ARTICLE

Characterizing Song Dynasty ceramics using molecular biology fluorescence technology

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ABSTRACT

We have used a new technology, fluorescent imaging, to examine Song Dynasty ceramics, renowned for their exquisite craftsmanship and unique crackle patterns. By capturing high-resolution images of microstructural features and crackle networks that are illuminated by specific wavelengths of light, we have been able to discern differences that seem to distinguish between products of the Northern and Southern Song dynasty periods; these can be further divided by the patterns into five major types of Ge-like ware. Fluorescence technology thus offers a relatively simple, inexpensive and non-invasive method for the characterization and study of ancient ceramic vessels. In addition, analysis of the emitted fluorescence provides insights into the composition and distribution of glaze materials that are not revealed by other methods, deepening our understanding of historical craftsmanship and technological innovation.

INTRODUCTION

We describe a novel technique for analyzing ancient ceramics that may be useful in future archaeological research. The technology, which is simple in application, was originally developed by molecular biologists for the detection of fluorescent proteins. As we illustrate, its use in characterizing ceramics reveals differences in particular glaze materials and patterns that, in conjunction with archaeological information, can further the understanding of their relative age and origin.

The current tools available for analyzing ancient ceramics are somewhat limited: a simple visual evaluation is used in most cases (Lahlil 2015). Scientific assessment of the material composition of the vessels by thermoluminescence (TL) is available, but the technology is expensive ($500 or more per test) and involves damage to the vessel by drilling to produce the tested material. The standard TL tests are designed to compare the radiation energy absorbed by a ceramic object since its original firing to the background radiation of the surrounding soil (Aitken 1964). A variation of the original TL testing protocol is now performed commercially without an in-situ background comparison, but the precision and the invasive nature of TL testing detracts from its use in analyzing important ancient ceramics. Non-invasive digital image processing techniques using standard, visible light photography have been explored to characterize ceramic glazes including those with crackle patterns, but this technique offers limited information (Lahlil et al., 2013). The most widely used technology for analyzing ancient Chinese ceramics is X-ray fluorescence (XRF) spectrometry in its various forms. In recent years, this technology has been widely used for diverse studies of Chinese ceramics (Franci 2020, Galli et al. 2022, Gianoncelli et al. 2021, Schipper et al. 2025). Handheld XRF scanners are commonly used to produce elemental reflective signature results for ceramic glazes. However, these devices are expensive, costing thousands of dollars, and the scanning field area (i.e., “spot size”) limits the devices’ ability to differentiate the composition of the submillimeter-width crackle of a glaze from the primary glaze composition. Finer spot sizes are achievable with even more expensive XRF equipment, with some hybrid techniques that may require an extracted sample from the piece. Increasingly, understanding an archaeological site relies on sherds from broken ceramics found at the site, and additional inexpensive, facile, and non-destructive technologies for characterizing such sherds are clearly desirable.

KEYWORDS

Chinese ceramics, fluorescent imaging, archaeological technology, Ge ware, crackled glaze, Song dynasty, Philippine prehistory, Kalaga Putuan Crescent

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BACKGROUND

Fluorescence technology

In 2005, biochemist Osamu Shimomura and colleagues described a method for labeling proteins by linking them to the green fluorescent protein (GFP), a protein that occurs naturally in the bioluminescent jellyfish Aequorea victoria (Shimomura 2009). Because of its fluorescence, the labeled protein can be readily and specifically identified, both *in vivo*, where it can be used to locate the protein anatomically (Schmidt et al., 2013), and *in vitro*, where it can be used to identify and quantify the protein in a complex mixture (Giacobassi 2020). Thus, the quantity and location of the protein can be followed under various physiological and pathological conditions. The broad application and importance of this discovery resulted in Shimomura being awarded the 2008 Nobel Prize in Chemistry. The utility of the technology has since been increased by the development of handheld light-emitting diode (LED) lights with a dual excitation wavelength capability (e.g., NIGHTSEA DFP Flashlight with royal blue and green LEDs) which stimulates the fluorescence.

Ge Ware Ceramics

We have applied this technology to a specific group of ceramics, discovered in the Southeastern Philippine Archipelago that appear to be from the Song Dynasty. The "golden thread, iron wire" glaze pattern, developed during the Song dynasty, was a famous and celebrated ceramic accomplishment. The pattern consisted of a primary network of dark crackle, and a secondary network of fine, light golden crackle that occurred within each polygonal block of the primary network. The elder of two brothers of the Zhang family, both famous potters of the Song era, was said to be responsible for this innovation (Rastelli 2021). At a 1992 international symposium organized specifically around the mysteries of Song Dynasty Ge and Guan (official) ware, Dr. Wang Qingzhong reported that the characteristic golden thread, iron wire pattern was first termed Gegedong ware in 1363 CE (Vainker 1993), a term that was later shortened to Ge ware (employing the Chinese word for older brother). Later dynasties heralded Ge ware as one of the five great ceramic forms of the Song period. Over the years, however, the true identity of Ge ware has been elusive and controversial, as pieces in prominent current collections (“museum Ge” or “handed-down Ge”) and other candidate forms from the Hangzhou and Longquan production areas do not seem to fully embody the described golden thread characteristics, nor do they elicit the veneration recorded in the ancient Chinese literature (Rastelli). In particular, the difference between Ge ware and Guan (“official”) ware has been problematic. Both types were made for the Song imperial court; examples of each, with some form of crackled glazing, have been documented in the ceramics literature and Vainker’s symposium summary provides a list of texts compiled by the Shanghai Museum’s Lu Minghua. These were extensively copied by the imperial kilns in Jingdezhen during the Ming and Qing dynasties. In general, vessels with both a primary and secondary crackle were considered ‘Ge’ or ‘Ge-like.’ While the 1992 symposium ended without a conclusive set of classification rules, Guo Yanyi, a researcher with the Shanghai Institute of Silicates, suggested that “it seems most likely that traditional Ge ware pieces were made in Henan alongside Northern Song Guan wares” (Vainker). Our findings in this report are consistent with this conclusion.

Several ceramic pieces that have been found in the Southeastern Philippine Archipelago seem to have the characteristic golden thread, iron wire pattern attributed to Ge ware. Despite an extensive search through the ceramics literature and documented public collections, no direct comparables to the glazes of the recovered pieces have been identified. To understand how these as yet unauthenticated pieces relate to each other, and potential comparables should they be brought forward in the future, we serendipitously discovered the usefulness of the fluorescence tool for characterizing these ceramic pieces. Fluorescence analysis of these ceramics; our findings are presented and discussed below.

EXPERIMENTAL PROCEDURES

Materials

Ceramic pottery, dual Flashlight by NightSea, yellow filters for viewing blue fluorescence, red filters for viewing green fluorescence, Nikon AFS Nikkor camera, and an otherwise unlit room for long exposure photography.

Fluorescence Methods

The Nightsea DFP-1 Dual Fluorescent Protein Flashlight is a dual color light source for viewing fluorescence. The flashlight uses high intensity light-emitting diodes (LEDs) that produce intense blue light (wavelength 390-490 nm) or green excitation light (wavelength 540-560 nm). In combination with the customized interference filters, which are available in wearable form as glasses, the light is effective in visualizing emission fluorescence from ceramic potteries, used for photography as described in the section below.

Photography Methods

Ceramics were digitally photographed using a Nikon D750 camera with a Nikon AFS Nikkor 24 - 120 mm 1.4 G ED lens. For ambient light photography, the camera was set to F13, ISO 100 and exposed for 3 seconds. For UV photography, the same settings were used as in ambient light photography except for the exposure time that was set to 30 seconds. The white balance was set to automatic. The brightness and contrast parameters of the resulting digital images have been adjusted for a better and more consistent visualization of the observed fluorescence.

Ceramic Vessels Analyzed

All of the ceramics presented in this analysis, which exhibit a golden thread, an iron wire, or a related pattern, are in the collection of the senior author, a research scientist with over 350 peer-reviewed biological research publications. The author’s ceramics collection and extensive ceramics literature collection were built over a period of approximately 50 years (Olivera et al. 2024), during which time he has acquired considerable expertise in Chinese ceramics, including those from the Song Dynasty. The objects from the collection that are analyzed in this paper include conical bowls, vases shaped in the form of ancient bronze vessels, a floral dish, and a vase-shaped wine bottle in the form of a double fish. These pieces are generally consistent with Song Dynasty ceramic styles and all have a two tier, nested (primary and secondary) crackled glaze. The ceramics were obtained over a period of decades from retail antique stores in the metro Manila area. In every case, these objects are supposed to have been buried for centuries and only recently unearthed as a result of modern activity such as road, irrigation and other construction projects, landslides and erosion, and, as reported by Estrella (2018), pervasive speculative grave digging for antique gold jewelry, fueled by the well-publicized discovery of buried troves of hand-worked gold in the early 1980s. Speculation about the probable period during which specific ceramic vessels were made is the result, in each case, of a considered assessment by the senior author, based on the scholarly literature associated with these types of ceramics. Although the archeological context of the objects analyzed in the study is not documented, their attribution, including the municipal or provincial location of recovery, was provided by well-established, reputable dealers.

RESULTS

We initially examined the fluorescence of three ceramic vessels recovered from Northeastern Mindanao, in the Southern Philippine archipelago. All have similar predominantly white glazing with a primary darkly colored crackle (iron wire) and a finer secondary crackle (golden thread). Two of the vessels are shown in Figure 1; both are conical bowls of a typical Song Dynasty shape for drinking wine or tea. The density of the crackle differs between the two. The bowl in Figure 1A is more sparsely crackled than the bowl in Figure 1B. Also, the ratio of the secondary crackle differs, being more dense in the bowl in Figure 1B.

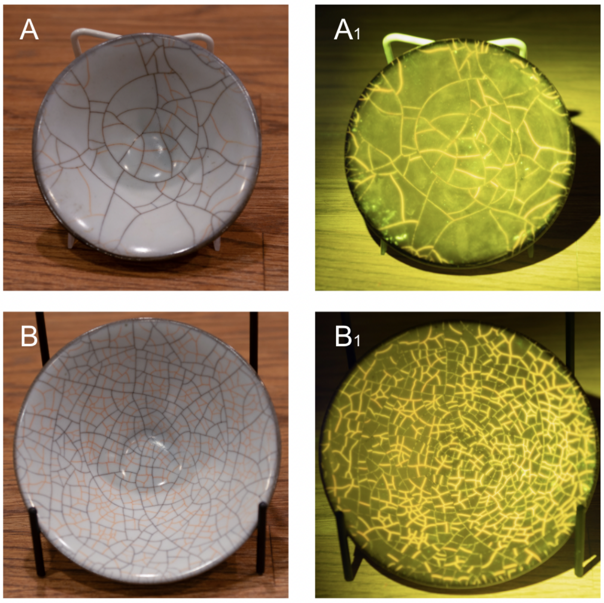

Figure 1: Northern Song bowls with gold thread iron wire glazes. Both are photographed under visible and fluorescent light. **A**: Bowl with less dense crackle pattern (D:13.0 cm). **B**: Bowl with denser crackle pattern (D:14.4 cm). *Private Collection.*

When photographed under blue light illumination using a yellow filter (see Experimental Procedures section above), the vessels both reveal a bright yellow fluorescence in which the primary iron wire crackle is less prominent than the secondary golden crackle (Figure 1, A1 and B1). Although the golden thread crackle is equally intense in both vessels, the iron wire crackle is noticeably less prominent in the vessel in Figure 1B. This suggests that the chemical composition of the golden thread crackle is the same in the two cases, but that the two iron wire crackles have some compositional difference or that there was a minor difference in the kiln firing regime or in positioning within the kiln. Further examination of the crackle composition may be possible with focused micro x-ray fluorescence spectrometry or physical sampling of the ceramic material, although the latter technique would be necessarily, and undesirably destructive.

The Song Dynasty had a strong antiquarian interest triggered in part by the unearthing of ancient bronze ritual vessels made over 2,000 years earlier in the Shang dynasty (Sena 2019). Ceramic copies of these recovered bronzes were commissioned and distributed by the Song celestial court for ritual purposes. One of the distinctive ancient bronze forms reproduced by the official court kilns is a ritual wine vessel called a hu (Christie's 2016). Court records of the Song Dynasty document that, in 1007 CE, a gift of ritual vessels was made to delegates of a tribute mission from a kingdom in the Philippines which the Chinese called Puduan; Yang, in his 2021 annotated translation of these records, states that this location "is generally identified as the Rajahnate of Butuan on Mindanao." A number of ceramic ritual vessels have been unearthed from dealer-reported locations in the Southeastern Philippine archipelago. A significant fraction of these pieces have seals that provide information about their manufacturing provenance.

A ceramic hu sourced from the Southeastern Philippines (Figure 2A) has the same distinctive glaze characteristics of the conical bowls shown in Figure 1, and the Chinese characters contained in its base seal, shown in Figure 3A, indicates that it was made in 1106 CE at the official kiln in the Northern Song capital city, Kaifeng.

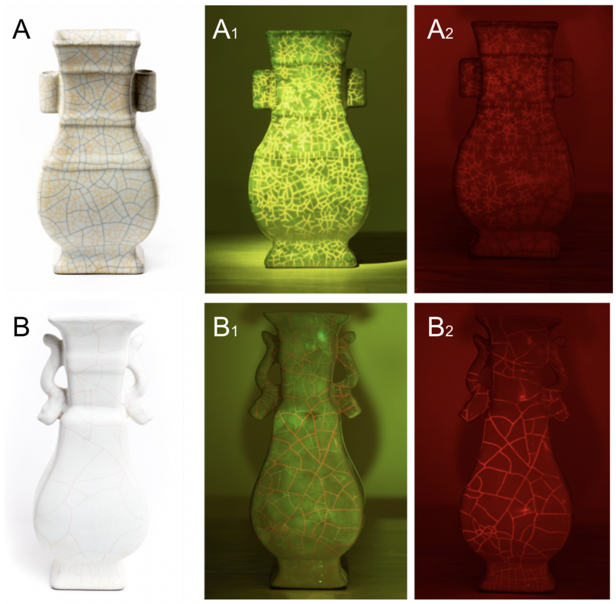

Figure 2: Ritual vessels with gold thread iron wire glazes, photographed under visible and fluorescent lighting. **A**: Northern Song hu (H:19.6 cm). **B**: Southern Song hu (H:23.2 cm). *Private Collection.*

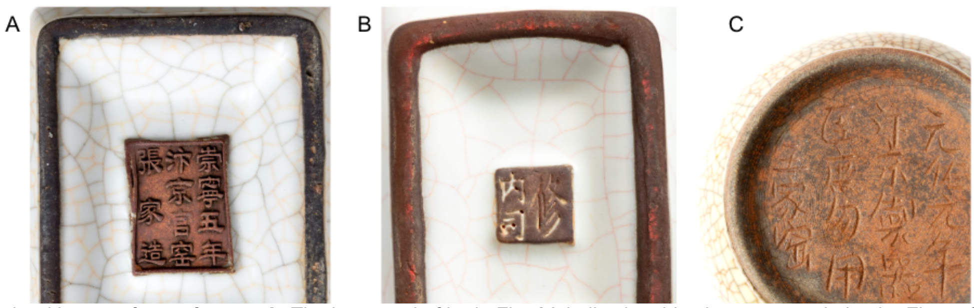

Figure 3: Base seals with year of manufacture. **A**: The base seal of hu in Fig. 2A indicating this piece was made by the Zhang family at the Bianjing (Kaifeng) official kiln in the 5th year of Chongning, Emperor Huizong's third reign name (1106 CE). **B**: The base seal of hu in Fig. 2B indicates Palace Maintenance Office (Xiuneisi), which is widely interpreted as a mark of the first official kiln in Zhejiang, the Southern Song capital. C: The base seal of a brown thread iron wire vase (see Discussion section) indicating it was made in Bianjing for official use only, by the Wang family, in the first year of Emperor Zhezong's reign name Yuanyou (1086 CE).

The Northern Song dynasty fell in 1126, merely 20 years after this hu was made, when Kaifeng was captured by the Jurchen Tartars. One of the Northern Song royal princes managed to escape, while the remaining members of the royal family were incarcerated and brought to the Jurchen capital. After the calamitous fall of Kaifeng, the Song capital was reestablished to the south in Hangzhou, near the mouth of the Yangtze River. The newly formed Southern Song dynasty court established new official kilns that attempted to recreate the sophisticated ceramic technology that characterized the kilns of the Northern Song dynasty. Among the ceramics obtained in the Philippines is a ceramic hu (Figure 2B), with a Chinese character seal on its base indicating that it was made by the first official kiln of the Southern Song dynasty (see Figure 3B). Together, these ceramic ritual vessels suggest that tribute and/or trade missions continued from Puduan beyond the fall of the Northern Song Dynasty.

The two hu-form ritual vessels were also exposed to incident light at the green wavelength and photographed using a red filter. The Northern Song vessel showed weaker fluorescence from the gold thread (Figure $2A_2$) and the primary iron wire crackle was not detectable. In contrast, the primary crackle of the Southern Song hu had an intense red fluorescence, but the secondary crackle was not detectable under these conditions (Figure $2B_2$). These results uncover significant differences between the crackle of the Northern and Southern Song ritual vessels. A closer view of both pieces is shown in Figure 4.

We have also analyzed other types of golden thread, iron wire crackled vessels that we believe date from the Northern Song dynasty. One of these vessels, a double fish wine bottle shown in Figure 5D, has a highly distinctive shape first popular in the Tang Dynasty. Several similar double fish bottles in different glazes and styles are reported to have been recovered from locations in the Southeastern Philippines (Figure 5). These are

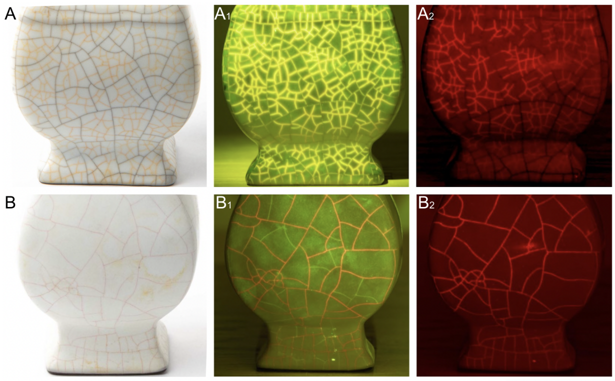

Figure 4: Closeups of ritual vessels with gold thread iron wire glazes, photographed under visible and fluorescent lighting. **A**: Northern Song hu (H:19.6 cm). **B**: Southern Song hu (H:23.2 cm). *Private Collection.*

products of the Changsha (5A) and Xing (5B) kilns of the late Tang Dynasty, and the Northern Song Jun kiln (5C).

Of the four double fish wine bottles, only the golden thread, iron wire double fish bottle exhibited fluorescence when lit with the tested wavelengths (Figure 6). Although the background glaze color is different (light gray vs. the white of the pieces presented above) and the secondary crackle has a different, web-like tessellation pattern, the double fish bottle shows the same bright yellow fluorescence as the vessels shown in Figures 1 and 2. However, the strong iron wire pattern of the double fish bottle's primary crackle is barely visible under the fluorescence conditions: it is not readily distinguished from the background glaze. This is an important difference between this piece and the golden thread, iron wire glazing of the conical bowls and Northern Song hu (in Figure 1 and 2A).

Figure 5: Double fish wine bottles recovered in the Philippines. **A**: Changsha kiln style (H:21.6 cm) , **B**: Xing kiln style (H:22.2 cm), **C**: An unusual Jun kiln style (H:26.0 cm), **D**: Golden Thread Iron Wire Style (H:26.3 cm). *Private Collection.*

Wine bottles C and D, likely from the Northern Song period, lack the 4 strap attachment lugs characteristic of the Tang bottles. This could reflect a change in social customs. During the Tang Dynasty, an evening curfew was imposed, but in the Northern Song period, people were allowed out at night in Kaifeng, and the equivalent of wine bars apparently flourished (de Pee, 2022). Perhaps a 'dine out' culture emerged leading to the strap attachment lugs being phased out of this ceramic form?

Figure 6: Northern Song golden thread iron wire double fish wine bottle, shown under visible and fluorescent lighting (H:26.3 cm). *Private Collection.*

Other Philippine-discovered pieces that we examined exhibited variations on the gold thread, iron wire crackle pattern. A Ge ware-like floral dish (Figure 7) found in the Southeastern Philippines has a light gray base glaze similar to the double fish wine bottle. It also exhibited a bright yellow fluorescence from the golden thread secondary crackle, but, like the double fish bottle, it did not exhibit fluorescence from the primary crackle pattern. A zun-style vase that exhibits an exemplary golden thread and iron wire pattern, but on a tan background glaze, did not fluoresce under the blue or the green lighting conditions. Another zun-style vase with two decorative handles and what is better described as a brown thread, iron wire crackle pattern displayed fluorescence similar to the conical bowls and similarly glazed hu under blue light conditions, but did not fluoresce under the green lighting conditions. These pieces are presented in Figure 8, as Group III and IV respectively, and the characteristics of five identified groups are described in more detail in Table 1 and the discussion section below. Most of the pieces presented have clear technical connections, discernible through a combination of visible and fluorescence inducing light, to the conical bowls and the hu attributed to the Northern Song period in accordance with the hu's base seal; in contrast, the Southern Song hu seems to represent an unsuccessful attempt at reproducing the two-tier golden thread iron wire crackle glaze technology of the Northern Song kilns.

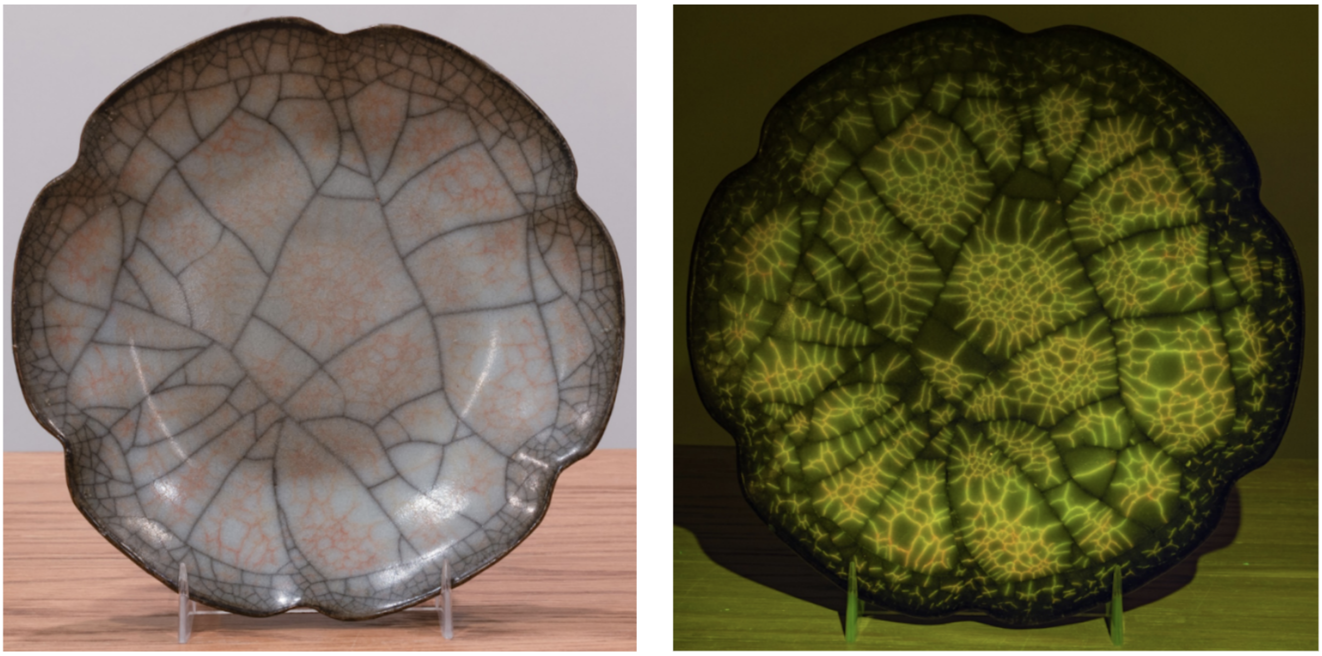

Figure 7: Golden thread iron wire dish under visible and fluorescent lighting. Floral dish with gray background glaze (D:20.0 cm). *Private Collection.*

Table 1: Characteristics of 5 groups of Philippine-recovered Song ceramics with secondary crackle.

					Crackle Fluorescence			
Group [general assignment]	**Visible Light**	**Base Glaze and Rim Effect**	**Primary Crackle**	**Secondary Crackle**	**Blue Light, Yellow Filter**	**Green Light, Red Filter**	**Secondary Crackle Tessellation**	**Base Seal Dating** (***Figure* #'s**)
Group I White with Iron Wire Golden Thread [Northern Song Ge ware]		White and Ivory White, Purple-Gray Rim	Dark Gray Iron Wire	Golden Thread	**Primary = yellow, sharp** **Secondary = brighter yellow, sharp**	Primary = not visible **Secondary = red, sharp**	Street-like Network	1106 CE (*1, 2A, 3A, 4A, 8, 9*)
Group II Light Gray with Iron Wire Golden Thread [Northern Song Ge-like ware]		Light Gray, Purple-Gray Rim	Dark Gray Iron Wire	Reddish-colored Golden Thread	Primary = minimally visible **Secondary = brighter yellow, sharp**	Primary = not visible **Secondary = red, blurry**	Web-like Network	n/a (*5D, 6, 7, 8, 9*)
Group III Tan with Iron Wire Golden Thread, No Fluorescence [Northern Song Ge-like ware]		Tan, Minimal Difference at Rim	Dark Gray Iron Wire	Dark Golden Thread	Primary = not visible Secondary = not visible	Primary = not visible Secondary = not visible	Street-like Network	n/a (*8, 9*)
Group IV Off-white with Iron Wire Brown Thread, Has Fluorescence [Northern Song Ge-like ware]		Off-white	Dark Gray Iron Wire	Brown Thread	**Primary = yellow** **Secondary = brighter yellow**	Primary = not visible Secondary = not visible	Street and Web-like Network	1086 CE (*3C, 8, 9*)
Group V White with Red Wire Invisible Thread [Southern Song guan ware]		White, No Difference at Rim	Medium Red	Clear Thread, Barely Perceptible	**Primary = orange, sharp** **Secondary = yellow green, sharp**	**Primary = red, sharp** Secondary = not visible	Sparse Network	Hangzhou kiln, post 1126 CE (*2B, 3B, 4B, 8, 9*)

DISCUSSION

We have applied a novel research tool, widely used by molecular biologists to detect fluorescently labeled proteins, to examine Chinese ceramics with crackle glazes that have been informally recovered in the Southeastern Philippine Archipelago. Our analysis has revealed significant differences between the composition of crackle in the vessels; the crackle distinctions that we observe align generally with established visual differentiations between ceramic products of Northern Song and Southern Song kilns. The fluorescence technique, which uses a hand-held light source and appropriate protective eyeglasses or camera filters, is commercially available, inexpensive, simple to use, and should be easily adaptable to archaeological field work, enabling an onsite examination of similarly glazed ceramics or sherds. Our study focused on the fluorescent characteristics of a small defined set of related ceramics with two-tiered crackle glazes; a more comprehensive study, including the historical and cultural context of these ceramics, is expected to be the subject of a future report. Here we present provisional conclusions from the present analysis.

As is shown in Figure 9, each of the five groups of distinctive glazing styles in Table 1 is represented by at least two ceramic vessels. The differentiation into groups is based solely on differences in florescence in the primary and secondary crackle and the presence of similar Chinese character-based seals on the bases (Groups I, IV and V). Within the table, we also include a provisional assignment of general provenance. The conventional method for assigning provenance is to compare the vessels being analyzed with standard examples in the ceramics literature. However, this is not possible for the material that is the focus of this study.

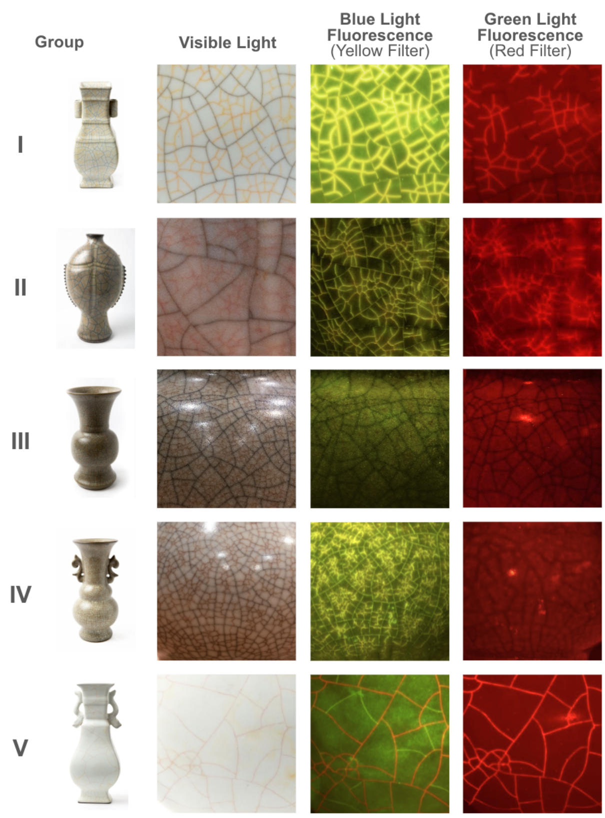

Figure 8: Examples of the Five Groups of Song Ceramics with Secondary Crackle. For each group, a closeup of visible and fluorescence is shown for an area approximately 5 cm by 5 cm.

There are no directly comparable intact vessels in the literature that can be used to reliably assign a provenance for each group. There is a complex set of historical reasons why this material recovered from the Philippines is unique, and these will be discussed in detail in a future article. Briefly, because of the Jurchen invasion and the dramatic fall of the Northern Song Capital in the early 12th century, there is very little authenticated material from this period that survived in China. Archaeological work has uncovered sherds at different kiln sites, and it is hoped that the study of the Philippine material can be correlated with the ongoing discoveries in China; indeed, the technology that we describe herein should greatly facilitate such a comparison.

In the absence of authenticated material on which a provenance assignment can be confidently based, the tentative assignment we have provided for each of the groups is based on several factors. The most important source for the assignments are the seals that are present on the bases of ceramics in some of the groups; these seals describe a reign date or a kiln site (or in some cases both). A second important input is the historical literature. The Song Dynasty court promoted traditional rituals and commissioned ceramic vessels for use in court-sanctioned official events (Bao, 2023). Many ceramics with crackle patterns were made for such rituals, and for other uses by the court. As documented in official Song court records (Yang 2021), these were on occasion given as gifts to official delegates of tribute or trade missions from foreign lands, including trade missions from a land referred to as Puduan in the Philippine archipelago.

Our results suggest that all five of the distinct glazing groups achieve either a visible two-tier iron wire and golden or brown crackle effect, or a fluorescing double crackle effect of some kind, or both. Group I (Figures 1, 2A) has a white or ivory-white glaze with a clear primary iron wire crackle and a contrasting golden thread secondary crackle; this double crackle pattern resembles a modern urban street network of arterial and local roads, represented by the iron wire and the golden thread crackles, respectively. Given the quality of the golden thread, iron wire glazing effect, combined with the base seal in one vessel of this type that specifically references manufacture by the Zhang family, Kaifeng official kiln, and a dating to 1106 CE, we suggest that Group I best aligns with classical descriptions of Ge ware. Figures 1, 2, and 9 show examples of the diverse ceramic forms in this group. There are a number of other crackle glazed ceramics (Groups II, III, and IV) with both a primary and secondary crackle pattern that appear related, but which differ systematically, and arguably aesthetically, from the core Group I vessels. To differentiate them from Group I, we will refer to these as Ge-like ware.

Group II (Figures 6 and 7), the first of the Ge-like groups, has a light gray glaze, an iron wire primary crackle with a secondary crackle that is denser, web-like, reddish in color, and somewhat blurry under normal illumination. The web-like golden thread crackle pattern may be that which Chinese ceramic connoisseurs have historically referred to as a “fish roe” pattern. This secondary pattern’s fluorescence is sharper under blue light illumination than under normal or green light illumination. The double fish wine bottle in Figure 6 and the floral dish in Figure 7 are both examples of this group.

Group III has a tan glaze with dark gray primary crackle and a darker golden thread secondary crackle, which emits a faint, barely detectable fluorescence. Group IV has a primary iron wire crackle and a brown, secondary crackle whose tessellation exhibits both street-like and web-like patterns. Both primary and secondary crackle fluoresce only under the blue lighting conditions of the experiments.

Group V is represented by the vessel shown in Figures 2B and 3B, and an additional vessel shown in Figure 9, and appears to have only a primary, light red crackle using normal lighting conditions. This crackle fluoresces orange under blue light and deep red under green incident light. Group V does have a secondary and infrequent clear crackle that is barely detectable to the naked eye. This secondary crackle is seen as sharp green lines under the blue light illumination. With these differences, Group V vessels fall short of assignment as Ge-like ware, but seem properly regarded as a rare type of Southern Song Guan (or official) ware. They were likely made with rudimentary knowledge of the kiln protocol necessary to achieve a colored primary crackle and a secondary (though barely visible) crackle. Further support for a loose connection to Ge and Ge-like ware arises from the white background glaze that fluoresces under blue light conditions, that pieces in Group I and Group 5 share.

Figure 9: A sampling of Philippine-recovered forms that exhibit the characteristics of the five described groups of Song Ceramics with secondary crackle (images not shown to exact scale). *Private Collection.*

One of the most poignant narratives of Chinese history may provide a more meaningful cultural context for the technical differences that are uncovered by fluorescence analysis. In the early 12th century, the Northern Song celestial court presided over a period of unprecedented economic prosperity and artistic achievement. The imperial capital, Kaifeng, was possibly the most refined and luxurious urban cultural center in the world at the time the golden thread, iron wire vessels in Figures 1 and 2A were likely produced. A variety of styles were crafted spanning at least the first 4 groups, described here with the aid of fluorescence technology and often imitating Shang dynasty bronze forms, presumably for the Northern Song court. Sophisticated ceramic vessels such as the double fish wine vessel shown and described in Figure 6, were part of life in the capital city.

We have earlier proposed, as evidenced by the official Song court records and ceramic recoveries in the Southeastern Philippine that apparently derive from the Northern Song dynasty, that there were regular maritime links between China and an Austronesian maritime kingdom in the Philippine archipelago (the Kalaga Putuan Crescent, or KPC kingdom). Presumably, most of the ceramics with crackle glazes found in the Southeastern Philippine Archipelago were given to delegates of tribute or trade missions in exchange for the high-end goods they presented to the celestial court (Olivera et al. 2024).

As mentioned above, in 1126, disaster struck. Kaifeng fell to the Jurchens, a nomadic tribe from the northwest. The entire Northern Song imperial court was captured and the city was looted and destroyed over a number of months. The one prince that managed to escape fled to the south where a new capital was sited in Hangzhou (Yang 2023), over 900 km to the southeast. The re-establishment of the Song court in Hangzhou marked the beginning of the Southern Song period. The literature and poetry of the Southern Song is suffused with the deep sadness felt over the loss of Kaifeng and its cultural accomplishments (Tregear 1982). An immediate effort was made to replicate the Northern Song art and culture in the new capital.

One can speculate that the vessels in Group V may have been an attempt to recapitulate the brilliance of the Northern Song ceramic artistry, with some knowledge of the materials and techniques that were involved. The attractive ceramic vessels with an impressive pure white base glaze and a visible single, light red crackle may have been results of such attempts. Importantly, a secondary, fluorescing crackle is present in these pieces, observed only under special illumination. The base glaze and the primary and secondary fluorescing glazes suggest that similar specialized glaze materials and firing processes may have been employed in the pursuit of replicating the golden thread, iron-wire effect. The pieces analyzed in this study do not support the achievement of a satisfactory replication by the Southern Song artisans. The desired primary, dark iron wire effect is instead a light red color that provides far less visual contrast. The secondary crackle is not golden, nor is it even visible to the naked eye. Consistent with this interpretation, the fluorescence results on the crackles are distinctly different.

While additional variations on the golden thread, iron wire theme (including many standalone iron wire crackle styles) continued to be produced by artisans during the Southern Song and later periods, these mostly fell short of achieving the brilliant golden thread, iron wire glazing attributed to the late Northern Song era. One can speculate that this failure was due to lost access to some combination of specific minerals and other glaze materials, artisan expertise, and the specific designs of the original Kaifeng-area kilns. Sadly, one consequence of the Jurchen sacking of Kaifeng was that the production of golden thread, iron wire ceramics, one of the highest forms ever achieved in the ceramics medium, was forever lost. Most of what we now know as Ge ware ceramics are presumed to have been destroyed en masse in Kaifeng when it was looted by the victorious Jurchens in 1126.

The reputation of the golden thread, iron wire glaze achieved by the elder Zhang brother apparently only grew in stature with time. The Northern Song court does not appear to have distinguished Ge ware and Ge-like ware as a separate category of ceramics. The base inscriptions that are documented in Figure 3 suggest that both Group I and Group IV ceramics, as defined by the analysis above, should be regarded as Guan ware, since both indicate their manufacture at the official kilns in Kaifeng. A distinction, however, appears to have been made at the time of manufacture by identifying the potters: the Group I ceramics were made by the family Zhang, and the Group IV ceramics were made by the family Wang. If we regard both (and possibly Groups II and III as well) as Guan ware, and consider that the first known reference to the term now known as Ge ware was not recorded until over 200 years after the fall of Kaifeng, we can perhaps better understand how the identities of Ge and Guan ware have been so confused in the ceramic literature.

The golden thread, iron wire glaze pattern attributed to the elder Zhang brother in Kaifeng appears to have been so desired that its replication was a primary initial goal once the first official kiln of the Southern Song dynasty was established. The early products of these efforts (e.g., the Group V ceramics) are perhaps best categorized as a subset of Southern Song Guan ware. However, these attempts likely did not meet the expectations of the survivors that had moved from the Kaifeng court to Hangzhou. The attempts to replicate the elder Zhang brother's achievement appear to have continued, with increasing but not full success, through the Southern Song and into the following Yuan dynasty. Defined after its manufacturing period, based on memories of Ge ware’s ideal form, but with a paucity or complete absence of surviving genuine examples, the scholarly literature on Ge ware in the centuries after the original ceramics produced by the family Zhang in the Kaifeng official kilns had been lost, has been largely shaped by the variety of replication attempts that evolved over time.

The definition of the Ge ware term so long after its production had ceased, the lack of recognized surviving pieces, and the diversity of Guan or official kiln styles combined to ensure that achieving consensus on Ge and Guan ware would be elusive. Because the original kiln sites at Kaifeng remain undiscovered, buried somewhere under mud deposited by a millennium of annual flooding by the Yellow River, the identity of both Ge and Northern Guan ware is unlikely to be verified through a systematic archaeological examination in the immediate vicinity of their manufacturing kilns. If new discoveries are made, or in the absence of new discoveries, it is hoped that the techniques and observations presented here can contribute to a foundation for furthering our understanding of Ge and Guan ware, working with the limited available evidence.

The variety of Chinese ceramics recovered in the Philippines are useful time markers for further elucidating precolonial history and, more specifically, maritime trade connections between China, the Philippines and beyond. Application of established archaeological technology and methods, in the field and laboratory, is needed to more rigorously investigate the historic trade linkage, between Song and other Chinese dynasties and the Southeastern Philippines that is suggested by the antiquarian evidence. The unique examples of pieces shown in this article, believed to span the late Northern and early Southern Song dynastic periods, are also of potential importance in expanding and deepening our current knowledge of Chinese ceramics themselves. And, as the fluorescence analysis methods in this article demonstrate, there appears to be fertile, interdisciplinary opportunities for developing techniques that better describe and classify Chinese ceramics and the ceramic technology of a thousand years ago. These new approaches to ceramics analysis should be considered as additional scientific exploration is hopefully planned, funded, and executed in the near future.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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