Clay mineralogy of the sediments in Sabzevar playa, NE Iran; implication for the late quaternary climate changes

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Clay mineralogy of the sediments in Sabzevar playa, NE Iran; implication for the late quaternary climate changes

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Introduction: The Quaternary period was characterized by drastic changes in climatic conditions worldwide (Roy et al., 2006) so that the escalation of eolian processes, desert formation and drying of lakes are attributed to this period (Koutavas et al., 2002). Playa is a region with negative water balance for more than half a year as well as capillary properties close to the surface and sediments (Rosen, 1994). In some cases, playa sediments are the only evidence of past environmental conditions in arid and semi-arid regions (Davis, 1994). Clay minerals are one of main proxies for paleoenvironment and paleoclimate studies (Thiry, 2000). Also, changes in clay minerals in sediments are often indicative of climate changes (Birks et al, 2012). The analysis of clay plains in playas and dried pluvial lake provides a good criterion for determining the origin of sediments and climate change (Oliveira et al., 2002); (Battarbee, 1999). Hence, some researchers (Bentz, 2017), (Jones, 1983), (Srodon, 1997), (Tateo et al., 2000), (Kadir et al., 2016 DeVogel et al., 2004) have conducted valuable studies on late Quaternary climate changes using clay minerals. The present study aims to reconstruct the late Quaternary climate based on clay minerals obtained from Sabzevar Playa in northeastern Iran.

Methods and Materials:

The studied Area

The Sabzevar playa is categorized as a typical playa in central Iran (Kearey, 2009), where located in the eastern part of the Great Kavir basin. Total surface area of this playa is about 2648 KM2 between latitude 35°55'00''–36°25'00'' N and longitude 56°15'00''–57°45'00'' E (Figure. 1). The topographical elevation values of the study area vary from 750 to 900 meters above sea level (a.s.l). Playa sediments are evaporative and clastic, producing in a region with geological features belonging to the Quaternary period (Survey of Geology of Iran, 2005). The playa has been surrounded by ophiolites, ultrabasic rocks and pelagic limestones. This area has a semi-arid climate with annual precipitation of 150–200 mm and annual temperature of 16–17 °C (Sabzevar synoptic station) in the period of 1950–2000.

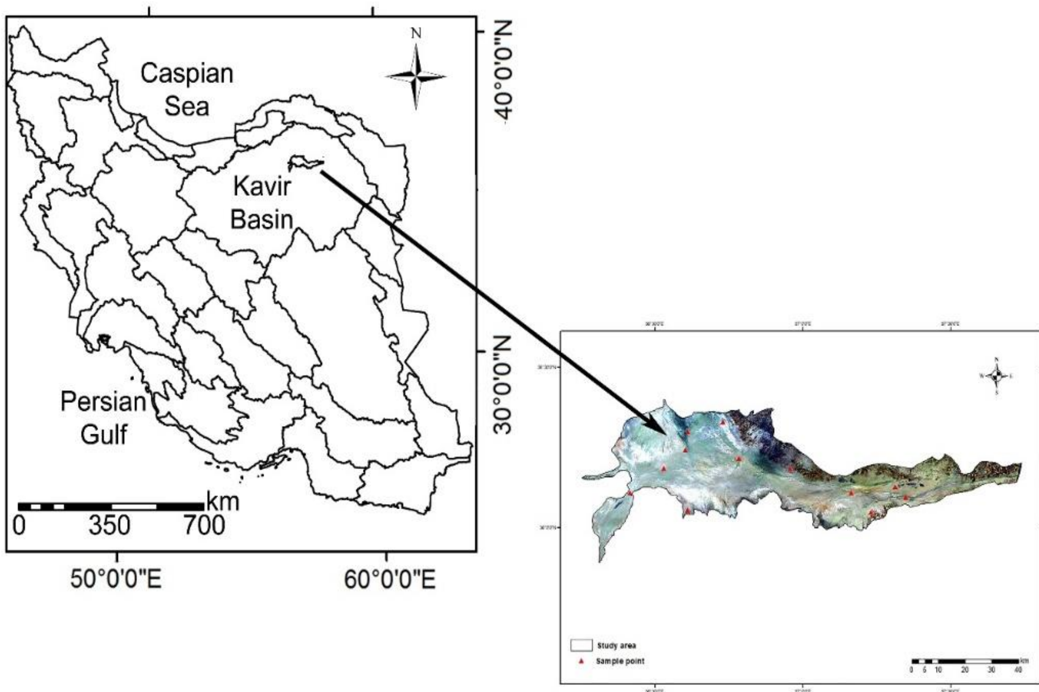

Figure 1. General position of the study area in great Kavir basin, central Iran

Methodology: The geological investigation of the region was conducted using four sheets 7262 (Abbas-Abad), 7362 (Davarzan), 7462 (Bashtin), and 7562 (Sabzevar) on a 1:100000 scale map. During a field observation and using GPS, the characteristics of sampled profiles were recorded in 12 areas at different geomorphic surfaces of the playa. All profiles were excavated by a handy auger, manufactured by the German company Windas, with a diameter of 5 cm and a depth of 1 M (Figure. 2). Additionally, to identify the type and formation of fibrous clay minerals, 10 samples of intact dry sediments were selected from different surfaces and depths. These samples were then covered with gold and analyzed by a Scanning electron microscope (SEM) at the central laboratory of Ferdowsi University of Mashhad (SPUTTER COATER SC7620) Next, SEM images and EDS were prepared for each element.

The clay minerals were determined by X-Ray diffraction analysis (XRD) in Tehran's Razi Applied Science Foundation. In doing so, carbonates and organic matters of the samples were removed by leaching for 12 hours (with 30 minutes of an ultrasonic bath) with 10% acetic acid and 10% H_2O_2. This step of this process is repeated several times until all carbonates and organic matters were removed. Using the X-Ray diffractometer device, the samples were then studied in three conditions; intact, saturated with ethylene glycol and heated (500 ° C) (Moore and Reynolda, 1989).

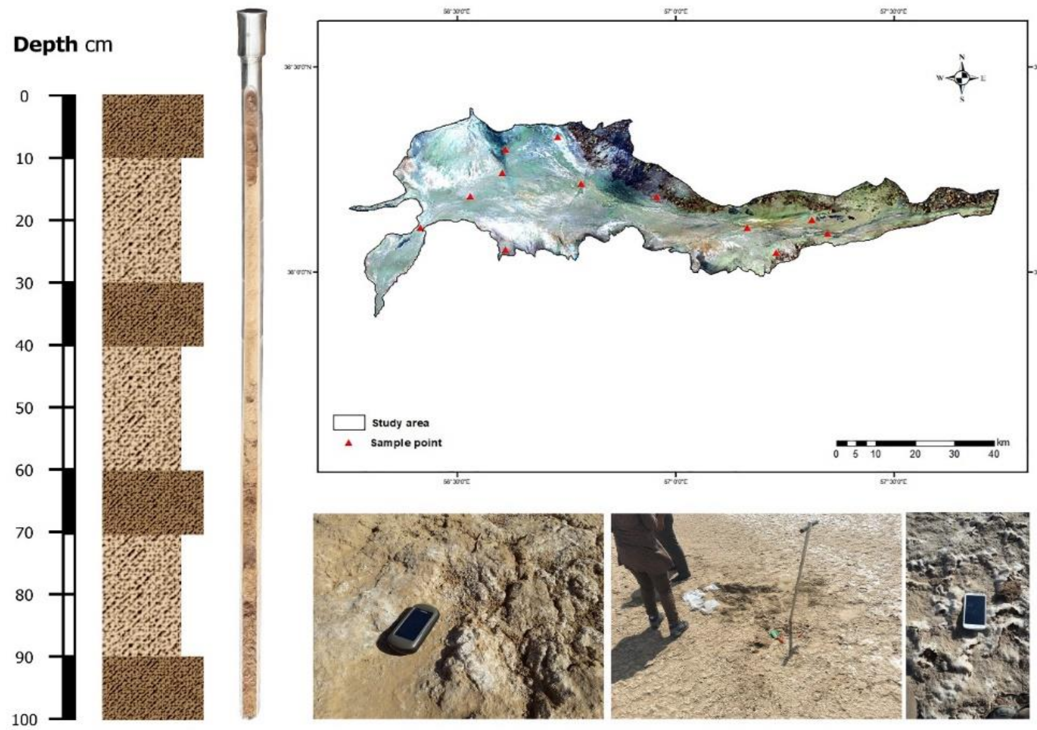

Figure 2. Sabzevar playa and the sampling localities

Results and Discussions:

The results of X-Ray diffractograms and Scanning Electron Microscope (SEM) images (Figure. 3) of clay minerals derived from four different depths in Sabzevar playa indicate the existence of authigenic and allogeneic clay minerals including Palygorskite, Sepiolite, Smectite, Illite, Montmorillonite, Chlorite and Kaolinite. Physical erosion and weathering of metamorphic and sedimentary rocks as well as mafic and ultramafic igneous rocks around Sabzevar playas are the source of many allogeneic clay minerals; however, some other clay minerals such as smectite and Palygorskite and Sepiolite fibres, are observed as both authigenic and allogeneic, due to the weak drainage and evaporative-saline environments in the playa. In fact those fibre clay minerals are characteristic of saline-alkaline regions (Kovda and Samiolova., 1969; Szaolcs, 1989), which are formed due to the evaporation and concentration of the brine rich in magnesium and alkaline carbonates (Hardie and Eugster, 1970). It can be argued that due to the dry climate, pH> 8 in the area and weathering of the surrounding rocks, magnesium and silicon dioxide-rich Illite has been transformed into Palygorskite. The EDX of SEM images at two depths of 90-100cm and 30-40 cm in profiles reveal the authigenic formation of Palygorskite and Sepiolite clay minerals under the dry and warm climate under suitable geochemical conditions.

Smectite is characteristic of saline-alkaline environments and warm and humid conditions. Also, it has an authigenic origin in poor drainage conditions where evaporation is progressive (Szaolcs, 1989). Vermiculite is also formed during the transformation of Illite to Smectite. The presence of authigenic Smectite and Vermiculite at depths of 60 to 70 cm in the profiles reflects more humid conditions compared to the present time. Kaolinite is generally formed by physical erosions with high hydrolysis in warm and humid climates (Moore and Reynolds., 1989; Perederij, 2001). However, in arid and semi-arid regions, due to unfavorable climatic conditions, this mineral is not formed. At a depth of 60 to 70 cm in the studied profiles, Kaolinite is found in high quantity. Given the presence of some authigenic Smectite minerals in this depth, it can be inferred that they have been formed in more humid conditions or moved around the playa by water currents and deposited in the playas Illites mostly appear at depths of 60 to 70 cm (Table 1), which reflects severe physical erosion and hot and humid climates. Today, due to the arid and semi-arid climate of the region, the conditions are not fertile for physical erosion of igneous rocks and Illite formation. Thus, shales and metamorphic rocks in the region can be the source of Illite in the playa (Pourali et al., 2020). The presence of chlorite in the surface and wind sediments in the region indicates the predominance of physical aeration processes and dry climatic conditions. Because chlorite, when exposed to acidite environment or groundwater, quickly loses its stability and is hydrolyzed, thereby transforming into Vermiculite or Smectite. (Dixon and Schulze., 2002).

Mean rate% Depth: 90-100	Mean rate% Depth: 60-70	Mean rate% Depth: 30-40	Mean rate% Depth: 0-10	Clay Minerals
7.8	7.6	6.4	7.5	palygorskite
8	18.1	17.4	12.8	Kaolinite
3.2	8.3	N	N	smectite
6.2	2.4	4.9	N	Sepiolite
2	6.3	N	3.8	Vermiculite
6.8	11.5	8.9	10.4	Montmorillonite
6	6.6	2.1	5	Illite

N: Not detected **Table1. Clay minerals composition (XRD) (quantitative data %)**

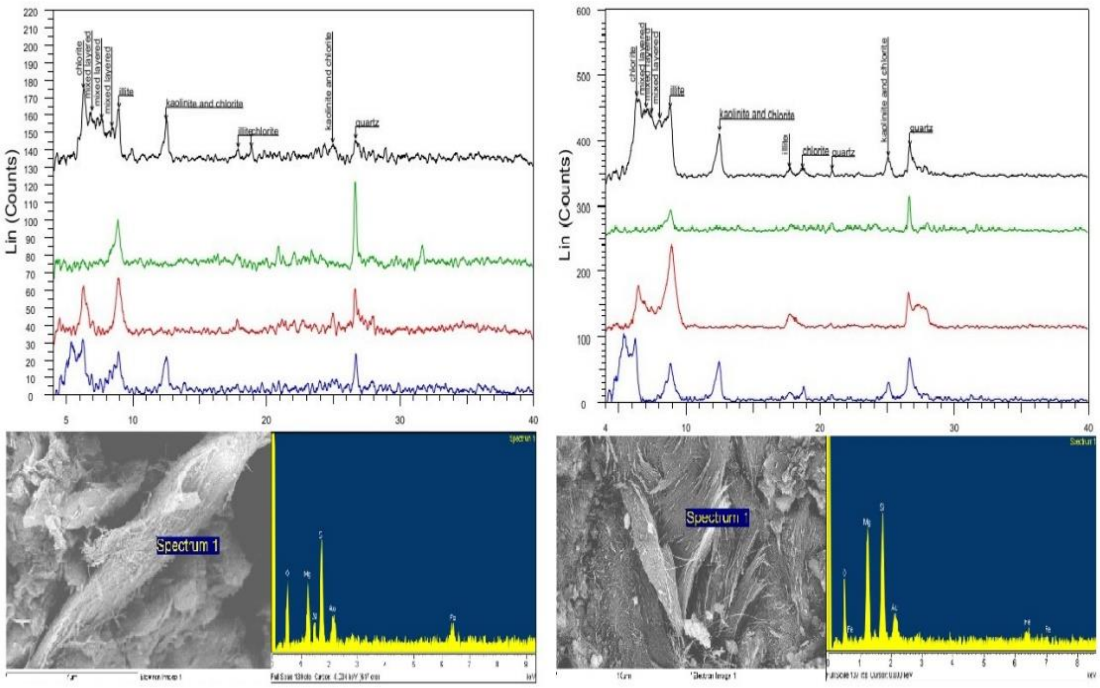

Figure 3. Multiple X-Ray diffractograms of the depths 0-10 cm, 60-70 cm, showing interpretation of major clay mineral from the three types runs, i.e. in air-dried, glycolated, and heated conditions.
Scanning electron microscope (SEM) images showing clay minerals

Conclusion:

The analysis of clay minerals in the Sabzevar playa at four depths (0-10, 30-40, 60-70, 90-100) indicates allogeneic and autogenic origin of minerals. The most important clay minerals in the area under investigation include Palygorskite, Illite, Kaolinite and Chlorite. Large amounts of Kaolinite minerals, together with the presence of Smectites and Vermiculites at a depth of 70-60 cm in the area indicate a warm and humid climate existed in the past. The presence of the highest percentage of clay minerals at this depth shows more weathering and more clastic sediment transport by rivers from the surrounding to the playa. It also confirms the warm and humid climate in the region and reveals the increase of the authigenic clay minerals of Palygorskite and Sepiolite from depth to the surface, suggesting the dominance of warm and dry climate.

Key words: Playa, Clay minerals, Palaeoclimate, Late quaternary

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