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Research paper

# Origin and distribution of clay minerals of soils in semi-arid zones: example of Ksob watershed (Western High Atlas, Morocco)

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ABSTRACT

The Ksob basin watershed is located in a region with a semi-arid climate; it is characterized by large area, variable geology and clay mineralogy, variable topography and different types of thin soils. In the aim to determine the origin and distribution of clay mineral of soils of this basin, three types of samples were considered in this study; the parent rock, the different horizon of soils and the recent river deposit. Clay mineralogical composition, particle size distribution, soil texture, carbonate, moisture and organic matter content (SOM), pH and conductivity were measured to identify the soil properties. Chlorite and illite of the studied soils basin were principally inherited from the parent materials, while vermiculite was principally formed in the soil environment. The other phases (dioctahedral smectite, illite-smectite mixed layers, kaolinite and palygorskite) can result from both inheritance and transformation. Ttrioctahedral smectite and palygorskite can also results from neoformation. Carbonate, SOM content and pH of the studied soils vary independently with clay mineralogy. However soils texture, parent rock, topography and climate strongly influence soil clay mineralogy and its evolution.

## 1. Introduction

Clay mineralogy plays a role of prime importance in the functioning of soils; it was found to be a dominant factor in controlling aggregate stability which is used as an indicator of soil structure (Six et al., 2000; Duiker et al., 2003). Clay minerals affect properties that influence aggregation: surface area, charge density, cation exchange capacity (CEC), dispersivity and expandability, and these in turn influence SOC decomposition rates (Dimoyiannis et al., 1998; Schulten and Leinweber, 2000). In high activity clays such as smectites and other 2:1 clays, aggregation is mainly high with high CEC, large surface areas and high soil organic carbon (Singer, 1994; Seta and Karathanasis, 1996; Amezketa, 1999; Schulten and Leinweber, 2000; Six et al., 2000). Furthermore, clay minerals have an important role in defining surface and subsurface processes (Kasanin-Grubin, 2013). The mineralogical compositions of soils have a particular influence on the erodibility of soils in dry climatic environment (Reichert and Norton, 1994; Jafarzadeh et al., 2013). Wakindiki and Ben-Hur (2002) consider the soils containing smectite more vulnerable to water erosion comparing to the soils containing kaolinite. Ben-Hur and Wakindiki (2004) suggested that mineralogical composition of soil should be considered during erosion modeling. However, most studies lack important information regarding clay mineralogy and their importance for weathering processes (Kasanin-Grubin, 2013).

The study of clay minerals in the weathering environment during soil formation is one of the most challenging activities pursued by clay mineralogists (Velde and Meunier, 2008; Ferrell Jr et al., 2013). In semi-arid climates, characterized by incomplete hydrolysis products of primary minerals (Curtis, 1990), several studies show that different factors are covarying with soil phyllosilicate mineralogy: erosional processes, pH and oxide content, which provide a different chemical environment, also land uses, topography, the type and quantity of organic matter entering the soil, and even soil structure and texture (Chorom et al., 1994; Haynes and Naidu, 1998; Ben-Hur and Wakindiki, 2004; Kasanin-Grubin, 2013; Barré et al., 2014). Notwithstanding, there is to our knowledge few reviews dedicated to the link between all these factors and phyllosilicate mineralogy even if they are inseparable.

In this work, we studied the clay mineralogy of different types of samples collected from different sectors (uppermost and deeper horizons of soil, bedrock, river terraces, and river bed). The study area selected is the Ksob watershed located in the western side of the High Atlas range (Morocco). It is an ideal site for this study because it is a large mountain catchment characterized by semi-arid climate, variable geology and clay mineralogy, variable topography, and different types

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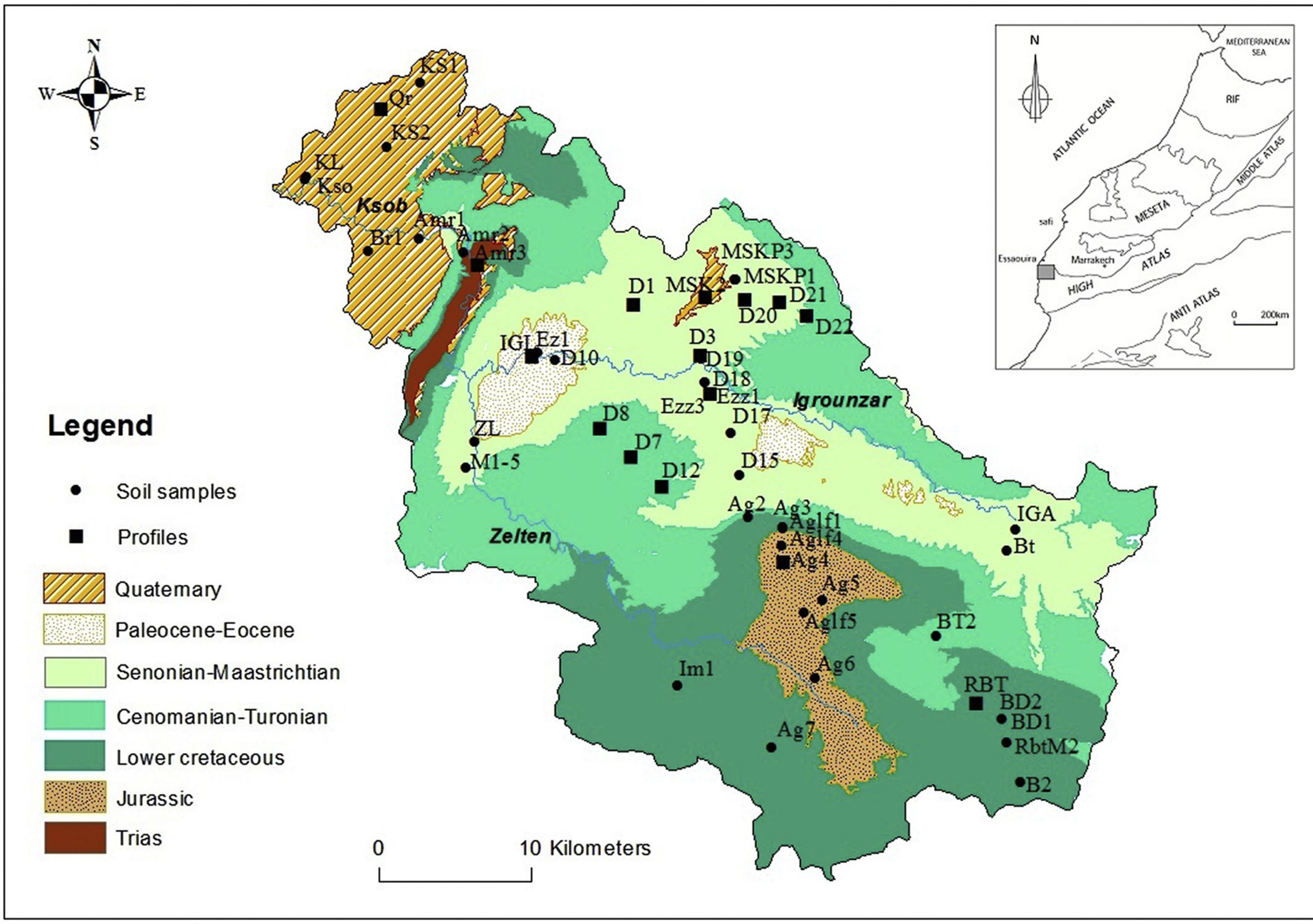


**Fig. 1.** Geological map of the studied area and location of the studied profiles.

of thin soils which are preserved. Moreover, the sedimentary sequences composing the bed rock of soils in the Ksob watershed were well studied and characterized in terms of lithology and clay mineralogy (Ben et al., 1996; Bouatmani et al., 2004; Daoudi et al., 2007, 2010; Ouajhain et al., 2009, 2011; Knidiri et al., 2014). The results obtained by these authors revealed the occurrence of kaolinite, chlorite, illite, palygorskite, I-S mixed layers and the smectite which is the dominant clay mineral of these formations. However the clay mineralogy of the corresponding soils has had less attention. The objective of the present study is not only to identify different clay mineral species developed in soils of this basin watershed, but also to determine their origin and distribution and to link the mineralogy of phyllosilicates to different factors controlling the evolution of the soils in semi-arid zones, through the example of the Ksob watershed.

## 2. Study area

The Ksob watershed situated in the central western part of Morocco (Fig. 1), lies between 9° and 9°46′ W longitude and 31°2′ and 31°30′ N latitude and covers approximately 1520 $km^2$. It comprises three sub-basins: Adamna in the North, Igrounzar in the Southeast and Zelten in the Southwest. The Ksob basin is located in a semi-arid zone, characterized by interferences between oceanic, continental and mountain influences (El El Mimouni et al., 2010, Zamrane et al., 2016). The annual average temperature is around 20 °C. The temperature difference between the warmest month (July) and the coldest month (January) does not exceed 6 °C; but the daily range is larger, up to 10 to 12 °C. The annual rainfall average is around 300 mm per year, often concentrated in the autumn and winter periods with irregular precipitations during the rest of the year, and also by droughts which take a considerable extent, especially in lowland areas where temperature and evaporation are high (Zamrane et al., 2016). The catchment elevation ranges from 50 to 1702 m above sea level (Omdi et al., 2017).

Regarding the geological setting, the study area belongs to the western High Atlas basin, it comprises diverse lithological facies which range from the Triassic to the Quaternary (Ouajhain et al., 2011). The outcrops of Plio-Quaternary are located in the downstream sector of the watershed; they are composed of friable formations of coastal and aeolian dunes. The Eocene outcrops composed mainly by marly and phosphatic deposits are exposed in the central part of the study area. The Jurassic-Cretaceous carbonates formations (dolomitic limestones, marly limestones and calcareous marl) represent the most dominant facies; they represent about 50% of the area of Zelten sub-basin and almost 85% of Igrounzar sub-basin (Geological map of Marrakech, 1/50000) (Fig. 1). Calcareous soils, isohumic soils, lithosols and regosols are the main soil series. According to the High Commissariat for Water, Forest and Fight against Desertification (HCEFLCD) (2012), agriculture is the most dominant land use pattern in the study site occupying about 60% of the total surface area of the Ksob watershed, while forests (Argan, Cedar, Green Oak and Scrub plants) occupy 30%.

## 3. Materials and methods

### 3.1. Materials

Eighty-nine samples from three types of samples were considered in this study: the bedrock, the soils with different horizons, and the river deposit.