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Characterization and Origin of Gypsum Rhizoliths of Ziban Oases Soil-Algeria

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Abstract: At the piedmont of the Boughzel Mounts, the field observation allowed to highlight the existence of rhizoliths with plant roots colonizes soils with gypsum accumulations of phreatic water.The high contents of calcium sulfate reveal the gypsum nature of the mineral roots. The study of the X-ray diffraction denoted that rhizoliths are composed mainly of gypsum and secondarily by quartz, calcite and hematite. Geochemical calculations showed that the horizons prospected by rhizoliths are controlled by super-saturated calcium sulfate water, for a precipitation of gypsum all-around plant roots of *Tamarix africana* and *Limoniastrum guyonianum* governed by high evapotranspiration. Microscopic observation shows that the gypsum precipitation affects the roots and absorbent bristles to form with the sand particles a sheath surrounding plant roots, after a process of concentration of the solution. Furthermore, the heights, the size and the gypsum rhizoliths density seem to be dependent on the movement of the soil solution through a sand substratum, of the distribution of plant roots movement of the phreatic water as well. Lastly, it is suggested that the formation of gypsum rhizoliths accompanied by a concomitant decline static phreatic water levels allow to predict that the Ziban oases soil undergo contemporary pedogenesis generating the differentiation of gypsum horizons.

Key words: Rhizoliths · Gypsum · Phreatic water · Saturation Index · Aridity · Ziban

INTRODUCTION

Satellite images analysis revealed that Ziban oases are well distinguished by soil with gypsum accumulations occupied by date palm [1]. These soils are in contact with permanent and shallow phreatic water contained in a quaternary sandy material [2, 3]. In this Southeast Algerian oases, the phreatic water is commonly; captured by false and shallow well in the palm groves; to be exploited for irrigation [4]. Thus, under comparable conditions; several studies have attributed the genesis of soil gypsum accumulations to gypsum precipitation by evaporation [5-8].

In oases of Ziban, there are two types of rhizoliths: the rhizoliths in carbonate shell found in the gypsum and limestone formations of medium quaternary [9, 10], making a strong effervescence with hydrochloric acid and free plant roots. Quite the opposite; in soils with gypsum accumulations subject to shallow phreatic water; the red-yellowish rhizoliths are very abundant and clearly differentiated in the oued banks at the piedmont of the Boughzel Mounts; along the national road Nº 46 between the city of Biskra and the region Tolga.

At present, many works were carried out in order to study the characterization origin and classification of carbonate rhizoliths [11-14]. They are; also; studied as hydrological [15] paleopedological [16, 17], sedimontological [18-20], paleoenvironmental [21, 22] and paleoclimatic indicators [23-25]. In contrast, only few works are devoted to the study of soils rhizoliths gypsum accumulations.

This study deals with the characterization of the mineralized roots of soils with gypsum accumulations of phreatic nappe in an oasis in the Algerian Sahara, to understand their formation mechanisms and their pedological meanings. To address this issue: a description of rhizoliths, an X-ray mineralogical analyzes and microscopic observation, confronted with a geochemical study of phreatic nappe and soils prospected by rhizoliths in order to clarify the differentiation of these mineral roots process.

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Presentation of the Area of Study

Geographical Setting: The study area is located a few kilometers southwest of the Biskra city (administrative centre) at 425 km in the south-east of the capital Algiers (Algeria). It occupies an area of 21Km long and 4km wide at the piedmont of the Boughzel Mounts. This area includes the palm groves of El Hadjeb, Ain El-Karma and Bouchegroun. The climate is arid with a dry period along the year. The highest average temperature is noted in July with 41,4c ° while the rainfall is 104.4mm / year. The annual evapotranspiration is of 2100 mm calculated using the Penman formula.

Soils: From a pedological perspective; the gypsum horizon is more differentiated. It is rooted at different depths in a sandy material [2, 9]. The soil profile is distinguished by the presence of rhizoliths and shallow phreatic water. It has 2-3 distinguished horizons: a horizon of sandy area, a second composed of sand gypsiferous and a third gypsum horizon, deeper and tender in contact with phreatic water. The profile is provided in gypsum, levels range from 13.25% to 71.3% with a decreasing gradient from bottom to top. $CaSO_4.2H_2O$ rates are consistent with those reported by [1]. Limestone is between 10 and 16%; this quantity decreases to low values for gypsum horizons. The pH is slightly alkaline. The assessment of the electrical conductivity values indicate a high salinity within an electrical conductivity of 6.1 dS / m; particularly; in date palm environment.

MATERIALS AND METHODS

Sampling: Field observations, description and rhizoliths samples were carried out in oued Ain Ben Naoui (34°48'26"N, 5° 39 '03"E, Z = 119m), in oued Kodiet RFIS (34° 44 '37"N, 5° 29' 23"E, Z = 152m), oued El Malleh (34° 44 '54"N, 5° 30' 28"E, Z = 144m). To better understand the role of phreatic water in the genesis of rhizoliths; geochemical analysis is executed out on 25 points of phreatic water and 30 representative horizons distinguished by gypsum accumulations under generalized forms (crust, crusting and gypsiferous sand) and localized deposits (rhizoliths).

Analysis Methods: The soil and water analyses are carried out according to the soil and plants analysis methods manual [26]. For soil, the extraction of soluble salts is carried out according to a 1/5 extract. The pH is measured using a pH meter according to the land / water ratio of 1 / 2.5. Carbonates and bicarbonates are determined by titration with sulfuric acid in the presence of phenolphthalein. Chloride is determined by titration with AgNO3 in the presence of potassium dichromate. The analysis of the sulphate is based on the formation of an insoluble compound with barium; the concentrations are determined by a colorimeter at 600 nm. Calcium and magnesium were determined by atomic absorption spectrophotometry. Sodium and potassium are determined by spectrophotometry is atomic emission. The gypsum is metered by the acetone method. The total limestone is determined by the calcimeter Bernard. The Organic material is evaluated by the Anne method. The principle consists in oxidation of organic carbon by dichromate potassium in strongly acidic medium with H_2SO_4; in steam-heated environment, titration is carried out with ammonium iron sulphate.

The saturation status of aqueous solutions with respect to the minerals is evaluated by its **S**aturation **I**ndex: SI > 0: supersaturated status of the aqueous solution, SI < 0: under-saturated status of the aqueous solution and SI = 0: the minerals in the aqueous solution are in equilibrium).The saturation index and activities of ions estimated from chemical analyzes were calculated using the law of Debye-Hückel through Phreeq program. This model is widely applied to different salt solutions [2, 4, 27, 28].

Mineralogical study is conducted by X rays diffraction, D8 ADVANCE-BRUKER, copper anticathode. Minerals are determined on the fraction of the soil sieved to 2mm; according to Bragg's law; using the software X 'Pert High Score, 2,1b Version (2, 1.2) produced by PANalytical.B.V.Almelo; in Netherlands, minerals identification is performed by the minerals Identification Manual Hand book of soil analysis of [29]. Microscopic examination is conducted on mineralized roots of millimetric sizes in a precision optical microscope, loaded with a camera like Sony Paralux, Model No. SSC -DC198P, seriated No. 405579, made in Japan.

RESULTS AND DISCUSSION

Morphological Characterization of Rhizoliths: The dislocation of the oued banks; under the effect of temporary runoff; has highlighted the existence of rhizoliths trapped in blocks of gypsum crust. *Tamarix africana* and *Limoniastrum guyonianum* are host plants around which grow the rhizoliths. These types of mineralized roots were; also; reported in the salty depression of the region of Fayum in Egypt [30] and in the gypsum crusts in northern Kuwait [31].

Fig. 1: Rhizoliths of gypsiferous sand

Fig. 2: Rhizoliths of gypsum crust.

Fig. 3: Gypsum crust overcomes the rhizoliths layer.

The rhizoliths encountered in the study area are distinguished in two colors: dark red rhizoliths (Figure 1) and red-yellowish rhizoliths (Figure 2). They are oriented

Fig. 4: Gypsum crusting prospected by rhizoliths.

Fig. 5: Circular forms of rhizoliths cross sections.

vertically and they crumbled by hand. In more advanced cases, they are forty centimeters of long. The first types of rhizoliths are well developed in a layer of gypsiferous sand of 1.35 meter thick capped by a hardened gypsum crust of 0.8mètre thick (Figure 3).. They are devoid of plant roots but are filled with sand. On the opposite, the second type of rhizoliths is provided with plant roots and root hairs; this is the reason for which we differentiate between new and old rhizoliths. These mineral colonize roots; at 3.5 meters deep; the softer layer of gypsum crust (Figure 4).

The observation of cross sections of rhizoliths show that they have circular shapes millimeter (Figure 5). They are structured by an envelope constitutes of particles of sand and gypsum microcrystalline well individualized under microscopy. It results from (Figure 6) that the mineralization of plant roots is dependent on a potting of soil particles with a

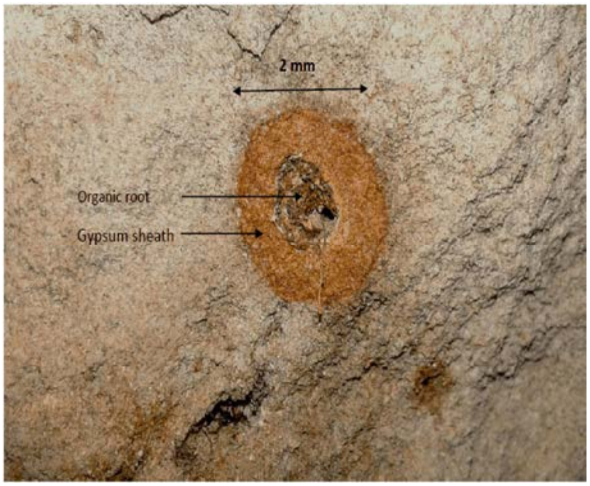

Fig. 6: Rhizoliths provided with plant roots.

concentration of the solution and precipitation of gypsum. This result in a plant root growth arrest for increasing the size of the mineralized root after minerals precipitation phase driven by a progressive aridity.

Thus, it is suggested that in evaporate conditions; the phreatic water feeds the soil in solution loaded with calcium sulfate, through a sand material, leading to the gypsum precipitation around the roots of living plants to produce gypsum roots. The plasticity of root systems of host plants appears as such as an explanatory mechanism of mineralization of plant roots; it also contributes; to the concentration of ions of less soluble salts to achieve supersaturation and precipitation of minerals. The heights of the mineralized root indicate static levels achieved by the supersaturated solution of calcium sulfate before the regression of the phreatic water, in a highly arid episode. Moreover; the denser structures of rhizoliths are; particularly; differentiated in the deepest horizons in contact with the phreatic water.

Finally; we can predict that the preservation of gypsum rhizoliths in the profile interprets contemporary pedogenesis of soil with gypsum accumulations driven by a soil solution in the presence of active phreatic water. In contrast, carbonated rhizoliths are studied as an indicator of palaeosols [16, 17, 32].

Rhizoliths Chemical Properties: Chemical properties represented by the Table below show that the rhizoliths include 55.63% of gypsum, 12.5% of limestone and 0.65% of organic matter. With an alkaline pH and EC of 1.7dm / m, the chemical facies of the rhizoliths solution is characterized by a predominance of calcium for cations and sulfates for anions.

Table 1: Physical and chemical properties of gypsum rhizoliths

CE ds/m 1 /5	pH 1 /2.5	$CaSO_4.2H_2O$ (%)		$CaCO_3$ (%)		MO (%)	
1.7	8.17	55.63		12.5		0.65	
	Ionic concentrations ($mMol.L^{-1}$)						
Paramètres	Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	SO_4^{--}	HCO_3^-
	11.1	3.2	2.8	0.3	1.53	15.03	0.5

Equilibrium Diagram of Solutions with Respect to Gypsum: To better appreciate the role of soil solution and phreatic water in the formation of rhizoliths of the study area; a geochemical study is conducted to this purpose.

The graphical representation of saturation diagram with respect to the gypsum shows that the phreatic water are supersaturated with gypsum (Figure 7.A) to the exception of few water points that are in equilibrium or under-saturated towards $CaSO_4.2H_2O$ in comparison with to the theoretical equilibrium equation: log (Ca $^{++}$) + log (SO_4^-) + 2 log (H_2O) = - 4.85. According to [2, 4, 27, 28, 33], the supersaturation status of the aqueous solution causes precipitation of minerals, while the under-saturation status leads to dissolution of minerals.

(Figure 7.B) shows that the horizons prospected by rhizoliths are those; exclusively; supersaturated with respect to gypsum. In addition; geochemical calculation of the state of saturation of the solution of rhizoliths shows that the saturation index (SI) of anhydrite and gypsum are superior to zero.

Thus; results consolidate the trend of the formation of gypsum rhizoliths under the impact of the phreatic water and soil loaded calcium sulfate solution. On the contrary, carbonated rhizoliths are formed; only; around the sources of fresh water rich in calcium bicarbonate as it was highlighted by [11, 12, 15, 21, 22].

Mineralogical Study of Rhizoliths: The study of X-ray diffraction reveals that mineral roots are differentiated; essentially; by the presence of calcium sulfate minerals (Figure 8). Gypsum and anhydrite are the most dominant; these two minerals are commonly associated [34, 35] and they are observed; frequently; in arid climate [36, 37]. Quartz and calcite are secondarily rhizoliths Minerals. [33, 38, 39, 40] have suggested that the increase of the gypsum content is proportional to the rate of regression of quartz and calcite.

Microscopic Study of Rhizoliths: Microscopic observation shows that the genesis of rhizoliths begins with a single coating by precipitation of gypsum in the form of clusters to the towers of the walls of plant roots and hair. This gypsum precipitation mechanism

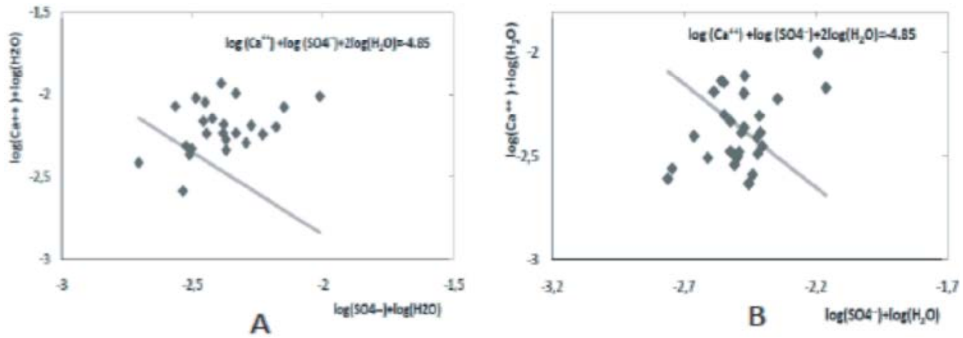

Fig. 7: Equilibrium diagram of solutions with respect to gypsum.

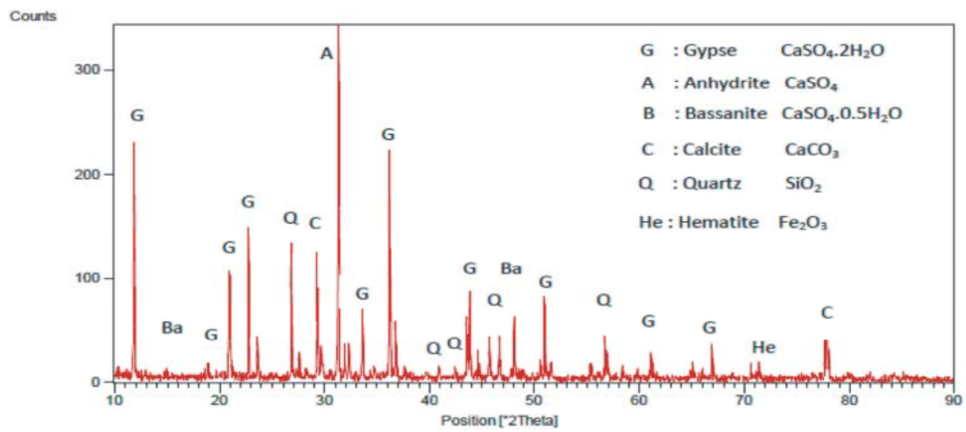

Fig. 8: X-rays diffraction of gypsum rhizoliths.

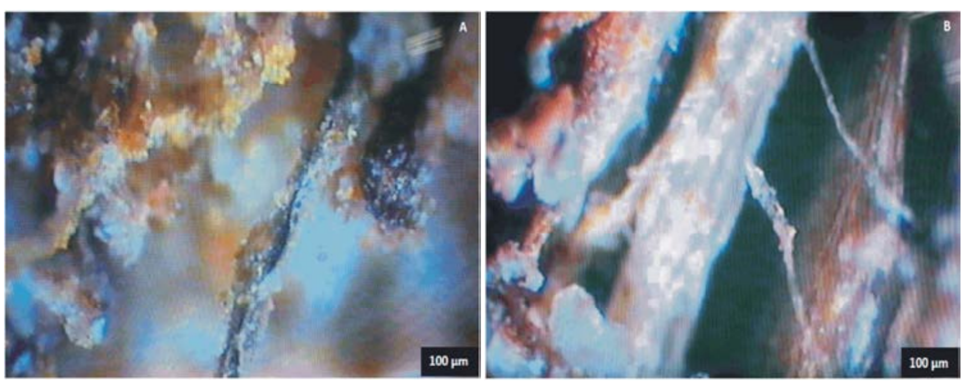

Fig. 9: Mineralization of plant roots (A) and absorbent bristles (B).

represents, according to [41, 42,43] an advanced step of crystallization of $CaSO_4.2H_2O$. Figure (9. A and B) shows that the calcium sulphate is the fundamental element of the structure of rhizoliths secondarily accompanied with grains of sand agglutinated by gypsum.

CONCLUSION

In the oases of Ziban, soils with gypsum accumulations of phreatic water are differentiated by the presence of rhizoliths. Field observations show that wherever static phreatic water levels are lowered, the concentration of the solution under the effect of high evapotranspiration; allowed the formation of rhizolithes around plant roots. The heights, the size and density of rhizoliths reveal the role of vegetation in building these mineral roots.

The geochemical study confronted with a mineralogical analysis and microscopic observation confirmed the nature of gypsum rhizoliths. The formation of these mineral roots depends by the soil solution and phreatic nappe supersaturated in calcium sulphate and high evapotranspiration. Finally, It's suggested that the formation of rhizoliths still happening now around the roots of living plants; this leads to the predict that the gypsum accumulations formation process continues to the present day led by phreatic water.

REFERENCES

1. Mostphaoui, T., R. Bensaid and M.L. Saker, 2013. Localization and Delimitation of the Arid Soils by Remote Sensing and In-Situ Measurements in an Arid Area: Case of Oued Djedi Watershed, Biskra, Algeria. World Applied Sciences Journal, 24(3): 370-382.
2. Chabour, N., 2006. Hydrogéologie des Domaines de Transition entre l'atlas Saharien et la Plateforme Saharienne à l'Est de l'Algérie. Thèse de doctorat, Université Mentouri Constantine.
3. Chebbah, M., 2007. Lithostratigraphie, Sédimentologie et Modèles de Bassins des Dépôts Néogènes de la Région de Biskra, de part et d'autre de l'Accident Sud Atlasique (Zibans, Algérie). Thèse de Doctorat d'Etat Université Mentouri, Constantine. Algérie.
4. Bouziane, M.T. and A. Labadi, 2009. Les eaux profondes de la région de Biskra (Algérie). European Journal of Scientific Research, 25(4): 526-537.
5. Khadami, H. and A.R. Mermut, 2003. Micrromorphology and classification of argids and Associated Gypsiferous Aridisols from Central Iran. Catena, 54: 439-454.
6. Rouchy, J.M. and M.M. Blan-Valleron, 2009. Les Evaporites. Matériaux Singuliers, Milieux Extrêmes. Ed. Société Géologique de France.
7. Abbaslou, H., A. Abtahi, M.P. Jose–Martin, M. Baghenajad and M. Razaei, 2012. Mineralogical Characteristics of Calcareous, Gypsiferous and Saline Materials of Arid Soils (Hormofgan Province, Southern Hran).Macla. Revista de la sociedad española de mineralogía, 16(12): 86-87.
8. Aznar, J.M., R.M. Poch R.M. and D. Badía, 2013. Soil Catena along Gypseous Woodland in the Middle Ebro Basin: Soil Properties and Micromorphology Relationships. Soil Spanish Journal of Soil Science, 3(2): 11-17.
9. Ballais, J.L., A. Marre et P. Rongon, 1979. Périodes Arides du Quaternaire Récent et Déplacement des Sables Eoliens dans les Ziban. Revue de Géologie Dynamique et Géographie Physique, 21(2): 97-108.
10. Ballais, J.L., 1986. Variations du Milieu à l'Holocène dans les Aurès (Algérie). Actes des conférences du 1986, du Symposium International des Changements Globaux en Afrique durant le Quaternaire, Sénégal, pp: 30-32.
11. Owen, R.A., R.B. Owen, R.W. Renault, J.J. Scott, B. Jones and G. Arshley, 2008. Mineralogy and Origin of Rhizoliths on the Margins of Sline, Alkaline lake Bogoria,Kenya, Rift Valley. Sédimontology Geology, 203: 143-163.
12. Wright, V.P., M.E. Tucker and C.F. Klappa, 2009. Rhizoliths in Terrestrial Carbonates: Classification, Recognition, Genesis and Significance. Sedimentology, pp: 149-165.
13. Gocke, M., Y. Kuzyakov and G.L.B. Wiesenberg, 2013. Differentiation of Plant derived Organic Matter in Soil, Loes Sand Rhizoliths based on n-Alkane Molecular Proxies. Biogeochemistry, 112(1): 23-40.
14. Holliday, V.T. and D. Killick, 2013. An Early Paleoindian Bead from the Mockingbird Gap Site. New Mexico Chicago Journals, 54(1): 85-95.
15. Kraus, M.J. and S.T. Hasiotis, 2006. Significance of Different Modes of Rhizoliths Preservation to Interpreting Paleoenvironmental and Paleohydrologic Settings: Examples from Paleogene Paleosols, Bighorn Basin, Wyoming, USA. Journal of Sedimentary Research, 76: 633-646.
16. Bertoni-Machado, C. and M. Holz, 2006. Biogenic Fossil Concentration in Fluvial Settings: an Example of a Cynodont Taphocoenosis from the Middle Triassic of Southern Brazil. Revista Bras, Paleont, 9(3): 273-282.
17. Texier, J.P., J.P. Raynal, D. Lefèvre, J.P. Daugas and F.Z. Sbihi-Alaoui, 2008. Le site Néolithique de Rouazi à Skhirat (Maroc): Contexte Stratigraphique et Evolution Morpho-Dynamique de son Environnement Littoral-Quaternaire, 19(3): 239-247.
18. Loope, D.P., 1988. Rhizolths in Anciens Eolianites. Sedimontology Geology, 56: 301-314.
19. Liutkus, C.M. and J.D. Wright, 2008. The influence of Hydrology and Climate on the Isotope Geochemistry of Playa Carbonates: a Study from Pilot Valley, NV, USA. Sedimentology, 55: 965-978.
20. Brasseur, F. Sémah, E.M. Sémah and T. Djubiantono, 2011. Approche Paléopédologique de l' Environnement des Hominidés Fossiles du Dôme de Sangiran (Java Central, Indonésie) Quaternaire, 22(1): 13-34.

21. Gocke, M., K.P. Pustovoytov, P. Kühn, G.L.B. Wiesenberg, M. Löscher and Y. Kuzyakov, 2011. Carbonate Rhizoliths in Loess and their Implications for Paleoenvironmental Reconstruction Revealed by Isotopic Composition: δ13C, 14C.Chemical Geology, 283: 251-260.
22. Tabor, N.J., T.S. Myers and M. Roy, 2015. Paleosols as Indicators of Paleoenvironment and Paleoclimate. Annual Review of Earth and Planetary Sciences, 43: 333-361.
23. Khokhlova, O.S., I.S. Kovalevskaya and S.A. Oleynik, 2001. Records of Climatic Changes in the Carbonate Profiles of Russian Chernozems. Catena, 43: 203-215.
24. Kuzyakov, Y., E. Shevtzova and K. Pustovoytov, 2006. Carbonate Re-Crystallization in Soil Revealed by 14C labeling: Experiment, Model and Significance for Paleo-Environmental Reconstructions. Geoderma, 131: 45-58.
25. Bai, Y., X.M. Fang, J.S. Nie, X.L. Wang and F.L. Wu, 2009. A preliminary Reconstruction of the Paleoecological and Paleoclimatic history of the Chinese Loess Plateau from the Application of Biomarkers. Palaeogeogr Palaeoclimatol. Palaeoecol., 271: 161-169.
26. Pauxwels, J., E. Van-Ranste, M. Verloo and Z.E. Mvondo, 1992. Manuel de Laboratoire de Pédologie, Méthodes d'analyses de Sols et de plantes; Equipement et Gestion des Stocks de Verrerie et de Produits Chimiques. Publications Agricoles A.G.C.D, Bruxelles, Belgium.
27. Rezaei, M., 2010. Application of Statistical Methods, Saturation Indices and the Composite Diagrams in the Groundwater Quality Assessment in the Kerman Plain Aquifer. Winter (IR-WRR), 5(3): 8-10.
28. Li, P., W. Jianhua and J. Hui Qian, 2014. Hydrogeochemistry and Quality Assessment of Shallow Groundwater in the Southern Part of the Yellow River Alluvial Plain (Zhongwei Section), Northwest China. Eart Sci. Res. J., 18(1): 27-38.
29. Pensu, M. and J. Gutheyrou, 2003. Handbook of soil analysis mineralogical,Organic and Inorganic Methods. Published by Spinger-Verlag.
30. Aref, M.A.M., 2003. Classification and Depositional Environments of Quaternary Pedogenic Gypsum Crusts (Gypcrete) from East of the Fayum Depression, Egypt. Sedimentary Geology, 155: 87-108.
31. Khalaf, F.I., A. Al-Zamel and I. Gharib, 2014. Petrography and Genesis of Quaternary Coastal Gypcrete in North Kuwait, Arabian Gulf. Geoderma, pp: 223-230.
32. McCarthy, P., I. Martini and D. Leckie, 1998. Use of micromorphology for palaeoenvironmental interpretation of complex alluvial palaeosols: an example from the Mill Creek Formation (Albian), southwestern Alberta, Canada: Palaeogeography, Palaeoclimatology, Palaeoecology, 143: 87-110.
33. Hamdi-Aissa, B., V. Valles, A. Venturier and O. Ribolzi, 2004. Soils and brine geochemistry Andmineralogy of hyperarid desert playa, Ouargla Basin, Algerian Sahara. Arid Land Research and Management, 18: 103-126.
34. Pinto, A.J., J. Carneiro, D. Katsikopoulos, A. Jimenez and M. Prieto, 2012. The Link between Brushite and Gypsum: Miscibility, Dehydration and Crystallochemical Behavior in the $CaHPO_4•2H_2O$-$CaSO_4•2H_2O$ System. Cryst. Growth Des, 12: 445-455.
35. López-Delgado, A., S. López-Andrés, I. Padilla, M. Alvarez and R. Galindo, 2014. Dehydration of Gypsum Rock by Solar Energy: Preliminary Study.Geomaterials, 4: 82-91.
36. Deshmukh, K.K., 2012. Mineralogical and Textural Characteristics of Soils from Sangamner Area, Ahmednagar District, Maharashtra, India. Cur. Wor. Environ., 7(1): 41-48.
37. Ghadimi, F. and M. Ghomi, 2013. Geochemical and Sedimentary Changes of the Mighan Playa in Arak, Iran.Iranian Journal Sciences, 5: 25-32.
38. Halitim, A. and M. Robert, 1987. Interaction du Gypse avec les autres Constituants du Sol. Analyse Microscopique des Sols Gypseux en Zone Aride de l'Algérie et étude expérimentale.. Micromorphologie des sols. Ed. AFES. Actes de la 7ème réunion internationale de Micromorphologie des sols 1987, pp: 176-185.
39. Halitim, A., 1988. Les sols des Régions Arides d'Algérie. Edition O.P.U.
40. Watson, A., 1988. Desert Gypsum Crusts as Palaeoenvirenemental indicators: A Micropetrographic Study of Crusts from Southen Tunisia and the Central Namib Desert.Journal of Arid Environments, 15: 19-42.
41. Boyadgiev, T.G. et A.H. Sayegh, 1992. Forms of Evolutions of Gypsum in Arid Soils and Soil Parent Materials. Pédologie, 11: 171-182.

42. Boumaraf, B., 2015. Caractéristiques et fonctionnement des sols dans la Vallée d'oued Righ, Sahara nord oriental, Algérie. Thèse de doctorat, Université de Biskra.

43. Moazallahi, M. and M.H. Farpoor, 2009. Soil micromorphology and Genesis along a Climotoposequence in Kerman Province, Central Iran. Australian Journal of Basic and Applied Sciences, 3(4): 4078-4084.