

THE CURRENT STATUS OF CHINESE FRESHWATER CULTURED PEARLS

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Chinese freshwater cultured pearls (FWCPs) are assuming a growing role at major gem and jewelry fairs, and in the market at large. Yet, it is difficult to obtain hard information on such topics as quantities produced, in what qualities, and the culturing techniques used because pearl culturing in China covers such a broad area, with thousands of individual farms, and a variety of culturing techniques are used. This article reports on recent visits by two of the authors (SA and LTZ) to Chinese pearl farms in Hanzhou Province to investigate the latest pearl-culturing techniques being used there, both in tissue nucleation and, much less commonly, bead (typically shell but also wax) nucleation. With improved techniques, using younger *Hyriopsis Cumingi* mussels, pearl culturers are producing freshwater cultured pearls in a variety of attractive colors that are larger, rounder, and with better luster. Tissue-nucleated FWCPs can be separated from natural and bead-nucleated cultured pearls with X-radiography.

The popularity of Chinese freshwater cultured pearls (FWCPs) has risen dramatically in the world's markets. The unique characteristics of the Chinese FWCP—in terms of size, shape, and color—have been key to this popularity (figure 1). Chinese FWCPs are available in sizes ranging from 2 mm to over 10 mm; in an interesting variety of shapes such as round, oval, drop, button, and baroque; and in rich colors such as orange and purple, often with a metallic luster. The vast majority of these Chinese FWCPs are nucleated by mantle tissue only, although some nucleation with spherical beads has taken place (Bosshart et al., 1993; "China producing nucleated rounds," 1995; Matlins, 1999; "China starts...," 2000; Scarratt et al., 2000). This makes them distinct from the overwhelming majority of cultured pearls from other localities, which are bead nucleated. Despite the growing popularity of Chinese FWCPs, details concerning their history, culturing areas, production figures, culturing techniques, and the characteristics of the pearls themselves are not widely known. In response to the growing

demand for information, two of the authors (SA and LTZ) visited six FWCP farms and one nucleus manufacturer in China's Zhejiang district; they also examined hundreds of Chinese FWCPs. The trip was made from July 25 to 29, 2000; information in this article has been confirmed and updated since then based on the second author's monthly trips to the pearl-farming areas to visit his pearl factory in Zhuji City, as well as to purchase freshwater cultured pearls for export. In addition, the first author has visited Chinese freshwater pearl-culturing areas several times during the past two years. This article reports on the current status of the Chinese freshwater cultured pearl, both the various culturing techniques used and the cultured pearls themselves, updating (and superseding) the pearl-culturing information in Scarratt et al. (2000).

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Figure 1. Chinese freshwater cultured pearls occur in a variety of attractive shapes and colors, as well as in sizes over 10 mm. The potato-shaped Chinese FWCPs in the strand on the left range from 9.3×11.3 mm to 10.6×12.7 mm. The near-round Chinese FWCPs on the right are approximately 9–10 mm. Photo © Harold & Erica Van Pelt.

HISTORY

The culturing of freshwater pearls was widespread in China by the 13th century. Tiny figures of Buddha formed of lead were cemented onto the nacreous interior of the shell produced by the freshwater mussel *Cristaria plicata* (zhou wen guan bang in Chinese). Over time, the mollusk coated the lead figures with nacre, and the blister pearls thus cultured were used as temple decorations or amulets (Ward, 1985; Webster, 1994). Even now, this culturing technique survives, although the images are larger and nucleated with wax rather than lead (figure 2). Today, images of Buddha, flowers, birds, animals, and other forms are molded with wax and inserted into the mussels. A similar technique is used to create the mabé-type hemispheric composite cultured blister pearls in white- and black-lipped pearl oysters, as well as in abalone (Wentzell, 1998).

Freshwater pearl culturing was attempted in Japan around 1910, but success was not achieved until 1924, when growers changed from the "Karasu" mussel (*C. plicata*) to the "Ikecho" mussel (*Hyriopsis schlegeli*). Following this success, commercial freshwater pearl culturing began in Japan in 1928. A bead-nucleating technique was first adopted, but growers eventually recognized that tissue nucleation produced better results. In 1946, freshwater-pearl farmers switched to tissue

nucleation, creating unique freshwater cultured pearls. Since then, Japanese FWCPs have been highly prized as "Biwas" (named after Lake Biwa,

Figure 2. The culturing of freshwater blister pearls was widespread in China by the 13th century. Tiny figures of Buddha were cemented onto the inner shell of freshwater mussels (*Cristaria plicata*), where they were coated with nacre. The same culturing technique survives today. Instead of tiny lead figures, larger wax images are commonly used to produce a variety of forms, although Buddha (as seen in this 8.3×10.8 cm shell) is still popular. Photo by Shigeru Akamatsu.





Figure 3. Most of the Chinese FWCPs cultivated with *Cristaria plicata* were of low quality: irregular shaped with many wrinkles on their surface (hence called "Rice Krispies"; here, 5 × 8 mm to 9 × 14 mm, produced in 1976). These pearls first appeared on the market in the late 1960s and early 1970s, with 600 grams imported into Japan in 1971. The quantity increased dramatically over the next several years (with Japanese imports of 49 tons in 1984), but the boom had faded by the late 1980s. Photo by Maha Tannous.

Figure 4. Chinese pearl farmers greatly improved the quality of their product in the 1990s by changing the mussel species from *Cristaria plicata* to *H. Cumingi*, the Chinese "triangle" mussel. With the use of *H. Cumingi* both as donor of the mantle tissue and for culturing, they produced larger cultured pearls with a smoother surface, rounder shape, and better color and luster. In particular, the color and luster of the mother-of-pearl in the tissue-donor mussel has a strong influence on the color and luster of the final cultured pearl; notice the differences among these four mussels, all of which were used to provide mantle tissue nuclei. Although earlier culturing with *H. Cumingi* was done using 2–2.5 year old mussels, these one-year old mussels are typical of the age at which *H. Cumingi* are nucleated today. Photo by Shigeru Akamatsu.



where most were grown). Over time, improvements in the culturing technique produced more pearls of better quality, and the Japanese freshwater pearl culturing industry flourished. Pearl culturing at Lake Kasumigaura began in 1962, and in 1980 production reached a peak of 6.3 tons. Production began to decline because of water contamination and the high mortality of the mussels (Toyama, 1991). By 1998, production of Japanese freshwater cultured pearls had dropped to 214 kg, only 3.4% of the peak in 1980 ("Statistics of fishery and cultivation," 2000).

It was in the late 1960s and early 1970s that China started full-scale FWCP production, and low-quality irregular-shaped cultured pearls with wrinkles on their surface (commonly known as "Rice Krispie" pearls) appeared in the market (Hiratsuka, 1985; figure 3). According to trade statistics published by the Japanese Ministry of Finance, in 1971 Japan imported only 600 grams of this material. Over the next 13 years, however, these imports increased dramatically: They reached 7.5 tons in 1978, 34 tons in 1983, and over 49 tons in 1984. Most were not consumed by the Japanese market, but instead were exported to Germany, Switzerland, Hong Kong, the Middle East, and the U.S. by Japanese distributors (Chinese FWCPs accounted for more than half the pearls exported from Japan in 1984). In the late 1980s, however, the demand for such low-quality pearls quickly died down, and the Chinese FWCP almost disappeared from the world market.

In the 1990s, however, Chinese FWCPs reappeared, with their quality remarkably improved ("China starts pearling revolution," 2000). Culturers had changed the species of mussel from *C. plicata* to *Hyriopsis cumingi*, which is generally called the "triangle mussel" (*san jiao* or *san jiao bang* in Chinese) because of its shape (figure 4; Fukushima, 1991). The triangle mussel inhabits wide areas along the Chang Jiang (Yangtze) River. Using the new mussel, growers started to cultivate 3–4 mm pearls with a smooth surface. Although some of these Chinese FWCPs were near-round, more often the commercial product had a bulbous oval "potato" shape (again, see figure 1). Over the last decade, quality continued to improve. Chinese cultivators now produce FWCPs in sizes from 2 mm to over 10 mm, in shapes from extreme baroque to perfect round, and in colors from white to pastel orange and purple, often with a metallic luster.

CULTURING AREAS AND PRODUCTION AMOUNT

The culturing region for Chinese FWCPs extends over wide areas along the Chang Jiang (also known as the Yangtze) River (figure 5). The provinces of Jiangsu, Zhejiang, Anhui, Fujian, Hunan, and Jiangxi are the main culturing areas, with Jiangsu and Zhejiang accounting for nearly 70% of the total FWCP production (He Xiao Fa, pers. comm., August 2000).

It is generally thought that pearls cultured in southern farms grow faster, coinciding with the rapid growth of the mussel. By contrast, pearls cultured in northern farms grow more slowly, but their compact nacre gives them a better luster. For this reason, some farmers who own both northern and southern farms initially cultivate pearls in the southern farms to accelerate nacre growth, then move the mussels to northern farms one year before harvest to improve the luster. In addition, northern farmers often buy nucleated mussels from southern cultivators. According to several pearl culturers in the cities of Zhuji and Shaoxing, transferring mussels from one farm to another during the pearl growth period (which may take up to six years) is not uncommon in China.

No accurate production figures exist for Chinese FWCPs. Two major culturers, He Xiao Fa of Shanxiahua Pearl Co. Ltd. and Ruan Tiejun of Fuyuan Pearl Jewelry Co. Ltd., estimate that annual production is currently about 1,000 tons. Because there are several thousand pearl farms, many of which are very small, it is impossible to give an accurate count. The farms range from major operations with over one million mussels, to tiny roadside swamps diverted from rice paddy fields that contain tens of thousands of mussels (see, e.g., figure 6). The mussels are suspended in nets (each typically containing two to three mussels; figure 7) from buoys that are often made of Styrofoam or recycled plastic bottles.

RECENT DEVELOPMENTS IN TISSUE NUCLEATION

From observations made during our frequent visits, and from conversations with several leading pearl farmers, we confirmed that the vast majority of freshwater cultured pearls produced in China today are, as stated in Scarratt et al. (2000), mantle-tissue nucleated. As the recent improvement in quality demonstrates, the growth techniques used to create the Chinese product have changed. Some of the changes can be counted as major technical improvements.

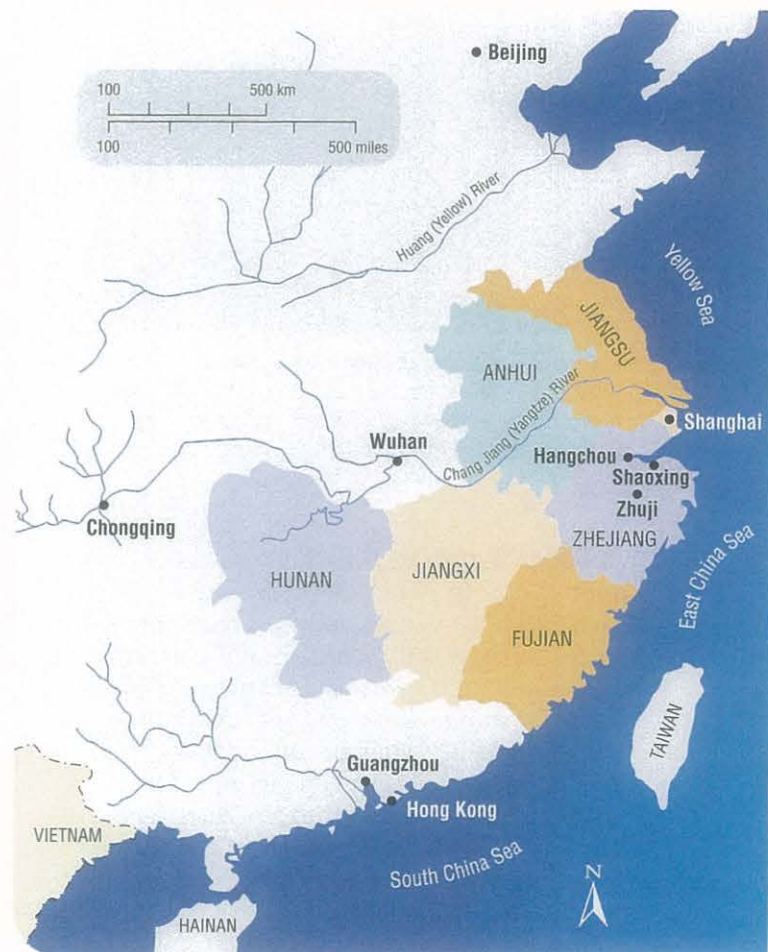


Figure 5. Freshwater pearl culturing areas extend widely along the Chang Jiang (Yangtze) River, including the provinces of Jiangsu, Zhejiang, Anhui, Fujian, Hunan, and Jiangxi. Mussels that have been tissue nucleated are not always cultivated in a single farm for the entire culturing process. Often they are transferred to other farms in different provinces, where cultivation continues.

New Mussel Species Used for Culturing. As noted above and in Scarratt et al. (2000), Chinese pearl cultivators have changed from the *C. plicata* mussel to the *H. cumingi* ("triangle") mussel. *H. cumingi* is a large bivalve of the same genus as the *H. schlegeli* used for pearl cultivation in Japan's Lake Biwa. Triangle mussels can produce attractive FWCPs with a smooth surface. With the introduction of hatchery techniques to propagate the *H. Cumingi*, mass production of mussels has become possible and enormous amounts are now used for pearl culturing.



Figure 6. In China, the number of farms culturing freshwater pearls is too large to be counted accurately. They vary in size from large lakes (left) to small farms converted from rice paddy fields (right). Note the soil piled around the paddy field to keep the water deep enough (1.5 m) for pearl culturing. Photos by Shigeru Akamatsu (left) and Li Tajima Zansheng (right).

A Longer Culturing Period. In the past, it was common for growers to perform tissue nucleation on two-and-a-half-year-old mussels, cultivate them for two to three years thereafter, and harvest 4–7 mm pearls (see, e.g., Jobbins and Scarratt, 1990). In recent years, however, some growers have been operating on significantly younger mussels, approximately one to one-and-a-half years old (figure 8, right), and cultivating them for four to six years. By extending the period between insertion of the tissue nuclei and the harvest, they have succeeded in producing commercial quantities of FWCPs larger than 8 mm. A one-year-old mussel has a small shell, one valve of which weighs only 10 grams (average dimensions: 7.2 × 4.3 cm) at the time of nucleation. That same valve will attain a shell weight at harvest after

five years of 260 grams (up to 16.4 × 10.5 cm), more than 25 times its starting weight (figure 8, left). The pearls grow as the mussels grow, but the rate of growth is not always proportional.

Even though the cultivation period from nucleation to harvest is the same for any given mussel, the growth rate of the many pearls nucleated in that mussel is not the same. Consequently, FWCPs of various sizes are harvested from a single mussel (figure 9). Table 1 lists the different sizes of FWCPs removed from a sample harvest of four mussels that were cultivated for 4.5 years in a farm in Shaoxing.

Figure 7. During pearl cultivation, two to three mussels typically are put in a net and suspended in the water from Styrofoam buoys or recycled plastic bottles. Photo by Shigeru Akamatsu.



Figure 8. A one-year-old “triangle” mussel at the time of tissue nucleation is very small (right)—an average of 7.2 × 4.3 cm, with an approximate shell weight (one valve) of 10 grams. A six-year-old *H. cumingi* mussel at the time of harvest (left) after five years of cultivation is very large—up to 16.4 × 10.5 cm, with a single valve now 260 grams in weight. Photo by Li Tajima Zansheng.



These results also indicate that cultivation periods of 4.5 years can produce FWCP sizes of over 9 mm. Note that these mussels were older and larger when the nuclei were inserted than is currently practiced

Improvement in the Mantle Tissue Nucleus. In earlier freshwater pearl culturing, a common technique was to cut a 2 × 2 mm piece of tissue from the mantle of a 2.5-year-old mussel, fold it, and then insert it into a pocket made in the mantle lobe of a host mussel (Jobbins and Scarratt, 1990). Because this piece of tissue was too thick to be worked into a round shape, most of the FWCPs produced had shapes such as rice, oval, and baroque. Recently, pearl farmers have changed the nature of the mantle-tissue nuclei. Instead of taking the tissue from a 2.5-year-old mussel, growers now use a one-year-old (*H. cumingi*) mussel for this part of the procedure. When a piece of tissue is removed from such a young mussel, it is thin enough to be rolled into a round ball. So the cultururer now cuts a larger (but thinner) 4 × 4 mm piece of mantle tissue (figure 10), and makes it as round as possible by rolling it before nucleation (figure 11).

Improvements in the Nucleation Technique. From their experience, pearl cultururers identified that the posterior mantle lobe of the mussel, where the mother-of-pearl has the desired color and luster, is the key location to produce a better-quality pearl with fine color and luster (again, see figure 4). So they started to cut pieces of tissue from the posterior part of the sacrificed "donor" mussel and then placed them into pockets in the same posterior mantle lobes of the host mussel (figure 12). With this new technique,

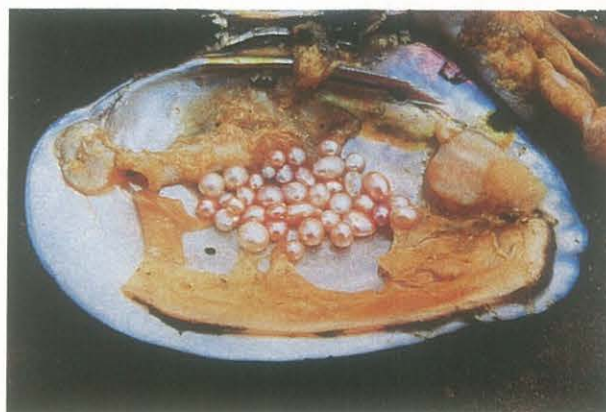


Figure 9. All the Chinese FWCPs in this photo were tissue nucleated and harvested from both valves of one mussel after 4.5 years. Even though the culturing conditions were the same, the resulting FWCPs range from 5 to 9 mm. Photo by Shigeru Akamatsu.

pearl cultururers are improving the color and luster of their FWCPs. Figure 13, taken in April 2001, shows a group of technicians performing different stages of the pearl nucleation technique at this pearl-processing operation in a suburb of Zhuji City.

Another improvement is the reduction in the number of tissue pieces used to nucleate a single mussel. In the past, when cultivators used relatively large, 2.5-year-old mussels to begin the process, about 20 pieces usually were inserted in each mantle lobe of the bivalve—for a total of about 40 pieces in a single mussel (Farn, 1986; Scarratt et al., 2000). Now, some growers typically insert 14 or fewer pieces of tissue in each mantle lobe of a one-year-old mussel—for a total of 28 or fewer in each mussel (figure 14).

TABLE 1. Freshwater cultured pearls produced from four mussels harvested in Shaoxing after cultivation for 4.5 years.^a

Size (mm)	Mussel 1		Mussel 2		Mussel 3		Mussel 4	
	No. of FWCPs	% of total	No. of FWCPs	% of total	No. of FWCPs	% of total	No. of FWCPs	% of total
4	0	0	1	2.9	2	3.8	0	0
5	4	9.5	5	14.3	20	37.7	1	3.0
6	12	28.6	13	37.1	21	39.6	8	24.2
7	13	31.0	12	34.3	6	11.3	16	48.5
8	10	23.8	3	8.6	3	5.7	8	24.2
9	3	7.1	1	2.9	1	1.9	0	0
Total	42		35		53		33	

^aNote that these mussels were older when they were nucleated, and had more nuclei inserted, than pearl farmers now prefer.

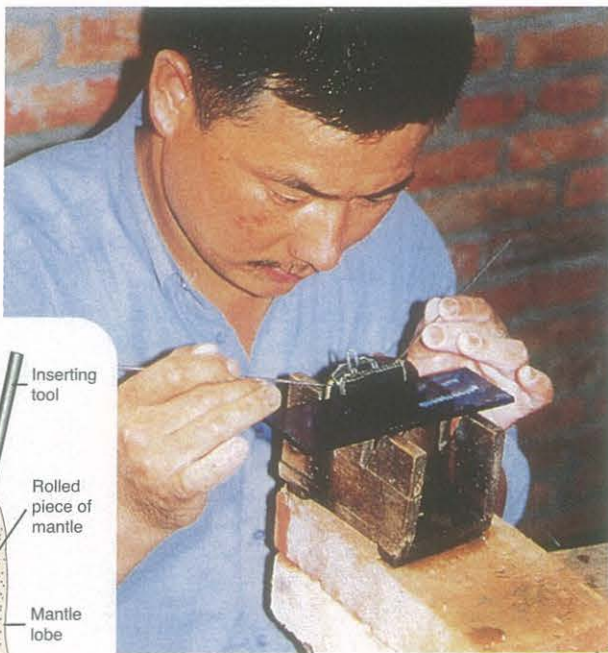


Figure 10. Using a knife, the technician cuts a piece approximately 4×4 mm from a strip of tissue that was removed from the mantle lobe of an H. Cumingi mussel of about the same age as the one-year-old H. Cumingi into which it will be inserted. Photo by Shigeru Akamatsu.



Figure 11. Just before nucleation, the thin pieces of mantle tissue are rolled as round as possible. Because the piece of mantle tissue is so thin, it can be rolled into a round ball more efficiently than the thicker (2×2 mm) pieces of tissue that were typically used in the past. Photo by Shigeru Akamatsu.

Figure 12. The operator places a one-year-old mussel on a fixing stand and opens the shell with care, making pockets in the posterior mantle lobes and inserting rolled pieces of mantle into them, as illustrated in the diagram (inset). A skilled technician can operate on 120 mussels a day. Photo by Shigeru Akamatsu.



Movement of Mussels Among Different Farms. We observed not only that culturers sold the live, operated mussels for further growth in the farm of another producer, but also that as they recognized deficiencies or changes in the environments of their farms, they often moved their own mussels to more suitable farms. Culturers also have found that the change in farms places the mussels under a type of "stress" that activates their respiration so that they produce more carbon dioxide (Koji Wada, pers. comm., 2001). The carbon dioxide converts to carbonate ions that combine with the calcium ions to form more calcium carbonate crystals. This improves the nacre growth, thus promoting good luster and color, as well as larger pearls.

FWCP CULTIVATION WITH SOLID NUCLEI

Although, as noted above, the vast majority of Chinese FWCPs currently are tissue nucleated, various methods to culture the FWCP by inserting a solid bead nucleus are being practiced ("China producing nucleated rounds," 1995). Use of a bead nucleus is still being done on a limited scale only, because of the higher cost of production and the inferior quality of the pearls produced. According to

Chinese pearl-culturing textbooks (Li and Zhang, 1997; Li, 1997), the main methods used to bead nucleate Chinese FWCPs are as described below.

Insertion of Bead Nuclei into Mantle Pockets. The Chinese textbooks cited above report that pockets are cut into the mantle lobes of large and healthy five- to eight-year-old *H. cumingi* mussels, and the same round shell beads typically used for saltwater pearl culturing are inserted together with pieces of tissue cut from the mantle of another *H. Cumingi* mussel (figure 15). The implantations typically take place from March through May and from September through November, but the latter period yields better results.

The spherical bead nucleus varies from less than 2 mm to over 8 mm, while the piece of mantle tissue usually is smaller than 2×2 mm. For the best product, the size of the piece of tissue must be consistent with the size of the bead nucleus. When the piece of tissue is too large relative to the bead, pearls with a poor shape, wrinkles, or blemishes commonly result. Conversely, according to the textbooks, if the piece of tissue is too small, it can easily separate from the nucleus, resulting in a tissue-nucleated FWCP and the possible expulsion of the bead. The solid nucleus normally is cut from the interior of a Chinese or American freshwater

Figure 14. Shown here is a one-year-old mussel just after a tissue-nucleating operation in July 2000. In accordance with the current practice of this cultivator, 14 pieces of mantle tissue were inserted into the posterior part of each of the two mantle lobes (to produce a total of 28 pearls). In recent years, fewer pieces of mantle tissue have been used to facilitate the production of larger FWCPs. Photo by Shigeru Akamatsu.



Figure 13. Several technicians are simultaneously preparing the mantle tissue and inserting the pieces into the young *H. Cumingi* mussels at this pearl-processing operation in a suburb of Zhuji City. Photo by Li Tajima Zansheng.

mussel (see "The Bead Nucleus" section below), but paraffin wax also is used by some pearl farmers.

When paraffin is used, typically spherical wax beads about 2 mm in diameter are inserted into a mussel (*H. cumingi*) to produce 5–7 mm FWCPs (figure 16). If these cultured pearls are heated when drilled, the liquefied paraffin will ooze out of the drill hole, leaving a small hollow core. Solvents such as bleaching reagents can easily enter such hollow FWCPs, facilitating this processing. Thus, the use of paraffin nuclei has a possible three-fold purpose: (1) produce round pearls, (2) lower the cost of the nucleus, and (3) facilitate processing after harvest.

Modified Direct (or "D") Operation. This method is similar to that used in South Sea and Tahitian pearl cultivation, with the exception that (as noted above)

BEAD NUCLEUS INSERTION

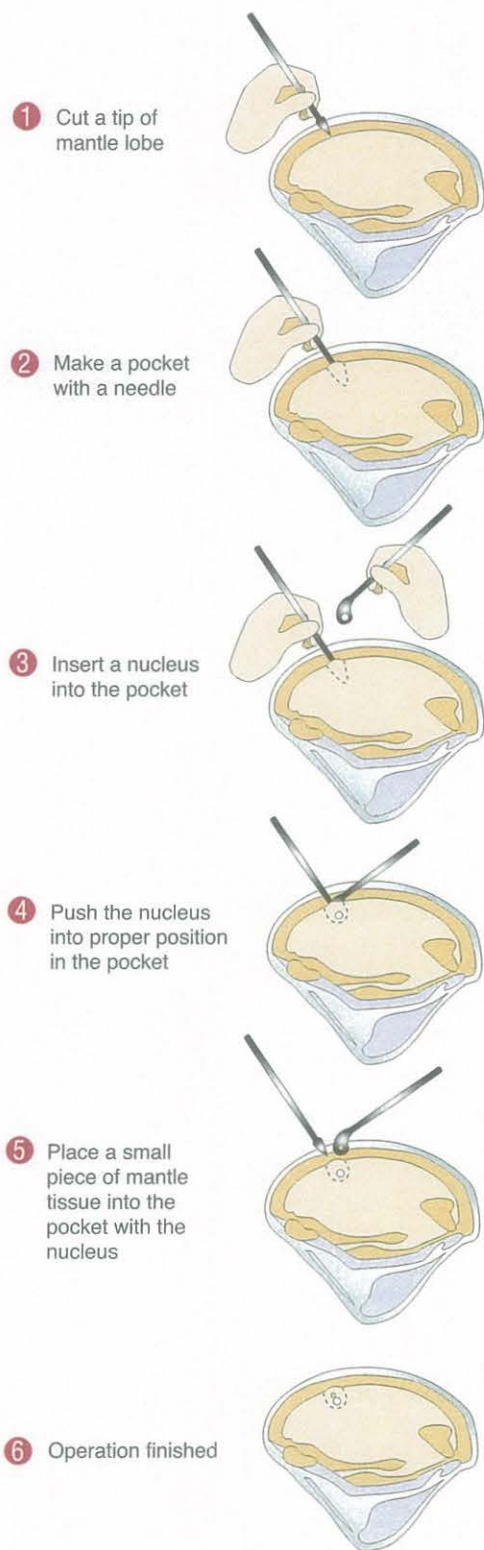


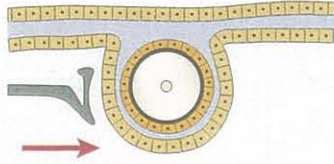
Figure 16. Recently, small paraffin balls also have been used as bead nuclei. When the cultured pearl is heated during drilling, the wax can melt out, leaving a small void that makes treatment easier. The cultured pearls shown here are 5–7 mm in diameter. Photo by Maha Tannous.

the bead nuclei are inserted into the mantle of the host mussel for (freshwater) Chinese cultured pearls, whereas for (saltwater) South Sea and Tahitian cultured pearls the bead is inserted into the gonad. After a mussel nucleated by the usual tissue-insertion operation is harvested, the technicians carefully cut out the FWCPs and then, rather than discarding the animal, they insert a shell bead nucleus into each pearl sac where a tissue-nucleated FWCP had grown (figure 17). With this procedure, there is no need to insert a piece of tissue with the bead nucleus because the pearl sac is already formed. Usually bead nuclei 5–6 mm in diameter are inserted into pearl sacs formed in the mantle lobes, and culturing continues for one to two years. Because at the time of the first harvest the mussel is already a little old, the color and luster of the bead-nucleated pearl produced by this second procedure typically will not be as good as that of the original tissue-nucleated FWCP (Li and Zhang, 1997; Li, 1997). Nevertheless, some attractive pearls have been cultured by this process (figure 18).

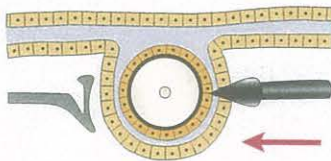
Figure 15. Bead nucleation of Chinese FWCPs usually involves insertion of the bead nucleus together with a piece of mantle tissue into a pocket made in the mantle lobe. Most commonly the beads are fashioned from the shell of a Chinese or American freshwater mussel. Adapted from Li (1997).

BEAD NUCLEATION by DIRECT OPERATION

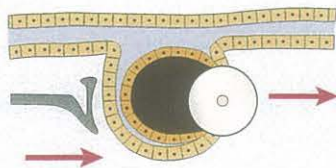
- 1 Place a curved holder on the inner surface of the mantle next to the pearl sac



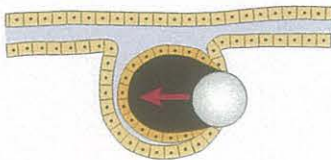
- 2 Cut open the tip of the pearl sac with a bladed needle



- 3 Remove the cultured pearl from the pearl sac by pushing with the curved holder



- 4 Insert a bead nucleus into the new vacant pearl sac and continue cultivation; there is no need for a piece of mantle to accompany the bead because the pearl sac is already formed



- 5 A bead-nucleated pearl is produced

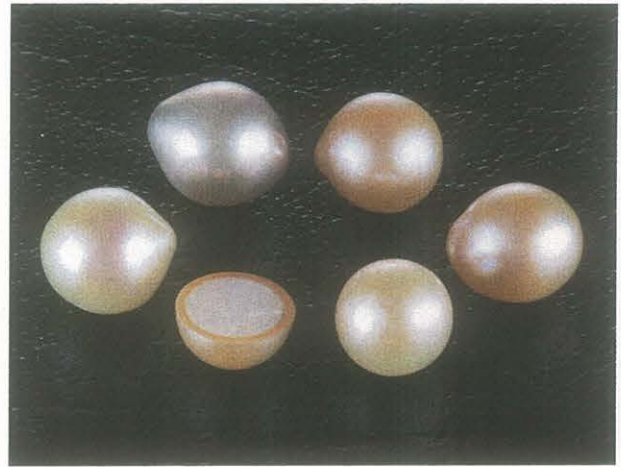
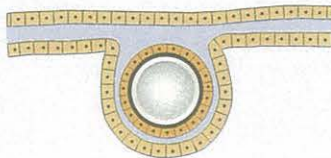


Figure 18. These Chinese FWCPs were bead nucleated by a modified “D” operation. The cross-section is 8 mm in diameter; the whole samples range from 7.5 mm in diameter to 9 × 10 mm. Photo by Maha Tannous.

Insertion of the Bead into the Mussel’s Body. To make FWCPs over 10 mm, relatively large nuclei (8 to 12 mm in diameter) are inserted together with pieces of tissue into the body of the *H. cumingi* mussel—as distinct from the mantle lobes in the bead-nucleation procedure described earlier—usually under the liver and/or the heart (figure 19). This is the same technique currently used to produce Kasumiga freshwater cultured pearls in Japan (Hänni, 2000).

The Bead Nucleus. Japan was once the only country that manufactured shell bead nuclei for pearl culturing, but now China also produces and supplies shell beads to Chinese pearl culturers. By visiting one of the nucleus manufacturers—Theng Xuan An of Penfei Youhezenzhu Co., Zhuji—two of the authors (SA and LTZ) learned about some of the Chinese nuclei. In China today, bead nuclei for saltwater as well as freshwater pearl culturing are fashioned

Figure 17. Some Chinese pearl farmers use a direct (or “D”) operation modified from a similar process used to produce saltwater cultured pearls in the South Seas and Tahiti. After removing the tissue-nucleated FWCP, the technician inserts a shell bead nucleus into the existing pearl sac to grow another pearl. Mantle tissue is not needed in this case because the pearl sac is already formed. Adapted from Li (1997).

BEAD NUCLEATION in MUSSEL BODY

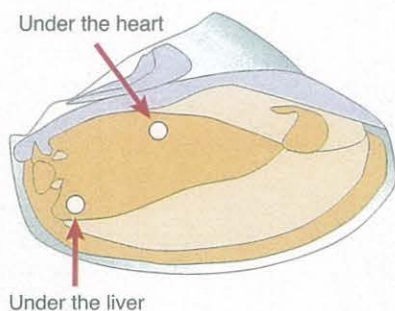


Figure 19. To produce FWCPs over 10 mm, some cultivators insert larger (8–12 mm diameter) but fewer (usually one or two) bead nuclei together with pieces of mantle tissue into the body of the mussel under the liver and/or the heart. Adapted from Li (1997).

from both Chinese and American freshwater mussel shells; Mr. Theng's factory uses the same triangle mussel in which the freshwater pearls are cultured as the shell for beads, too. We are aware that shells cut from other mussels, such as *Lamprotula leai*, are also used for bead cultivation in China (D. Fiske, pers. comm., 2001). To fashion the nuclei (typically 5–7 mm in diameter), Penfei Youhezenzhu Co. uses machines imported from

Figure 20. Commercial round Chinese FWCPs range from 2 mm to over 13 mm. The sizes of tissue-nucleated FWCPs are closely related to the culturing period: 2 mm FWCPs such as the one on the far left can be produced by a culturing period of less than two years, but the 13 mm FWCP on the far right typically requires more than six years. Note also the range of colors and the metallic luster in some of these samples. Photo by Li Tajima Zansheng.



Japan and the same procedure as is used in Japan. These beads are also exported to other pearl-producing countries such as Japan and Tahiti.

Reports in the trade literature have suggested that some bead nuclei are made by grinding tissue-nucleated FWCPs into a round shape (Matlins, 1999; Roskin, 2000). In our visits with a Chinese nucleus manufacturer and numerous pearl cultivators, we found no evidence of the commercial manufacture of such nuclei. Recently, one of the authors (SA) asked a Japanese nucleus manufacturer to fashion such nuclei from tissue-nucleated 10 mm "potato" FWCPs to examine the appearance and potential effectiveness of such a bead. By the usual shell-bead manufacturing procedure, the FWCPs were ground to round. The result was not satisfactory, because the nacre peeled unevenly during grinding to produce a poor sphere.

CHARACTERISTICS OF CHINESE FWCPs

Materials and Methods. As described in the introduction, Chinese FWCPs are distinctive in terms of size, shape, color, and luster. Their internal structure also is unique. To study these characteristics, two of the authors (SA and LTZ) examined approximately 500 sample Chinese FWCPs—ranging from 2 mm to 13 mm (figure 20)—that were selected from the stock (about 100 kg) of Stream Co. These are representative in color and luster of the better-quality cultured pearls being sold in China at this time. The stock was harvested from a few Zhuji and Shaoxing pearl farms in July 2000. The buyers at Stream Co. purchased all of these samples as tissue-nucleated FWCPs; only a few farms in these areas culture bead-nucleated FWCPs.

All of the pearls were examined visually by two of the authors (SA and LTZ). Approximately 50 tissue-nucleated FWCPs were cut in half so that we could examine the internal structure with a loupe.

Structure. Because the vast majority of Chinese FWCPs are tissue nucleated, solid nuclei are not normally seen. Most of the sawn tissue-nucleated FWCP sections showed traces of the tissue nucleus at the center, although in some samples they were difficult to discern (figure 21). For this reason, as discussed in depth in Scarratt et al. (2000), the separation of natural from tissue-nucleated cultured pearls is best done with X-radiography (see Appendix A). The cross-sections of the more strongly colored samples also showed distinct concentric color bands



Figure 21. The evidence of tissue nucleation in Chinese FWCPs can be very subtle. In most of these four tissue-nucleated samples, the nucleus can be seen as a fine line toward the center of the sphere. Because such sawn sections are a highly destructive means of identifying the type of nucleus, and even they may not reveal the necessary evidence (if, for example, the tissue nucleus is slightly off-center), X-radiography is the best method to separate tissue-nucleated cultured pearls from their natural or bead-nucleated counterparts. During cultivation, growth rings of different colors form in some FWCPs. Photo by Shigeru Akamatsu.

between nacreous layers. These bands seem to be related to the same mechanism that produces the various colors observed in the shell nacre of the host *H. cumingi* mussel (figure 22).

Shape. In the past, Chinese FWCPs were typically elongated and wrinkled or pitted (again, see figure 3). Although most Chinese FWCPs continue to be oval or other shapes, the improvements in culturing techniques described above (e.g., the use of younger, thinner pieces of mantle tissue that can be rolled into a ball) have brought a greater number of round and near-round FWCPs to the marketplace (figure 23).

Today, the most popular shapes are round, near-round, oval, button, drop, semi-baroque, and others such as sticks and crosses. This wide variety of shapes is characteristic of FWCPs from sources around the world. The group we examined were specifically selected to be round to near round.

Color. Chinese FWCPs occur in three main hues—white, orange, and purple—all of which were represented in our sample. Combinations of tone and saturation yield a broad range of color appearances (figure 24) from which very attractive and distinc-



Figure 22. When the periostracum (the outer layer of the shell) of the triangle mussel *H. Cumingi* is removed, the beautiful color and luster of the nacre are revealed. Insertion of mantle tissue taken from the posterior of the mussel into the posterior of the live mussel is the key to producing better color and luster. Photo by Shigeru Akamatsu.

tive jewelry has been fashioned (figure 25). Pearl dealers have described some Chinese FWCPs as "wine," "cognac," "lavender" (figure 26), "blueberry," and "apricot." This color range is believed to be associated with: (1) the color of the mother-of-pearl in the donor mussel from which the piece of mantle tissue was taken, (2) the environmental conditions of the culturing farm, and/or (3) the age

Figure 23. The new tissue-nucleation techniques being used in China have led to a greater number of round freshwater cultured pearls in the marketplace. Photo by Shigeru Akamatsu.

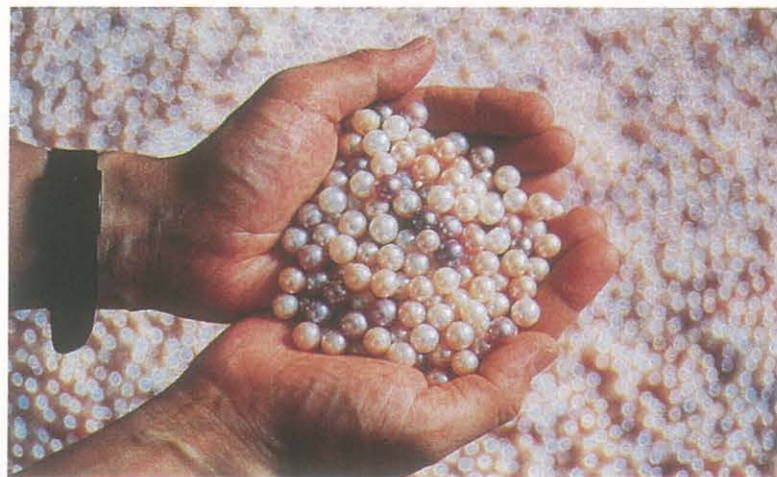
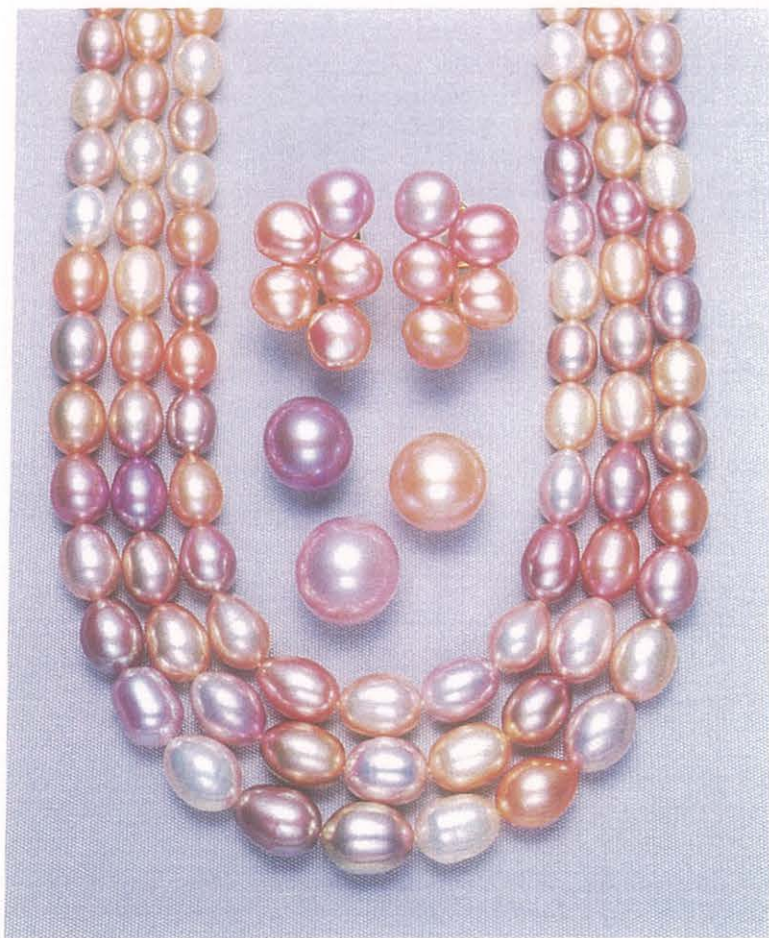




Figure 24. Chinese FWCPs occur in different tones, saturations, and combinations of white, orange, and purple. Photo by Li Tajima Zansheng.

Figure 25. This contemporary jewelry takes advantage of the combination of unusual colors offered by Chinese FWCPs. Jewelry courtesy of Stream Co.; photo © A. Takagi/Bexem Co. Ltd.



of the host mussel. The first of these probably has the greatest effect on the color of an individual FWCP (Li and Zhang, 1997).

Luster. Our sample Chinese FWCPs demonstrated a wide range of luster, from dull and chalky to metallic. On the basis of on-site investigations and interviews with several cultivators in Shaoxing, two of the authors (SA and LTZ) concluded that the following four factors can influence the luster of Chinese FWCPs:

- The nature of the piece of mantle tissue used
- The location in the mussel where the tissue piece is inserted
- The age of the mussel that has been nucleated
- The environmental conditions of the culturing farm

As an example of this last item, experienced cultivators know that the water quality at Shaoxing pearl farms is different from that of pearl farms along the Chang Jiang River.

Pearl farmers carefully choose mussels with shell nacre that shows good luster as the source of the mantle tissue to be used in the nucleation process. As noted above, to achieve the best luster (and color), the technicians insert the pieces of tissue into the posterior of the mantle lobe. This region of the mantle also experiences the most growth. A young mussel bears lustrous pearls, but as it becomes older (more than five or six years), the luster of the pearl gradually decreases as its size increases. Pearl culturers claim that the water quality (probably the difference in mineral content) of their farms is the key to producing pearls with a shiny metallic luster, but that regardless of the farm the metallic luster will disappear if the cultured pearl is left in a mussel that is more than five or six years old.

In addition to these four factors, the mussel species itself will affect pearl luster. Pearls with very fine luster are produced when the pieces of mantle tissue are cut from the mantle of a *C. plicata* and inserted into the mantle of an *H. cumingi*. However, almost all of the pearls produced with this combination have heavy surface wrinkles.

CONCLUSION

Annual production of freshwater cultured pearls in China is estimated at about 1,000 tons, with approximately 650 tons usable in the jewelry trade. However, the present expansion of cultivation indicates a sub-

stantial increase within the next two or three years. Although more high-quality FWCPs are being produced as cultivation methods improve, most of the Chinese FWCPs are still of moderate to low quality.

The improvements in size, shape, surface condition, luster, and color seen in recent years are the result of many advances in the culturing materials and techniques used. These include changing mussel species from *C. plicata* to *H. cumingi*, nucleation of younger (one-year-old) mussels, improvement in the tissue nucleation (rolling a thinner piece of mantle into a round shape and inserting fewer pieces into the host mussel), a relatively longer culturing period, and a frequent change of culturing farms.

Bead-nucleation techniques also are being developed, but our experience indicates that bead-nucleated FWCPs continue to represent a very small percentage of the total production in China. This appears to be due to the technical difficulties and culturing costs involved. For example, bead nucleation doubles the labor required because both a bead *and* a piece of tissue must be inserted into the pocket, whereas tissue nucleation requires only a single action to insert the piece of tissue. In any event, as discussed in Appendix A, the separation of bead-nucleated from tissue-nucleated cultured pearls, and of the tissue-nucleated product from its natural counterparts, is readily accomplished with contemporary X-radiography techniques.

While this information represents the study of several pearl operations and hundreds of FWCPs, the fact that China has many thousands of pearl farms and produces tons of cultured pearls annually makes it impossible to provide a complete story. We believe, however, that the information we have provided is representative of the Chinese product seen in the market today and that the new nucleation and culturing techniques promise an even better product in the future.

ABOUT THE AUTHORS

Mr. Akamatsu is former manager of the Pearl Research Laboratory and currently general manager of the Sales Promotion Department, K. Mikimoto & Co. Ltd., Tokyo, Japan. Mr. Li, who started his Chinese freshwater cultured pearl business in 1985, is president of Stream Co., Tokyo and Hong Kong; in 1998, he established a pearl-processing operation in Zhuji City, China. Mr. Scarratt is laboratory director at the AGTA Gemological Testing Center, New York; and Mr. Moses is vice president of Identification Services at the GIA Gem Trade Laboratory, New York.

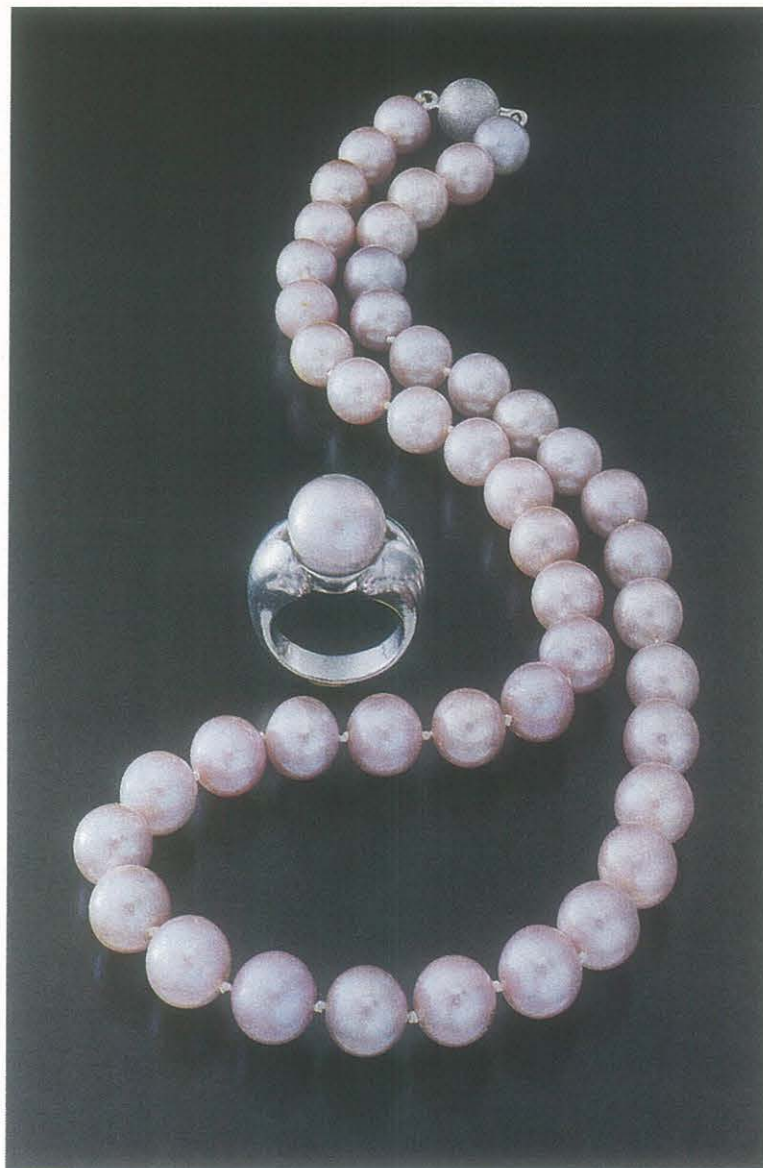


Figure 26. Lavender is one of the distinctive colors in which Chinese FWCPs occur. The rounds in the strand are approximately 9.5 mm in diameter; the cultured pearl in the ring is 12.3 mm. Photo © Harold & Erica Van Pelt.

ACKNOWLEDGMENTS

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APPENDIX A: IDENTIFYING CHINESE FRESHWATER CULTURED PEARLS BY X-RADIOGRAPHY

Cultured pearls form a significant portion of all gem materials traded. Yet the one nondestructive method that can be used to identify the growth technique or separate cultured from natural pearls—X-radiography—is available only to a limited number of gemologists who have access to the necessary equipment. Nevertheless, it is important that all gemologists understand the principles behind X-radiography and its capabilities in pearl identification. While the general method and operating procedures have been published by, for example, Webster (1994) and Kennedy (1998), this box provides specific information regarding the use of X-radiography in the identification of freshwater cultured pearls (FWCPs) grown by a variety of techniques in China. The information is based on the experience of two of the authors (TMM and KS) with taking and interpreting tens of thousands of pearl X-radiographs over the last two decades, many of which were of Chinese FWCPs.

Pearl Structure. Both natural and cultured freshwater pearls are formed of concentric layers, of variable thickness, that are comprised of aragonite and/or calcite along with some organic matter. As the pearl grows, more organic matter may be accumulated during one period than another, as seen in figure A-1. Some pearls—natural or cultured by tissue nucleation—have a growth structure similar to that between points A and B in figure A-1, whereas others have one similar to that between points B and C throughout. Most Chinese freshwater cultured pearls (FWCPs) that are nucleated only with tissue also contain a characteristically shaped cavity near their center. If such samples are sawn adjacent to this cavity, it may reveal itself only as a fine line (figure A-2). For a more complete explanation of the growth structure of pearls, see chapter 22 of Webster (1994).

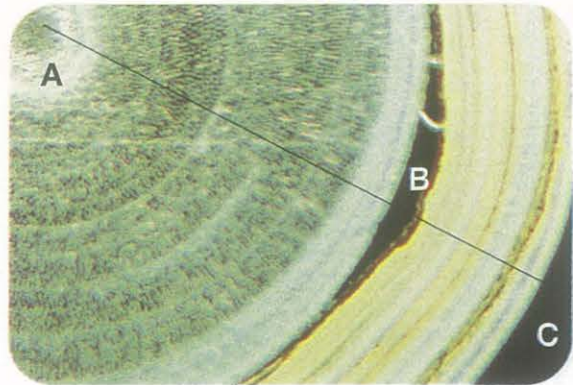
To better understand the identification criteria discussed below, it is important to note the less obvious organic layers between points B and C in figure A-1, as well as the obvious ones. Note also the concentric growth between A and B in figure A-1, and the structures in figure A-2.

X-radiography Equipment. For more than 70 years, X-radiography has formed the backbone of pearl identification. Fortunately for the industry, there are a number (albeit limited) of gemologists with extensive experience in producing and interpreting X-radiographs. Although pearl X-ray units have gone through many incarnations, today there are several industrial units that are well suited to perform the tasks required for Chinese FWCP identification.

While we recognize that the latest digital or similar X-radiography units give the user a degree of convenience, it is the experience of these authors (TMM and KS) that the identification of Chinese FWCPs requires a resolution that at this time is available only through the use of very fine-grain X-ray film—wet radiography. The instruments used by the authors are Faxitron models 43855B and 43856A. These air-cooled units are powered by normal electrical outlets, have variable kV and mA control, and offer an extended timed exposure capability. The distance between the X-ray tube target and the sample is adjusted by moving the shelving under the pearls.

Procedures. The samples should be placed in direct contact with a sheet of high-resolution fine-grain industrial X-ray film; the film and the as-yet-unidentified pearls are then placed in a position—and at a distance—that will allow all the samples to be contained within the X-ray beam (figure A-3). Next, depending first on the size of the pearls, X-rays are generated for a specifically timed exposure at predetermined kV and mA settings. Then, based on the internal structures observed in the resulting X-radiograph, the technician may increase or decrease the

Figure A-1. In this thin section of a natural freshwater pearl, the center of the pearl is located at the top left (A). Note the various stages of growth along the line A-B-C. Between A and B is an evenly deposited arrangement of concentric layers, inside of which are radially arranged crystals. At B the structure abruptly changes, with a large organically lined void that is followed by several yellow and dark, mostly organic, layers interspersed with the more crystalline (gray) layers toward the edge of the pearl (C).



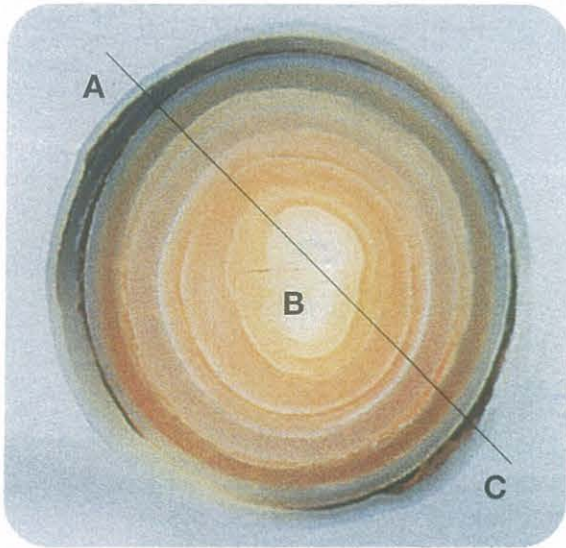


Figure A-2. In this sawn half of a known tissue-nucleated cultured pearl, the slight dark line in the center (at B) is the only visual evidence of the tissue implant. Note, however, as in figure A-1 the varying amounts of organic material (dark) associated with the concentric growth structures.

exposure times, target-to-pearl distances, and kV and mA settings.

All X-radiographs are normally examined at magnifications between 2× and 10× (hence the need for fine-grained film) using a variety of back-illumination techniques. The X-radiograph may show one or more of the following features, depending on the nature of the sample:

1. *If the sample was a coherent solid composed of aragonite or calcite, without any organic matter:* The image would be simply an opaque white disc against a black background. That is, the aragonite or calcite would have absorbed the X-rays and left the film immediately below it unexposed (white), whereas the remainder of the film would have been fully exposed and thus black when processed. This is how the shell bead portion of a bead-nucleated cultured pearl would look, and is not uncommon for a non-nacreous (e.g., conch) "pearl."
2. *If the sample was aragonite or calcite with internal organic material or voids:* The image would reflect the difference in the ability of the X-rays to pass through the aragonite or calcite, the organic material, and any voids present. Organic layers and voids pass X-rays more readily than calcium carbonate does, so they reveal themselves on the processed X-ray film as dark gray to black lines or shapes set against the white background of the cal-

cium carbonate. If voids are present, the contrast between these and the calcium carbonate generally will be greater than that for organic material.

If one takes the more familiar example of a human bone contained within the flesh of the human body, a similar principle applies. The human bone absorbs the X-rays more than the flesh that surrounds it and thus stands out clearly as "white" against the gray to black areas that comprise the flesh (organic). In addition, any fractures or fissures in the bone (voids) will appear black on the processed film.

Once the initial observations have been completed, the technician takes additional X-radiographs, now optimized for the suspected type of pearl—natural, cultured (bead or tissue nucleated), etc.—being examined, in several different directions, to provide images that can be interpreted as characteristic of the sample in three dimensions.

The scattering of X-rays as they pass through and around a pearl may at times reduce the quality of the image. Two techniques that the authors have found to be successful in absorbing the scattered X-rays (and thus enhancing the image) are: (1) for necklaces, immersing the pearls in a scatter-reducing fluid; and (2) for single pearls, surrounding the sides of the sample with a thin layer of lead foil.

Characteristics of Tissue-Nucleated and Bead-Nucleated Chinese FWCPs. X-radiographs of tissue-nucleated FWCPs will show features that depend to some extent on when they were grown. "Rice Krispie" tissue-nucleated Chinese FWCPs grown in the 1970s typically have somewhat twisted internal organic structures and voids (figure A-4, left). X-radiographs of more recently grown tissue-nucleated Chinese FWCPs—with

Figure A-3. The samples (here, a baroque strand ranging from 12.0 × 9.15 to 15.20 × 11.15 mm) are placed on the film immediately below the X-ray beam in the Faxitron unit. Photo by E. Schrader.



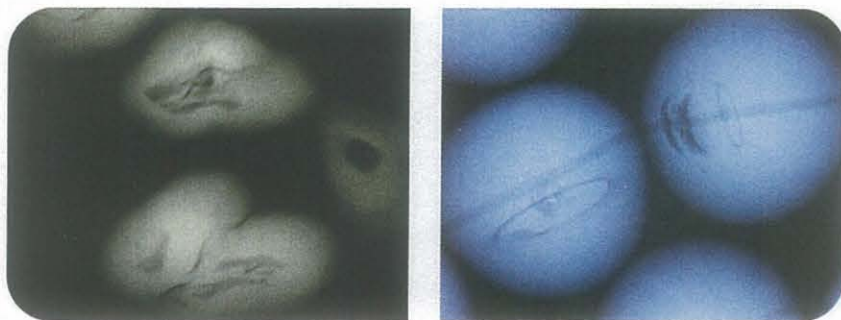


Figure A-4. The dark gray “twisted” structures shown on the left are typical of the tissue-nucleated Chinese FWCPs produced in the 1970s. In the X-radiograph on the right of more recent FWCPs, ovoids mark the original tissue implant.

their characteristic implant lines—were published by Scarratt et al. (2000; figure A-4, right). In both cases, the X-radiographs are totally unlike those of either natural pearls (figure A-5) or of cultured pearls produced from a shell bead nucleus.

The X-radiographs of shell bead-nucleated Chinese FWCPs resemble those of shell bead-nucleated saltwater cultured pearls (figure A-6). Centrally located beads with no internal growth structures are separated from the nacre overgrowth by a layer that is mostly organic. Any possible confusion with tissue-nucleated FWCPs caused by dark areas on the X-radiograph inside the area of the central bead would be dispelled by X-radiographs taken in other directions.

The X-radiographs of wax bead-nucleated Chinese FWCPs also show characteristic features (figure A-7). Each contains a nearly circular central area that is black or dark gray. Additional layers are defined by fine black concentric growth structures within the white crystalline areas of the Chinese FWCP (which are not visible in figure A-7). There are similarities between the X-radiographic struc-

tures seen in this type of Chinese FWCP and those sometimes observed in natural pearls. However, natural pearls differ from Chinese FWCPs in that they show additional structures within the central area.

The short descriptions given here about the equipment needed, procedures, and expected results must be supplemented by operator experience—the most important element.

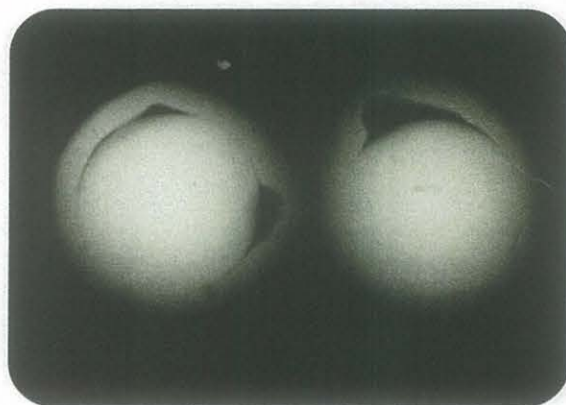


Figure A-6. This radiographic image of shell bead-nucleated Chinese freshwater cultured pearls is typical of the images seen for this product.

Figure A-5. Natural pearls typically do not show evidence of a nucleus, only the structures that indicate organic matter or voids. Note also the concentric rings throughout this pearl.

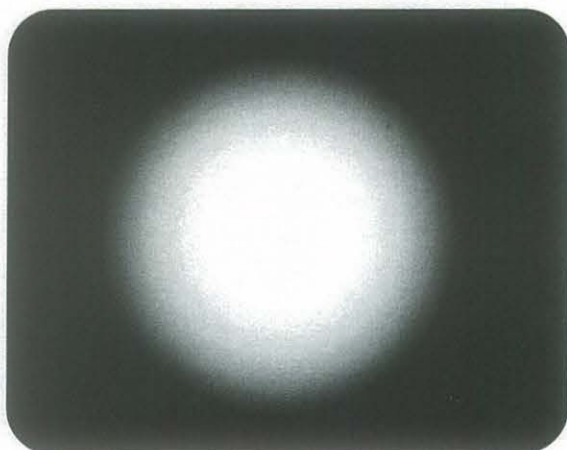
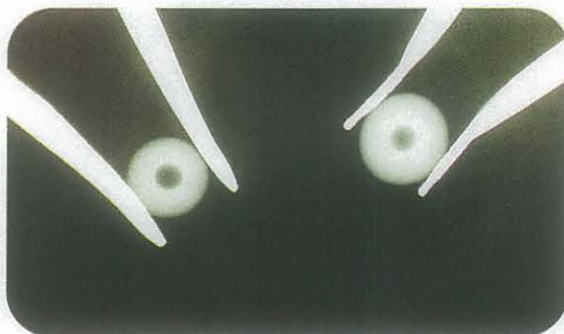
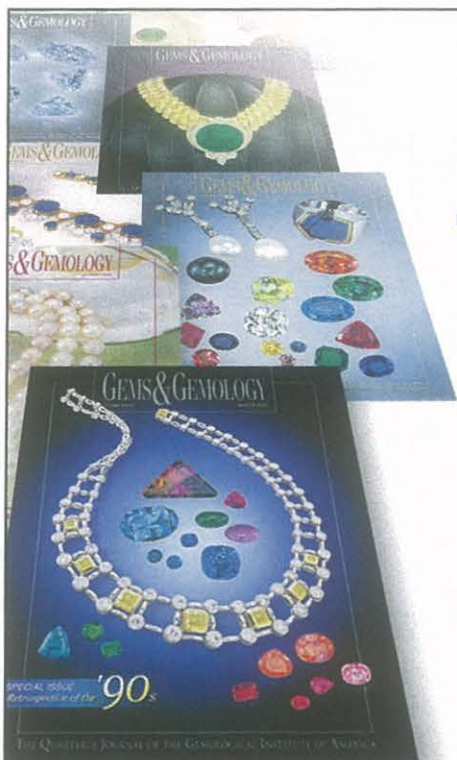


Figure A-7. Recently produced wax bead-nucleated Chinese FWCPs have the characteristic radiographic structures shown here.



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