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# TL and IRSL dating of Jiahu relics and sediments: clue of 7th millennium BC civilization in central China

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**Abstract**

Thermoluminescence (TL) dating of pottery and infrared stimulated luminescence (IRSL) dating of sediments from early Neolithic layers at the Jiahu site, Henan Province, east-central China, have been achieved. The pottery TL ages range from 6800 (±450) to 8900 (±640) years and the sediment IRSL ages from 6750 (±760) to 8860 (±870) years confirming former $^{14}C$ data. Both TL and IRSL ages agree well with each other. They reinforce the very early existence of a fully developed Neolithic civilization in central China, starting already in the first half of the 7th millennium BC and lasting about 2100 years. From these layers finds of bone flutes and Chinese characters have already been reported [X. Li, G. Harbottle, J. Zhang, C. Wang, The earliest writing? Sign use in the seventh millennium BC at Jiahu, Henan Province, China, Antiquity 77 (2003) 31–44; J. Zhang, G. Harbottle, C. Wang, Z. Kong, Oldest playable musical instruments found at Jiahu early Neolithic site in China, Nature 401 (1999) 366–368.] The Jiahu pottery of the 7th millennium BC belongs to the earliest in China and elsewhere.


*Keywords:* Ceramics; Luminescence dating; Neolithic; Jiahu; Central China

## 1. Introduction

The Jiahu relics in Wuyang County, Henan Province, central-east China are known since 1962. From 1983 to 1987, six excavation campaigns were performed by the 'Henan Institute of Cultural Relics and Archaeology of China'. The excavated area comes to 2400 $m^2$. Altogether 45 ancient house sites, 370 cellars, 389 tombs (including 40 tombs with pottery) and 10 dog pits were excavated, in which more than 4500 pieces of artefacts were recovered, including 2300 pieces of pottery, 1000 stone artefacts as well as 1100 bones and teeth. After detailed archaeological classification of the different artefacts, three cultural periods, belonging to the early Neolithic, have been identified at Jiahu [14].

Among the artifacts, several bone flutes were found at the ancient site of Jiahu, which are regarded as the first appearance of Chinese music instruments and cultivated rice, respectively [13–15]. An excavated tortoise shell bears an inscribed character, which is considered the earliest in China [8]. Since then, the site of Jiahu is of great archaeological interest.

By archaeological reasoning, ages between 12 000 and 7000 years have been assigned to the site [15]. Radiocarbon dating of charcoal and rice remnants from the cultural layers places the site between 9000 and 7700 cal BP, corresponding to about 7000 and 5700 cal BC [14].

It is the aim of the present paper to confirm as well as to supplement the previous radiocarbon dates of this key site by an independent dating method. For this

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purpose luminescence, that is thermoluminescence (TL) and optically stimulated luminescence (OSL) dating are applied to the excavated pottery fragments and associated sediments, respectively, from different periods at Jiahu site. Comprehensive reviews on the principles of luminescence dating are given, e.g. by Aitken [2,3] and Wagner [11]. A noteworthy advantage of luminescence over other physical dating techniques is that it enables the age determination of the archaeological context itself. In the specific study this means that one dates the production of the ceramics as well as the formation of the archaeological layers directly. Commonly, dating is achieved only through accompanying materials such as, for instance, charcoal remains by radiocarbon dating which may be older than the context of actual interest. The luminescence dating of sediments relies on the phenomenon that during the sedimentary deposition the mineral grains are exposed to daylight resetting their OSL-signal. Once covered by the next sedimentary layer and kept in darkness, the OSL-signal of the grains builds up again so that it reflects the age of deposition. On the other hand, by TL-dating pottery one determines the moment when the ceramics were fired.

## 2. Site and material

The archaeological site of Jiahu is located on the western edge of the Huang-Hui-Hai plain, east of the Funiu Mountains; at 33°36′50.3″N and 113°39′43.2″E and ca. 67 m a.s.l. in the floodplain of the River Huai in Wuyang County, Henan Province, east-central China (Fig. 1). The site of relics covers an elliptical area of about 55 000 $m^2$ which is partially located within the present village of Jiahu. The three cultural layers are found between ca. 0.6 and 1.6 m below ground level. The thickness of less than 1 m of alluvial cover above the Neolithic layers is astonishingly little in view of the fact that this alluvial plain frequently is flooded. It appears that flooding might be a relatively recent phenomenon in this region.

At Jiahu three cultural layers, named I through III from bottom to top, are recognized. The silty layers can be distinguished by sedimentologic characteristics (Fig. 2). Altogether they are nearly 1 m thick. As already mentioned, organic material from these layers had been previously dated by radiocarbon. The three layers gave stratigraphically consistent $^{14}C$ ages: layer I 6600–7000 cal BC, layer II 6200–6600 cal BC, and layer III 5700–6200 cal BC [14].

All three layers contain pottery fragments. The potsherds excavated from the three cultural layers show very different shapes and features. The ones from the first period are simple with rough surfaces without decoration, and improved gradually during the second and third periods. The outside of the potteries is decorated with signatures and bears red covers made of hematite. Six pottery sherds and 10 sediment samples were dated by luminescence. The ceramics had been collected already during previous excavations in the 1980s from each of the three cultural layers. Table 1 gives the stratigraphic position and the petrographic description of the ceramic samples used for TL dating. In October 2000 two nearby trenches were dug and sediment samples were taken from the cultural as well as the underlying and overlying archaeologically sterile layers for IRSL dating. Fig. 2 describes the stratigraphy as well as the sedimentology of the two sampled profiles and indicates the position from where the sediments were taken for IRSL dating. Due to the high groundwater level at the time of sample collection the sediments were water-saturated.

## 3. Sample preparation and dose determination

For both, TL on ceramics and IRSL on sediments, the fine-grain dating technique was applied [2,11]. While the material for TL dating was handled under subdued red light, the preparation of the sediment samples for IRSL dating took place under strongly subdued green light. The 4–11 μm grain-size fractions, from which all carbonate and organic material had been eliminated, were extracted from the sherds and the sediments. The fine-grain separates were mounted on aluminium discs (diameter 8 mm). Laboratory irradiation was carried out using two $^{90}Sr/^{90}Y$ beta-sources of 0.7 and 9 Gy/min and an $^{241}Am$-alpha source of 4 Gy/min. Dose determination was carried out by the multiple aliquot additive and regenerative techniques.

For TL dating of ceramics up to 52 aliquots were taken: 6–10 aliquots for natural TL, three groups of 6 aliquots each for α-dose induced TL to obtain the $ED_\alpha$-values, two groups of 6 aliquots each for β-dose induced TL to obtain the additive $ED_\beta$-values and three groups of 4 aliquots each for regenerated TL to get the intercept values $I_0$. All TL measurements were performed on a Risø-DA15 TL/OSL-reader with aliquots being heated up to 500 °C at 10 °C/s in pure $N_2$ atmosphere. For $ED_\alpha$ and $ED_\beta$ calculations G. Duller's *Analyse* routine was used. While measurements for the $ED_\alpha$ and $ED_\beta$ determinations were carried out after the additively irradiated aliquots had been stored in the dark for at least 4 weeks at room temperature, an additional set of maximum dosed aliquots (N + β) was irradiated immediately before the TL measurements in order to check for anomalous fading of the luminescence signal [12]. The TL signal was recorded through a blue filter (Corning 5-58).

Dose determination for IRSL sediment dating was carried out on a Risø-DA12 TL/OSL-reader applying the Heidelberg multiple aliquot additive protocol for