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Palygorskite occurrences and genesis in calcisol and groundwater carbonates of the Tensift Al Haouz area, Central Morocco

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ABSTRACT

Palygorskite has been identified as a major constituent of the clay fraction in carbonate soils of arid and semi-arid regions. This fibrous clay has a great significance as a paleoclimatic indicator and is of fundamental importance for a more complete understanding of conditions under which petrocalcic horizons and groundwater carbonates precipitate. The present study was undertaken in order to evaluate the occurrence, the genesis as well as the micromorphological aspects of palygorskite in calcisol and groundwater carbonates. The samples were analyzed by X-ray Diffraction (XRD), scanning electron microscopy (SEM), and chemical analysis (XRF). Two modes of genesis for palygorskite were identified: (1) In the petrocalcic horizons, the palygorskite is the dominant clay mineral; palygorskite fibers and fiber bundles extend from euhedral or subhedral calcite crystals showing an authigenic origin of palygorskite. The palygorskite is formed in the vadose environment from infiltrating soil water through the intense evaporation of subsurface water after calcite precipitation. (2) In the groundwater carbonates, smectite flakes appear to terminate palygorskite fibers suggesting formation of palygorskite through the alteration of precursor smectite. The increasing aridity would have caused the intense evaporation conducive to the precipitation of calcite and an increase in pH, which lead to dissolution of smectite and formation of palygorskite.

1. Introduction

Carbonate soils occur in arid and semi-arid ecosystems in more than half of the world's land area (Khademi and Mermut, 1999). Carbonate soils and sediments are not pure, and generally include clay minerals, sand, gravel, silt and rock fragments. Various clay minerals can be associated with calcisols such as chlorite, illite, palygorskite, kaolinite, smectite, and sepiolite (Reeves, 1976). Palygorskite is often reported as the predominant clay mineral in calcareous environments and often, in calcisols in particular (Hassouba and Shaw, 1980; Watts, 1980 and Sancho et al., 1992); it is a significant paleoenvironmental and geochemical indicator (Khademi and Mermut, 1999; Sancho et al., 1992). In the international literature, palygorskite occurrences and genesis have received much attention (Ingles and Anadon, 1991; Kadir and Eren, 2008; Pimentel, 2002; Rodas et al., 1994; Verrecchia and Le Coustumer, 1996). Multiple modes of occurrence of palygorskite in calcisols have been proposed depending on local conditions. It can be inherited/detrital (Khademi and Mermut, 1998; Singer, 1971) or authigenic formed by direct precipitation from solution (Galán and Pozo, 2011; Millot, 1970; Yalçın and Bozkaya, 2011) or by diagenetic alteration of precursor smectite or other phyllosilicates (Galán and Pozo, 2011; Kaplan et al., 2013; Yalçın and Bozkaya, 2011).

In Morocco, palygorskite deposits and occurrences have been recorded in different lithological successions ranging in age from Cretaceous to Quaternary. In the western High Atlas as well as in the Meseta domains, Tertiary sediments appear to be the main host of lithogenic palygorskite, where is the dominant clay mineral in shallow marine and restricted environments (Daoudi, 1996, 2004; Knidiri et al., 2014). This fibrous clay has been detailed in several studies according to its distribution, occurrences, genesis and palaeoenvironmental significance (Daoudi, 2004; Knidiri et al., 2014; Pletsch et al., 1996). However, although calcisols and groundwater carbonates cover large areas of the territory (Ducloux and Laouina, 1986; Kaemmerer et al., 1991; Ruellan, 1967), limited studies are available concerning the palygorskite in calcisols reported by Badraoui et al. (1992) and Millot et al. (1969) from the low Moulouya and Chaouia region respectively.

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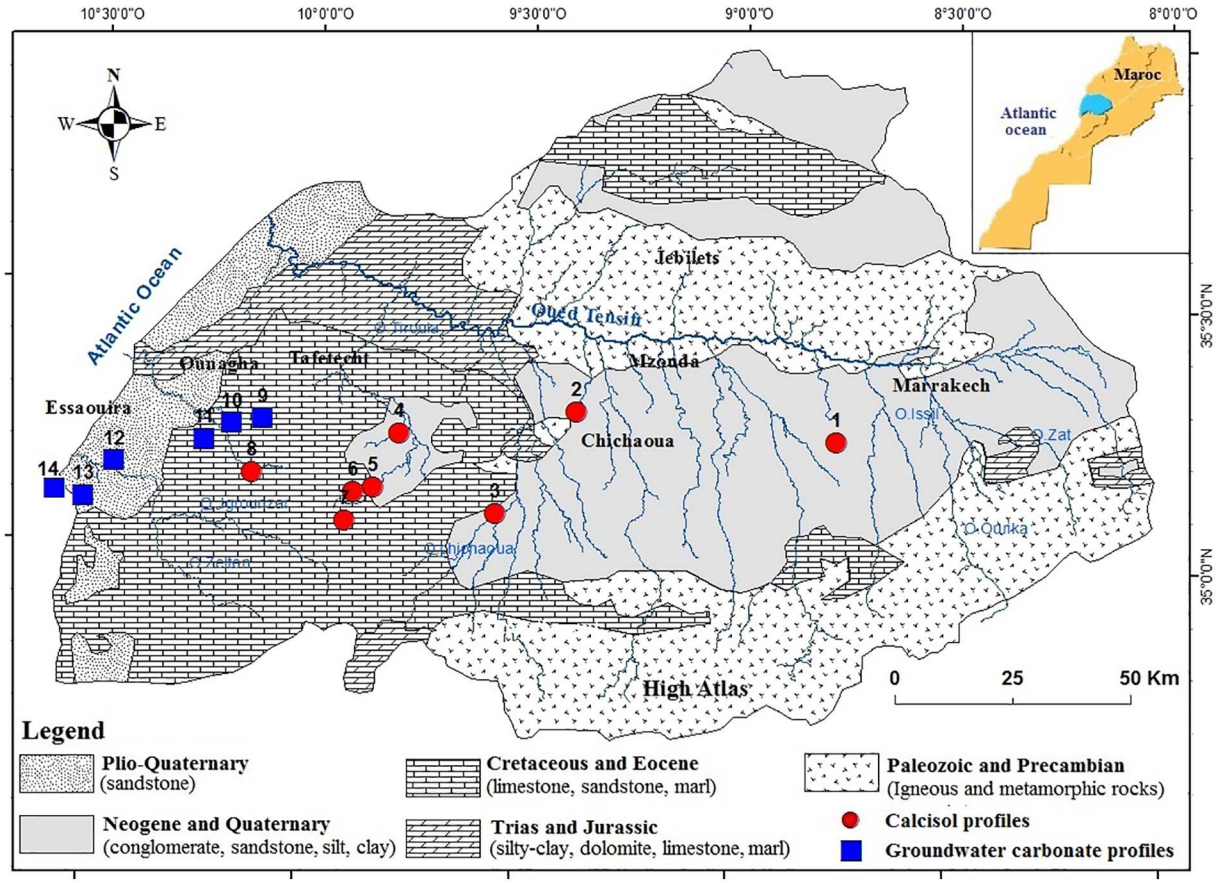

Fig. 1. Geological map and location of the studied soil profiles.

The recent study conducted by Elidrissi et al. (2017) in the Tensift Al Haouz, one of semi-arid regions where calcisols and groundwater carbonates are ubiquitous and variable in morphology, has contributed to the understanding of the evolution as well as the distribution of calcisols in this vast region. The objective of the present study is to determine the genesis of palygorskite in calcic horizons and groundwater carbonates in the Tensift Al Haouz area. In this respect, this research focuses on the mineralogical study of soil profiles and detailed microscopic features of palygorskite, in the aim to determine the relationships with calcite and associated clay minerals and to discuss the origin and genesis of palygorskite. Moreover, the study of lateral distributions can provide indicators of paleoenvironment and paleoclimate conditions under which carbonate precipitates.

2. Study area

2.1. General context

The Tensift Al Haouz region is located in the central part of Morocco (Fig. 1) with land area of about 20,500 km^2. It is composed of three geographically distinct regions: the plain of Marrakech-Al Haouz and Chichaoua at the east, the coastal plain of Essaouira at the west and the High Atlas at the south.

In the western part of the region, the oceanic influences interfere; the climate is characterized by a sub humid tendency, whereas the eastern part is characterized by clear continental influences (Chehbouni et al., 2012).

The geology of the study area is represented mainly by Precambrian and Paleozoic basement composed of igneous and metamorphic rocks, forming the platform of the Atlas Mountains (Piqué, 1994). The plain of Marrakech-Al Haouz and Chichaoua comprises mainly alluvium from the dismantling of the Atlas mountain range and accumulated in the Neogene and in the Quaternary. These facies include conglomerates, sandstones, silts and clays. In the western part, the overlying sedimentary sequences consist of epicontinental and marine sediments of Cretaceous and Eocene dominated largely by limestone, calcareous sandstones and marls (Weisrock, 1980). In the coastal zone, the Plio-Quaternary outcrops are composed of calcareous sandstones of coastal and eolian dunes (Weisrock, 1980).

2.2. Calcisols and groundwater carbonates development

The precipitation of calcium carbonate is common in modern, extant soils of the Tensift Al Haouz area. It produces a wide variety of forms and differentiated soil profiles. There are two distinct types of mature carbonate (Elidrissi et al., 2017): (1) profiles with calcic and petrocalcic horizons widespread in the central part of the study area and (2) profiles with groundwater carbonates in the west (Fig. 1).

The first-type of profiles correspond to older quaternary soils that accumulate pedogenic calcium carbonate and still at the surface. Prior micromorphological study revealed a pedogenic origin with the presence of pisoliths and beta textures (biogenic micro-features) (Elidrissi et al., 2017). These calcisols formed by precipitation of calcium carbonate in the vadose zone with illuvial processes (Alonso-Zarza, 2003;