

Mineralogy and Geochemistry of Calcareous Pedons in Relation to Soil-Forming Factors

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INTRODUCTION

Soil geochemistry and mineralogy are influenced primarily by the composition of the parent material, but climate (i.e., average annual precipitation and mean temperature) also is a major factor as pointed out by Woodruff et al. (2009). The concentrations of elements in soils depend mainly upon the bedrock type, from which the soil parent material is derived, and pedogenic processes acting upon it (Mitchell, 1964). The influence of the parent material on elements and minerals tends to decrease with soil development (Zhang et al., 2002).

Soil chemical and physical properties like redox conditions, pH and water content affect the rate of transformation of metals in soil, and, along with addition and depletion of material (salts, carbonates, clays, organic matter), determine absolute and relative changes in element contents through the soil profile (Palumbo et al. 2000, Kabata-Pendias and Pendias, 1992). Knowledge about the concentration and spatial distribution of naturally occurring chemical elements in calcareous soils is remarkably limited. Therefore, the research was performed with the aim of determining mineral composition and major element distribution to assess genesis and evolution of soils that developed on calcareous materials.

MATERIALS AND METHODS

The studied area is Bonrood Zanganeh Basin, with calcareous soils, xeric soil moisture and mesic temperature regimes, located in western of Fars province (southern Iran) (Fig. 1). The mean annual rainfall and temperature are 1127.4 mm and 14 °C, respectively.

For this work, ten representative soil samples were air-dried and passed

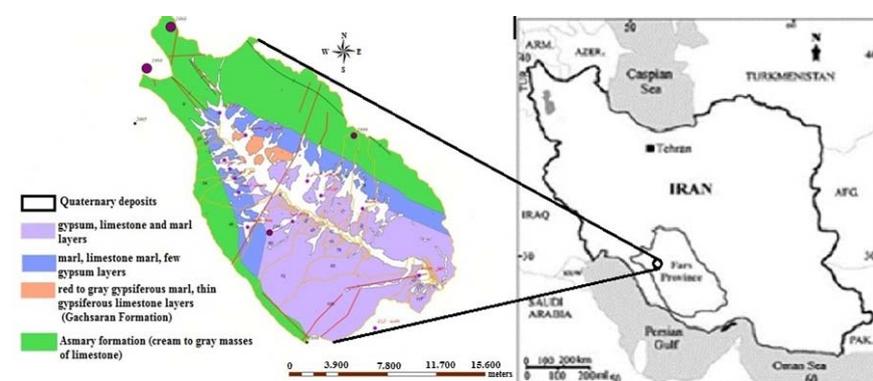


fig 1. Geological map and location of Bonrood Zanganeh Basin in Iran map

through a 2-mm sieve prior to laboratory analyses and different physicochemical properties such as soil acidity by electrometric method by using a pH meter, electrical conductivity by conductivity-meter, soil texture by pipet method, cation exchange capacity by replacing of the exchangeable sodium ions with ammonium ions, organic carbon content by wet combustion, Calcium carbonate equivalent by titration method, were determined.

Mineral and chemical compositions of samples were determined by X-ray diffraction (XRD, Fig. 2) and major elements as percent of oxides were analyzed by XRF.

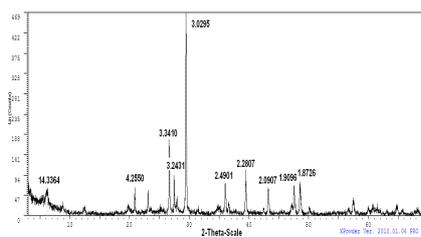


fig 2. Diffractogram of the soil sample "10-C1".

Principal Component Analysis (PCA) was used on the dataset in order to reveal possible relationships between soil properties. Statistical analyses were

performed with the MS Excel application XLstat and SPSS 17.0. A probability level of $p \leq 0.05$ was chosen to establish statistical.

RESULTS AND DISCUSSION

Some soil properties and chemical composition of the samples are summarized in Tables 1 and 2. Studied soils were classified as Entisols, Inceptisols, Alfisols, Vertisols and Molisols with calcic, cambic, argillic horizons and ochric and mollic epipedon.

Topography and climate are two important soil forming factors affecting genesis and mineralogy of soils. Weathering and dissolution of carbonate in parent material and precipitation is considered the main mechanism for carbonate neoformation in the soils. Chlorite, smectite, illite, interstratified minerals and vermiculite are the major clay minerals and calcite, quartz, 14Å- phyllosilicate, alkali feldspars, plagioclase, and muscovite are the common soil minerals in decreasing order.

Chlorite and illite in soils are considered mainly of inherited origin from parent

No.	Horizon	Depth cm	Clay %	Sand%	Silt %	pH	Ec. dSm ⁻¹	OM %	CEC cmolc kg ⁻¹	CaCO ₃ %
1	C ₁	25-60	38.16	28.56	33.28	7.91	0.18	1.47	5.35	47.09
2	B _{tk1}	15-30	15.44	24	60.56	7.8	0.22	0.95	7.08	85.31
3	A _p	0-14	35.44	14	50.56	7.74	0.41	2.06	15.29	17.57
4	B _w	40-75	38.16	27.28	34.56	7.59	0.52	5.84	24.60	39.04
5	B _{tk}	26-42	37.28	30.72	32	7.6	0.86	0.95	10.89	36.5
6	B _{tkss}	55-100	42.16	36.56	21.28	7.79	0.20	0.88	14.73	56.46
7	B _{kss1}	77-105	45.44	20.56	34	7.85	0.41	0.95	10.61	42.41
8	A	0-27	41.44	18	40.56	7.77	0.45	1.57	12.89	41.9
9	B _{t1}	14-40	41.44	26.56	32	7.82	0.18	1.50	15.29	20.81
10	A _p	0-26	36.16	24.56	39.28	7.59	0.48	2.09	15.26	36.15

Table 1. Soil properties of ten representative soil profiles.

materials. Both inheritance and transformation from mica (illite) is believed to be the main mechanisms for the occurrence of smectite in the other studied pedons.

We observed several significant correlations between total amounts of elements in soils that could be related to susceptibility of minerals to weathering and likely due to extend of pedogenic process. Lower concentrations of certain elements such as Ca, Na and K in some soils can be explained by the breakdown of primary minerals, particularly plagioclase and K-feldspar, while the enrichment of Fe, Ti, and Al can be attributed to the formation of clay minerals.

Weathering and soil formation leave characteristic imprints in the chemical composition of soils. Molecular weathering ratios revealed changing chemical proportions as a result of processes or properties like clayeyness (Al₂O₃/SiO₂), and base cation loss (Al₂O₃/(CaO + MgO + Na₂O + K₂O)). Conclusions for climate can be drawn from the degree of depletion of alkali (Na⁺, K⁺) and alkali-earth (Ca²⁺, Mg²⁺) elements normalized to silica and alumina. Negative strong correlations between the molecular ratio of bases/alumina and mean annual rainfall can be observed in soil subsurface (Bt) horizons. Minerals were indicators of the amount of weathering that has taken place and the presence or absence of particular minerals gives information as to how soils formed.

Chemical Index of Weathering (CIW) proposed by Harnois (1988) was used as a weathering index to investigate the

level of soil weathering in different soil orders. CIW ranged from 11.38% (in C horizon of Entisols) to 71.5% (in Bt horizon of Alfisols). It can be concluded that clay and calcium carbonate equivalent (CCE) are important and determining factors in development of calcareous soils. The degree of soil development depends on depletion of calcium carbonate and increase of clay content. The highest amount of Al₂O₃ and lowest amount of K₂O, Na₂O, and CaO were found in Alfisols.

PCA (Fig. 3) was used to discriminate soil profiles and horizons to assess the relationship between physicochemical parameters and major elements. A relative increase in the carbonate fraction will consequently cause a decrease in the silicate fraction and vice versa. The major elements have a high correlation with each other. Sand and silt and also carbonate calcium equivalent (CCE) followed different trend with Al₂O₃, CEC, CIW, and clay content.

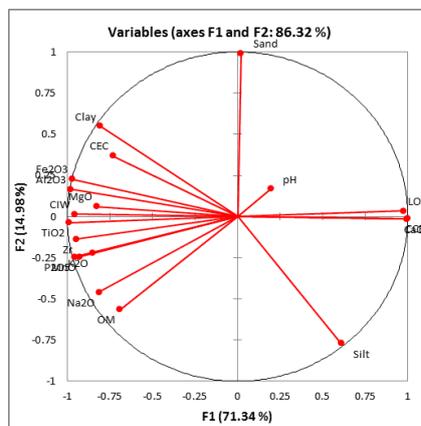


Fig 3. Biplot based on principal component analyses of soil physicochemical properties and soil mineralogy.

	Min.	Max.	Mean	SD
SiO ₂	9.85	47.23	30.37	14.32
Al ₂ O ₃	2.95	12.80	8.44	3.56
Fe ₂ O ₃	1.38	6.27	4.14	1.77
MnO	0.02	0.13	0.08	0.05
MgO	0.82	3.23	2.23	0.96
CaO	12.36	46.84	28.42	12.90
Na ₂ O	0.001	0.39	0.23	0.21
K ₂ O	0.66	2.47	1.58	0.79
TiO ₂	0.11	0.79	0.46	0.25
P ₂ O ₅	0.046	0.2	0.12	0.06
Zr*	41	190	120	62.88

Table 2. Chemical composition of ten representative soil profile, wt% except Zr in ppm.

The fluctuations observed in both the major and trace elements are closely related to variations in mineralogy and in the grain-size distribution.

According to mineralogical analysis (lack of palygorskite and presence of high amounts of smectite), removing out much bases from some soil pedons developed on calcareous parent material, and formation of argillic horizons, it can be concluded that the soils of the study area are moderately developed.

Besides, illuviation/elluviation, decalcification, and humification are the most soil forming processes in the study area.

REFERENCES

- Harnois, L. (1988): *The CIW index: A new chemical index of weathering*. Sed. Geol., **55**, 319-322.
- Kabata-Pendias, A. & Pendias, H. (1992): *Trace Elements in Soils and Plants*. 2nd edn. CRC Press, Boca Raton, FL, 365 pp.
- Mitchell, R.L. (1964): *Trace elements in soils*. In: Bear, F.E. (Ed.), *Chemistry of Soil*. Oxford & IBH, Calcutta, pp. 320-368.
- Palumbo, B. Angelone, M. Bellanca, A. Dazzi, C. Hauser, S. Neri, R. & Wilson, J. (2000): *Influence of inheritance and pedogenesis on the metal distribution in soils of Sicily, Italy*. Geoderma, **95**, 247-266.
- Woodruff, L.G. Cannon, W.F. Eberl, D.D. Smith, D.B. Kilburn, J.E. Horton, J.D. Garrett, R.G. & Klassen, R.A. (2009): *Continental-scale patterns in soil geochemistry and mineralogy: Results from two transects across the United States and Canada*. Appl. Geochem., **24**, 1369-1381.
- Zhang, X.P. Deng, W. & Yang, X.M. (2002): *The background concentrations of 13 soil trace elements and their relationships to parent materials and vegetation in Xizang (Tibet), China*. J. Asian Earth Sci., **21**, 167-174.