Micromorphology of Gypsum Crystals in Southern Iranian Soils under Different Moisture Regimes

S. S. Hashemi¹, M. Baghernejad¹*, and H. Khademi²

ABSTRACT

Gypsiferous soils occur in xeric, ustic, and aridic moisture regimes. Environmental conditions affect the mode of gypsum formation. Gypsiferous soils in Fars Province, southern Iran, are found in piedmont plains, flood plains, and alluvial plains. The objective of this work was to investigate the micromorphology of gypsum crystals formed under different soil moisture regimes. The results indicate that lenticular crystals of gypsum have been frequently found in more developed soils, whereas under aridic soil moisture regime such form is rare and they are frequently found in the subsurface horizons. Columnar, prismatic, and blade forms of gypsum are found in areas with aridic moisture regime, where soils are highly leached. Formation of gypsum pendant under gravels is dominant in piedmont plains with limited moisture in the profile. Complex gypsum crystals were found in low rainfall regions. It seems that surface runoff, as well as hydrological system of the region, transfers gypsum from geological sediments in higher elevations to coarse-textured soils of flood plains. In landscapes with xeric and xericaridic soil moisture regimes, lenticular, euhedral and subhedral crystals of gypsum were abundant. The results of this study indicate that, in addition to soil moisture, texture and landscape position play a significant role in the formation of pedogenic gypsum. Well crystallized gypsum was observed in soils with silt loam, sandy loam, and loamy texture. Observation of gypsic horizons suggests that the accumulation of gypsum took place under per descendum process in the soils studied.

Keywords: Gypsiferous soil, Gypsum crystal forms, SEM analysis, Soils of Iran

INTRODUCTION

High amounts of gypsum are frequently found in soils of arid and semi-arid environments. Formation of gypsum in the soil is mostly associated with gypsiferous rocks and sediments of different origins, where leaching is insufficient to remove gypsum from the soil profile. Gypsum can also form on non-gypsiferous rocks, where CaSO₄ enters the soil by atmospheric deposition. Soils having undergone leaching processes reveal unusual increases of SO₄²⁻ at 40-50cm depth. This may be an indicator of more recent SO₄²⁻ input due to atmospheric deposition since the beginning of industrialization. It is supposed that gypsum is formed by the reaction of atmogenic sulfuric acid with different Ca sources in soils (Dultz and Kühn, 2005).

Worldwide, gypsiferous soils cover about 186 million ha, representing 1.5% of the world soil cover (FAO, 1993). Eswaran and Zi-Tong (1991) have estimated 207 million ha of soils with gypsic or petrogypsic horizons. Gypsum is the most common sulfate mineral in soils of arid and semi-arid areas (Doner and Warren, 1989), and is highly correlated with soil moisture regime. Although gypsum is found over a wide range of temperatures (Waston, 1988; FAO,

¹Department of Soil Science, College of Agriculture, Shiraz University, Shiraz, Islamic Republic Iran.

^{*}Corresponding author, e-mail: hashemy558@gmail.com

² Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan, Islamic Republic of Iran.

1990), most gypsic soils are formed under xeric, ustic, and aridic moisture regimes (FAO, 1990).

Gypsum can accumulate in soils through the following four processes: (1) *In situ* weathering of existing parent material (Carter and Inskeep, 1988; Taimeh, 1992), (2) Sulfate-enriched precipitation from an oceanic source (Podwojewski and Arnold, 1994), (3) Aeolian or fluvial input of gypsum or sulfate-rich sediment (Van Hoesen, 2000; Buck and Van Hoesen, 2002) and (4) *In situ* oxidation of sulfide minerals (Podwojewski and Arnold, 1994).

Shape, size and position of gypsum crystals within the soil matrix have been used to determine their source and mode of formation (Buck and Van Hoesen, 2002). Pedogenic gypsum crystals can occur as individuals and as masses within the soil groundmass and pores (Eswaran and Zi-Tong, 1991). Previous studies have found that gypsum accumulates in the soil through time in a similar manner as calcium carbonate (Van Hoesen, 2000; Buck and Van Hoesen, 2002). Gypsum first forms thin filaments, then, small nodules. and. eventually, massive indurated horizons. Unlike calcium carbonate, however, gypsum also forms small snowballs in early pedogenesis (Van Hoesen, 2000; Buck and Van Hoesen, 2002). Pedogenic gypsum in gravelly soils mostly occurs as pendants bellow pebbles (Waston, 1985). In nongravelly materials, pedogenic gypsum is observed as whitish, powdery or crystalline, soft masses, or diffused in the soil matrix. Rainfall and topographic setting strongly influence the quantity and the location of gypsum in the soil (Waston, 1985).

Diagenetic gypsum has been characterized by subhedral to anhedral crystals that completely filled voids (Carter and Inskeep, 1988). Pedogenic gypsum in soils exhibits a variety of crystal forms that may represent different environments of formation.

Lenticular disk, tabular pseudo-hexagonal, tabular hexagonal, microcrystalline, prismatic lath and fibrous gypsum crystals have been observed (Amit and Yaalon, 1996; Jafarzadeh and Burnham, 1992). Such diversity results from changes in microenvironmental condition in soils with time (Amit and Yaalon, 1996).

Buck and Van Hoesen (2002) describe a new morphology of pedogenic gypsum in soils of southern New Mexico as they call it snowball morphology. They noted that snowballs are composed of numerous small, euhedral gypsum crystals of different habits including tabular, pseudo-hexagonal, hexagonal, and lath.

Various methods have been used to study the micromorphology of gypsum crystals formed in soils, in the field as well as in the laboratory. Owliaie *et al.* (2006), Buck and Van Hoesen (2002), and Jafarzadeh and Burnham (1992) used scanning electron microscopy (SEM) analysis to study size and shape of crystals formed in soils on gypsiferous material. They reported different forms of gypsum crystals including pseudohexagonal, needle-like prismatic, lenticular, and columnar.

The objective of this study was to investigate the diversity of gypsum crystals in arid and semi-arid regions of southern Iran under different moisture regimes using analytical SEM analyses.

MATERIALS AND METHODS

Geomorphic Settings

The study sites are located in an area of about 132,000 km² in Fars province, southern Iran (Figure 1). The area has different soil moisture and temperature regimes including xeric, ustic and aridic soil moisture regimes and mesic, thermic and hyperthermic soil temperature regimes (Banaei, 1998). Precipitation ranges from 200 mm in the arid areas in the north, the south, and the southeast to 800 mm in the mountainous region of the northwestern area. However, a large part of the study area receives 200-300 mm, of rainfall. Potential evaporation ranges from 1100 mm in the (Sarvestan Plain) east with mesic



Figure 1. Soil moisture regimes in the area studied.

temperature regime to 1900 mm in the arid area with hyperthermic temperature regime.

The overall climate of the province is arid and semi-arid. The natural vegetation of Fars Province consist of: *Rose sulfurea, Malva* sylvestris, Agropyrum ramousum, Alhagi camelorum, Glycryrrhiza glabra, Cartamus oxicanthus, and Brasica napus.

The study area is a part of the post-Tethyan sea environment where sediments are rich in soluble salts and gypsum in most of the southern and southeastern parts (Zahedi, 1976). Results of sulfur isotope geochemistry of gypsiferous aridisols of central Iran strongly support the hypothesis that such areas were cut off from the Tethys Seaway at the end of Mesozoic era and, as a result, the lower Cretaceous sulfate has controlled the sulfur geochemistry of the younger sediments (Khademi, 1997).

The main geological units containing gypsum include Cambrian (Hormoz formation), Mid-Upper Cretaceous (Sachun formation), and Tertiary (Gachsaran and Razak formation) rocks. Hormoz formation consists mainly of salt, anhydrite, crushed dolomites, basic igneous rocks and red siltstones. Suchun formation consists of cherts marls, marlstones and silt, off-white limestones. These are followed by gypsum and dolomites that are overlain by off-white and brown-ochre marlstones and dolomites. The upper part is composed of massive gypsum, marls and ribs of dolomites. Gachsaran formation is one of the evaporitic kinds of sediments, showing thick-bedded alternating layers of anhydrite and marl (James and Wynd, 1965).

In the north and northeastern parts, aridic moisture regime is dominant. The temperature regime varies from mesic and thermic in the north and northeast, hyperthermic in the southern and the ustic and ustic-aridic prevail in the western and south-central parts. Xeric moisture regimes prevail in northwest and temperature regimes vary from mesic in the higher elevations to thermic toward the center of province (Figure 1).

Most gypsum-enriched soils in Fars province occur in alluvial plains, flood plains, and piedmont plains and are rarely found in younger lowlands.

Field Sampling and Laboratory Methods

Based on the soil survey and remote sensing reports (Hashemi *et al.*, 2007), there are seven major soil series in the study area, out of which only four are gypsiferous. Thirty five pedons were initially studied and then reduced to 12 pedons for detailed studies. Most pedons are located in flood plains and piedmont plains, in which different soil horizons were sampled for macro- and micromorphological studies. Pedons were described and classified according to the Soil Survey Manual (Soil Survey Staff, 1999) and Keys to Soil Taxonomy (Soil Survey Staff, 2006). The locations of the 12 pedons studied are shown in Figure 2.

Due to the high content of gypsum, the laboratory analyses of gypsiferous soil present some special problems. Particle size analysis was performed on each horizon in the 12 sampled soil profiles using the hydrometer method described by Gee and (1986). Organic Bauder carbon was measured by wet oxidation with chromic acid and back titration with ferrous ammonium sulfate (Nelson, 1982). Calcium carbonate equivalent (CCE) was measured by acid neutralization (Salinity Laboratory Staff, 1954).

Soil pH was measured with a glass electrode in a saturated paste (mixture of water and soil). Electrical conductivity (EC) was measured in the saturation extract (Salinity Laboratory Staff, 1954). Cation exchange capacity (CEC)



Figure 2. Climate map of the area studied showing the location of the profiles.

was determined using sodium acetate at a pH of 8.2 (Chapman, 1965).

Gypsum was quantified with the revised acetone method (Soil Conservation Service, 1972) and corrected for hydration water (Nelson *et al.*, 1978). This procedure involved changing soil/water ratio from 1/5 to 1/500, increasing the first shaking period from 0.5 to 24h and increasing the sedimentation period from 0.5 to 2h after adding acetone (Toomanian *et al.*, 2001).

Electron microscopy: Soil aggregates separated from 27 dried samples of By and Bym horizons from 12 pedons were studied by scanning electron microscope (SEM). Samples were mounted on Al stubs using double-sided tape and carbon paste, then, coated with Au in a sputter coater (Cambridge, SC 7640) and examined using LEO SEM. Identification of the chemical composition of minerals was carried out using EDX analysis. SEM and EDX analyses were performed to characterize the micromorphology of gypsum crystals in the soil and to determine if the gypsum was formed during pedogenesis.

RESULTS

General soil properties: Selected properties of pedons including their parent material, location, precipitation, evaporation, elevation, and classification are presented in Table 1 and morphological and physicochemical properties are depicted in Table 2.

Since the parent material of the study area contains gypsum, the soils are also highly gypsiferous. Alluvial soils (Entisols) and moderately developed soils with gypsic and cambic horizons (Inceptisols and Aridisols), comprise about 95% of soils in the area. The soils rich in gypsum cover a large area in the flood and piedmont plains. These soils are in aridic and ustic moisture regimes in the southern, northwestern, and eastern parts with precipitation less than 300 mm and extremely high evapo-transpiration. They also occur in the vicinity of saline and alkaline lakes and are classified as Typic Haplogypsids, Typic Calcigypsids, Gypsic Haplustepts and Gypsic

Haplosalids. Gypsiferous and saline soils are mainly bare or under pasture. Those with very deep water table can partly be used for crop production.

As shown in Table 2, most of the soils have a texture of silt loam, clay loam, sandy loam, or sand. Textural analysis ternary diagrams of the 12 profiles indicate that silt loam textural class is dominant for soils textures. All soils are highly gypsic throughout containing, on the average, more than 35% CaSO₄·2H₂O₁ increasing with depth. These fine (0.5-1mm) pedogenic gypsum crystals showed powdery spheres (snowball morphology), nodules and thin filaments.

With the exception of pedon number 9, all other soils were non-saline (EC<4 dS/m). It is interesting to note that even soils subjected to leaching processes show accumulation of SO_4^{2-} at 50 cm depth.

Morphology and composition of withish efflorescence: In this study, SEM analysis of soil gypsum crystals from 27 small soil aggregate samples indicates a pedogenic origin with no evidence of re-crystallizations, or detrital transport.

Element detection by EDX indicates that all of the B horizons of the pedons contain gypsum, the most common calcium sulfate mineral in soils. The EDX spectra recorded of the whole area indicates a clear enrichment of Ca and S. Al and Si, which are inherited by different silicates, especially feldspar, mica and clay minerals quartz (contains no Al), fade in the spectra. The presence of significant Au and Pd reflects the type of sputter coating used on the sample (Figure 3d, 4d, f; 6d; 7c). Gypsum crystals occur in different shapes and sizes such as euhedral lenticular, rosette-like, granular, rod-like, subhedral, hexagonal, columnar, tabular, prismatic, etc.

Habitus of Gypsum Crystals in Relation with Moisture Regimes

1. Xerix moisture regime: Abtahi (1977) suggests the geosynclinals of gypsum and anhydrite formation of the Mesozoic and Tertiary era, such as Sachun and Tarbur.

Lenticular (Figure 3a1, a2, b) and lenticularcolumnar crystals (Figure 3c) of gypsum were found in pedons 1, 2, 3. These forms occur where disk shaped lenticular crystals were developed in the soil matrices, in addition to the prismatic crystals observed. They also precipitate as 50-1000 µm sized individual crystals in the soil matrix. With increasing the soil depth the diversity of crystal forms were increased. Down in the lowest part of pedon 2 lenticular, rod like and subhedral forms of gypsum were clustered. While in its Byss1 horizon, only lenticular crystals and in the surface horizon rod like crystals were abundant. Per descendum is a dominant process and thus drying after rain is slow, this may result in greater length/width ratios and looser crystal packing like lenticular crystals and rod like crystals (Figure 3g, h, i). The relation between gypsum crystal forms and soil moisture regime is shown in Table 3.

Lenticular crystals are lozenge, half moon shaped in cross-section and resemble convex lens (Figure 3i). These are spar sized ranging between 50 and 1400 μ m. Disk shaped crystals developed from 111 crystal faces and even so sometimes from 103 crystal faces.

2. Ustic moisture regime: Ustic regime is similar to xeric regime regarding the rainfall but its temperature is higher than 22°C. Pedons 5 and 10 are classified as a hypergypsic Aridisols (Figure 4a, b). Combshape gypsum crystals of Bym horizon indicate that evaporation causes the water from underneath of the gravels to recrystallize as vertically arranged columnar, cubic, and needle form apex crystals (Figure 4a, b). Gypsum leaching through coarsetextured soils leads to an increased accumulation of gypsum crystals in deeper parts of the profiles studied. Allabastrin gypsum crystals with white color, soft and smooth like flour could be seen in pedon 5 (Figure 4c). These gypsum crystals show frequent high super saturation and evaporation in the upper parts of the soil profile.

[DOR: 20.1001.1.16807073.2011.13.2.3.8]

_
_
ω.
3
ai
63
$\tilde{\mathbf{\omega}}$
—
<u> </u>
-
0
0
m.
È.
0
0
∞
Ú,
—
<u> </u>
$\overline{\mathbf{O}}$
ō
<u> </u>
<u>.</u>
ล
N.
$\overline{}$
ž
Ц
<u> </u>

	Special features		Fine root,	Few gypsum mycelium	Common gypsum mycelium	Many gypsum mycelium		Many Fine root, cracking	Few gypsum (snowball)	Gelling, Few gypsum (snowball)	Few gypsum mycelium	Full gelling		Few gypsum powdery pocket	common gypsum powdery pocket	Many gypsum powdery pocket	Many gypsum powdery pocket	Many gypsum granular		Few gypsum granular	Many gypsum crystal	Few gypsum crystal		Few gypsum mycelium	Many gypsum crystal	Many gypsum crystal	Few gypsum crystal		Fine root	Very few gypsum on granular	few gypsum, fossil of carbonate	few gypsum, fossil of carbonate
	MO		0.56	0.1	0.1	0.43		0.04	0.4	0.5	0.6	0.7		1	0.2	0.6	0.1	0.3		0.6	0.07	0.2		0.4	0.5	0.2	0.3		0.27	0.2	0.3	0.3
	Gypsum (%)		0.5	6.7	5.7	36.1		0.3	13.4	9.4	6.4	0.3		80.4	80.4	81.7	79.1	72.4			44.2	16.1		14.7	31	40.3	64		3.5	3.6	7.0	3.5
	CCE		27	27	26.5	31		19	25	37	39	39		6	12	10	15	14		49	28	27		51	49	48	27		59	57	49	46
	Na ⁺		195.2	324	348	341		126	344	71	61	58		2.7	52	47.5	60	60		3.0	3.0	145		51	32.5	191	15		30	99	482	66
	- K ⁺ (meq/L)	nbagh)	0.08	0.08	0.08	0.1	oagh)	0.2	0.1	0.1	0.06	0.03	estan)	0.05	0.07	0.08	0.08	0.07	(mo	0.3	0.22	0.2	yr)	0.2	0.2	1.25	1.25	rab)	0.3	2.1	1.5	1.2
	Ca ²⁻	Gharel	36	36	39	39	Gharehl	21	38	L	19	21	s (Sarve	24	23	24	23	29	ts (Jahr	26	64	27	ts (Gh	21	28	29	24	ts (Da	28	25	24	23
	CEC (Cm olc kg ⁻¹)	cerepts (14.6	15.3	17.4	17.4	xerets ((17.4	14.6	17	19	20	oxerepts	7.3	7.3	8.3	9.4	13.2	loustep	41	37	33	lciustep	13	9.5	23	25	lciustep	24	24	24	25
	EC dsSm ⁻¹	sic Haploy	1.9	2.3	2.8	2.8	uic Haplo	1.1	2.7	0.8	5.2	0.5	psic Hapl	0.2	0.4	0.4	0.5	0.5	ypsic Hap	0.2	0.2	0.2	Gypsic Ca	0.5	0.3	1.7	0.3	Jypsic Ca	3.0	1.4	0.6	0.6
÷.	SO4 ²⁻ (meq/ L)	1.Gyp	5	25	31	36	2.Aq	39	46	17	21	26	3. Gy	26	31	30	28	30	4. G	20	26	30	5.0	24	18	32	20	6. (12	9	13	ю
tudie	Hq		7.6	7.9	7.9	8.1		7.7	8.2	8.2	8.1	7.9		7.7	8.1	8.1	8.0	7.9		7.5	7.5	8.4	1	7.9	7.9	8.1	7.9	1	7.9	8.3	8.4	8.2
edons s	Clay		40.6	55.4	29.3	42.2		51.3	63.32	64.04	67.32	73.32		3.88	1.88	1.88	1.88	.54		13.32	7.32	46.6		12.6	12.6	16.6	38.76		1.32	1.32	1.32	1.32
f the p	Silt %		12	24	50	43.9		43.5	26.44	30.72	19.44	15.44		38	38	48	48	51.34		42	24	24		32.72	42.72	50.72	44.16		55.28	71.28	59.28	89.28
erties o	Sand		47.4	20.6	20.7	13.8		5.5	26.44	5.24	13.24	11.24		58.12	60.12	50.12	50.12	48.12		44.68	68.68	29.4		54.68	44.88	32.68	17.08		43.4	27.4	39.4	9.4
mical prop	Color (moist)		10YR4/4	5YR4/4	5YR4/6	5YR3/4		7.5YR4/2	5YR3/4	5YR4/4	5YR4/4	5YR5/2		5YR2/7	5YR3/7	5YR3/6	5YR3/6	5YR6/6		5YR5/3	5YR3/4	10YR3/4		7.5YR6/2	7.5YR5/2	5YR6/3	7.5YR5/4		10YR6/4	7.5YR5.5/4	7.5YR6/4	7.5YR6/4
hysico-che	Depth (cm)		0-30	30-70	70-110	110-150		0-15	15-35	35-85	85-103	>103		0-16	16-34	34-77	77-105	105-140		0-15	15-53	53-80		0-11	11-44	44-60	60-110		0-18	18-51	51-86	>86
Table 2. F	Horizon		A	Bky1	Bky2	Bky3		A	Byss1	Byss2	Cyg1	Cg2		Ay	Byl	By2	By3	Cy		A	By1	By2		Ay	Bky1	Bky2	Cy		А	Bw	Bky1	Ck

JAST

															ß								ocket								
	Special features		No visible feature	Few gypsum crystal	Many gypsum crystal	Many gypsum crystal	Very little gypsum powdery Very little gypsum powdery		Few fine root, cracking	Few gypsum (snowball)	Many gypsum (snowball)		Full salt crystal	Many gypsum crystal (lath)	Many gypsum crystal (lath),gellir	Gelling, no gypsum		Few gypsum mycelium	Many gypsum crystal	Layer of gypsic		Few gypsum mycelium	Gypsum crystal, lime powdery pc	Gypsum crystal with gravel	Full gypsum crystal with gravel		No visible feature	lime powdery pocket	lime powdery pocket	Coarse pendant, many gravel	Coarse pendant, many gravel
	MO		.05	0.6	0.5	0./8	0.45 0.38		1.8	1.28	0.45		0.35	0.45	0.28	0.21		0.2	0.1	0.1		0.86	0.17	0.17	0.17		0.1	0.12	0.2	0.01	0.02
	Gypsum (%)		0.6	8.7	0.5	0 ;	12.7 32		0.9	6.4	9.7		2.3	21.4	9.7	2.7		0.5	27	68		4	8	15	19		0.5	1.5	3.6	63	70
	CCE		34	29	33	32	23 15		26	31	25		35	24	15	21		55	46	21		60	65	69	70		22	55	43	20	21
	Na^+		1521	1225	1151	1040	379 50		93.7	155.5	159		4764.5	3952.8	4119.1	3109.5		30.1	66.3	483		2.7	2.4	2.3	2.7		235	184	85	73	165
	K ⁺ (meq/L)		2.0	0.88	0.7	0.25 0.2	0.2 0.18	0	0.2	0.2	0.2		3.5	2.5	2.8	2.8		0.1	0.12	0.29	u)	0.1	0.1	0.02	0.02	(1	2.8	4.8	2.1	2.1	2.9
	Ca ²⁺	ls (Darab)	42	35	34	33	30.2 27	ert (Nyriz	36	99	76	ls (Nyriz)	67.2	100.6	88	91	pts (Ghyr)	29	27	28	s (Kazero	7.9	13	25	27	ls (Abadel	54	34	28	28	56
	CEC (Cmol _c kg ⁻¹)	Haplogypsic	9.4	8.3	6.3	10.4	12.5 10.4	ic Gypsitorr	17.4	18	18.1	ic Aquisalic	14.6	14.6	15.3	13.2	sic calciuste	25.9	8.3	4.5	c Haplustept	12	14	6	8	petrogypsic	15	12	8.3	S	5.5
lied.	EC dsm ⁻¹	7.Ustic	5.0	2.5	2.6	2.2	2.0 1.6	8.Chrom	0.5	1.5	1.5	9. Gyps	38.0	38.0	38.0	8.0	10. Gyp:	0.5	2.0	2.0	11. Gypsid	0.7	0.5	0.6	0.4	12. Typic	0.5	1.5	1.5	0.7	0.7
ons stue	SO4 ²⁻ (meq/ L)		30	21	25	32	36 49		5	16	23		27	37	40	35		4	22	35		4	15	25	32		ю	L	5	31	36
he ped	Hq		8.2	8.4	8.5	8.4 6.0	8.5 8.5		7.6	T.T	7.4		7.8	8.1	7.9	8.0		7.5	7.6	7.6		7.7	7.9	8.1	7.9		7.8	7.8	7.6	7.9	7.9
ies of t	Clay		2.04	2.04	2.04	2.04	2.04 0.04		31.28	50.5	56.0		10.76	6.76	4.76	4.0		12.6	10.76	16.6		17.4	22.4	22.4	11.4		10.76	1.88	1.88	3.88	13.88
propert	Silt (%)		67.28	43.28	71.28	19.28	51.28 51.28		60	42	43.28		37.28	73.28	59.28	58.2		32.72	37.28	50.72		45.2	44.2	40.2	20.2		37.28	48	48	36	20
chemical	Sand		30.68	54.68	26.68	18.68	46.68 48.68		8.72	7.5	0.72		51.96	19.96	35.96	37.8		54.68	51.96	32.68		37.4	33.4	41.4	68.4		51.96	50.12	50.12	60.12	66.12
. Physico-c	Color (moist)		10YR4/3	10YR4/4	10YR5/3	10YK5/3	10YR5/4 10YR5/3		10YR6/4	10YR6/4	10YR4/4		5YR6/2	5Y5/2	10YR4/4	10YR4/3		10YR7/2	10YR7/2	10YR6/4		10YR4/3	7.5YR4/4	10YR4/4	10YR4/4		10YR6/4		10YR7/2	10YR6/4	10YR7/4
continued	Depth (cm)		0-15	15-30	30-52	52-85	85-104 >104		0-20	20-75	>75		0-15	15-55	55-80	>80		0-15	15-60	60-110		0-30	30-50	50-80	80-110		0-19	19-36	36-52	52-95	95-125
Table2 o	Horizon		V	By1	Bw	By2	By3 Cy		Ap	Byss	Cy		Azg	Byzg1	Byzg2	Bg		A	Bky	$_{\rm Bym}$		A	Bky	Byl	By2		AP	BK1	BK2	Byml	Bym2



Figure 3. Back scattered electron images of the crystal habits of pedogenic gypsum in xeric moisture regimes together with EDX spectra of gypsum crystal, (a1, a2). Cluster of gypsum crystal, By1, By2 horizon of pedon 1 (b). Lenticular crystals from the By horizon, pedon 2 (c). Lenticular to columnar gypsum crystals, By1 horizon, pedon 3 (d). EDX spectra of lenticular crystal (a1 image) indicating a relative abundance of Ca and S (g). Lenticular gypsum crystals of the By1 horizon of pedon 3 (h). Lenticular gypsum crystal of a Byss horizon with a large thickness, pedon 2 (i). Subhedral to anhedral forms of gypsum, Cy horizon of pedon3.

In areas with ustic moisture regimes, evaporation occurring soon after sufficient rainfalls, therefore, rapid soil drying allows a short period for crystal growth and favors smaller length/width ratios and tight packing of more equant crystals. This type of gypsum crystallizes in a displaced way; either displacing the host soil material or forming shattered fragments inside the cracks of shattered gravel.

3. Aridic-ustic moisture regime: Euhedrals to sub-hedrals are the most common crystals observed in the aridic-ustic transitional regime (pedons 4, 6, 7). These crystals grow in-situ and do not undergo transportation or relocation. They are randomly oriented throughout the soil profile with transportation and re-crystallization rings associated with re-hydration of anhydrite or simple re-crystallization from alternating wetting and drying cycles. There is no evidence of corrosion or comb-shaped edges at the soil boundary, but suggest dissolution occurred on the irregular surfaces. There are solution pits on the surface of the crystal (Figure 5 a_1 , a_2 , b). Acicular to blade form of gypsum crystal of Cy horizon (Figure 5c) and Needle form with blade apex gypsum crystal of Ay horizon were observed in this regime. Pseudo-hexagonal tabular lath

gypsum crystals are of microspar size, (ranging from 20 to 50µm); the six sided lath shaped crystals elongate to 101 and 111 where one axis of the hexagon is longer than the other (Figure 5h, i). This habit is exclusive to ustic moisture regime since, evaporation occurs soon after the rainfall, and thus small and thin crystals are produced. In pedon 4 with ustic moisture regime, crystals of blade, columnar, needle forms are dominant, while in pedon 6 and 7 aridicustic moisture with regime, subhedral, subhedral-hexagonal and associated lenticular shapes were observed (Figure 5h, i). This regime resembles the pervious regimes i.e. xeric and ustic regimes, and has per descendum mode. Gypsum crystal forms in relation to the respective soil horizon in this regime are shown in Table 3.

4. Xeric- Aridic moisture regime: Globular and tabular crystals are the most common shapes of gypsum crystals observed in the xeric-aridic transitional regime. Clusters of these crystals (Figure 6a, b, e) are found in soils with xeric and aridic moisture regimes. In these regions, as the soil depth increases, the presence of longer and thicker crystals of gypsum were found to be abundant. But, such a trend was not observed in pedon 9

Soil moisture	Symbol of horizon, Number of	Gyneum crystals forms							
regime	pedon	Gypsun Gystais forms							
	By1; pedon 1								
	By1; pedon 3	Lenticular (aboundant)							
Xeric	Byss1, pedon 2								
	By2; pedon 1	Lanticular columnar Rod like							
	Byss2; pedon2	Lenucular-columnal, Rou like							
	Cy ; pedon 3	Cluster of Lenticular (superfluity)							
Ustic	By; pedon 5	Cubic by needle form							
	By; pedon 11	Lenticular (rarely)							
	Bym, By; pedon 10	Comb-structure, Needle form							
	Ay; pedon 4	Needle form							
· · · · · · · ·	By; pedon 4	blade form							
Aridic-Ustic	Byz1; prdon 7	Cluster of lenticular,							
	By; pedon 6	Pseudo-hexagonal to lenticular							
	Byz2; prdon 7	Tabular							
	Cy; pedon 4	Large blade form, Acicular							
	Byss; pedon 8	Globular							
Xeric-Aridic	Byg1; pedon 9	Tabular							
	Byg2; pedon 9	Tabular-lenticular							
	Byk ; pedon 12	Fibrous, Acicular							
Aridic	Boundary of Bym1: pedon 12	Sheet of Rhombohedral,							
	Boundary of Bylli1, pedoli 12	Blade form and fibrous							
	Bym2; pedon 12	Prismatic, Interlocked plates							

Table 3. Morphology of gypsum crystals in relation with soil moisture regime.

since this profile occurs near a lake. However, upward movement of water with capillary rise and subsequent evaporation has been suggested as the mechanism of generation and accumulation of gypsum in the soil surface around lakes. Contrary to the previous regimes, in areas close to the lake, especially pedon 9, gypsum crystals are located below the surface crust and are formed by the per ascendum mode in the presence of high amounts of sodium Macroscopically chloride. spear like morphology was observed at this condition. 5. Aridic moisture regime: Pedon 12, occurring in the piedmont plain with little progress in soil development, shows gypsum pedofeatures with speckled and pendants. Gypsum crystals increase in the groundmass of lower horizons (depth 50 to 125Cm). Gypsum enters the old gravelly alluviums through run off; evaporation causes this water from underneath the gravels to recrystalize as vertically arranged prismatic, columnar, blade form, interlocked plates and fibrous crystals (Figure 7). The gypsic prisms are euhedral and they crystallize

282

perpendicular to the plane of fracture, shattered fragments or gravel surfaces (Figure 7b). As the process continues, neoformation of such crystals was occurred. The prominent cleavage of gypsum is accentuated by dissolution observed in the Bym horizon, pedon 12 (Figure 7f). This process forms gypsic fibers and eventually centimetric threads underneath gravels. These bearded gravels are called gypsic pendants.

Considering the soil data and taxonomic proposals (Eswaran and Zi-Tong, 1991) the soil could be classified as a hyper gypsic (profile 10 and 12). Under this condition, crystals grow happens in two directions whereby the third one is quite thin, resulting in platy crystals. However, most of the gypsum crystals such as prismatic, tabular lath, fibrous and blade have moderate length so that their size is more than 50 μ m. Based on this observations concluded that the aridic regime has the *per descendum* mode. Since in the area with mesic soil moisture temperature regime, soil drying is slow the crystals growth is moderate and is long in



Figure 4. Back scattered electron images of the crystal habits of pedogenic gypsum in ustic moisture regimes together with EDX spectra of gypsum crystal (a). Cubic with needle form apex of gypsum crystal of Bym horizon of pedon 10 (b). Comb-shape gypsum crystal of Bym horizon of pedon 10 (c). Allabastrin gypsum crystal of the By horizon of pedon 5 (d). EDX spectra of gypsum crystal of Bym horizon of pedon 10 (e). Irregular surface of crystal affected by dissolution, By horizon of pedon 11 (f). EDX spectra of gypsum crystal of By horizon of pedon 11 (e).

length. Because pedons 10 and 12 don't have sufficient time (moderate developed soil) and have coarse texture; however, we couldn't observed lenticular, powdery and smooth crystals in aridic regime. A prismatic pseudo-hexagonal crystal can occur in gypsum crystals with strongly developed 100 and 110 faces, as suggested by Jafarzadeh and Burnham (1992). These investigators showed that in the per ascendum experiments larger lenticular crystals sometimes appear in corporation of matrix grains, especially with silt loam texture. Waston (1988) proved that massive crusts or subsurface petrogypsic horizons were characterized by large lenticular crystals whose formation has presumably taken a very long time. Our results also support this view. Due to the existence of gravel in this pedon with silt loam texture and rapid leaching we couldn't observe lenticular crystals.

DISCUSSION

Gypsum crystals in soils differ in shape and size. Distribution of these morphological forms has a relative

relationship with soil depth and soil moisture regimes. This study shows gypsum crystals diversity in By and Bym horizons. The length and thickness of crystals varied in the different soil moisture regimes. We observed that gypsum crystals within developed soils and inmature soils are different. The transition from lenticular to allabastrine gypsum accumulation is a consequence of crossing an intrinsic threshold in soil development. In addition, gypsum crystal morphology is different in surface and subsurface horizons; as a result we concluded that subsurface horizons have more diversity of gypsum crystals than in surface horizons. In all pedons, together with soil depth the number of longer crystals of gypsum observes increased, for example in Ay horizon of pedon 4, needle form is dominant, while in By of pedon 4 has found blade form of gypsum crystal and in the Cy horizon of pedon 4 large blade form crystals have observed (Table 3). The results indicate that the formation of lenticular gypsum crystals needs a long time and is frequent in more developed soils (with more rainfall and low evaporation); thus they are found in aridic moisture regimes rarely. The conditions needed to form lenticular crystals are high ionic impurities and deposition in a



Figure 5. Back scattered electron images of the crystal habits of pedogenic gypsum observed in aridicustic moisture regimes (a1). Columnar gypsum crystal of the By horizon of pedon 4 (a2). Large blade form of gypsum crystal of the Cy horizon, pedon 4 (b). Blade form of gypsum crystal of the By horizon of pedon 4 (c). Acicular-blade form of gypsum crystal of Cy horizon, pedon 6, (h). Pseudo-hexagonal to lenticular gypsum crystals of the By horizon, pedon 6 (i). Tabular gypsum crystals of Byz2 horizon, pedon 7.

void system, where the space is not a limiting factor. Our results indicate that lenticular gypsum crystals are more abundant in subsurface horizons than in surface horizons. Jafarzadeh and Burnham (1992) have reported similar observations. Formation of prismatic, columnar and blade like crystals occur in soils with very low rainfall and short period of time such as in aridic moisture regime (Bym1 and Bym2, pedon 12). There are gypsic pendant in the profiles, crystal growth and length are moderate. The complex crystal habits of pedogenic gypsum are observed in soil moisture regimes, indicating that they may have been formed under slightly different environmental conditions. Subhedral, subhedral-hexagonal gypsum crystals are dominant in aridic-ustic moisture regime (pedon 6 and 7), but when soil moisture trend to xeric-aridic moisture regime globular (By, pedon 8) and tabular-lenticular (Byg1 horizon of pedon 8) are found. Our results showed that lenticular crystals are formed in the absence of organic matter, whereas curved faces are formed in the presence of sodium chloride. Furthermore, we observed that prismatic crystals are found at around pH 7.5 and higher, whereas previous studies had stressed that prismatic

gypsum are mostly found in acidic conditions (Edinger, 1973; Carenas et al., 1982). As can be seen in micrographs, some spaces are filled with anhedral crystals that are granular gypsum crystals. In natural crusts, the granular gypsum may infill the cracks in the crust (Figure 4a, b). In ustic moisture regime, similar to xeric regimes, sufficient rainfall occurs with relatively high evaporation. As a result, rapid soil drying that allows only short time for crystal growth, favors small length/width ratios and tight packing of equant crystals. Soils with high sodium chloride content in pedons near the lake, especially pedon 9, showed gypsum crystals under the surface crusts that have been formed by *per ascendum* process. Spear like form morphology is also noticed in this condition by naked eye. It seems that water tables can bring gypsum-saturated water near the soil surface and evaporation is high enough to elongate the crystals that are affected by soil moisture regime.

Moreover, the presence of high amount of salt plays an important role in curving crystal faces during their growth. Salts in the soil may affect dehydration and, consequently, gypsum crystal growth is rapid.



Figure 6. Back scattered electron images of the crystal habits of pedogenic gypsum xeric-aridic moisture regimes together with EDX spectra of gypsum crystal (a). Globular gypsum crystals of the Byss horizon, pedon 8 (b). Tabular gypsum crystals of the Byg1 horizon, pedon 9 (c). EDX spectra of gypsum crystal of the Byss horizon of pedon 8 (i.e a image), (d). EDX spectra of gypsum crystal of the Byg1 horizon, pedon 9 (i.e b image) (e). Cluster of gypsum crystal of the Byg2 horizon, pedon 9. (f) Hexzagonal in gypsum crystal matrix, Byss horizon, pedon 8.

In a previous study, an indication was obtained that the crystal habit of pedogenic gypsum can be linked to the presence of soil impurities and the degree of soil solution supersaturation with respect to gypsum (Jafarzadeh and Burnham, 1992).

The evaporation rate affects soil drying rate. Hence, in areas where temperature is low (pedon 12, Abadeh), soil drying will be slow. Therefore, the crystal growth is moderate as well as large in length. In case of rainfall, soil drying is rapid and crystals growing in a short period of time will morphologies produce with smaller length/width ratios. In addition to. evaporation helps the movement of water in per ascendum mechanism and causes rapid growth of gypsum crystal.

According to Sadeghi *et al.* (2002), the agroclimatological index (P/ET° i.e. ratio of mean annual precipitation to mean annual reference crop evaportranspiration) varies from less than 0.2 in arid areas of the north, east, and south to more than 0.6 in the mountainous regions of the northwest. This variation is also in accordance with the soil moisture and temperature regime map of Fars Province. This finding shows that ET.

value in the aridic moisture regime is high and in the xeric moisture regime is low, confirming the discussion about evaporation rate and its effect on soil drying rate and gypsum crystal formation.

CONCLUSION

The amount of gypsum accumulation in soils of the study area depends on soil moisture regimes, but not on the soil temperature regimes. Gypsiferous soils occur more commonly in aridic moisture regimes. Micromorphology of gypsum crystals changes in different moisture regimes. In aridic moisture regime, interlocked plates, acicular, fibrous, prismatic and blade forms are more common, while, in xeric moisture regimes, lenticular crystals are dominant; but, in the subsoil, cluster of lenticular, rod like, and tabular subhedrals are observed. Under ustic soil moisture regime, evaporation induces water moving by capillary rise of the gravels to recrystalize vertically arranged columnar, cubic, and needle form crystals. In the intermediate moisture regimes, however, we observed gypsum crystals between either xeric



Figure7. Back scattered electron images of the crystal habits of pedogenic gypsum aridic moisture regimes together with EDX spectra of gypsum crystal (a1, a 2). Blade form and fibrous gypsum crystal of the Bym1 horizon, pedon 12 (b). Prismatic gypsum crystals of the Bym2 horizon, pedon 12 (c). EDX spectra of prismatic (i.e b image) gypsum crystals, (d) fibrous gypsum crystals, Byk horizon. .(e) EDS spectral images of blade form and fibrous gypsum crystals (d image). (f). Sheet of rhombohedral gypum in soil boundary of the Bym horizon, pedon 12 (occurrence of accentuated cleavage) (g). Acicular Gypsum crystal of the Bym1 horizon of pedon12.

and aridic moisture regimes or ustic and aridic. Therefore, near the aridic regimes, more crystals grow length wise with limited thickness (such as columnar, fibrous. perpendicular, blade and needle forms), while with increasing rainfall, like in xeric regime, more crystals grow in width with higher thickness (such as lenticular, globular, tabular and rosette-like forms). Indeed, as rain water becomes saturated with gypsum and continues successive evaporate, phases to of crystallization and renewed crystallization would constantly follow. Gypsum saturated runoff removes the soil materials from alluvial fans and plateaus towards the piedmont plains.

The textural analysis data reveals that the dominant classes are silt loam, sandy loam, and loam, respectively. In pedons with high clay content, the amount of gypsum is <15%. However, in other light textures, CaSO₄·2H₂O content was $\geq 25\%$. SEM approved for studying the shape of gypsum crystals. For spatial determinations of gypsum crystals, the use of large thin sections and polarization microscopy would be promising.

REFERENCES

1. Abtahi, A. 1977. Effect of Saline and Alkaline Ground Water on Soil Genesis in Semiarid Southern Iran. Soil Sci. Soc. Am. J., 41: 583-588.

- Amit, R. and Yaalon, A. D. 1996. The Micromorphology of Gypsum and Halite in Regsoils: the Negev Desert, Israel. *Earth Surf. Processes and Landf.*, 21:1127-1143.
- 3. Banaei, M. H. 1998. Soil Moisture and Temperature Regime Map of Iran. *Soil and Water Research Institute, Ministry of Agriculture*, Iran.
- Buck, B. J. and Van Hoesen, J. G. 2002. Snowball Morphology and SEM Analysis of Pedogenic Gypsum, Southern New Mexico, U.S.A. J. Arid Environ., 51: 469-487.
- Carenas, B., Marfile, R. and De La Pena, J. A. 1982. Modes of Formation and Diagnostic Features of Recent Gypsum in a Continental Environment, La Mancha, Spain. *Estudios Geolog.*, 38: 345-359.
- Carter, B. J. and Inskeep, W. P. 1988. Accumulation of Pedogenic Gypsum in Western Oklahoma Soils. *Soil. Sci. Soc. Am. J.*, 52: 1107-1113.
- Chapman, H. D. 1965. Cation Exchange Capacity. In: "Methods of Soil Analysis", (Ed): Black, C. A., part 2. Am. Soc. Agr, Madison, WI. 891-901.
- Doner, H. E. and Warren, C. L. 1989. Carbonate, Halid, Sulfate and Sulfide Minerals. In: "Minerals in Soil Environments" (Eds) : J. B., Dixon, and S. B. Weed. 2nd Ed. *Soil. Sci. Soc. Am.* Publ. Madison, WI, USA. PP 279-330.

- 9. Dultz, S. and Kühn, P. 2005. Occurrence, Formation and Micromorphology of Gypsum in Soils from the Central German Chernozem Region. *Geoderma.*, **129**: 230-250.
- Edinger, S. E. 1973. The Growth of Gypsum. An Investigation of the Factors Which Affect the Size and Growth Rates of the Habit Faces of Gypsum. J. Crystal Growth., 18: 17-224.
- Eswaran, H. and Zi-Tong, G. 1991. Properties, Genesis, Classification and Distribution of Soil with Gypsum. In: "Occurrence, Characteristic, and Genesis of Carbonate, Gypsum and Silica Accumulation in Soils" (Ed): Nettleton, W. D., SSSA special publication., 26: 89-119.
- 12. FAO. 1993. Agriculture: Toward 2010. Rome. Italy.
- FAO. 1990. Management of Gypsiferous Soils. FAO Soils Bulletin 62. 81pp.
- Gee, G. W. and Bauder, J. W. 1986. Particle Size Analysis, In Methods of Soil Analysis: part 1-Physical and Mineralogicla Methods. Soil Science Society of America Book Series, 5, Am. Soc of Agro, Inc, Mdison, Wisconsin, U. S. A. PP. 383-411.
- Hashemi, S. S., Baghernejad, M. and Pakparvar, M. 2007. GIS Classification Assessment for Mapping Soils by Satellite Images. *Middle East Spatial Technology 4th Conference and Exhibition*. December 2007, Bahrein.
- Jafarzadeh, A. A. and Burnham, C. P. 1992. Gypsum Crystals in Soils. *Soil Sci.*, 43: 409-421.
- 17. James, G. A. and Wynd, J. G. 1965. Stratigraphic Nomenclature of Iranian Oil Consortium Agreement Area. Bull. *Am. Assoc. Petrol. Geolog.*, **12**: 2182-2245.
- Khademi, H. 1997. Stable Isotope Geochemistry, Mineralogy and Microscopy of Gypsiferous Soils from Central Iran. PhD. *Thesis, Univ. Saskatchewan*, Canada.
- Nelson, R. E. 1982. Carbonate and Gypsum. In: "Methods of Soil Analysis". (Ed): page, A. L., Part2. Am. Soc. Agro, Madison, WI, PP. 181-199.
- Nelson, R. E., Klameth, L. C. and Nettleton, W. D. 1978. Determining Soil Gypsum Content and Expressing Properties of Gypsiferous Soil. *Soil. Sci. Soc. Am. J.*, 42: 659-661.
- Owliaie, H. R., Abtahi, A. and Heck, R. J. 2006. Pedogenesis and Caly Mineralogyical Investigation of Soils Formed on Gypsiferous and Calcareous Materials, on Transect, Southwestern Iran. *Geoderma.*, 134: 62-81.

- 22. Podwojewski, P. and Arnold, M. 1994. The Origin of Gypsum in Vertisols in New Caledonia by Isotopic Characteristics of Sulphur. *Geoderma.*, **63**: 170-195.
- Sadeghi, A. R., Kamgar-Haghighi, A. A. Sepaskhah, A. R., Khalili, D. and Sh, Zandparsa. 2002. Regional Classification for Dryland Agriculture in Southern Iran. *J. Arid Environ.*, **50**: 333-341.
- Salinity laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. Agriculture Handbook, vol 60. U. S. Department Agriculture, Washington, DC.
- 25. Soil Conservation Service. 1972. Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples. Rev. ed. USDA-SCS, Soil Survey Investigation Report No. 1, U. S. Government Printing Office, Washington DC.
- 26. Soil Survey Staff. 1999. Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Survey. USDA. Handbook No. 436. U. S. Government Printing Office, Washington, DC, 754P.
- 27. Soil Survey Staff. 2006. Keys to Soil Taxonomy. USDA. NRCS. 326 P.
- Taimeh, A. Y., 1992. Formation of Gypsic Horizons in some Arid Regions of Jordan. *Soil Sci.*, 153: 486-498.
- Toomanian, N., Jalalian, A. and Eghbal, M. K. 2001. Genesis of Gypsum Enriched Soils in North-west Isfahan, Iran. *Geoderma.*, 99: 199-224.
- Van Hoesen, J. G. 2000. Pedogenic Gypsum in Southern New Mexico: Genesis, Morphology and Stable Isotopic Signature, Ms Thesis, Las Vegas, University, Neveda, Las Vegas, U.K.182P.
- Watson, A. 1985. Structure, Chemistry and Origin of Gypsum in Southern Tunisia and in Central Namib Desert. *Sedimentology.*, 32. 855-875.
- 32. Watson, A. 1988. Desert Gypsum Crust as Paleoenvironmental Indicators: A Micropetrographic Study of Crusts from Southern Tunisia and the Central Namib Desert. J. Arid Environ., **15**: 19-42.
- Zahedi, M. 1976. Explanatory Text of the Esfahan Quadrangle Map 1:250000. Geological Survey of Iran.

میکرومورفولوژی کریستالهای گچ در خاکهای جنوب ایران تحت رژیمهای رطوبتی متفاوت

س. س. هاشمی ، م. باقرنژاد و ح. خادمی

چکیدہ

خاکهای گچی بیشتر در رژیمهای رطوبتی زریک، یوستیک واریدیک دیده میشوند. شرایط محیطی در تشکیل گچ اثر گذار است. خاکهای گچی استان فارس در جنوب ایران،بیشتر در دشتهای دامنهای، سیلابی و آبرفتی یافت میشوند. هدف از این تحقیق بررسی میکرومورفولوژی کریستالهای گچ تشکیل شده تحت رژیم-های رطوبتی متفاوت است. نتایج نشان میدهد که کریستالهای عدسی گچ معمولا در خاکهای توسعه یافته به وفور یافت میشوند، در حالی که تحت رژیم رطوبتی اریدیک کمیاب هستند. این کریستالها در افقهای زیر سطحی به وفور یافت میشوند. شکلهای ستونی، منشوری و تیغهای گچ در نواحی با رژیم رطوبتی اریدیک که خاکهای آنها شستشوی بالا داشته اند، یافت میشوند. تشکیل پندانت گچ در نواحی با رژیم رطوبتی اریدیک که دامنهای، با رطوبت محدود فراوان است. در نواحی با بارندگی کم کریستالهای گوناگونی از گچ تشکیل شده است. به نظر میرسد که رواناب به عنوان یک سیستم هیدرولوژی منجر به انتقال رسوبات زمینی از ارتفاعات بالا اریدیک، رشد کریستالهای عدسی، انوهدرال و ساب هدرولوژی منجر به انتقال رسوبات زمینی از ارتفاعات بالا اریدیک، رشد کریستالهای عدسی، انوهدرال و ساب هدرول گچ فراوان است. نتایج مطالعه نشان میدهد که علاوه بر رطوبت خاک، بافت خاک و موقعیت تو پوگرافی، نقش مهمی در تشکیل کریستالهای گونی از گچ جنگیل دارند. تبلور خوبی از گچ در بافتهای سیلت لوم، شنی لوم و لوم دیده شد. مشاهده افقهای جیسیک پیشنهاد می-کند که تجمع گچ در خاکهای مورد مطالعه بیشتر تحت فر آیند Per dscendum مورت گرفته است.