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Celadon Glazes

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Abstract: Celadon (called *"seiji"* in Japanese) is a reduction-fired glazed ware originated in China during the Song Dynasty (960–1270), thereafter spread quickly across Asia and had been widely used is in the Far East between the 10th and 14th centuries. In ancient China, the ashes of cedar wood, cherry tree, ferns, plants were also included in the glaze batches. Celadon was named in the 18th century by green cloths of a shepherd named Celadon. The colours of celadon glazes vary from grey–green to yellow–green. Iron, chromium, tin, titanium and nickel compounds in the composition of the glaze are effective on colour, mainly under reduction. Celadon glazed ceramics are generally formed by the reduction of iron oxide doped glazes to the surfaces of reinforced clays substrates containing iron during firing. In this paper the journey of celadon glazes from past to present time is given.

Keywords: Celadon, glaze, history, application, objects.

Seladon Sırları

Öz: Seladon (Japonca'da "*seiji*" olarak adlandırılır), Song Hanedanlığı döneminde (960–1270) Çin'de ortaya çıkmış, daha sonra hızla Asya'ya yayılmış, 10. ve 14. yüzyıllar arasında Uzakdoğu'da yaygın bir biçimde uygulanmıştır. Eski Çin'de sır harmanın içerisine sedir ağacı, kiraz ağacı, eğrelti otu gibi bitkilerin külleri de katılmıştır. Adını, 18. yüzyılda Seladon adlı bir çobanın yeşil renkli giysilerinden almıştır. Sarı–yeşilden gri–yeşile değişen bir yelpazesi vardır. Renk açısından etkin parametreler; pişirim atmosferinin indirgenliği, sırın bileşiminde yer alan Fe, Cr, Sn, Ti ve Ni bileşikleridir. Seladon sırlı seramikler, genellikle demir içeren pekişmiş kil altlık yüzeylerine yine demir oksit katkılı sırların, pişirim sırasında fırın ortamında indirgenmesi ile elde edilmektedirler. Bu makalede seladon sırlarının geçmişten günümüze yansımaları anlatılmıştır.

Anahtar kelimeler: Seladon, sır, tarihçe, uygulama, örnekler.

1. Introduction

Celadon is defined as a spesifical name for pottery referring the wares covered by glazes in the jade green colour and a unique transparent type glaze, often having small cracks. It has been originated in China, and later its production spread to other Asian regions (Japan, Korea and Thailand) [1–3]. For centuries, the Chinese Imperial court have highly preferred celadon wares. In Korea they were made in the Goryeo Dynasty and are still accepted as the classical Korean porcelains.

Modern celadons usually have their high glossiness thanks to high levels of alkali oxides often causing *crazing* problem, which could be overcome by replacing some of Na_2O with MgO having comparingly lower thermal expansion or CaO and raising SiO_2 [4].

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Reduction fired glaze with green or blue–green colour has been coloured by iron oxide. The modern celadons are known to be glossy and transparent ones whereas the ancient ones were waxier and opaque. Blue celadon typically has high ratio of sodium/potassium, high silica, little amount of Fe, and low Ti. Some claim that small amount of TiO_2 and/or $BaCO_3$ will facilitate the achievement of blue colour [4].

Figure 1. Longquan celadon from Zhejiang, 13th century [5]

2. Types of Ceramic Glazes

Ceramic Glazes Fired in Neutral Furnace Atmosphere

Matte Glazes: The surface of the ceramic product is covered with a matte glaze, and it can be defined as glaze which is generally covering the features, and increases the quality of the piece.
Crackle Glazes: The glaze is defined by a cracked network.

Collected Glazes: They are drawn in the form of veins and islets during firing, and glazes are collected on the surface in such a way that the underlying glaze or mud is visible.

Fluent Glazes: As the name, flowing glazes are artistic glazes that flow more than normal during firing.

Crystal Glazes: A variety of factors plays a role in the emergence of crystallization. At the beginning of these factors, the fluidity of the glaze is higher than it is. The crystals of each substance show different formation and growth trends.

Ceramic Glazes Fired in Reductive Furnace Atmosphere

The reduction furnace atmosphere is obtained by providing carbon monoxide in the furnace. There are 3 types of glazes which are Chinese red, lustre and celadon.

Chinese Red Glazes: For the first time the Chinese were applied them onto porcelain. A red colour is obtained with copper oxide in the reducing atmosphere.

Lustre Glazes: The pearlescent, metallic and wavy coloured appearances are obtained on the surfaces by reduction. 10–20 % silver chloride or silver nitrate is added by incorporating a transparent or coloured glaze.

Celadon Glazes: Between the 10th and 14th centuries, this glaze was very much applied in the Far East. The colours of celadon glazes vary from grey to yellow–green [6].

3. History

Bright tricolour lead glazes, luminous celadons and dazzling porcelains speak to the taste and power of the Chinese imperial court, long before there were synthetic dyes and plastics, ceramic glazes offered artisans an unparalleled range of permanent colours and textures, which could be manipulated to satisfy a diversity of cultural demands. In most cultures, glazed ceramics were prestige goods–something that remained beyond the reach of common people because the necessary materials, know–how and manufacturing skill were often difficult to acquire. In 16 and 17th centuries Europe, monarchs collected Chinese porcelains so avidly that they sometimes risked bankrupting their treasuries. The European appetite for this “white gold” motivated prominent scientists to try to replicate porcelain during the early stages of the industrial revolution [7].

Thailand celadon production has been reported to continue developing from its early beginnings, which was 700 years ago, till the present time. “Celadon” was derived from two Sanskrit words: “sila” (so called “stone”) and “dhara” (with the meaning of “green”) [8] and is coming in many tones and styles, which have been found in shades of light and help the occurrences of green, blue–green, olive green, dark grey, green–yellow, honey yellow and brown colours [9].

Figure 2. Yuan Dynasty, Late 13th century, beginning of 14th century [10]

Figure 3. Celadon guan jar from the Ming Dynasty (Late 14th century–beginning of 15th century) [10]

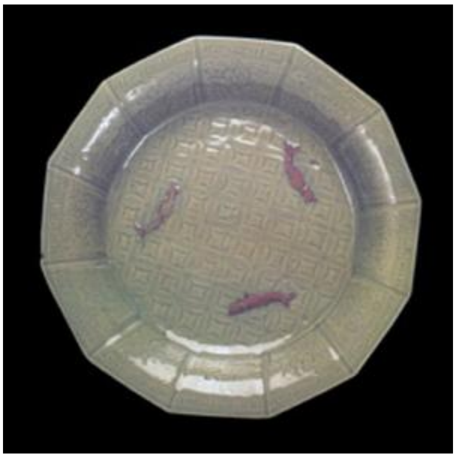

Figure 4. Celadon plate from Ming Dynasty, 15th century. In the middle, the relief fish patterns are in red because of being left unglazed [10]

Figure 5. Celadon basin from Yuan Dynasty, the first half of the 14th century [10]

Figure 6. Celadon plates, Ming Dynasty, the beginning of the 15th century [10]

Yue ware known as the noteworthy ceramic wares, was first made in the Han Dynasty (206–220) of China, being the earliest celadon; Its glaze employed was brownish green or olive in colour [**11**].

Figure 7. Longquan celadon wine jar and cover, Song Dynasty, 12th century [**11**]

Figure 8. Korean bottle with a celadon glaze and inlaid decoration *named as mishima*,13th century **[**11**]**

The inlaid decoration beneath the glaze is the major determining factor between Korean celadons and Chinese ones.

Figure 9. *Punch'ŏng* stoneware, Korea, 15–16th centuries [11]

Striking point of Thai celadons which were influenced by Chinese wares is that they have a translucent glaze being generally greyish green in colour and often crackled on a greyish white body.
In Japan, during the Kamakura Period (1192–1333) Yue ware importation and the respect given to Korean celadon resulted in an imitative production near Seto of Aichi Prefecture. Old Seto is the most important ware of this period, classified as a true celadon being often oxidized to what the Japanese call a "dead leaf" colour [11].

4. Types of Celadon Glazes

4.1. Chinese celadons

It is known that during Eastern Han Dynasty the earliest celadons were thought to be produced in Yue kilns of Zhejiang. Since then, this kind of product became the major ceramic product of China for a long period of time [12]. The tomb excavations in Zhejiang pieces with a celadon ceramic glaze belonging to Eastern Han Dynasty (25–220) have been recovered and became well known during the Three Kingdoms (220–265) [13]. The earliest main type of celadon was Yue wares, named as northern celadons. During the Northern Song Longquan celadon wares have been first produced, but flourished under the rule of Southern Song [14–16]. They were the glazes in olive green, blue–green and bluish colours and the relevant substrates increasingly have possessed high contents of alkali and silica, resembling later porcelain wares being produced at Jingdezhen and Dehua [17].

Figure 10. Longquan and Dapu kiln sites

Considerable amounts of Longquan celadon have been found to be exported throughout eastern and south–eastern Asia as well as the Middle East in 13–15th centuries [18]. After about 1500, the production quality and quantity were much reduced, although there have been some antiquarian revivals of celadon glazes on Jingdezhen porcelain in later centuries [19].

Figure 11. Yaozhou ware, 10th century [5].

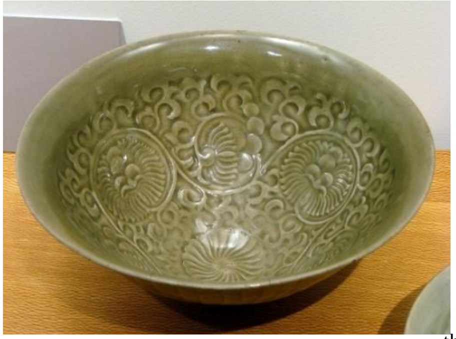

Figure 12. Yaozhou ware, Song Dynasty, 10–11th centuries [5]

Figure 13. Flower vase with iron brown spots, Yuan Dynasty, 13–14th centuries [5]

Figure 14. Longquan celadon, Ming Dynasty, 14–15th centuries [5]

4.2. Korean celadons

After being produced in China, as a result of increased contact with the Song Dynasty, across Asia and in Korea celadon wares quickly gained popularity specifically from the 9th century [20]. Korean wares were initially rather crude, however, when reached to 12th century they were even finer than those Chinese similar ones with their soft pale grey–green colour. The green coloured celadon is achieved by firing the clay substrate in a furnace under reduction with low level of iron oxide (*cheolhwa*) containing glaze. Firing temperatures were around 1150 °C [21]. When the Mongolian invaded the peninsula in the 13th century the systematic destruction of workshops was made bringing the production of celadons to a halt. One of the main characteristical properties seen in Korean vases is being nearly always in the tall form elegantly curved while other pieces such as those indicating the figures of animals and people are intricately carved. Vessels were decorated with low or high relief designs, especially floral patterns with the lotus leaf and flower, peony and chrysanthemum flowers and birds [22].

Figure 15. A celadon incense burner with kingfisher glaze, 12th century, Korea [5]

The objects, which were left as undecorated, frequently have engraved simple linear designs worked on them while others have more intricate brown, black, red and white clay inlays in a technique named as “Sanggam” that is unique to Korea [23]. Adding a dark red colour to pick out designs or used for outlines became quite common in the later period of Korean celadons, being possible by employing a copper underglaze [24]. The museums of Haegang Ceramics and the Goryeo Celadon are two regional museums focusing on Korean green ware [25].

Figure 16. Celadon ceramics purchased by Carles after William R. Carles, Life in Corea [26]

Figure 17. A celadon gourd–shaped ewer decorated with lotus petals. 13th century, Goryeo Dynasty, Korea [24]

Figure 18. A celadon fish–dragon ewer, 12th century, Korea [24]

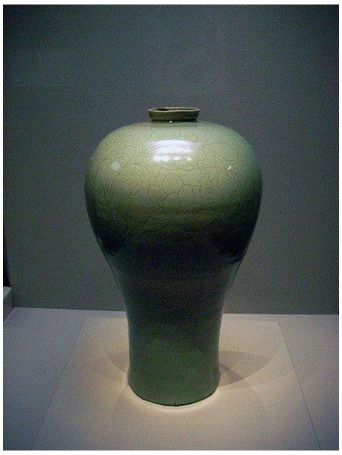

Figure 19. A *maebyeong* celadon vase with lotus decoration, 12th century, Goryeo Dynasty, Korea [24]

4.3. Japanese celadons

In Japan Chinese characters for green ware is said *seiji* (青磁), which was introduced during the Sung Dynasty from China and via Korea [27]. Longquan style production has been centred around Arita, Saga and in the Saga Domain [28]. Green ware is also closed entwined with *hakuji* white porcelain. The glaze with mixed icy, bluish white colours is named *seihakuji* porcelain [20]. In China, this glaze type is known as Qingbai ware [29]. Artists from the mid to late Showa Era were Shimizu Uichi, Suzuki Osamu, Miura Koheiji [27] Suzuki Sansei, Fukami Sueharu, and Takenaka Ko.

Figure 20. Kyō ware vase, 19th century [5]

Figure 21. Miyanaga Tozan's (1868–1941) celadon vase [33]

Figure 22. Celadon glazed tea bowl known as "Bakohan" [34]

The artists are Masamichi Yoshikawa [30], Kawase Shinobu [21], Minegishi Seiko [31], Kubota Atsuko, Yagi Akira and Kato Tsubusa during the Heisei Era. Fukami Sueharu, Masamichi Yoshikawa and Kato Tsubusa also make abstract pieces [32].

4.4. Thai celadons

Thai ceramics have their own tradition in green ware production. Medieval Thai wares have initially been affected by Chinese green ware, however, Tai people developed their unique technique and style. One of the most famous furnaces of the Sukhothai Kingdom were at S(r)i

Satchanalai, around the districts of Si Satchanalai and Sawankhalok. Production started in the 13th century and continued until the 16th century and the art reached its peak in the 14th century [35].

Figure 23. Thai 14–15th centuries celadon glazed stoneware jarlet [23]

Figure 24. Handmade Thai glazed celadon vase, "jungle blooms" [36]

Figure 25. A rare Thai celadon ewer, 14–15th centuries, the spout in the form of a phoenix head, with ribbed body and translucent glaze, Sawankholok kiln [37]

The Japanese adopted celadon which was also mannered by the Koreans. It is specifically in the pale green colour obtained from the iron oxide present in the glaze (although it consists of much less than Tenmoku). Celadon is a hard glaze to be used, because of being in quite uneventful colour unless a special working condition is reached in the furnace like reduction [38].

Figure 26. A large Thai celadon bowl, 14th–16th centuries, covered in a glassy crackle glaze, moulded with geometric pattern, Si Satchanalai kiln [37]

5. Manufacturing of Celadon Glazes

The whole production steps can be summarized as below:

- Clay preparation for celadon production,
- Combining powdered clay with water in order to cleanse it and remove any remaining debris,
- After compression in the pug mill, exposing the clay to open air for a short time for allowing organic substances in the clay to assemble,
- Finely kneading the clay for removing air bubbles,
- Forming the clay with various forming processes,
- Allowing the product to dry naturally before being refined one more time,
- Hand–carving ornate details into the refined product,
- Biscuit firing the products at 800 ^{o}C for 7–8 hours to achieve a light–brown product,
- Inspecting the "biscuit" for fractures and other defects.
- Coating the product with a glaze prepared from rice paddy top–soil and laurel ash, before being dried, and glazing again to perfection and to eliminate air bubbles,
- Firing at 1260–1300 ^{o}C for 12 h and leaving to cool within the kiln for an additional 8–10 h before the kiln is opened [39].

"True celadon" at least requiring the furnace temperature of 1260 °C, a desired range of 1285 to 1305 °C, and firing under reduction, emerged at the beginning of the Northern Song Dynasty. Green colour was usually desired with the remembrance to Chinese jade, invariably accepted as the most valued material in Chinese culture [40]. Celadon glaze colour supplies yellow, tan, grey, grey–light–olive–blue–greens. It depends upon iron oxide level, and Fe^{2+} and Fe^{3+} concentrations affecting the glaze colour directly based upon the kiln atmosphere [41].

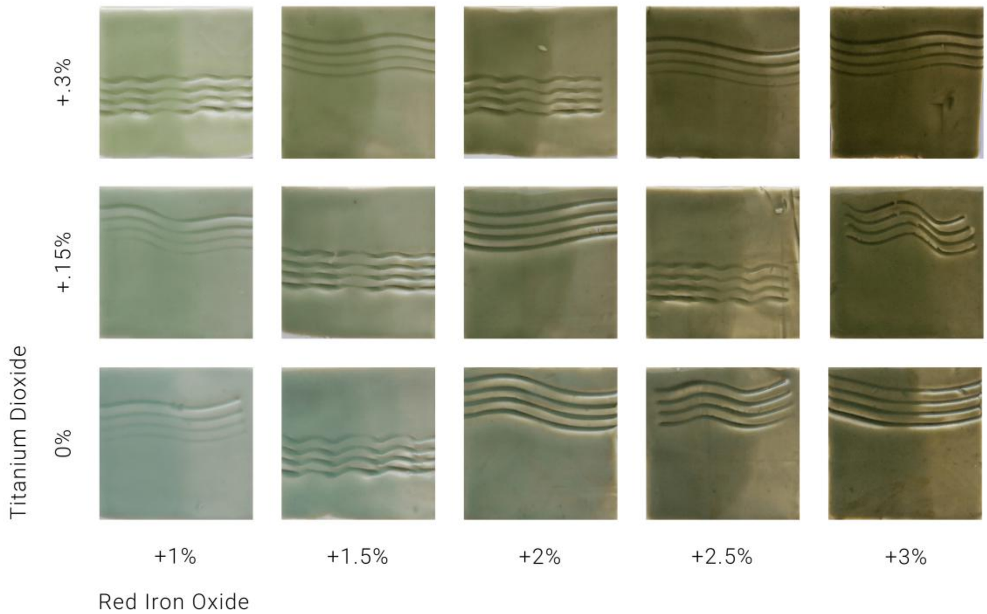

Figure 27. Red iron oxide and titanium dioxide additions to Pinnell Clear (Silica 35, potash feldspar 25, whiting 20, New Zealand halloysite 20) [42]

5.1. Recipes of different types of celadon glazes

In the traditional celadons, resultant colour is usually determined by the starting raw materials naturally consisting of Fe. Comparingly small levels of Ti, Mn, Cu and even Co can affect colour in significant ways. It can be said that Chinese ceramic's beauty is coming from the ancient potter's skills using domestic raw materials, and how the resulting aesthetic of each furnace's wares was in important part driven by the nature of those materials.

In one study the test mentioned below being a simple biaxial blend indicating the effect of Fe and Ti upon the base glaze colour was conducted. It is possible that further tests could be made by employing low levels of Mn, Cu and Co, besides varying the fluxing agents and SiO_2: Al_2O_3 ratio.

5.2. Ceramics Bible blue–green celadon

The kilns are very good at reducing. The colour is very deep, the surface glossy with small indents on the surface. There is a fair amount of large bubbles in the glaze melt but no crazing on Coleman Porcelain (crazed on stoneware oxidation firing) with great response to texture/lots of depth. The oxidation test lacks the indents on the surface but has very fine foggy bubbles. It is a pale yellow in oxidation [43].

Figure 28. Ceramics Bible blue–green celadon [43]

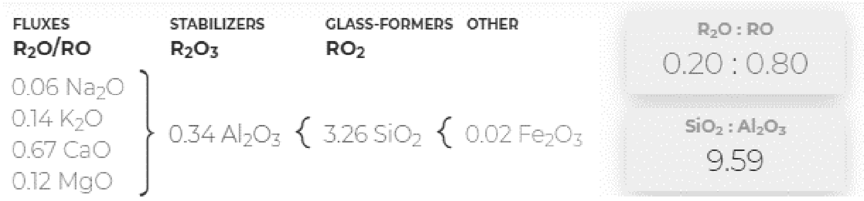

Figure 29. Chemical analysis of ceramics Bible blue–green celadon [43]

Table 1. Percent analysis of ceramics Bible blue–green celadon [44]

Material	Amt.	SiO_2	Al_2O_3	Na_2O	K_2O	MgO	CaO	P_2O_5	TiO_2	Fe_2O_3	LOI
Custer Feldspar	**40.00**	27.13	6.73	1.19	3.96		0.12			0.04	0.12
Silica	**25.00**	24.75									
Whiting	**20.00**						11.11				8.69
EPK	**10.00**	4.53	3.70	0.01	0.03	0.01	0.02	0.03	0.04	0.08	1.47
Amtalc-C98 Talc	**5.00**	2.65	0.01		0.01	1.46	0.17		0.00	0.02	0.59
Red iron oxide	**1.00**									0.94	0.05
Total	**101.00**	59.06	10.45	1.19	4.01	1.47	11.42	0.03	0.04	1.08	10.92
Adjusted Total (100%)		66.55	11.77	1.35	4.52	1.66	12.87	0.03	0.05	1.22	

5.3. Strontium Bible celadon base

Reformulated from bible celadon, using equal molar amounts of strontium. Colorants as tested in reduction 1 % RIO = blue w/tint of green, 1 % nickel carbonate = green grey [43].

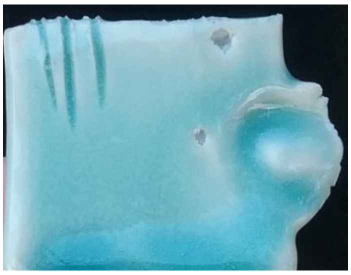

Figure 30. 1 % RIO, the barest hint of green, some sign of crazing [43]

Blue Celadon Recipes

Blue celadons require less than 1 % iron and the lowest possible amount of titanium, so low–titania kaolin like Grolleg and New Zealand halloysite are often used. These glazes should be fired in moderate to strong reduction. Additions of barium and tin have been indicated to improve glaze colour.

Figure 31. 1 % Nickel carbonate [43]

Green Celadon Recipes

Green celadons can be easily made by using a base clear recipe and adding 1–2 % iron oxide. The simplest example is the classic Leach 4321 with 2 % red iron oxide.

Figure 32. Chemical analysis of strontium bible celadon base [43]

Yellow Celadon Recipes

So–called “yellow” celadon are somewhat related to tea dust and other crystallizing iron glazes. David Leach yellow celadon will give a mustard colour in cone 9–10, but fire to a typical celadon at cone 12 [44].

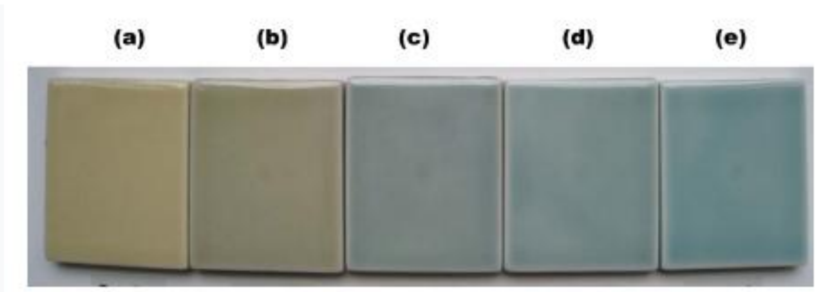

Figure 33. The colour change of celadon glazes on white porcelain heat–treated at 1300 °C at (a) 0, (b) 0.5, (c) 1, (d) 2, and (e) 4 % of CO [41]

Table 2. Percent Analysis of strontium Bible celadon base [43]

Material	Amt.	SiO_2	Al_2O_3	Na_2O	K_2O	MgO	CaO	SrO	P_2O_5	TiO_2	Fe_2O_3	LOI
Custer Feldspar	**36.40**	24.91	6.18	1.09	3.64		0.11				0.04	0.11
Strontium Carbonate	**27.30**							19.15				8.13
Silica	**22.70**	22.68										
EPK	**9.10**	4.16	3.40	0.01	0.03	0.01	0.02		0.02	0.03	0.07	1.35
Amtalc-C98 Talc	**4.60**	2.46	0.01		0.01	1.36	0.16			0.00	0.02	0.55
Total	**100.10**	54.20	9.59	1.10	3.68	1.37	0.29	19.15	0.02	0.04	0.13	10.13
Adjusted Total (100%)		60.52	10.71	1.22	4.11	1.52	0.32	21.38	0.03	0.04	0.14	

6. The Colour of Celadon Glaze on White Porcelain

Katsuki et al. prepared a celadon glaze with feldspar, kaolin, α–quartz, $BaCO_3$ and Fe_2O_3 powders. Its Seger formula was given as $0.3KNaO·0.7BaO·0.5Al_2O_3·5SiO_2$. Fe_2O_3 content in the glaze powder was reported to be 2 mass %. The biscuit of white porcelain had around 0.5 % of α–Fe_2O_3.

Table 3. L*, a* and b* values of some celadon [41]

Concenration of CO (%)	L*	a*	b*
0	67.2	−2.2	17.9
0.5	61.6	−4.5	5.9
1	65.8	−4.9	5.9
2	69.7	−5.6	5
4	69.6	−6.7	4.2

The heat treatment was applied to the sample by employing butane at 1300 °C for 0.5 h. Controlling the firing atmosphere which was reductive has been possible by adjusting flow ratios of butane and air from 900 to 1300 °C. After heat–treatment in the crucible, the surface of glassy celadon glaze with 12 mm thickness was sliced and afterwards crushed and pulverized for Mössbauer measurement.

7. Comparison between Different Types of Glazes

Thermal history of glass, frit and two glaze types are shown here. Glass is held at a high temperature to melt impurities and allow bubbles to escape; while being formed, the glass may be reheated many times. A frit is sintered (partially melted) at a high temperature, cooled rapidly, ground into powder, applied as a glaze and refired at a lower temperature.

Light bounces cleanly off a smooth glaze surface (specular reflection), whereas it scatters off a rough surface. A matte glaze contains crystals that roughen the surface and scatter light in all directions. In Song Dynasty Longquan celadons, the surface is slightly rough, embedded with quartz crystals measuring between 10 and 100 microns, and reflects a combination of specular and diffuse light. Different glaze compositions reflect and absorb varying amounts of light. A soda–lime glaze reflects about 4 % of the incoming light, whereas a lead glaze reflects about 8 %, which gives a brighter appearance.

In celadons, anorthite crystals grow during firing; the white crystals cover the grey clay body causing the blue–green glaze to appear brighter and more intense [45]. The simplest and most reliable colouring technique is to add a pigment, such as magnetite black and copper oxide red. Microscopic particles of gold, silver or copper produce colours by absorption, scattering and refraction. The most subtle and interesting colours are often produced by a solution of transition–metal ions.

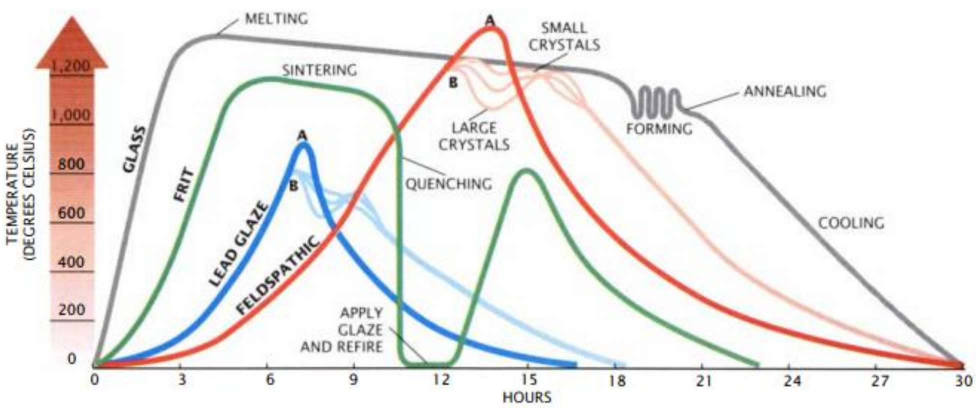

Figure 34. Clear lead and feldspathic glazes are held at peak temperature briefly (A). To achieve translucency, the glaze is cooled slightly (B) to nucleate crystals and then held at a higher temperature for some time to allow the crystals to grow [6]

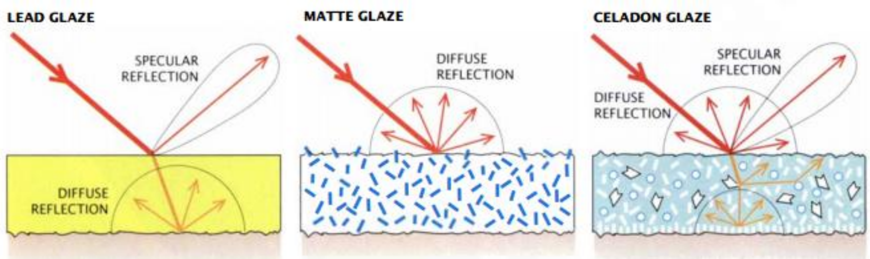

Figure 35. Light interacts in different ways with different glazes. A lead glaze (left) is transparent and highly reflective. A matte glaze (centre) has crystalline protrusions at the surface, which scatter light. A celadon glaze (right) contains quartz particles, bubbles and micron–size crystals, which bend and scatter light. A crystal layer at the glaze–body interface also reflects light [6]

These ions include iron (which can produce colours ranging from yellow and green to brown and black), manganese (purple to brown), chromium (pink to green), cobalt (blue) and copper (green to blue) depending on concentration and oxidation state. They can be tricky to use, since the energy level of their outer electrons is strongly influenced by the surroundings. Hence, copper is blue in an alkaline glaze but green in a lead glaze. If 0.5 % of iron oxide is added to an alkaline glaze or glass, each iron ion becomes surrounded by oxygen atoms, and the resulting absorption pattern gives a Coke–bottle green colour. If a sulphur or carbon ion replaces one or more of the oxygen, the resulting colour is a beer–bottle brown, because an iron–sulphur or iron carbon pair absorbs more light across the entire spectrum.

Air bubbles also interfere with the path of light through the glaze. Bubbles may form because trapped air pockets expand with heat or aggregate as melting particles clump together or because salts in the raw materials decompose and release gases. If the glaze is allowed to melt to a fairly fluid state, most of the air bubbles rise to the surface and escape. But if the glaze remains viscous, the bubbles are trapped, much like bubbles in pumice. Large numbers of bubbles brighten a glaze, because the smooth interfaces between air and glass offer many reflective surfaces. In addition to colorants and air bubbles, another important feature of the glaze is the presence or absence of crystalline particles. If a glaze or glass consists of 0.5 % by volume of fine particles of less than a micron in size, it appears translucent, not transparent. If the concentration exceeds about 10 % by volume, the glass or glaze appears opaque. The crystals may have a higher refraction index than the surrounding glass, in which case light bends as it passes into a crystal and traverses a longer path through the glaze, creating an illusion of greater depth. If the refraction index of the crystal is much greater than that of the glass, light bends by such a large angle that the glaze becomes quite opaque.

In addition, celadon glaze, unlike Yue, contains numerous crystalline particles, mainly needles of anorthite several microns in length and spherical particles of pseudo–wollastonite. When analysed the chemical composition across the thickness of the glaze, it was found that areas high in potassia and alumina but low in lime contain mainly anorthite, whereas areas rich in lime contain mainly pseudo–wollastonite. These local variations were caused by combining coarsely ground raw materials, such as limestone, with China stone and ash and mixing them incompletely. Since in Yue ware the same materials were finely ground and well mixed, celadon was clearly the result not of careless workmanship but of an intentional technology. The firing process also underwent a change. Undissolved quartz particles in celadon are surrounded by a halo of molten silica, which indicates the glaze was kept at a high temperature for a long time–but not so long that the molten silica could recrystallize into cristobalite. Based on replication experiments, it was concluded that celadons were fired at a temperature of between 1200 and 1250 ^{o}C and then cooled over many days. This process allowed anorthite and pseudo–wollastonite crystals to form in the glaze. Nearly 9 centuries after the invention of celadon, engineers at Corning Glass Works developed a high–tech analogue in Corelle Ware. The ware is formed as a clear glass and then placed in a controlled furnace that allows crystals to precipitate and grow. The process strengthens the glass and turns it an opaque white [6].

8. Celadon Glazes in Ottoman Empire

In the Topkapı Palace Museum Chinese and Japanese porcelain collections, which are displayed in the palace's Imperial Kitchens (Matbah-ı Âmire), can be mentioned as one of the most invaluable collections. These pieces can be classified as celadon ware, blue whites, monochromes and polychromes.

Celadon ware: Its collection is the world's largest one with 1354 pieces that nearly all were produced during the 14 and 15th centuries. Ottomans, like those in other Islamic countries, preferred them due to the belief of revealing the poison presence.

Blue–whites: The collection consists of 5373 blue and white porcelain pieces of the middle 14 to 19th century.

Monochromes: This collection covers 31 pieces of white porcelain dated from the early 15th century. They are patterned with either underglaze reliefs or scored decorations.

Figure 36. Typical example of celadon glazes in Topkapı palace

Polychromes: Porcelains decorated with polychrome enamels were first made and exported during the middle period of the Ming Dynasty but they reached their peak during Qing Dynasty. The most important group of early Qing porcelains is the group known as Famille verte (green variety). Another group was Famille rose (pink variety) produced in the late Kangxi Period using rose pink and matte white enamels.

Japanese Porcelains: There are approximately 700 Japanese porcelains in the Topkapı Palace Museum. Nearly the entire collection came from Arita localised on the northern part of Kyushu island. The Imari blue and white porcelains have an important place in the Topkapı palace collection as well [46–55].

9. Old and Modern Celadons

9.1 Old celadons

The pieces made it down through time to the present, are not necessarily the best or most beautiful of their era. Considerable amounts of the old celadon today, is less than spectacular and often appears malformed, damaged, or severely weather–beaten. After firing, the pieces of sand were broken off but left tell–tale markings on the old celadon piece bottom. Modern celadon is on the other hand made in neat, sterile furnaces and has no such markings.

The artisan who produced modern celadon nearly always put the marks seen in Chinese characters, but old celadon mostly did not have such marks, or if it did, it is so faded to be unrecognizable. Glazed bottoms being common on all modern celadon, were sometimes not used on older celadon due to the difficulty in keeping the base debris free.

Figure 37. White porcelain pieces with inlaid decoration, the 12 or 13th century [56]

Figure 38. On the left–hand side Korean celadon bottle, the early 12th century. Chinese celadon bottle on the right belongs to the late 11th to early 12th century [56]

Figure 39. Sculptured incense burner, 12th century [56]

Figure 40. *Mae–byeong* vase, 12th century [56]

Figure 41. Inlaid celadon oil bottle, 13th century [56]

9.2. Modern celadons

The appearances of modern celadon vary depending upon its production date. The ability of celadon artisans has improved when the time passes, so emphasising that the earlier pieces would generally have a less vibrant or uniform glaze colour, less symmetry in their shapes, and less detail in the inlaid designs. Works more recently made mostly have a symmetrical shape, uniform colour and fairly well detailed inlay. One can notice in the detail the difference between high and lesser quality modern celadons in terms of the inlay or painting, the uniformity and glaze colour. The depth and colour of the glaze are another feature. The deep jade–green glaze of quality works has a rich colour, and clarity that far surpasses that of lesser works.

Figure 42. Mu–ji (plain) vase and bottle [56]

Figure 43. Lotus and rabbit incense burner [56]

Figure 44. Pink peony vase and bottle [56]

Figure 45. Chrysanthemum and lunettes oil bottle [56]

9.3. Comparisons

Celadon characteristic glazes are now available in many colours to be used on all clay bodies, not just the traditional porcelain. The colour of celadon owes much to the glaze raw materials as well as to the firing conditions inside the furnace. Firing temperatures were commonly around, or below, 1150 ºC, and the oxygen level within the furnace was considerably reduced at some stage of the firing. A celadon glaze is quite a simple type, though difficult to get a particularly good one. The glaze application is important. It has to be quite thick to get the right effect. Celadon glazes are glossy, transparent, and great to add beautifully vivid accents to textured and carved surfaces. When closely inspected, the inlaid and painted portions of a piece with lower quality will appear somewhat blurred and indistinct, while those of better quality will be clear in detail [12]. Scientists have found that these two category ceramic products are also be differentiated in composition due to the use of different type raw material. A green or blue–green reduction fired glaze has been stained using iron oxide. The celadons that potters are accustomed to firing today are glossy transparent whereas the ancient versions were waxier and opaquer.

10. The Latest Studies

15th century porcelains and celadons are the most interesting ancient Vietnamese ceramics, both from the material and aesthetic points of view. Colomban et al. reported the composition, microstructure and technological processing of the Chu Đâu–My Xa ceramics. Samples come either from the kiln site or from the Cù Lao Chàm shipwreck [57].

Kim et al. investigated the colour dependence of a celadon glaze on the chemical composition and the electronic state of Fe by Mössbauer spectroscopic and chromaticity analysis [58]. Zhu et al. analysed 10 celadon pieces of the Xicun kiln and 8 celadon samples of the Yaozhou kiln in situ non–destructively by energy dispersive x–ray fluorescence microprobe and optical microscopy [59].

Li et al. used the energy dispersive x–ray fluorescence (EDXRF) to sort out the chemical compositions of Longquan celadon body and glaze at Fengdongyan kiln in Yuan and Ming Dynasties. [60].

Recently, an increasing number of researchers tend to support the viewpoint that proto–celadon has a multi–origin in Southern and Northern China during this period. Hao et al. carried out the study of the sherds from these two sites as well as those from Xiaolongjing Cemetery of Zhejiang Province by the employment of dilatometer and laser ablation–inductively coupled plasma–mass spectrometry [61].

The celadon with black body is a special and famous type of ceramic artefact in the Chinese history. Lingtong et al. collected some ceramic fragments of Longquan celadon with black body from two kiln sites (Xiaomei Town and Wayaoyang) and Southern Song Guan wares of Laohudong, Hangzhou and applied the energy dispersive x–ray fluorescence (EDXRF) analysis to determine the similarities and differences in chemical composition. [62]. According to the archaeological materials, many experts agree that the ceramic industry of Jingdezhen, the porcelain capital of the ancient world, can be dated back at least to Tang Dynasty (618–907). Wu et al. comparatively analysed the chemical composition and processing features of the celadon aforementioned to shed light on the early celadon of Jingdezhen and its initial development [63]. He et al. applied high irradiance femtosecond laser ionization time–of–flight mass spectrometry (fs–LI–TOFMS) to determine the porcelain body's elemental composition as well as glaze from Yue kiln (in southern China) and Yaozhou kiln (in northern China) of different cultural eras [64].

Representative Longquan celadon products are Ge ware (Ge meaning elder brother, black body celadon) and Di ware (Di meaning younger brother, grey body celadon) of the Song Dynasty (960–1279). Duan et al. collected and studied Ge and Di ware shards excavated from Wayaoyang kiln site in Longquanwere [65]. He et al. employed EDXRF to determine the chemical composition of celadon body and glaze in Longquan kiln (at Dayao County) and Jingdezhen kiln [66].

Shi et al. investigated 5 Dynasties celadon body of Yaozhou kiln as the major study objects. Based on the analysis of XRF, XRD, SEM/EDS, UV/Vis/NIR spectrophotometers and XPS, the chemical compositions, microstructure and optical quality of the white and black bodies have been searched for [67]. Wu et al. used proton induced X–ray emission technique to analyse the celadon samples, kiln slag and no 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 [68].

For a long time, due to the structural complexity of the amorphous glaze, the exact microstructure of the iron–based colorant in the celadon glaze, especially the local structure, is not well determined. You et al. exploited a unique opportunity to investigate the glazes of the earliest Chinese celadon recently excavated from Jinshan, by x–ray absorption fine structure (XAFS) spectroscopy [69]. To search for the raw materials, firing process and product quality about them, Lingtong et al. collected some pieces with reddish and green glazes from this kiln site, and analysed the chemical composition, firing temperature and phase composition [70]. Identification of Longquan celadon and its imitation is more and more caught the attention of experts in different fields. Wang et al. determined body and glaze of samples from Zhejiang Longquan celadon and its imitation in Dapu kiln of Guangdong in the Ming Dynasty of China by using laser ablation–inductively coupled plasma mass spectrometry (LA–ICP–MS) and other analytical methods [6]. Li et al. worked on 23 pieces of high–fired glazed samples from the archaeological excavations of the Dong Xia sites in Russia's Primorye region [71].

Zang et al. used proton induced X–ray emission (PIXE) technique and factor analysis to study the recovery of making technology of Chinese Longquan celadon made in the late Southern Song Dynasty (1127–1279) [72].

11. Conclusion

Celadon glazes with their long, amazing history and being glossy, transparent, and great to add beautifully vivid accents to textured and carved surfaces leading to beautiful appearances still attract the attentions of both ceramic artists and scientists. Beside their imitations to ancient versions, new and modern approaches are being made and seem to be made in future. With the modern touches of the determined and highly skilled artists we will hopefully carry on having pleasure preserving celadons in our lives. Additionally, their archeometric studies will enlighten the history of those invaluable items. It seems that celadon glazes will preserve their precious place in soon and far future.

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