The Provenance of Export Porcelain Recovered from the Nan'ao One: A Shipwreck in the South China Sea

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Abstract

A compositional study employing neutron activation analysis was performed on eleven fragments of Ming dynasty blue-and-white export porcelain recovered from the Nan'ao One shipwreck and 64 samples from three kiln sources. Examination of the compositional data was successful in determining the provenance of the porcelain fragments from the shipwreck. The results indicate that the blue-and-white export porcelain recovered from the Nan'ao One came from two sources: the Jingdezhen and Zhangzhou kilns.

Keywords: China, Ming dynasty, shipwreck, porcelain, international trade

Introduction

Chinese porcelain, silk and tea have been commodities of international trade for more than a millenium. As early as the ninth century, trade contacts between China, India, and the Persian Gulf were well established. By the fourteenth century, Chinese porcelain, silk and spices were known to Europe—most likely the result of traders who travelled across central Asia by the "Silk Road." Chinese porcelains, in particular, became regarded as items of great rarity and luxury. The peak of Chinese ceramic trace occurred between mid-16th century and mid-17th century after the *carreira da India* (sea route to India) had been established for half a century. Two production zones operating in China during this period—Jingdezhen and the Southeastern coastal area were the major manufacturers of export porcelain for the overseas market.

Kaolin clay, an essential ingredient for porcelain manufacture, was amply available such that the porcelain with the purest white paste was produced in the Jingdezhen kilns (Ming et al. 2014). The Jingdezhen blue-and-white porcelain, a type of underglaze decorated porcelain, was manufactured by a one-step firing process after glazing, using a firing temperature of around $1250^{o}C$. The demand for blue-and-white porcelain developed rapidly, and the manufacturing technique was copied by the kilns in other areas.

In the southeastern coastal area, the leading porcelain producing area was Zhangzhou city located in Fujian province. The volume of porcelain produced by the Zhangzhou kilns was much greater than any other region, but the quality was generally considered below that of Jingdezhen. Another porcelain producing region was Dapu county in Guangdong province. Dapu porcelain wares were considered inferior to those from both Jingdezhen and Zhangzhou due to the presence of a pale yellow color in the paste. In general, the high-quality, late Ming export porcelain was produced in Jingdezhen and made for the European and middle eastern markets; the middle-low quality late Ming export porcelain was produced in various sites in the southeastern coastal area and made for the inter-Asia trade (Volker 1954: 59).

With the growth in the maritime trade, acts of piracy increased. The piracy problem became so severe that the Ming Hongwu Emperor placed a ban on all trading activities on the high seas in 1371. The ban forced private merchants to move away from the coastal regions which

induced great harm to legitimate trade. The ban proved to be ineffective as the pirates would travel deeper and deeper inland to make their attacks, and smuggling activities increased.

The fifteenth century was of a period of global exploration by Portuguese and Spanish navigators seeking ocean routes to East Asia. By the start of the sixteenth century, ocean routes were established and one of the most important periods of cultural exchange and conflict in human history began.

The earliest contacts between the Portuguese and Chinese in the southeastern coastal region of China were filled with difficulties in establishing trade due to the Ming ban. Initially, the Portuguese were relegated to desolate islands where they traded with smugglers at the risk of confronting Chinese imperial authority. In spite of the risks and with the great demand coming from Portuguese merchants, considerable amounts of Chinese export porcelain were traded in this manner (Ma et al. 2009).

Conditions began to change gradually by 1543 when the Portuguese were allowed to establish a trading center at Nagasaki, Japan and by 1557 when they were allowed to colonize Macau. During the first year of the Longqing reign (1567), the maritime trade ban was officially revoked. After this, Chinese export porcelain prospered. Many potters began to produce porcelain objects specifically for export. Most of the vessels were decorated with Islamic and European motifs including crests and coats of arms (Canepa 2010). In Europe, the blue-and-white export porcelain became known as *kraak* porcelain after the name of the Portuguese ships (i.e., Carracks) in which it was transported. The Portuguese shipped goods from Macau to the port of Malacca on the Malayan peninsula. Malacca became a transshipment port for cargo to ports in Europe, the Near East, and other destinations in Southeast Asia.

The Spanish arrived in East Asia slightly later than the Portuguese by sailing west across the Pacific. However, their requests to establish trade with China from the port of Amoy in 1574 and Guangdong in 1598 were refused by the Ming dynasty. For a time, the Spanish utilized a port on the island of Taiwan where they engaged in smuggling activities. But, later they located a permanent trading base in the Philippines. In order to transport Chinese products from the Philippines to Europe, the Spanish established the Manila Galleon, which sailed

across the Pacific to Acapulco where the cargo was transferred to Veracruz, and finally loaded onto other ships which sailed across the Atlantic to Europe.

The Dutch joined the Asia-Europe trading network decades after the Portuguese and the Spanish, but they caught up in the competition soon after the turn of the 17th century. The Dutch established their center of operations first at Banten and then relocated to Batavia (present-day Jakarta), Indonesia. From there, they aggressively monopolized all European and regional trade with China through the Dutch East India Company (Vereenigde Oostindische Compagnie, VOC) for almost two centuries. Huge amounts of Chinese export porcelain were traded during this period. The Dutch East India Company alone traded 16 million porcelain wares to markets in Southeast Asia, Central Asia and Europe between 1602 and 1682 (Volker 1954: 223-225).

The geographer, Zhang Xie (1617), describes the development of overseas commerce between the southern Fujian province and foreign countries in southeastern Asia and Europe in his book *Investigations of the Eastern and Western Oceans*. The locations recorded in his book are the places where merchant ships travelled. The Selden map of 1619, recently rediscovered by Batchelor (2013), shows the East Asian ports and shipping routes. The routes linked Japan to the north, the Philippines to the east, and Indonesia to the south. The Western Ocean and the Eastern Ocean as defined by the ancient Chinese were separated by the Kalimantan Island. The trading routes to the Western Ocean went to ports on the mainland of Southeast Asia and Western Indonesia, and the trading routes to the Eastern Ocean went to ports in Japan (although direct trading with Japan was officially banned by the Ming government) and the maritime Southeast Asia which mostly included the Philippines and Eastern Malaysia.

Shipwrecks

Shipwrecks and their cargoes that remained undisturbed on the sea bed for centuries can provide vital information about the interactions between ancient civilizations. Because they are analogous to time capsules, studies of shipwrecks offer insight into ancient shipbuilding, navigation, trade, and sea routes. The total number of shipwrecks lying on the bottoms of the World's oceans, lakes, and rivers may reach into the hundreds of thousands. Due to the many

challenges of conducting underwater archaeology, a mere fraction of shipwrecks have been studied.

In some regions, such as the Mediterranean and Caribbean, underwater archaeology has been active since the middle of the 20th century, thanks to the development of scuba diving equipment. However, underwater archaeology in China is a discipline with barely 20 years of history. Approximately one-dozen shipwrecks have been discovered off the south China coast to date. Until recently, the resources necessary to recover and study these shipwrecks have been limited.

The Nan'ao One

The discovery of an ancient shipwreck off the coast of Nan'ao Island, about six nautical miles from Shantou, Guangdong, China, is one of the best examples of China's recent efforts to promote the study of underwater archaeology. The shipwreck known as the Nan'ao One was accidentally discovered by local fishermen in 2007. Preliminary studies identified the ship as a Chinese merchant ship from the late Ming dynasty. Typological examination of the ceramics onboard was used as the main dating method which suggested that the Wanli reign is the most probable date of the ship (Cui 2011). The great majority of the ceramic commodities onboard were identified as Zhangzhou products. The Zhangzhou kilns did not start to become active until after the maritime trade ban was officially revoked in the first year of the Longqing reign (1567AD). According to various interpretations of ancient Chinese and Western documents of maritime trading in the late Ming period and materials unearthed from the excavations of Zhangzhou kilns, the Wanli reign was the time during which the Zhangzhou kilns had their greatest production and exportation (Canepa 2010, Li 2001: 158). Therefore, the Wanli reign appears to be the most likely date of the Nan'ao shipwreck. In 2010, the Nan'ao One received an award as one of the top 10 new archaeological discoveries of China.

Underwater salvage operations on the Nan'ao One were conducted during three seasons (2010-2012). The ship was determined to be of typical Chinese construction, with dimensions of 25m length and 7.5m width. The Nan'ao One had 25 rooms and thousands of cultural relics, including porcelain, bronze, iron, tin, stone and lacquer. The ship was also armed with several cannons. Of the more than 30,000 artifacts recovered from the Nan'ao One, 95% are

blue-and-white export porcelain. Most of the blue-and-white porcelains have been visually identified as products of the leading workshops in Zhangzhou and Jingdezhen. However, the origins of the remaining vessels could not be determined by eye examination alone. Some of the larger porcelain bowls found on the vessel were probably made for foreign trade, as they were of a design not commonly used in Chinese daily life. To further our knowledge of the Nan'ao One and its accompanying cargo, a compositional study of several fragments of blue-and-white porcelain recovered from the ship is reported here.

Previous provenance studies on Chinese export blue-and-white porcelain

A large number of provenance studies of Chinese porcelain have been carried out during the past few decades, and quite a few of them have reported on the chemical compositions of Jingdezhen porcelain and the chemical variation trends in Jingdezhen porcelain over time. The most thorough study is one by Pollard et al. (1986) which studied the major and minor element compositions of more than 150 Jingdezhen porcelain bodies of various ceramic types covering the 12th century to post-18th century, and suggested a likely chronology for the development of the art of porcelain manufacture at Jingdezhen.

Although a large quantity of analytical data is available for Jingdezhen porcelain, very few of these concern late Ming export porcelain. And, there are even fewer scientific studies concerning late Ming export porcelain from production sites other than Jingdezhen. Ma et al. (2012) studied the trace element composition of late Ming dynasty porcelain from the Jingdezhen and Zhangzhou kilns using ICP-MS, and established a method for identifying Jingdezhen and Zhangzhou Ming dynasty export blue-and-white porcelain by use of principal components analysis (PCA) and rare earth element (REE) distribution curves. Another study by Dias et al. (2013) determined the chemical compositions of 25 major and trace elements in Ming dynasty export porcelain excavated from sites in Portugal using neutron activation analysis (NAA). With the aid of cluster analysis and REE distribution curves, three compositional groups were identified. A few of the samples were specifically attributed to the Jingdezhen and Zhangzhou kilns.

2. Samples and locations

In the present investigation, eleven blue-and white export porcelain fragments recovered from Nan'ao One were made available for compositional analysis by NAA. Before proceeding with the analysis, visual examinations and discussions were carried out with archaeologists.

Among the eleven samples, two displayed the features of Jingdezhen export porcelain and two others show the typical characteristics of southeastern coastal products from Zhangzhou. The origins of the remaining seven samples could not be identified by eye examination.

Forty-three late Ming blue-and-white export porcelain sherds excavated from Zhangzhou were selected as reference samples to establish a compositional signature for Zhangzhou products. The Zhangzhou samples came from five different kiln sites: Huazailou kiln (HZ) and Tiankeng kiln (TK) of Nansheng Village, Pinghe County, Fujian Province and, Dalong kiln (DL), Erlong kiln (RL) and Beigou kiln (BG) of Wuzhai Village, Pinghe County, Fujian Province.

The largest late Ming export porcelain production complex found in Jingdezhen, so far, is the Guanyinge site. Although it was not exclusively used to produce export porcelain like the Zhangzhou kilns, blue-and-white export porcelain vessels were the major products (Bai 1995). Fourteen late Ming blue-and-white export sherds from Guanyinge site were selected to serve as reference samples for the compositional signature of Jingdezhen products.

Lastly, seven late Ming blue-and-white porcelain sherds from the Dapu kilns were included in the study for additional comparisons. The locations for all sites are shown in Figure 1. Detailed descriptions for the samples are presented in Table 1.
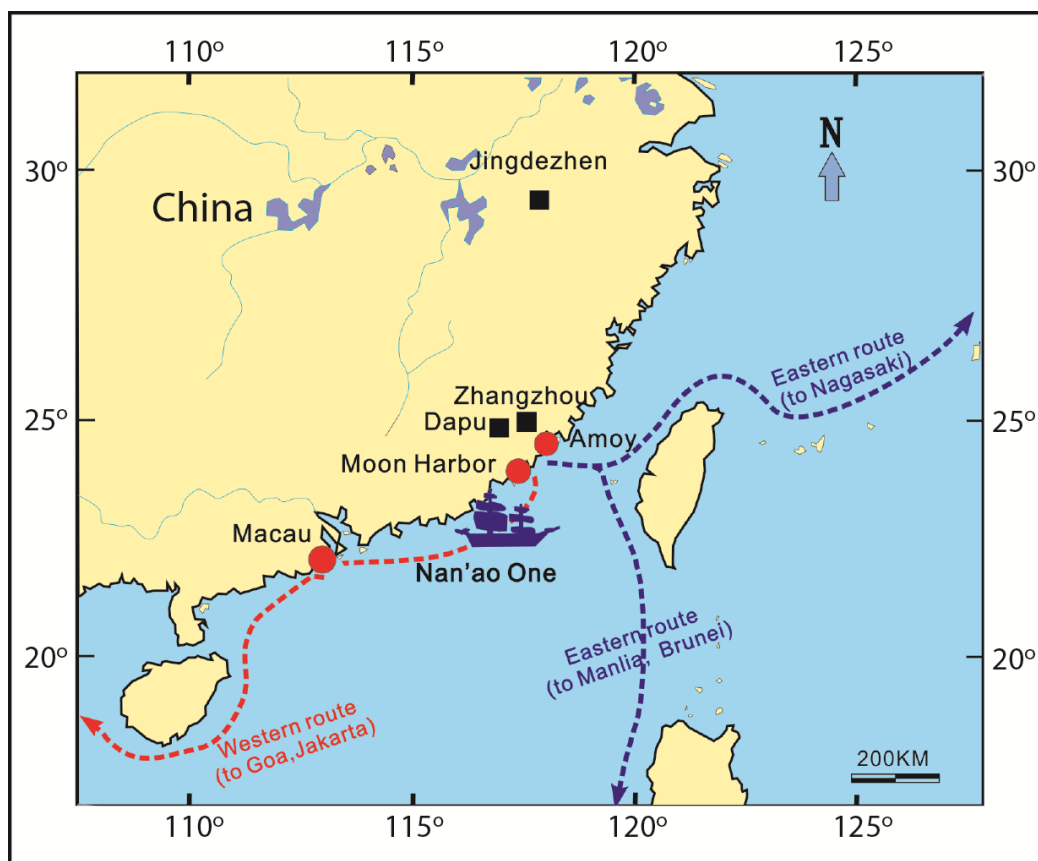
Fig. 1. Map of southeastern China showing the locations of Nan'ao One shipwreck, trade routes, and kilns mentioned in the text. (It should be noted that the route to Japan was officially banned by the Ming government for all Chinese merchant ships).

Table 1. Summary description of the sherds in this study.

Sample ID	No. Samples	Site	Typological Classification
1~43	43	Zhangzhou, Pinghe County, Fujian Province	
44~57	14	Jingdezhen, Jiangxi Province	
58~66	9	Dapu, Dapu County, Guangdong Province	
67~68	2	Nan'ao One shipwreck	Jingdezhen
69~70	2	Nan'ao One shipwreck	Zhangzhou
71~77	7	Nan'ao One shipwreck	Uncertain

3. Experimental

3.1. Sample preparation

The surface of each sample was abraded using a diamond dental drill to remove all glaze and surface deposits. Afterward, the samples were cleaned with a brush, rinsed in deionized water, and cleaned again using an ultrasonic bath filled with pure alcohol to remove any loose surface contaminants. After cleaning, the samples were ground into fine powders, stored in glass sample vials, and dried for a minimum of 24 h at 105°C.

Two analytical samples were prepared from each powdered sample by weighing 150 mg of powder into a high-density polyvial and 200 mg of powder into a high-purity quartz vial. Standards were prepared from SRM-1633b Coal Fly Ash and SRM-688 Basalt Rock, and quality control samples from SRM-278 Obsidian Rock and Ohio Red Clay were also prepared. The standards create a calibration for the NAA measurements, and the quality control samples provided a check on measurement accuracy and precision.

3.2. Measurements

Measurements by NAA were carried out at the University of Missouri Research Reactor (MURR) using procedures described by Glascock (1992). The samples in polyvials were irradiated for five seconds, allowed to decay for 25 min, and counted for 720 seconds to measure the short-lived elements: Al, Ba, Ca, Dy, K, Mn, Na, Ti, and V. The samples in quartz vials were irradiated for 24 hours and counted twice. The first count followed a decay time of seven days to measure the medium-lived elements: As, La, Lu, Nd, Sm, U, and Yb. The second count followed an additional three weeks of decay to measure the long-lived elements: Ce, Co, Cr, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr.

4. Results

Compositions for the above-mentioned 33 elements are measured in a majority of the ceramic analyses conducted at MURR. However, three of the elements (As, Ni, and V) were below detection in most of the shipwreck and kiln samples, and they were eliminated from further consideration. An inspection of the results for the quality control samples found the remaining 30 elements to have good accuracy and precision (typically <3%). The supporting dataset is available for download from http://archaeometry.missouri.edu/datasets/.

4.1 Defining compositional groups for the kilns

As an initial step toward interpretation of multivariate data (Glascock et al. 2004), the compositional groups for the kiln samples were inspected for outliers possibly indicating either contamination or misclassified samples. The inspection identified three samples for recommended removal. Sample 63 was removed from the Dapu kilns group due to an extremely low Ca concentration Ca relative to other kiln samples, and samples 40 and 43 were removed from the Zhangzhou kilns group due to high Ca concentrations. The Jingdezhen kilns group was left intact.

A well-established procedure for handling large multivariate datasets is the use PCA. The procedure uses an orthogonal transformation to convert a set of possibly correlated variables (elements) into values (scores) from a set of linearly uncorrelated variables known as principal components (PCs). The first PC describes the largest possible variance in the dataset, and each successive PC has the highest remaining variance on the conditions it must be orthogonal (uncorrelated) to all preceding PCs. The number of PCs will always be equal to the original number of variables. The main advantage of PCA is that the first few PCs almost always contain a majority of information necessary to differentiate between groups in a dataset. By examining plots of the principal components, it is often possible to visualize groups from which provenance identifications can be made (Baxter 1994, 47-48).

In this study, the principal components were calculated from the log base-10 normalized data. Figure 2 shows a biplot of the first and second principal component scores for the samples from the kilns at Jingdezhen, Zhangzhou and Dapu along with element vectors that indicate the contributions of individual elements to group differences.
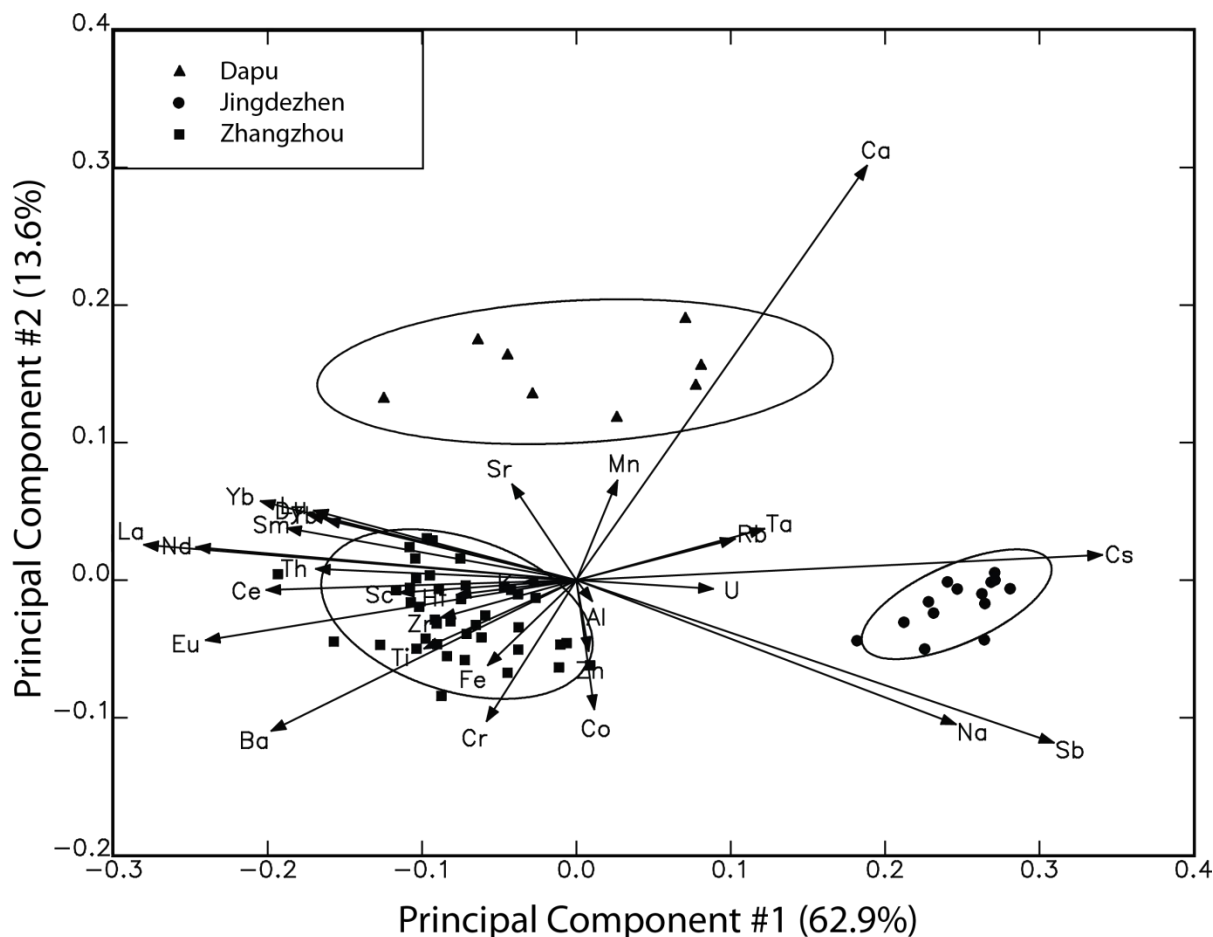
Fig. 2. Biplot of principal components #1 and #2 shows the compositional groups for kilns and the element vectors indicating differences. Groups are surrounded by 90% confidence ellipses.

As shown in Figure 2, the kiln samples are completely separated such that there is no overlap between the different kiln groups. This supports our expectation that the first and second PCs can be used with great confidence to assign unknown samples from each of the three different kiln sources. The first principal component explains 62.9% of the variance and the second component explains 13.6% of the variance. Thus, the cumulative variance explained by Figure 2 is 76.5%. The element vectors show the relationships between the elemental concentrations and the kiln compositional groups. The rare earth elements and several of the transition elements (Ti, Fe, and Cr) are more highly concentrated in the Zhangzhou kilns group. The Jingdezhen kiln group has higher concentrations for Cs, Na and Sb; and the Dapu kiln group has the highest Mn concentrations and low concentrations for Cr and Co. Table 2 lists the means and standard deviations for each of the three kiln groups.

Table 2. Element concentration means and standard deviations in parts per million measured in Ming dynasty export blue-and white porcelain compositional groups from kilns.

Element	Dapu (n=8) Mean & S.D.			Jingdezhen (n=14) Mean & S.D.			Zhangzhou (n=41) Mean & S.D.		
Na (%)	0.14	±	0.11	0.92	±	0.18	0.19	±	0.12
Al (%)	9.52	±	1.06	11.4	±	1.7	10.7	±	0.8
K (%)	3.50	±	1.03	2.74	±	0.24	3.60	±	0.41
Ca (%)	1.46	±	0.64	0.40	±	0.24	0.10	±	0.05
Sc	6.05	±	1.12	2.86	±	0.63	7.46	±	2.00
Ti	1239	±	495	1038	±	219	2122	±	396
Cr	2.66	±	2.06	3.92	±	2.62	5.00	±	2.22
Mn	1334	±	605	667	±	178	523	±	125
Fe (%)	0.62	±	0.13	0.66	±	0.08	1.13	±	0.32
Co	3.85	±	3.13	10.1	±	5.4	7.8	±	3.9
Zn	43	±	15	56	±	9	57	±	17
Rb	329	±	92	428	±	78	195	±	25
Sr	74	±	43	36	±	13	47	±	16
Zr	104	±	35	82	±	9	147	±	24
Sb	0.25	±	0.31	2.19	±	1.17	0.24	±	0.16
Cs	10.7	±	5.0	50.7	±	8.6	4.03	±	0.87
Ba	156	±	73	136	±	54	579	±	126
La	101.0	±	87.8	12.5	±	3.9	87.0	±	30.2
Ce	82.5	±	22.4	24.2	±	5.2	110	±	21
Nd	86.5	±	80.8	12.9	±	3.3	68.3	±	24.4
Sm	20.9	±	16.2	4.33	±	0.59	14.8	±	5.4
Eu	1.46	±	1.18	0.47	±	0.12	2.35	±	1.09
Tb	2.65	±	1.43	0.70	±	0.08	2.04	±	0.85
Dy	15.4	±	7.9	3.77	±	0.57	11.8	±	5.0
Yb	9.13	±	4.10	1.73	±	0.21	6.89	±	2.75
Lu	1.33	±	0.53	0.33	±	0.13	0.96	±	0.32
Hf	4.81	±	0.90	3.20	±	0.21	5.79	±	0.46
Ta	3.86	±	1.32	5.23	±	0.97	2.12	±	0.36
Th	27.0	±	6.3	10.2	±	1.2	35.0	±	4.0
U	5.93	±	1.08	10.9	±	2.2	5.70	±	1.46

4.2 Assigning provenance to sherds from Nan'ao One

In order to identify sources for the individual Nan'ao One sherds, the PCA scatterplot in Figure 3 projects the Nan'ao One sherds against the 90% confidence ellipses established from Figure 2 for the compositional groups describing the kilns. A majority of the shipwreck sherds plot inside the confidence ellipse for Zhangzhou, with samples 75 and 76 located nearby. Samples 67 and 68 are located outside but near the confidence ellipse for Jingdezhen and sufficiently distant from both Zhangzhou and Dapu. Inspection of the data for samples 67

and 68 finds that the main differences between these samples and the Jingdezhen kilns group are lower concentrations for Cs and Na. For samples 75 and 76, the elements Ca and Mn are higher than those for the kiln samples from Zhangzhou.
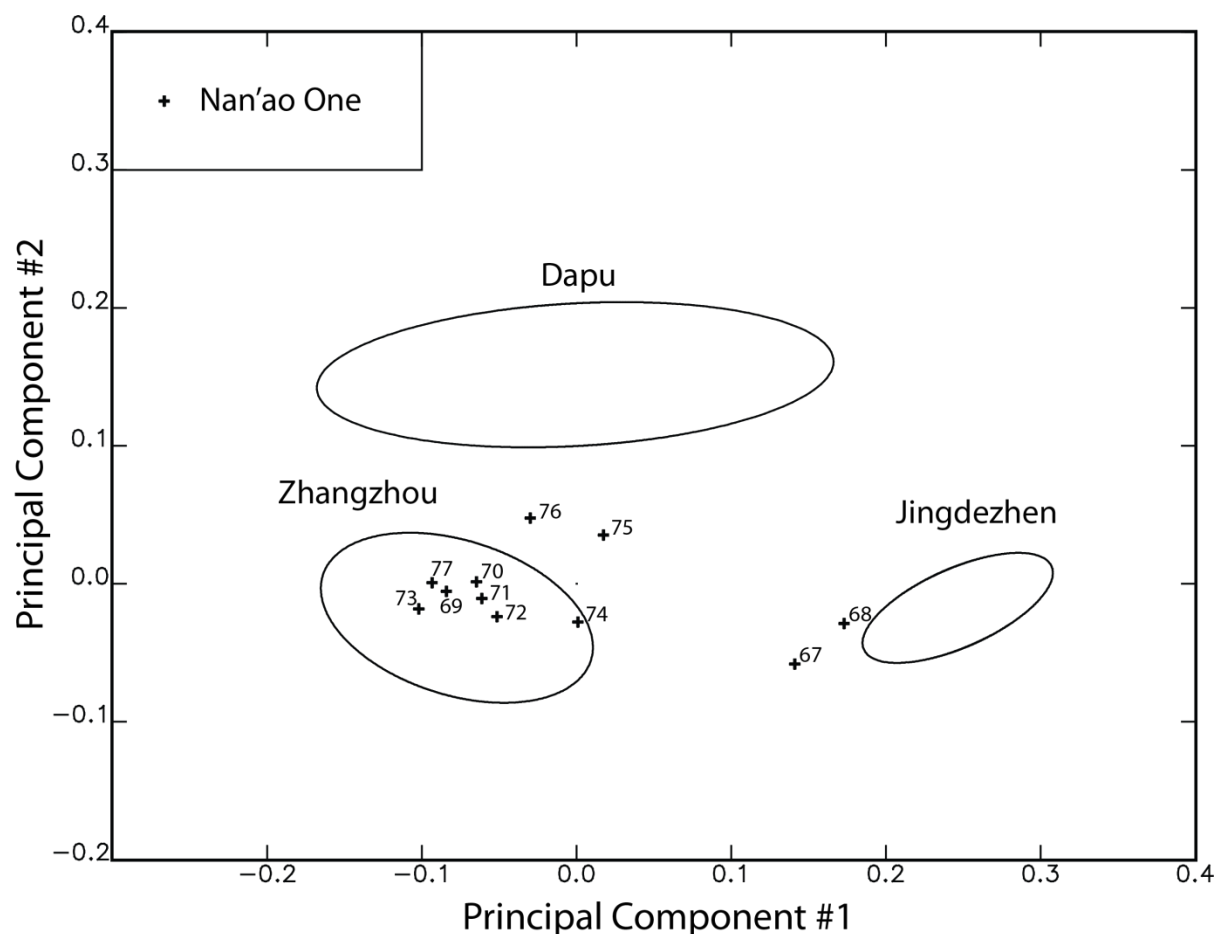

Fig. 3. Plot of principal components #1 and #2 showing samples from the Nan'ao One projected against confidence ellipses for the kilns.

Provenance studies of ceramics from other shipwrecks have been reported in the literature (Pradell et al. 1996, Taylor et al. 1997, and Waksman 2011). The earlier studies described serious difficulties in studying a range of highly mobile elements (Na, Mg, K, Ca, Mn, Rb, Sr, Cs, and Ba) present in ceramics recovered from underwater environments. All of the above-mentioned studies involved ceramics fired at much lower temperatures than the temperatures used to fire porcelain. Although we noticed discrepancies when comparing the concentrations for Na, Mn, Ca and Cs from the porcelain sherds on the shipwreck to the kiln samples, the remaining elements were barely affected. Thus, we interpret this to mean that because porcelain is vitrified (i.e., harder and more durable), it is better able to withstand long-term exposure to sea water without its chemical composition being significantly affected.

Therefore, it seems reasonable that samples 67 and 68 should agree with their visual identifications made to Jingdezhen. Similarly, the remaining nine sherds from 69 thru 77 can be assigned to the kilns in Zhangzhou province.

5. Discussion

According to the design of the ship and material evidence recovered from the underwater excavation, the Nan'ao One was a Chinese trading vessel that departed from the Zhangzhou port heading to a destination in the Western Ocean during the late Ming period (most likely the Wanli reign—AD 1573-1620). The Zhangzhou port was the major international trading port for China during this period, and the location where the ship sank was along the route from Zhangzhou port to the 'Western Ocean' as described by Zhang Xie (1617).

During the late Ming period, the ship's first stop after sailing out of Zhangzhou bay should have been Amoy, where the cargo would have been inspected. After leaving Amoy, trading vessels for the Western Ocean and the Eastern Ocean would head out on separate routes for their different voyages. The location where the Nan'ao One sank was at the beginning of the voyage to the Western Ocean, less than one day's sailing from Amoy. Because the ship sank at the beginning of its journey, any of the ports on the Western Ocean voyage may have been its destination.

Although we cannot be certain of the precise destination of the Nan'ao One ship, the presence of more than 30,000 pieces of porcelain from kilns at Jingdezhen and Zhangzhou suggests the export porcelain was headed to a port with wealthy buyers who had connections to European markets. This is also supported by the fact that both European and inter-Asian trading networks were controlled by the European powers during this time period. Because the Spanish and British did not arrive until later then the Wanli reign, this leaves the Portuguese and the Dutch as the most probable trading partners. The Portuguese were mainly using the port of Macau and the Dutch were just beginning to use the port of Batavia. Based on this assessment, it is our interpretation that the Nan'ao One was most likely headed to the port of Macau or possibly to the port of Batavia on the island of Java.

6. Conclusions

Geochemical analysis of blue-and-white porcelain samples from kilns at Jingdezhen, Zhangzhou, and Dapu by NAA was successful in establishing the differences in composition

between the three kilns. Multivariate analysis by PCA and scatterplots were used to examine the data and to identify an efficient method for assigning provenance. In spite of contamination/leaching issues induced for some of the mobile elements while resting in an underwater environment for four centuries, the provenance of porcelain samples from the Nan'ao One shipwreck could be determined with an acceptable level of confidence. Analysis of eleven porcelain sherds from the shipwreck found that nine of the sherds were linked to Zhangzhou, and two of the sherds were linked to Jingdezhen. By associating the results from scientific analysis and previous historical studies, the most probable sailing destinations for Nan'ao One were first Macau and second Batavia (Jakarta).

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Captions for Figures and Tables

Fig. 1. Map of southeastern China showing the locations of Nan'ao One shipwreck, trade routes, and kilns mentioned in the text. (It should be noted that the route to Japan was officially banned by the Ming government for all Chinese merchant ships).

Fig. 2. Biplot of principal components #1 and #2 shows the compositional groups for kilns and the element vectors indicating differences. Groups are surrounded by 90% confidence ellipses.

Fig. 3. Plot of principal components #1 and #2 showing samples from the Nan'ao One projected against confidence ellipses for the kilns.

Table 1. Summary descriptions of the sherds in this study.

Table 2. Element concentration means and standard deviations in parts per million measured in late Ming dynasty export blue-and-white porcelain compositional groups from kilns.