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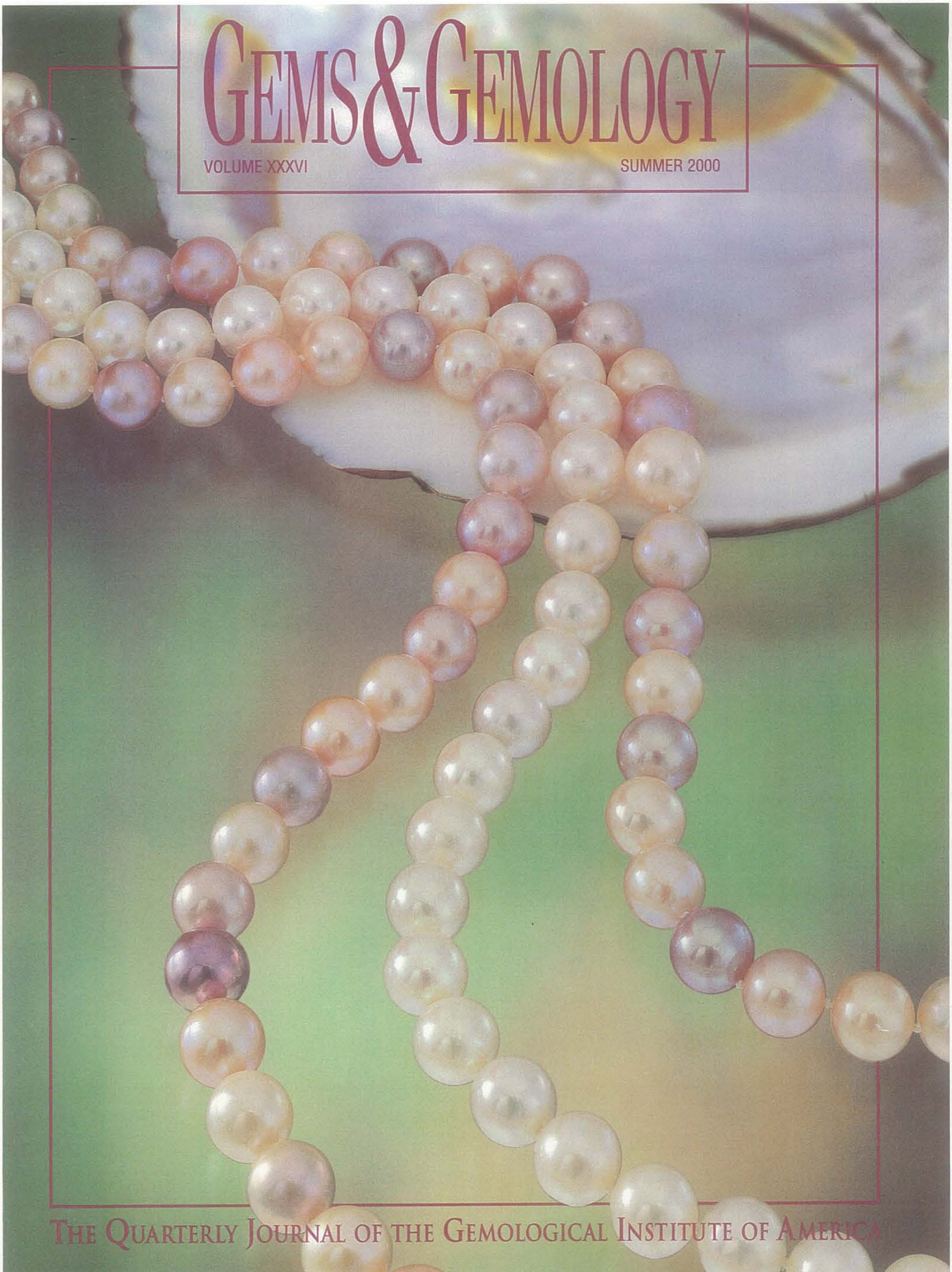

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CHARACTERISTICS OF NUCLEI IN CHINESE FRESHWATER CULTURED PEARLS

By Kenneth Scarratt, Thomas M. Moses, and Shigeru Akamatsu

*There has been considerable debate in the gem trade concerning the nucleation procedures being used to grow large round Chinese freshwater cultured pearls (FWCPs). Of particular concern are claims that most of these cultured pearls are nucleated by reject mantle-tissue-nucleated FWCPs, and that such a product would be difficult to separate from normal tissue-nucleated cultured pearls and in some cases from natural pearls. However, field research indicates that many Chinese growers are currently using larger mussels (*Hyriopsis cumingi*), combined with new tissue-insertion techniques, to grow larger, better-shaped FWCPs. For this study, X-radiographs of approximately 41,000 Chinese freshwater cultured pearls from dozens of farms were examined, and 10 samples were sectioned. All showed evidence of mantle tissue nucleation only; the presence of a bead, whether shell or a tissue-nucleated FWCP, would be identifiable by distinctive features seen in the X-radiograph.*

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Please see acknowledgments at the end of the article.

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China is producing an estimated 600 to 1,000+ metric tons of freshwater cultured pearls (FWCPs) annually, of which totally round FWCPs larger than 8 mm represent a fraction of a percentage point ("China starts pearling revolution," 2000; Xie Shaohe, pers. comm., June 2000). Typically, Chinese FWCPs are tissue nucleated; that is, they are composed almost entirely of nacre, without the internal bead used to produce saltwater cultured pearls. However, since the appearance over the past several years of large (10+ mm) near-spherical freshwater cultured pearls from China, in a variety of colors (see cover and figure 1), the trade has been rife with rumors about how they are grown. Pearl dealers, industry authors, and some gemologists have suggested that the implant made to grow these cultured pearls is more than tissue alone.

Most recently, articles in the trade press (see, e.g., Matlins, 1999–2000a and b, 2000; Ward, 2000) have claimed that the vast majority of large FWCPs currently being described as "non-nucleated" *are* bead nucleated, with the largest sizes obtained by multiple insertions and reinsertions of nuclei formed from low-quality, all-nacre freshwater cultured pearls. The main concerns expressed in these publications have been that cultured pearls produced in such a manner require shorter growing times than are typically claimed for tissue-nucleated FWCPs, and that they are indistinguishable from normal tissue-nucleated cultured pearls—and in some cases from natural pearls—on X-radiographs. Similar claims about the reuse of tissue-nucleated FWCPs to produce large round FWCPs in China have also appeared in the professional literature (Rinaudo et al., 1999).

Matlins based her assertions on an examination of two Chinese FWCPs that had been sawn in half (A. Matlins, pers. comm., February 2000). However, neither these specific samples, nor descriptive photographs or X-radiographs of them, have yet been made publicly available. Ward's most

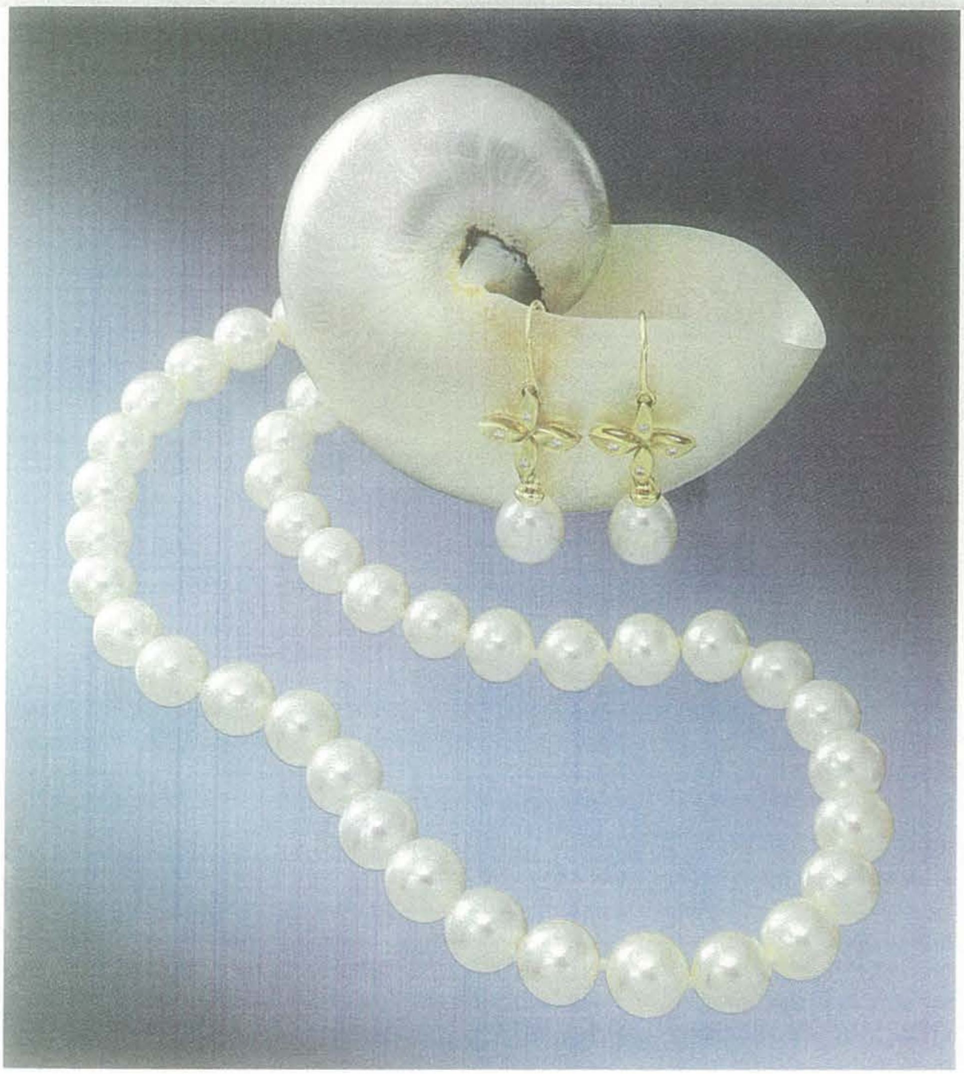


Figure 1. Attractive large, round Chinese freshwater cultured pearls have entered the gem market in recent years. These 9–10 mm Chinese mantle tissue–nucleated FWCPs are courtesy of Honora, New York. Photo © Harold & Erica Van Pelt.

recent analysis of the situation is based largely on his observations of changes in the Chinese product and on interviews with a number of pearl dealers (Ward, 2000). Following their introductory statements about the use of tissue-nucleated cultured pearls as nuclei in large round Chinese FWCPs, Rinaudo and her colleagues used a number of sophisticated techniques to study a strand of Chinese FWCPs. However, their paper does not present a clear conclusion with regard to the nucleation process determined for these samples.

The present study was conducted to address these issues and provide a better understanding of the identification of tissue-nucleated cultured pearls. Accordingly, this article: (1) reports on how Chinese FWCPs have been produced in the past, (2) describes new techniques being used to cultivate freshwater pearls in China, (3) investigates the possible use of rounded tissue-nucleated cultured pearls as the nuclei for Chinese FWCPs currently in the U.S. market, and (4) discusses whether such bead-nucleated cultured pearls could be identified nondestructively by X-radiography.

THE NUCLEATION OF FRESHWATER CULTURED PEARLS IN CHINA

Historical Background. Kunz and Stevenson (1908) reported that bead-nucleated freshwater cultured pearls were being produced in China at least as early as 1900, with cultured blister pearls widespread in the 13th century. We have seen samples of almost-whole Chinese FWCPs with shell bead nuclei that date back to the 18th century (figure 2). It is interesting to note that the bead nuclei shown in figure 2 were inserted into the mollusk together and connected by a fine thread. Carl V. Linne used a similar method in Sweden in 1761 (Webster, 1994), but he employed a "T" shaped metal holder to help keep the shell beads away from the shell itself in order to obtain near-whole cultured pearls (figure 3).

Commercial freshwater pearl cultivation in China, however, dates back only to the late 1960s and early 1970s, when tremendous quantities of small, irregularly shaped "rice" or "Rice Krispie" FWCPs entered the market. Although these "Rice Krispie" cultured pearls dominated Chinese production through the 1980s—in 1984, for example, 49

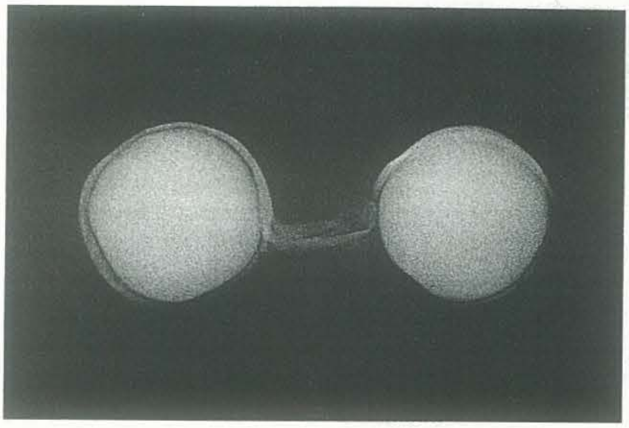
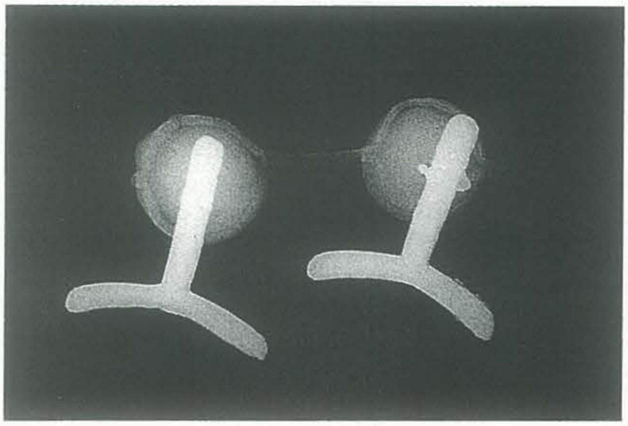


Figure 2. This X-radiograph shows two cultured pearls that were grown with a shell bead nucleus by the Chinese in the 18th century. The bead nuclei appear as opaque white spheres that are separated from the nacre overgrowth by a black line corresponding to an organic layer. Note the narrow nacre-coated thread that passes over the top of the bead on the right (inside the cultured pearl) and joins it to the cultured pearl on the left. Specimen recovered by Fred Woodwood from British Museum (Natural History) surplus.

tons were imported into Japan alone—eventually Chinese pearl farmers began to realize the importance of quality as well as quantity. Gradual changes in technology and, most importantly, in the mussel used, resulted in the production of greater quantities of larger and more lustrous round, near-round, and baroque cultured pearls in a variety of colors.

Figure 3. This X-radiograph of pearls cultured by Carl V. Linne in 1761 reveals two shell beads that are strung together with thread (as in the Chinese example in figure 2). The cultured pearls are separated from the shell surface by two T- shaped metal posts. In this manner, Linne produced cultured pearls that were almost entirely coated with nacre. Specimen loaned to Fred Woodwood by the Linaeus Society, London.



Current Practices. Saltwater cultured pearls are grown by the insertion of a bead with a piece of mantle tissue (to provide the epithelial cells that produce nacre) into the gonad of the oyster. However, Chinese "rice" pearls and their successors typically have been grown by nucleation with mantle tissue only in the mantle of the mussel.

Tissue Nucleation. The basic technique used today is similar to that described by Crowningshield (1962) for Japanese tissue-nucleated cultured pearls and observed by one of the authors (KS) in 1989 during a visit to a pearl-culturing farm in Yangxin, China, about 170 km southwest of Wuhan (Jobbins and Scarratt, 1990). At Yangxin, the parent mussel, then *Cristaria plicata*, was subjected to culturing when it reached 8 cm long. Some mussels were sacrificed for their mantle tissue: A strip (or graft) approximately 1.5 to 2 cm wide was taken from the outer edge of the mantle, and then sliced lengthwise and crosswise to make numerous pieces of flat tissue, each about 1 mm square (figure 4). At that time, 40 "squares" of tissue were inserted into the mantle of each host mussel, yielding 40 cultured pearls (figure 5). (Typically, only one bead is inserted into the gonad of a saltwater oyster.)

Co-author KS has identified three significant improvements made in the quality of the Chinese FWCP over the last several years: surface smoothness, roundness of shape, and size. The first, improving surface quality, was accomplished by changing from the *C. plicata* mussel (which, though abundant and easy to grow quickly, produces a cultured pearl with many wrinkles and other surface irregularities) to the *Hyriopsis cumingi* (figure 6). Also known as the "triangle mussel" (*san jiao bang* in Chinese) because of its shape, this mollusk yields a better product with a very smooth surface.

The second improvement, production of a more spherical cultured pearl, required the development of a new insertion technique. Although it is difficult to generalize about pearl culturing in China, because there are literally hundreds of small independent farms, one of the authors (SA) has observed a number of changes during his visits to Chinese pearl farms in recent years. One of these is the use of newly modified tissue. Some farms are using larger and thicker pieces of mantle tissue (about 4 mm × 4 mm) from sacrificed *H. cumingi* mollusks. They

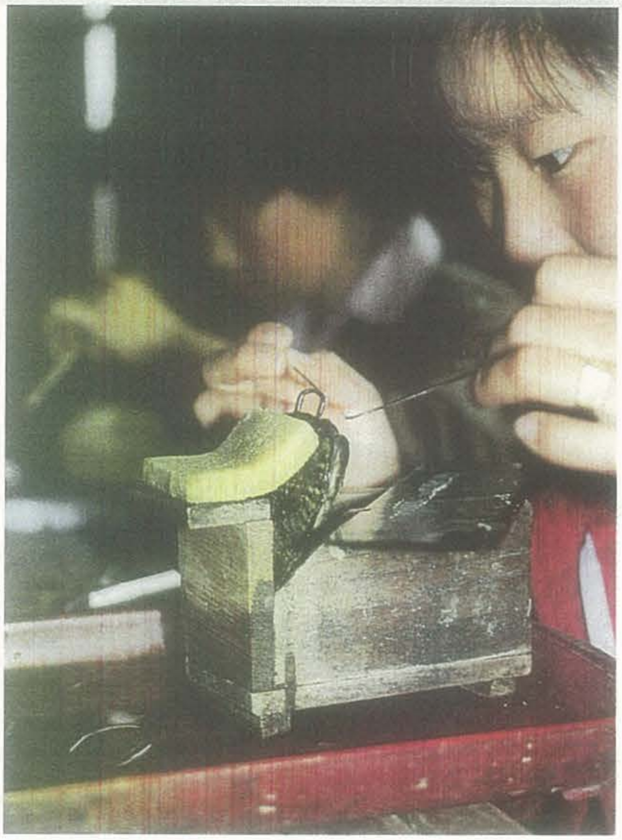


Figure 4. The basic tissue-nucleation technique involves slicing a strip of mantle tissue into small squares (shown here on the glass slide below the left hand of the operator) and then carefully inserting them into the mantle of a mussel. This photo was taken at a pearl culturing farm in Yangxin, China, in 1989 by Kenneth Scarratt.

roll the tissue into a round shape and then place it in a mantle pocket, thus facilitating the cultivation of a round pearl. Mr. Yip of Evergreen Pearls Co. Ltd. has also stated (Sheung, 1999) that the new culturing techniques use fewer but larger ("the size of a soya bean") mantle-tissue nuclei.

The third improvement, in size, was accomplished with a longer cultivation period and the use of younger mussels. In the case of an 8 mm FWCP, at least six years are needed. When the pearl cultivator starts tissue nucleation with a larger mussel, it will grow too old to produce a large pearl during the cultivation period required. Therefore, many pearl farmers have changed to using younger (about one and a half years old) mussels as hosts. The FWCPs grow larger along with their hosts.

Another factor, though probably unintentional, in the greater size of the Chinese FWCPs is the move from one pearl farm to another during cultivation. It takes approximately two years to cultivate a 4 mm tissue-nucleated pearl and, as noted above, at least six years for one over 8 mm. In need of funds to pay double-digit interest rates, one farmer will sell his four-year-old, six-year-old, or even older mussels to another farmer, who will move them to his lake or pond for further growth (and larger product). In some cases, the second farmer will resell them to a third. The change in environment (e.g., water temperature and water conditions) stimulates the mussels, causing them to secrete more nacre. The change in environments may also have some impact on the internal growth structure of these cultured pearls, such as changes in color from growth in one pond to growth in another.

Figure 5. This C. plicata *mussel at the Yangxin farm yielded several near-spherical cultured pearls during the 1989 visit. Photo by Kenneth Scarratt.*

Bead Nucleation. Although considerable research has been done into bead nucleation of freshwater cultured pearls in China, historically there have been difficulties with rejection of the bead (Crowningshield, 1962) and high mussel mortality.

Figure 6. The use of the Hyriopsis cumingi, *or "triangle," mussel by Chinese farmers in recent years has contributed to the cultivation of larger freshwater cultured pearls with better surface quality.*

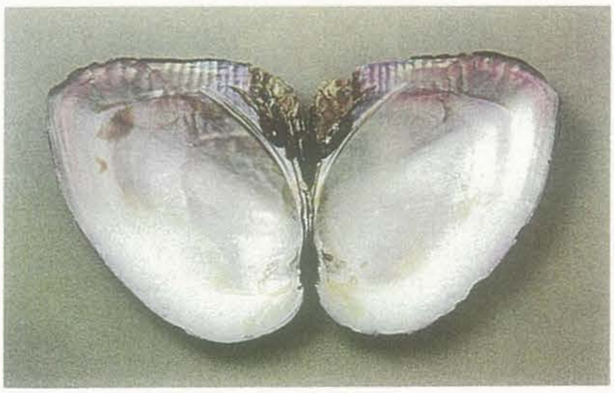


Figure 7. These round Chinese freshwater cultured pearls are representative of the samples examined for this study. The largest white FWCPs shown are 10–11 mm in diameter. Photo by Elizabeth Schrader.

One of the authors (KS) observed first-hand the problems associated with bead nucleation of FWCPs at a pearl farm on the banks of Ho Tay in Hanoi, Vietnam, in 1992 (Bosshart et al., 1993). In the procedure used, a freshwater shell bead was implanted along with a piece of mantle tissue into the mantle of *C. plicata* mollusks. Although the success rate was said to be three nucleated, nacre-coated pearls out of every six to eight beads implanted, X-radiographs of 15 FWCPs obtained at the time of the visit revealed a bead nucleus in only two of the samples (see X-radiographs published in Bosshart et al., 1993). The remainder were grown from the tissue implanted at the same time as the bead (tissue nucleated), which indicates that the beads had been ejected early in the 18 to 24 month growth period.

In recent years, however, at least one large Chinese cultivator is said to have been successful with bead-nucleated freshwater pearls: Xie Shaohe of Shaohe Pearl in Chenghai, Guangdong Province ("China producing nucleated rounds," 1995; "China starts pearling revolution," 2000). In 1998, Doug Fiske of GIA Education visited one of Mr. Xie's pearl-culturing farms during the preparation of the new GIA Pearls course. He observed that, in three-year-old *H. Cumingi* mussels that measured about 12 cm (4.7 inches) from dorsal to ventral edge, nucleators inserted pieces of mantle tissue along with two to four round shell beads (up to 6 mm) in the mantle of each valve (D. Fiske, pers. comm., March 2000). Mr. Xie, a marine biologist, claimed that much of his early success was due to the development of exceptionally strong mussels and carefully choosing the size of the bead ("China producing nucleated rounds," 1995).

Mr. Xie was interviewed by Dr. Taijin Lu of GIA Research in late June 2000, at which time Mr. Xie confirmed that he was producing "a few hundred kilograms" annually of freshwater bead-nucleated cultured pearls, a very small portion of which are 10+ mm round FWCPs. He explained that approximately four to eight small shell beads (*not* reject tissue-nucleated FWCPs) are inserted into the outer (mantle) portion of the animal, with a single large (over 8 mm) bead inserted deep into the inner portion. The bead-culturing process takes approximately five to seven years: three to four years to grow the mussels, and two to three years to cultivate the pearls. The maximum size he produces is 14–15 mm. The nacre thickness ranges from 0.5–2.0 mm. The mortality of the mussel with bead nucleation continues to be a problem. Also, he estimates a bead rejection rate of about 20%, although James Peach of the United States Pearl Company feels the rejection rate for some bead nucleation operations could exceed 50% (pers. comm., 2000). In his conversation with Dr. Lu, Mr. Xie confirmed that most of his product was sold within China, although the largest, highest-quality pearls are distributed through a Hong Kong company, which we believe to be Man Sang Jewellery Company. Man Sang indicated that they do distribute "Shaohe pearls," but neither they nor Mr. Xie were able to provide any samples for our research.

MATERIALS AND METHODS

For this study, two of the authors (KS and TM) borrowed 791 strands (in traditional hank lengths) of Chinese FWCPs from the New York-based company Honora, which specializes in the Chinese product. These cultured pearls were represented to be recent production from dozens of farms in China. We also purchased two strands of 8 mm Chinese FWCPs, and individual larger samples, for possible destructive testing. In total, we examined approximately 41,000 Chinese-grown FWCPs. A variety of shapes and colors were included, in sizes ranging from 4 to 11 mm (see figure 7 and table 1). Thus, the samples included both the larger cultured pearls that are claimed to be bead nucleated, and the smaller ones that could be used as nuclei. All were believed to be tissue nucleated.

We studied all of these samples by X-radiography, using the standard technique: First, the cultured pearls were placed in close contact with a fine-grained X-ray sensitive film and exposed to a beam of X-rays generated by a Faxitron X-ray unit for 20 to 30 seconds at 80 to 90 kV and 3 ma. Then the X-radiographs were examined at 10× magnification with various types of background lighting to ensure that no details were missed. Darker areas on X-radiographs represent greater exposure of the film to X-rays. In cultured pearls, such dark areas correspond to cavities or organic material, because these more easily allow passage of the X-rays than the crystalline aragonite or calcite of which the nacre is composed.

Ten Chinese FWCPs (8–12 mm) were sawn in half with a standard rotary gemstone saw. Each half was examined with a gemological microscope and various lighting techniques.

To supplement this research, KS and TM reviewed their previous records of pearls examined over the past 25 years, placing particular emphasis on those from the past six years.

TABLE 1. Chinese freshwater cultured pearls studied for this report.

	Number of strands	Size (mm)
	16	10–11
	2	8
	129	7–8
	81	6.5+
	56	6–6.5
	322	5.5–6
	187	4–4.5
Total:	793	

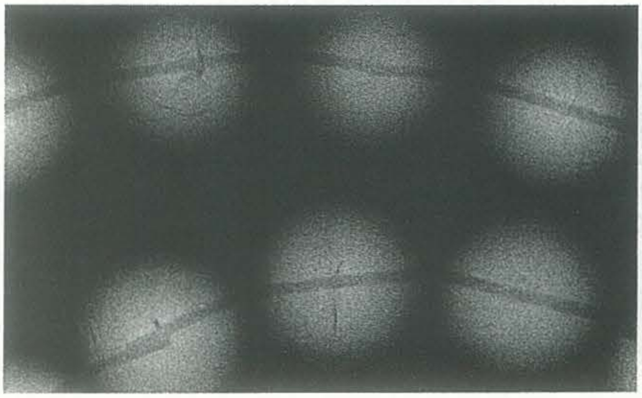
RESULTS

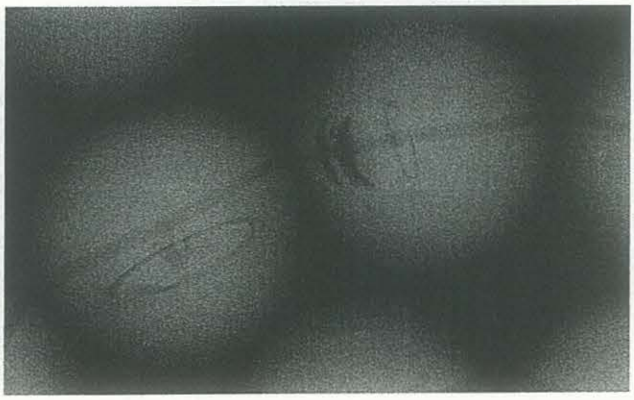
X-Radiography. Accurate interpretation of pearl X-radiographs requires considerable expertise. It is important to understand that while the image is two-dimensional, the structures seen actually occur at varying depths within the pearl. Several X-radiographs are commonly taken of a given sample to gain a three-dimensional "picture" of the interior from different angles. Therefore, we have used line drawings to illustrate some of the features seen in the X-radiographs.

The X-radiographs in figures 8–11 are typical of the Chinese FWCPs in our sample. The gray tube-like features that run through each sample and are aligned along the strand are drill holes. Also visible in each sample is a faint gray shadow that starts at the rim and diminishes in intensity as it approaches the center; these should be ignored, as they are aberrations of the printing process (they are not on the original X-radiographs). Relevant growth structures are discussed below and in the figure legends.

All tissue-nucleated cultured pearls contain a characteristic elongate cavity that appears dark in the X-radiographs (figure 8). This cavity, which

Figure 8. These X-radiographs of Chinese FWCPs (10–11 mm) show characteristics typical of tissue nucleation. On the left, large twisted cavities related to the original tissue implant are evident in the top row, second from left, and bottom row, center. In the image on the right, the original tissue implant is represented by ovoids. Note that the tissue-related cavity is not apparent in all of the FWCPs illustrated here, although all were found to have such a cavity. It is important to take several X-radiographs of pearls, from different directions and often at different exposures, to reveal the distinguishing features. A single strand may require seven or eight X-radiographs.





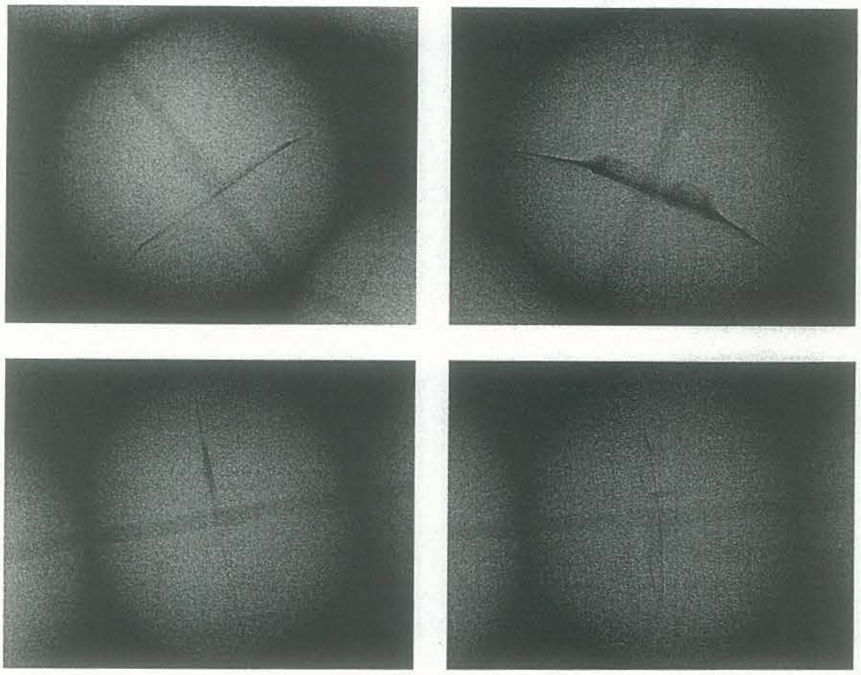


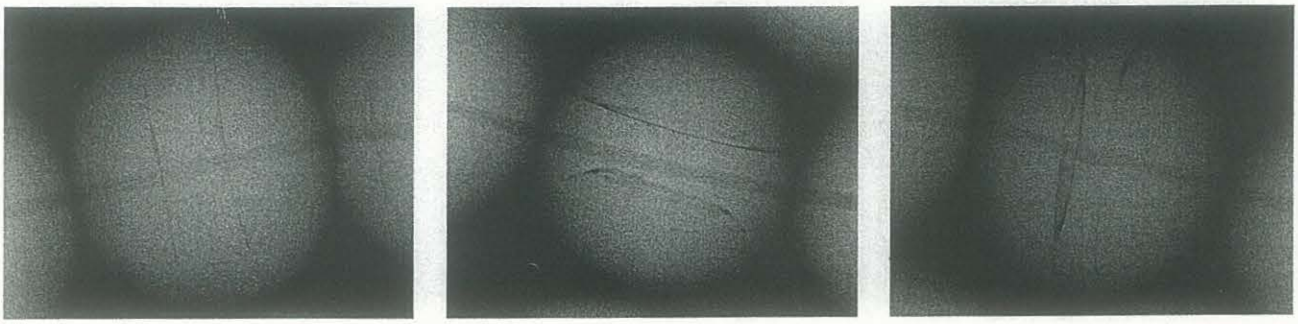
Figure 9. These X-radiographs of Chinese freshwater cultured pearls (10–11 mm) show a single dark line that relates to the tissue implant. Top left, the off-center implant line that crosses the FWCP on this X-radiograph takes up approximately 80% of the diameter of the entire sample. Top right, this off-center thick, dark implant line takes up approximately 90% of the sample's diameter. Bottom left, this centrally located implant line takes up 80%–90% of the diameter. Bottom right, the centrally located thick dark line takes up approximately 70% of the sample's diameter.

often has the appearance of an apple core, is related to the original tissue implant; it is typically, but not always, located at or near the center of the cultured pearl (figure 9). In some samples, it appears that two implants (i.e., tissue nuclei) are responsible for the growth of each cultured pearl (figure 10). Concentric growth structures, which also typically are seen in tissue-nucleated cultured pearls, are revealed by the presence of organic zones that are more transparent to X-rays than the adjacent crystalline zones (see, e.g., figure 11). Both the various types of implant structures and related organic zones are also illustrated in the line drawings shown in figure 12.

In more than 50% of the larger (7–11 mm) cultured pearls we examined, X-radiography revealed that the tissue-related structure occupied 60% to 99% of the host's diameter (see, e.g., figures 9 and 10), which contradicts the use of any kind of bead. The concentric growth structures—in this case having as a common core a line rather than a central point—appear to evolve from the core implant structure (see, in particular, figure 11).

For the most part, the cavities and other growth structures associated with the tissue implant in the larger samples were proportionately larger than those observed in the smaller (less than 6 mm) specimens. Importantly, none of the samples showed any growth features (such as a uniform organic layer surrounding a potential bead) that are indicative of a "bead" nucleus—whether a shell bead, a polished

Figure 10. The Chinese freshwater cultured pearls illustrated here all revealed a double implant structure on their X-radiographs. In the FWCP on the far left, the doubled tissue implants are revealed by two dark near-parallel lines. In the FWCP in the center, the tissue implants can be recognized by two dark ovoid structures; note that these implant-related structures take up at least 80% of the diameter of the sample. On the far right, the two dark lines relating to the tissue implants take up more than 90% of the sample's diameter.



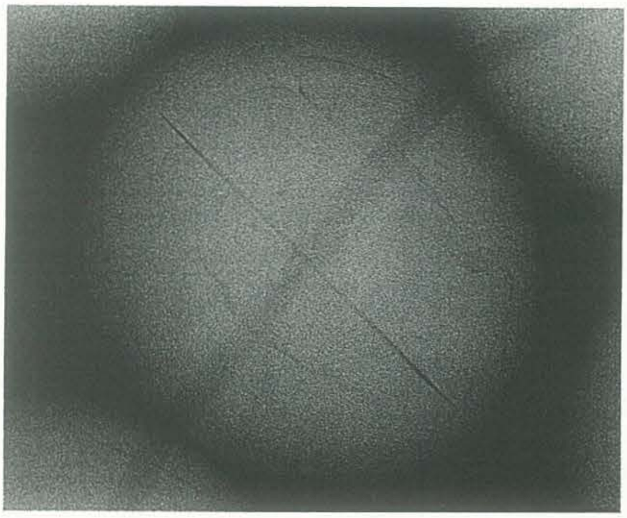


Figure 11. Concentric rings, related to the growth of this 10–11 mm Chinese FWCP, can be seen circling the elongate implant line in the center and a smaller implant "core" to the right. Note, however, that the central implant line takes up approximately 80% of the diameter of this FWCP, crossing some of the concentric lines, so the presence of a bead or cultured pearl nucleus would be impossible.

round tissue-nucleated cultured pearl, or an unfashioned tissue-nucleated cultured pearl.

Over the years, both KS and TM have recorded X-radiographs of cultured pearls with unusual nuclei. Some of these, because they are unlike almost any other samples we have examined, appear to be the result of experimentation by the growers. Figure 13 reveals a large saltwater cultured pearl that contains three nuclei: two shell beads and one tissue-nucleated cultured pearl. Note that the X-radiograph clearly shows an organic layer (revealed as a black line) that separates the tissue-nucleated cultured pearl from

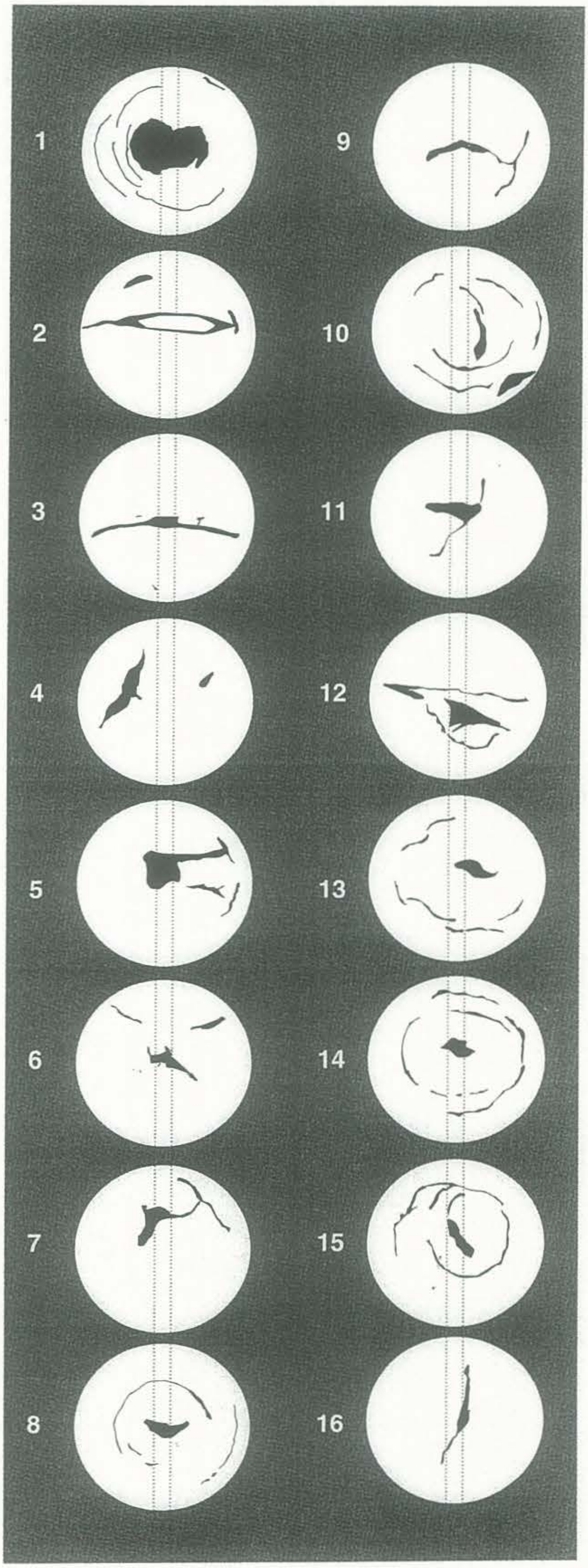


Figure 12. These line drawings illustrate details of the X-radiographic images that were recorded for some of the 10–11 mm Chinese FWCPs examined for this study. The various dark structures inside the white circles (which indicate the cultured pearls themselves) represent the normal cavities seen within tissue-nucleated cultured pearls and related "growth rings." Note that the implant-related cavities are very large in many instances (1, 2, 3, 4, 5, 7 on the left; 9, 11, 12, and 16 on the right); some are centrally located, whereas many are positioned off-center. There was no evidence of any form of bead in any of the cultured pearls examined for this study. Rather, it appears that large pieces of mantle tissue were used as the implants.

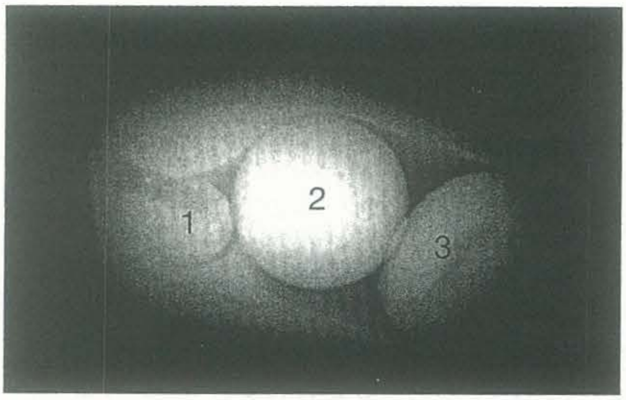
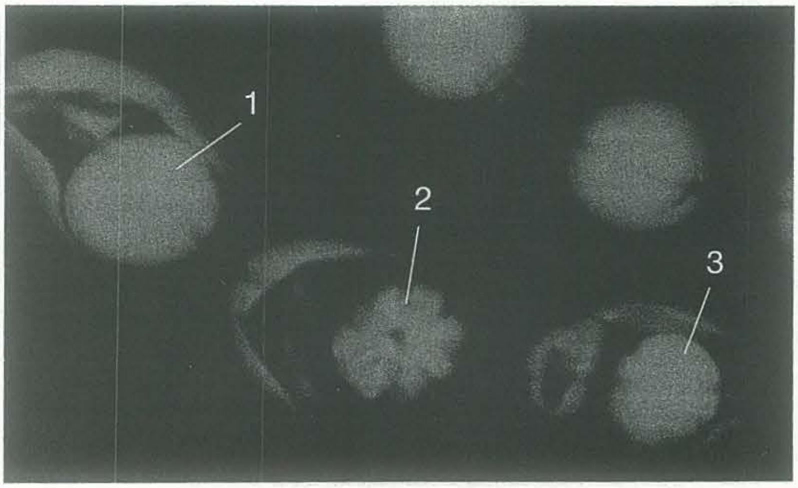


Figure 13. This X-radiograph shows an atypical single cultured pearl that has three solid nuclei: two shell beads (1 and 2) and one tissue-nucleated cultured pearl (3).

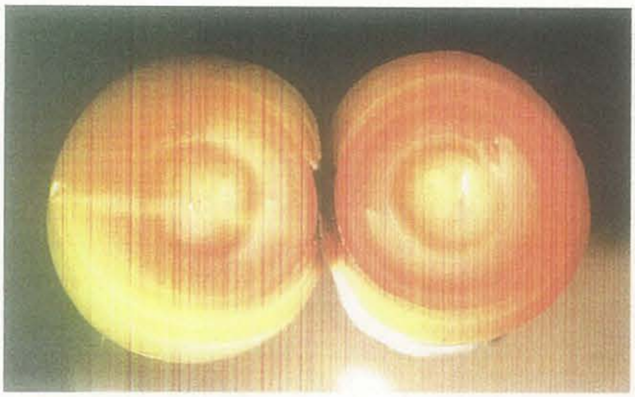
the cultured pearl overgrowth. In the Summer 1988 Lab Notes section of *Gems & Gemology*, Bob Crowningshield reported on the X-radiograph of a cultured pearl that had been nucleated with a wax bead. Most recently, in March 2000, one of the authors (TM) X-radiographed a necklace that revealed several unusual beads (figure 14). These examples represent what is only a small number of such cultured pearls that the authors have encountered in their laboratory experiences, and illustrate the effectiveness of radiography in identifying different kinds of nuclei.

Figure 14. The necklace shown in this X-radiograph revealed a variety of unusual features (bottom row, from the left): (1) a bead-nucleated cultured pearl, with the bead clearly visible at the bottom right and a large cavity evident to the left and above; (2) a cultured pearl in which the mollusk surrounded the bead with a large amount of organic matter that deteriorated and resulted in the bead becoming loose—multiple drill holes in the bead testify to the various attempts made to drill the cultured pearl; and (3) a cultured pearl with two bead nuclei, one (on the right) a normal shell bead (again showing multiple drill holes) and the other (on the left) a tissue-nucleated cultured pearl.



Sawn Chinese Freshwater Cultured Pearls. The sawn samples include one that measured approximately 12 mm (figure 15 left) and nine others that ranged from 8 to 10 mm (see, e.g., figure 15 right). In all cases, the growth structures observed were those normally expected for this kind of cultured pearl, that is, concentric, often randomly spaced ring arrangements. No signs of any kind of bead nucleation were seen. It is notable that only slight indications of a tissue implant cavity may be evident in sawn samples (see figures 15 and 16). This could be due to: (1) removal of the cavity by sawing through it, or (2) an off-center location of the cavity. Thus, there are distinct advantages to the different perspectives that can be achieved with X-radiography.

As with the interpretation of X-radiographs, the interpretation of growth structures in a sawn sample also requires caution. It is important to remember that some features in natural freshwater pearls can resemble those seen in Chinese freshwater cultured pearls, or those expected for cultured pearls nucleated by reject tissue-nucleated cultured pearls. See, for example, the thin sections of American natural freshwater pearls shown in figure 17, which were made by Basel Anderson during his original study of natural versus cultured pearls, probably in the 1930s. The freshwater pearl on the left in figure 17 shows a distinct color variation within its growth structure that might be misinterpreted as progressively larger tissue-nucleated FWCP "beads" (as described in Roskin, 2000, and Ward, 2000). The natural freshwater pearl in the center of figure 17 also contains growth features that could easily be misinterpreted as a "bead" implant: Some growth rings are continuous, while others are broken, and the outer portion is a different color and contains more organic matter than the inner section. The pearl on the far right in figure 17 reveals structures similar to those seen in many Chinese-grown tissue-nucleated FWCPs (especially those that don't show the tissue implant structures when sectioned). Note



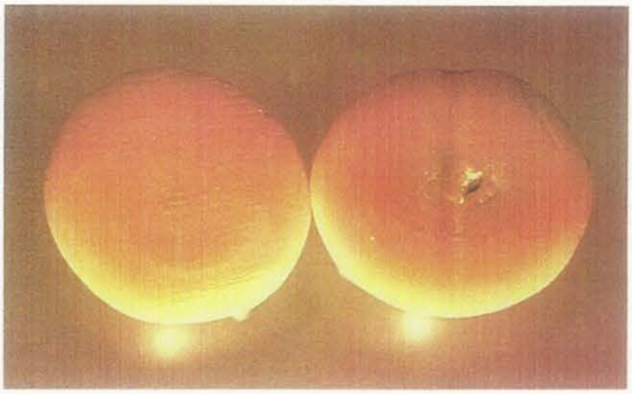


Figure 15. The concentric growth structures in these 12 mm (left) and 8.5 mm (right) Chinese FWCPs that have been sawn in two are entirely normal for tissue-nucleated freshwater cultured pearls. No indications of a solid nucleus of any type were seen. Photos by Kenneth Scarratt.

(e.g., at the 10 o'clock position) that certain growth "indentations" extend from the surface of the pearl to the point where the entire structure changes. Such indentations were seen running from the edge all the way to the center of some of the Chinese tissue-nucleated freshwater cultured pearls examined for this study.

DISCUSSION

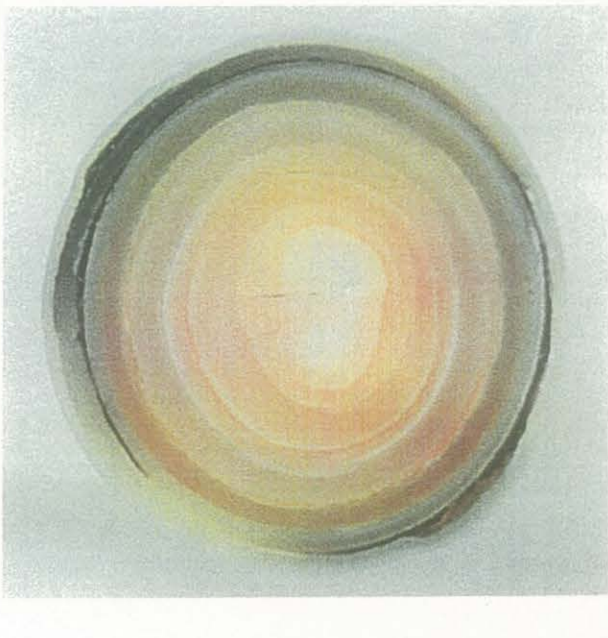
The recent reports in the trade literature that tissue-nucleated freshwater cultured pearls are being used as "nuclei" to produce most of the recent large round Chinese FWCPs appear to be based on growth structures observed in pearls that have been cut in half (see, e.g., Matlins, 1999–2000a, 2000; Roskin, 2000; Ward, 2000). Specifically, Matlins (1999–2000a, p. 5) refers to the presence of "several different colorations of nacre rings, each different 'color zone' indicating where there has been a reinsertion."

In our experience, and again as illustrated in figure 17, *all* natural and cultured pearls have internal growth structures that correspond to periods of slower or interrupted growth, changes in the material being deposited (crystalline or organic), and/or resumption in growth. In particular, the growth structures shown in figure 17 (left) are similar to those described by Matlins.

Our research also contradicts the claims that nonspherical tissue-nucleated cultured pearls are polished into round nuclei and then inserted into freshwater mollusks as nuclei for most larger round FWCPs (see, e.g., Matlins, 2000; Ward, 2000). If, for example, an oval tissue-nucleated FWCP was polished to a round shape, the finished bead would exhibit surface banding where the nonspherical concentric growth layers are cross-cut by the polishing process (figure 18). Also, the internal growth structures of the bead would no longer align themselves with the exterior shape.

To test this idea, we polished several oval- and drop-shaped Chinese FWCPs into spheres. As expected, the concentric growth layers appeared as bands on the surface of the rounded beads (see figure 18C). If this polished bead were reinserted into another mollusk, the growth features seen in figure 18D should result and be readily apparent on an

Figure 16. In this sawn half of a known tissue-nucleated cultured pearl, note the slight dark line toward the center of the cross section. This is all that may be seen of the tissue implant when this type of cultured pearl is cut in half. X-radiography would have revealed more detail.



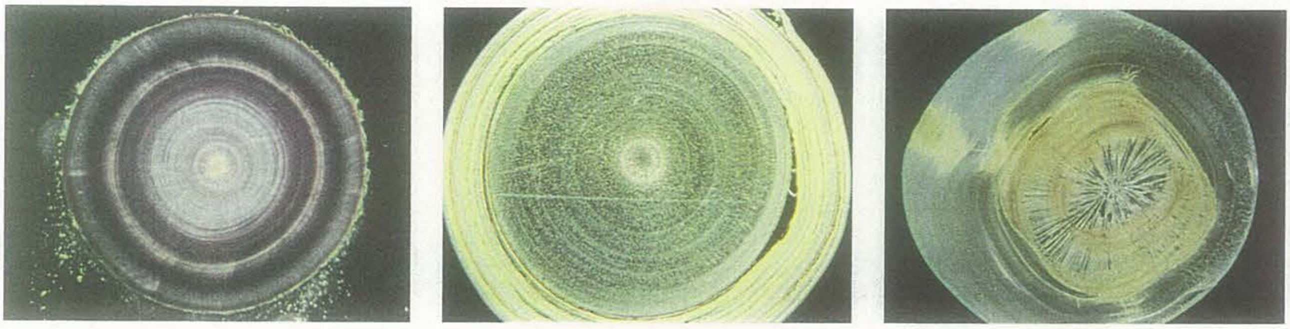


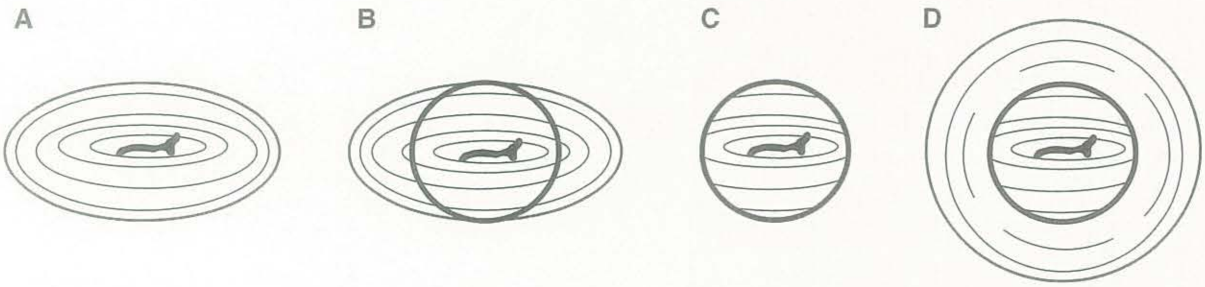
Figure 17. All three thin sections of American natural freshwater pearls show color variations and structural features related to changes in the aquatic environment as the pearls grew. Note especially the dramatic appearance of the central pearl, which could easily be interpreted as having a bead nucleus composed of another natural pearl, whereas the pearl on the left has an appearance similar to that described for FWCPs that reportedly have been nucleated with progressively larger tissue-nucleated cultured pearls. The structures in the thin section on the right are very similar to those observed in many Chinese FWCPs.

X-radiograph. Specifically, the internal growth structures of the cultured pearl nucleus would be misaligned with respect to one another and to the overgrowth, and they would not be concentric. Also, the tissue implant–related cavity would be small in relation to the fully grown (10–12 mm) cultured pearl. Moreover, the reinserted bead would have to be accompanied by a piece of tissue, and we found no evidence of this in any of the cultured pearls examined. Finally, a dark ring (corresponding to a thin organic layer) surrounding the "nucleus" would be expected.

None of the 41,000 Chinese FWCPs examined for this study, or any of those examined in the authors' laboratories over the past six years, revealed unusually small internal cavities together with misaligned or nonconcentric growth banding. As can be seen from figures 8–12, the growth structures normally recorded are concentric, or at least aligned with discernible abnormal growth that is related to other growth structures throughout the sample (e.g., the tissue-implant line). The authors have not examined any Chinese FWCPs that could have been grown by a production technique similar to that described by Matlins and Ward.

Rather, our observations are consistent with the new methods for tissue-nucleated freshwater pearl cultivation in China that were discussed in

Figure 18. (A) This line drawing shows a cross-section of an idealized oval tissue-nucleated freshwater cultured pearl. (B) If the idealized oval FWCP in "A" were to be made round, the inner circle scribed over the line drawing here would be the likely result, with growth features as illustrated in "C" (i.e., they would no longer be concentric with the outer surface). (D) If the rounded tissue-nucleated cultured pearl in "C" were to be inserted into a mollusk and further nacre was deposited, examination of the internal structure, either by radiography or by sectioning, would reveal the rounded tissue-nucleated FWCP in the center as having a structure alien to the overgrowth.



the "Current Practices" section above: For the most part, the cavities that correspond to the mantle tissue inserts are large relative to the pearls' cross sections, which suggests the use of larger implants in larger mussels. The fact that these large tissue-related structures are not always centrally located further rules out any form of bead nucleation.

CONCLUSIONS

Over the last six years, two of the authors (KS and TM) have examined a sizable number of large Chinese FWCPs, taken X-radiographs to study their internal growth characteristics, and even cut several specimens in half to examine the growth characteristics directly. At no time have they observed any evidence to suggest the nucleation process described by Matlins (2000) or Ward (2000). Similar examinations by gemologists in other leading laboratories have led to the same conclusion (H. Hänni, S. Kennedy, C. Smith, N. Sturman, and M. Superchi, pers. comms., February 2000). This is consistent with the experience of co-author SA, who has visited many Chinese pearl-culturing operations over the past few years, and communicated with several leading dealers. Indeed, all evidence points toward the predominance in the marketplace of a simple tissue-aided nucleation process to produce large, round FWCPs.

X-radiography of approximately 41,000 Chinese freshwater cultured pearls in the U.S. market revealed growth characteristics consistent with normal tissue-nucleated cultured pearls. In particular, the tissue-implant structure was large relative to the entire FWCP, not small as one would expect if a reject tissue-nucleated FWCP bead had been used. They are consistent with current tissue-nucleated pearl cultivation practices in China, that is, the use of larger mussels and larger, modified pieces of tissue to promote the growth of larger, rounder pearls. Microscopic examination of several large samples that were sawn in half confirmed the presence of concentric rings but no evidence of any type of bead.

Although it is known that there are commercial operations for the shell bead nucleation of FWCPs, and it is possible that some experimental Chinese FWCPs have been grown using beads of smaller freshwater cultured pearls, they are the exception rather than the rule. If such bead-nucleated cultured pearls became common in the future, they would be readily identifiable by routine X-radiography.

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