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Soil-parent material relationship in a mountainous arid area of Kopet Dagh basin, North East Iran

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ABSTRACT

The effects of parent rock types on soil evolution in arid areas were studied in a sequence of soils, derived from different lithologies in the Kopet Dagh basin (Northeastern Iran) using micromorphology, clay mineralogy, magnetic susceptibility and physico-chemical properties. The selected parent rocks and associated soils were shale (Haplocalcids), claystone (Haplotorrerts), gypsiferous marl (Haplogypsids), limestones (Haplocalcids and Torriorthents), siltstone and sandstones (Torriorthents). The results showed that the properties and development of soils were mainly affected by grain size and mineralogy of parent materials. Soil magnetic susceptibility (χ_{lf}) variations were attributed to the types of parent material and pedogenic processes. Redistribution of calcite and gypsum in soil profiles and natural and pedogenic formation of ferrimagnetic minerals were responsible for χ_{lf} variations. The soils clay mineral origins were found to be mainly of inheritance from parent materials. Smectite was the dominant clay mineral of the most soils.

Based on the micromorphological index of soil evolution (MISECA), the soils studied were categorized into weakly developed Orthents, weakly to moderately developed Aridisols (Gypsids and Calcids) and moderately developed soils including Calcids and Torrerts. The degree of microstructure development, alteration of weatherable minerals and calcitic features were the most important criteria influencing assessment of soil development degree by MISECA index. The vertic features were only observed in soils of claystone in which there were considerable amounts of clay and smectite. High amounts of gypsum and low smectite content were mainly responsible for the lack of vertic behavior in other fine grained soils derived from shale and marl.

1. Introduction

The Kopet Dagh depositional basin, located in northeastern Iran and southern Turkmenistan, is a mountainous area dominated by sedimentary rocks and arid climate. The mean annual precipitation, temperature and potential evapotranspiration are 255 mm, 13 °C and 764 mm, respectively. The geomorphic surfaces of the area are young and have a close relation with geological structure in which anticlines make mountains and synclines form intermountain basins (Afshar-Harb, 1979). Parent materials play a key role in soilscape diversity in arid and semi-arid areas (Badía et al., 2013). Yousefifard et al. (2015) have observed different pedogenetic paths related to types of parent material under semi-arid condition in northwestern Iran. Soil parent material characterization is of paramount importance in soil genesis studies in arid and semi-arid conditions and soils on young surfaces (Schaetzl and Anderson, 2005). Parent materials affect many soil properties that may be critical for soil series separation and to develop soil mapping models. Soil properties and landscape evolution could indicate the type of underlying parent materials in arid regions as well.

It has been stated that the mineralogy of soils in arid area is largely affected by parent material (Woodruff et al., 2009). Inheritance of clay minerals from parent rocks is the most important factor influencing the clay mineral composition of soils which is influenced by weathering intensity and relief (Graham and O'Geen, 2010), climate (Ruffell et al., 2002), vegetation, drainage (Abtahi and Khormali, 2001) and different response of bedrocks to chemical weathering, can lead to different landscapes and weathering products (Dultz, 2000; Yousefifard et al., 2012). Although the clay mineralogy of sedimentary rocks in the Kopet Dagh basin has recently been investigated (Khormali and Amini, 2015), no study has been made on the effects of mineralogy of parent rocks on soil evolution.

The presence of different forms of Fe oxides in soils is highly affected by the type of parent material under variable condition such as moisture, temperature, pH, Eh, organic matter and iron release from iron bearing minerals (Filho et al., 2015). Fe_d (free Fe oxides) indicates the amount of fine-grained secondary Fe oxides released from Fe-bearing minerals during pedogenic processes (Mehra and Jackson, 1960). Fe_d

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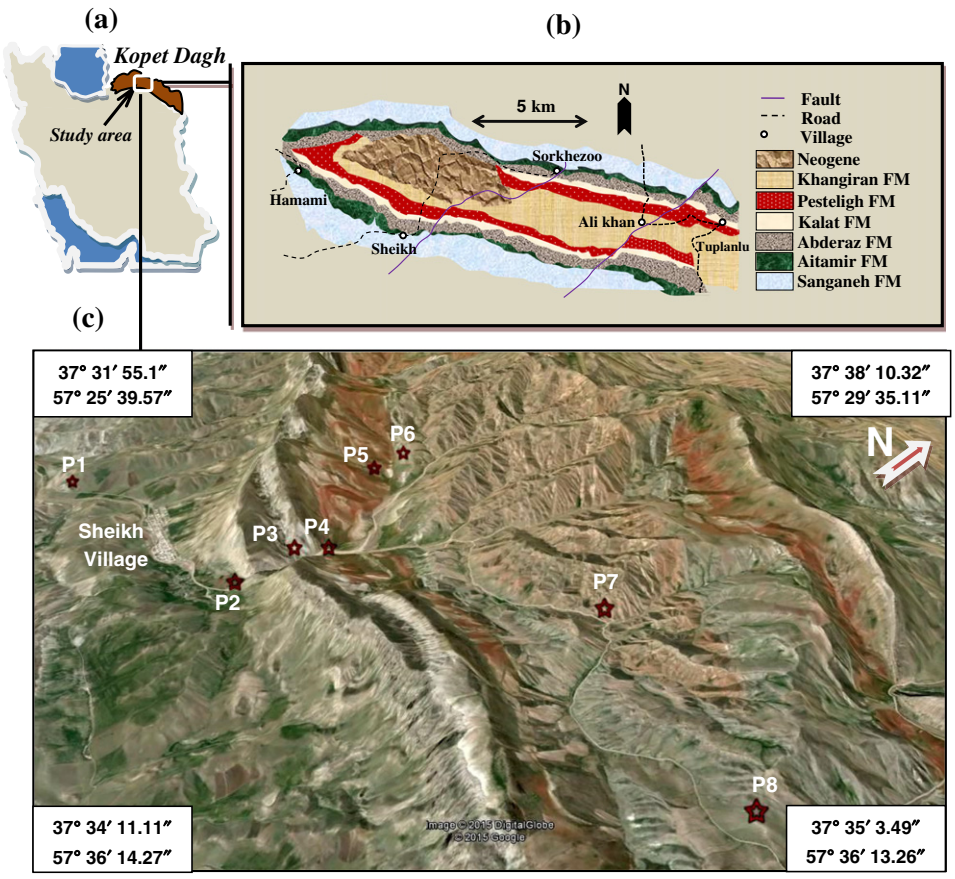

Fig. 1. Location map of the study area, in Kopet Dagh basin, in northeastern Iran (a), simplified geological map of the study area as a part of Sheikh syncline (b), Google earth image of Sheikh syncline showing locations of soil profiles formed on selected lithologies of different formations: P1: shale of Sanganeh formation, P2: glauconitic sandstone of Aitamir formation, P3: limestone of Abderaz formation, P4: limestone of Kalat formation, P5: claystone of Pesteligh formation, P6: sandstone of Khangiran formation, P7: siltstone of Neogene and P8: gypsiferous marl of Neogene (c).

content of soils, which is strongly affected by parent material, could represent the degree of pedogenesis (Filho et al., 2015; Hu et al., 2004). Fe_o reflects the concentration of poorly crystalline Fe oxides in soils (Schwertmann, 1973). The ratio of Fe_o/Fe_d reflects Fe oxides crystallinity in soils and has been used to evaluate genetic processes and for assessing degree of profile development (Hu et al., 2009).

The magnetic susceptibility of soils, can be measured by fast, cheap and nondestructive methods and has been used in different aspects of pedogenic studies such as climate change records in loess-paleosol sequences, description and diagnosis of parent material uniformity and chronosequence of soils (Jia et al., 2012; Fine et al., 1992; Maher, 1998; Singer et al., 1992; Williams and Cooper, 1990).

The magnetic enhancement of soils is mainly related to in situ pedogenic formation of ferrimagnetic minerals and strongly affected by soil-forming factors (Feng and Johnson, 1995; Fine et al., 1992; Singer and Fine, 1989). Slight changes of ferrimagnetic mineral will significantly influence low-field magnetic susceptibility (χ_{lf} values) (Maher, 1998). The χ_{lf}/Fe_d ratio reflects the proportion of ferrimagnetic mineral to total secondary Fe oxides and its correlation with Fe_d, Fe_o and Fe_o/Fe_d are indicators to evaluate the relations between magnetic susceptibility, Fe oxide crystallinity and pedogenesis (Hu et al., 2009).

The main objective of the present study is to investigate soil-parent material relationship using free and active Fe oxide, clay mineralogy, micromorphology as proxies for degree of soil development and soil-parent material homogeneity.

2. Materials and methods

2.1. Description of the study area

The Kopet Dagh Basin covers an area of approximately 500 km^2 in northeast Iran (Fig. 1a). The basin formed as a result of the enclosure of the Paleotethys Ocean induced by convergence of the Iranian and Turanian plates during early Cimmerian orogeny. The final collision folded the entire rocks that had been deposited in the basin from the Jurassic to the Miocene and formed the Kopet Dagh Mountains. (Berberian and

Table 1
Selected parent rocks of studied formations in Sheikh Syncline.

Formations, Ages		Sanganeh, Albian	Aitamir, Albian-cenomanian	Abderaz, Turonian	Kalat, Maastrichtian	Pesteligh, lower paleocene	Khangiran, Eocene	Neogene, Miocene	Neogene, Miocene
Selected lithologies		Shale	Glauconitic sandstone	Limestone	Limestone	Claystone	Sandstone	Siltstone	Gypsiferous Marl
Soil profile locations*	North:	37° 33′ 20.5″	37° 33′ 41.7″	37° 33′ 57.6″	37° 34′ 4.2″	37° 34′ 27.4″	37° 34′ 36.9″	37° 34′ 36.4″	37° 34′ 17.6″
	East:	57° 31′ 53.2″	57° 33′ 47.3″	57° 33′ 37.8″	57° 33′ 43.2″	57° 33′ 11.8″	57° 33′ 9.1″	57° 34′ 57.4″	57° 36′ 4.7″
Elevations (m above sea level)		1110	1236	1230	1251	1300	1303	1318	1494