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PIXE analysis of early Yue wares from Shangyu and Nanjing (2nd–6th centuries AD)

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ABSTRACT

Proton induced X-ray emission (PIXE) technique was used to analyze the samples of celadon, kiln slag and non-celadon ware from kiln site dating from the Eastern Han Dynasty to the Six Dynasties in Shangyu, Zhejiang Province, as well as the celadon samples from city site and tombs of the Six Dynasties in Nanjing, Jiangsu Province. The results show that the early celadon is of high calcium glaze system and there is no historical change in the composition of body of celadon unearthed from the kiln sites. According to analysis of Rb-Sr-Zr of the body, the only two celadons probably origin from Shangyu area.

1. Introduction

Yue kiln began in the Eastern Han Dynasty (25–220 AD), flourished in the Tang Dynasty (618–907 AD) and the Five Dynasties (907–960 AD), and declined in the Song Dynasty (960–1279 AD), which altogether lasted nearly a thousand years [1]. The Yue kiln sites are numerous and widely distributed in Yuyao and Shangyu et al. areas of Zhejiang Province of China, which were governed by Yue Zhou city during Tian-bao period (742–756 AD) of the Tang Dynasty of China. In these kilns, celadon was fired, called Yue ware, one of the Chinese famous traditional porcelains decorated by green glaze on the surface.

The earliest celadon appeared in the Eastern Han Dynasty and was only fired in Yue kiln of *Xiaoxiantan* [2]. Although *Xiaoxiantan* was excavated as early as 1970s, due to the scarce sample and the restriction of technique condition at that time, study on early celadon unearthed from it is too limited. In the recent years, with the excavation of Yue kiln sites such as *Xiaoluao*, *Dayuanping*, *Nigupo* and *Zhangzishan*, studies of early Yue ware intensified especially the excavation of kiln sites such as *Jinshan* in 2014 and *Fenghuangshan* in 2016.

In order to study the occurrence and development of early Yue ware, we collected 56 samples from 5 different kiln sites in Shangyu area, dating from the middle and late period of the Eastern Han Dynasty, the Three Kingdoms and the Western Jin Dynasty, to the Eastern Jin Dynasty and the Southern Dynasty. At the same time, 5 samples from Nanjing city also were collected to analyze their provenance.

Proton induced X-ray emission (PIXE) [3–5] is an efficient technique for the analysis of archaeological artifact, allowing quick multi-elemental determination of elemental concentrations non-destructively. At Fudan University, PIXE has been used for many years systematically to study ancient Chinese pottery, porcelain and Jade, etc. Recently, we did a PIXE study on early Yue ware made at different kilns and in the different periods. Among many chemical compositions, we try to find the elemental features that would be characteristic or specific for the early Yue ware. We also hope to explore the provenance of the sample from Nanjing city.

2. Experimental

2.1. Samples

The sample information is listed in Table 1. The samples from the kiln sites are provided and catalogued by Zhejiang Province Institute of Cultural Relics and Archaeology. The five kiln sites are *Xiaoluao* (XLA), *Shimenkan* (SMK), *Fenghuangshan* (FHS), *Shengtoushan* (STS) and *Yaoshiqian* (YSQ) (Fig. 1). All of them are located the side of the Caoe river and the area of the piedmont hills, the distance between each other is less than 5 km. Fig. 2 show the parts of the samples unearthed from the kiln sites. Information about these five kiln sites as follows:

XLA: the kiln site was as early as the middle and late period of the Eastern Han Dynasty, much earlier than the *Xiaoxiantan* kiln site, which is commonly regarded in literature as the first and the most typical celadon-producing kiln site in ancient China. Excavation of XLA in 2004–2005, the stamped-stoneware, proto-porcelain and celadon were

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Table 1
Basic information of samples from kiln sites, city site and tombs at Zhejiang and Nanjing.

Sites	Time periods	N	N1	N2	N3	Patterns	Sources
XLA	EH	16	2	14	–	Bowl, jar, bottle, bu(瓿)	ZICA; Surface collection
SMK	EH	12	–	11	1	Bowl, jar, bottle, basin, yu(水盂), kiln slag	ZICA; Excavation and Surface collection
FHS	TK-WJ	16	–	16	–	Bowl, jar, bottle, basin, yu(水盂), ware	ZICA; Excavation
STS	EJ-SD	6	–	6	–	Bowl, jar, bottle	ZICA; Excavation and Surface collection
YSQ	EJ-SD	6	–	5	1	Bowl, jar, bottle, kiln slag	ZICA; Excavation and Surface collection
YC	TK-WJ	1	–	1	–	Basin	NICA; Excavation
Tombs	SD	4	–	4	–	Bowl, jar, bottle	JNM; Excavation

N: total number; N1: number of non-celadon ware; N2: number of celadon; N3: number of kiln slag.
ZICA: Zhejiang Province Institute of Cultural Relics and Archaeology; NICA: Nanjing Institute of Cultural Relics and Archaeology; JNM: Jiangning Museum in Nanjing.
EH: Eastern Han Dynasty (25–220 AD); TK-WJ: Three Kingdoms-Western Jin Dynasty (222–316 AD), Zhejiang Province located in Wu area between 229 and 316 AD; EJ-SD: Eastern Jin-Southern Dynasty (317–589 AD); SD: Six Dynasties (222–589 AD), a collective term for six Chinese dynasiest during the period from the Three Kingdoms, the Jin Dynasty to the Southern and Northern Dynasty.

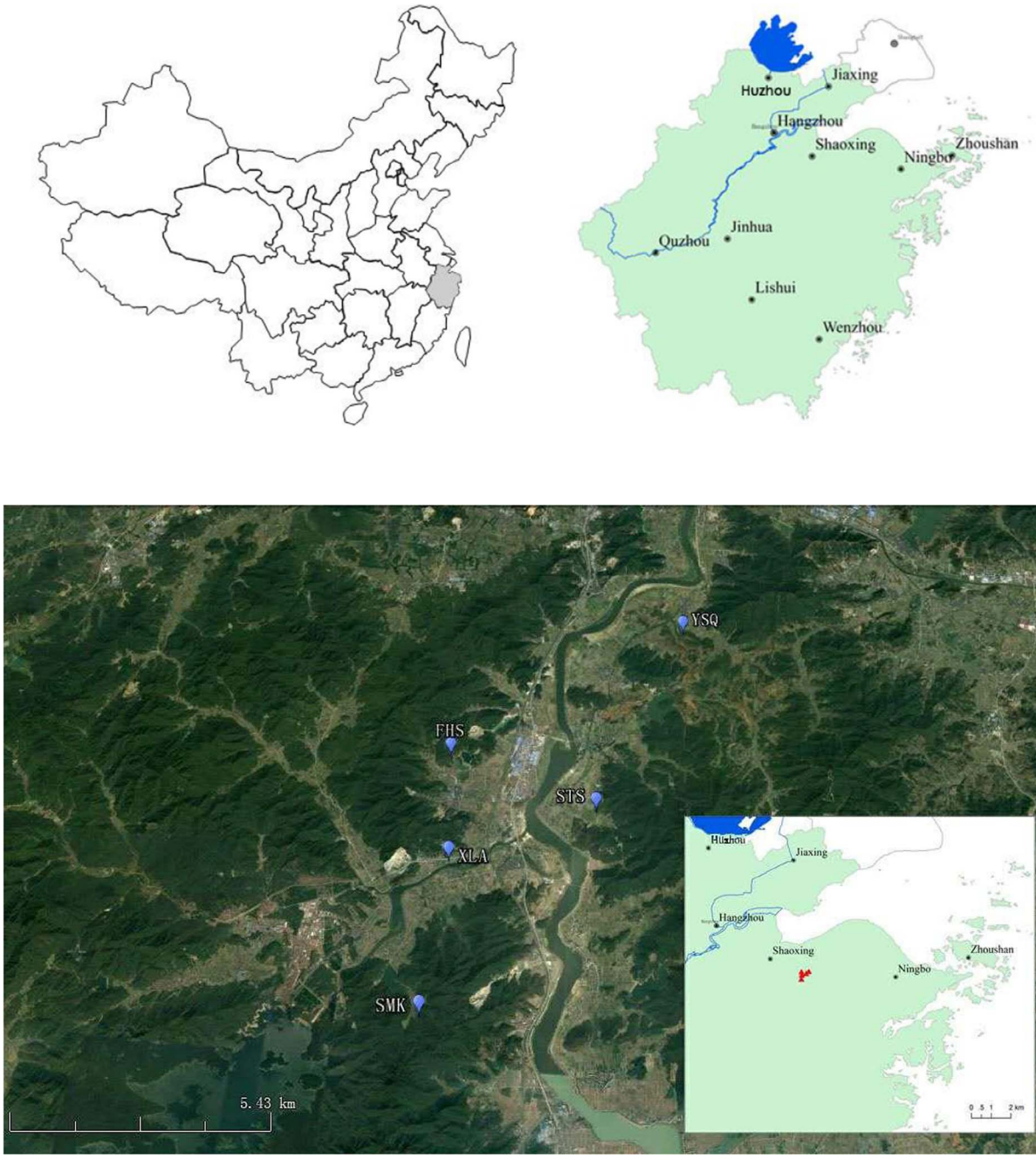

Fig. 1. Map of the location of 5 kiln sites (the base map adapt from google map).