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Petrography, Mineralogy and Geochemistry of Gypsiferous Soils in Selected Areas in Middle of Iraq

Linaz Anis Fadhil* and Afyaa Saleem Abd Al-Ameer**
*Geophysics Dept., College of Remote Sensing and Geophysics, Al-Karkh University of Science. E-mail linaz_maki@yahoo.com, linaz@kus.edu.iq
**Ministry of Education. E-mail afyaa.saleem@gmail.com

Annotation: The present study deals with gypsiferous soils in selected areas in middle of Iraq, the field study includes ten sits chosen according to their abundant of gypsum, one site in Al Diwaniya governorate, one site in Al Najaf governorate five sites in Al Najaf-Karbala area and three sites in Karbala governorate.

Petrographic study and grains size analysis were used to identify the texture, type of minerals and their forms. Scanning electronic microscope technique was also used for illustrating habits of gypsum within soils.

X-ray diffraction was used to classify minerals that occur while using the technique of X-ray fluorescence to determine the chemical composition of major oxides.

The percentage of gypsum in the studied sits was compared with several classifications to determine its suitability for irrigated agriculture and crops.

Key words: Gypsiferous Soils, Field Study, Grains Size Analysis, Major Oxides, Irrigated Agriculture

Introduction

Gypsiferous soils are one of Iraq's abundant soils that can classify low solubility mineral ($2.6gl^{-1}$) by the ample amounts of gypsum $CaSO_4.2H_2O$, (FAO, 1990). Soils with gypsum of pedogenic origin are present in areas of arid and semi-arid moisture regimes (Nettleton et al. 1982).

In Iraq there are two type of gypsum due to their origin according to Buringh, (1960): 1- Primary gypsum which originates with a geological substratum containing gypsum and anhydrite interlayers or with Pleistocene terraces connected with such deposits. 2- Secondary gypsum which originate according soil formation processes as a result of transferring gypsum from the areas contain gypsum and anhydrite as dissolve form in ground water or the groundwater could have been above the soil surface and high in calcium and sulphuric ions in some time, the enrichment waters according to extreme evaporation made secondary gypsum deposited in the horizons of the soil.

In wet period the secondary gypsum was concentrate in the vugs and channels which found in soil texture. It was redistributed in dry time for many times according to depositional processes and biological activity which increased the secondary gypsum ratio in these soils (Barazanji, 1973).

Many researchers have studied gypsum soils including Barazanji (1973) who have studied gypsum soils in several local sites in Iraq; selected soils have been classified according to the content of gypsum. Mansour and Toma (1983) have taken the initiative of drawing up a map on a scale of 1: 000 000 showing the distribution of gypsum rocks and gypsum soils in Iraq.

Saeed (1994) studied the distribution of gypsiferous soils in Iraq and showed that there is no formal classification for those soils where gypsum may vary from (1 – 70) %. Razouki et al. (1994) studied the structural failures caused by gypsum soils in Iraq and examined the fundamental geotechnical properties of those soils. Al-Baidari (1996) studied Injana Formation sedimentology and geochemistry in the Najaf – Kerbala area and described the gypsum horizons as paleogypcrete. Yassin (2006) studied gypsum soils in several locations in central Iraq. He was concerned with mineralogy and hydrochemistry of soil – water extracts and geotechnical characteristics of these soils. A proposal was attempted to classify gypsiferous soils. Namiq and Nashat (2011) investigated the effect of leaching by a laboratory testing system on the volume shift of gypseous soil.

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The present paper deals with study of gypsiferous soils in several sits in middle of Iraq to find out mineral constituents and their arrangement, soil texture, soil morphology, abundant minerals and oxides and their relationships, in addition to determine the suitability of soil samples for irrigation agriculture and crops

The study area

The studied area is located in the centered part of Iraq between (N394118.308 to N3609198.973) and (E 464823.337 to E 3517485.74) Table (1); Figure (1).

Table 1: Coordinates of Sampling Sits.

Sampling Site Number	Longitude	Latitude
1	459800	3518000
2	437500	3543000
3	424400	3535000
4	422000	3540000
5	421100	3546000
6	421500	3551000
7	409200	3557000
8	399600	3604000
9	398800	3605000
10	399000	3607000

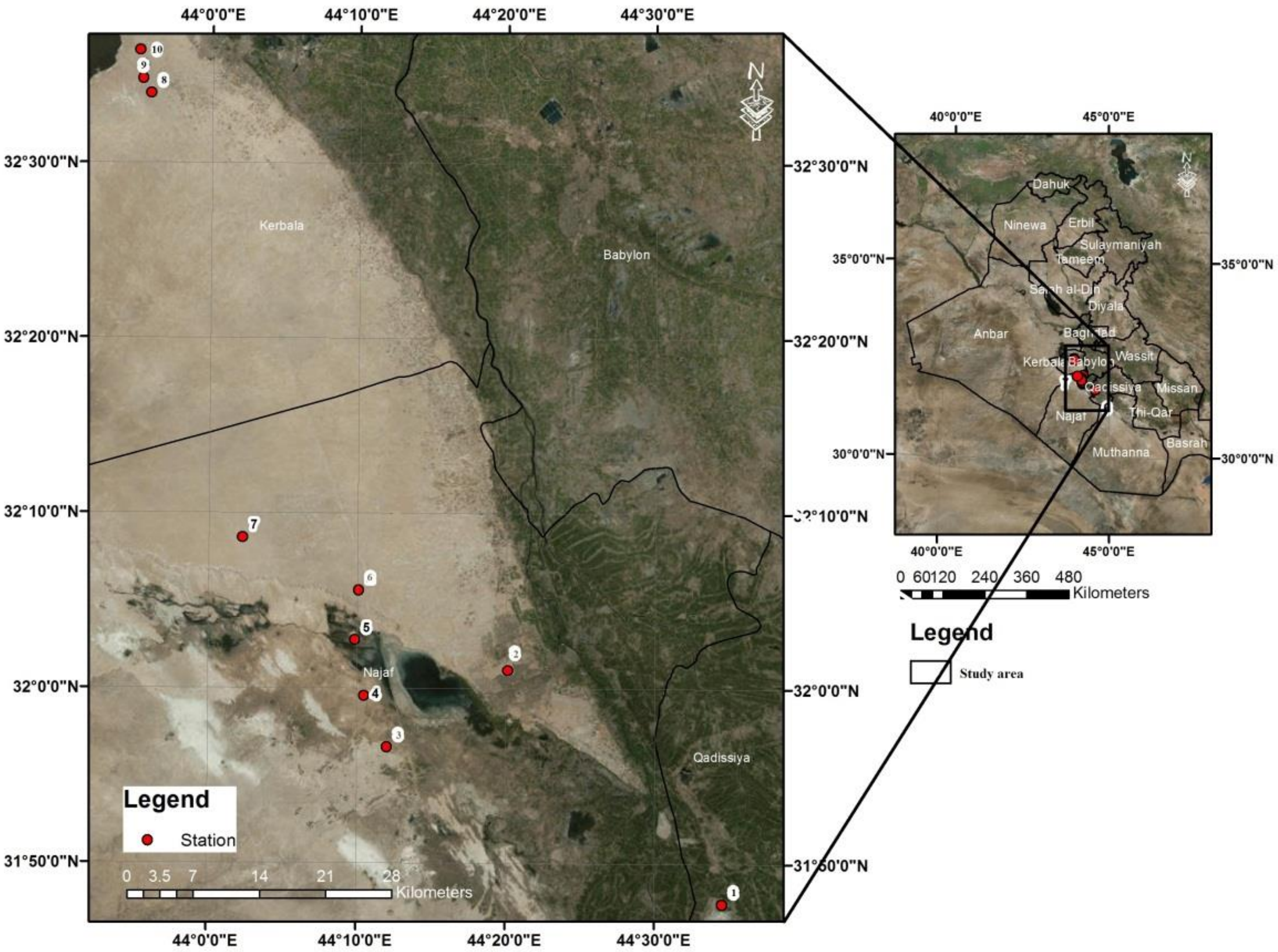

Figure 1: Satellite image represented the studied area and sampling sits.

Geological Context

The geology of the area in question is briefly outlined below. It covers: stratigraphy, geomorphology and tectonic.

- **Stratigraphy**

  According to Barwary and Slewa (1994) and (1995) the exposed geological formations and Quaternary deposits from older to younger are:

  1. Euphrates Formation (Lower Miocene): It is consisting of limestone that pale grey to yellowish grey color almost fossiliferous with marl intercalations.
  2. Formation of Nfayil (Middle Miocene). It is composed of of marl and calcareous alteration.
  3. Injana Formation (Upper Miocene): It is consisting of red partly greenish, silty calcareous claystone of grey brownish greenish and yellowish sandstone lenticels. The interaction between Injana Formation and Dibdibba Formation appears as a soft layer of gravel.
  4. Dibdibba Formation (Pliocene-Pleistocene): It is well exposed on both ridges of Tar Al Najaf and Tar Al Sayyed occupying the top most part of the exposed sequence, thus forming the bed rock of the desert plain between Karbala and Al Najaf. The predominant lithological component is sandstone, which is generally white, pink and light gray, is often recorded as ill sorted, fine-coarse grained, small pebbles. Gypcrete is unconformably covering the top of formation everywhere followed by aeolian sand and silt.
  5. Quaternary Deposits (Pleistocene-Holocene)

     Numerous types of Quaternary deposits are formed in the studied region, such as Gypcrete, Sabkha, Sand dunes, Alluvial fan, Flood plain, Valley fill and Depression fill deposits. The gypcrete is the most widespread and covers the majority of the Karbala- Al Najaf alluvial fan.

- **Geomorphology**

  According to Hamza (1997) and Yacoub (2011), the studied area includes various areas of morphogenesis which are Mesopotamian-plain, Desert plain and lowland Bahr Al Najaf- Razzaza. The Mesopotamian plain is covered by geomorphic accumulation units, primarily of fluvial and aeolian origin and it is bounded on the west by the desert plain while the desert plain (Dibdibba-plateau-like) extending between Al Najaf and Karbala cities. It is bounded by the Mesopotamian plain from the east, and Tar (Cliff) Al Najaf, from the south, Tar Al Sayyed from the west Tar and Al Razzaza Lake from the eastern embankment.

  The two cliffs are the most significant geomorphological features form erosional ridges suffer from various types of mass movements.

  Bahr Al Najaf consists of Tar Al Najaf depression and gently sloping land and base; the depression is shallow and closed. Razzaza area can be considered as continuation Al Razzazas depression.

- **Tectonically**

  According to Fouad and Sissakian (2011), the studied area is within Stable Shelf of Nubio-Arabian plate form which subdivided into Rutba-Jazira and Salman zone while part of it within Mesopotamian zone of the Unstable Shelf. The part which is covered by Quaternary deposits belong the Mesopotamian zone (Tigris subzone and Euphrates subzone).

Material and Methods

Field work:

The field work trip includes sampling ten sits; their chosen were according to abundant with gypsiferous soils; Table 1, Figure1. Most of these sits were close to private factories for manufacturing plaster of paris. The samples were at depth (10-100) cm from Al Diwaniya and Al Najaf Governorates (G_1 and G_2), Karbala-Al Najaf area (G_3, G_4, G_5, G_6 and G_7); Figure 2, and Karbala Governorate (G_8, G_9 and G_{10}). The samples were light brown to white color, brittle to semi consolidated.

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Figure 2: Sampling site G_3.

Laboratory work:

This work includes the following steps:

Petrographic study

In workshop of the Department of Geology, College of Sciences. University of Baghdad, a total of 20 thin sections were prepared and studied using polarized microscope (type Leitz) to identify mineralogical components, occurrence ratio and arrangements.

Grain Size Analysis

Wet sieve analysis and hydrometer method was used to find the soil texture according to grain size in General Organization for Geological Survey and Mining. It was following GEOSURV work procedures (Al-Haimus, 1994).

Scanning Electron Microscope (SEM)

SEM technique is used to clarify the microstructure of gypsiferous soil. It has been carried out in the Nanotechnology and Advance Materials Research Center, the University of Technology.

X-ray Diffraction Technique

X-ray diffraction technique is used to determine the mineralogical composition of the samples selected. The following conditions are adjusted: target Cu, Cu Kα radiation (λ=1.54°A), 40KV power, current 30 mA, Ni filter speed of 10 deg / min. Bulk samples were scanned in the Department of Materials, College of Engineering, University of Babylon, with 2 theta scale 0-50 degree.

X-ray Fluorescence Technique

Major oxides of gypsum bulk soil are calculated by X-ray fluorescence for the contents of SO_3, CaO, SiO_2, L.O.I, MgO, Na_2O, Al_2O_3 and K_2O in the Iraqi-German Geological laboratory, Department of Geology, College of Sciences. Baghdad University.

Results and Discussion

The volume percentage of mineral constituents was calculated by used point counter the results represented in Table 2.

Gypsum, quartz, clays, heavy minerals, carbonates and feldspars were diagnosed in different proportions by studying thin sections.

The examination of thin section reveals that there are several types of secondary gypsum which their size ranges between coarse silt to coarse sand adopted Wentworth scale (Wentworth, 1922).

Euhedral-subhedral prismatic form is the main form of secondary gypsum in the most of studied sits with variation in size (Plate1 and Plate2), but other forms like tabular, acicular and disseminate are found in the same thin section. In some sits, the faces are clear, while they are difficult to determine because of their interlocked with each other. The description of these features were according to Mees and Stoops (2010).

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Observation of these types of diversity represents changes in micro-environmental soils conditions over time (Amit and Yaalon, 1996).

The gypsum is euhedral-subhedral indicating the growth in situ and was not transported or relocated (Jafarzadeh and Burnham,1992)

Quartz is clear in thin sections Monocrystalline and Polycrystalline, rounded to sub rounded coated most time with iron oxides and clays. For certain crystals, wavy and straight extinction is also observed indicating the origin of these crystals; their sizes vary from very fine to very coarse sand sizes according to Wentworth scale. Many of the quartz grains (Zircon and Rutile) have inclusions. Carbonates are represented as rock fragments with very fine to medium sand surrounds or as binding materials. Many of the gypsum crystals are replaced partly by micritic calcite. Opaque minerals, Amphibole, and Pyroxene represent heavy minerals. Clays are used as binding materials, and gypsum and quartz crystals can be painted. Sub rounded fragments of clay are often found with a coarse sand.

Most feldspar is orthoclase and microcline and few of plagioclase with different sizes, subhedral to anhedral with moderately sorting some of orthoclase is partially alteration to sericite and clay minerals.

Distribution of gypsums soils is controlled by the geology of the parent materials (Eswaran and Zi-Tong,1991) and/or mechanisms that introduce the required cations and anions (Buck et al.,2002; Herrero and Porta,2000) such as a changing ground water level (Mees,1999).

Table 2: Percentages of mineral constituents according of petrographic study.

Station Name	Gypsum %	Quartz%	Carbonates%	Heavy Minerals %	Clays %	Feldspars%
G1	68.3	19.2	6.5	2.3	2.5	1.2
G2	62.7	16.6	5.2	4.6	5.7	5.2
G3	68.4	10.8	4.2	5.6	5.3	5.7
G4	75.2	9.3	3.6	2.9	2.9	6.1
G5	61.4	14.6	7.9	3.5	3.9	8.7
G6	67.7	13.9	4.4	6.2	3.5	4.3
G7	73.5	9.5	3.6	3.1	5.1	5.2
G8	56.3	20.6	8.3	4.9	6.2	3.7
G9	68.1	11.7	6.6	1.1	7.3	5.2
G10	51.8	18.3	9.2	3.2	10.4	7.1
Mean	65.34	14.45	5.95	3.34	5.28	5.24
Range	51.8-75.2	9.3-20.6	3.6-9.2	1.1-6.2	2.5-10.4	1.2-8.7

One of the most textural elements in clastic rocks is particle size because of its relation to the dynamic transportation and deposition conditions of. The results of grain size analysis are shown in Table 3 after plotting the percentage ratio on Folk triangle.

According to Van Alphen and Romero (1971) the texture of gypsiferous soils almost depending on the nature of the materials from which gravel, sand, and clay are derived, and the degree of their mixing with gypsum deposits. Gravely Muddy Sand, Slightly Gravely Sand and Gravely Sand were the main soil nomenclature in the studied sits.

Table 3: Sieve analysis results and their nomenclature according to Folk (1954).

Station Name	Gravel%	Sand%	Silt%	Clay%	Soil nomenclature
G1	10	71	14	5	Gravelly Muddy Sand
G2	15	60	10	15	Gravelly Muddy Sand
G3	3	84	13	-	Slightly Gravely Sand
G4	4	74	12	10	Slightly Gravely Sand

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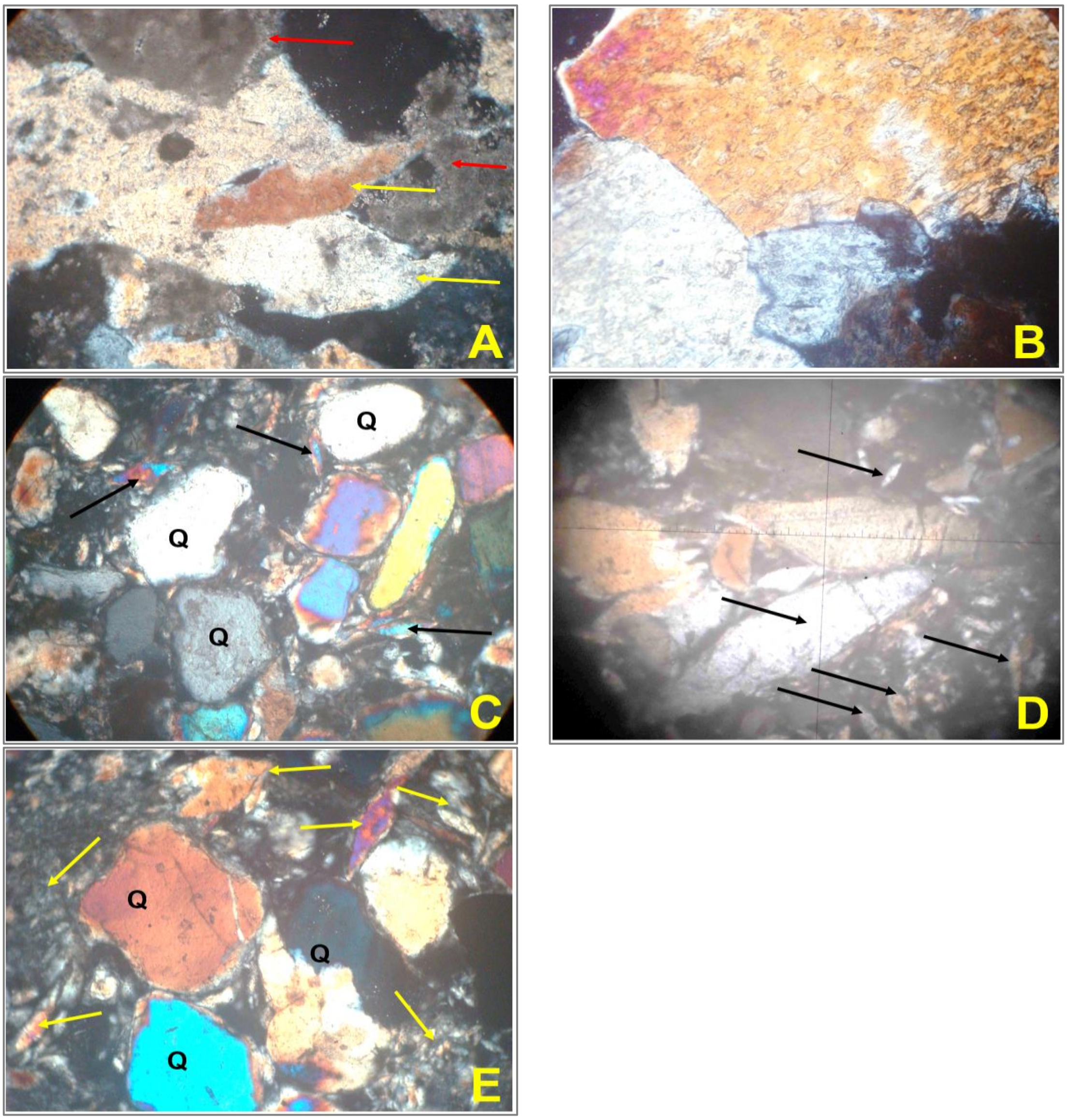
G5	20	75	5	-	Gravely Sand
G6	22	71	-	7	Gravely Sand
G7	4	68	25	3	Slightly Gravely Sand
G8	13	73	14	-	Gravelly Muddy Sand
G9	13	62	17	8	Gravelly Muddy Sand
G10	3	77	20	-	Slightly Gravely Sand

Plate 1



(A-Subhedral- anhedral prismatic and tabular form of secondary gypsum, G1. B-Euhedral tabular gypsum with interpenetrating boundaries probably due to preferential growth of gypsum, G2. C-Subrounded quartz grain, prismatic like and laths of secondary gypsum, G3. D- Subrounded quartz grain, associated with prismatic like and acicular of secondary gypsum, G4. E-Monocrystalline and polycrystalline quartz grains subrounded-subangular, with prismatic and acicular form of secondary gypsum, G5) 10X, XPL.

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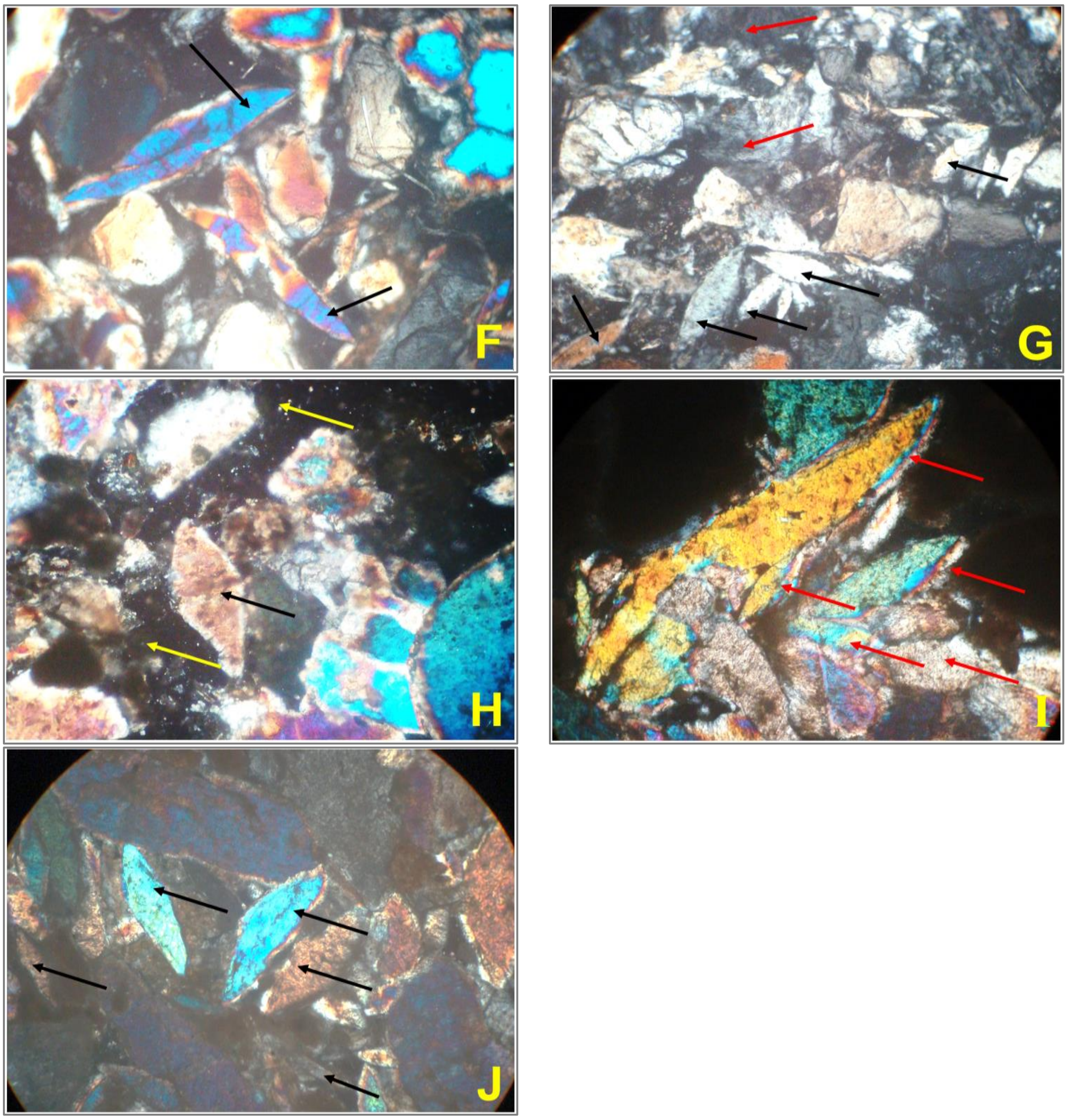

Plate 2

(F-Different sizes of prismatic like secondary gypsum associated with quartz grains, G6. G- Interlocking of secondary gypsum with prismatic and irregular form, G7, H-Prismatic and disseminated form of secondary gypsum coated with clays. G8, I-Large scale subhedral prismatic form of secondary gypsum, G9, J-Euhedral –subhedral prismatic form of secondary gypsum, G10) 10X, XPL.

The morphology of selected gypsiferous soils samples can be distinguished by SEM image as shown in Figures 2, 3, 4 respectively.

Evaporation induces water moving by the capillary rise of gravel to recrystallize vertically arranged prismatic and needle-shaped crystals which are the abundant forms in this study When the capillary of gypsum-bearing groundwater is located near the gypsum surface, as a result of alternating rainfall and evapotranspiration that precipitate.

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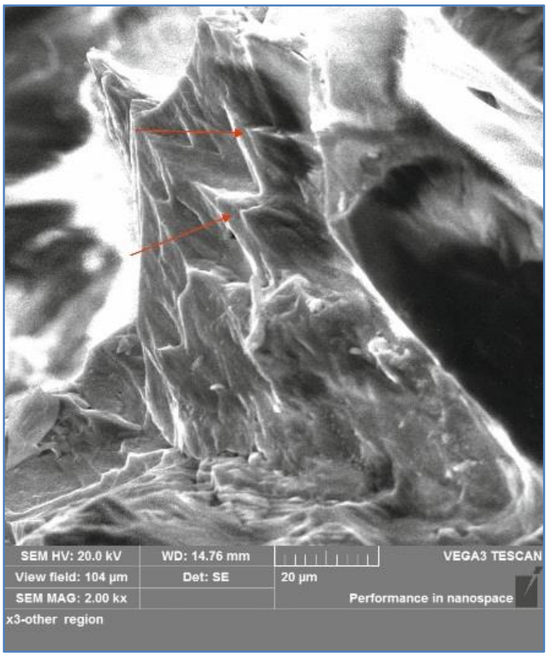

Figure 2: SEM image of prismatic habit and dissolution feature of secondary gypsiferous soil in G1.

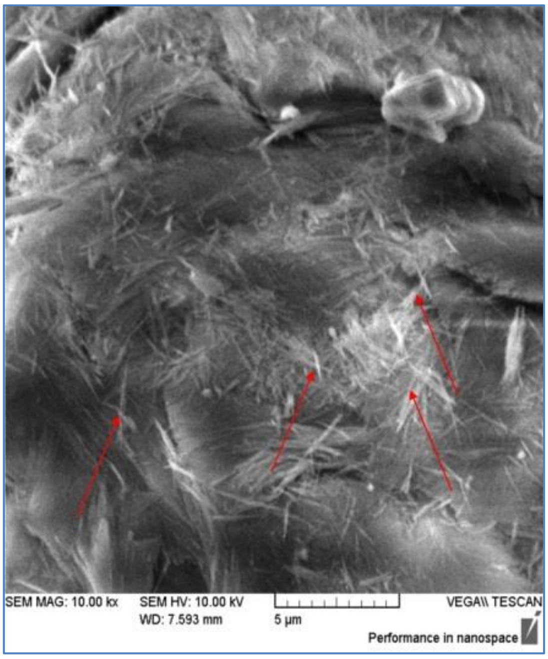

Figure 3: SEM image of acicular habit of secondary gypsiferous soil in G4.

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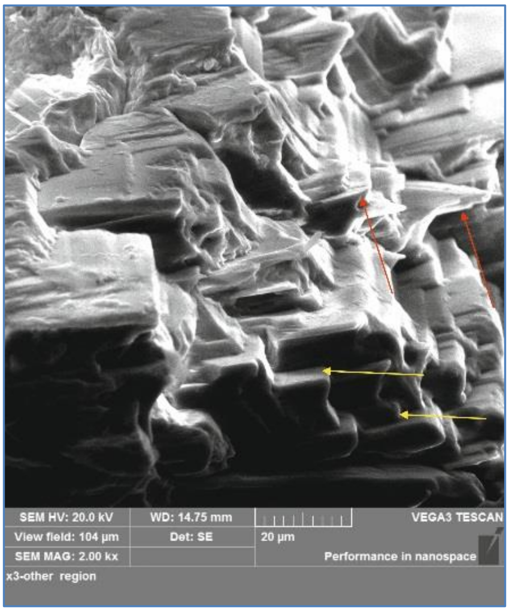

Figure 4: SEM image of tabular with prismatic habit in some boundaries, the prominent cleavage of gypsum is accentuated by dissolution feature in some parts of secondary gypsiferous soil in G9.

The mineralogical study by x-ray diffraction method represented that gypsum is the main minerals in all stations with variation in Quartz, Calcite and Dolomite as shown in Figures (5, 6, 7, and 8).

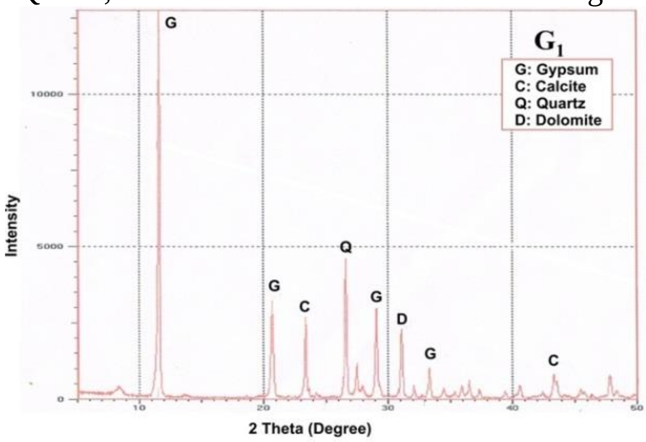

Figure 5: X-Ray Diffractogram of Gypsiferous soil, G1 Station.

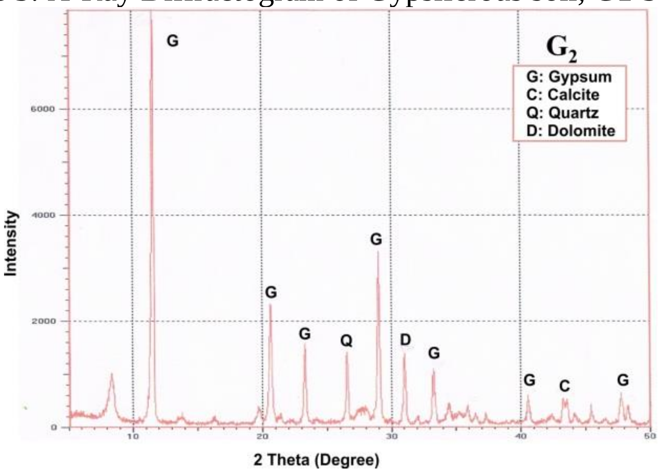

Figure 6: X-Ray Diffractogram of Gypsiferous soil, G2 Station.

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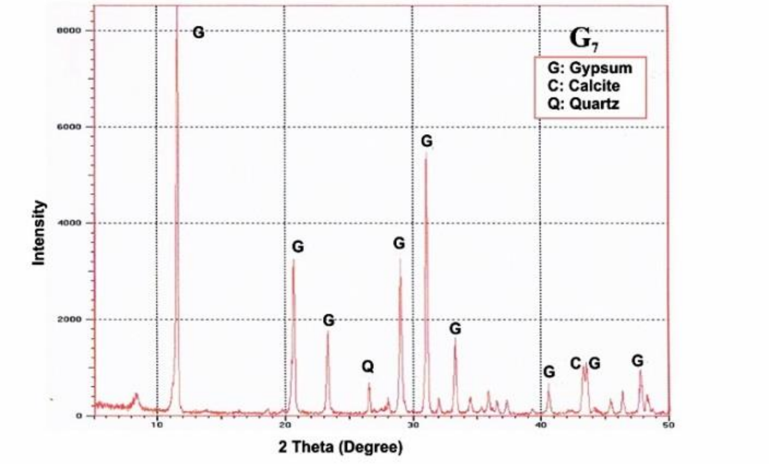

Figure 7: X-Ray Diffractogram of Gypsiferous soil, G7 Station.

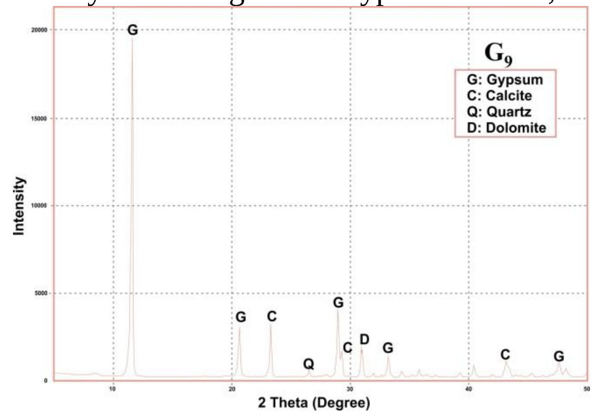

Figure 8: X-Ray Diffractogram of Gypsiferous soil, G9 Station.

The results of concentration of the major oxides are represented in Table 4. SO_3 is the most common oxide in all station reflected the abundant of evaporate mineral (Gypsum).

Table 4: Concentration of Major Oxides of gypsiferous soils.

Station Name	SO_3 %	CaO %	SiO_2 %	L.O.I %	MgO %	Na_2O %	Al_2O_3 %	K_2O %
G1	29.1	20.3	24.5	12.33	3.88	2.5	3.4	1.57
G2	31.28	21.92	18.13	13.3	3.57	3.6	2.99	1.8
G3	33.98	23.82	11.6	15.25	3.72	4.66	1.85	1.27
G4	38.31	27.56	10.76	16.33	4	0.89	1.2	0.36
G5	30.32	21.23	22.99	13.89	3.5	2.13	3.21	1.33
G6	33.09	23.18	17.06	14.07	3.6	2.15	2.89	1.32
G7	36.5	25.46	12.98	15.45	3.9	2.58	2.07	0.47
G8	28.49	19.97	26.03	12.11	2.8	4.04	3.9	1.38
G9	34.88	24.45	14.94	14.83	3.9	3.22	2.38	0.41
G10	26.97	18.9	25.54	12.47	2.7	4.32	3.74	1.63
Mean	32.29	22.68	18.45	14.00	3.56	3.01	2.76	1.15
Range	26.97-38.31	18.9-27.56	10.76-26.03	12.11-16.33	2.7-4	0.89-4.66	1.2-3.9	0.36-1.8

Classification of soil is an aid to soil surveying and mapping soil and to describe the relationship between soil conditions and plant growth. Gibb et al. (1967) identified three types of gypsum soils: less than 10% gypsum suitable for all crops; 10-50% gypsum suitable for a small number of crops; more than 50% gypsum suitable for irrigated agriculture. Sys and Riquier (1980) consider that for most crop plants in the world the

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optimum amount of gypsum is less than 5 percent. Plant growth is marginal when the volume of gypsum in the root zone is 5 to 25 percent and when the gypsum content exceeds 25 percent strictly reduced.
Barzanji (1973) distinguished five classes of gypsum soils, non-gypsum if gypsum <0.3%, 0.3-10% slightly gypsum-like, 10-15% moderately gypsum-like, root growth inhibited while highly gypsum-like, root growth is minimized, not suitable for irrigated agriculture when gypsum 25-50%.
The percentage of gypsum measurements are either from slides (Table2) or by converting the sulfur oxide by multiplying it by a factor of 2.146, therefore the ratio exceeds 50%, and thus the sites in this study are not suitable for “irrigated agriculture”.
According to Gibb et al. (1967) and strictly limited according to Sys and Riquier (1980)
while not suitable for “irrigated agriculture” according to Barzanji (1973)

Conclusions

Examination of thin sections were identified different proportions of gypsum, quartz, carbonates, heavy minerals, clays and feldspars respectively. Studying thin section diagnoses variety forms of secondary gypsum. Prismatic form is the main form in addition to tabular, acicular and disseminated crystals.
According to grain size analysis, Gravely Muddy Sand, Slightly Gravely Sand and Gravely Sand were the main soil textures in the studied sits.
Prismatic, acicular and tabular were the main habits of secondary gypsum crystals according to SEM study.
Gypsum, quartz, calcite, dolomite was diagnostic by XRD analysis. Gypsum was the main mineral.
The results of XRF show that sulfur trioxide in the samples represent the highest percentage with significant proportions calcium oxide and silicon oxide.
The high percentage of gypsum in the selected sites makes it unsuitable for irrigated agriculture and crops.

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