Microstructure of Gypsiferous Crust and Its Importance to Unsaturated Soil Behaviour

Ghazi Mokdad[1], Omran Alshihabi[1], and Leo Stroosnijder[2]

[1] Faculty of Agriculture, Damascus University, Syria ghazi57@scs-net.org, omran-alshihabi@hotmail.com

[2] Department of Irrigation and Soil & Water Conservation, Wageningen Agricultural University, The Netherland Leo.Stroosnijder@wur.nl

Summary. Formation of gypsiferous crust in agriculture lands deters seedling emergence, which constitutes a major problem around the world. The objective of this study is to investigate the micro-morphology of gypsiferous crust and its influence on unsaturated soil behavior. Samples containing 47% of gypsum were taken from Granada (North Syria), then left to dry under natural conditions. Undistributed soil samples (8×8 cm) of the crust and underlying soil material were taken in tins and impregnated with polyester resin. Thin sections were prepared, and examined with a petrographic microscope (Olympus) in plane and polarized light. The microstructure of these samples showed the distribution of soil materials and the types of pores. The crust consisted of clay, silt, calcite and gypsum attributed to the mechanical impact of raindrops. The main effect of raindrops on the soil surface layer was clogging the pores by means of the mentioned materials, which was the dominant mechanisms of crust formation. According to the structure of these soils, the infiltration rate reached a very low value and a remarkable increase in stiffness was observed.

Key words: undistributed soil, unsaturated soil, microstructure, gypsiferous crust, infiltration rate

Introduction

Gypsiferous soils Make up 22% of Syrian agricultural soil, with gypsum content of 1–80% (Ilaiwi 1983). A crust forms when these soils are exposed to rainfall or irrigation (Stroosnijder 1995). This crust hinders seed germination, and possible recultivation and planting. This study was initiated to describe the micromorphology of gypsiferous crust.

Gypsum crusts have been reported from many (semi-) arid regions. Their geographic distribution closely coincides with the areas receiving less than 250 mm rainfall per year (Watson 1982). Extensive gypsum crusts have been described in Middle East countries, where they are a major limitation for crop production because water infiltration rate, seedling emergence and crop growth are largely controlled by the thickness and gypsum content of the crust (Nafie 1989). The severity of the mechanical hindrance that gypsum crusts oppose to crop development can be assessed by measuring penetration resistance. Morphological and micro morphological study of gypsiferous soils from the Middle Euphrates Basin (Syria) have been studied (Habib and Robert 1992). The effect of moisture and gypsum content on the penetration resistance of gypsiferous horizons has been studied by Poch and Verplancke (1997) but gypsum crusts developing on the soil surface have not been given yet the same attention (Jafarzadeh 1991). The objective of the present paper is to investigate the microstructure of gypsiferous crust in the soil surface.

Materials and Methods

Soils: The soils chosen for this study from Granada which are located in North-East Syria (35°57′9″N – 38°48′4″E and 290 m above the sea). The mean annual rainfall is 250 mm, distributed in winter season with high rainfall intensity (47 mm/h) and long period of drought. The soils were silty loam (gypsiferous soil). Soil samples are taken from the top layer (0–20 cm) of uncultivated area, The samples were characterized for particle size distribution using hydrometer method (Gee and Bauder 1986), calcium carbonate content using the volumetric calcimeter method (Nelson 1986), and organic matter content by wet combustion (Nelson and Somers 1986). Results are presented in Table 1. Gypsum content in the soil is high (47%). The organic matter content in the soil was low (1.2%). Other undistributed samples are taken, packed with boxes and then coated by cotton to maintain the crust surface with no alterations.

Thin sections preparation: Undistributed soil samples (8 × 8 cm) of the crust and underlying soil material were packed with boxes and coated with cotton to maintain the crust surface with no alterations. To study the micro morphology of the soil crust in Wageningen university (Holland). Thin sections preparation were made according to the method of (FitzPatrick 1993), the samples were oven dried (40–50°C) for 48 hours to remove hydroscopic water. Then the samples were taken in tins and impregnated with polyester resin, and it is included at vacuum for four weeks, to be given the cohesion. After that samples were cut, polished, trimmed with oil used, and lastly covered and in examined with a petrographic microscope (Olympus) in plane and polarized light. The micro morphological description used the terminology of Bullock et al. (1985).

The determination of the mineralogical gypsum crust was carried out with X-ray diffraction technique. For that a Philips PW 1710/1820 diffraction equipped with a co X-ray tube was used ($\lambda = 1.7889$ Å).

Table 1. Physical and chemical analysis of Granada soil

Symbol soil	USDA Texture.T	Granulo. Analysis			pH 1:2.5	ECs dS/m	Organic matter OM%	$CaCO_3$ %	Gypsum %
		Clay	Silt	Sand					
G	Si.L	35.4	55.9	8.5	7.8	4.2	1.2	13.0	47.0

Results and Discussion

Crust Formation

The crust consists of two layers (layer 1 and layer 2, Fig. 1), which are parallel oriented to each other. Each layer displays a textural fining upward towards the soil surface

Layer 1 is situated at the soil surface. The upper part is 100 μm thick (Fig. 2) densely packed and it consists of a mixture of clay and silt sized calcite particles (< 10 μm). Occasional gypsum crystals of similar sizes are present. The microstructure is compact grain microstructure, macro voids (> 10 μm) are absent.

The lower part (Fig. 3) is built up of denticular gypsum crystals (100–300 μm) and micro aggregates consisting of a mixture of clay and calcite crystals (< 10 μm). Occasionally calcite crystals ranging in size from 10–150 μm are present. Voughs (50–150 μm) frequently occur showing that the lower part of layer 1 is more porous than the upper part.

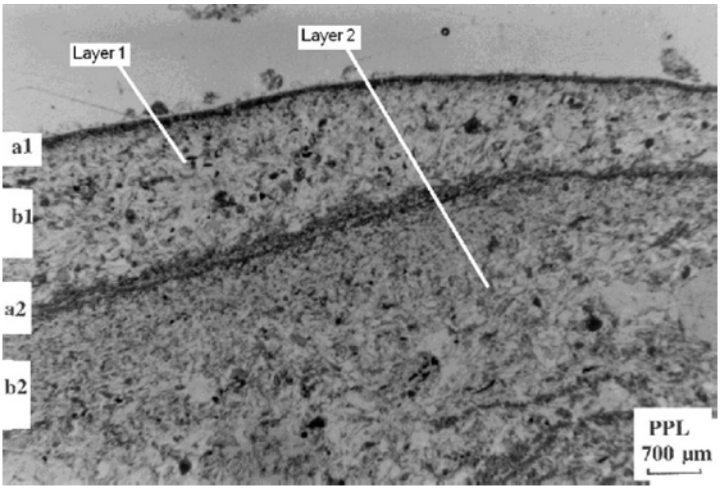

Fig. 1. General overview of the crust

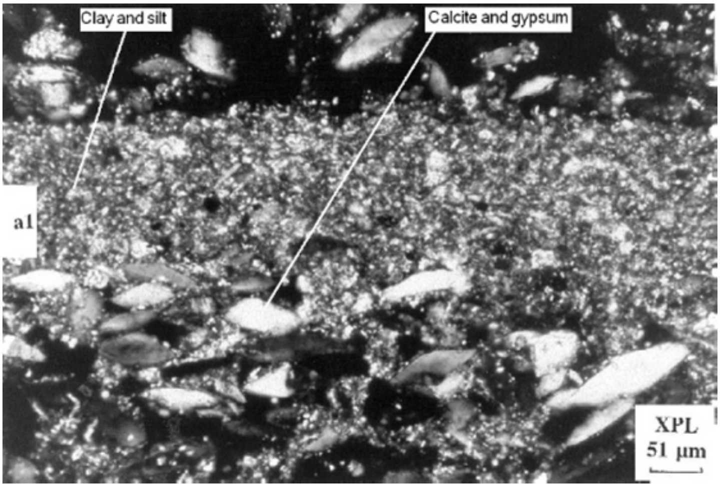

Fig. 2. Detail of the upper part of layer 1

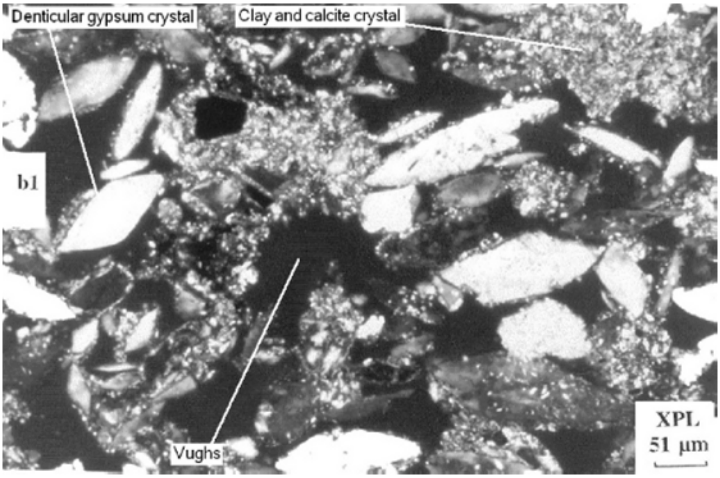

Fig. 3. Detail of the lower part of layer 1

Layer 2 is situated below layer 1.

The upper part (Fig. 4) is similar to the upper part of layer 1 regarding the grain size distribution, mineralogy, density and microstructure. The thickness of the upper part ranges from 150 to 250 µm.

The lower part (Fig. 5) is built up of denticulated gypsum crystals smaller sized than those of layer 1 (50–100 µm). In addition micro aggregates (50–100 µm) consisting of clay and fine (< 10 µm) calcite crystals are present. Occasionally calcite crystals (50–100 µm) occur. Few voughs (< 50 µm) are present, the microstructure is compact grainy. Layer 2 is finer textured, sig-

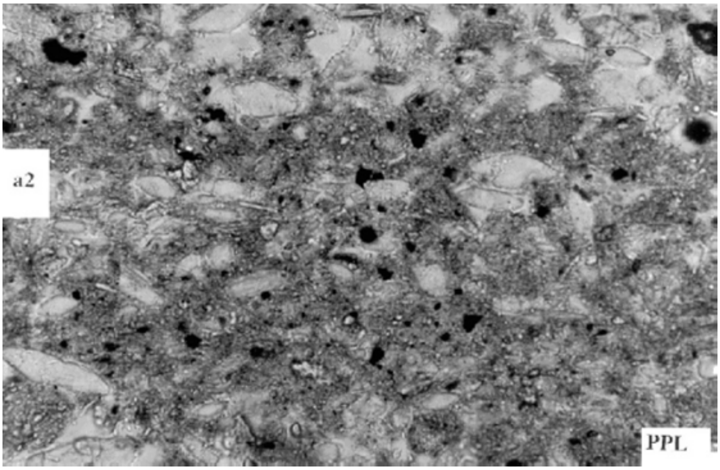

Fig. 4. Details of the upper part of layer 2

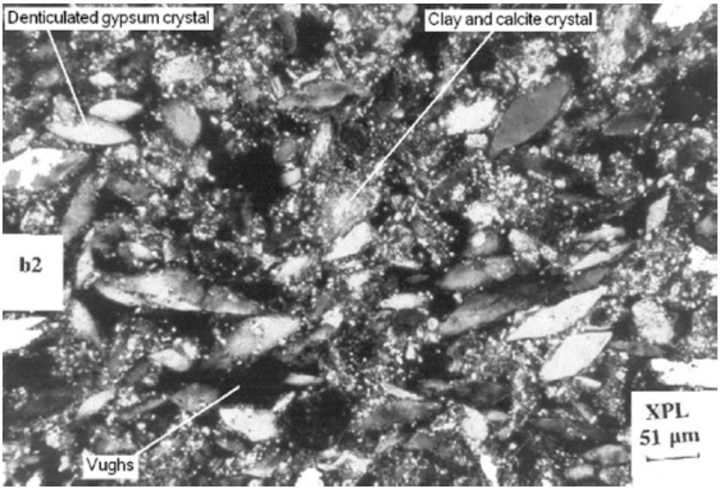

Fig. 5. Detail of the lower part of layer 2

nificant less porous than layer 1. Some plant tissues are present. The boundary between layer 1 and layer 2 is within 50 μm. The total thickness of the crust is approximately 2–3 mm.

The Soil Groundmass

As it is shown in Fig. 6, the groundmass consists of gypsum crystals and gypsum aggregates up to 1 cm. Occasionally calcite crystals occur. The fine material ($< 10\,\mu m$) consists of clay and calcite particles. The distribution

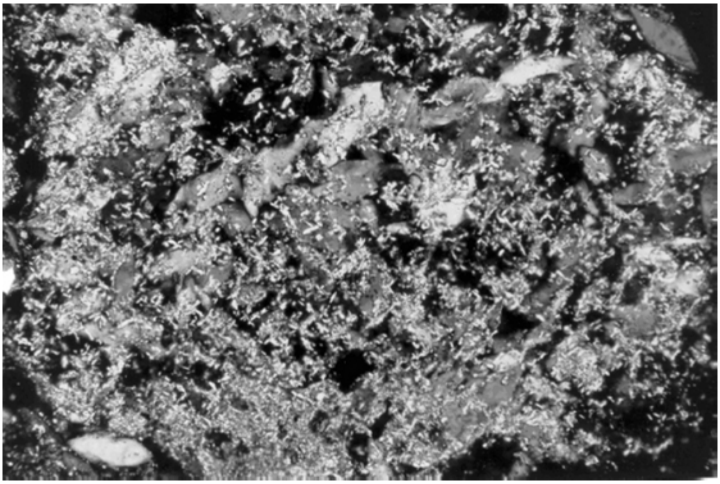

Fig. 6. Detail of the soil groundmass

pattern of the gypsum crystals and the fine material is random. Fragments of crusts are frequently found. They reflect previous stages of crust formation.

The results of X-ray diffraction analysis of undistributed samples of gypsum crusts are presented very much gypsum on the crust, much calcite, moderate amounts of quartz and few clay minerals.

The two distinguished layers within the observed crust represent two different stages of surface crust formation. Lenticular gypsum crystals are produced under semiarid conditions by gypsum weathering.

Eswaran et al. (1981) reported the occurrence of many very fine, lenticular crystals of gypsum, very closely packed. A petrogypsic horizon surface crust is governed by a complex sequence of soil particle detachment and transport processes at the soil surface. First particle detachment is achieved by various mechanisms:

- Disaggregation by entrapped air compression upon moistening of aggregates.
- Disaggregation by rain drop impact and/or flow turbulence.
- Micro cracking by shrinking and swelling.
- Physicochemical dispersion, resulting in the detachment of aggregates which individually greatly vary.

The textural fining upward within one layer in the crust is typical for water deposition: first sedimentation of the coarse particles continuously followed by deposition of the finer particles.

Both layers depend on particle transport and sedimentation modes, which determine two main morphological types, i.e structural crust and deposition crust (Chen et al. 1980). Compaction due to raindrop impact may play a great part in soil crusting. McIntyre (1958) attributed skin seal formation to this process.

Capillary Barrier

Considering the porosity of the crust, it is condensed but especially the fine textured, dense packed upper part of both layers could hinder water conductivity.

Current polarized light one insert two polarized filters in the microscope. All lights waves are observed, but a crystalline mineral placed between the polarizer's results in birefringence.

The loss of porosity in the upper part of layer one and two and the smallest volume of it is considered as a clear incidence of the rainfall energy. This energy is reduced the volume of macroporisity and elongated porosity. The loss porosity by clogging it with disintegration of aggregate soils to smaller and finer units. As gypsum and calcite (Poch and Verplancke 1997). As a result the crust strength will be increased and the infiltration are decreased. Also for vughs are presented in the lower part of layer one and two in microstructure crust have irregular shape, and some of it are spherical and it is correlated with escaping of compressed air under the surface, and the soil ponding with rainfall, and the fine grains these factors are limited the air from escaping and substituted with water infiltration which limited. Microstructure of crust formation reduced the porosity from 30 to 90% (West et al. 1990).

Conclusions

Morphological descriptions of gypsiferous crusts are a useful tool to help explain crust behavior and to provide direct evidence of processes that have been important to the development of the crust. Pore size, shape, and amount in the crust as compared to uncrusted soil, layers of micromass accumulation and it consist of gypsum, calcite, silt and clay mineral. Additionally, these characteristics when coupled with crust thickness, low porosity and crust strength may help to explain the decline infiltration and seedling emergence in gypsiferous crust behavior observed.

References

Bullock P et al. (eds) (1985) Handbook for thin section description. WAINE Research Publications. Albrighton, Wolverhampton, UK

Chen Y, Tarchitzky J, Brouwer J, Morin J, Banin A (1980) Scanning electron microscope observations on soil crusts and their formation, Soil Sci 130:45–55

Eswaran H, Ilawi M, Osman A (1981) Mineralogy and micromorphology of aridsols. In: Proc 3rd Int Soil Classification Workshop, ACSAD/SS/P17, Damascus, Syria:153–174

FitzPatrick EA (1993) Soil microscopy and micromorphology. ohn Wiley & Sons, New York

Gal M, Arcan L, Shainberg I, Keren R (1984) Effect of exchangeable sodium and phosphogypsum on crust structure-scanning electron microscope observations, Soil Sci Soc Am J 48:872–878

Gafarzadeh AA, Zinck JA (2000) Penetration resistance of gypsum crust from laboratory experiments. Thesis, Wyecollege, University of London, UK

Gee GW, Bauder JW (1986) Particle size analysis. In: Klute A (ed) Methods of soil analysis, Part 1, 2nd ed. Agron Monogr No 9, ASA and SSSA, Madison, WI:383–409

Gooderham PT (1973) Soil physical conditions and plant growth. PhD Thesis, University of Reading, UK

Habib H, Robert M (1992) Morphological study of som gypsiferous soils from the Middle Euphrates Basin (Syria)

Ilaiwi M (1983) Contribution to the knowledge of the soils of Syria. PhD Thesis, University of Ghent, Belgium

Jafarzadeh AA (1991) Experimental studies of gypsum migration and deposition in soil profiles. PhD Thesis, Wye College, University of London, UK

McIntyre DS (1958) Permability measurements of soil crusts formed from raindrop impacts, Soil Sci 85:185–189

Nafie FAA (1989) The properties of highly gypsiferous soils and their significance for land management. PhD Thesis, Wye College, University of London, UK

Nelson RE, Somers LE (1986) Total carbon, organic carbon and organic matter. In: Page AL, Miller Rh, Keeny DR (eds) Methods of Soil Analysis, Part 2, 2nd ed. Agron Monogr No 9, ASA and SSSA, Madison, WI:539–577

Nelson RE (1986) Carbonate and gypsum. In: Page AL, Miller Rh, Keeny DR (eds) Methods of Soil Analysis, Part 2, 2nd ed. Agron Monogr No 9, ASA and SSSA, Madison, WI:181–196

Poch RM, Verplancke H (1997) Penetration resistance of gypsiferous horizons, Eur J Soil Sci 48:535

Stroosnijder L (1995) Crust formation, crust properties and crust control. Lecture 2. In processes and models in soil and water conservation. K200–507. Department of irrigation and soiul & water conservation, Wageningen Agricultural University, The Netherland

Watson A (1982) The origin, nature and distribution of gypsum crusts in deserts. PhD Thesis, University of Oxford, UK

West LT, Bradford JM, Norton LD (1990) Crust morphology and infiltrability in surface soils from the southeast and Midwest U.S.A. In: Douglas LA (ed) Soil micromorphology: A basic and applied science. Elsevier, Amesterdam, Developments in soil science 19:107–113