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Grain size, magnetic susceptibility and geochemical characteristics of the loess in the Chaohu lake basin: Implications for the origin, palaeoclimatic change and provenance

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ABSTRACT

Rare studies on the aeolian deposit located in north bank of the Yantgze River are documented. Recently, it is found in the field investigations and in bore sections that the loess in the Chaohu lake basin has the largest thickness of over 40 m. In this study, the probability cumulative curves, frequency distribution, the grain size distributions and the discriminant function of the grain size suggest that the loess in the Chaohu lake basin is of eolian origin. The magnetic susceptibility curves of the loess in the basin coincide perfectly with those of the loess in the northern China and the marine isotope stages (MIS), and show that paleoclimatic cycles and sub-cycles were documented since L3 during middle–late Pleistocene in the basin. The MS curve of Paleosol S1, Paleosol S2 and loess L3 in the basin coincide perfectly with MIS5, MIS-7 and MIS-8, respectively. The good correspondence indicates that the loess in the basin has given a sensitive response to the globe paleoclimatic change since L3. On the other hand, the climate changes in some stages recorded by the loess has regional characteristics obviously, which might be the result of the dual effect of globe climate changes and East-Asia monsoon climate changes. The result of geochemical characteristics suggests that the loess in the basin has undergone moderate to strong chemical weathering. Most elements are mobilized during chemical weathering; Na and Ca of the loess are markedly lost and the removal of K is also evident, and chemical weathering doesn't evidently turn into the Si removal stage. The chemical weathering of the loess is more intensive than that of the loess deposits in northwestern China and the upper reaches of the Yantgze River. The intensive chemical weathering has been documented by the loess might be related to strong monsoon climate in Chaohu lake basin. The provenance of the loess also differs from that in northern China, and is discussed firstly with the lithofacies palaeogeography. The well-developed alluvial–lacustrine deposits in the Huaihe floodplain seem to be the major source materials of the loess.

1. Introduction

A number of studies have been conducted on the loess deposits in the semi-arid continental monsoon climate regions of NW China, which provided a significant amount of information about their origin, source provenance, and paleoclimate conditions (Liu, 1985; Wen, 1989; Gallet et al., 1998; Ding et al., 1999, 2001; Gu et al., 2000; Chen et al., 1996, 1998, 2001; An et al., 2001; Jahn et al., 2001; Sun and An, 2002; Liu et al., 2002; Sun and Wang, 2005; Liu et al., 2005, 2006; Stevens et al., 2006; Sun et al., 2008; Xiong et al., 2010). In order to obtain more detailed information about Quaternary environmental changes, and further catch East Asian winter monsoon activity and the consequent southward displacement of Northern Hemisphere westerlies (Liu, 1985; Yang et al., 1991; Hong et al., 2013), it is necessary to study the loess deposit of eastern and southern regions with relatively humid climate.

The loess–paleosol sequences in the middle–lower reaches of the Yantgze River are fundamental geological records of environmental processes and have been powerful tools to study climate changes for the humid subtropical climate regions. In recent years, more attention has been paid to investigate the southern deposit of

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Middle–Late Pleistocene in these regions (Liu, 1985; Yang et al., 1991; Li et al., 1997, 2001; Wu et al., 1992; Qiao et al., 2003, 2011; Hao et al., 2010; Hong et al., 2010, 2013). Previous studies of the southern aeolian deposit have mostly focused on grain-size characteristic (Li et al., 1997, 2001; Qiao et al., 2003; Hu et al., 2005), chemical weathering (Yang et al., 2001,2004; Chen et al., 2008; Hong et al., 2010), environmental magnetism (Zhang et al., 2007; Qiao et al., 2003), isotopic compositions (Qiao et al., 2011; Hong et al., 2013; Liu et al., 2014) and provenance (Liu, 1985; Yang et al., 1991; Li et al., 1997, 2001; Hao et al., 2010; Qiao et al., 2011; Hong et al., 2013) in south of the middle–lower Yangtze River (e.g. Nanjing, Zhenjiang, Xuancheng, etc.), while, so far, rare relevant studies on the aeolian deposit in north of the river are documented.

The occurrence of continuous loess deposits requires a sustained source of dust and adequate wind energy to transport the dust (Pye, 1995). There is no agreement on the source of the loess in southern China, among the existing studies (Liu, 1985; Yang et al., 1991; Li et al., 1997, 2001; Qiao et al., 2003). The predominant and traditional view is that the southern loess materials were mainly derived from the deserts of northern China (Yang et al., 1991; Li et al., 1997, 2001), while the others propose that fine-grained floodplains in local river valleys or lake beds, exposed during glacial times, played an important role as the provenance areas (Wu et al., 1992; Qiao et al., 2003, 2011; Hao et al., 2010; Hong et al., 2013). The loess in the Chaohu lake basin of Anhui Province (Fig. 1a–c) is widely scattered in the Jianghuai plain in eastern China and has the largest thickness of over 40 m (Fig. 1d). There are two views about its origin. One is that the loess is fluvial (Xu, 1936), while the other proposes that it is eolian (Yu and Peng, 2008). Meanwhile, its chemical weathering intensity and provenance have not yet been carried out that would be particularly helpful to climate change. Thus, a study of the loess in the Chaohu lake basin is significant to the loess source and reconstruction of middle–late Pleistocene paleoenvironments in the northern subtropical region. Furthermore, the study on the provenance and Quaternary environmental changes is helpful to discuss the cause of the Chaohu lake which is still in suspense.

Moreover, the Chaohu lake basin is bordered by the Dabie Mountains to the southwest, the Jianghuai hilly region to the northeast, the Huaihe floodplain to the northwest, and the South Anhui Mountains to the southeast (Fig. 1c) (Bureau of Geology and Mineral Exploration, 1990). Such geographic surroundings could have greatly promoted eolian deposition in the Chaohu lake basin via the strengthened East Asian Monsoon during the glacial periods of the mid-late Middle Pleistocene through the Late Pleistocene. Because the loess in the Chaohu lake basin has similar lithological characteristics to the Xiashu loess in the Nanjing and Zhenjiang regions in the Jiangsu Province, it was ever named "Xiashu Formation" (Regional Geological Survey Team of Anhui Province, 1988; Yu and Peng, 2008). Studies on the loess located in north of the middle–lower Yangtze River are very limited, although a considerable number of studies have been conducted on the Xiashu loess located in south of the middle–lower Yangtze River, such as Nanjing and Zhenjiang in the Jiangsu Province and Xuancheng in the Anhui Province (Li et al., 1997, 2001; Yang et al., 2001, 2004; Xia et al., 2007; Chen et al., 2008; Qiao et al., 2003, 2011; Hao et al., 2010).

In this study, we selected a representative bore (ZK0711) to analyze grain-size, magnetic susceptibility and the geochemical characteristics of the loess in the Chaohu lake basin, East China. Specifically, the objectives are as follows: (1) the origin and source of the loess; (2) magnetic susceptibility curves, the chemical composition and their climatic significance.

2. Materials and methods

2.1. Materials

The loess section of the ZK0711 bore (117°12′11″E, 31°28′13″N) with a surface elevation of 22.40 m in the Chaohu lake basin is a typical loess section in north of the middle–lower Yangtze River (Fig. 1a and b), and the lithology is mainly composed of yellow, brown silty clay (Fig. 2a and b). It is 35.2 m thick, with the Yicheng Formation underneath it and about 1 m thick cultivated soil on top of the loess (Fig. 2a). Based on the structure feature, color and high resolution of magnetic susceptibility (Fig. 3), the strata revealed in the ZK0711 bore from bottom to top are as follows:

Layer 1: Yellow-colored silty clay, containing offwhite calcareous concretions and iron and manganese (Fe–Mn) nodules, 2.80 m thick.
Layer 2: Yellow-colored silty clay, containing Fe–Mn nodules of 3–5%, 1.95 m thick.
Layer 3: Gray yellow-colored silty clay, 3.55 m thick.
Layer 4: Yellow-colored silty clay, containing Fe–Mn nodules of 5%, 3.90 m thick.
Layer 5: Light brown-colored silty clay, containing few Fe–Mn nodules, 1.80 m thick.
Layer 6: Ginger-colored silty clay, 3.30 m thick.
Layer 7: Light brown-colored silty clay, 0.70 m thick.
Layer 8: Yellow-colored silty clay, containing Fe–Mn nodules of 5%, 0.35 m thick.
Layer 9: Ginger-colored silty clay, 2.20 m thick.
Layer 10: Yellow-colored silty clay, containing Fe–Mn nodules of 6%, 2.65 m thick.
Layer 11: Ginger-colored silty clay, 1.00 m thick.
Layer 12: Yellow-colored silty clay, 0.60 m thick.
Layer 13: Ginger-colored silty clay, containing few Fe–Mn nodules, 1.75 m thick.
Layer 14: Yellow-colored silty clay, 2.35 m thick, corresponds to u1–u2 in Fig. 2b.
Layer 15: Brown-colored silty clay, 2.40 m thick, corresponds to u3 in Fig. 2b.
Layer 16: Gray yellow-colored silty clay, 1.9 m thick, corresponds to u4–u5 in Fig. 2b.
Layer 17: Gray brown-colored silty clay, 0.9 m thick, corresponds to u6 in Fig. 2b.
Layer 18: Gray yellow-colored silty clay, 1.1 m thick, corresponds to u7 in Fig. 2b.

A total of 1696 samples were taken from this loess section, of which 10 samples were used for dating by optically stimulated luminescence (OSL), 92 samples for geochemical analysis collected at different interval, 889 samples for grain-size analysis taken at 4 cm interval, and 705 samples for magnetic susceptibility analysis collected at 5 cm interval.

2.2. Methods

All the geochemical samples were air-dried and grounded to pass through a 200 mesh sieve.

Samples for dating were analyzed by the Optical luminescence measuring instrument of Daybreak 2200 type in the Institute of Earth Environment, Chinese Academy of Sciences.

The grain-size samples were analyzed at Nanjing Normal University after the pretreatment by a Mastersizer 2000 laser particle size analyzer made by the British Malvern company, with a