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**Article** · July 2019

DOI: 10.15739/IJAPR.19.009



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International Journal of Agricultural Policy and Research Vol.7 (4), pp. 80-90, July 2019
Available online at https://www.journalissues.org/IJAPR/
https://doi.org/10.15739/IJAPR.19.009

ISSN 2350-1561

*Original Research Article*

# Study of soils formation origin based on mineralogical studies (A case study: Marand region, Iran)

Received 10 June, 2019 Revised 4 July, 2019 Accepted 9 July, 2019 Published 19 July, 2019

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**Parent material is considered as the most important soil forming factor in arid and semiarid regions. This study was carried out to determine the effect of parent materials on the origin of soil formation and evolution of studied soils. Four different locations in the North East of Marand region were selected for excavation and description of soil profiles. Then, soil samples were taken and soil physicochemical and mineralogical properties were determined for representative profiles and their related parent rocks. X-ray diffraction (XRD) patterns revealed that the soils were similar in clay-mineral compositions, consisting of illite, smectite, chlorite, kaolinite, and quartz for the different profiles, but vary in the relative amounts of these minerals. Also, XRD analysis of powder refers mainly to the presence of calcite and feldspar with aforementioned clay minerals. Clay mineralogy showed that smectite, illite, chlorite, kaolinite and mica (except 2Bk horizon sample of profile 4) were present in all the soils studied and seem to be inherited from parent materials by weathering processes. Also, a little amount of smectite in profile 1 (B sample) has pedogenic origin. Briefly, mineralogical characteristics showed that soil formation was mainly lithologic origin than pedogenic.**

**Key words**: Autogenic, parent material, soil physical and chemical properties, clay mineralogy, soil taxonomy.

## INTRODUCTION

Growing of population in one side and people demanding for better life on the other hand prerequisite attention to nature and in this among soil has specific position. The population of the world in the half of the next century will be doubled and reach from 5.3 billion in 1990 to more than 10 billion in 2050 (Bongaarts, 1994). Thus, according to the soil importance in relation with food security of growing population in the world, the recognition of physicochemical and mineralogical properties of soil is important (Tavakoli et al., 2008). Soil with different properties can be formed by transported and in situ formed parent materials, therefore, clay identification is one of the recognition ways for identifying of soil properties, and some of physicochemical characteristics such as water holding capacity, permeability, cation exchange capacity (CEC), soil fertility, etc can be affected by type and amount of minerals especially clay minerals. The perception of clay minerals properties in soil and their relation with soil physicochemical characteristics helps the researches for predicting soil behavior in agriculture background and environment act successfully (Olyaei et al., 2007).

Munroe et al. (2007) reported that X-ray diffraction can reveal chlorite present in all bedrock samples and some saprolites weathered from bed rockes, hydrobiotite, vermiculite, kaolinite, gibbsite, and goethite formed in the soil. Rezapour et al. (2009) reported distribution of potassium (K) forms in calcareous soils of Iran. Noruzi Fard et al. (2010) has documented that physicochemical properties, clay mineralogy and soil classification and emphasise that these significantly affect composition of parent materials. Therefore, the objective of this research was to explain the effects of parent materials on the origin of soil formation and evolution of studied soils North East Marand region of Iran.

## MATERIALS AND METHODS

### Study area

This study was undertaken in the North East of Marand, Iran (Figure 1).The study area is semi- mountainous that is located between 45° 49' 16" to 45° 57' 12" East longitude and 38° 23' 55" to 38° 28' 59" North latitude with soil moisture and temperature regimes of Xeric and Mesic and lies 1000 to 3414 m above sea level (Banaei, 1998; Soil Survey Staff, 2014). Geological formations of Marand region is related to second, third and four geological times and it's stratigraphy includes Triassic, Jurassic and Cretaceous period. In this area species of sandstones and fossiliferous limestones were created by destruction and dissection of limestone formations. Physiographic units in this area include alluvial deposits of gravelly fan-shaped (fans), alluvial plains and river sediments (Anonymus, 1998). Accordingly, 4 profiles from pediment and plain units with different overall slope percentage around Aberghan village in the North East of Marand (Marand is a city found in East Azerbaijan, Iran) were selected for the study.

After sampling, the soil and bedrock samples from same horizons were transported to the laboratory and air dried. The soil samples were passed through a 2mm sieve and bedrocks powdered by agate stone pounder for analysis. Thereafter the soil samples and bedrocks powdered were analyzed. Particle size distribution (soil texture) was determined by hydrometer method (Gee and Bauder, 1979). Saturation moisture percentage was obtained according to Tan (2005); USDA- SCS (1992) and the soil color was determined following Munseel (2009). Calcium carbonate equivalent (CCE) was measured by acid neutralization approach (Hesse, 2002; Tan 2005; USDA-SCS (1992). Gypsum ($CaSO_4.2H_2O$) was determined by precipitation with acetone (Tan 2005). Soil organic matter was determined by wet oxidation of potassium dichromate ($K_2Cr_2O_7$) and soil organic carbon calculated by multiplication of organic matter by 0.58 (Nelson and Sommers, 1982). The soil pH and EC were determined in saturation paste extract by a pH and EC meter (Consort, multi- parameter analyzer, C3010) (Bower and Wilcox 1965; Tan 2005). Soil CEC was determined using ammonium acetate ($NH_4OAc$) at pH 7.0 (Jackson, 1969; Bower, 1952; Hesse, 2002; Tan, 2005). Soil depth, boundary, structure and consistence was determined after FAO (2006).

### Mineralogical Analyses

For mineralogical analysis, one mixed sample from each profiles of 1, 2, 3 and two samples from profile 4 were selected. These samples included B, Bw, Bk and Bt, 2Bk from profiles 1, 2, 3 and 4, respectiviely. Prior to mineralogical analyses, the soil samples were washed to remove gypsum and soluble salts (Kunze and Dixon, 1986; Klute, 1992; Tan, 2005; Marc and Gautheyrou, 2006). The carbonates were removed using 1 N sodium acetate and continued until no effervescence was observed with 1 N HCl (Jackson 1969; Tan 2005; Marc and Gautheyrou, 2006). Organic matter was oxidized by treating the carbonate free soils with 30% $H_2O_2$ (Tan, 2005; Marc and Gautheyrou, 2006). Free iron oxides were removed from the samples by citrate dithionate method (Mehra and Jackson, 1960; Tan, 2005; Marc and Gautheyrou, 2006). Separation of clay fractions were carried out according to Kittrick and Hope (1971). The clay fractions of soil and parent rocks were treated to prepare the following oriented slides: Mg-saturated and glycerol-solvated, K-saturated, K-saturated and heated at 550 °C. These slides were scanned using a D8 Advance X-ray diffractometer (SEMENC Diffracometer D5000) (Whitting and Allardice, 1986; Tan 2005; Deng et al., 2009). Quantification of clay minerals was done following Alexiades and Jackson 1966; U.S. Geological Survey 2001; Kessler and Ramasamy 2012.

## RESULTS AND DISCUSSION

All soil pedons physiography, morphological, physicochemical and mineralogical properties are reported in Tables (1- 4) and Figures (1- 6).

Physiography of studied pedons is pediment for 1, 2 and 3 pedons and plain for 4 pedon (Figure 1). Morphological characteristics of studied pedons (Table 1) showed that deep salum (112 cm) in pedon 1 > than pedon 2, 3 and 4. The relative amounts of smectite (91.3%) in this pedon can also be a sign of soil evolution. Whereas, high percentage of coarse sand particles (81%) in pedon 3 inversely indicated little development. Physico- chemical properties of studied pedons (Table 2) showed that CCE, EC and SM content of pedon 4 horizon $Btk_2$ are more than other pedons. It can be related to argillic or calsic soil horizon in this pedon. Also, in this pedon high amount of CCE related to accumulations of calcium carbonate. Generally, pH value ranged 6.98- 7.98, gypsum 0.02- 0.74 and CEC 6.1- 32 in the studied soils. High levels of CEC was noted in pedon 4, Bt horizon may be due to the accumulation of silicate clays. Low amount of gypsum indicated no effect on physicochemical properties of soils on its formation. Mineralogical examination on soil and parent material samples was performed and XRD of clay fraction (<2mm) of the selected soil and bedrock samples by various sources and interpreted (Tan, 2005; Deng et al., 2009). According to mineralogical examination and semi quantitative method, (Table 3), dominant clay mineral is smectite was noted in the B sample. Origin of this mineral not only was inherited from parent material but also was result of some pedogenic processes like altering chlorite to smectite or new formation of smectite due to the present

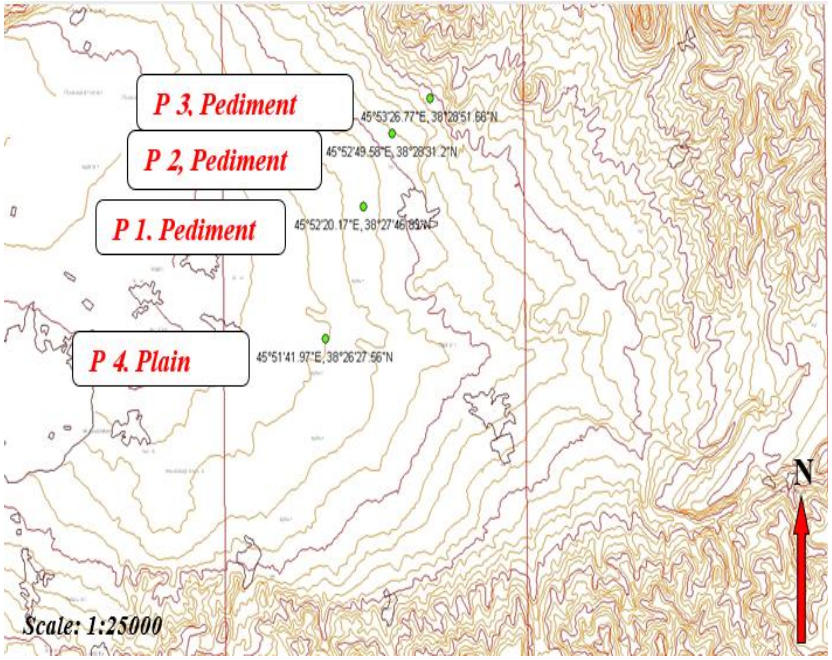


**Figure 1**: Location of the study area (profiles position and physiography), North East of Marand, Iran (Banaei 1998)

**Table 1.** Morphological characteristics and classification of the studied pedons

| Pedon no | Horizon | Depth (cm) | Color (moist) | Boundary | Structure | Consistence moist | Consistence dry |
|---|---|---|---|---|---|---|---|
| **Fine loamy, Smectitic, Superactive, Mesic, Typic Calcixerept (pedon 1. pediment)** | | | | | | | |
| 1 | **Ap** | 0-18 | 10YR4/2 | aw | 2fabk | fr | vh |
| | **Bw** | 18-64 | 10YR4/3 | gw | 2mabk | vfr | eh |
| | **Bk** | 64-112 | 10YR4/3 | dw | 2cabk | vfr | vh |
| | **C** | >112 | 10YR4/3 | - | m | lo | lo |
| **Coarse loamy, Mixed, Superactive, Mesic, Fluventic Haploxerept (pedon 2. pediment)** | | | | | | | |
| 2 | **Ap** | 0-18 | 5YR3/2 | as | 2vcgr | vfr | h |
| | **$Bw_1$** | 18-35 | 10YR3/4 | gw | 1mabk | vfr | vh |
| | **$Bw_2$** | 35-72 | 10YR3/4 | dw | 1fabk | vfr | h |
| | **C** | 72-115 | 10YR3/3 | gw | sg | vfr | h |
| | **2Bw** | >115 | 7.5YR4/4 | - | 1mabk | fr | eh |
| **Loamy Skeletal, Mixed, Superactive, Mesic, Typic Calcixerept (pedon 3. pediment)** | | | | | | | |
| 3 | **A** | 0-18 | 7.5YR3/2 | gw | 1fgr | lo | lo |
| | **Bk** | 18-67 | 10YR3/2 | aw | 1vfabk | lo | lo |
| | **C** | >67 | 10YR3/2 | - | sg | lo | lo |
| **Clay over loamy, Mixed, active, Mesic, Calcic Haploxeralf (pedon 4. plain)** | | | | | | | |
| 4 | **Ap** | 0-23 | 10YR4/3 | aw | 3mbk | fr | vh |
| | **$Bt_1$** | 23-51 | 10YR4/3 | gw | 2fabk | vfr | sh |
| | **$Btk_2$** | 51-80 | 10YR4/3 | db | 2fabk | fr | h |
| | **2Bk** | 80-100 | 10YR4/3 | aw | 1vfabk | efr | eh |
| | **3C** | >100 | 10YR3/3 | - | gr | lo | lo |

soil conditions. Mineralogical examination and semi quantitative method in Bw sample showed that dominant clay mineral is kaolinite and also BK, Bt and 2Bk samples demonstrated that kaolinite and chlorite are dominant clay minerals. It seems these minerals inherited from parent material by weathering processes in Bw, Bk, Bt and 2Bk samples with an exception for 2Bk sample. It showed existence of lithic discontinuity that could be distinguished from semi quantitative method. In representative soils the peak of smectite with Mg- saturated and glycerol-solvated was 16.8 to 17.3 Angstrom (Å), illite 10 - 10.6 Å, kaolinite 7.1 - 7.2 Å, chlorite 14.2 - 14.8 Å and quartz 4.3 - 4.8 Å

**Table 2.** Physical and chemical properties of the studied pedons

| Pedon no | Horizon | Depth (cm) | Particle size distribution (%) | | | pH (paste) | OC | CCE | Gypsum | CEC (cmol (+) kg$^{-1}$) | EC (dS m$^{-1}$) | SM (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Clay | Silt | Sand | | (%) | | | | | |
| **(pedon 1. pediment)** | | | | | | | | | | | | |
| | **Ap** | 0 - 18 | 21 | 29 | 50 | 7.85 | 0.90 | 7.0 | 0.74 | 15.8 | 1.55 | 31 |
| **1** | **Bw** | 18 - 64 | 25 | 30 | 45 | 7.80 | 0.63 | 9.0 | 0.04 | 17.0 | 0.60 | 37 |
| | **Bk** | 64 – 112 | 17 | 33 | 50 | 7.74 | 0.59 | 14.3 | 0.02 | 18.0 | 0.82 | 33 |
| | **C** | > 112 | 4.0 | 3,0 | 93 | 7.98 | 0.43 | 7.6 | 0.25 | 6.1 | 0.60 | 27 |
| **(pedon 2. pediment)** | | | | | | | | | | | | |
| | **Ap** | 0 – 18 | 34 | 18 | 48 | 7.57 | 0.47 | 5.7 | 0.04 | 15.9 | 0.45 | 25 |
| | **$Bw_1$** | 18 – 35 | 34 | 18 | 48 | 7.48 | 0.39 | 4.6 | 0.03 | 17.6 | 0.33 | 24 |
| **2** | **$Bw_2$** | 35 – 72 | 9.0 | 15 | 76 | 7.27 | 0.20 | 7.5 | 0.02 | 11.6 | 0.44 | 33 |
| | **C** | 72 – 115 | 14 | 8.0 | 78 | 7.76 | 0.47 | 13 | a little | 15.8 | 0.32 | 33 |
| | **2Bw** | > 115 | 37 | 15 | 48 | 7.92 | 0.39 | 24 | 0.01 | 26.3 | 0.88 | 33 |
| **(pedon 3. pediment)** | | | | | | | | | | | | |
| | **A** | 0 – 18 | 8.0 | 11 | 81 | 7.25 | 1.10 | 10 | a little | 15.0 | 0.64 | 28 |
| **3** | **Bk** | 18 – 67 | 21 | 18 | 61 | 7.43 | 0.63 | 14.6 | 0.05 | 14.0 | 0.58 | 28 |
| | **C** | > 67 | 14 | 10 | 76 | 7.43 | 0.55 | 10.9 | a little | 13.0 | 0.44 | 32 |
| **(pedon 4. plain)** | | | | | | | | | | | | |
| | **Ap** | 0 – 23 | 31 | 18 | 51 | 7.49 | 0.63 | 3.4 | 0.02 | 21.5 | 0.89 | 28 |
| | **$Bt_1$** | 23 – 51 | 59 | 40 | 1.0 | 7.11 | 0.55 | 10.8 | 0.20 | 32.0 | 1.16 | 45 |
| **4** | **$Btk_2$** | 51 – 80 | 63 | 23 | 14 | 6.98 | 0.52 | 18 | a little | 23.8 | 2.63 | 54 |
| | **2Bk** | 80 – 100 | 12 | 20 | 68 | 7.21 | 0.39 | 10 | 0.23 | 16.0 | 2.29 | 32 |
| | **3C** | > 100 | 2.0 | 7.0 | 91 | 7.25 | 0.39 | 2.5 | a little | 17.0 | 1.46 | 27 |

OC: Organic Carbon, CCE: Carbonate Calcium Equivalent, CEC: Cation Exchange Capacity, EC: Electrical Conductivity, SM: Saturation moisture.

**Table 3.** Relative abundance of clay minerals of the studied pedons

| Pedon no | Sample | Chlorite | Illite | Kaolinite | Smectite |
|---|---|---|---|---|---|
| | | | (%) | | |
| **1** | **B** | a little | 2.8 | 4.5 | 91.3 |
| **2** | **Bw** | 18.8 | 12.5 | 50.0 | 12.5 |
| **3** | **Bk** | 26.7 | 6.7 | 46.7 | 13.3 |
| **4(1)** | **Bt** | 47.8 | 18.8 | 24.6 | 7.2 |
| **4(2)** | **2Bk** | 55.2 | 18.4 | 24.6 | 0.6 |

(Figure 2- 6). High amount of calcite in powder was identified in Bw and Bk samples (Table 4), compared to other profiles. It is probably due to calcareous parent materials that prevented soil evolution. With regard to weathering order of pyroxene before amphibole, the presence of pyroxene in pedons 2 and 3 refers to low weathering and little development. It seems that in all samples, kaolinite inherited from parent material.

The results of analysis of soil and powder in all samples showed that there are four main types of clay minerals (chlorite, illite, kaolinite, smectite and quartz) (Table 3 and 4) and generally proceeding of changes in soil and powder were the same. In Iran presence of chlorite, illite, kaolinite, smectite and quartz minerals in different soils was reported by Bahmaniar and Abtahi (2004); Abbaslou and Abtahi (2007); Noruzi Fard et al., (2010); Bayat et al., (2011); Nadimi and Farpoor (2011). Moreover, presence of these minerals in various soils around the world are documented by Lesovaya et al. (2008); Hur and Jung (2009); Diaz at al. (2010); Mavris at al. (2010); Mella and Mermut (2010). Measuring of vermiculite mineral with laboratory method was carried by Alexiades and Jackson (1966) in representative soils that showed that there was no vermiculite in the studied samples. But there is a little exception in pedons 1 and 4 that in pedon 1 smectite can be pedogenesis and formed by transformation of chlorite to smectite or new formation from soil solution under condition of weak drainage, presence of moisture and basic cations in lowlands. Dadgari and Abtahi (1985) noticed that chlorite can change to smectite in severe leaching under < pH 6.0 conditions. In studied soils the existence of chlorite and smectite confirmed that there is no reason for changing chlorite to smectite.

With regard to obtained results in studied soils with pH more than 6.0, no severe leaching and absence of chlorite-smectite, transforming chlorite to smectite is possible. Abtahi and Khormali (2001); Ayoubi et al., (2002); Torabi et al., (2005) indicated formation of smectite from chlorite

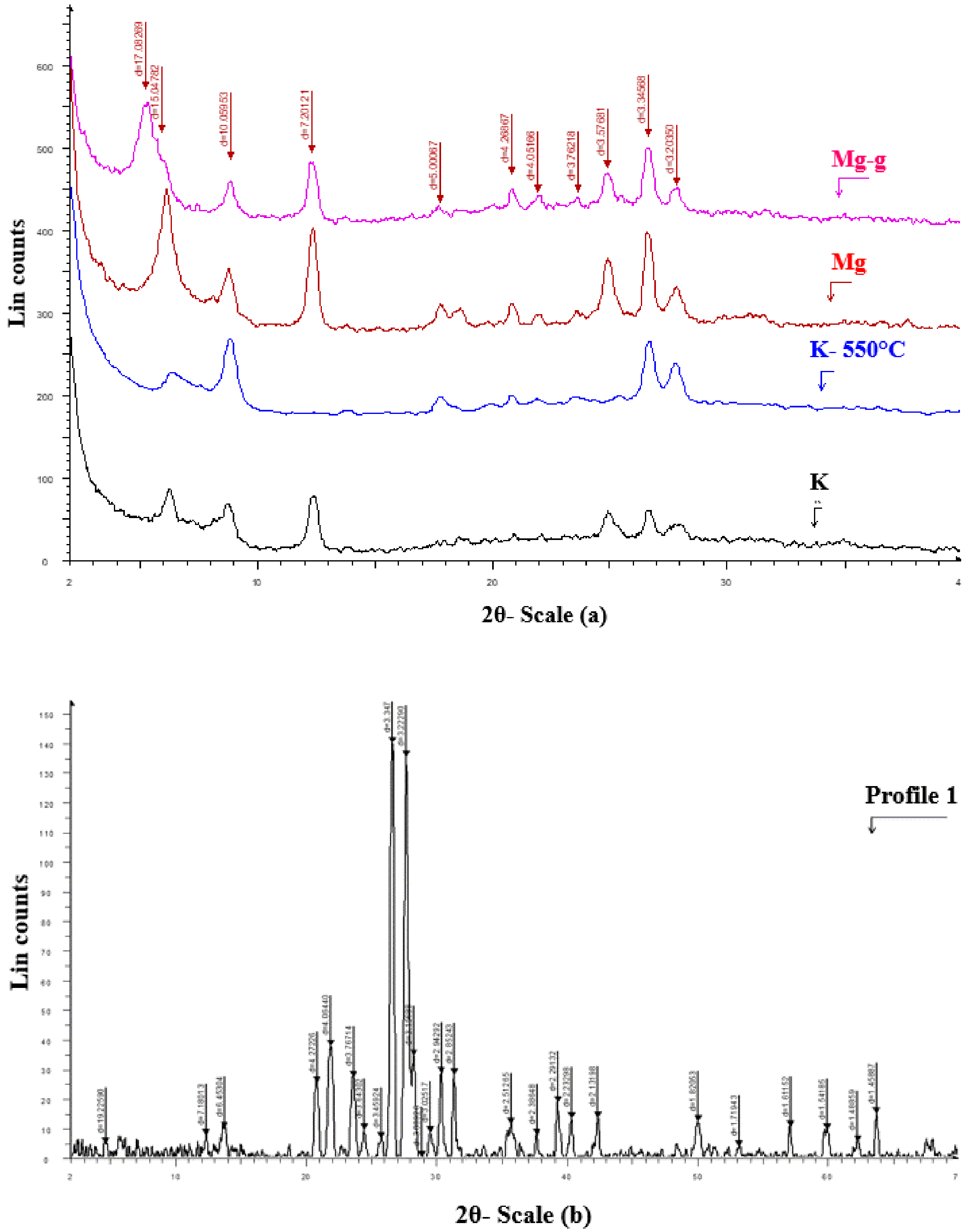


**Figure 2**: X-ray diffractogram of (a) clay particles and (b) powder in the **B (mix of Bw and Bk) sample of profile 1**
Mg: magnesium, g: glycerol, K; potassium, Mg- g: magnesium treatment with glycerol

in various kind of soils in Iran. Also, Egli et al., (2001) reported that the origin of smectite could be traced back to both chlorite and trioctahedral mica which supports the fact that smectite is the end product of chlorite alteration and regularly interstratified mica/smectite (or even smectite). Also, the end product of mica weathering was

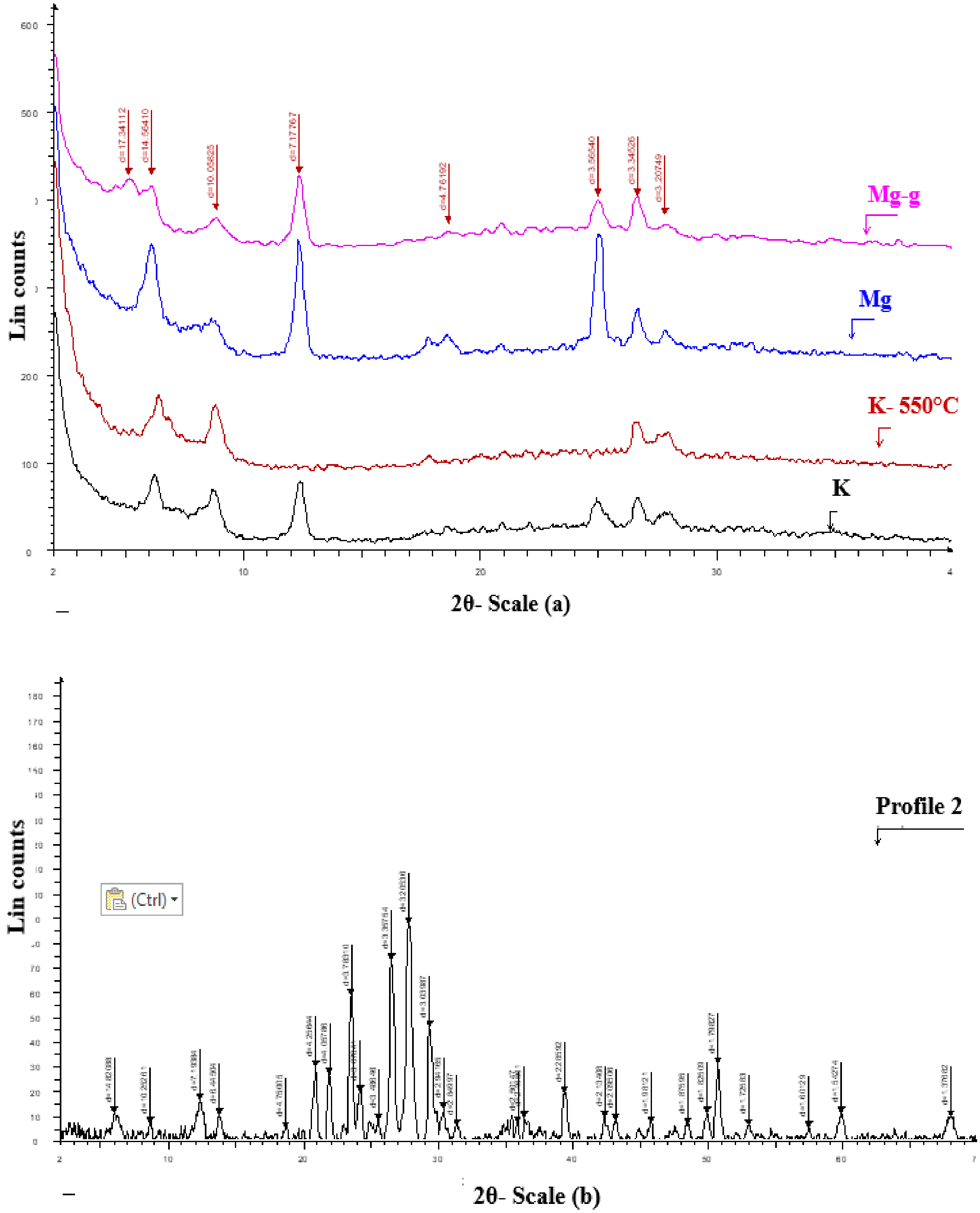


**Figure 3**. X-ray diffractogram of (a) clay particles and (b) powder in the **Bw (mix of $Bw_2$ and $Bw_1$) sample of profile 2** Mg: magnesium, g: glycerol, K; potassium, Mg- g: magnesium treatment with glycerol

found in strongly leached and acidified horizons. Borchardt (1989); De Santiago Buey et al., (1998) referred to potential for smectite that form from mica and chlorite or from illite. Khormali and Abtahi, (2001) reported that transformation processes could be the origin for the formation of smectite and palygorskite clay minerals in Dashte Palang and Kheir Abad, while in Darab plain due to more favorable drainage conditions, new formation seems to be dominant. In pedon

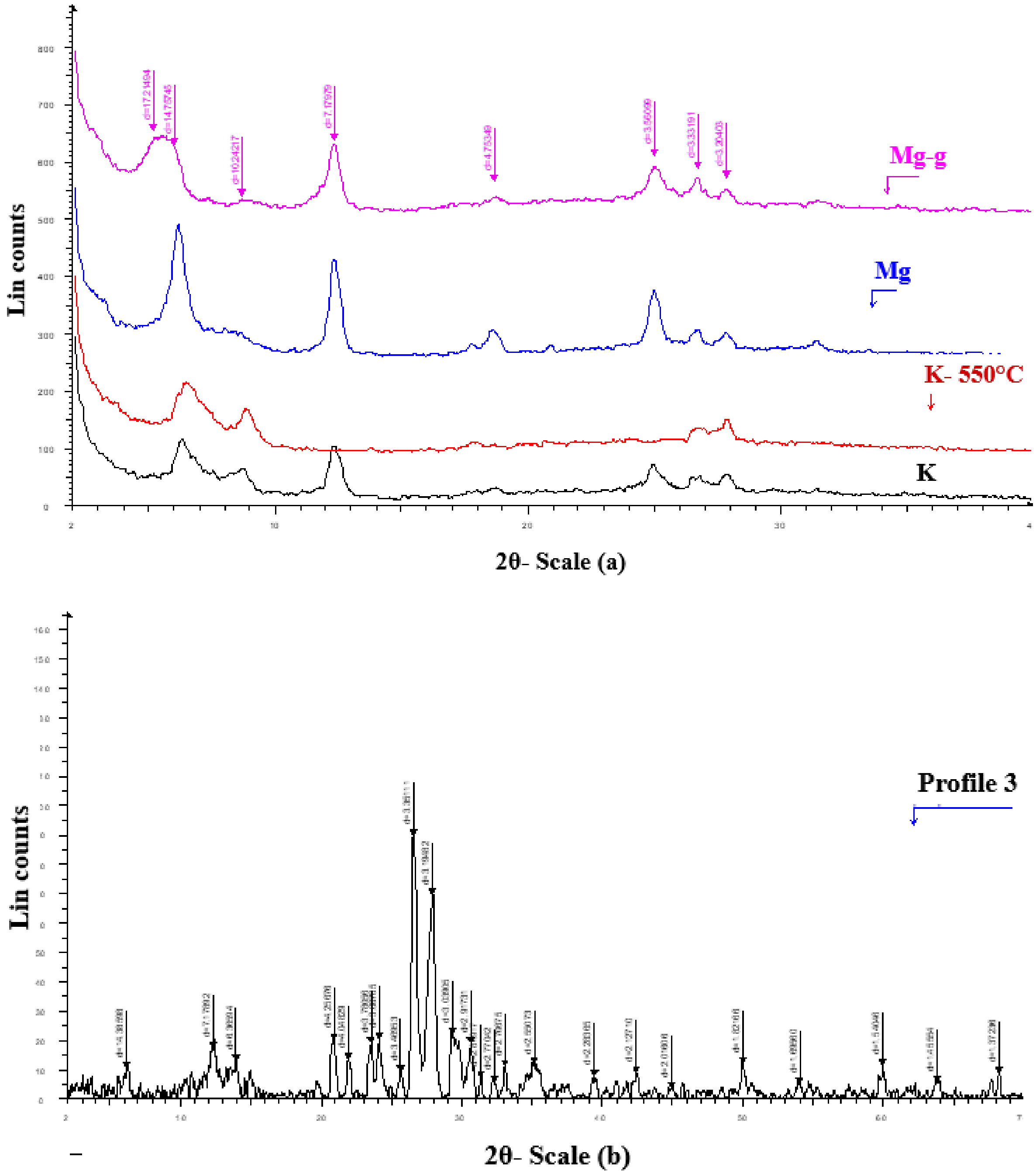


**Figure 4**. X-ray diffractogram of (a) clay particles and (b) powder in the **Bk sample of profile 3**
Mg: magnesium, g: glycerol, K; potassium, Mg- g: magnesium treatment with glycerol

4 (2Bk horizon sample) proceeding of changes in soil and powder is not the same and it is probably can be related to presence of lithologic discontinuity in 2Bk horizon.

## Conclusions

According to X- ray diffractogram, mineralogical composition in all profile samples are the same and include smectite, illite, chlorite, kaolinite and quartz with the majority of smectite, chlorite and kaolinite in semi quantitative study. These indicated that the origin of clay minerals was related to inheritance of parent materials and can be released by in situ weathering (autogenic) and proved that lithologic processes are dominant in soil formation than pedogenic factors in studied region. Comparison of clay minerals indicated changing in soil and

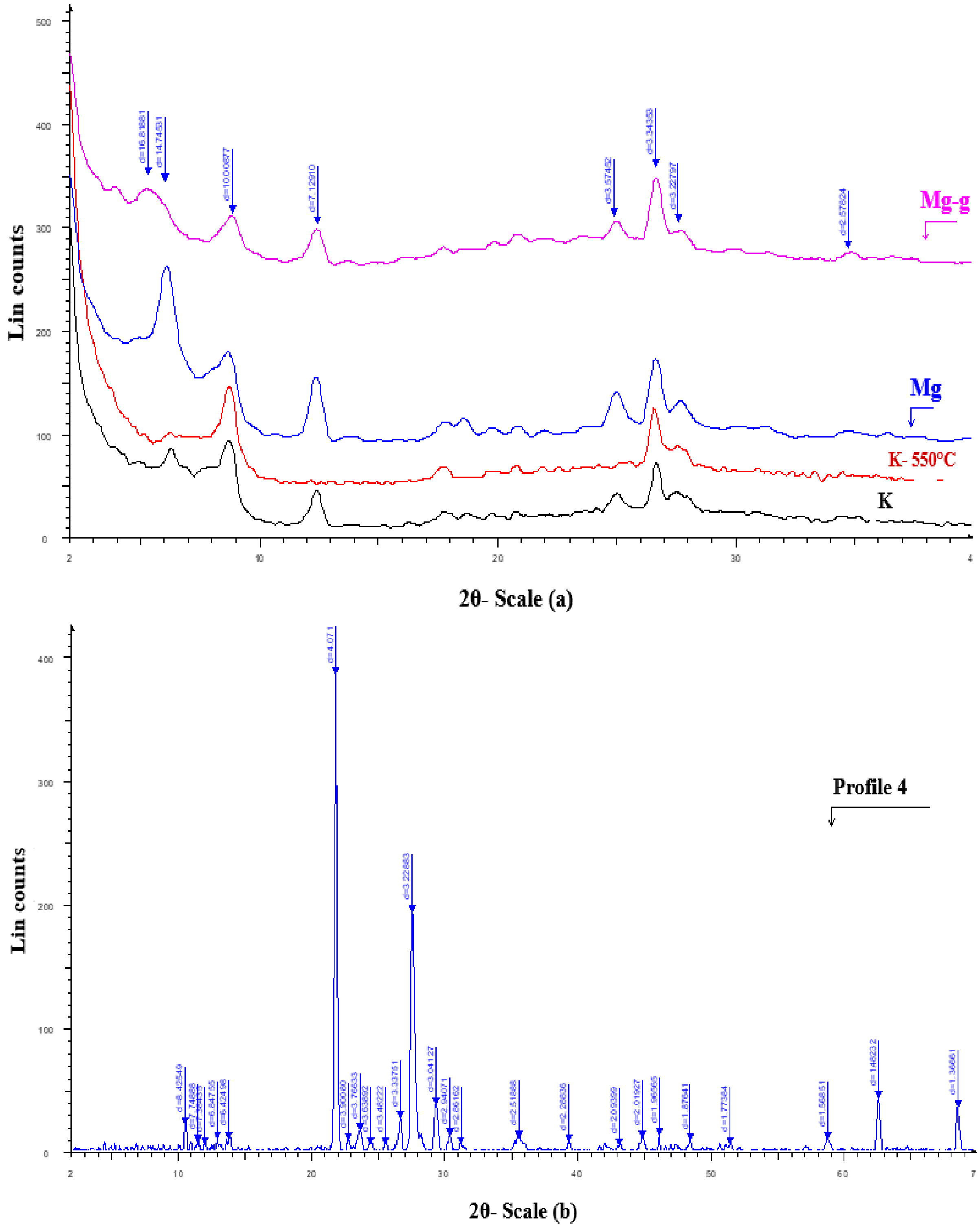


**Figure 5**. X-ray diffractogram of (a) clay particles and (b) powder in the **Bt (mix of $Bt_1$ and $Bt_2$) sample of profile 4**
Mg: magnesium, g: glycerol, K; potassium, Mg- g: magnesium treatment with glycerol

powder and it seems that clay minerals are formed from parent material except clay minerals in 2Bk horizon of pedon 4 that is related to lithologic discontinuity. Generally, clay percentage and solum depth refer to young soils in alluvial soil plains. Briefly soil evolution in the studied pedons can be described as follows: 1 > 4 > 2 > 3.

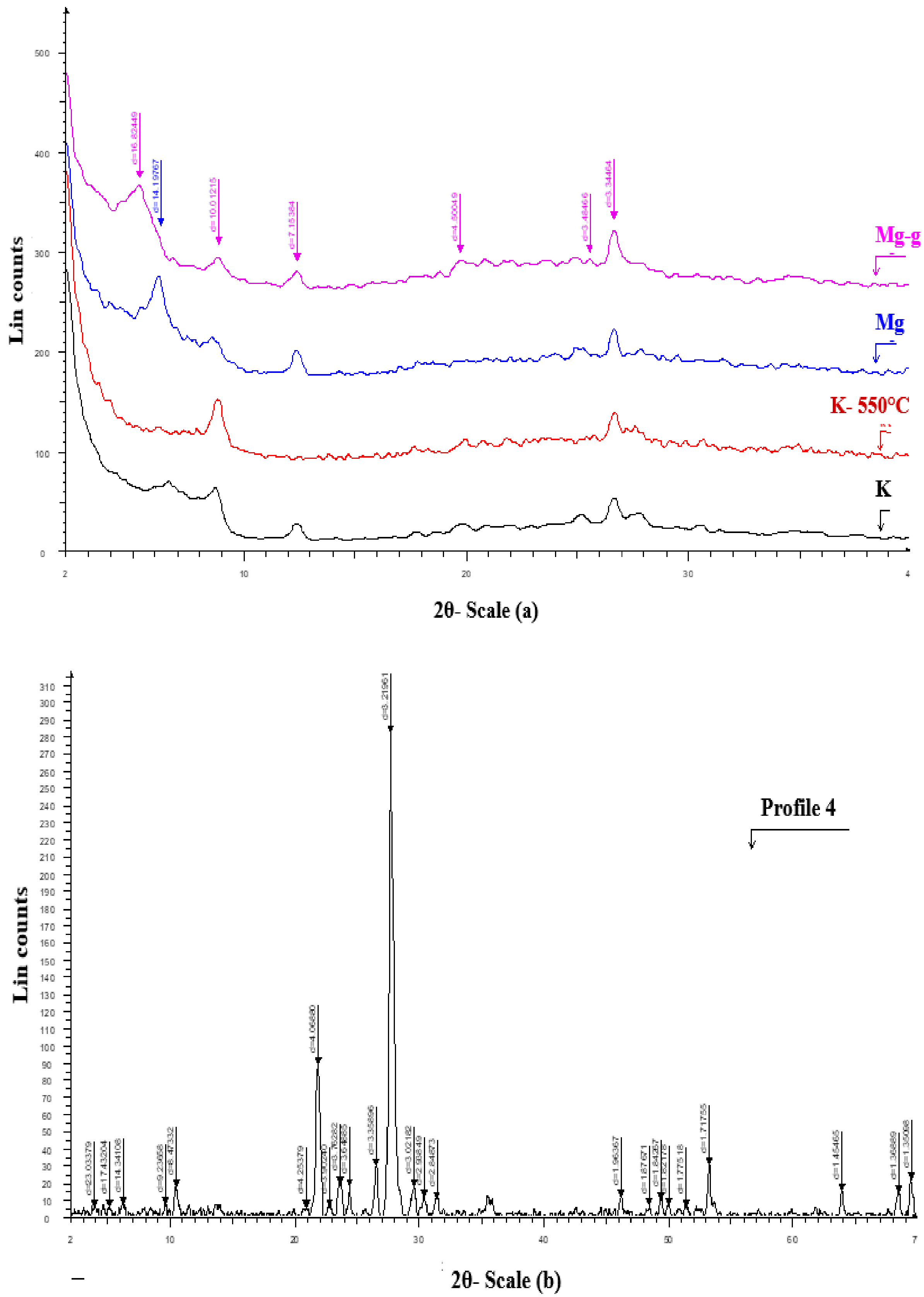


**Figure 6.** X-ray diffractogram of (a) clay particles and (b) powder in the **2Bk sample of profile 4**
Mg: magnesium, g: glycerol, K; potassium, Mg- g: magnesium treatment with glycerol

**Table 4.** Relative minerals abundance of the studied parent rocks

| Pedon no | Sample | Feldspar | Calcite | Quartz | Opal Cristobalite | Pyroxene | Amphibole | Other clay minerals |
|---|---|---|---|---|---|---|---|---|
| | | (%) | | | | | | |
| **1** | **B** | 61.7 | - | - | 17.0 | 16.6 | - | 5.1 |
| **2** | **Bw** | 45.0 | 11.2 | - | 11.0 | - | 6.6 | 26.2 |
| **3** | **Bk** | 45.9 | 15.3 | - | 17.0 | - | 8.2 | 12.7 |
| **4(1)** | **Bt** | 31.0 | 3.5 | 60.0 | - | - | 3.9 | 2.0 |
| **4(2)** | **2Bk** | 88.9 | 1.6 | - | 1.8 | - | 6.3 | 1.4 |

## Conflict of interests

The authors declare that they have no conflicting interests.

## REFERENCES


Abbaslou H, Abtahi A (2007). Origin and Distribution of Clay Minerals in Calcareous, Gypsiferous, Saline Soils and Sediments of Bakhtegan Lake Bank, Southern Iran, Iran Agric. Res., 26:1-2.

Abtahi A, Khormali F (2001). Genesis and morphological characteristics of mollisols formed in a catena under water table influence in Southern Iran, Soil Sci. Plant Analysis, 32(9-10):1643 – 1658.

Alexiades CA, Jackson ML (1966). Quantitative clay mineralogical analysis of soils and sediments. In Clays and clay minerals. (pp. 35-52). Pergamon.

Anonymus (1998). Development master Plan of Marand district (existing reports), Aban Consulting Engineers Co, Vol. 1.

Ayoubi Sh, Jalalian A, Eghbal MK, Khademi H, Rouzitalab MH (2002). Identification and genesis of clay minerals in two Paleosols from Sepahanshar ( Isfahan) and Emam-Gheis (Chaharmahal_ Bakhtiari), Irananin J. Crystallography Mineral., 29(5):522 – 527.

Bahmaniar MA, Abtahi SA (2004). Effects of climate on morphological and clay mineralogical characteristics of some soils developed in calcareous parent material in forestry regions of northern Iran, J. Agric. Sci. Natur. Resour., 11(3),

Banaei MH (1998). Map of moisture and tempreture regimes of Iran soils, Soil and Water Research Institue, Tehran, Iran (in Persian).

Bayat O, Karimzadeh HR, Khademi H (2011). Clay minerals in two paleosols on geomorphic surfaces in Eastern Isfahan, Irananin Journal of Crystallography and Mineralogy, (Issue 1).

Bongaarts J (1994). Can the growing human population feed itself, Scientific American Magazine, 36- 42.

Borchardt G (1989). Smectites, In: Dixon, J.B., Weed, S.B. (Eds.), Minerals in Soil Environments, 2nd ed. SSSAJ Special Publication No. 1, Soil Sci. Soc. Am., Inc.,Madison, Wisconsin, USA, pp. 675–727.

Bower CA (1952). Exchangeable Cation analysis of saline and alkali soils, Soil Sci., 73: 251- 261.

Bower CA, Wilcox LV (1965). Soluble salts. In: Black, C. A., (Ed.) Methods of Soil analysis, American Society of Agronomy, Madison, WI, USA, pp. 933 – 940.

Dadgari F, Abtahi A (1985). Genesis, morphology, chemical and mineralogical studies of soil Dasht – Arjan inter mountain basin, Iran agricultural research. 4: 71- 88.

De Santiago Buey C, Suarez Barrios M, García Romiero E, Dominguez Diaz MC, Doval. Montoya M (1998). Electron microscopic study of the illite– smectite transformation in the bentonites from Cerro del Aguila (Toledo, Spain), Clay Miner. 33, 501–510.

Deng Y, White GN, Dixon JB (2009). Soil Mineralogy laboratory Manual, 11th edition, Published by the authors, Department of Soil and Crop Sciences, Texas A&M University, College Station, Texas 77:843-2474.

Diaz FJ, O'Geen AT, Rasmussen C, Dahlgren RA (2010). Pedogenesis along a thermal gradient in a geothermal region of the southern Cascades, California, www. elsevier. com/locate/geoderma, Geoderma 154: 495 – 507.

Egli M, Mirabella A, Fitze P (2001). Clay mineral formation in soils of two different chronosequences in the Swiss Alps, www. elsevier. com/locate/geoderma, Geoderma,104:145-175.

FAO (2006). Guidelines for soil description. 4th edition

Gee GW, Bauder JW (1979). Particle size analysis by hydrometer: a simplified method for routine textural analysis and a sensitivity test of measurement parameters 1. Soil Science Society of America J. 43(5):1004-1007.

Hesse PR (2002). A textbook of Soil Chemical Analysis, CBS Oublishers and Distributors, 4596/1-A, 11 Darya Ganj, New Delhi- 110 002 (India).

Hur J, Jung MC (2009). The effective of soil properties on the turbidity of catchment soils from the yongdam dam basin in Korea, Environ Geochem Health 31: 365 – 377.

Jackson ML (1969). In: Soil Chemical Analysis, An Advanced Course, Univ. Wisconsin,. Madison, USA, p. 498.

Kessler L, Ramasamy N (2012) A semi-quantitative assessment of clay content in sedimentary rocks using portable X-ray fluorescence spectrometry. Int. J. Earth Sci. Engineering. 5(2):363-364.

Khormali F, Abtahi A (2001). Soil genesis and mineralogy of three selected regions in Fars, Bushehr and Khozestan provinces of Iran, formed under highly calcareous conditions, Iran Agricultural Research, 20(1):67- 82.

Kittrick JA, Hope EW (1971). A procedure for the particle size separation of soils for X- ray diffraction analysis, Soil Sci. Am. Proc., 35:621 – 626.

Klute A (1992). Methods of Soil Analysis, Part 1.Physical and Mineralogical Methods, Second edition, American Society of Agronom, Soil. Sci. Soc. Amer., Madison, Wisconsin USA.

Kunze GW, Dixon JB, (1986). Pretretment for Mineralogical Analysis, In: Methods of Soil Analysis, Part 1, 2nd ed, ASA and SSSA, Madison, USD.

Lesovaya SN, Lebedeva-Verban MP, Chizhikova P, Romanov OV (2008) .Genesis of Soils Developed from Red-Brown Clays and Loesslike Loams in the Southwest of the Central Russian Plain (the Belogor'e Reserve), ISSN 1064-2293, Eurasian Soil Science, 41(11):1137–1147.

Marc P, Gautheyrou J (2006). Hand Book of Soil Analysis (mineralogical, organic and inorganic methods), Springer – Verlag Berlin Heidelberg.

Mavris C, Egl M, Plötze M, Blum JD, Mirabella A, Giaccai D, Haeberli W (2010). Initial stages of weathering and soil formation in the Morteratsch proglacial area (Upper Engadine Switzerland), www. elsevier. com/locate/geoderma, Geoderma 155: 359 – 371.

Mehra OP, Jackson ML (1960). Iron oxide removal from soils and clays by a dithionite–citrate system buffered with sodium bicarbonate, Clay Mineral. 7, 317–327.

Mella W, Mermut AR (2010). Genesis and mineralogy of soil formed on uplifted cora reef in West Timor, Indonesia, www. elsevier. com/locate/geoderma, Geoderma 154,544 –553.

Munroe JS, Farrugia G, Ryan PC (2007). Parent material and chemical weathering in alpine soils on Mt. Mansfield, Vermont, USA, www. elsevier. com/locate/catena, Catena 70 :39–48.

Munseel Soil Color Chart (2009). edition, new Revised, US Soil Conservation Service.

Nadimi M, Farpoor MH (2011). Genesis and clay mineralogy of soils on different geomorphic surfaces in Mahan-Joupar area, central Iran, Arab J Geosci, 0350(3):1–9.

Nelson DW, Sommers LE (1982). Total carbon, organic carbon, and organic matter, In:page.Al, Miller RH and Keeney DR(Eds.), Methods of Soil Analysis. Part II, 2nd ed. American Society of Agronomy, Madison, WI, USA, pp.539 – 580.

Noruzi Fard F, Salehi MH, Khademi H, Davoudian Dehkordi AR (2010). Genesis, Classification and Mineralogy of Soils Formed on Various Parent Materials in the North of Chaharmahal-Va-Bakhtiari Province, J. Water and Soil 24(4):647-658.

Olyaei HR, Abtahi A, Adhami A (2007). Origin and distribution of soil clay minerals in diffrent climate origions of Kohgiluyeh Boyer Ahmad, 10th Soil Sci Congress Iran.

Rezapour S, Jafarzadeh AA, Samadi A, Oustan Sh (2009). Impacts of clay mineralogy and physiographic units on the distribution of potassium forms in calcareous soils in Iran, Clay Minerals; 44(3):327-337;

Soil Survey Staff, 2014, Keys to Soil taxonomy, 12th edition

Tan KH (2005). Soil Sampling, Preparing, and Analysis, 2nd ed. S593. T35, 2005, 631.4'1'0278 – dc22.

Tavakoli M, Raiesi F, Salehi MH (2008). Evaluation of selected soil quality indicators in almond orchard located on north and south-facing slopes in Saman region, Shahrekord, J. Agric. Sci. Natur. Resour., Vol. 15(1), July-Aug 2008 www.jasnr.info, www.sid.ir www.magiran.com/jasnr.

Torabi H, Eghbal MK, Jalalian A (2005). Mineralogy of soils and differentiation of hydroxy interlayer smectite from vermiculite on Sefidrud river terraces in central Gilan province, Irananin J. Crystallography and Mineralogy, (Issue 1).

U S. Geological Survey Open-File Report (2001). A Laboratory Manual for X-Ray Powder Diffraction, https://pubs.usgs.gov

USDA, Soil Conservation Service (1992). Soil Survey Laboratory Methods and Procedures for collecting soil sample, USDA – SCS. Soil SCS, Soil Survey, In vest, Ret. No. 2. U. S. Gov. Print. Office, Washington, DC

Whitting LD, Allardice WR (1986). X – Ray Diffraction Techniques, In: A. klute(ed). Methods of Soil Analysis, Part 1. 2nd 9ed). Agro