومرفولوژیک مختلف منطقه شمال غربی شهر اصفهان می‌باشد. در این مطالعه منطقه شمالی حوزه آبریز رودخانه زاینده رود که نماینـده خوبی از کل اراضی خشک استان اصفهان است انتخاب شد و پانزده پروفیل از کـوه جعفرآبـاد تـا دشـت دامنه‌ای وسط حوزه و در واحدهای مختلف ژئومرفیک حفر و مورد مطالعه قرار گرفتند. بـرای طبقـه‌بنـدی کردن خاکها از تاکسونومی خاکهـای امریکـا (۱۹۹۹، ۱۹۹۸، ۱۹۹۶، ۱۹۹۴ و ۱۹۹۰) و روش بـین المللـی منابع خاکهای جهان (۱۹۹۸، ۱۹۹۴، WRB) که ادامـه روش FAO (۱۹۷۴،۱۹۸۸) اسـت اسـتفاده شـد. در طبقه‌بندی این خاکها، نامگذاری افقهای گچی بر اساس میزان گچ آنها، عمق و ضخامت افقهـای گچـی و دیگر خصوصیات این خاکها مورد توجه دقیق قرار گرفته است. سطح اراضی مـورد مطالعـه شـامل سـطوح

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ژئومرفیکی از قبیل آبرفتهای درشت دانه بادبزنی شکل، آبرفتهای درشت دانه قدیمی (کواترنری) ودشت دامنه‌ای بوده است. با توجه به مواد مادری این خاکها و منشاء گچها، خاکهای حاصل عموما" دارای افق گچی و آهکی هستند. روش طبقه‌بندی آمریکائی تاسال ۱۹۹۴ توان تفکیک کامل این خاکها را نداشت ولی توسعه مناسب سال ۱۹۹۴ موجب بهبودی قابل توجهی در این روش برای در نظر گرفتن خصوصیات بیشتری از خاکها شده است. ولی کلیدهای جدید تر از آن(سالهای۱۹۹۸،۱۹۹۶) وروش جامع آن (۱۹۹۹) در کیفیت رده‌بندی کردن اینگونه خاکها بهبودی ایجاد نکرده اند. سیستمهای فائو (۱۹۸۸ ، ۱۹۷۴) و جانشین آن WRB (۱۹۹۸ ، ۱۹۹۴) متوالیا روشهای خود را در طبقه بندی کردن خاکها بهبود بخشیده اند. سیستم WRB (۱۹۹۸) امکانات بیشتری برای بکارگیری مشخصات کاملتری از خاکها را پیش آورده است. این سیستم خاکهای مورد مطالعه را با کارآئی بالاتری طبقه‌بندی نموده است.

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