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Environmental humidity changes inferred from multi-indicators in the Jianghan Plain, Central China during the last 12,700 years

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ABSTRACT

Time sequence of the JZ-2010 profile derived from AMS^{14}C dating and the content of the sediment elements Ti, Rb and Sr, the Rb/Sr values as well as the granularity and the magnetic susceptibility are utilized to reconstruct the environmental humidity changes in the Jianghan Plain since 12,700 cal. BP. The comprehensive analyses of multiple alternative indicators indicate that the regional moisture turned from relatively dry to wet after the Late-Glacial period and reached its optimum until the mid-Holocene. However, the trend was punctuated by several decreased humidity phases. Beginning with the severe dry event approximately 4400–4100 cal. BP, the environment was dry as a whole, with modest humidity from approximately 3900 cal. BP. Humidity changes in the study area are dominated by the East Asian monsoon system, which is under the influence of the gradual southward migration of the ITCZ, driven by the summer solar insolation changes in the Northern Hemisphere due to orbital forcing. As the first attempt to apply Rb/Sr value and Ti concentration in tracing moisture evolution in a region with typical subtropical humid climate, this study highlights the different effects and consequences of the proxies throughout the palaeoenvironmental change process, and the impacts of regional topography that sustained tectonic subsidence since the Cretaceous as well as the southeast tilt that opened the plain to the summer monsoon. Moreover, the fluctuation of magnetic susceptibility is associated with the granularity feature, the reduction–oxidation conditions, and the impact of human factors on the natural sedimentary environments during the historic period in the Jianghan Plain.

1. Introduction

An examination of the chemical properties of specific elements, granularity and the environmental magnetic characteristics in sediments may reveal valuable information regarding the relevant depositional environment, which helps to explain past climate changes (Dearing, 1986; Thompson and Oldfield, 1986; Lowe and Walker, 1997; Schilman et al., 2001). In recent years, content distributions of Ti, Rb, Sr and alterations in Rb/Sr values have been adopted as alternative indicators for palaeoclimate reconstruction (Chen et al., 1999a, 2001; Haug et al., 2003; Pang et al., 2007; Yu et al., 2010). Integrated with the granularity and the magnetic susceptibility parameters, these indicators have resulted in considerable progress in the study of regional environmental changes and the corresponding causes (Li et al., 2003; Yancheva et al., 2007; Wang et al., 2008a; Ver Straeten et al., 2011). These alternative environmental indicators are widely applied in climate stratigraphy. However, uncertainties have been reported as this research approach has spread (Chen et al., 1999a, 2001; Li et al., 2003; Pang et al., 2007; Li et al., 2010).

Climate conditions in the vast area of East Asia are regulated essentially by the monsoon circulation, and Central China is a key area for understanding the spatial variability of the Asian monsoon

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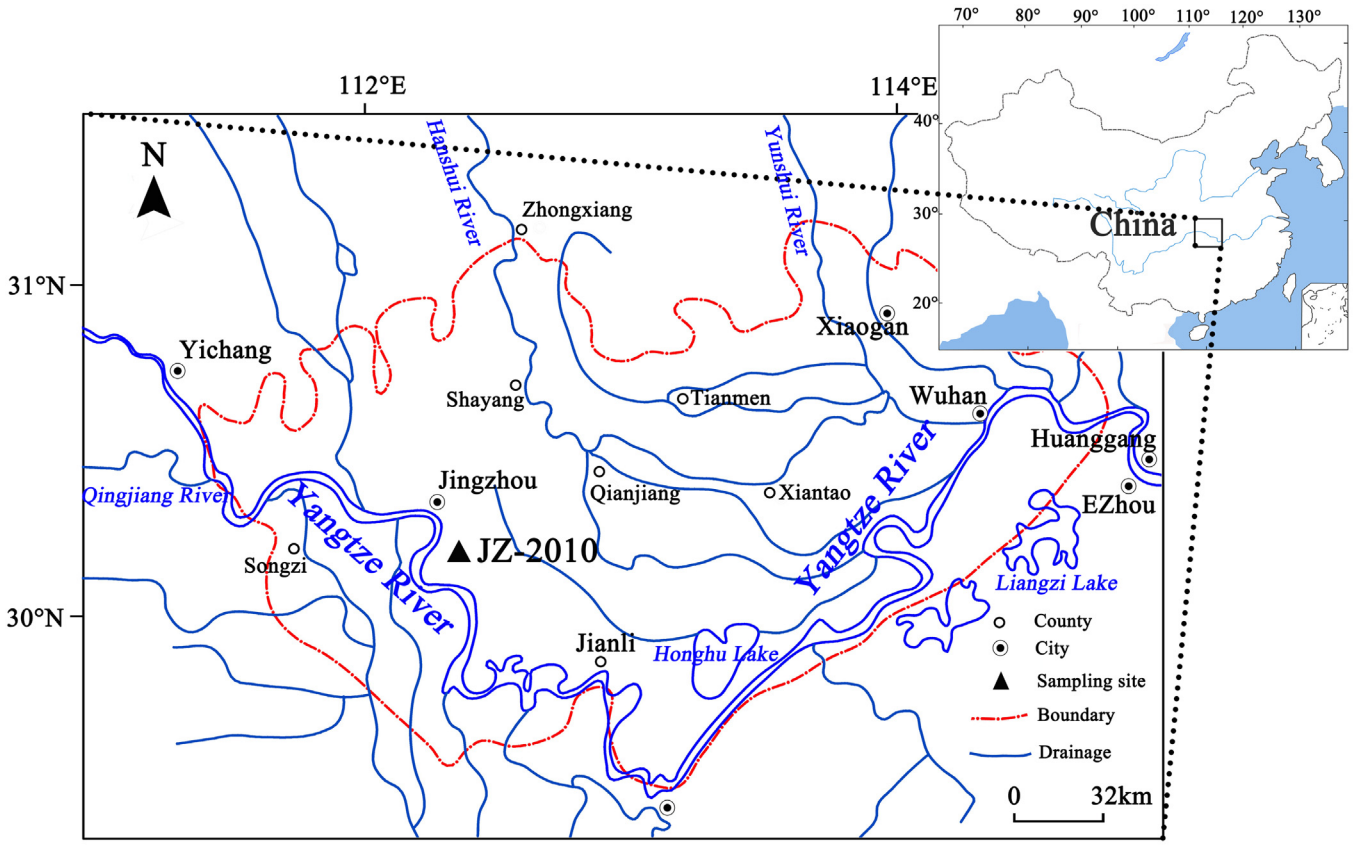

Fig. 1. China and the Research Area map. The red dot-dash line indicates the conceptual boundary of the Jianghan Plain. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

system (Chao and Chen, 2001; Ma et al., 2008; Cai et al. 2010; Zhu et al., 2010). The Jianghan Plain, situated in Central China, is a typical floodplain of the middle Yangtze and the Hanjiang River composed of many interchannel depressions, with a variety of complicated geological factors, including sedimentary provenance, hydrodynamic conditions, microrelief of rivers and lakes, climate, and sedimentary environment. Controlled by the monsoonal climate, both temperature and precipitation of the plain exhibit remarkable seasonal variability. Archaeological research has demonstrated that since the Neolithic, intensive human activity in the Jianghan Plain has significantly influenced the environmental changes there (Zhou, 1994; Guo, 2005; Zhu et al., 2007). Various alternative indicator-based approaches, such as those using data from drilling in Honghu Lake (since the 1990s), palynology, granularity, organic carbon isotopes and magnetic susceptibility, have been applied in the Jianghan Plain to investigate the local climate fluctuation, environmental changes, lake-group evolution and the relationship of these phenomena with human activity (e.g. Zhang, 1996; Yang et al., 1998; Boyle et al., 1999; Xie et al., 2006; Yin et al., 2007; Chen et al., 2009; Fang and Hou, 2011; Li et al., 2011a). Nevertheless, these studies are inadequate for a comprehensive description of the geology of the Jianghan Plain. Therefore, we attempted to determine the Ti, Rb and Sr content, the granularity and the magnetic susceptibility of a sedimentary profile in this area. The results were subjected to comparative analyses of the element distribution, the varieties of the Rb/Sr values, the granularity, and the magnetic susceptibility. The results were correlated with a stratigraphic chronology based on AMS ^{14}C dating, which facilitated the investigation of the climate fluctuations and the changes in the sedimentary environment in the Jianghan Plain since 12,700 cal. BP.

This study pioneers the palaeoclimatic and palaeoenvironmental reconstruction of the Jianghan Plain using the distribution of Ti, Rb and Sr, and may improve the understanding of the application characteristics of these alternative indicators. Long-term global monsoon intensity has been suggested to be controlled by external forcing such as solar radiation, sea-land distribution and topography of continents. How well is this hypothesis supported by the geological records? Here we aim at a scientific and practically significant understanding of the evolution in the perspective of river-lake systems and regional tectonic environment, and ultimately, a detailed reconstruction of past climate changes in Central China and a deeper knowledge of the history of the East Asian (EA) monsoon system.

2. Materials and method

An artificial stratigraphic outcrop (JZ-2010) was selected for study. The outcrop is located in the Jiangbei Farm of the Jiangling District, Jingzhou City, at 30°11′01″N and 112°22′02″E with a surface elevation of 42.32 m (a.s.l) (Fig. 1). In March 2010, the outcrop was excavated and cleaned to reveal a fresh profile with a total depth of 637 cm. The bottom part exhibited an approximately 303-cm-thick interbedded sequence composed of gray-brown, yellow-brown and brown-black silt and clayey silt, carbon debris and plant residue inclusions, and rich organic matter accompanied by rust-like ferromanganese nodules. The middle stratum was a layer of black, dark blue-grey peat approximately 103 cm thick. The upper stratum exhibited approximately 164 cm interbedded sediment, composed of dark-brown, red-brown and gray-red silt. Well-developed horizontal strata ranged from 3–5 mm to 10–20 cm thick. The top stratum was a layer of approximately 67 cm that