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Regional variations in magnetic properties of surface sediments in the Qaidam Basin and their paleoenvironmental implications

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ABSTRACT

The Qaidam Basin is the largest intermontane basin on the northeastern edge of the Tibetan Plateau. At present, systematic rock magnetic studies of surface sediments in this basin are scarce because of the vast area and poor accessibility. In this paper, multi-parameter rock magnetic investigations of surface sediments from a wide area in the Qaidam Basin have been conducted. We find that pseudo-single domain and multidomain ferrimagnetic minerals (i.e. magnetite and maghemite) dominate the magnetic properties of surface sediments in the basin. Surface sediments from the western part of the basin exhibit the lowest magnetic concentration values χ, χ_{ARM} and SIRM. In contrast, samples from the upwind sides of the basin and the eastern margin of the basin show the highest magnetic concentration values. The spatial distribution of magnetic parameters in the Qaidam Basin suggest that wind environments and the supply of clastic sediments possibly provide the main control on the regional variations of magnetic parameters. Our results also provide new insights into the mechanisms of magnetic variations of late Pliocene lacustrine sediments in the western Qaidam Basin.

1. Introduction

The Qaidam Basin covering an area of ~120,000 km^2 is the largest intermontane basin at the northeastern edge of the Tibetan Plateau. The basin has received up to 12,000 m of lacustrine sediments during the Cenozoic, which provides an excellent opportunity to reconstruct the tectonic and climatic evolution of the NE Tibetan Plateau (Liu et al., 1998; Yin et al., 2008; Sun et al., 2005; Fang et al., 2007; Kapp et al., 2011; Lu and Xiong, 2009; Lu et al., 2012; Alexander et al., 2013). Since the concentration and types of magnetic minerals in lacustrine sediments are closely related to sediment provenance and/or climate changes (Thompson and Oldfield, 1986; Dunlop and Özdemir, 1997; Evans and Heller, 2003), many scholars have attempted to use magnetic proxies for high-resolution reconstruction of paleoclimatic changes and the erosional history in this region (Lu and Xiong, 2009; Lu et al., 2012; Zhang et al., 2012; Herb et al., 2013).

However, controlling factors for the variability of magnetic parameters in lacustrine sediments in the Qaidam Basin remain controversial. A number of rock magnetic investigations demonstrated that changes in source material appear to provide the main control over the magnetic properties of these sedimentary sequences (Lu and Xiong, 2009; Lu et al., 2012). In contrast, rock magnetic studies on a ~940-m-long drill core from the western Qaidam Basin indicated that low-temperature oxidation in the catchment area predominantly controlled the variability of magnetic parameters in the core and comparison with pollen record revealed a climatic origin for the magnetic variations (Zhang et al., 2012; Herb et al., 2013). In this context, detailed rock magnetic investigations on surface sediments across the Qaidam Basin not only provide an opportunity to improve our understanding of the mechanism causing spatial variations of magnetic parameters in the NE Tibetan Plateau, but also possibly provide new evidence for paleoenvironmental interpretations of rock magnetic signatures of late Pliocene lacustrine sediments in the basin.

So far, data regarding magnetic properties of the surface sediments in the Qaidam Basin are limited because of its huge areal extent and poor accessibility. In this study, we performed extensive and systematic sample collections of surface sediments across the Qaidam Basin.

2. Materials and methods

The Qaidam Basin is surrounded by the Qiman Tagh and East Kunlun Mountains to the south, the Altyn Mountains to the northwest, the Qilian Mountains to the northeast, and the Ela Mountains to the east (Fig. 1). The interior of the basin has an average elevation of almost 2800 m above sea level (m asl), with surrounding mountains reaching elevations of about 4000 to 5000 m asl (Fig. 1). In the northeastern Qiman Tagh, plutonic rocks such as Mesozoic and Paleozoic granites, and Mesozoic granodiorites and diorites are dominant (Fig. 2). The piedmont of the Kunlun Mountains mainly consists of late Paleozoic granites and granodiorites. The eastern basin margin is formed by melanges, shallow-marine and volcanic-rich strata of the Qaidam belt. The Southern Qilian Shan is dominated by a metamorphic belt of Upper Paleozoic marble and Hercynian intrusives (Fig. 2). In the

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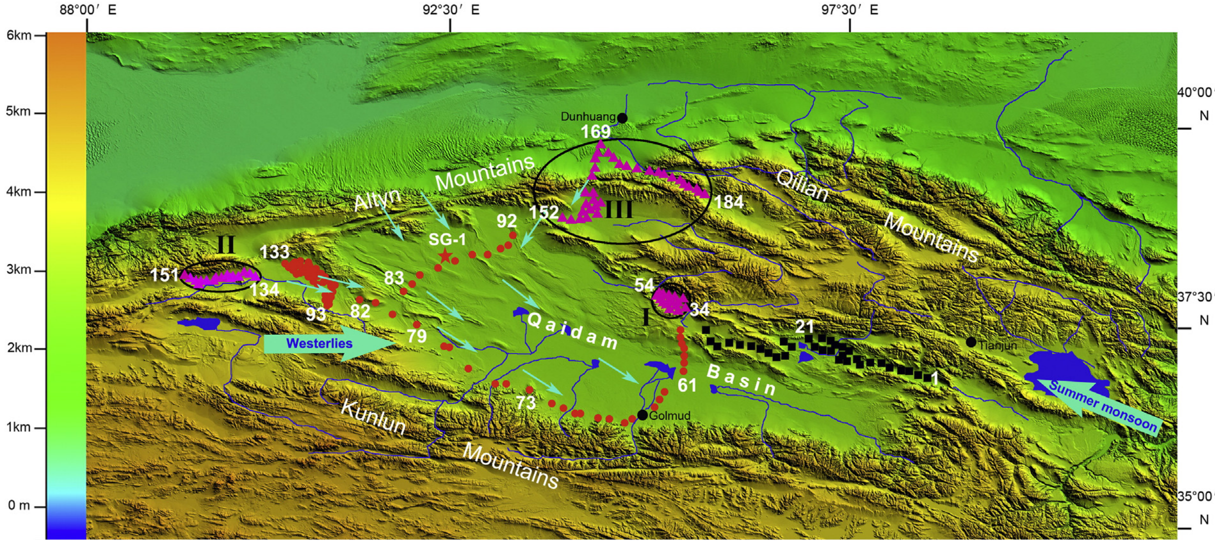

Fig. 1. Digital elevation map of the Qaidam Basin with sampling locations. Black squares show the locations of surface sediment samples 1–33 from southeast of the basin; red circles show the locations of surface sediment samples 55–133 with lower magnetic concentration parameters from the western part of the basin; Roman numerals I, II and III show the locations of three areas with higher magnetic concentration parameters, where surface sediment samples are indicated by pink triangles; arrows indicate main wind directions; blue lines show the fluvial systems in the Qaidam Basin. The red star is the location of core SG-1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

southern flanks of the Altyn Mountains, Jurassic rocks, metamorphic complexes and some Ordovician rocks are dominant (Rieser et al., 2005).

At present, Gobi landforms (including the deserts), yardangs, desiccated playas and salt lakes constitute the main features of the basin. A total of 184 surface sediment samples were collected across the Qaidam Basin. Each sample included the upper 2 cm from the surface and they are far away from industries and villages to avoid anthropogenic iron phase contamination.

In the laboratory, the samples were air-dried and separated into two sub-samples by passing through a 1 mm sieve. Known weights of samples with diameter less than 1 mm were packed into plastic bags for a series of magnetic measurements. Low-frequency and high-frequency magnetic susceptibility were measured with an AGICO MFK1-FA Kappabridge at frequencies of 976 Hz and 15,616 Hz; mass-specific values (χ) in this paper represent low frequency results and frequency dependent susceptibility $\chi_{fd}\%$ was calculated by $[(\chi_{976\ Hz} - \chi_{15,616\ Hz}) / \chi_{976\ Hz}] \times 100\%$. Anhysteretic remanent magnetization (ARM) was imparted in a 100 mT peak alternating field with a superimposed 0.05 mT direct field using a 2 G Enterprises SQUID magnetometer with an attached degausser system; the ARM was normalized by the bias field to obtain ARM susceptibility (χ_{ARM}). Saturation isothermal remanent magnetization (SIRM) was imparted in a 1.5 T field using a Magnetic Measurements MMPM9 pulse magnetizer, and was measured with a Molspin Minispin magnetometer. A backfield IRM was imparted at 0.3 T ($IRM_{-300\ mT}$) by reversing the orientation of the samples. The S-ratio and "hard" isothermal remanent magnetization (HIRM) were determined by $^{-}IRM_{-300\ mT}$ / SIRM and $(SIRM + IRM_{-300\ mT}) / 2$ (Thompson and Oldfield, 1986; Evans and Heller, 2003; Bloemendal and Liu, 2005), respectively. Temperature-dependent susceptibility was measured using a MFK1-FA Kappabridge equipped with a CS-4 high-temperature furnace (Agico Ltd., Brno,

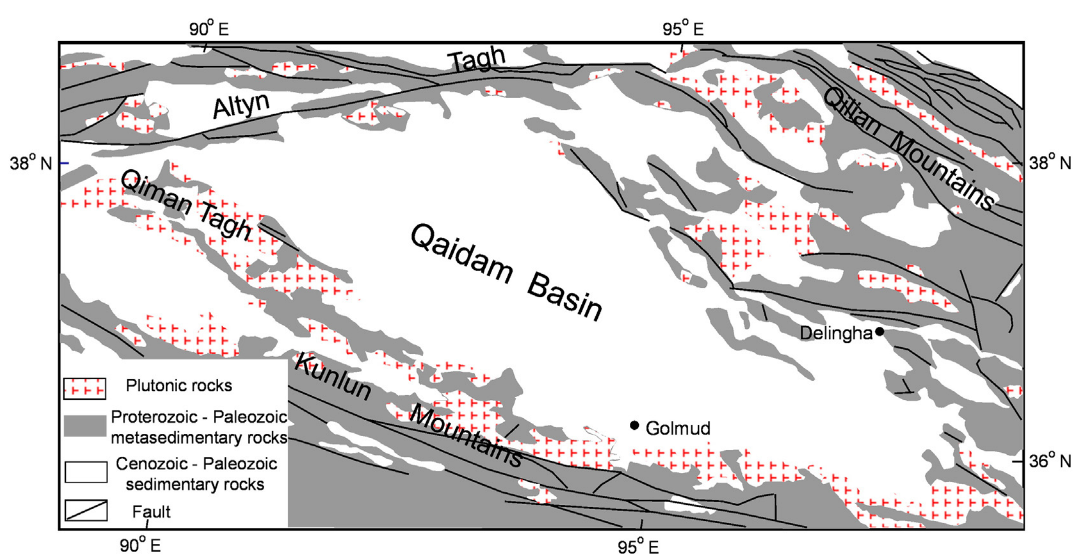

Fig. 2. Simplified geological map of the Qaidam Basin and its adjacent areas. Map modified from Wang et al. (2005).