Climate change in Northeast Iran based on the morphology of palygorskite and pedogenic carbonates in loess deposits

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Loess/paleosol sequences near the city of Mashhad in Northeast Iran date back to last glacial/interglacial cycle. The Holocene loess containing a weakly developed Bk horizon and a paleosol of last interglacial period (Oi 5) with a Bk horizon have developed. Loess deposits in this area appear to have a local origin and their main source is Pliocene gypsiferous marl containing a high amount of palygorskite. The aims of this study were (i) to identify palygorskite in different landforms and sediments, (ii) to investigate the microscopic and submicroscopic analyses of palygorskite and associated pedogenic carbonates and (iii) to understand the paleoclimatic conditions prevailing in the area.

From west to east, Robat-e Khakekari section on a plateau-like geomorphic surface in the granitic hilly lands and Tappah Salam section in the piedmont of granitic hilly lands containing loess/paleosol sequences, Astane Ghods section in the piedmont plain and Tangal Shour section in the gypsiferous nearly hilly lands were studied. The clay fraction of soils and sediments were analyzed using X-ray diffraction (XRD) and transmission electron microscope (TEM) techniques. Undisturbed soil samples were impregnated with resin and thin sections were prepared and studied using polarizing microscope. Unsturbed samples were mounted on Al stubs and examined by a scanning electron microscope (SEM).

The XRD patterns showed the presence of palygorskite in different horizons of Tangal Shour section, Bk horizon of Holocene soils of Robat-e Khakekari and Astane Ghods sections, saline layers of Tappah Salam section and also in gypsum enriched layers in loess deposits that showed the evidence of solution and recrystallization of gypsum. The short
fibers of polygorskite are visible in TEM micrographs of the Ap and Bk horizons of Robate Khakestari section, Bk and less layers of Tappach Salam section and in less quantity in Bw horizon of Astanes Ghoush section. The SEM analysis of undisturbed samples showed that polygorskite fibers were as long as 5-10 microns in the gypsumiferous marl and the lower parts of Tappach Salam section. In the Bk horizons and gypsum enriched layers, a few short fibers of polygorskite could be observed. The micromorphology revealed different form of carbonate accumulation in Bk and Bk horizons. In the Bk horizon, the typical carbonate nodules as a result of impregnation of groundmass without any translocation (orbic nodules) were observed. Some nodules encompass the coarse grains (Nucleic nodules). In the Bk horizons the carbonate nodules have been separated from the groundmass and represent some translocation or rotation but the internal fabrics of nodules are similar to groundmass (disartic nodules). The carbonate nodules in Bk horizons have been covered by nonlaminated dusty clay coating representing polygenetic development.

In conclusion, based on the amount and morphology, four kinds of polygorskite in sediments and soils were distinguished: 1) A high amount of well-grown fibers in the gypsumiferous marl of Tappach Shour section and the saline part of Tappach Salam section as a product of in situ formation. The clay mineralogy of Miocene gypsumiferous marl in the area is in agreement with Late Miocene sediments in Southern Iran and Oligo-Miocene sediments from Central Iran. 2) A somewhat high amount of polygorskite in weakly developed Bk horizons of Holocene soils on less deposits and layers containing recrystallized gypsum, as a result of illuviation of polygorskite in association with carbonates or gypsum which is easily detectable by XRD. 3) The lesser amount of polygorskite in the red Bk horizons (OIS 5 paleosols) in less sections. The existence of carbonate nodules covered by clay coating represents a moist condition after carbonate illuviation and unstable environment for polygorskite during last interglacial. 4) Very little amount of detrital polygorskite in unaltered less deposits originating from gypsumiferous marly material during less deposition.

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