# Unearthing the potential of celadon civilian wares
## – scientific analysis of ceramic sherds from Wuzhou

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## 1. Introduction

The history of ceramics in China is a long and successful one. Among different types of ceramics throughout times, celadon (or greenware) enjoyed enormous fame across the world. Celadon is a type of porcelain made of greyish body with high-fired yellowish-green or bluish-green glaze on the surface. The emergence of celadon production can be traced back as far as the Spring and Autumn period (770-476 BC) in south China. Six celadon-producing centres (Fig. 1) initially formed in the Tang dynasty (618-907 AD). The zenith of celadon production was in the Song dynasty (960-1279 AD) when the Yue celadons were sent as tribute wares to the imperial court in north China.

Twenty-four ceramic sherds from the nine civilian kilns at Wuzhou, spanning from 7th to 17th century, have been selected as the objects for the study and examined under the electron microprobe. The primary reason for choosing Wuzhou civilian kilns was that they are one of the least studied kiln among the other five celadon-producing centres in south China. Another reason is because few studies of Chinese ceramics touched on technological aspect of civilian wares, and this study attempts to show that the technological characterisations of the civilian ceramic wares have the potential to contribute as much to the understanding of ceramic developments as the imperial wares do.

Here, the study attempts to answer the following questions:

- Analysing the chemical compositions
- Differentiating the fluxes in glazes
- Relating the human behaviours to the ceramic production

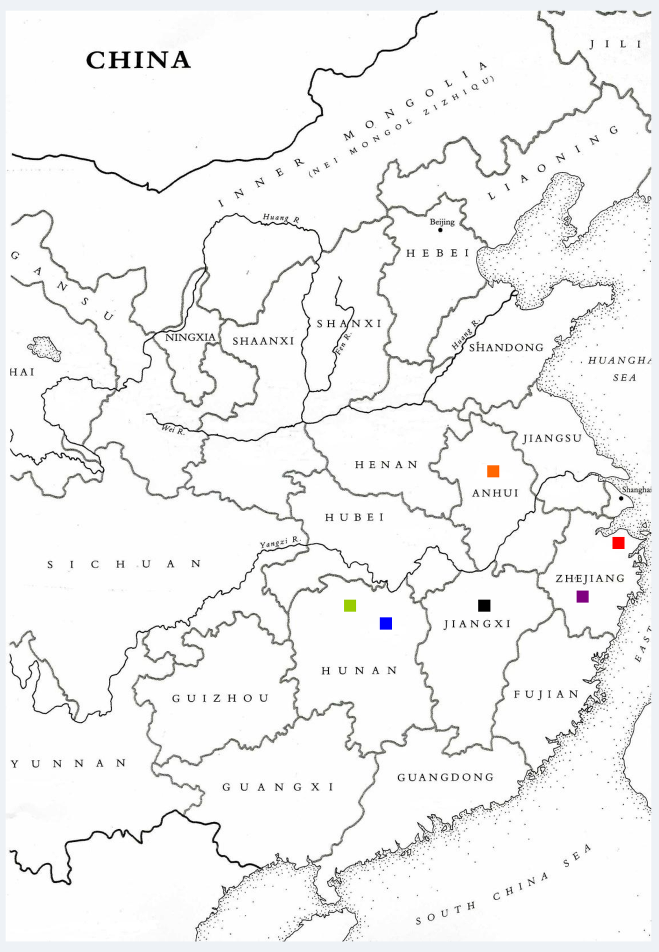


Fig. 1: Map of China with six celadon-producing centres in the Tang dynasty: Yuezhou in Zhejiang, Wuzhou, Hongzhou, Yuezhou in Hunan, Dingzhou and Shouzhou. (adapted after White and Otsuka 1993: 11).

## 2. Methodology

The state-of-the-art electron microprobe (Fig. 2) in the Archaeology Department at the University of Nottingham was used to perform the scientific analysis of the selected ceramic sherds. In the electron microprobe, the high energy electron beams (typically 10-30kV; 20kV for this analysis), which are emitted from a tungsten cathode and are accelerated towards an anode in an electron gun, pass through pairs of scanning coils in the objective lens, and focus on a particular plane of the specimen's surface (Fig. 3). Through these processes, the primary electron beam effectively spreads and fills an interaction volume, which lead to the subsequent emission of electrons, secondary electrons and backscattered electrons (Reed 1993: 3-18). Backscattered images are usually employed to show compositional differences, while the secondary image shows topographical differences. The electron microprobe is strong in compositional analysis, which will be given more emphasis in this analysis.

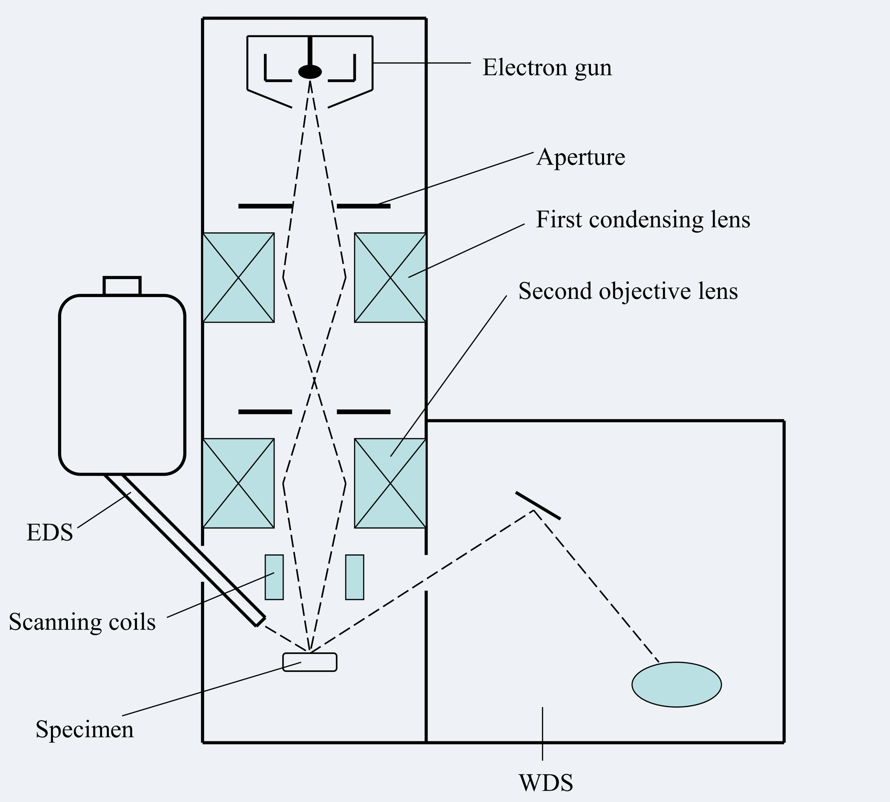


Fig 2: Schematic diagram of electron microprobe (reproduced after Reed 1993: 13).

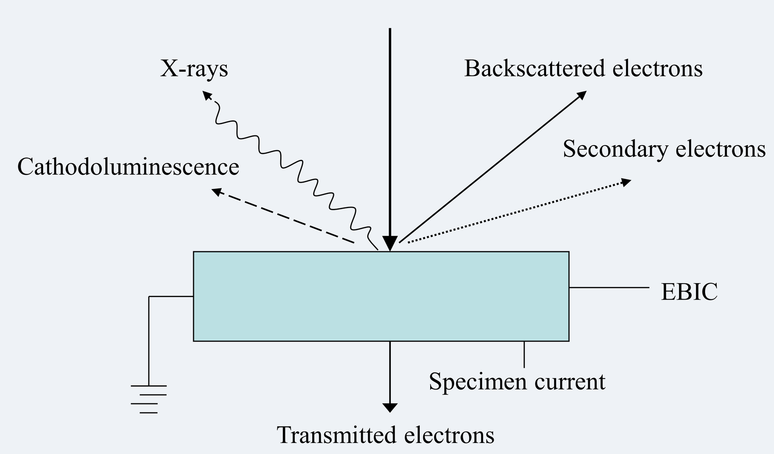


Fig 3: Interaction between the electron beam and the specimen (reproduced after Goodhew et al. 2001)

## 3. Results and discussion

### 3.1 Results – bodies

*3.1.1 Overview*

| Time period | Location | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | FeO | $TiO_2$ | $P_2O_5$ | MnO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tang | LYFT | 67.37 | 20.67 | 0.90 | 0.77 | 5.98 | 1.76 | 2.12 | 0.38 | 0.02 | 0.03 | 100.00 |
| Tang | JSLL | 70.56 | 19.35 | 0.35 | 0.66 | 5.08 | 0.56 | 3.14 | 0.25 | 0.02 | 0.04 | 100.00 |
| Tang | JHHZ | 69.36 | 19.94 | 0.71 | 0.65 | 5.10 | 1.69 | 2.25 | 0.25 | 0.02 | 0.05 | 100.00 |
| Song | QZDGT | 58.00 | 33.74 | 0.09 | 1.00 | 3.13 | 0.10 | 3.46 | 0.39 | 0.04 | 0.04 | 100.00 |
| Yuan | JYT1 | 69.65 | 20.83 | 0.13 | 1.56 | 4.18 | 0.11 | 3.21 | 0.27 | 0.02 | 0.03 | 100.00 |
| Yuan | JHTD | 71.31 | 19.46 | 0.16 | 0.99 | 4.11 | 0.20 | 3.32 | 0.36 | 0.04 | 0.04 | 100.00 |
| Yuan | JSYJS | 69.38 | 22.36 | 0.27 | 1.20 | 3.44 | 0.10 | 2.96 | 0.24 | 0.03 | 0.03 | 100.00 |
| Song-Yuan | JSWY | 70.58 | 21.96 | 0.16 | 0.60 | 3.86 | 0.08 | 2.49 | 0.29 | 0.03 | 0.02 | 100.00 |
| Ming | LYGC | 75.75 | 16.68 | 0.17 | 0.62 | 3.41 | 0.22 | 2.81 | 0.29 | 0.02 | 0.05 | 100.00 |

Table 1: Chemical compositions of Wuzhou bodies from nine kilns and the results of each location here are the average of the chemical compositions of all the bodies analysed from that location. (Tang 618-907 AD; Song 960-1279 AD; Ming 1368-1644 AD).

*3.1.2 Siltstone or porcelain stone*

We know from the literature that there was a special kind of clay – siltstone, which is very abundant in Wuzhou, Zhejiang province. It is a kind of plastic red clay, high in $SiO_2$, $Al_2O_3$, and $Fe_2O_3$, which gave a dark grey or purple colour to the ceramic bodies after it has been fired (Gong 1988: 35). Apart from siltstone, there is another kind of clay – porcelain stone. It is composed mainly of quartz and potassium mica, which results in light grey bodies after it has been fired. The provinces of Zhejiang, Jiangxi, Fujian, Jiangsu and southern Anhui in south China (see Fig. 1), all have vast deposits of porcelain stone. The composition of the porcelain stone from different places is approximately the same, and all have a high quartz content which is the raw material for making porcelain rich in silica (Zhou et al. 1983).

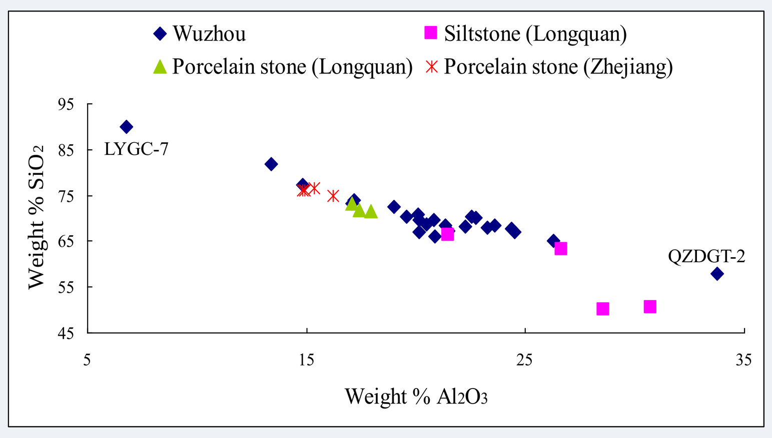


Fig. 4: Weight % $Al_2O_3$ versus weight % $SiO_2$ in 24 Wuzhou ceramic bodies compared with porcelain stone and siltstone from Zhejiang province.

From the published chemical compositions of porcelain stone and siltstone (Guo 1987: 7; Zhou 1973: 137) in Zhejiang province, Fig. 4 can be produced. Some of the porcelain stone was collected from Longquan, which is geographically very close to Wuzhou and the others within the Zhejiang province. The siltstone was only collected from Longquan. The level of silica in most Wuzhou bodies are lower than those of porcelain stone and higher than siltstone. The level of iron oxides in the Wuzhou bodies was also sitting in between of that in porcelain stone and siltstone (Fig. 5). It indicates a possible mixture of these two raw materials.

The siltstone, abundant in Wuzhou, was employed by the local potters to make ceramic bodies from 3rd century AD. The porcelain stone with lower level of iron oxides was later discovered as a more ideal raw material for making whiter bodies with higher quality. It has gradually replaced the siltstone as the primary raw material to make ceramic bodies since the Tang dynasty in Wuzhou, especially for making imperial wares. The production of the imperial wares was usually in a leading position of technological innovation while the production of the civilian wares slowly followed the trend. Therefore, it is quite possible for the potter to still follow the old tradition of using siltstone while at the same time gradually adding porcelain stone to make the bodies in Wuzhou in order to balance the availability of the raw materials and the quality of the bodies.

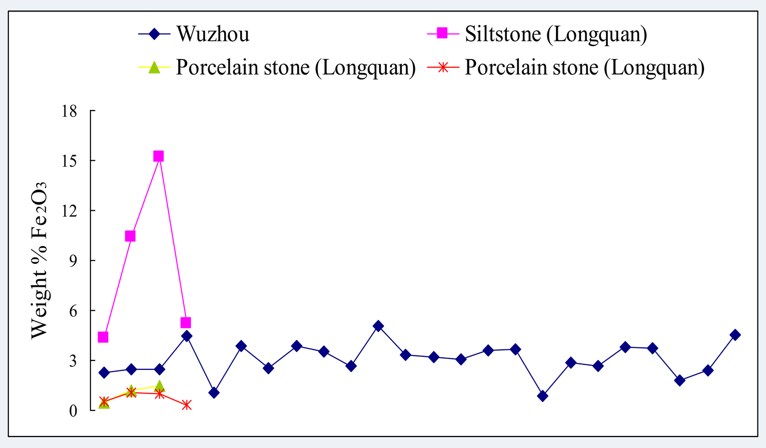


Fig. 5 Weight% of $Fe_2O_3$ in 24 Wuzhou ceramic bodies compared with porcelain stone and siltstone from Zhejiang province (the results of weight% of $Fe_2O_3$ of Wuzhou bodies are converted from weight% of FeO).

### 3.2 Results – glazes

*3.2.1 Overview*

| Time period | Location | $SiO_2$ | $Al_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | FeO | $TiO_2$ | $P_2O_5$ | MnO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tang | LYFT | 55.42 | 10.81 | 21.36 | 3.96 | 2.09 | 0.74 | 2.28 | 0.62 | 2.03 | 0.69 | 100.00 |
| Tang | JSLL | 57.60 | 12.61 | 19.27 | 3.01 | 2.28 | 0.30 | 2.61 | 0.57 | 1.07 | 0.67 | 100.00 |
| Tang | JHHZ | 59.63 | 12.15 | 17.90 | 2.60 | 1.66 | 0.62 | 2.87 | 0.74 | 1.32 | 0.51 | 100.00 |
| Song | QZDGT | 54.22 | 14.00 | 19.56 | 3.10 | 2.40 | 0.17 | 3.50 | 0.58 | 1.55 | 0.97 | 100.00 |
| Yuan | JYT1 | 59.32 | 10.35 | 18.51 | 3.54 | 2.35 | 0.14 | 2.74 | 0.59 | 1.50 | 0.96 | 100.00 |
| Yuan | JHTD | 61.38 | 12.60 | 14.78 | 3.20 | 2.58 | 0.26 | 2.86 | 0.53 | 1.01 | 0.82 | 100.00 |
| Yuan | JSYJS | 62.56 | 12.12 | 14.02 | 2.37 | 1.95 | 0.09 | 4.60 | 0.53 | 1.06 | 0.70 | 100.00 |
| Song-Yuan | JSWY | 64.94 | 16.84 | 10.99 | 1.02 | 3.91 | 0.12 | 1.86 | 0.12 | 0.09 | 0.12 | 100.00 |
| Ming | LYGC | 59.05 | 14.06 | 15.53 | 3.50 | 2.52 | 0.25 | 2.39 | 0.43 | 1.38 | 0.88 | 100.00 |

Table 2: Chemical compositions of Wuzhou glazes from nine kilns and the results of each location here are the average of the chemical compositions of the interior and exterior glazes from that location. (Tang 618-907 AD; Song 960-1279 AD; Ming 1368-1644 AD).

*3.2.2 Plant ash or limestone*

Since calcium oxide and alkali are the major fluxes employed by the potters from South China, the levels of these fluxes determined the types of glazes. As is observable from Fig. 6, the majority of the Wuzhou glazes are located in the area of low alkali and high calcium oxide (circle A), which could be fluxed either by wood ash or limestone.

Most of those located in circle A are roughly sitting on lines, where the potassium and magnesium oxides and the potassium oxide and phosphorous pentoxide are positively correlated (Fig. 7). These positive correlation indicate the application of wood ashes in the glazes (Barkoudah and Henderson, 2006: 311).

Therefore, the Wuzhou glazes should have been high in alkali, but from Fig. 6, they are very low in alkali. There may be two possible explanations. Either the wood ash added was 'washed' so thoroughly that their alkali contents were virtually eliminated, or fairly large amounts of limestone may have been intermixed with the plant ashes in the original recipes (Wood, 1999: 32). Though it is still difficult to tell which possibility the Wuzhou glazes fall into, the relatively higher level of manganese oxide in the glazes than that in the bodies is a possible indication of washed wood ash being added into the glaze recipe.

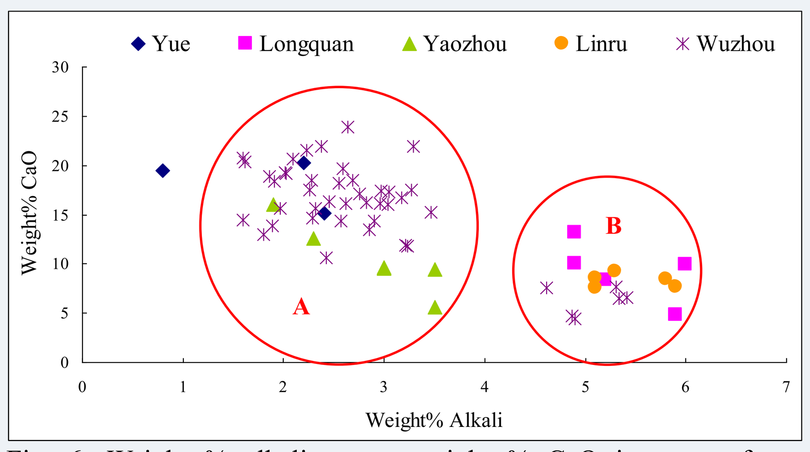


Fig. 6: Weight % alkali versus weight % CaO in twenty-four Wuzhou ceramic glazes (including exterior and interior glazes) compared with the glazes of Yue and Longquan from south China and Yaozhou and Linru from north China.

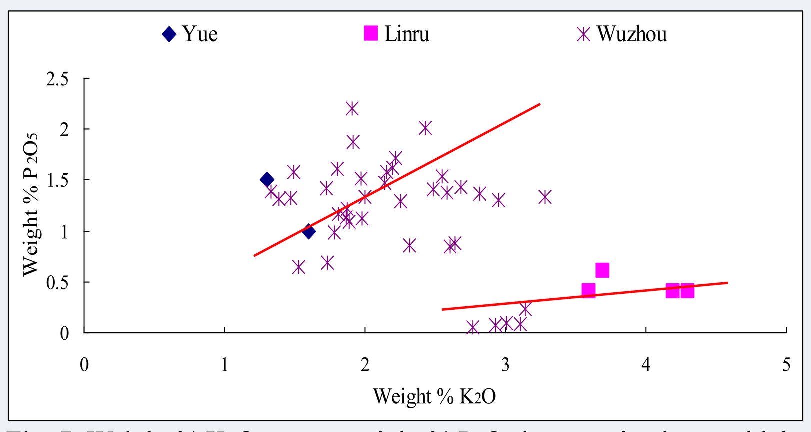


Fig. 7: Weight % $K_2O$ versus weight % $P_2O_5$ in ceramic glazes which were sitting in circle A in Fig. 5.

## 4. Conclusions

The analysis shows that the Wuzhou bodies were possibly made of the mixture of siltstone and porcelain stone and the high-fired glazes were probably fluxed by wood ash. Considering the long time period (a period of over 1,000 years), we can see that the Wuzhou bodies and glazes from nine kilns, which are geographically separated in five different locations, still demonstrate a relatively coherent chemical compositions. This relative coherence suggests that the local raw materials – siltstone and porcelain stone – were used throughout times with slight difference in the treatment of raw materials (e.g. the different mixing ratio of two raw materials). Most Wuzhou glazes are lime glazes, which follow the lime-eutectic principle and only in the later period of times, some lime-alkali glazes emerged.

It is probably an indication of a ceramic production site characterised by full-time or part-time potters who inherited their craftsmanship from the older generations and produced similar ceramic wares in different workshops and at different time periods. However, the fact that the majority of potters were connected with small-scale family workshop production outside the central government-controlled system meant that slight differences exist in the treatment of raw materials which were freely altered by potters.

An inadequate number of the sherds and lacking of precise information of the field-work increase the difficulty of exploring further the particularities of the techniques and their related social context. These greatly decrease the reliability of the deductions. If a larger number of sherds could be obtained from more reliable archaeological contexts, there is a potential to get more specific information.

**5. References**

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