

Physico-chemical characteristics and clay mineralogy composition of selected soils in arid and semiarid regions of Iran

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Knowledge of soil types and their properties is highly important in determining constraints and potential as well as better utilization of soils. Clay minerals are important fractions of the soil solid phase and many soil physical and chemical characteristics are controlled by clay minerals. Identification of clay minerals in soils is very important so that Brady (1990) believed that the type of soil minerals showed stages of soil weathering. This depends on the type and quantity of the clay minerals. Better understanding of characteristics of clay minerals and their relationship to soil physico-chemical properties help researchers to better predict behavior of soils in the fields of agriculture and environment (Wilson, 1999). Various studies conducted on the clay minerals in the arid and semiarid environment, showed the existence of, chlorite, illite, smectite, vermiculite, and palygorskite minerals (Khademi and Mermut, 1998; Owliaie et al., 2005). The purpose of this research was to study mineralogical composition of soils developed under dry climatic condition in Karaj and Eshtehard regions located in central part of Iran.

Eight sites were selected from dominant soil series developed under arid and semiarid condition. The soils were classified under Aridisols and Entisols orders. The composite soil samples were taken from 0-25 cm. Particle sizes analyses were made using the hydrometer method with reading during 48 hours (15 time interval) and made all corrections for determining particle size distribution (Sparks et al., 1996). Soil pH and EC were measured in a saturation extract. Organic matter was determined using Walkley–Black wet digestion method and cation exchange capacity (CEC) was measured according to the ammonium acetate (pH=7.0) method (Sparks et al., 1996). Equivalent calcium carbonate was measured using titration method (HCl 1M) (Sparks et al., 1996). Water soluble Na and K were determined in saturation extract by Flame photometer. Water soluble Ca and Mg were measured by titration method (EDTA) (Sparks et al., 1996). For clay mineralogical identification, the soil samples were washed with distilled water and checked with silver nitrate (AgNO₃) for removal of soluble salts. Then, samples were treated with 30% H₂O₂ and heated on a water bath (60 -70 °C) to remove organic matter. The soil samples were treated with 1 M sodium acetate (pH=5) solution, and heated on a water bath (60 -70 °C) to remove CaCO₃. The samples were dispersed and fractionated into clay fractions (<2 mm) according to the Stokes' Law. The oriented clay mineral aggregates were studied using an X-ray diffractometer (Pw1800) (Kunze and Dixon, 1986; Whittig and Allardice, 1986). Transmission Electron Microscopy (PHILIPS, EM 208S model) and Scanning Electron

Microscopy (ZEISS, DSM 960A model) techniques was utilized to identify palygorskite and sepiolite clay minerals in eight dominant soil series.

Table1. Physical and chemical characteristics of soils.

	Clay (%)	Silt (%)	Sand (%)	Texture	EC (dS/m)	pH	Na ⁺ (mg/L)	K ⁺ (mg/L)	Ca ⁺⁺ (mg/L)	Mg ⁺⁺ (mg/L)
Soil 1	28.75	51.87	19.37	Silty Clay Loam	1.003	8.6	79.30	19.92	90.18	37.67
Soil 2	27.02	43.82	29.16	Loam	0.864	8.52	64.24	9.90	120.23	14.58
Soil 3	22.56	24.67	52.77	Sandy Clay Loam	4.45	8.34	479.28	25.94	480.94	80.21
Soil 4	28.66	29.95	41.39	Clay Loam	0.995	8.39	27.21	14.91	108.21	29.17
Soil 5	16.70	23.14	60.16	Sandy Loam	0.62	8.46	11.18	16.92	110.21	13.98
Soil 6	54.11	29.36	16.53	Clay	1.678	8.67	251.24	19.42	100.20	14.58
Soil 7	54.26	42.97	2.78	Silty Loam	88.5	7.19	25418.98	132.09	4158.09	3238.64
Soil 8	58.85	38.19	2.95	Clay	60.1	7.73	17627.90	70.05	1372.67	436.27

	CEC (meq/100g)	CaCO ₃ (%)	OC (%)	SAR	CEC/Clay	Soil Classification	Soil type
Soil 1	11.69	22.03	0.97	1.77	40.66	Haplo Cambids	Nonsaline
Soil 2	13.90	11.83	0.56	1.06	51.44	Haplo Cambids	Nonsaline
Soil 3	11.29	15.86	0.80	5.33	50.04	Haplo Cambids	Saline
Soil 4	27.80	8.43	2.43	0.60	96.99	Xeric torriorthents	Nonsaline
Soil 5	9.52	10.20	0.31	0.27	57.00	Xeric torriorthents	Nonsaline
Soil 6	20.07	31.47	1.26	6.21	37.09	Aquic Natrargids	Nonsaline
Soil 7	12.87	21.40	0.60	71.82	23.72	Haplo Salids	Saline-Sodic
Soil 8	17.65	21.15	0.51	106.13	29.99	-	Saline- Sodic

Table 1 shows physical and chemical properties of the soils studied. X-ray diffraction analysis indicated that illite and chlorite clay minerals were the dominant clay minerals in the soils studied (Fig. 1). The origin of illite and chlorite was mainly from the parent materials. The amount of vermiculite and smectite were higher in the soil 4 developed under irrigated orchards (Fig. 2). This could be the result of the removal of interlayered K and the leaching of K ions from the illitic clay minerals due to intensive irrigation and cultivation practices. The higher ratio of cation exchange capacity to percent clay content of soil 4 (96.99 cmol Kg⁻¹ clay) indicated the higher amounts of expansible clay minerals in this soil. Illite and chlorite clay minerals were also higher in the soils formed in the higher elevation on the calcareous parent material. Palygorskite and smectite were found in the higher amounts in the lower areas under the saline and sodic condition. The SEM and TEM (Figs. 3 and 4) confirmed the higher amounts of the palygorskite in the soils developed under highly saline-sodic condition (EC > 60 dS/m and SAR > 70). This study indicated that the clay minerals including illites and chlorites were the major clay minerals in most of the soil studied, but palygorskite was present in higher amounts in the highly saline -sodic soils developed on the marl formation during the Miocene period.

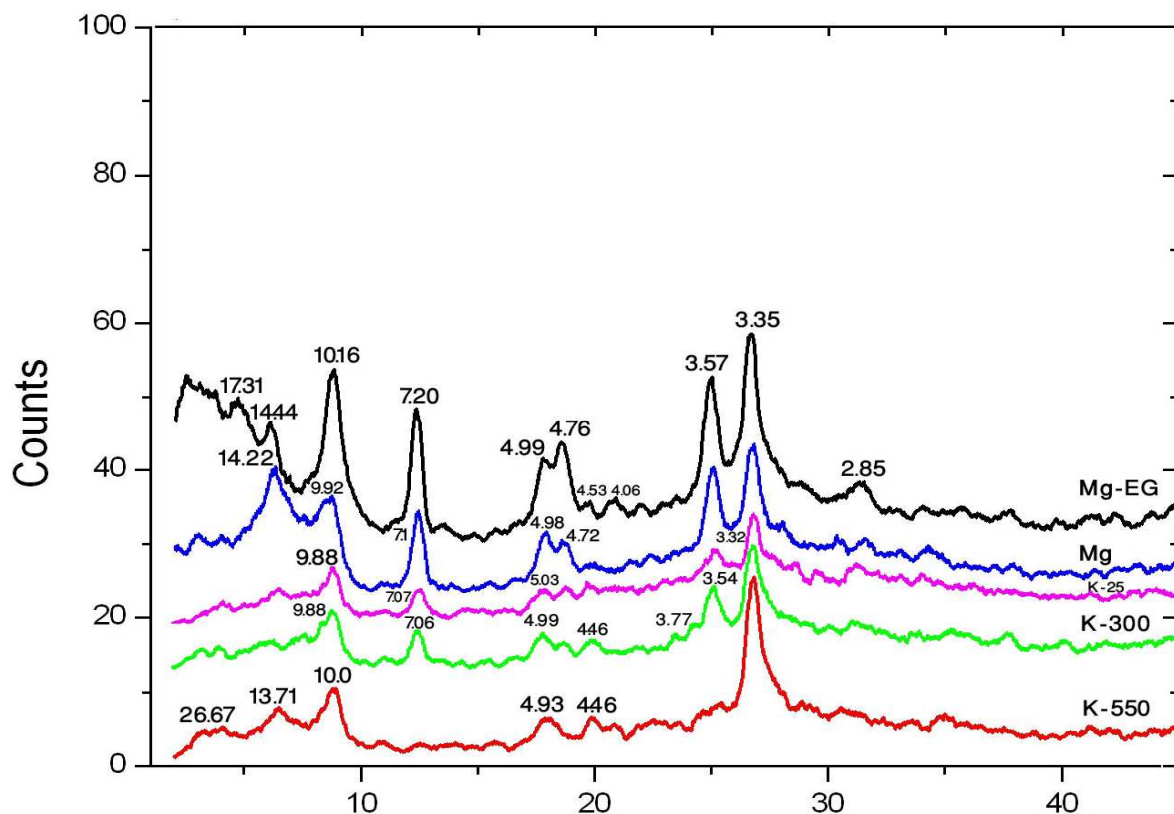


Fig.1. The X-ray diffractograms of the clay fraction.

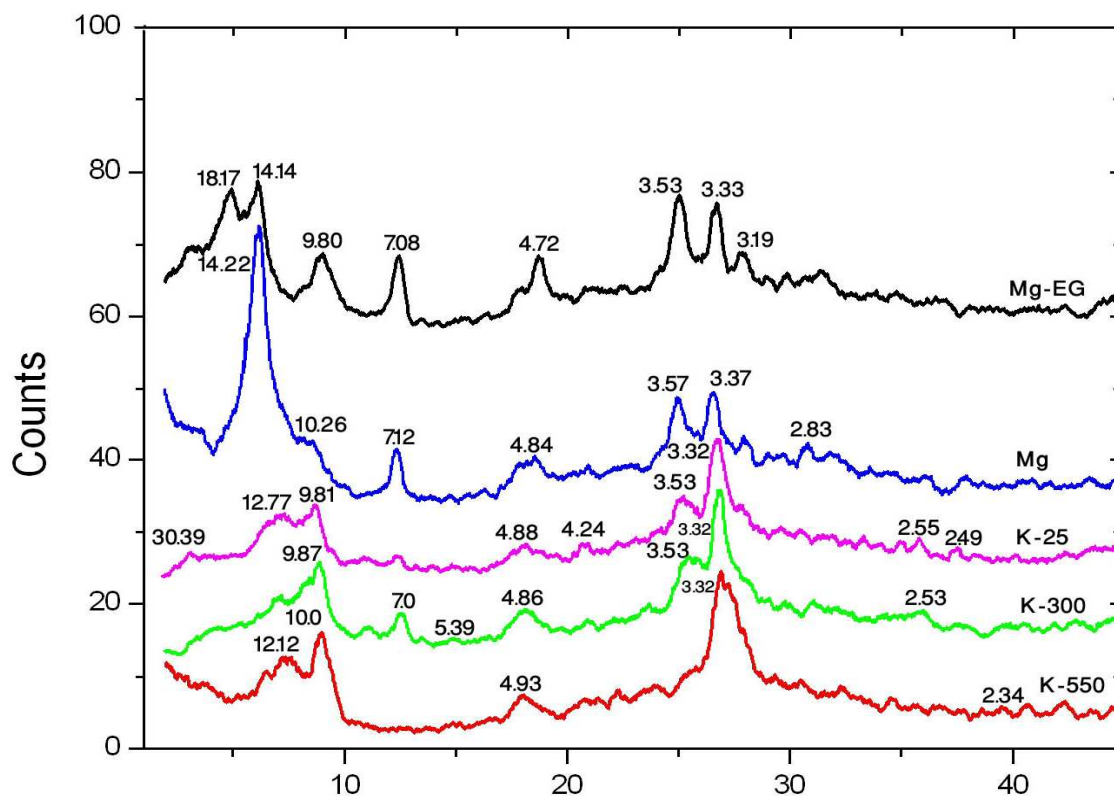


Fig. 2. X-ray diffractograms of the clay fraction (soil 4).

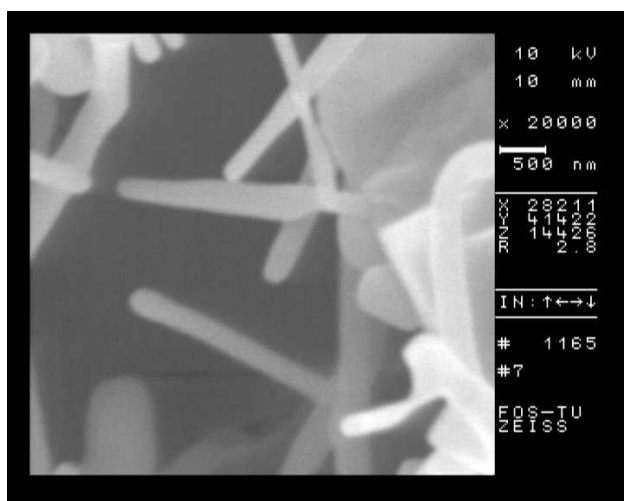


Fig. 3. SEM image of palygorskite.

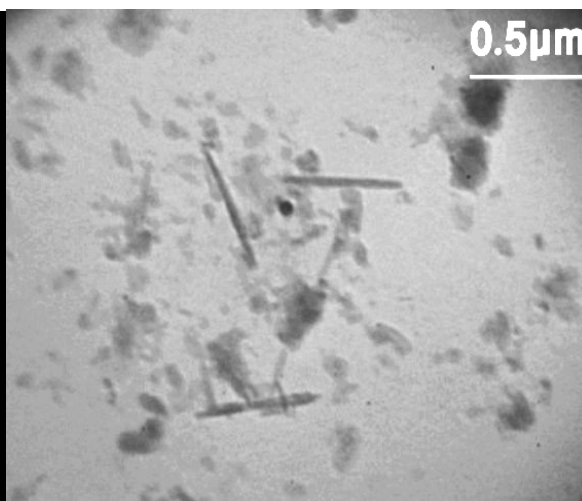


Fig. 4. TEM image of palygorskite.

References

- Brady NC (1990) The nature and properties of soils. (10th Edition, MacMillan Publishing Company, New York).
- Khademi H, Mermut AR (1998) Source of Palygorskite in gypsiferous aridisols and associated sediments from Central Iran. *Clay Mineral.* **33**, 561-575.
- Kunze GW, Dixon JB (1986) Pretreatment for mineralogical analysis. In: Klute, A. (Ed.), *Methods of Soil Analysis. Part1. Physical and Mineralogical Methods.* pp. 91-100 (American Society of Agronomy, Madison, WI).
- Owliaie HR, Abtahi A, Heck RJ (2005) Pedogenesis and clay mineralogical investigation of soils formed on gypsiferous and calcareous materials, on a transect, southwestern Iran. *Geoderma* **134**, 62-81.
- Sparks DL, Page AL, Helmke PA, Leoppert RH, Soltanpour PN, Tabatabai MA, Johnston GT, Sumner ME (1996) *Methods of soil analysis.* (Soil Sci. Soc. of Am. Madison, Wisconsin, USA).
- Whittig LD, Allardice WR (1986) X-ray diffraction technique, In: Klute, A. (Ed.), *Methods of Soil Analysis. Part1. Physical and ineralogical Methods.* pp. 331-362. (American Society of Agronomy, Madison, WI).
- Wilson MJ (1999) The origin and formation of clay minerals in soils: past, present and future perspectives. *Clay Miner.* **34**, 7-24.