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Calcic soils as indicators of profound Quaternary climate change in eastern Isfahan, Iran

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ABSTRACT

In the high plateau region of central Iran, there is both a lack of information on calcic soil processes and aspects of Quaternary paleoclimate. Thus, the research discussed here was undertaken as a first step to assess the utility of calcic soil research in the region. The properties and isotope composition of calcic soils was studied on a complex of alluvial fans, located about 50 km SE of the city of Isfahan. At least three geomorphic surfaces have formed during an interval from the middle Pleistocene to the Holocene. These geomorphic surfaces contain calcareous soils and paleosols. Interpretation of the pedogenic evidence indicates that there have been multiple periods of clay formation and carbonate accumulation over time, with an overall trend of increasing environmental aridity. Microscopy shows that overprinting is a major factor responsible for the accumulation of calcrete, suggesting the impacts of climate oscillations on the calcrete formation. Stable isotope composition of pedogenic carbonates in soils of differing ages is suggestive of a decrease in plant density and an increase in evaporation as soils become younger. This research highlights the utility of the morphology and isotope chemistry of calcic soils for constraining environmental change during the Quaternary.

1. Introduction

Soil is the product of biogeochemical alteration of parent materials, and is an important part of the Earth's critical zone (Amundson, 2005). Soils formed at different times in arid environments provide important information on rates of geochemical processes and, in some circumstances, provide data on changes in regional climate conditions over geological time (McDonald et al., 2003; Oerter et al., 2016).

The rates of calcic soil formation (e.g. Machette, 1985) and climate history (e.g. Dworkin et al., 2005; Zhou and Chafetz, 2009; Ebeling et al., 2016; Bayat et al., 2017a) have been topics of research. Because climate is one of the important factors of pedogenesis, soil-based paleoclimatic interpretations have grown in use during recent years (e.g. Pfeiffer et al., 2012; Oerter et al., 2016; Bayat et al., 2017a). Oerter et al. (2016), using the stable isotope composition of pedothems (pedogenic carbonate clast coatings), found changes in atmospheric circulation pattern over North America during marine isotope stage (MIS) 4. Based on pedologic features, Pfeiffer et al. (2012) detected alternating climate cycles in central Chile that extend back to at least MIS 11.

Calcic soils form via different pathways on calcareous (e.g. Rabenhorst et al., 1991; Bayat et al., 2017b) and noncalcareous (e.g. Monger and Daugherty, 1991; Whipkey et al., 2002; Achyuthan, 2003) parent materials. External sources of Ca ions (dust or Ca ions in rain water) are important for the development of pedogenic carbonates in noncalcareous parent materials. On other hand, pedogenic carbonates forms more quickly in calcareous parent materials due to in situ alteration of the relatively soluble calcareous minerals.

Calcareous soils and paleosols formed in geomorphic surfaces of differing ages provide information for discrete points or intervals in

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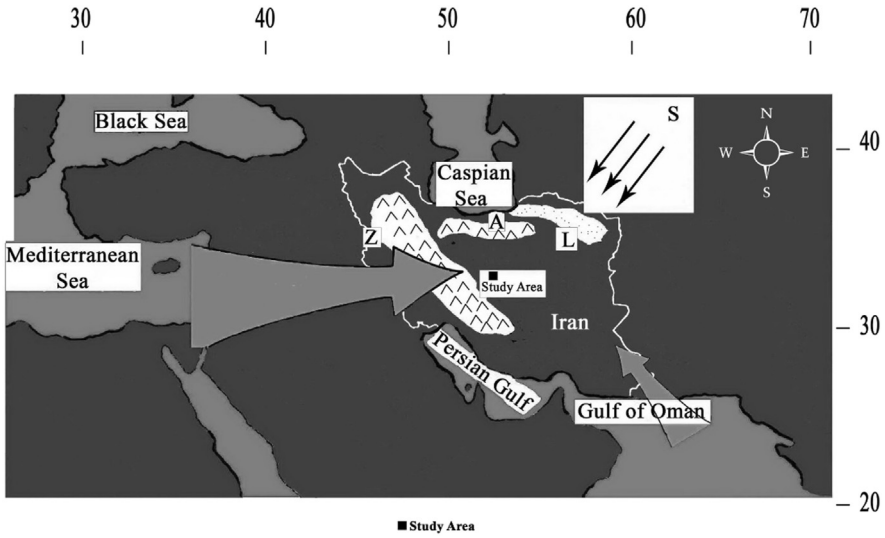

Fig. 1. Study area in central Iran; Z: Zagros Mountains, A: Alborz Mountains, L: loess deposits of northeastern Iran, S: Siberia High. Thickness of arrows shows the importance of moisture source from the Mediterranean Sea or the Gulf of Oman (monsoon) for Iran.

time (e.g. McDonald et al., 2003; Young et al., 2004; Bayat et al., 2017b). A geomorphic surface is defined as a mappable landscape element formed during a given time period. Surfaces are distinguished from one another by distinctive topographic features, weathering characteristics and pedogenic development (Christenson and Purcell, 1985; Bull, 1991; Schaetzl and Anderson, 2005). Geomorphic surfaces may be depositional, erosional or a combination of both (Schaetzl and Anderson, 2005). Geomorphic surfaces of alluvial fans are commonly used as the basis for chronostratigraphic studies of arid soils (e. g. McDonald et al., 2003; Bayat et al., 2017b) and the nature of pedogenic processes (Sauer et al., 2015).

Central Iran possesses a transitional climatic region, at the boundary between a westerly-dominated zone in north (from the Mediterranean and Black Seas) and a zone influenced by a sub-tropical High to the south. Thus, relative shifts in the strength of either of these systems should produce significant changes in the local climate. However, there is a considerable lack of information on aspects of Quaternary paleoclimate. Thus, the research discussed here was undertaken as a first step to assess the utility of calcic soils as a paleoclimate tool in the region.

2. Geographic setting

The field area chosen for this study is a complex of alluvial fans about 50 km SE of the city of Isfahan (Fig. 1). Geologically, the study area is situated in the Sanandaj-Sirjan tectonic zone, which is the most active tectonic zone of Iran (Aghanabati, 2004). The area is similar in structure to that of the Basin and Range Province of the USA (Karimzadeh, 2002; Bull, 1991). The alluvial fans drain a small mountain range along the southern margin of the Zayandehrud River valley. This river, like many in this region, is internally drained and enters the Gavkhoni playa 80 km SE of the field area (Figs. 1 and 2). Alluvial fans are major landforms in central Iran (e.g. Le Dortz et al., 2011; Jones et al., 2014), with great expanses of these features in the Isfahan region (Fig. 2).

The study area is affected by a rain shadow effect of the Zagros Mountains (Fig. 1). The Zagros Mountain range is separated from central Iran by the Zagros thrust fault. Due to interest in the rates of offset along this fault system, Le Dortz et al. (2011) have provided geochronological constraints on the ages of the alluvial fans in that region. While these sites are 250 km to the SE of the area studied here, the similar elevations and geological setting suggest that the work of Le

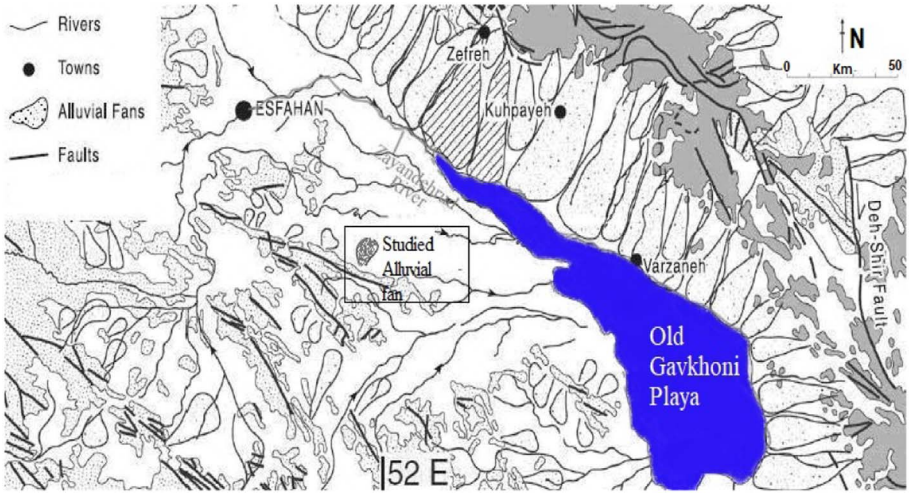

Fig. 2. Location of the alluvial fans in the eastern Isfahan region (after Jones et al., 2014). Notice the fault along the mountain front of the studied fans.