A Brief History of Pearl Testing through the pages of *Gems & Gemology*
珍珠測試簡史

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作者簡述現今的常規珍珠檢測，涉及各種常規寶石學與高階儀器方法技術之應用的發展，這些鑑定技術與過去一個世紀的珍珠養殖和收採後處理的進步同步發展。

Current routine pearl testing involves the application of various basic and advanced gemmological techniques. These methods have been developed in parallel with the advances in cultured pearl farming and post-harvest treatments over the past century.

A brief history of pearl testing could be constructed by reviewing key articles published in major gemmological periodicals, which have become an invaluable resource of information on all types of gemstones, offering a wealth of up-to-date research studies and industry news. In this paper, I have conducted such a review mainly based on articles published in GIA's *Gems & Gemology*, one of the oldest journals dedicated to the field of gemology (Fig. 1). Articles referenced in this review can provide insight, historical trends, and technological advances related to pearls, and might also be said to have helped shape and define our understanding of this beautiful organic gem material and contemporary testing techniques.

Pearl Testing During the 1930s and 1940s

Although pearl culturing was recorded in Chinese literature about 600 years ago and was widely practiced in China by the late 19th century, it was Japan's Kokichi Mikimoto who made pearl culturing commercially successful and laid the foundation for the cultured pearl industry. This also led to the need to develop methods that could distinguish scientifically between natural and cultured pearls. Endoscopic examination within drill holes proved to be a quick and decisive method of identification for the majority of pearls in the early days of pearl testing during the 1930s. Additional techniques such as "candling" and UV fluorescence observation were also mentioned in the literature but were determined to be of limited usefulness (Shipley Jr., 1934).

On the other hand, in America, GIA founder Robert Shipley advocated strongly for jewellers across the nation to disclose and describe this relatively new product to the general public accurately, as many at the time still did not fully understand the differences between cultured and natural pearls (Shipley, 1936). The endoscope and candling methods used for pearl identification were refined further and combined with a microscope, which resulted in an innovative instrument named the pearloscope, designed and developed by GIA during the 1940s (Shipley Jr., 1947). This unique optical pearl-

Fig. 1 Gems & Gemology has offered a wealth of up-to-date research and industry news since 1934.
Gems & Gemology 自 1934 年以來一直提供豐富的最新研究和行業資訊。
Photo © GIA

testing instrument embodied both the double-mirror and single-mirror methods of endoscopic pearl testing as well as the candling method (Fig. 2). To pursue this idea Atalay (1994) built a handy brass instrument equipped with a red laser to inspect and identify natural and bead cultured pearls.

Meanwhile, interest in using various X-ray techniques for pearl testing was also growing. X-ray diffraction, X-ray fluorescence, and X-ray radiography all proved useful in separating natural and bead cultured pearls, according to Alexander (1941). X-ray diffraction patterns could separate natural pearls and bead-cultured pearls, although some pearls might show anomalous patterns, depending on their nacre thickness and crystal structures. X-ray fluorescence also proved to be a quick and powerful way to distinguish marine natural pearls from bead-cultured pearls and freshwater pearls, as the latter two types contained higher amount of manganese, which was responsible for the fluorescence reaction under X-ray excitation. Dr Alexander further confirmed the effectiveness of the X-ray radiography technique for pearl testing, as the separation could be achieved by observing radiographic images on the internal structures of the pearls, provided that optimal settings (exposure time, voltage, and current), high film quality, and a proper masking agent were applied during the test. Additional in-depth studies on X-ray radiography and X-ray diffraction techniques for pearls were also reported in *Gems & Gemology* during the 1940s (Barnes, 1946, 1947) and later compared by Hänni (Hänni, 1983).

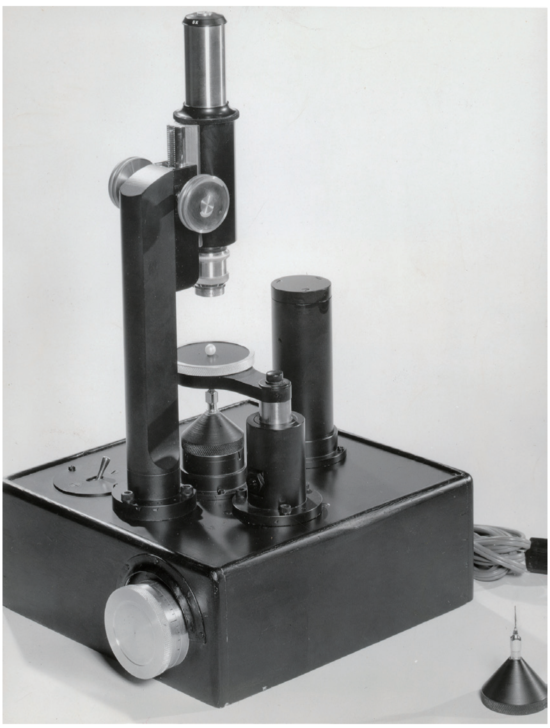
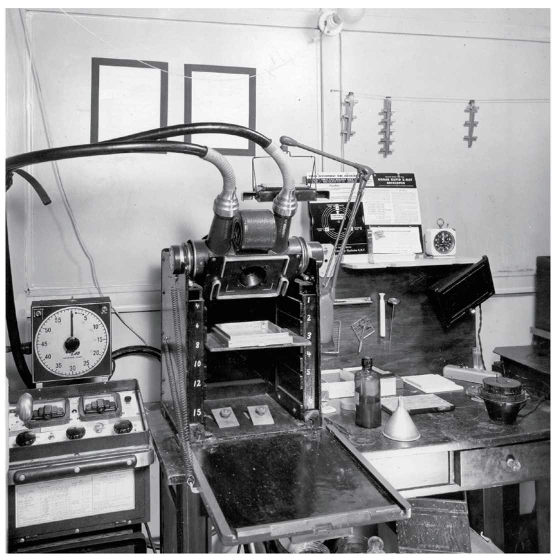


Fig. 2 The first half of the 20th Century was a period of great advancement in the development of scientific instruments designed particularly for gemmological research. This pearloscope combining microscope, endoscope, and candling for pearl identification was designed and developed by GIA in the 1940s.
20世紀上半葉是專為寶石學研究而設計的科學儀器發展取得巨大進步的時期。這種將顯微鏡、內窺鏡和照明相結合的珍珠檢測儀是由GIA在1940年代設計和開發的。
Photo by Dick Whittington Photography.

Evolution of the X-Ray Radiographic Technique

As the cultured pearl industry grew, the need for practical, up-to-date X-ray analysis for pearl testing became apparent. In 1950, a newly designed X-ray instrument was announced by the Gemmological Laboratory of the London Chamber of Commerce. This apparatus was slightly larger than a household refrigerator and capable of doing both radiography and fluorescence observation (Webster, 1950).



(Top of photograph states "please return to Gem Trade Lab 5. E.47th St.)

Especially adapted X-ray medical unit showing automatic timer, pearl tray, lead glass protective cover and accessories used in X-radiography

Fig. 3 A specially adapted X-ray unit showing an automatic timer, a pearl tray, a lead glass protective cover, and accessories used in X-ray radiography.
這特別改裝的 X 射線裝置，顯示了 X 射線攝影中使用的自動計時器、珍珠托盤、鉛玻璃保護蓋和附件。
Photo © GIA.

Fig. 4 Advanced real-time X-ray microradiography (left) and X-ray computed microtomography (right) instruments at GIA's Bangkok laboratory.
GIA 曼谷實驗室的先進實時 X 射線顯微放射成像（左）和 X 射線計算機顯微斷層掃描（右）儀器。
Photo © GIA.

In 1951, the GIA Gem Trade Laboratory in New York also installed a new X-ray instrument specially designed for pearl testing with radiography and fluorescence observation functions. It could generate excellent results showing clear details of the concentric nacreous layers surrounding the nucleus of a cultured pearl (Fig. 3; see Benson, 1951). GIA's new unit served as a very useful tool for pearl testing for the following decade and acted as a prototype for future models. As the technology progressed, newer, more compact X-ray units were made and used throughout the history of pearl testing, but the overall concept and theory of using radiography and X-ray fluorescence observation remained the core methods for differentiating natural and cultured pearls. In recent decades, digital real-time X-ray equipment has largely replaced film X-ray equipment used in various gemmological laboratories around the world. The adaptation of flat panel detector (as opposed to image intensifier) and X-ray computed microtomography (μ-CT) for use in testing pearls further improved the overall image resolutions with which fine small growth features inside a pearl could be easily detected (Karampelas et al., 2010; Krzemnicki et al., 2010; Karampelas et al., 2017). Such advanced instruments are also currently used by GIA in different laboratory locations where pearl services are provided (Fig. 4) and have also helped the researchers to study and analyse pearls' internal structures better by generating images of growth features with greater details (Sturman et al., 2016; Nilpetploy et al., 2018).

Pearl Types and Localities in Gems & Gemology

Reports and reviews on pearls of different types and from various localities were common subjects in *Gems & Gemology*. These topics changed throughout history following the industry trend and public popularity among different types of pearls. While Akoya pearls from oysters cultured in Japan dominated the industry during the 1930s and 1940s (Foshag, 1947), natural pearls, especially those from the Persian Gulf, still played an important part in the trade (Hohenthal, 1938; Alexander, 1948). Meanwhile, renewed interest in freshwater pearl culturing in post-World War II Japan resulted in the increase of freshwater cultured pearls seen in the market during the 1960s (Crowningshield, 1962). The majority of these pearls were produced in Lake Biwa (Fig. 5), and they were highly prized in the trade. Since the 1980s, China has overtaken Japan as the largest producer of freshwater

Fig. 5 Freshwater pearl farming in Lake Biwa, Japan.
日本琵琶湖的淡水珍珠養殖。
Photo © GIA.

Fig. 6 Three groups of freshwater pearls from various origins: natural pearls from North America (left), cultured pearls from China (middle), and cultured pearls from Tennessee of USA (right).
三組不同產地的淡水珍珠：來自北美州的天然珍珠（左）、來自中國的養殖珍珠（中）和來自美國田納西州的養殖珍珠（右）。
Photo by Diego Sanchez.

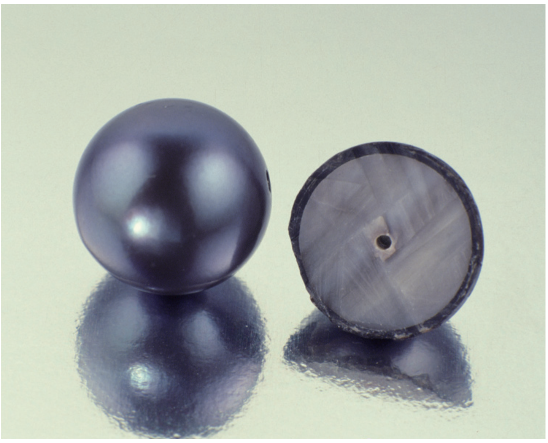
cultured pearls, and these pearls' gemmological characteristics and culturing methods have been reported several times in *G&G* (Scarratt et al., 2000; Akamatsu et al., 2001; Fiske, 2007). North America has also had a long history of freshwater natural pearling, and culturing experiments have also been successfully conducted in Tennessee, as described in an excellent review in *G&G* (Sweaney and Latendresse, 1984).

Nowadays China remains the largest producer of freshwater cultured pearls. After starting with non beaded mantle grown pearls, innovative techniques were developed there to produce large beaded cultured pearls in the gonad (Hänni, 2011). The identification of freshwater pearls remains a challenging task for gemmological laboratories, as the external appearances and internal structures overlap for some of these pearls (Fig. 6).

Review articles on other types of pearls from various localities have appeared in *G&G*, providing valuable information on the historical backgrounds and gemmological characteristics of these specimens. For instance, natural and cultured black pearls from French Polynesia, Micronesia, and Baja California have been summarised in several *G&G* articles (Goebel and Dirlam, 1989; Carino and Monteforte, 1995; Kiefert et al., 2004; Cartier et al., 2012). The history and properties of natural pearls from Australian *Pinctada maxima* pearl oysters were also well documented in a detailed report by Scarratt et al. (2012). Featured summaries on pearls produced within certain types of species such as abalones, Queen conchs, and pen pearls also appeared in *G&G*, in addition to numerous pearl Lab Notes reported by laboratory staff on a regular basis (e.g., Bostwick, 1938; Fritsch and Misiorowski, 1987; Sturman et al., 2014).

Black and "Golden" Pearl Identification

Detection of treatments, particularly colour modification, has been an important part of pearl identification since the early days of GIA. Black pearls were the focus, since goods were



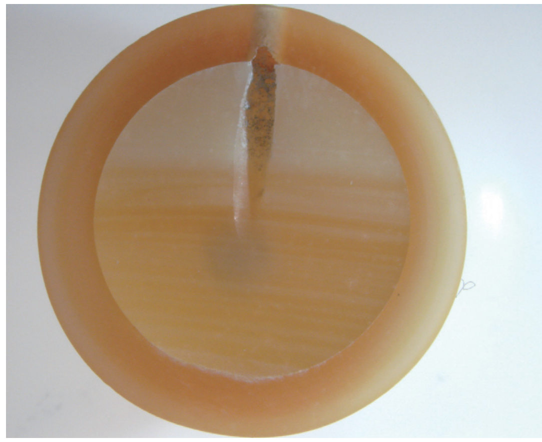


Fig. 7 Left: Surface and cross-section of a dyed black pearl. *Photo by Robert Weldon.*
Right: Cross-section of a dyed "golden" pearl. *Photo by Chunhui Zhou.*
左：染色黑珍珠的表面和橫截面。右：染色"金色"珍珠的橫截面。

routinely being treated to imitate the dark body colours of naturally coloured black pearls (Fig. 7 left). Early testing methods on black pearls involved microscopic observation of the surface for potential colour concentrations, colour observation of the internal bead nucleus, long-wave UV fluorescence reaction, weak acid test, infrared colour film, and the detection of silver by energy-dispersive X-ray fluorescence (EDXRF) (Benson Jr., 1960; Komatsu and Akamatsu, 1978). More advanced analytical techniques, such as ultraviolet-visible (UV-Vis) reflectance spectroscopy and Raman photoluminescence, have been used to aid in the identification of black pearls in recent decades. They were particularly useful in identifying certain unique treatments applied to cultured pearls from *Pinctada margaritifera*, such as "chocolate" and "pistachio" coloured pearls (Fig. 8) (Elen, 2002; Wang et al., 2006; Karampelas et al., 2011; Zhou et al., 2016).

Much as black pearls had done in earlier decades, "golden" cultured pearls from the South Sea's *Pinctada maxima* pearl oysters gained popularity steadily during the 1990s and 2000s. As demand for these cultured pearls has grown, colour-treated "golden" cultured pearls have also entered the market (Fig. 7, right). While some of these treatments could be detected by microscopic observation of the surfaces—where spotty colour concentrations might be found within blemished areas and around drill holes—many have improved to the point that they show little surface evidence and require more advanced analytical techniques for identification. A number of studies have found that UV-Vis reflectance spectroscopy, Raman photoluminescence, and UV fluorescence observation can help to identify such well-treated "golden" pearls (Elen, 2001; Elen, 2002; Zhou et al., 2012). These techniques have been routinely applied for the identification of "golden" colour pearls in gemmological laboratories.

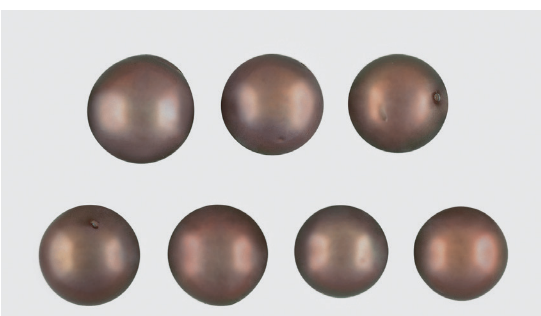


Fig. 8 Left: "Chocolate" coloured Tahitian pearls treated by Ballerina Pearl Co. *Photo by Suchada Kittayachaiwattana.*
Right: "Pistachio" coloured Tahitian pearls treated by Ballerina Pearl Co. *Photo by Sood Oil (Judy) Chia.*
左圖：由 Ballerina Pearl Co. 處理的"巧克力"色大溪地珍珠。右圖：Ballerina Pearl Co. 處理的"開心果"色大溪地珍珠。

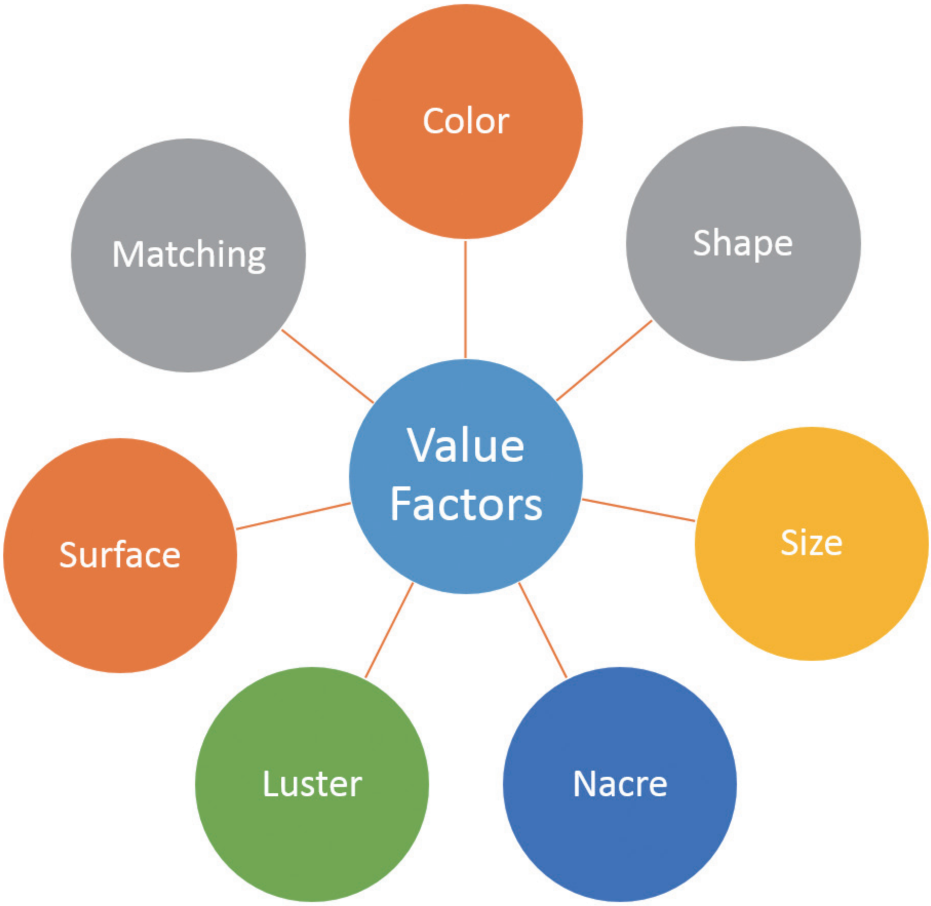


Fig. 9 GIA's 7 Pearl Value Factors: *Size, Shape, Color, Nacre, Luster, Surface, and Matching.*
GIA 的 7 項珍珠評價因素：*大小、形狀、顏色、珍珠層、光澤、表皮和匹配度。*

Unconventional Techniques and Classification of Pearls

Currently, most pearls can be identified using conventional gemmological and advanced analytical techniques. Despite decades of pearl testing experience, some challenges remain within laboratories, which spurred the need for investigating additional unconventional techniques for pearl testing. Some of the notable methods that have been reported in recent years include radiocarbon age dating - particularly applied to historical pearls, deoxyribonucleic acid (DNA) barcoding, in-depth trace-element geochemistry and isotope analysis, and 3D reconstruction of internal structures (Meyer et al., 2013; Krzemnicki and Hajdas, 2013; Zhou et al., 2017; Saruwatari et al., 2018; Zhou, 2018; Homkrajae et al., 2019). While these techniques have their own limitations and are usually more time-consuming and costly to perform, the application of these methods could be the answer to some of the more challenging pearl testing issues.

Finally, the discussion on devising a pearl classification system similar to the 4Cs of diamond first appeared in *Gems & Gemology* in 1942 (Rietz, 1942). The author suggested classifying pearls into several categories such as gem quality, extra-fine quality, fine quality, good quality, fair quality, imperfect, and poor quality, based on several factors (shape, lustre, surface blemishes, colour distribution, and iridescence). This pearl classification system was further refined, and a new system based on pearls' various value factors was suggested by Richard T. Liddicoat, Jr. (Liddicoat Jr., 1967). This eventually resulted in the creation of GIA's current pearl classification system, the GIA 7 Pearl Value Factors (Fig. 9), which has been widely adopted in the industry for describing and classifying pearls.

Conclusions

Pearl testing is a unique branch of gem testing that requires specialised skills, knowledge, and techniques. A wealth of such knowledge can be found in numerous *Gems & Gemology* publications in the forms of feature articles, field reports, Lab Notes and Gem News International entries. Although this is by no means comprehensive and there are many excellent pearl articles published in other periodicals, the author hopes that this review might serve as a guideline for an in-depth understanding of how modern pearl testing has advanced throughout its brief history.

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(Ed. comment – for further reading other periodicals to be referenced are: Journal of Gemmology, Facette, Gemmologie, Revue de Gemmologie, The Journal of The Gemmological Association of Hong Kong, etc.)

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