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Loess and early land use: Geoarchaeological investigation at the early Neolithic site of Guobei, Southern Chinese Loess Plateau

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ABSTRACT

Prehistoric land use at the Guobei site and its relationship with the local environment are examined by applying OSL dating, micromorphological examination and geo-physical analysis. The majority of the OSL dates are of early to middle Holocene ages and are thus comparable to many OSL dates derived from other studies in the same region. According to the particle size analysis, silt-sized particles (2–60 μm) were predominant throughout the profiles examined. However, there are spatial and temporal variations of different size groups of particles throughout the profiles, which provide complementary information for the micromorphological interpretation. The total organic component of the samples examined through LOI is relatively high (all >2%), with those of the overlying Holocene deposits higher than those of the underlying Malan loess by about 0.2%. Moreover, in all three profiles, the highest organic contents appear in the palaeosols, confirming that there was greater organic accumulation during soil formation periods. The groundmass of most slides collected from the early to middle Holocene horizons displays a very homogeneous pattern, while the abundance and distribution of different kinds of pedofeatures, mainly including clay textural, calcitic, iron/Mn and crustal features, vary greatly temporally and spatially. These different lines of information demonstrate diversified pedo/sedimentary processes due to variations in micro-environmental conditions and cultural activities. We discuss the importance of a palaeo-ecological perspective, allowed by the geoarchaeological study, to an improved understanding of the relationship between loess, changing hydrology, prehistoric farming practice and land use, and long-term landscape change in the Chinese Loess area. This will thus contribute to a comparison on the dynamic relationship between loess and prehistoric farming in other regions of the world such as Europe and North America.

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1. Introduction

Loess is widely distributed in North China, Central and Eastern Europe and Central North and South America and has been considered as fertile land for farming (Liu, 1985; Schaetzl and Anderson, 2005). This importance to agriculture in Europe and the formation of loessic landscapes has been intensively researched (Doolittle, 2002; Pulleman, 2002). Richthofen, the great geographer who introduced Chinese loess to the west, for instance, noted the long history of crop cultivation in North China "without use of manure" and attributed this sustainable agriculture to the "porosity of loess" (cited from Catt, 2001). This opinion was adopted and further elaborated by many agronomic scientists who tried to explain why this porous structure of loess is important and how loess supported sustainable farming without manuring (Catt, 2001).

The physical and chemical properties of loess are proved to be vital to the development of farming practices (Catt 2001). The key to disentangle the long-term interaction between loess, agriculture and prehistoric societies lies in an in-depth understanding of the palaeoecology and landscape of prehistoric farming through interdisciplinary inquiry. Agriculture has a long history in the Chinese loess area, yet there has been a pronounced lack of such interdisciplinary investigations, unparallel with the great achievement in modern agronomic research in the loess area (Li, 2007). There is thus a pressing need to examine the palaeo-ecology and environmental backgrounds of early farming and associated land use in the Chinese loess area.

This paper is concerned with the earliest Neolithic Culture, the Laoguantai Culture (c.8000–7000 BP) in the Western and Southern Chinese Loess Plateau (CLP) (Bettinger et al., 2010a, 2010b; they provide evidence of earlier origins of agriculture in this region, but it remains controversial), a culture first recognized in 1950s (Wei and Yang, 1986) with its distinctive pottery assemblage. While years of excavations and research in other parts of North China have unearthed remains of contemporary cultures and investigated the similarity and difference between them, the ecological diversity and importance of local environments in the Laoguantai Culture are rarely addressed. A geoarchaeological survey was carried out at the Guobei site and its

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vicinity in the Southern CLP. Optimal Stimulated Luminescence (OSL) dating was applied to aid stratigraphical interpretation based on field observation. Within this basic chronological framework, soil micromorphology and geo-physical analyses were used to obtain detailed information of sedimentary and pedogenetic processes and long-term land use history. The results from the case study are then discussed with archaeological discoveries and environmental data derived from other studies in the same region.

2. Site, material and methods

2.1. The site and the fieldwork

Guobei is located on the alluvial plain of the Taipingyu River in the Southern CLP, 416 m above sea level and only about 4 km to the north of the Qinling Mountains (Fig. 1). The surrounding landscape is typical in the Southern CLP, that is, a flat alluvial plain is situated immediately next to the foothill of the Qinling Mountain, with topography quickly descending from >2000m to around 400–500 m above sea level. A rough estimation of the size of the site is around 60,000 m^2. The site was found in 2008 in a regional archaeological survey. After the pilot fieldwork in 2009, two more fieldwork seasons were carried out at Guobei in 2010 and 2011. Ceramics of Laoguantai culture (c.8000–7000 BP) and Longshan culture (c.5000 BP) were found from the surface and collected from exposed profiles. A deep, continuous section was dug for mud-brick manufacture, which provides an excellent overview of the stratigraphy at the site, and from which artefacts and archaeological features (e.g., pits) of the Laoguantai culture and Longshan period can be seen.

Unfortunately, the upper part (of Late Holocene age) of the wind-blown and reworked loess and the palaeosol has been removed in some localities. Detailed description in the field of the sediments is provided in Table 1. Nine sections were cleaned and examined (Fig. 2), all showing comparable stratigraphies (Fig. 3 and Table 1). 25 micromorphological, 14 OSL dating and 59 bulk samples were collected from five profiles (Profiles 5–9, Fig. 2). Below is a brief summary of the collection, processing and analysis of the samples; more details are given in the Appendix.

2.2. Sampling, processing and analyses of geo-physical and micromorphological samples

Undisturbed soil samples were collected by using knives and other tools, from the examined sections after fresh section walls were cleaned and clear stratigraphies displayed. Bulk samples were normally collected with 10cm intervals, from bottom to top and with the top 30–50 cm neglected to avoid contamination. Micromorphological samples were manufactured at the McBurney Laboratory for Geoarchaeology at the University of Cambridge following the method described by Murphy (1986) with modification by Julie Boreham, Charles French and Tonko Rajkovaca. These thin sections were analysed using a polarizing microscope, with microstructures, coarse and fine fractions of groundmasses, anthropogenic and heterogeneous inclusions and pedo-features examined and semi-quantified (after Bullock et al., 1985; Stoops 2003). Very often one slide is divided into different units as changes in textures and abundance of key pedo-features are observed. The geophysical analyses were processed at the Laboratory for Physical Geographic Science, Department of Geography, University of Cambridge, under the supervision of Dr. Steve Boreham and Mr. Chris Rolfe. The processing methods follow the standard protocols described by the Laboratory for Physical Geographic Science (http://www.geog.cam.ac.uk/facilities/laboratories/techniques/).

Fig. 1. Locations of the Guobei site.

2.3. Collection and processing of OSL dating samples

Special metal tubes (c.30 cm long) with one end sealed were made to collect OSL samples. These tubes were entirely hammered into cleaned profiles. After the tubes were taken out of the profiles, the other end of the tubes was quickly sealed by sponge and paper. They were then labeled and wrapped with black plastic bags and tapes. Wet bulk samples were also collected to measure water contents for dose rate calculation and calibration.

The pre-treatment, dating of these OSL dating samples and measurement of water contents for dose rate calibration were completed at the TL and OSL Dating Laboratory at the School of Archaeology and Museology, Peking University, following standard single-aliquot regenerative dose methods described by Duller et al. (2003). All procedures were completed in the dark room of the laboratory. U, Th and K for dose rate calculation were measured at the China Earthquake Administration.

In the dark room, samples in the two ends of the tubes were first removed into self-sealing bags with knives for dose rate measurement. This rules out the possibility of partial exposure to sunlight during sampling, which may significantly affect dating results. About 100 g of the sediments in the middle of each tube were placed into glass beakers before being dried in the oven with 40 °C overnight. The dried samples were slightly grounded in an agate mortar to break down small aggregates. They were then sieved using 200, 125 and 20 μm mesh sieves, with each separated fraction packed into different self-sealing bags. The 20 μm samples were used for the obtainment of fine quartz grains for OSL dating. These 20 μm sediments were first added with 30% HCL and 30% H_2O_2 to remove carbonates and organic material, respectively. They were then immersed in hydrofluorosilicic acid, H_2SiF_6 (30%), in tubes for 4–5 days to obtain fine-grained quartz. All measurements were performed using an OSL reader (produced by the Riso National Laboratory, Denmark) with blue-light-emitting diodes (LEDs). Details of the determinations of De, dose rates and errors will be discussed separately in future work. This paper only presents the results and discusses some preliminary observations.

3. Results

3.1. Results of OSL dating

The results of OSL dating at Guobei (Table 2), except for the GBP6:4 which has a very high dose rate (≈6.7 Gy/Ka), vary slightly within the range of 3.3–4.0 Gy/Ka. These dose rates are also comparable to dose rates obtained from other similar studies in the same area (Lai and Wintle, 2006; Lu et al., 2007; Zhao et al., 2007). Such consistent dose rates indicate that the sediments of the examined profile at Guobei were not exposed to abnormal radiations and the calculations here are reliable. The equivalent doses (De) were divided by the dose rates.

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