Scientific Papers. Series A. Agronomy, Vol. LXI, No. 1, 2018
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

EVOLUTION MICROMORPHOLOGY OF ARGILLIC HORIZONS IN SOME ARID SOILS IN THE WEST OF URMIA LAKE IN WESTERN AZERBAIJAN PROVINCE, IRAN

Tina JAHAN, Shahram MANAFI

Urmia University, Faculty of Agriculture, Department of Soil Science, 11 Km. Sero Road, Urmia, West Azerbaijan province, Iran. PO Box 165, Postal Code: 57159- 44931

Corresponding author email: smanafy@yahoo.com or sh.manafi@urmia.ac.ir

Abstract

Argillic horizons are subsurface diagnostic horizons and presence and identification of argillic horizons in soils of arid and semiarid regions can be used as an important tool for soil classification, interpretation of soil forming processes and condition of their formation. In this study, argillic horizons were investigated micromorphologically and SEM technique. According to micromorphic studies, accumulations of illuvial clay in these soils are present as coatings on skeletal grains and void faces and their thickness varies from 20 to 30 μm and they comprise about 2-5% of argillic horizons. In some argillic horizons, illuvial clay has filled all of pore spaces and comprises about 10% of horizon. In some soils carbonates have covered clay coatings and in some cases clay coatings have been disappeared. Co-existence of argillic and calcic horizons is indicative of polygenesis. A calcic horizon containing illuvial clay is usually interpreted as indicator of climate change. Thus, the formation of complex argillic-calcic horizon shows that these soils are polygenetic and argillic horizons in these soils have been formed in a more humid past climate.

***Key words**: Argillic horizon, clay coating, semiarid, Iran, Western Azerbaijan.*

INTRODUCTION

An argillic horizon is normally a subsurface horizon with a significantly higher percentage of phyllosilicate clay than the overlying soil material. It shows evidence of clay illuviation. The argillic horizon forms below the soil surface, but it may be exposed at the surface later by erosion (Soil survey Staff, 1999, 2014). Because there is little or no evidence of illuvial clay movement in soils on the youngest landscapes, soil scientists have concluded that the formation of an argillic horizon requires at least a few thousand years. On some late Pleistocene landscapes, argillic horizons are more strongly expressed in soils under forest vegetation than in soils under grass. Therefore, the kind of flora and associated fauna is thought to have an influence on the rate of development or degree of expression of the argillic horizon. Climate also is a factor. There are few or no examples of clay films in soils with perudic soil moisture regimes. Textural differentiation in soils with argillic horizons results from one or more processes acting simultaneously or sequentially, affecting surface horizons, subsurface horizons, or both. The degree to which a process or several processes operate varies widely from soil to soil. In some soils clay illuviation is significant, while in others clay illuviation is overshadowed by in situ weathering. Not all of the processes are completely understood. The ones thought to be most important are: a) Clay eluviation and illuviation, b) Clay dissolution in the epipedon, c) Selective erosion, d) *In situ* clay formation, and e) Clay destruction in a subsurface horizon (Ransom et al., 1997; Pal et al., 2003; Soil survey Staff, 1999, 2014).
The argillic horizon represents a time-landscape relationship that is locally and regionally important. Because an argillic horizon forms at a relatively slow rate, its presence indicates that the geomorphic surface has been relatively stable and that the period of stability has been long. If the argillic horizon occurs in an area of an aridic moisture regime and is rarely moist or has free carbonates throughout, it probably indicates an old soil and stable geomorphic surface of such great age that the climate has changed since the formation of the horizon. In the present environment, the precipitation is not sufficient to remove carbonates from the soil or to

translocate clay to the base of the argillic horizon (Pal et al., 2003; Gunal and Ransom, 2006; Soil survey Staff, 1999, 2014).
Regarding above and also importance of argillic horizons in arid and semiarid regions, the argillic horizons in calcareous semiarid soils in the south west of Urmia Lake were studied micromorphologically to demonstrate their genesis and paleoclimatic significance.

MATERIALS AND METHODS

This study was conducted in the south west of Urmia Lake-in the West Azerbaijan province Iran, located about 20 km of Naghadeh and 10 km of Mohammadyar cities, near the south west of Urmia Lake, from 37° 4.74′ to 37° 6.7′ N latitude and 45° 25.97′ to 45° 28.41′ E longitude (Figure 1a). The mean elevation of the study area is 1303.9 m above sea level. A total of 6 soil profiles were dug along a toposequence in order to demonstrate the variation in physiography and topography in the south west of Urmia Lake. The parent material of this area is white grey limestone of Miocene and according to soil moisture and soil temperature regimes map of Iran (Banaei, 1998), the soil moisture and soil temperature regimes of study area are Dry Xeric and Mesic respectively. Profiles 1 and 2 are located in Hills physiographic Unit, profiles 3 and 4 in Plateaux and profiles 5 and 6 in Piedmont Plain (Figure 1b). Soil profiles in each physiographic unit had different slope and elevation. These 6 pedons were described and classified according to Soil Survey Staff (2014) and were sampled using standard techniques. Preparation of soil thin sections was done on undisturbed samples using standard techniques (Benyarku and Stoops, 2005). Micromorphological descriptions and interpretations were done based on criteria and terminologies of Stoops (2003). SEM analyses were performed with a ZEISS DSM 940A Electronic Scanning Microscope.

RESULTS AND DISCUSSIONS

Based on field and micromorphic studies and laboratory data, argillic horizons were present only in soils located in the piedmont plain (profiles 5 and 6, figure 1b), but calcic horizons were present in in soils in the Plateaux (profiles 6 and 4) and Piedmont plain (profiles 5 and 6) physiographic units and profiles 1 and 2 had no argillic nor calcic horizons (Figure 1b). So, profiles 5 and 6 (piedmont plain) had both argillic and calcic horizons.
According to the micromorphic observations, accumulations of illuvial clay in these soils are present as coatings on skeletal grains and void faces and their thickness varies from 20 to 30 μm and they comprise about 2-5% of argillic horizons. In some argillic horizons, illuvial clay has filled all of pore spaces and comprises about 10% of horizon (Figure 2).
SEM observations on some samples containing clay coatings revealed presence of these features on coarse fragments (Figure 3). EDAX analysis showed higher amounts of Si and Al and lower amounts of Ca, Fe and K, which confirm clayey composition of these coatings (Figure 4).
Clay coatings in these soils show weavy extention which indicates well orientation of clays. All pedons with argillic horizons were enriched in pedogenic carbonates and described with pedogenic carbonate features in the B horizons. Although all pedons had >5% pedogenic carbonate accumulations and more than 15% in the B horizons, so, they were classified as having calcic horizons (Figure 2).
Pedogenic carbonate and clay films have been observed at approximately the same depth (Figure 2 c and d). This is an indication of a complex history of carbonate leaching, subsequent illuviation of clay, and redeposition of calcite. Some of calcium carbonate accumulations were superimposed on clay coatings. This suggests that the soils are polygenetic and that clay illuviation preceded carbonate accumulation. Polygenetic soils occur when climate changes are great enough to produce new soil properties without obliterating existing properties (Chadwick et al., 1995). Stoops (2003) described such features as juxtaposed compound pedofeatures. The juxtaposition occurs due to the changing of local or environmental conditions (Stoops, 2003). The clay coatings that were coated with calcans appeared to be undamaged and exhibit birefringence.
Theoretically, the pedogenic processes of clay illuviation and calcium carbonate

accumulations should be contradictory to each other, since large quantities of Ca^{2+} tend to cause clay flocculation and reduce illuviation. However, these pedogenic features may be observed in the same soil at approximately the same depth (Gile and Grossman, 1968; Ransom et al., 1997; Pal et al., 2003; Khormali et al., 2003; Soil survey Staff, 1999, 2014). The presence of both accumulation of calcium carbonate and oriented clay in the same horizon implies a complex history of carbonate leaching, deposition of secondary calcite, and clay illuviation. Gile and Grossman (1968), Ransom et al. (1997), Pal et al. (2003), Khormali et al. (2003), Khademi and Mermut (2003), and Gunal and Ransom (2006) observed obliteration of clay films in some parts of the argillic horizon because of pedogenic carbonate accumulation, especially for those clay coatings that occurred on the surfaces of sand grains and pebbles. Pal et al. (2003) reported that poorly oriented clay platelets are often find associated with $CaCO_3$ grains. However, Ransom and Bidwell (1990) did not observe any evidence of disruption of clay skins in horizons where secondary carbonate was accumulating.

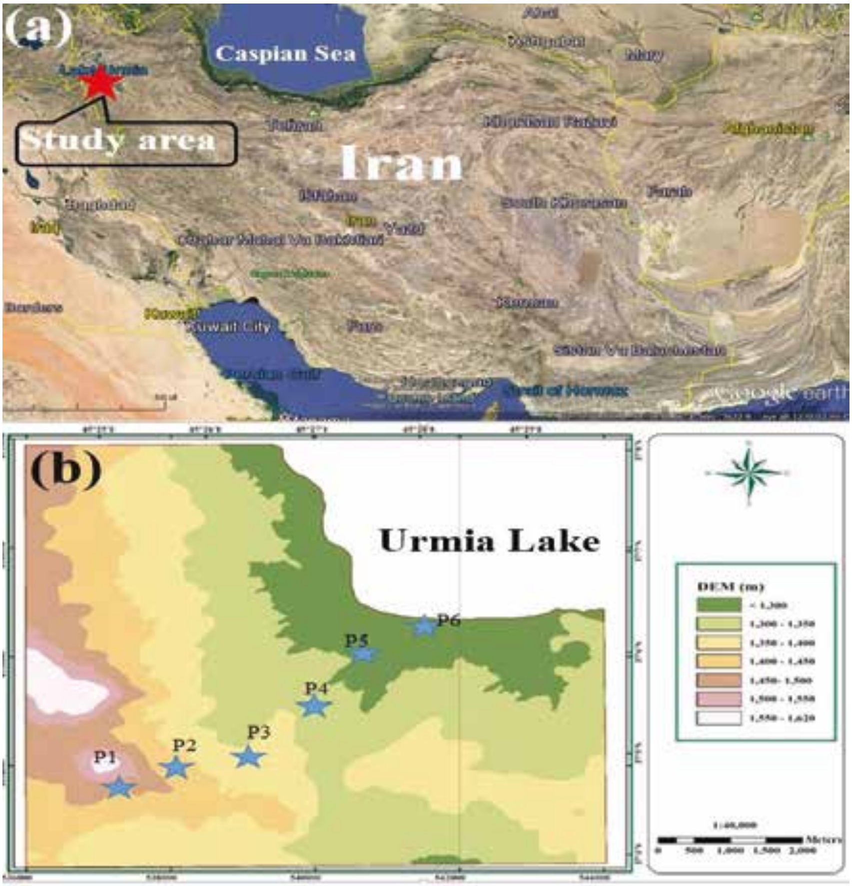


Figure 1. Position of study area in Iran (a), and the location of soil profiles along a toposequence in the south west of Urmia Lake (b)

They reported that the clay coatings were intact.

The coexistence of argillic and calcic horizons in these calcareous semiarid soils is a peculiar combination, suggesting a multistage pedogenesis in this area. Plaeo-argillic horizons were likely developed under a moister environment than today. Sufficient rainfall contributed to the removal of carbonates from the topsoil and subsequent eluviation of clay to form the argillic horizon.

Presence of clay pedofeatures and calcium carbonate is common in soils of arid and semiarid climates.

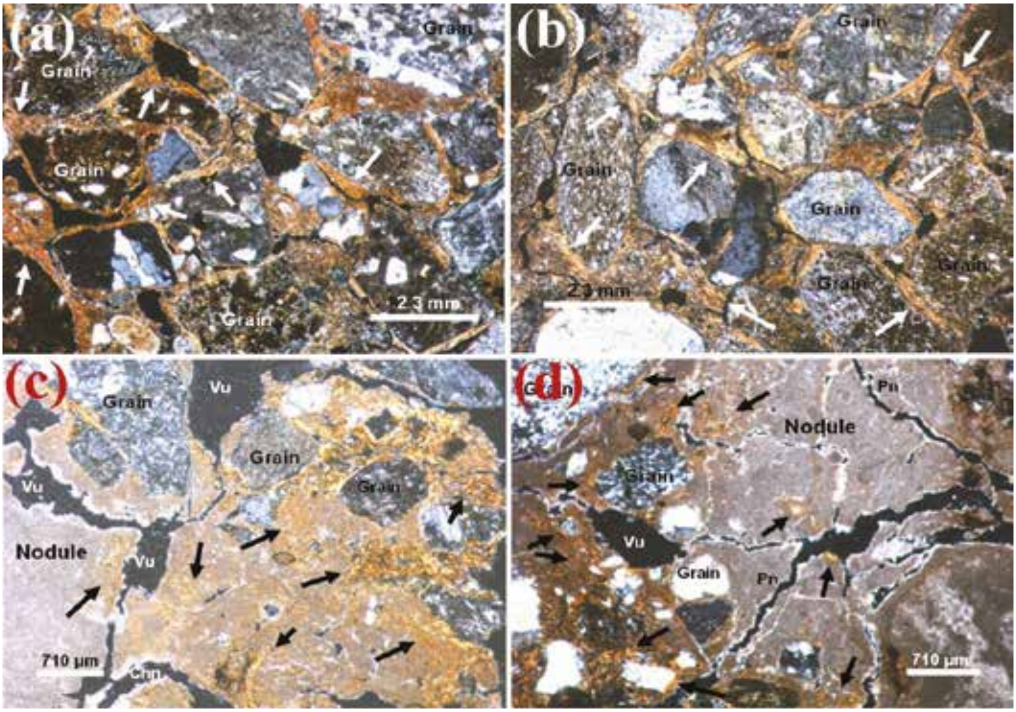


Figure 2. Clay coatings in studied calcareous semiarid soils. Figures a) and b) clay coatings around skeletal grains, and figures c) and d) show clay coatings engulfed by calcium carbonate. Figures have been taken under XPL light

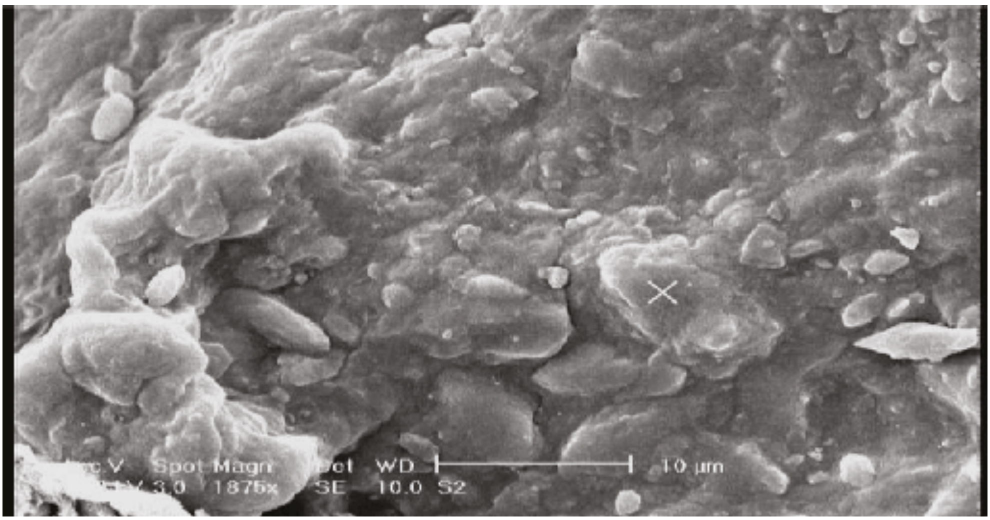
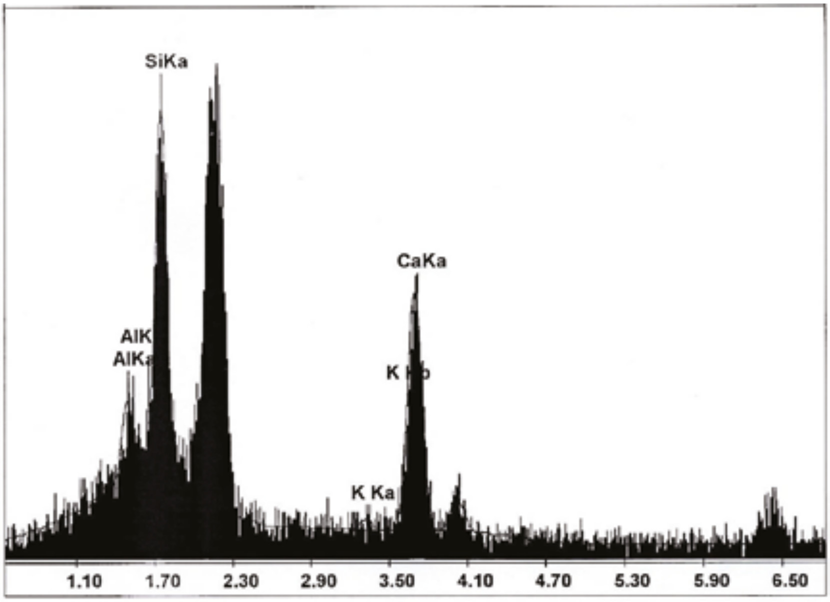


Figure 3. SEM Image and EDAX analysis of clay coatings in studied calcareous semiarid soils.
Figure represents clay coatings on a skeletal grain



EDAX ZAF Quantification (Standardless)
Element Normalized

Element	Wt %	At %
AlK	9.83	11.84
SiK	43.39	50.20
K K	2.07	1.72
CaK	44.70	36.24
Total	100.00	100.00

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
AlK	11.75	12.05	7.69	0.97
SiK	49.18	9.93	2.89	4.95
K K	1.88	5.75	27.15	0.33
CaK	37.09	5.75	3.27	6.45

Figure 4. EDAX analysis of clay coatings in Figure 3

A calcic horizon containing translocated clay is commonly interpreted to represent climate change. Gile et al. (1966) indicated that clay was translocated in a moister climate, but was later engulfed by carbonate when climate become drier, and the clay orientation was also disturbed by accumulation of carbonate. Finally, we conclude that these illuvial features may not be the products of the recent climate, but probably formed in amore humid climate.

CONCLUSIONS

Argillic horizons are subsurface diagnostic horizons and Presence and identification of argillic horizons in soils of arid and semiarid regions can be used as an important tool for soil classification, interpretation of soil forming processes and condition of their formation. According to micromorphic studies, accumulations of illuvial clay in these soils are present as coatings on skeletal grains and void faces and their thickness varies from 20 to 30 μm and they comprise about 2-5% of argillic horizons. In some argillic horizons, illuvial clay has filled all of pore spaces and comprises about 10% of horizon. In some soils carbonates have covered clay coatings and in some cases clay coatings have been disappeared. Co-existence of argillic and calcic horizons is indicative of polygenesis. A calcic horizon containing illuvial clay is usually interpreted as indicator of climate change. Thus, the formation of complex argillic-calcic horizon shows that these soils are polygenetic. In arid and semiarid climates, due to lack of moisture, presence of carbonates and other inhibiting factors, the illuviation of clay does not take place or is very slow, in which, some scientists believe that clay illuviation in arid and semiarid climates is impossible or the amount of illuviated clay is not enough for development of argillic horizons. Regarding that argillic horizons in this study are present in deep horizons and also the climate is arid and semiarid and soils are carbonatic, it seems that dispersion and subsequently illuviation of to the this extent and to these deep depth is impossible. Thus, argillic horizons in these soils have been formed in a more humid past climate.

ACKNOWLEDGEMENTS

This project was supported by the vice canceller of research and technology of Urmia University. We thank vice canceller of research and technology for their financial support. We also thank to the department of soil science of Urmia University for laboratory equipments. We also thank to the department of soil science of Urmia University for laboratory equipments.

REFERENCES

Banaei M.H. (Ed.), 1998. Soil Moisture and Temperature Regime Map of Iran. Soil and Water Research Institute. Ministry of Agriculture, Iran.

Benyarku C.A., Stoops G., 2005. Guidelines for preparation of rock and soil thin sections and polished sections. Departament de Medi Ambient i Ciències del Sòl. Universitat de Lleida, Spain.

Chadwick O.A., Nettleton W.D., Staidl G.J., 1995. Soil polygenesis as a function of quaternary climate change, Northern Great Basin, U.S.A. Geoderma, 68: 1-26.

Gile L.H., Grossman R.B., 1968. Morphology of the argillic horizon in desert soils of southern New Mexico. Soil Science, 106: 6-15.

Gile L.H., Peterson F.F., Grossman R.B., 1966. Morphological and genetic sequences of carbonate accumulation in desert soils. Soil Sci. 101, 347-360.

Gunal H., Ransom M.D., 2006. Clay illuviation and calcium carbonate accumulation along a precipitation gradient in Kansas. Geoderma, 68: 59-69.

Khademi H., Mermut A.R., 2003. Micromorphology and classification of argids and associated gypsiferous aridisols from central Iran. Catena. Vol. 54: 439-455.

Khormali F., Abtahi A., Mahmoodi S., Stoops G., 2003. Argillic horizon development in calcareous soils of arid and semiarid regions of southern Iran. Geoderma, 53: 273-301.

Pal D.K., Srivastara P., Bhattacharyya T., 2003. Clay illuviation in calcareous soils of the semiarid part of the Indo-Gangetic Plains, India. Geoderma, 115: 177-192.

Ransom M.D., Nettleton W.D., Porter D.A., Fraser S.H., 1997. Micromorphology of Ustolls and Ustalfs from Western Kansas, U.S.A. 10th int. working meeting on soil micromorphology. Moscow.

Ransom M.D., Bidwell O.W., 1990. Clay movement and carbonate accumulation in ustolls of central Kansas. In: Douglas L.A. (Ed.). Soil Micromorphology: A basic and applied science. Developments in soil science 19. Elsevier.

Stoops G., 2003. Guidelines for the analysis and description of soil and regolith thin sections (SSSA, Madison, WL). 184 p.

***Soil survey Staff, 1999. Soil taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. 2nd Edition. USDA, Natural Resources Conservation Service, Washington D.C. 886 p.

***Soil survey Staff, 2014. Keys to soil taxonomy. 12th Edition. USDA, Natural Resources Conservation Service, Washington D.C. 332 p.