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Loess-like deposits in the Pearl River delta area, southeast China

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ABSTRACT

A layer of yellow silt is widely distributed in the late Quaternary succession of the Pearl River delta, southeast China. A representative section at Xi Lingang was analyzed using particle size analysis, scanning electron microscope observation, geochemical analysis and OSL dating to determine the characteristics and genesis of the yellow silt. Grain size composition of the yellow silt is homogeneous and comparable to typical north China loess (10–50 μm as "basic grain size group", <5 μm as "secondary grain size group"). Grain size parameters and frequency distribution curves of the yellow silt also indicate an aeolian origin. Aeolian micro-textures with subangular–subrounded grains characterized by dished surface collision pits during wind transportation. Homogeneous major element composition of the yellow silt suggests that the dust has been well mixed and sorted prior to deposition, a typical feature of aeolian origin, but Chemical Index of Alteration values indicate that the yellow silt has suffered intense weathering after deposition. Five OSL dates obtained in this study and other geochronological data indicate that the yellow silt has a Last Glacial Maximum age. The grain size of loess across China becomes finer from northwest to southeast because of increasing transportation distance, and implies that the loess component of the yellow silt in the Pearl River delta area is also derived from a northwest China provenance.

1. Introduction

Yellow silt ranging from tens of centimeters to several meters in thickness is widely developed within the Quaternary sequence of the Pearl River delta, southeast China. The yellow silt is also known as "mottled clay" (Huang, 1982), and is termed the "Sanjiao layer" (Q_3^{sj}) (Guangdong Geologic Survey Institute, 2000). The layer is underlain by Late Pleistocene fluvial-marine gray-black clayey to silty sand or marine mud (Xi'nan formation; Q_3^{xn}), and overlain by Holocene black marine mud (Q_4). This indicates that the yellow silt lies between two marine transgressions and has been inferred to be the product of weathering of exposed Late Pleistocene marine or floodplain deposits during the Last Glacial Maximum (LGM) when sea level was comparatively low (Huang, 1982, Huang and Cai, 2007; Lan, 1996; Guangdong Geologic Survey Institute, 2000; Liu et al., 2012). The distribution of the yellow silt in inland and several foreland areas of the Pearl River delta indicates that the yellow silt is not only present in the Quaternary succession of sedimentary basins (a portion of which were later uplifted), but also overlies both fresh and weathered bedrock, suggesting that it may be weathered residual material (Zhu, 1993; Huang et al., 1996; Qi et al., 2011). However, grain size and material composition of the yellow silt is very homogeneous; it is easily windborne, has a silty feel when rubbed, and usually has perpendicular cracks developed in the upper part. These features suggest that the yellow silt is not the product of in-situ weathering, which is characterized by highly variable grain size, color and material composition. Also, the yellow silt is not a common sediment of a coastal area, i.e., fluvial, marine, lacustrine or deltaic. The main investigated sites of this study include outcrop sections and drill cores as shown in Fig. 1. A typical exposure (Xi Lingang section) of the yellow silt within the Quaternary sequence of the Pearl River delta was selected for detailed study of its sedimentary characteristics in order to best determine its origin.

2. Geological setting of Pearl River delta and Xi Lingang section

Located in Guangdong Province, southeast China, with an area of about 56,000 square kilometers, the Pearl River delta is one of the largest deltas in China (Fig. 1). The formation, evolution, neotectonics, palaeogeography and Quaternary sediments of the Pearl River delta have been intensively studied (e.g., Huang, 1982; Lan, 1996; Guangdong Geologic Survey Institute, 2000; Chen et al.,

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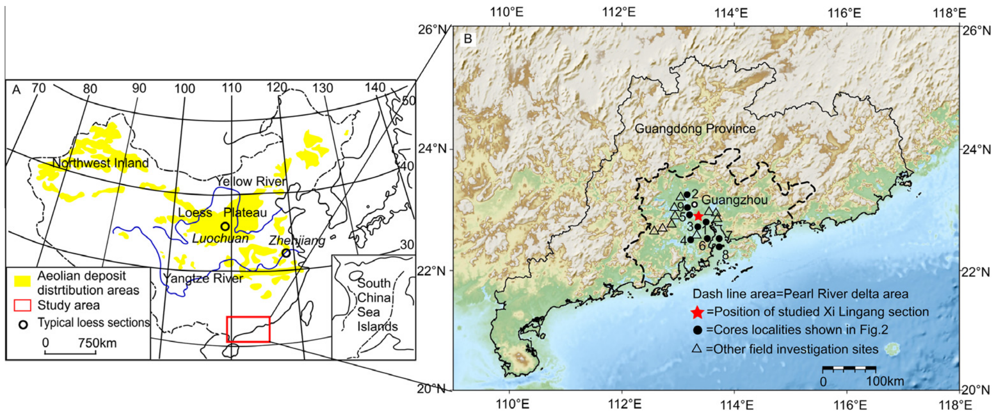

Fig. 1. Maps showing: left: loess distribution in central and northern China and location of typical loess sections (after Yang et al., 2005); right: sites examined in the Pearl River delta area. Topography from http://topex.ucsd.edu/, map based on GMT software.

2002; Yao et al., 2008; Zong et al., 2008; Liu et al., 2012). Radiocarbon (^{14}C) and thermoluminescence (TL)/optically-stimulated luminescence (OSL) dating of the late Quaternary Xi'nan Formation (Q_3^{xn}) sediments underlying the yellow silt (Q_3^{sj}) yield ages of 23–40 ka, and those of Holocene deposits (Q_4) overlying the yellow silt have ages of ~10 ka (Huang, 1982; Lan, 1996; Guangdong Geologic Survey Institute, 2000). In the delta plain, the thickness of the yellow silt is mostly not more than 5 m and the depth of burial ranges from a few meters to 20 m (Figs. 2 and 3A, B). In the higher parts of the delta (platform areas), the yellow silt is typically conformably associated with uplifted Quaternary sediments (Fig. 3C and D), but in some places it shows a disconformable relationship with the Quaternary sediments and may also directly overlie fresh and weathered basement rocks with a sharp boundary (Fig. 3E–I). Here, the composition and textures of the yellow silt are very different from the underlying rocks, indicating that it is not an in-situ weathering product of underlying substrates.

The study site at Xi Lingang (23°0.098′N; 113°11.309′E) is a small N–S trending hill in the central part of the Pearl River delta (Fig. 1). Recent excavation has exposed an excellent Quaternary section (Fig. 4A and B). Sedimentary bedding dips 7°S with an outcrop thickness of 2.5 m. Yellow-gray, medium to fine-grained sand is intercalated with gray-white silty-clay at the base of the section (Fig. 4B) and represents estuarine sediment of the Pearl River deposited during the latest Pleistocene transgression ("Xi'nan Formation" (Q_3^{xn})). The overlying yellow silt is 2 m thick, well cemented and unbedded, with well developed vertical joints (Fig. 4A and B), corresponding to the "Sanjiao layer" (Q_3^{sj}) of the delta plain area. It is covered by modern agricultural soil with a thickness of 1 m on the SWW side of the excavation site (Fig. 4B and C). The contact between the yellow silt and underlying gray silty-clay is an erosion surface (Fig. 4B).

Stratum on the SWW side of the excavation site are continuous, but precluded sampling of the upper part because of vegetation cover (Fig. 4B). According to topography and lithostratigraphic correlation, samples were collected as shown in Fig. 4C. These were used for determination of sedimentary characteristics, OSL age, and origin of the yellow silt.

3. Sample treatment and laboratory measurements

3.1. Yellow silt separation

Because of strong weathering of bedrock in the Pearl River delta area, residual material such as quartz grains and rock fragments are often mixed within the yellow silt layer, and it often constitutes 5–20% of the yellow silt sections on terraces. On the other hand, the composition of yellow silt in buried areas is essentially homogeneous with <2% residual coarse-grained clastic material. To obtain a pure yellow silt or matrix fraction, which was the main object of our study, samples were first separated by elutriation. After being repeatedly stirred and cleaned in distilled water, the yellow suspension was repeatedly decanted into another beaker to separate fine grains (yellow silt) from coarser material; the two size components of each sample were thoroughly separated

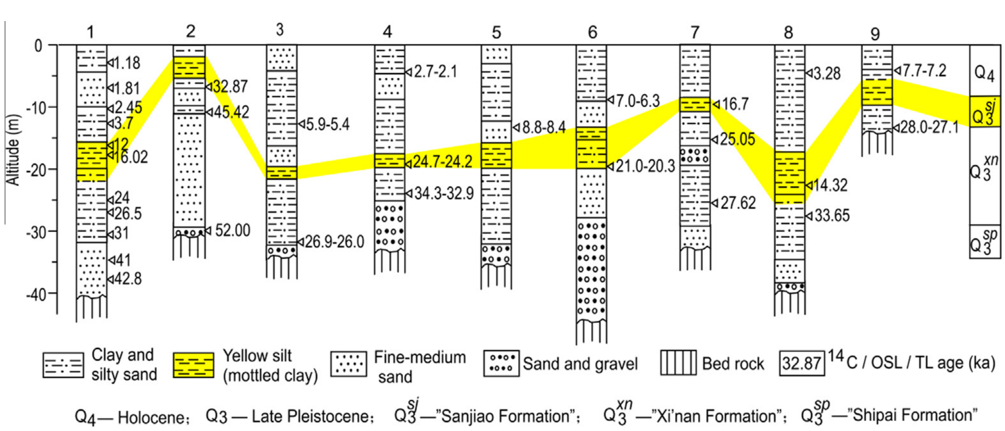

Fig. 2. Late Quaternary stratigraphic correlation of low-lying (plain) area of the Pearl River delta (after Tang et al., 2013; Nos. 3–9 cores from Huang (1982) and Zong et al. (2008)). Cores sites shown in Fig. 1.