# Regional distribution of the Loess-like Red Clay in Subtropical China and its Paleoclimatic implications

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**Abstract**
Grain-size and geochemical characteristics of 18 Quaternary Red Clay (QRC) profiles in the lower and middle reaches of the Yangtze River between 25°N - 31°N in subtropical China were studied. The results showed that the QRC, distributed along the Yangtze River between 29°N - 31°N, shares the loess-like characteristics with the Xiashu Loess, which may originate from aeolian dust deposits. The QRC, mainly distributed between 28°N - 29°N, however, is in double-part structure: The upper part also shows the loess-like characteristics; the lower part indicates alluvial features. The loess-like QRC is mainly distributed along the Yangtze River, but gradually declines southwards and is rarely seen to the south of 28° N. The existence of the loess-like QRC is strong evidence for the occurrence of heavy dustfalls in the modern red-soil areas in subtropical China during the Quaternary glacial periods. The loess-like QRC is located approximately 3° latitude south of the Xiashu Loess, implying that the loess/red clay boundary in the Yangtze Valley had frequently oscillated with the alternations between glacial and interglacial climates during the Quaternary period. This leads to multiple or overlapped soil parent materials in the region. Soil properties are not totally determined by modern climate. The possible influence of paleoclimate on soil genesis should also be considered.

**Key Words**
Quaternary Red Clay (QRC), Xiashu Loess, Loess-like characteristics, Quaternary glacial and interglacial climates

## Introduction

The dustfall has continuously occurred in northern China at least since the beginning of the Quaternary period (Liu 1985). The loess-like deposits widely distributed in the lower and middle reaches of the Yangtze River in southern China are called the Xiashu Loess. Recent studies (Li *et al.,* 2001; Yang *et al.,* 2004) believed that the Xiashu Loess shares the similar source provenance with the loess in the Chinese Loess Plateau. The typical Xiashu Loess is mainly distributed along the Yangtze River approximately north of 31°N latitude. The landscape, south of the Xiashu Loess, is gradually changed into red clay. The red clay in southern China is acidic and strongly weathered, resulting from long-term warm and humid climate (Gong, 1985). The transition of the Xiashu Loess to the red clay reflects a great change of geographical zone in the Yangtze Valley. The sedimentary red clay in southern China, without any pedogenic relationships with underlying rocks, is conventionally called the Quaternary red clay (QRC) (Gong, 1985; Hu *et al.,* 2003, 2009). Yang (1991) found that the red clay along the Yangtze River is extremely similar to the Xiashu Loess, and then proposed that it is really old loess formed in the Early or Middle Pleistocene. So far, only the QRC in Xuancheng and Jiujiang was deeply studied and believed to be in aeolian dust origin (Hu *et al.,* 1998; 2005; Xiong *et al.,* 1999; 2002; Hu and Gong, 1999; 2001). Further study is needed to scrutinize whether the loess-like QRC really exists and what spatial range it is distributed in. In this study, 18 typical QRC profiles mainly located in the lower and middle reaches of the Yangtze River in subtropical China between 25°N and 31°N were selected, the grain size and geochemistry of which were measured, aiming to prove the existence of the loess-like QRC further, and then to reveal its regional distribution and paleoclimatic implications.

## Methods

18 QRC profiles with typical morphological features located in subtropical China approximately between 25° N - 31° N were selected (Fig. 1), coded with the abbreviation of geographical names (e.g. a profile in Jiujiang was coded as P-JJ) . The soil samples were collected at an interval of 10 cm in all the profiles, and then air-dried, ground and passed through a 2 mm sieve. As previously described (Hu *et al.,* 2005; 2009), the grain-size distributions of the soil samples (<2mm) were measured by a Laser Grain-size Analyzer (LS13320), with a measuring range from 0.04-2000 μm, after being pretreated. 10 major elements and 19 trace elements were determined by the X-ray Fluorescence Spectroscopy (XRF) (Hu *et al.,* 2008).

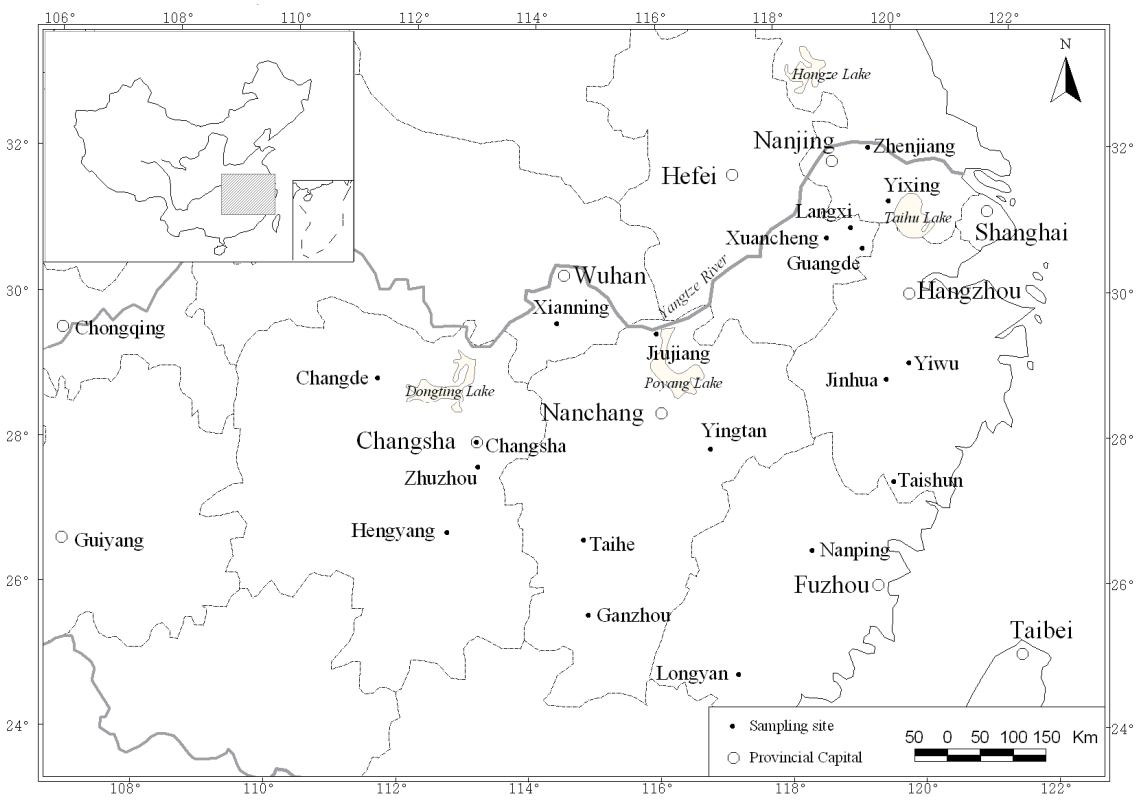


**Figure 1. Sketch map showing the locations of the 18 QRC profiles in subtropical China. A shadow square in the inset map shows the location of the study areas in mainland China.**

## Results

*Grain-size distribution of the QRC*

The 18 study profiles can be classified into three types according to their grain-size characteristics: The grain sizes of Type A, including P-JJ, P-XC, P-YX, P-LX, P-GD and P-XN and mainly distributed along the Yangtze River between 29° - 31° N latitude, are characterized by fine and uniformity (e.g. Figure 2.), with no gravel (>2mm) and low sand (>63μm), mostly < 5%, but high content of basic dust fraction (10μm - 63μm), which are much comparable to those of the Xiashu loess and hence called the loess-like QRC. The grain sizes of Type B, including P-YT, P-TH, P-GZ, P-NP, P-TS, P-HY and P-LY and mainly distributed to the south of 28° N, are significantly different from Type A, which show alluvial features, with gravel layers, low content of basic dust fraction and vertically instable grain-size distribution. Type AB, including P-CS, P-CD, P-ZZ, P-YW and P-JH and mainly distributed between 28° - 29°, show double-layer structure: The upper part is identical with Type A and belongs to the loess-like red clay; the lower part shows water-reworked alluvial features like Type B.

*Geochemical characteristics of the QRC*

Major element contents of the QRC profiles are excellently correlated with their grain-size distributions: The curves of major elements of Type A are vertical stable and uniform (e.g. Figure 2.) and comparable to the Xiashu Loess. In contrast, these of Type B often vertically fluctuate, implying the material inconsistency and alluvial features. These of Type AB also show the dualistic properties: The upper part is vertically uniform and similar to Type A and the Xiashu loess; the lower part vertical fluctuates like Type B. Trace element distributions of the QRC profiles were also study. These of the typical layers of Type A are extremely similar to the Xiashu Loess, suggesting their similar source provenance. These of Type B show different patterns from Type A and the Xiashu Loess, implying its different source provenance from the aeolian loess. These of Type AB are also dualistic as studied above.

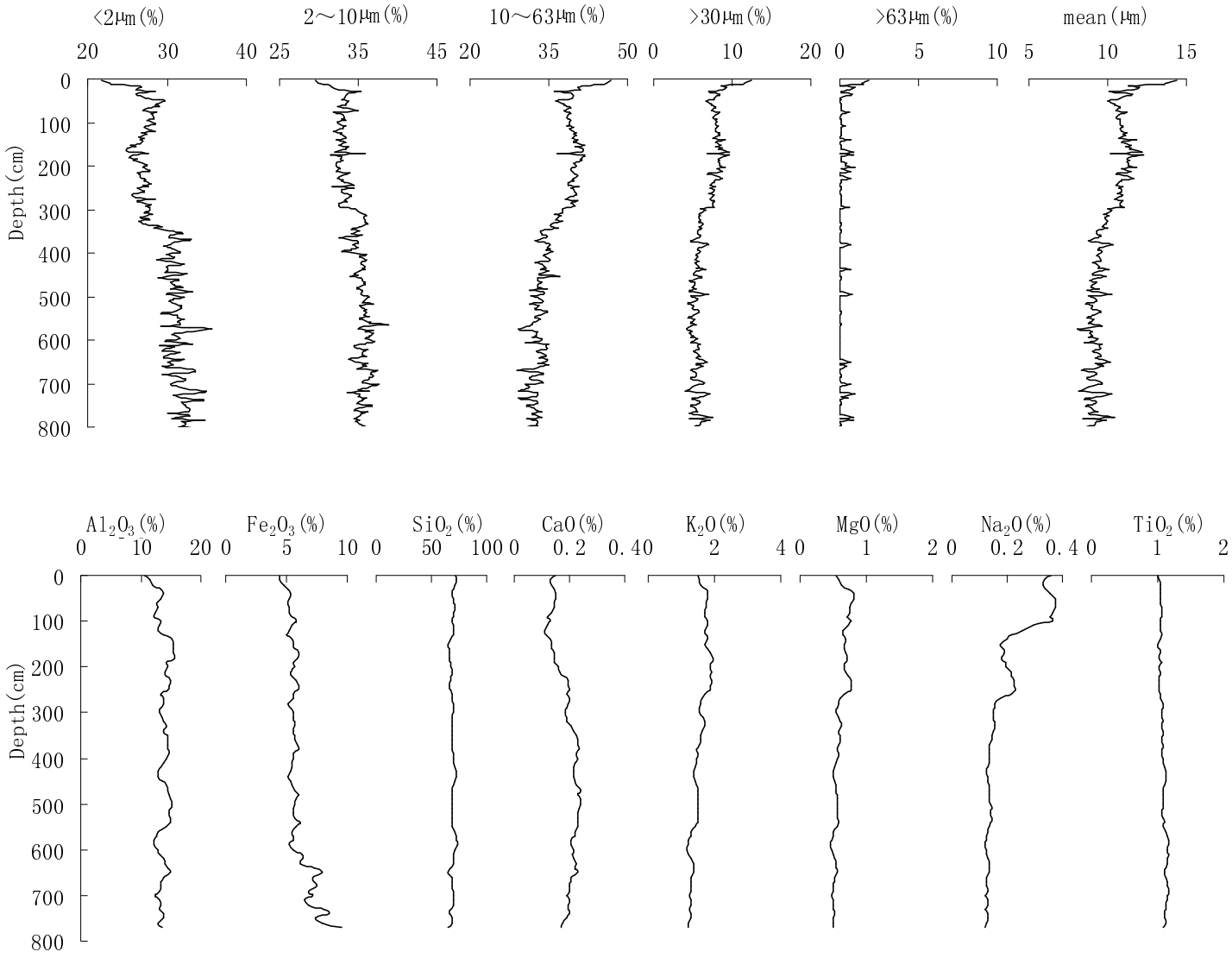


**Figure 2. Vertical distributions of grain-size fractions (above) and major element contents (below) of P-XC in Xuancheng, Anhui province, China.**

## Conclusions

The study of the grain size and geochemistry of the QRC has fully suggested that the QRC with the aeolian dust characteristics like the Xiashu Loess really exists in subtropical China, which originated from aeolian dust deposits. This loess-like QRC is mainly distributed along the Yangtze River between 29° N - 31° N, but gradually declines southwards and is rarely seen to the south of 28° N.

The region distributed with the loess-like QRC is approximately 3° latitude south of the Xiashu Loess. This strongly suggests that the dust deposits had ever extended to the modern red soil areas, south of the Xiashu Loess. It is believed that the boundary between the highly weathered red clay and the aeolian loess in the Yangtze Valley had oscillated to and fro with a range of about 3° latitude corresponding to the multi-cyclical paleoclimatic changes during the Quaternary period: Under the glacial climates, the stronger winter monsoon drove aeolian dust southwards at least till 28° N latitude and formed loess-like soils there; under the interglacial climates, however, the dustfall was weakened and replaced by the laterized processes in the southern areas, which caused the northward shift of the loess/red clay boundary.

The existence of the loess-like QRC suggests that the QRC with highly weathered property was not a product of a long consecutive warm-humid climate. At least, its parent material, which is believed to be dust deposits, was formed under a cold and warm climate. Therefore, the loess-like QRC had actually

experienced both cold-dry and warm-humid climates, implying that some great paleoclimatic changes had ever occurred in the Yangtze Valley during the Quaternary period.

The loess-like QRC profiles are believed to consist of the cyclical alternations between loess deposits and pedogenesis, like the loess – paleosol sequences in the Loess Plateau, but such cyclical information was severely overlapped and combined and cannot be clearly distinguished any more.

The loess-like QRC also was formed during multiple stages. The weathering degree of the red clay developed in the Middle Pleistocene is more intensive than that in the Late Pleistocene. The old red clay can also be a parent material of modern soil due to water erosion. This leads to the co-existence of different zonal soils, such as ultisols and alfisols, in the region. Therefore, soil properties are not totally determined by modern climate, and the possible influence of paleoclimate on soil genesis and types should also be considered.

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