Experiments in using atypical 'beads' and mantle interference in the production of cultured pearls with Australian Pinctada maxima

By

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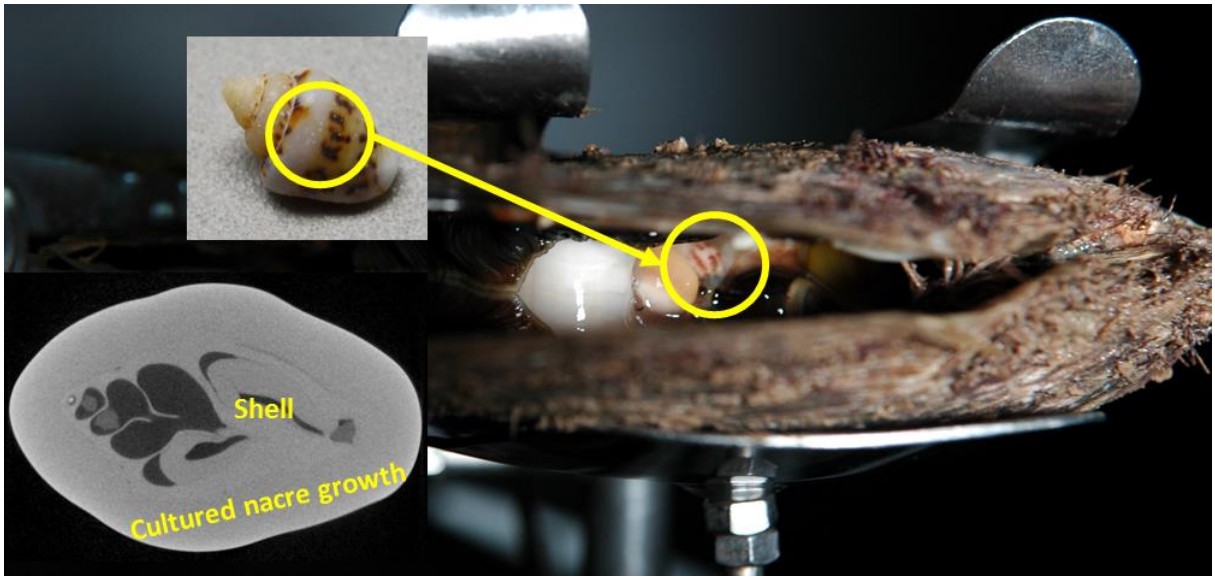

Figure 1: As a part of the atypical 'beading' experiments small shells were inserted into the gonads of several Pinctada maxima to act as substrates on top of which cultured nacre produced by donor mantle tissue (inserted along with the shells) could be induced to grow. Here one shell (full image inset upper left) can be partially seen inside the gonad of the depicted P. maxima. A µCT slice from the resulting cultured pearl is inset lower left. Main image N. Sturman, inset image Lhapsin Nillapat.

Abstract

Since approximately 2010 a practice has been developed of using low quality natural pearls as the substrates for cultured nacre growth – natural pearls used as 'beads' in the production of 'bead' cultured pearls. This practice involves the placing of these low-quality natural pearls into the gonads of *Pinctada maxima* along with a piece of donor mantle tissue, or in some cases into the cultured pearl sacs created by first or subsequent operations, in order to facilitate the growth of cultured nacre on to their surfaces.

Given that gem laboratories by normal practice examine the internal micro structures of pearls by x-rays to determine natural or cultured origins the use of natural pearls as 'beads' in the cultured process is clearly designed to deceive the gemmologist, the pearling industry and from there potentially the public.

With numerous examples of these deceptions already on the market in 2011, the authors initially conducted mainly nondestructive and a few destructive examinations of 100 reported atypical bead cultured pearls (aBCPs) that were provided by Umit Koruturk of Australian Pure Pearls, Sharjah. These examinations were by RTX (Real-time microradiography) and µCT (micro-computed x-ray tomography).

Following the results of the examination of the 100 reported aBCPs the authors began ninety one controlled experiments in order to gain a better understanding of the processes used and the results likely to be obtained from the use of unconventional culturing techniques and then comparing these with known natural and cultured pearl growth data. The authors used Australian *Pinctada maxima*; seventy five of the experiments consisted of the insertion of various types of atypical 'beads' (natural abalone, scallop, *Pteria sterna* and *Pinna*, and assumed caracol panocha *"Astrea (Megastrea) turbanica"* aka "wavy turban shell" pearls, partially drilled coral 'beads', faceted sapphire 'beads' of various colors, freshwater non-bead cultured pearls, various shells and rough coral and an assortment of plastic, glass, quartz and agate 'beads'), while sixteen consisted of irritating, folding, or inserting tissue into the mantle of *Pinctada maxima*.

Each of the atypical 'beads' used in the experiments were examined, photographed, weighed and had microradiographs recorded prior to the experimentation date. Of the ninety one experiments performed only twenty three resulted in cultured nacre growth over the atypical 'beads' and formed 'bead' cultured pearls (Table 1), nevertheless the authors were able to record the limitations of the processes and the resulting twenty three cultured pearls provided excellent data for future comparisons with natural pearl structures. No whole pearls resulted from the sixteen irritating, folding, or tissue insertion experiments detailed in Table 2, although in two cases shell blisters appeared.

Details of the experiments along with the results are presented along with RTX and µCT images of some of the successful operations. In most instances the atypical 'beading' could be identified with either RTX or µCT imaging although the identification process is not without its challenges.

Keywords: *Pinctada maxima*, atypical 'bead', shell, pearl, culture, Australia

Figure 2: Examples of Galatea Cultured Pearls showing how the nacre coating has been carved to allow the 'bead' to be seen; It is said that Galatea Carved Pearls were first created in the late '90s when Chi Huynh, founder of Galatea: Jewelry by Artist, accidentally damaged a pearl. The damage exposed the cultured pearl's mother-of-pearl 'bead' and this fascinated him, and he wondered what would happen if he carved the entire pearl. He did and the result are to be seen in his product today. Photo by Nuttapol Kitdee.

Introduction

Since the inception of the bead cultured pearl[i] (USA Patent No. US1176090 A, 1915) (USA Patent No. US1328008 A, 1919) (Cahn, 1949) (Müller, 1997) (Akamatsu, 1999) (Wada, 1999) (Wada, 1999) it was assumed that to gain a good product it was essential that a round bead cut from one of the American freshwater shells, e.g., *Megalonaias nervosa* - the Washboard mussel, from the Mississippi (Claassen, 1994) was used as the substrate for nacre growth; indeed for the major commercial activities this still holds true today even though supply issues have been of some concern (Fassler, 1996). In recent times several publications and trade announcements have indicated that there have been numerous experiments with alternatives (Roberts & Rose, 1989) (Wentzell & Reinitz, 1998) (Hänni H. , 2000) (Scarratt, Moses, & Akamatsu, 2000) (Segura & Fritsch, 2012) (Cartier & Krzemnicki, 2013) (Sturman & Strack, 2010) (Zhou C. , 2013) (Strack, 2011) (Hänni H. , 2011) (Segura & Fritsch, 2014). Indeed for some time now Galatea Pearls have been marketing various carved cultured pearls that have been successfully grown around a variety of unusual substrates (Figure 2) to give a uniquely artistic approach to pearl culturing.

Recently these atypical 'bead'-culturing practices have raised two issues that have the potential to negatively impact the general image of both natural and cultured pearls, one of these is the use of shell beads manufactured from *Tridacna gigas*, a protected species

(CITES, 2009) (Gervis & Sims, 1992) (Superchi, Castaman, Donini, Gambini, & Marzola, 2008) not only in pearl culturing but also in the manufacture of imitation pearls (Hänni H. , 2004) (Zhou & Zhou, 2015) which while not being the subject matter of this paper is nevertheless worthy of note, and the other is the practice of using low quality natural pearls to produce atypical 'bead' cultured pearls (aBCP) - with natural pearls at their centre. The latter practice involves the placing of these low-quality natural pearls into the gonads of *Pinctada maxima* along with a piece of donor mantle tissue, or in some cases into the cultured pearl sacs (Dix, 1973) created by first or subsequent operations, in order to facilitate the growth of cultured nacre on to their surfaces[1].

Umit Koruturk who has "made numerous visits to the region and knows a number of the individuals involved", informed the authors that "a farm operator in Indonesia learned of successful but scientifically oriented atypical beading experiments that were taking place nearby and as a result of this information began the production of aBCPs".

The presence of such aBCPs in the market place was clearly demonstrated when around 100 samples of reported aBCPs using a variety of different natural pearl 'beads' were given to laboratories in Bangkok (Gemological Institute of America - GIA) and Bahrain (The Gem & Pearl testing Laboratory of Bahrain - GPTLB) in 2012 and these were stated to be a part of a much larger lot that Umit Koruturk distributed to a total of five international laboratories. These examples revealed a variation in the type of 'bead' used and the resulting nacre thickness.

The 100 samples of reported aBCPs that were submitted for study were medium to high quality pearls produced in *Pinctada maxima* (silver- lipped and gold-lipped pearl oysters) with sizes ranging from 8mm to 15mm. The internal microradiographic structures of all the samples were studied using x-ray imaging (RTX and µCT) and these reported aBCPs were sorted based on these structures (see Figure 4 to Figure 60). Most of the reported aBCP samples revealed structures that would raise concerns during any normal laboratory examination, i.e., they would have raised suspicions of an unnatural growth process having been employed. However, a few provided some difficult challenges.

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1 While this current concern relates to commercial practices that have evolved since 2010, it should be noted that experimentation in pearl culturing processes are continuous. Indeed one of the authors received information from Gina Latendresse in the years 2000 and 2001 that technicians at the American Pearl Company had been instructed to implant natural but low quality, low lustre, wing shaped pearls into fifty molluscs in 1998 following experimentation dating back to 1991. Gina reported that "In just eighteen months the results were phenomenal. Our low lustre scrap natural pearls were transformed into smooth, lustrous high quality cultured pearls maintaining the general wing shape" (Latendresse, 2000/2001). See Figure 3.

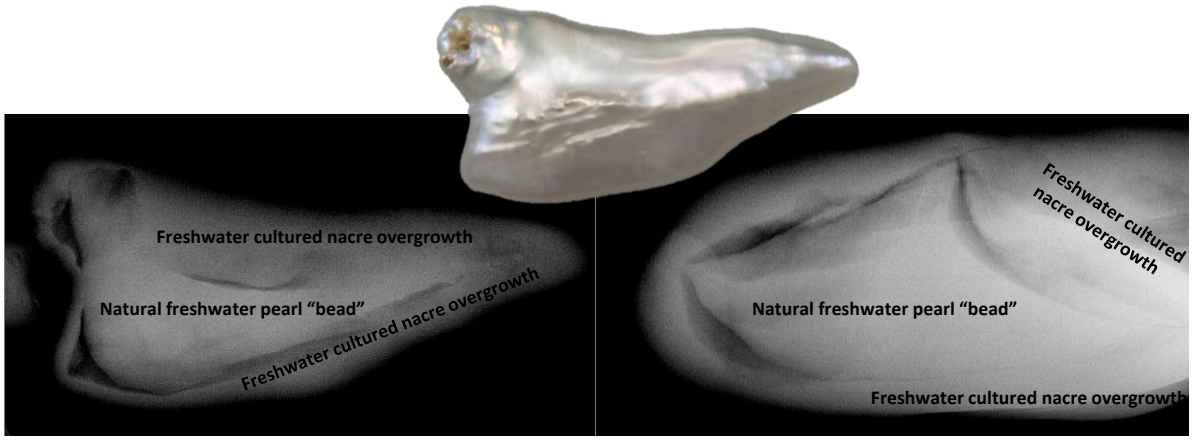


Figure 3: An atypical American freshwater bead cultured pearl weighing 4.99ct and measuring 20.08 x 9.40 x 4.31mm (centre), produced experimentally by the American Pearl Company at the turn of the new millennium, and two directional RTX images showing the position of the natural pearl bead and its demarcation from the overgrowth of cultured nacre.

The RTX and µCT microradiographic structures of reported aBCPs exhibiting clearly defined aBCP microradiographic and µCT structures.

Figure 4: Sample 100306142275, a cream button/oval-shaped reported aBCP weighing 9.00ct. Photo Ayoob Bahman

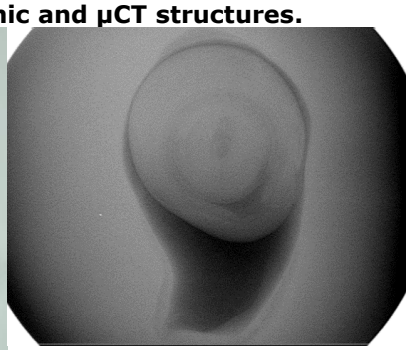


Figure 5: An RTX image of the reported aBCP in Figure 4 showing a natural pearl at the centre separated by a clear demarcation and an 'organic tail' (often seen in bead cultured pearls [BCPs]) from the cultured nacre overgrowth. No organic growth arcs are present in the cultured nacre.

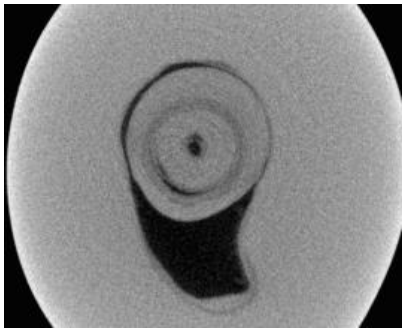


Figure 6: A slice from the µCT scan of the reported aBCP in Figure 4 showing the natural pearl 'bead' with a higher definition of the demarcation and the organic tail often observed in bead cultured pearls.

Figure 7: Sample 100306142277, a white drop shaped reported aBCP weighing 4.42ct. Photo Ayoob Bahman.

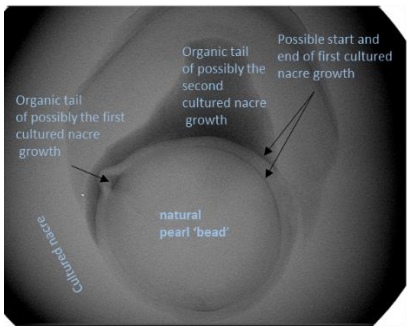


Figure 8: An RTX image of the reported aBCP in Figure 7. It might be speculated from this and the µCT imaging in Figure 9 that a natural pearl 'bead' (marked) had previously been used to form an aBCP (note the small amount of possible cultured nacre surrounding it [marked] and original organic tail [marked]). This aBCP being used to form a much larger aBCP resulting in the larger organic tail (marked) and a much greater thickness of cultured nacre overlaying (marked).

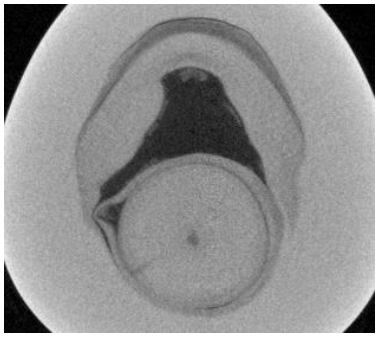


Figure 9: A slice from a µCT scan of the reported aBCP in Figure 7, showing a higher definition of the demarcation of the natural pearl 'bead' in the speculated first and the second atypical 'beading' process with the organic gaps often observed in bead-cultured pearls.

Figure 10: Sample 100306142273, a white button/oval-shaped reported aBCP weighing 6.33ct. Photo Ayoob Bahman.

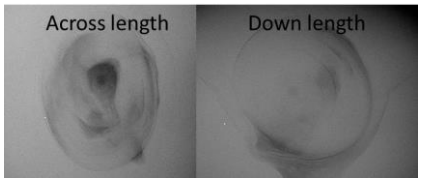


Figure 11: RTX images of the reported aBCP in Figure 10 showing a natural pearl has been used as a 'bead'. The demarcation between the pearl 'bead' and the cultured nacre is not clear when examined across the length but is more defined down the length when the organic tail shows clearly.

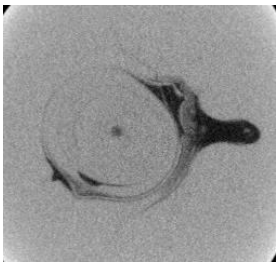


Figure 12: A slice from the µCT scan of the reported aBCP in Figure 10 showing higher definition of the demarcation of the pearl 'bead', the organic tail and the overlaying cultured nacre.

Figure 13: Sample 100306142087, a white drop-shaped reported aBCP weighing 4.99 cts. Photo Ayoob Bahman.

Figure 14: An RTX image of the reported aBCP in Figure 13 showing a natural pearl used as a 'bead' with a light core surrounded by concentric ring structure and outlined by an obvious demarcation with a small 'organic tail' at one end overgrown with cultured nacre. No organic growth arcs are present in the cultured nacre which may indicate rapid growth during the atypical bead culturing process.

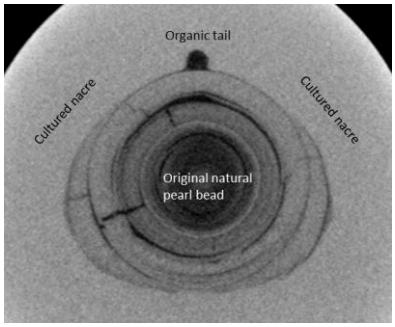


Figure 15: A slice from the µCT scan of the reported aBCP in Figure 13, showing a very clear demarcation between the natural 'bead' pearl and the cultured nacre growth.

Figure 16 Sample 100306142278, a white off-round reported aBCP weighing 6.33ct. Photo Ayoob Bahman.

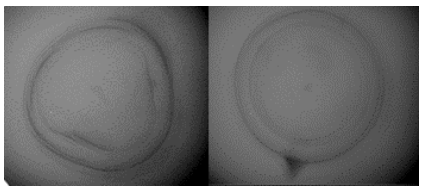


Figure 17: RTX images of the reported aBCP in Figure 16 showing the presence of a natural pearl 'bead'. The demarcation is unclear in one direction (left) due to conchiolin surrounding the natural pearl 'bead'. However in another direction (right) the demarcation between the natural pearl 'bead' and the cultured nacre is clear along with the presence of an organic tail.

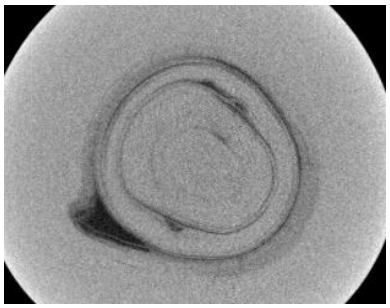


Figure 18: A slice from the µCT scan of the reported aBCP in Figure 16 showing the natural pearl used as a 'bead' with a higher definition of the demarcation between the natural pearl 'bead' and the cultured nacre and the organic tail often observed in bead-cultured pearls.

The RTX and µCT microradiographic structures of a reported aBCPs that might be deceptive if examined from one direction only.

Figure 19: Sample 100306142113, a white oval-shaped reported aBCP weighing 3.48ct. Photo Ayoob Bahman.

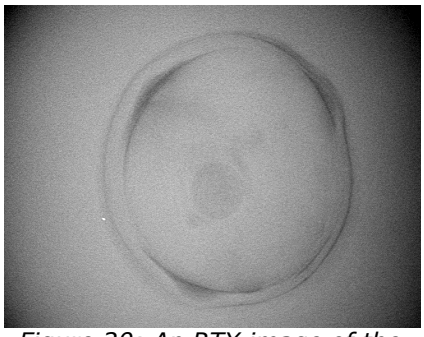


Figure 20: An RTX image of the reported aBCP in Figure 19 a natural pearl 'bead' with a faint rounded, organically dominated, centre. The demarcation between the natural pearl 'bead' and the cultured nacre is clear but the organic gap is 'defused' and has the appearance of a conchiolin accumulation on the edges of the natural pearl 'bead'. Note that no concentric arcs are visible in the cultured nacre.

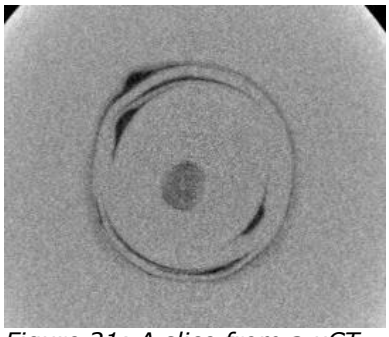


Figure 21: A slice from a µCT scan of the reported aBCP in Figure 19 showing a greater definition of the demarcation between the natural pearl 'bead' and the cultured nacre.

Figure 22: Sample 100306142123, a white oval-shaped reported aBCP weighing 5.13ct. Photo Ayoob Bahman.

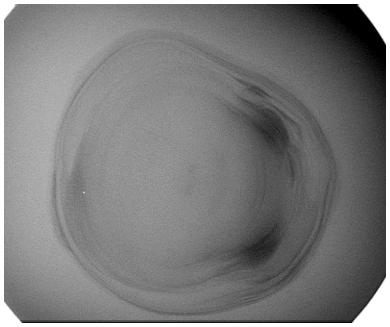


Figure 23: An RTX image of the reported aBCP in Figure 22 showing a natural pearl 'bead' with unclear demarcation between it and the cultured nacre due to the surrounding conchiolin rich areas. The centre structures are weak. Note that no concentric arcs are present in the cultured nacre which is similar to the other samples submitted.

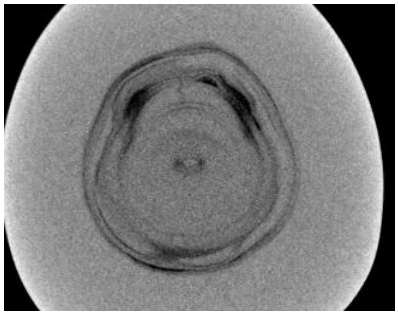


Figure 24 A slice from the µCT scan of the reported aBCP in Figure 22 showing a greater detail than was possible with RTX and a clearer demarcation between the natural pearl 'bead' and the cultured nacre.

Figure 25: sample 100306142125, a white button-shaped reported aBCP pearl weighing 5.76ct. Photo Ayoob Bahman.

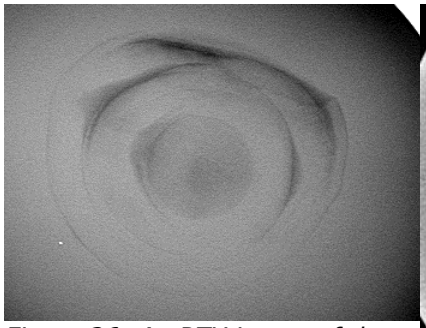


Figure 26: An RTX image of the reported aBCP in Figure 25, a natural pearl 'bead' with faint demarcation between the natural pearl 'bead' and the cultured nacre growth. One side of the pearl 'bead' is broken and small organic gaps are visible but are unclear. No concentric arcs are present in the cultured nacre overgrowth.

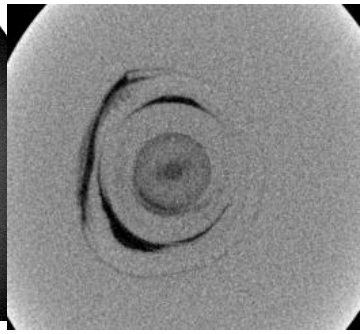


Figure 27: A slice from the µCT scan of the reported aBCP in Figure 25, shows the meaty center of the natural pearl 'bead' surrounded by concentric rings. The demarcation surrounding the natural pearl 'bead' is of higher definition than in the RTX images and note that two distinctive organic gaps are seen.

The RTX and µCT microradiographic structures of a reported aBCPs that reveal the use of non-beaded cultured pearls (freshwater and possibly saltwater) as atypical 'beads'.

Figure 28: sample 100306142300, a white drop-shaped reported aBCP weighing 5.53ct. Photo Ayoob Bahman.

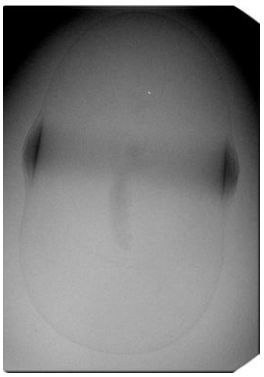


Figure 29 An RTX image of the reported aBCP in Figure 28. Here a non-beaded cultured pearl 'bead' has been used as a substrate for cultured nacre growth. A clear demarcation is visible between the 'bead' and the cultured nacre growth with two organic gaps at the sides of the oval internal outline of the cultured pearl 'bead'.

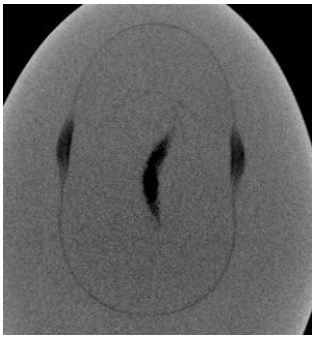


Figure 30: A slice from the µCT scan of the aBCP in Figure 28. showing a defined demarcation between the elongated oval cultured pearl 'bead' with the typical void in the centre and organic gaps at both sides

Figure 31: Sample 100306142241, a baroque cream reported aBCP weighing 5.70ct. Photo Ayoob Bahman.

Figure 32: An RTX image of the reported aBCP in Figure 31. The microradiographic structures and fluorescence observations reveal that two freshwater non-bead cultured pearl 'beads' have been used as the substrate to overgrow cultured nacre.

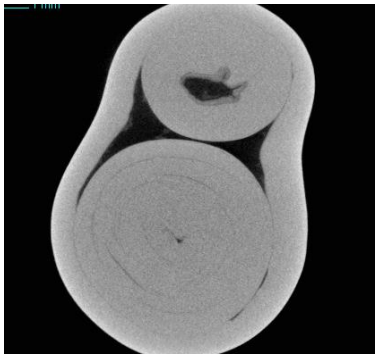


Figure 33: A slice from the µCT scan of the reported aBCP in Figure 31 showing the defined structures and demarcation of two 'beads' that are freshwater non-bead cultured pearls.

The RTX and µCT microradiographic structures of a reported aBCPs that reveal unusual rounded features in the demarcations between the 'bead' and cultured nacre overgrowth.

Figure 34: Sample 100306142289, a white button-shaped reported aBCP weighing 3.28ct. Photo Ayoob Bahman.

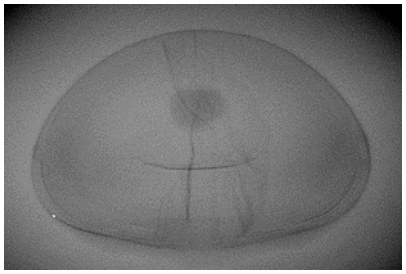


Figure 35: An RTX image of the reported aBCP in Figure 34 where a conchiolin rich natural pearl with radial structures and cracks running through it has been used as an atypical 'bead'. Obvious demarcation between the natural pearl 'bead' and the cultured nacre is visible all around the 'bead' and no concentric arcs are present in the outer cultured nacre.

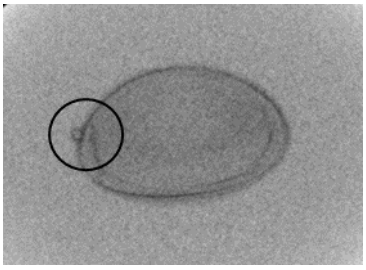


Figure 36: A slice from the µCT scan of the reported aBCP in Figure 34 reveals a strange rounded feature present within the demarcation (circled) and the natural pearl 'bead' appears strangely isolated from the overall aBCP structure.

Figure 37: sample 100306142290, a white drop/oval shaped reported aBCP pearl. Photo Ayoob Bahman.

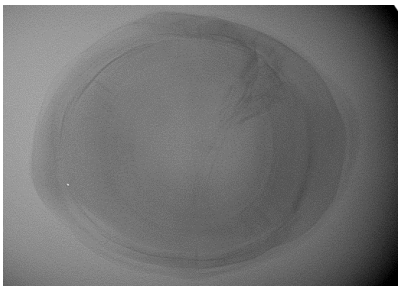


Figure 38: An RTX image of the reported aBCP in Figure 37 here a conchiolin rich pearl (likely Pinna species) 'bead' with radial structure and cracks running through it has been used. The demarcation between the natural pearl 'bead' and the cultured nacre overgrowth is unclear due to the conchiolin rich areas surrounding the 'bead' but it is still discernable.

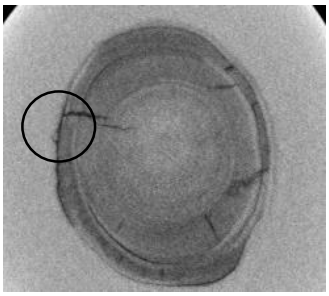


Figure 39: A slice from the µCT scan of the reported aBCP in Figure 37. The natural pearl 'bead' has distinct cracks running through it. The internal structure is of higher definition compared with the RTX imaging and a few small organic gaps and an unusual rounded (circled) feature appears around the demarcation.

The RTX and µCT microradiographic structures of a reported aBCP with unusual elongated features at the demarcation between the natural pearl 'bead' and the cultured nacre.

Figure 40: sample 100306142098, a white rounded reported aBCP weighing 5.19cts. Photo Ayoob Bahman.

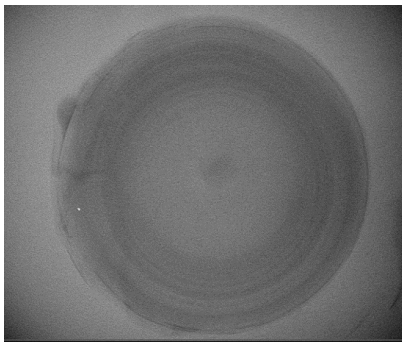


Figure 41: An RTX image of the reported aBCP in Figure 40 with a natural pearl 'bead' revealing its radial structure. The demarcation between the natural pearl 'bead' and the cultured nacre overgrowth is unclear and a few conchiolin rich arcs are present in the cultured nacre.

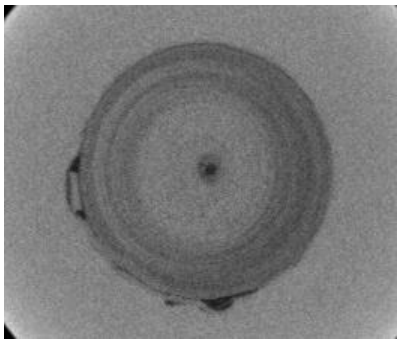


Figure 42: A slice from a µCT scan of the reported aBCP in Figure 40 reveals greater detail of the internal structure than gained by RTX. Organic gaps are present at the demarcation between the natural pearl 'bead' and the cultured nacre overgrowth and an elongated feature is present inside an organic gap at the left in this image.

The RTX and µCT microradiographic structures of reported aBCP's that possibly use Tridacna species or other natural porcelaneous pearls as 'beads' and details of destructive methods used to achieve these research based identifications and their results.

Figure 43: Sample 100306142244, a cream drop-shaped reported aBCP weighing 6.30ct. Photo Ayoob Bahman.

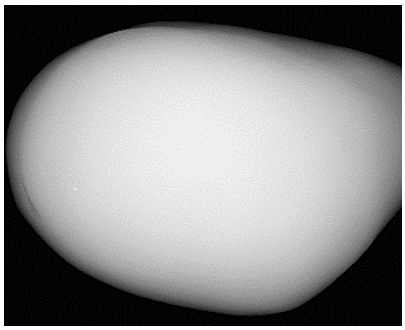


Figure 44 An RTX image of the reported aBCP in Figure 43 showing what may be a natural Tridacna (clam) pearl overgrown by a very thin layer of cultured nacre. One end (the left side of the image) shows a clear demarcation and overall there is a clear difference in radio-opacity between the cultured nacre and the 'bead'.

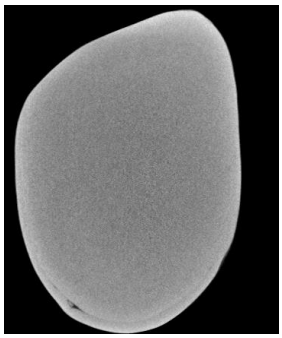


Figure 45: A slice from the µCT scan of the reported aBCP in Figure 43, revealing what may be a natural Tridacna (clam) pearl 'bead' coated with a thin layer of cultured nacre (so thin that the flame structure of the 'bead' could be seen through the coating which fact led to sample 100306142335 being sacrificed, see Figure 48), with a weak demarcation between the two (not a line all around just shadow) running close to the edge of the pearl.

Figure 46: Sample 100306142335, a light yellow reported aBCP weighing 6.41cts. Externally the pearl had a bumpy pitted surface and looked normal. Photo Ayoob Bahman.

Figure 47: An RTX image of the reported aBCP in Figure 46 a natural Tridacna (clam) pearl (see Figure 48) overgrown by a thin layer of cultured nacre. Note that it is hard to visualize a demarcation between the 'bead' and the cultured nacre in this RTX. The center of the pearl 'bead' reveals an extremely faint void and a faint line (demarcation) on the curved end of the pearl.

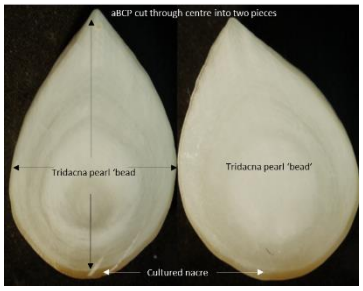


Figure 48: The reported aBCP in Figure 46 was cut through its center to reveal the non-nacreous porcelaneous structure of a low quality natural Tridacna (clam) pearl which was used in the atypical beading process.

The RTX and µCT microradiographic structures of a reported aBCP's that used a drilled natural pearl 'bead'.

Figure 49: Sample 100306142301, a white drop-shaped reported aBCP weighing 3.55ct. Photo Ayoob Bahman.

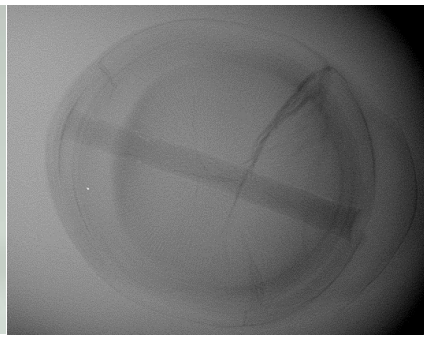


Figure 50: An RTX image of the reported aBCP in Figure 49. A drilled natural pearl has been used as the 'bead' and is now overgrown with cultured nacre. The demarcation between the natural pearl 'bead' and the cultured nacre is not very clear but is clearly visible in relation to the presence of the drill-hole in the natural pearl 'bead'. Note that there are no concentric arcs present in the cultured nacre.

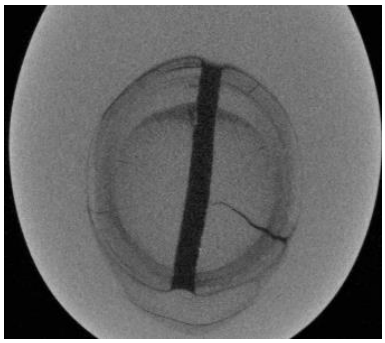


Figure 51: A slice from a µCT scan of reported aBCP in Figure 49. The drilled natural pearl 'bead' and its radial structure with cracks running through are clear. Note that the demarcation between the cultured nacre and the natural pearl 'bead' is much clearer than in the RTX image.

The RTX and µCT microradiographic structures of a reported aBCP's with unusual internal configurations.

Figure 52: Sample 100306142238 a cream rounded reported aBCP weighing 9.54ct. Photo Ayoob Bahman.

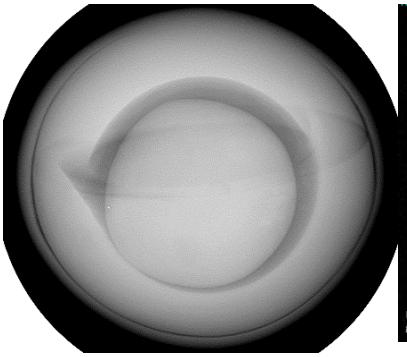


Figure 53: An RTX image of the reported aBCP seen in Figure 52. A pearl 'bead' surrounded by a significant organic gap with a ring feature surrounding the entire pearl. From this image alone it would be difficult to predict origin of 'pearl'.

The authors were informed that this aBCP came from early experiments.

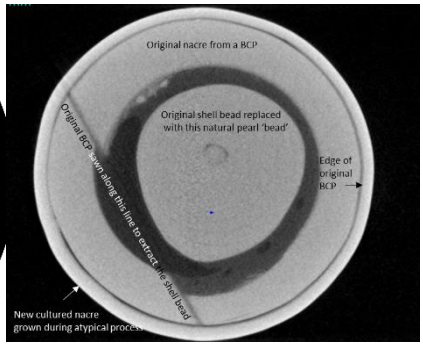


Figure 54: A slice from a µCT scan of the reported aBCP in Figure 52 shows what appears to be a natural pearl 'bead' at the centre of some unusual features. Further analysis revealed that a BCP was cut through on one side: The shell bead replaced by a natural pearl. This was now used as the 'bead' in the atypical beading process to produce the aBCP in Figure 52. The outer final cultured nacre growth is relatively thin.

Figure 55: Sample 100306142236 a silver-white drop-shaped reported aBCP weighing - 17.16ct. Photo Ayoob Bahman.

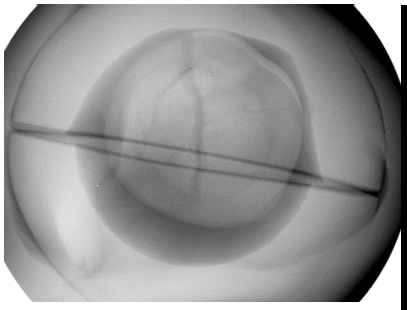


Figure 56: An RTX image of the reported aBCP in Figure 55. A natural pearl 'bead' similar to that in sample 100306142238, Figure 52, can be seen but with a greater definition. Note that in this sample the external appearance of pearl (Figure 55) is similar to that often observed in BCPs.

The authors were informed that this aBCP came from early experiments.

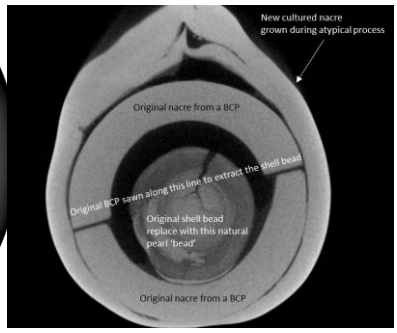


Figure 57: A slice from the µCT scan of the reported aBCP in Figure 55. An irregular natural pearl appears to have (as in sample 100306142238) been placed inside the nacre of a BCP, glued back together and used as a 'bead' in the atypical beading process.

Figure 58: sample 100306142239 a cream rounded reported aBCP weighing 10.52ct. Photo Ayoob Bahman.

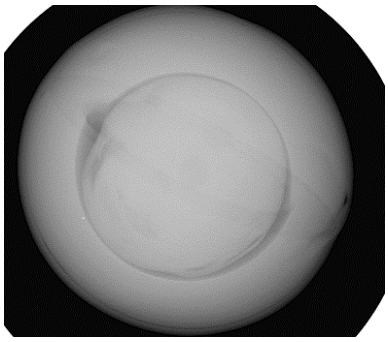


Figure 59: An RTX image of the reported aBCP in Figure 58. The natural pearl 'bead' similar to those in samples 100306142238 and 100306142236 with a less defined ring-like feature.

The authors were informed that this aBCP came from early experiments.

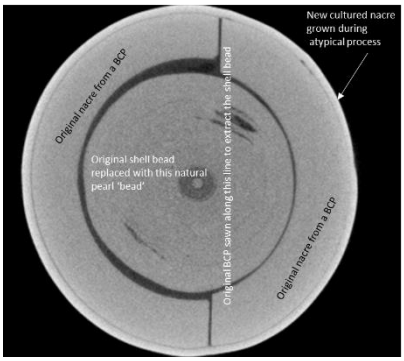


Figure 60: A slice from the µCT scan of the reported aBCP in Figure 58. The slice reveals that in this sample the pearl 'bead' has a white core at the center and is surrounded by concentric growth lines. The pearl 'bead' is close to the same size as the original shell bead that was removed from the BCP as in samples 100306142238 and 100306142236. This is one of the best samples as the organic gap surrounding the pearl 'bead' is small. Note that the cultured nacre growth produced during the atypical culturing process is very thin.

The reader will notice that in the descriptions of the reported aBCP in Figure 4 to Figure 60 'aBCP' is always qualified with the word 'reported'. This word format is used simply because the authors were not present at the pearl farms where the stated atypical culturing process took place and there was no valid chain of custody provided. Further the external appearance of the reported aBCPs provides little insight about how these 'pearls' were formed. It follows therefore that the only evidence supporting that an atypical 'beading' process had been used to produce the reported aBCPs in Figure 4 through to Figure 60 (apart from that cited in Figure 46) supplied to GIA and G&PTLB comes from the examination and interpretation of the RTX and µCT imaging of each sample. Given the forgoing it should be understood that the caption explanations for Figure 4 to Figure 60 may contain professional assumptions that not every observer may concur with. Indeed it is this very situation where professional assumptions, rather than facts, have been endemic in such interpretations, that led the authors to conducting their own experiments in atypical bead culturing. Experiments where detailed accounts from the selection and detailing of the atypical 'beads', through the insertion operations, husbandry, harvesting and in-laboratory examinations of the final products were recorded and the chain of custody maintained. The hope being that the results will assist in future RTX and µCT imaging interpretations.

However, the supplier did authorize the authors to selectively cut six of his 100 aBCPs into two pieces in order that the internal structures could be examined and in each case the nature of their mixed-mollusc formation was clear to see e.g., the sample seen in Figure 61 clearly shows a Pen pearl forming the 'bead'.

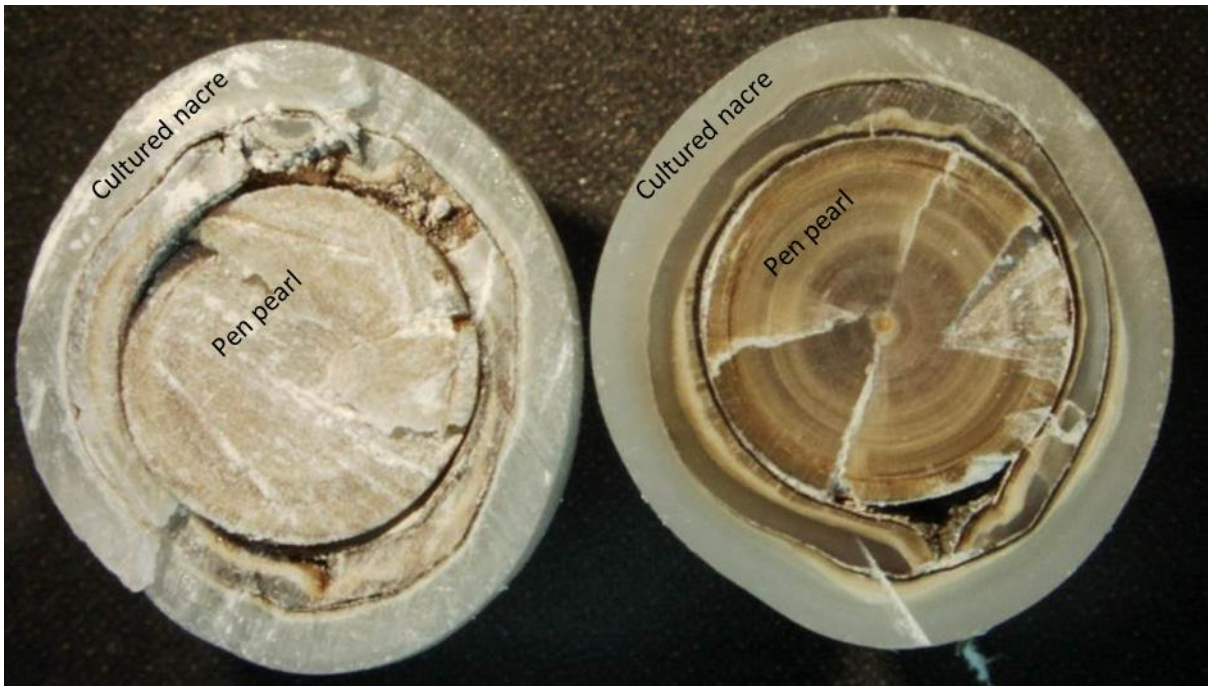


Figure 61: A nacreous Pinctada maxima aBCP submitted for research in 2012 to GIA and GPTLB with numerous other aBCPs. The pearl was cut through its centre to reveal the non-nacreous Pinna (pen) pearl used as the 'bead' in the culturing process. One half (left) remained unpolished while the other half (right) was polished to show the structural detail more clearly. Photo Adirote Sripradist.

Nevertheless, under normal circumstances cutting through the centre of a potentially natural pearl to examine what instigated growth is not something that is allowable for the testing of pearls where the procedures are by necessity essentially non-destructive. Indeed the normal practice for the examination of the internal micro structures of pearls is by x-ray imaging (RTX or µCT) only.

In addition to the end product aBCPs the supplier (Umit Koruturk of Australian Pure Pearls, Sharjah) also submitted a range of natural pearl 'beads' that were claimed as being the type of materials used in the formation of similar aBCPs (Figure 62). These included whole nacreous and non-nacreous/porcelaneous pearls from various molluscs as well as broken pieces, some cut examples and even a few blister pearls of various types.

Figure 62: In addition to the end product aBCPs the supplier (Umit Koruturk of Australian Pure Pearls, Sharjah) also submitted a range of 'beads' that were claimed to be used in the formation of similar aBCPs. This image shows some of the whole nacreous and non-nacreous/porcelaneous pearls from various molluscs that are said to be used. Photo Adirote Sripradist.

The use of x-ray imaging has been essential to the identification process that determines whether a pearl is natural or cultured, and indeed has been the only reliable method, for almost one hundred years (Dauvillier, 1924) (Dauvillier, La différenciation des perles naturelles et cultivées. , 1926) (Webster, 1955) (Webster, X-rays and Their Use in Gemmology: Part V: Laue Patterns., 1955) (Farn, 1986) therefore the use of natural pearls as 'beads' in the culturing process, which results in evident natural growth structures in the x-ray images seen in the heart of a (cultured) pearl is clearly designed to deceive the gemmologist, the pearling industry and from there, the public. (Hänni, Krzemnicki, & Cartier, Innovation in bead-culturing pearls, 2010) (Hänni, 2011) (SSEF, 2011) (Krzemnicki, 2012) (Hänni, Krzemnicki, & Cartier, 2010) (Cartier & Krzemnicki, 2013) (Hänni H. , 2011).

Experimentally other objects such as small sea shells have also been used as a substrate for cultured nacre growth; these also being designed to confuse or mislead the gemmological testing process as several natural pearls have been found to have shells or other marine debris as having instigated pearl growth (Lee & Webster, 1961) (Scarratt, et al., 2012) (Somsa-ard, 2015) (Zhou, Yazawa, & Sturman, 2016) (Segura, 2016).

With the potential of more of these deceptive practices becoming evident on the market, the authors conducted ninety one controlled experiments with the aim of gaining an understanding of the possibilities and likely results that might be obtained from the use of unconventional culturing techniques and comparing these with known natural and cultured pearl growth data. In these experiments the authors used Australian *Pinctada maxima*;

seventy five of the experiments consisted of the insertion of various types of atypical 'beads' (natural abalone, scallop, *Pteria sterna* and *Pinna*, and assumed caracol panocha *"Astrea (Megastrea) turbanica"* aka "wavy turban shell" pearls, partially drilled coral 'beads', faceted sapphire 'beads' of various colors, freshwater non-bead cultured pearls, various shells and rough coral and an assortment of plastic, glass, quartz and agate 'beads'), while sixteen consisted of irritating, folding, or inserting tissue into the mantle of *Pinctada maxima*.

Each of the atypical 'beads' used in the experiments were examined, photographed, weighed and had microradiographs recorded prior to the experimentation date. Of the ninety one experiments performed only twenty three resulted is cultured nacre growth over the atypical 'beads' and formed cultured pearls (Table 1 and Table 2), and no whole pearls resulted from the sixteen irritating, folding, or inserting tissue experiments – although shell blisters did appear in two specimens. Nevertheless the authors were able to record the processes and the resulting twenty three aBCPs provided excellent data for future comparisons with natural and cultured pearl structures.

Materials and Methods

Seventy five 'beads' were used as potential substrates onto which cultured nacre could potentially be induced to grow. These 'beads' were composed of two natural Abalone pearls, eleven natural scallop pearls, nine natural pearls from *Pteria sterna*, one natural pinna pearl, eight partially drilled coral 'beads', nine natural caracol panocha *"Astrea (Megastrea) turbanica"* aka "wavy turban shell" pearls, eight natural sapphires, two freshwater non-bead cultured pearls, one glass, eleven shells, six coral rough, and an assortment of eight plastic, quartz and agate. All 'beads' were weighed (recorded weights being from 0.36 to 7.90ct) and these along with the type of 'bead' are listed in Table 1. The SG's of most of the 'beads' were calculated by the hydrostatic method and recorded also in Table 1.

All experiments during the 'seeding phase' were carried out aboard the P4 (one of the Paspaley fleet of pearling vessels) which is fitted out with state of the art (clinical) operation rooms and the operations being carried out by a Paspaley technician with observations, recording and control of specimens being carried out by authors KS and NS.

The equipment used during the operations was similar to that used since the beginning of pearl culturing (Figure 63). The shell were relaxed in a relaxant and pegged in preparation for the operation (Figure 66). At the time of the operation the shell were opened a little more, the pegs removed, and held open with the shell speculum (Figure 63). With the gills pulled back and the gonad visible a small incision was made into the gonad wall. The 'bead' was then lifted with the nucleus (bead) lifter and gently pushed through the incision and into the gonad, this being immediately followed by the placing of a small piece of the donor mantle tissue (the graft) onto the surface of the inserted 'bead'. The shell speculum was then removed allowing the shell to close. An excellent schematic that described the grafting and for formation of a cultured pearl sac can be seen in Figure 8 of Cochennes-Laureau et.al. (Cochennes-Laureau, Montagnini, Saulnier, & Fougerouse, 2010).

Sixteen further experiments were carried out to establish if by irritating the mantle pearl growth could be encouraged and these are recorded in Table 2. Irritations were carried out by deliberately poking the mantle with the sharp pointed instrument (Figure 64) in an attempt to stimulate pearl growth in other cases a spatula together with a hooked instrument (Figure 65) were used to scarify and smear the mantle. The same instruments were used to cut and fold the mantle as well as insert donor mantle tissue into the host's mantle.

Following the operations each shell was placed into a pocket within a holding panel with an alphabetic notation tag in place and a numbered shell tag attached to each pocket.

Both the panel and shell tags were recorded along with the type of operation that had taken place (Table 1 and Table 2). All the shell were then held under 'nursery' conditions to make sure they had survived the operations and then transported to a permanent off-shore site where they were held for two years with regular checks and cleaning, before being brought back to the P2 to harvest the results (the retrieval phase).

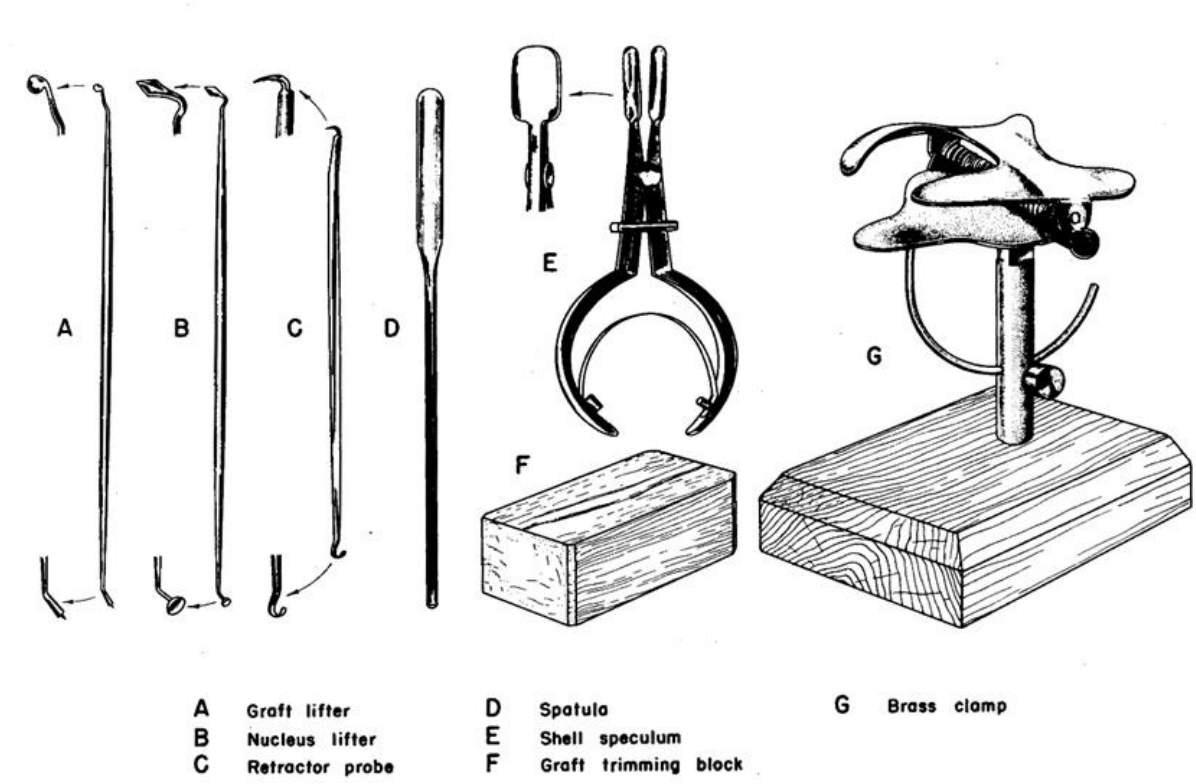
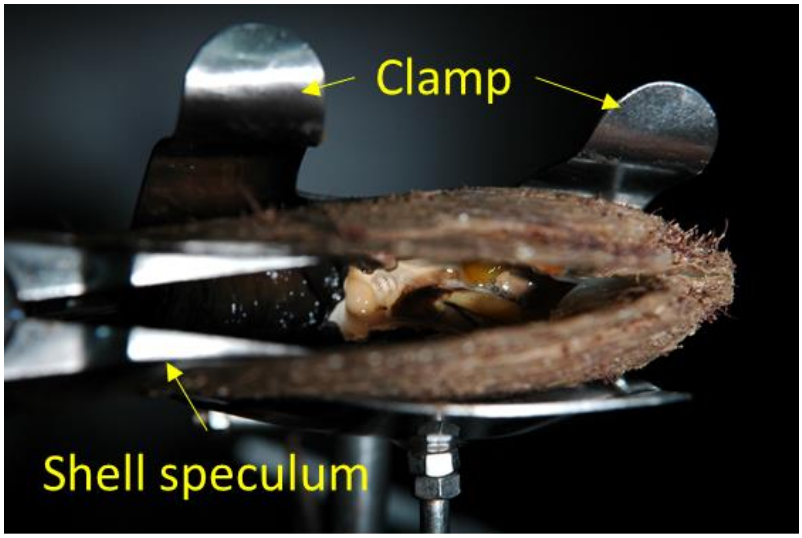


Figure 63: Special tools used for the bead insertion operation, above line drawing showing the graft lifter, bead (nucleus) lifter, retraction probe, spatula, shell speculum, graft trimming block and brass clamp– drawing taken directly from (Cahn, 1949). The latter three also being seen to the right and in Figure 64.



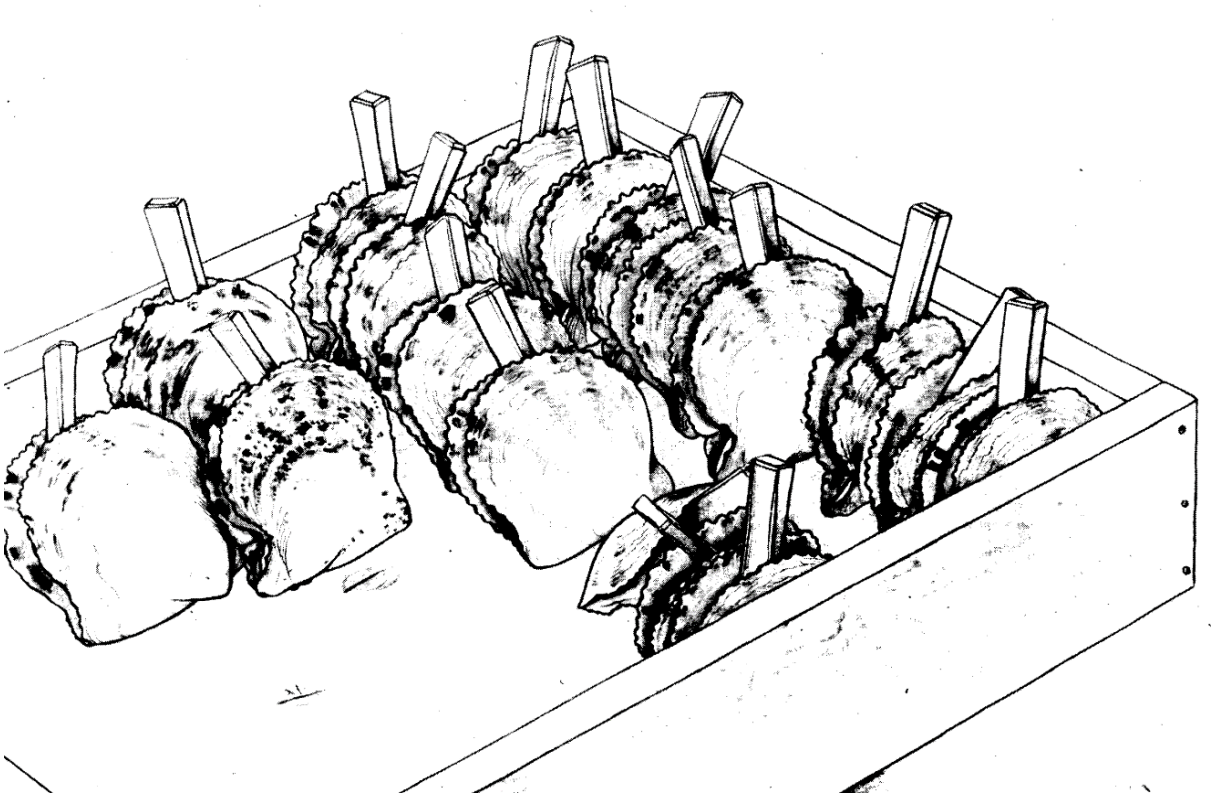


Figure 66: Line drawing showing shell being held open with wooden pegs, a technique common to all culturing processes – drawing directly from (Cahn, 1949).

Figure 65: A sharp pointed instrument used to irritate the mantle by 'poking' in an attempt to stimulate pearl growth.

Figure 64: A spatula–like (D in Figure 63) together with a hooked instrument (similar to A in Figure 63) were used to scarify and smear the mantle in an attempt to stimulate pearl growth.

Figure 67: Author KS aboard P2 removing shell from one of the shell holding panels used in these experiments two years after the operations took place. Some of the blue shell tags are clearly visible. Photo Chunhui Zhou.

Figure 68: Following removal from the shell holding panels the shell were placed into a 'relaxant' until they opened up sufficiently for the halves to be pulled apart for the collection of the pearls. Photo K. Scarratt.

Figure 69: A relaxed Pinctada maxima with gills easily visible. Photo K. Scarratt.

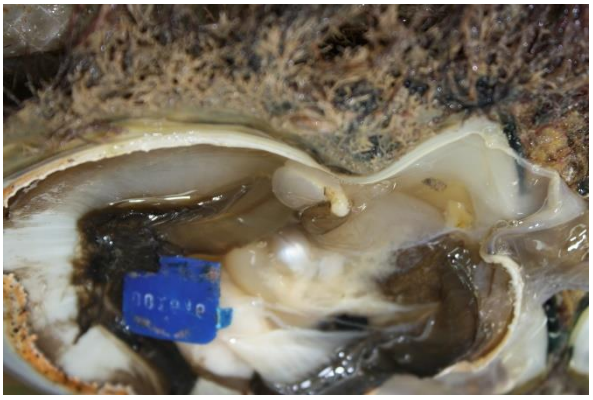


Figure 70: An opened Pinctada maxima with cultured pearl present and the blue shell tag removed from the shell pocket and placed here for recording purposes only. Photo K. Scarratt.

Once back on the P2 for the retrieval phase the shells and the shell tags were carefully removed from the panels and kept together while in the relaxant (Figure 67 and Figure 68). Once the shell were relaxed they were opened and the two halves laid flat by cutting through the adductor muscle. Any resulting cultured pearls were then extracted from the gonad with macro photography being taken both before and after extraction. Any (atypical) 'bead' cultured pearls were then placed in individual bags along with the relevant shell tag. The entire harvest was then transported to the laboratory for examination.

Primary data was collected on all the resulting aBCPs using real-time microradiography with the Faxitron CS-100AC and/or the Matrix XT-3 and µCT imaging using the Procon µCT-MINI, all with variable operating conditions that were sample dependent. Further data was collected as necessary using EDXRF (using an ARL Quant'X EDXRF Analyzer) Raman (using a Renishaw InVia confocal Raman microscope with a 514nm Ar-ion laser) and x-ray fluorescence observations (using a purpose built Verifier PF-100).

Results

The authors conducted ninety one controlled experiments in order to gain a better understanding of the processes used and the results likely to be obtained from the use of unconventional culturing techniques and comparing these with known natural and cultured pearl growth data. Seventy five of the experiments involved the insertion of various types of atypical 'beads' (natural abalone, scallop, *Pteria sterna* and *Pinna*, and assumed caracol panocha *"Astrea (Megastrea) turbanica"* aka "wavy turban shell" pearls, partially drilled coral 'beads', faceted sapphire 'beads' of various colors, freshwater non-bead cultured pearls, various shells and rough coral and an assortment of plastic, glass, quartz and agate 'beads'), while sixteen experiments consisted of irritating, folding, or attempting to insert donor tissue into the mantle of *Pinctada maxima.*

Table 1 and Table 2 present an overview on the experiment results. Over the two year period allowed for the growth of the cultured nacre some shell and panel tags were 'lost-at-sea' as they required mechanical cleaning from time to time, in addition some shell died, nevertheless the authors were able correlate and authenticate all samples relative to the individual experiment.

Expanding upon Table 1 and Table 2, the results of seven samples are described here and in Figure 71 through to Figure 108 in more detail.

Sample 100306144539 from shell tag 1641 is a natural abalone pearl that is green in colour and weighs 0.49ct (Figure 71). Used as an atypical 'bead' the RTX images of this natural pearl prior to these experiments displayed very distinctive characteristic growth features Figure 72. Following the two year growth period a considerable amount of cultured nacre had deposited over the surface of the pearl, the cultured nacre having no discernable growth structures present contrasts greatly with the structures seen in the abalone pearl. This contrast is clear in the RTX images but even more so in a single slice of the µCT scan (Figure 73 and Figure 74). Notable in both the RTX and µCT images is the dark organic tail emanating from the right side of the abalone pearl relating to the positioning of the donor mantle tissue (sometimes referred to as the saibo), in both images that is often recorded in bead cultured pearls in general. The resulting aBCP is shown in Figure 75. The growth rate over the two year period produced a sizable pearl considering the weight of the 'bead' used.

Another abalone pearl used in these experiments failed.

Sample 100306144563 from shell tag 1627 is a partially drilled coral 'bead' that is orangey pink in colour (Figure 76). Used as an atypical 'bead' the RTX images of this coral 'bead' reveal little apart from the width and depth of the drill-hole (Figure 77). Following the two year growth period a considerable amount of cultured nacre had deposited over the surface of the coral 'bead', the cultured nacre having very distinctive growth structures relative to the drill-hole (Figure 78 and Figure 79); a distinctive organic growth line within the cultured nacre growth can be seen to be following the external shape of this coral 'bead' (atypical) cultured pearl and multiple deposits or cultured nacre and organic matter forming 'U' shaped structures can been seen in the drill-hole in both the RTX and µCT slice images. As with sample 100306144539 a distinctive dark organic tail can be seen emanating from top, in this case, of the coral 'bead' that is often recorded in bead cultured pearls in general. The resulting aBCP is shown in Figure 80.

Another coral 'beaded' (atypical) cultured pearl, sample 100306144565, was produced where there was a very clear organic growth line separating the coral 'bead' from the cultured nacre overgrowth and similar in the drill-hole structures.

Six other drilled coral 'beads' were included in these experiments but all these failed.

Figure 71: Sample 100306144539 from shell tag1641, a green natural abalone pearl weighing 0.49ct used as an atypical 'bead' in bead culturing experiments, see Figure 72, Figure 73 and Figure 74.

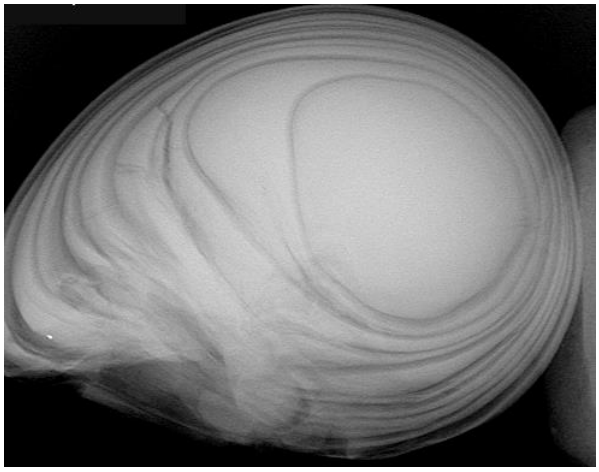


Figure 72: An RTX image of the abalone pearl seen in Figure 71 note the very clear natural growth structures.

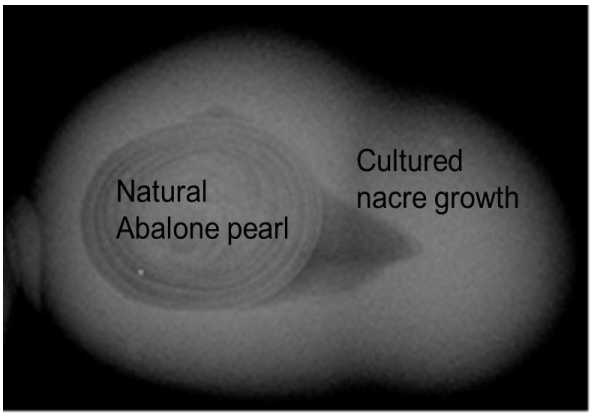


Figure 73: An RTX image of the abalone pearl seen in Figure 71, Figure 72 and Figure 74 now overgrown with nacre following atypical beading experiments. Note the 'organic tail' seen to the right of the abalone pearl that is often observed in bead-cultured pearls

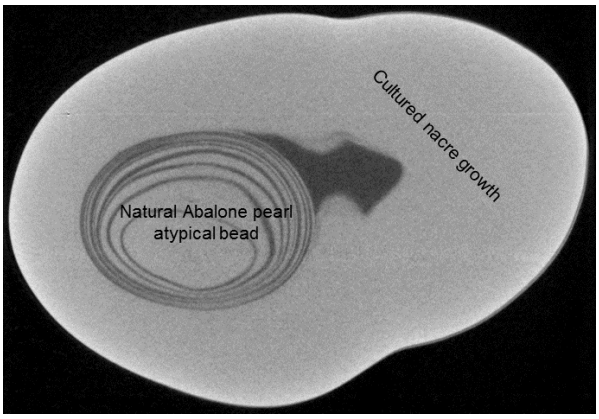


Figure 74: A slice from aμCT scan of the abalone pearl seen in Figure 71, Figure 72 and Figure 73 now overgrown with cultured nacre following atypical beading experiments. Note the 'organic tail' seen to the right of the abalone pearl that is often observed in bead-cultured pearls also the higher definition of the μCT v. RTX.

Figure 75: The resulting aBCP using the 'bead' seen in Figure 71, weighing 6.952ct and measuring 13.58 x 9.32 x 8.04mm Photo by Lhapsin Nillapat.

Figure 76: Partially drilled coral 'bead' used as an atypical 'bead' in 'bead' culturing experiments, see Figure 77, Figure 78 and Figure 79.

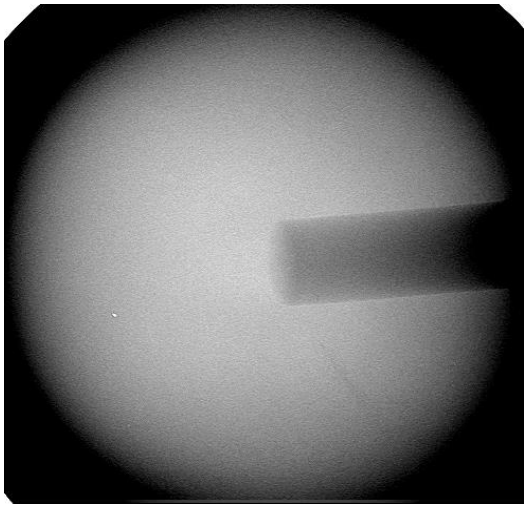


Figure 77: An RTX image of the partially drilled coral 'bead' seen in Figure 76. Note that the drill-hole is clearly visible.

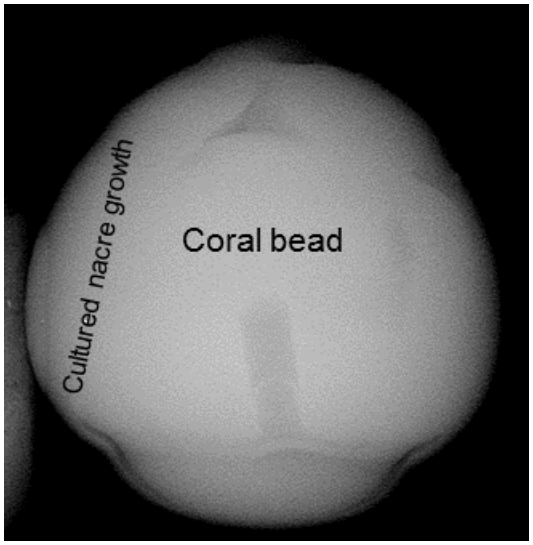


Figure 78: An RTX image of the coral bead seen in Figure 76, Figure 77 and Figure 79 now overgrown with cultured nacre following atypical beading experiments. Note the demarcation between the nacre and the bead and that the drill-hole is part filled with nacreous growth

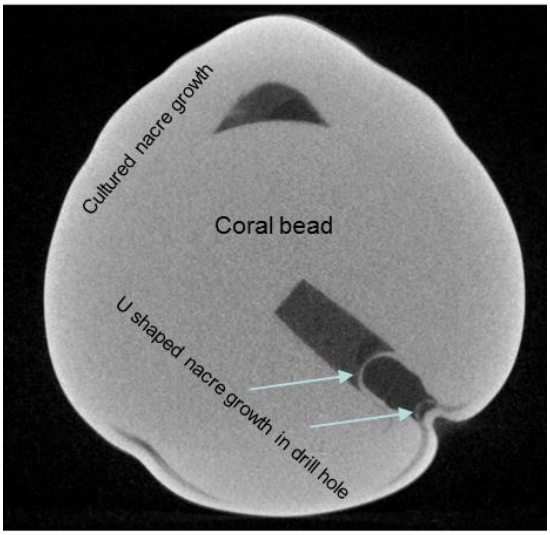


Figure 79: A slice from a µCT scan of the coral bead seen in Figure 76, Figure 77 and Figure 78 now overgrown with cultured nacre following atypical beading experiments. Note the demarcation between the nacre and the bead and that the drill-hole is part filled with nacreous growth. Also, note the higher definition of the µCT v. RTX.

Figure 80: The resulting aBCP using the bead seen in Figure 76, weighing 5.084ct and measuring 9.42 x 9.15 x 9.00 mm. Photo by Lhapsin Nillapat.

Figure 81: A small shell weighing 0.41ct used as an atypical 'bead' in 'bead' culturing experiments, see Figure 82, Figure 83, and Figure 84.

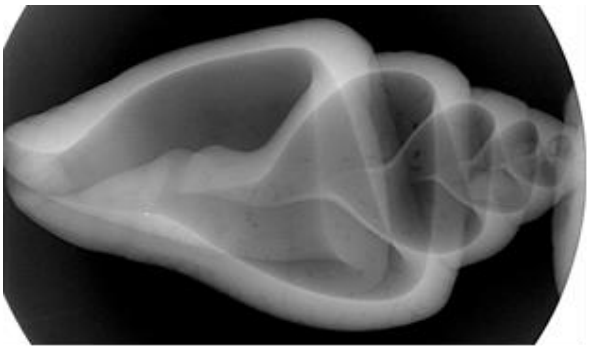


Figure 82: An RTX image of the shell seen in Figure 81.

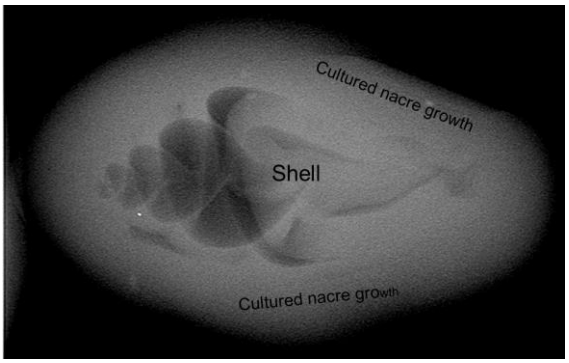


Figure 83: An RTX image of the shell 'bead' seen in Figure 81, Figure 82 and Figure 84 now overgrown with nacre following atypical beading experiments.

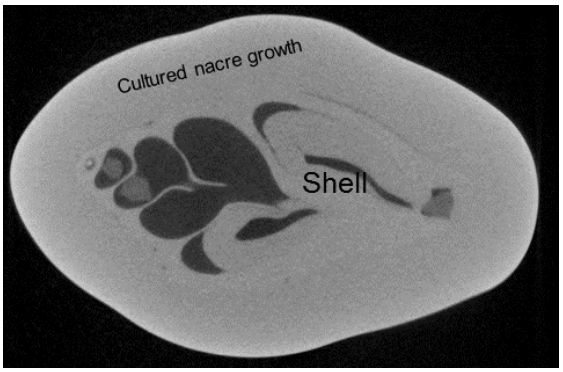


Figure 84: A slice from a µCT scan of the shell seen in Figure 81, Figure 82 and Figure 83 now overgrown with nacre following atypical beading experiments. Note the demarcation between the nacre and the shell also note the higher definition of the µCT v. RTX.

Figure 85: The resulting aBCP weighing 3.110ct and measuring 10.25 x 7.43 x 6.64 mm. Photo by Lhapsin Nillapat.

Sample 100306144669 from shell tag 1653 is a very small shell weighing 0.41ct (Figure 81). Used as an atypical 'bead' the RTX images of this shell prior to these experiments displayed very distinctive growth structures that revealed large empty chambers with spiraled walls (Figure 82). Following the two year growth period a considerable amount of cultured nacre had deposited over the surface of the shell Figure 83 and Figure 84) and while the demarcation between the shell and the cultured nacre is discernable in both the

RTX and µCT images the cultured nacre itself has no discernable growth structures. The resulting aBCP is shown in Figure 85.

Three other shells used as atypical 'beads', 100306144670, 100306144675 and 100306144662 in these experiments also produced atypical 'bead' cultured pearls with similar resulting RTX and µCT images, one 100306144668 failed to produce an atypical 'bead' cultured pearl, however a non-bead (Keshi[ii]) cultured pearl (Figure 88) was found in the gonad and six others failed to produce.

The non-bead cultured pearl (NBC) sample was interesting since it is well known that such accidental or unintentional pearls are produced when the 'bead' inserted into a mollusk, either in the 1st operation with a piece of mantle tissue, or in an already existing cultured pearls sac in subsequent operations, is ejected. In the first scenario the mantle tissue continues to form a cultured pearl sac and a pearl without a bead (non-bead/keshi) forms instead, while in the second scenario the existing pearl sac often collapses and also creates a more baroque but thin/flat non-bead cultured pearl (Hänni H. , 2006) (Hänni H. , 2006) (Hänni H. , 2007) (Hänni H. , 2012) . The authors know that in the case of 100306144668 the shell (Figure 86) inserted must have been ejected but the pearl sac still formed post operation and a NBC pearl formed.

Sample 100306144792 from shell tag 1662 is a drop-shaped bluish Violet briolette natural sapphire weighing 0.97ct (Figure 90). Used as an atypical 'bead' the RTX images of this sapphire prior to these experiments displayed little more than ghosting from some of its facet edges (Figure 91). Following the two year growth period a considerable amount of cultured nacre had deposited over the surface of the sapphire (Figure 92 and Figure 93), the demarcation between the sapphire and the cultured nacre being very clear in both the RTX and µCT images and the differences in x-ray transparency being clearly obvious. Again there were no discernable growth structures seen within the cultured nacre. On the other hand a noteworthy feature in both the RTX and µCT images was the distinctive dark organic tail seen emanating from the right of the sapphire 'bead' (Figure 92 and Figure 93), again something that is often recorded in bead cultured pearls in general. The resulting aBCP is shown in Figure 94.

Seven other sapphire 'beads' were used in these experiments but all failed to produce bead cultured pearls.

Sample 100306144650 from shell tag 1646 is a small 'drilled' plastic imitation of pearl weighing 1.14ct (Figure 96). Used as an atypical 'bead' the RTX images of this plastic 'bead' prior to these experiments reveal it to be quite transparent to x-rays (Figure 98) Following the two year growth period a considerable amount of cultured nacre had deposited over the surface of the plastic with the nacre now contrasting greatly with the largely x-ray transparent 'bead' in both the RTX and µCT images (Figure 95 and Figure 97). Also of note is that the cultured nacre growth has penetrated deep into the 'drill-hole'. The resulting aBCP with two obvious eye-visible indentations on the surface relating to the underlying drill-hole void at each end is shown in Figure 99.

One other similar plastic 'bead' was used in these experiments (100306144651) but failed to produce a bead cultured pearl.

Sample 100306144580 from shell tag1643 is a small freshwater non-bead cultured pearl weighing 1.41ct (Figure 100). Used as an atypical 'bead' the RTX images of this cultured pearl revealed structures that are expected for a freshwater non-bead cultured pearl (Figure 101). The single RTX image in Figure 102 reveals a significant overgrowth of additional cultures nacre when compared with the image in Figure 101, however without this benefit of this prior image the demarcation between 'bead' and overgrowth is unclear. Further and expanded RTX images may however reveal more detail. On the other hand the µCT slice in Figure 104 reveals the boundary much more clearly. While the internal

growth structures would identify this as a cultured pearl and lead one to assume a freshwater origin the surface chemistry of this sample is now consistent with a sea-water pearl which may cause some confusion. However, for this sample the fluorescence induced by x-rays is the characteristic bright yellow/green of a freshwater origin. The resulting aBCP is shown in Figure 103.

One other freshwater cultured pearl using in these experiments failed to produce an aBCP.

Figure 86: A small shell weighing 0.752ct used as an atypical 'bead' in 'bead' culturing experiments, see Figure 87, Figure 88, and Figure 89

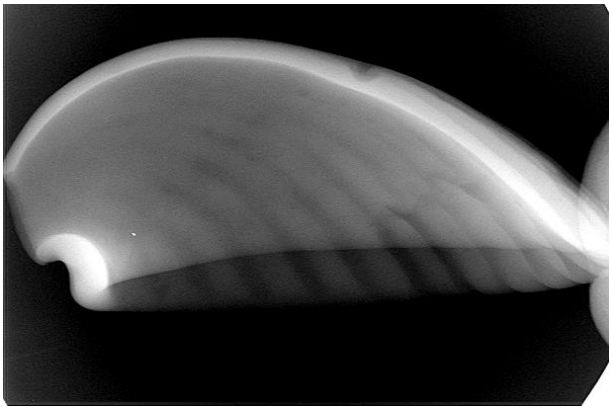


Figure 87: An RTX image of the shell seen in Figure 86.

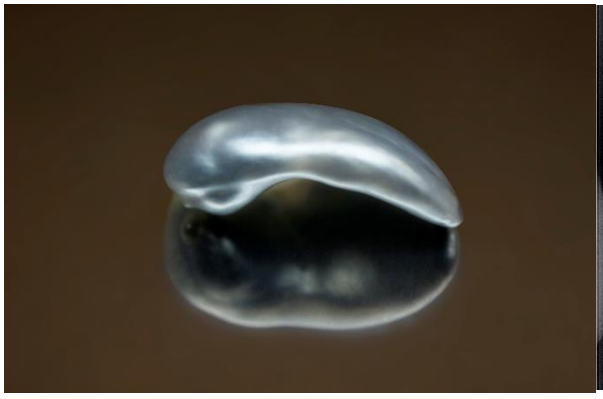


Figure 88: Non-bead cultured pearl weighing 1.016ct and measuring 9.92 x 5.74 x 1.95 mm, produced by the rejection of the shell 'bead' (Figure 86) after being inserted into the gonad of the mollusc with the intension of producing a 'bead' cultured pearl. See Figure 87 , and Figure 89 Photo by Lhapsin Nillapat.

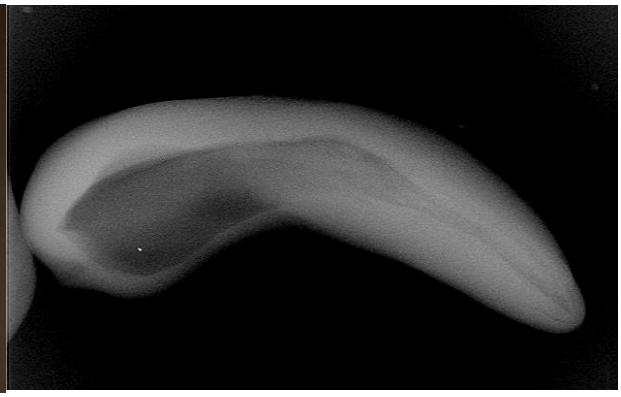


Figure 89: An RTX or the pearl (Figure 88) produced from the mollusc in which the shell 'bead' (Figure 86) was ejected and the resulting pearl formed without a 'bead'. The organic rich structure is characteristic of such accidental or unintentional non-bead cultured pearls.

Figure 90: A small sapphire 'bead' weighing 0.97ct used as an atypical 'bead' in 'bead' culturing experiments, see Figure 91, Figure 92 and Figure 93.

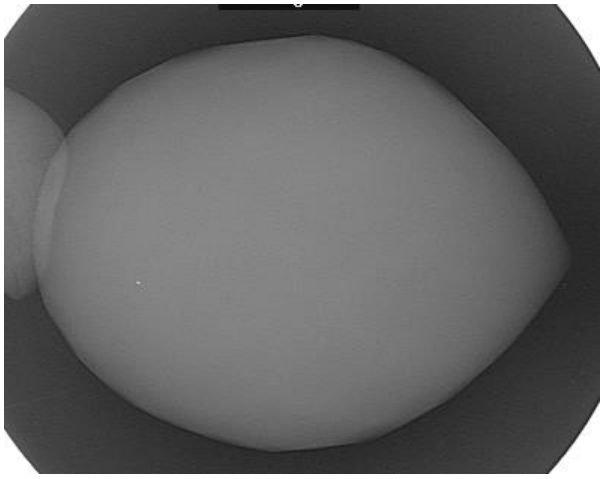


Figure 91: An RTX image of the sapphire 'bead' seen in Figure 90.

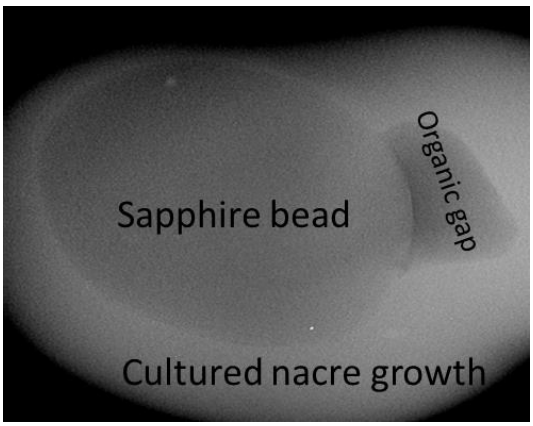


Figure 92: An RTX image of the sapphire 'bead' seen in Figure 90, Figure 91 and Figure 93 now overgrown with cultured nacre following atypical beading experiments. Note the demarcation between the cultured nacre and the sapphire is very clear, as are the straight facet edges; note also the 'organic gap' seen to the right of the sapphire that is often observed in bead-cultured pearls.

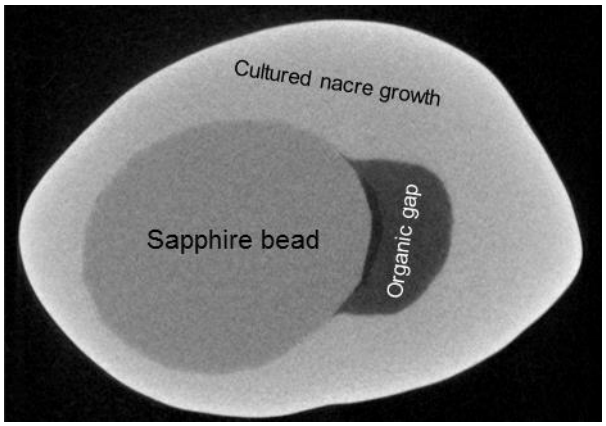


Figure 93: A slice from a μCT scan of the sapphire 'bead' seen in Figure 90, Figure 91 and Figure 92, now overgrown with cultured nacre following atypical beading experiments. Note the demarcation between the cultured nacre and the sapphire is very clear as are the straight facet edges; note also the 'organic gap' seen to the right of the sapphire that is often observed in bead-cultured pearls also note the higher definition of the μCT v. RTX.

Figure 94: The resulting aBCP from using the 'bead' in Figure 90, weighing 2.931ct and measuring 8.83 x 7.29 x 5.95mm. Photo by Lhapsin Nillapat.

Figure 96: A small 'drilled' plastic imitation pearl weighing 1.14ct used as an atypical 'bead' in 'bead' culturing experiments, see Figure 98, Figure 95 and Figure 97.

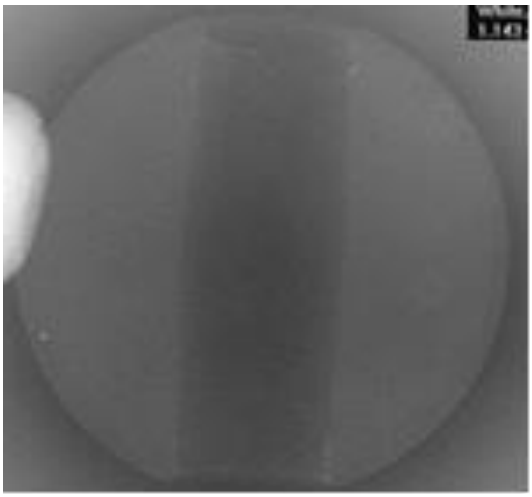


Figure 98: An RTX image of the 'drilled' plastic imitation pearl seen in Figure 96. The drill hole appears dark and running vertically in this image.

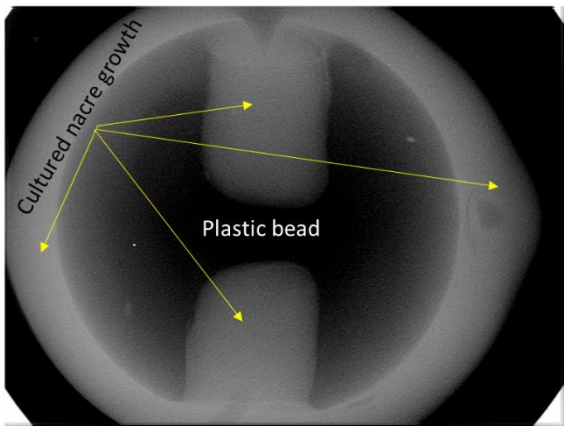


Figure 95: An RTX image of the 'drilled' plastic imitation pearl seen in Figure 96, Figure 98 and Figure 97, now overgrown with cultured nacre following atypical beading experiments. Note that the cultured nacre growth also penetrates deep into the drill hole.

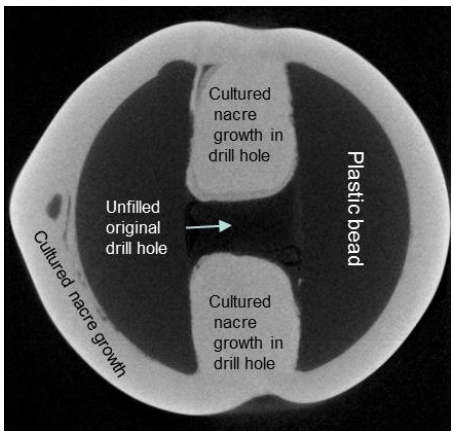


Figure 97: A slice from a µCT scan of the plastic bead seen in Figure 96, Figure 98 and Figure 95 now overgrown with nacre following atypical beading experiments. Note the demarcation between the nacre and the plastic bead is very clear; note also that the cultured nacre growth has penetrated deep into the 'drill hole' also note the higher definition of the µCT v. RTX

Figure 99: The resulting aBCP, using the bead seen in Figure 96 weighing 4.414ct and measuring 10.51 x 9.62 x 9.30mm. Photo by Lhapsin Nillapat.

Figure 100: A small freshwater non-bead cultured pearl weighing 1.41ct used as an atypical 'bead' in 'bead' culturing experiments, see Figure 101, Figure 102, and Figure 104.

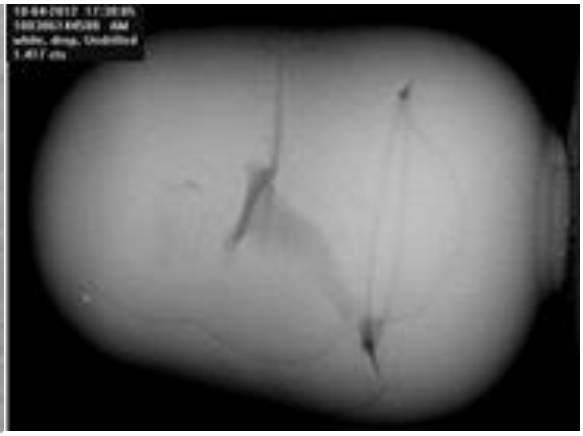


Figure 101: An RTX image of the small freshwater non-bead cultured pearl seen in Figure 100.

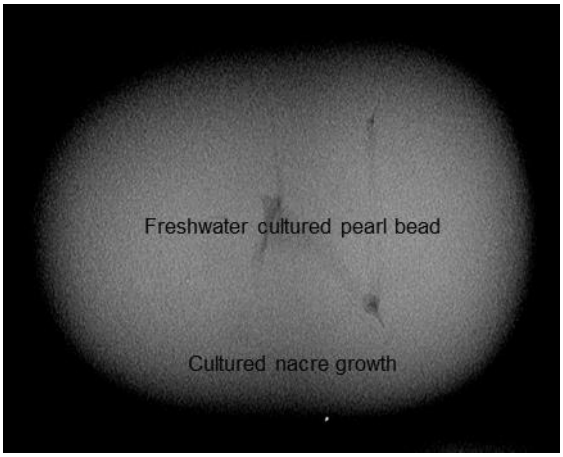


Figure 102: An RTX image of the freshwater non-bead cultured pearl seen in Figure 100, Figure 101 and Figure 104 now overgrown with nacre following atypical beading experiments. Note that the demarcation between the freshwater 'bead' and the new cultured nacre growth is unclear but whilst the exterior of this cultured pearl now has saltwater chemistry it fluoresces strongly under x-ray excitation, which is typical of a freshwater origin, and the internal grown structures betray the origin of the 'bead'.

Figure 103: The resulting aBCP, using the 'bead' seen in Figure 100, weighing 3.207ct and measuring 8.55 x 7.02 x 6.87mm. Photo by Lhapsin Nillapat.

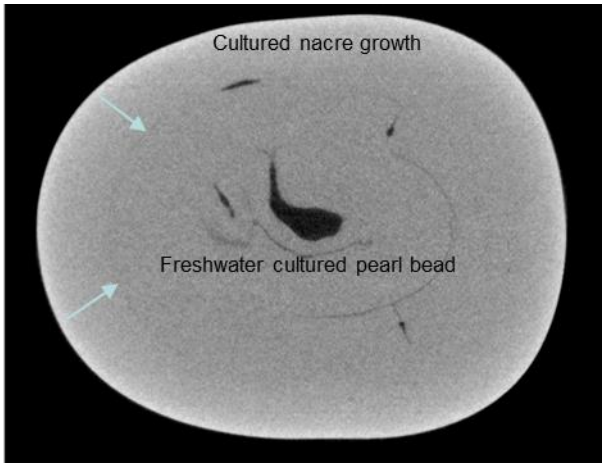


Figure 104: A slice from a µCT scan of the freshwater non-bead cultured pearl seen in Figure 100, Figure 101 and Figure 102, now overgrown with nacre following atypical beading experiments. Note the demarcation between the cultured nacre and the 'bead' is unclear even with this higher definition µCT imaging (see white arrows).

Figure 105: A 0.85ct natural pearl from the Pteria species used as an atypical 'bead' in bead culturing experiments, see Figure 106, Figure 107 and Figure 108.

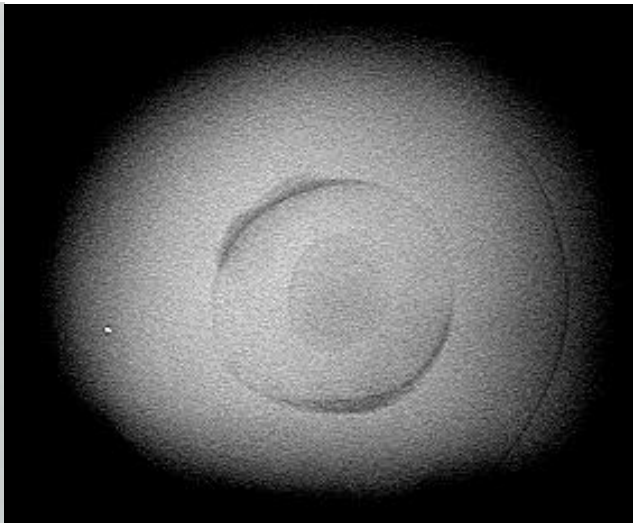


Figure 106: An RTX image of the natural pearl from the Pteria species seen in Figure 105.

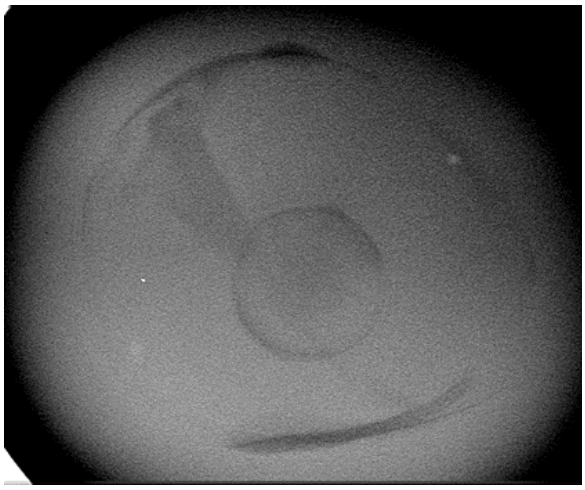


Figure 107: An RTX image of the natural pearl from the Pteria species seen in Figure 105, Figure 106 and Figure 108, now overgrown with nacre following atypical beading experiments. Note that the demarcation between the natural pearl 'bead' and the new cultured nacre growth is very clear.

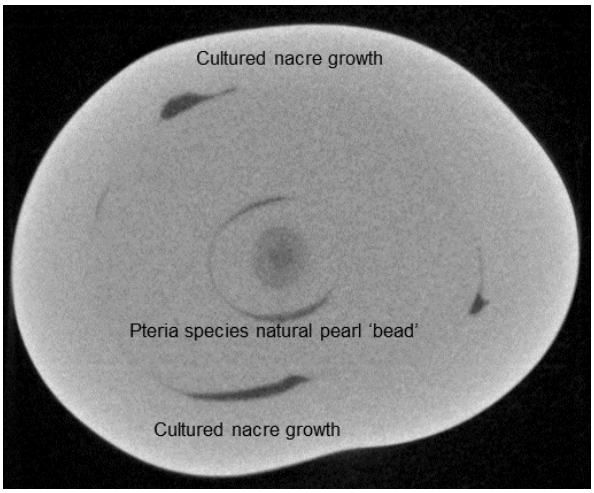


Figure 108: A slice from a µCT scan of the natural pearl from the Pteria species seen in Figure 105, Figure 106 and Figure 107, now overgrown with nacre following atypical beading experiments. Note the demarcation between the cultured nacre growth and the natural pearl 'bead' is very clear; note also the higher definition of the µCT v. RTX.

Figure 109: The resulting aBCP, using the 'bead' seen in Figure 105, weighing 2.657ct and measuring 8.17 x 7.21 x 6.26mm. Photo by Lhapsin Nillapat.

Sample 100306144550 from shell tag 1607 is a small natural pearl from the *Pteria* species weighing 0.85ct (Figure 105). Used as an atypical 'bead' the RTX images of this natural pearl prior to these experiments reveal fairly characteristic natural growth structures although in Figure 106 it could itself be mistaken for an atypically 'bead' cultured pearl. Following the two year growth period a considerable amount of cultured nacre can be seen to have been deposited which is clear from the RTX image in Figure 107 and the µCT slice in Figure 108. The boundary between the natural pearl and the cultured nacre overgrowth is clear in both the RTX and µCT images, with the latter being a little clearer. The resulting aBCP is shown in Figure 109.

Eight other Pteria species natural pearls were used in these experiments but all failed.

Sample 100306144541 from shell tag 1620 is a brown scallop pearl weighing 1.720ct. Used as an atypical 'bead' the RTX images of this natural pearl prior to these experiments reveal relatively weak natural growth structures as is generally expected from this type of pearl. Following the two year growth period a considerable amount of cultured nacre can be seen to have been deposited which is clear from the RTX image in and the µCT slice in. The boundary between the natural pearl and the cultured nacre overgrowth is clear in both the RTX and µCT images, with the latter being a little clearer. The resulting aBCP is shown in Figure 114.

Sample 100306144554 from shell tag 1617 is a purplish pink and white scallop pearl weighing 3.950ct. Used as an atypical 'bead' the RTX images of this natural pearl prior to these experiments reveal relatively weak natural growth structures internally with one clear growth structure towards the edge of the pearl. Following the two year growth period surprisingly, when compared with other experiment results, only a thin layer of cultured nacre was deposited making identification as an aBCP very challenging, in fact if this pearl were to be received 'blind' in a laboratory it is likely that only the highest resolution µCT imaging would give a clue as to its true composition. Indeed even with this imaging, a laboratory might be reticent in providing a definitive result without destructive testing. The resulting aBCP is shown in Figure 119

Interestingly in addition to the aBCP a small NBCP (keshi) was discovered in the gonad of the host mollusc as well.

Discussion

The use of atypical 'beads' in the culturing process adds to the identification difficulties faced by pearl laboratory gemmologists; the most significant of these difficulties is created with the use of low quality natural pearls or marine debris such as fragments or whole shells, as the substrates for cultured nacre growth.

While the quantities submitted to the pearl laboratories of GIA (Bangkok and New York) and GPTLB (Bahrain) by clients for routine identification since 2011 have not been high, numbering in the low 100s to date, cases do appear regularly enough to create some identification challenges where even µCT analysis may not produce a clear resolution to identification problems. Most of aBCPs submitted thus far have been found to have had natural pearls or freshwater non-bead cultured pearls used as the substrates for the cultured nacre growth

The use of orangey-pink coral 'beads' result in images that are (notwithstanding the clearly visible partial drill-hole as in the samples used) similar to those seen in shell bead cultured pearls, however, the colour of the coral in these experimentations was strong enough to show through even the relatively thick nacre to give the atypical beaded cultured pearl a pinkish orange undertone. This unusual colour certainly raising suspicions in a 'blind test'

scenario. The use of both the plastic and the sapphire 'beads' produced very distinctive x-ray images that would leave the examiner in no doubt as to their identity.

Figure 110 : A 1.720ct natural scallop pearl used as an atypical 'bead' in bead culturing experiments, see Figure 111, Figure 112 and Figure 113

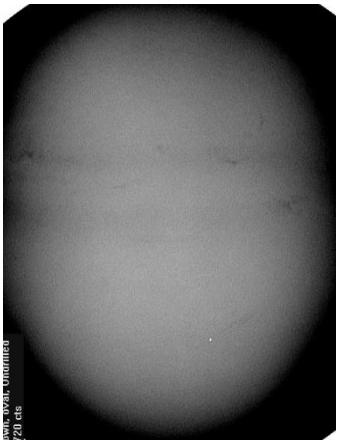


Figure 111: An RTX image of the natural scallop pearl seen in Figure 110.

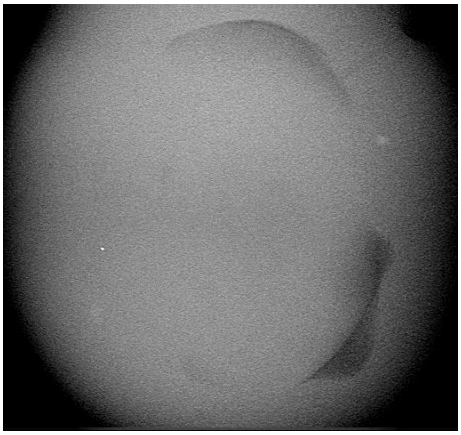


Figure 112: An RTX image of the natural scallop pearl seen in Figure 110, Figure 111 and Figure 113, now overgrown with nacre following atypical beading experiments. Note that the demarcation between the natural pearl 'bead' and the new cultured nacre growth is very clear.

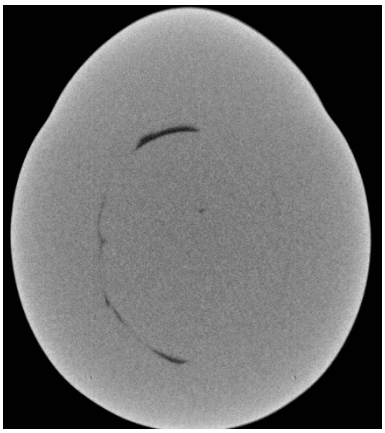


Figure 113: A slice from a µCT scan of the natural scallop pearl seen in Figure 110, Figure 111 and Figure 112, now overgrown with nacre following atypical beading experiments. Note the demarcation between the cultured nacre growth and the natural pearl 'bead' is very clear.

Figure 114: The resulting aBCP, using the 'bead' seen in Figure 110, weighing 8.385ct and measuring 12.14 x 10.11 x 10.09mm. Photo by Lhapsin Nillapat.

Figure 116: A 3.950ct natural scallop pearl used as an atypical 'bead' in bead culturing experiments, see Figure 118, Figure 115 and Figure 117.

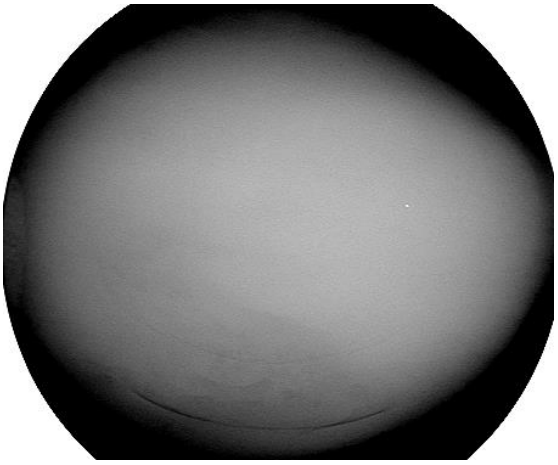


Figure 118: An RTX image of the natural scallop pearl seen in Figure 116.

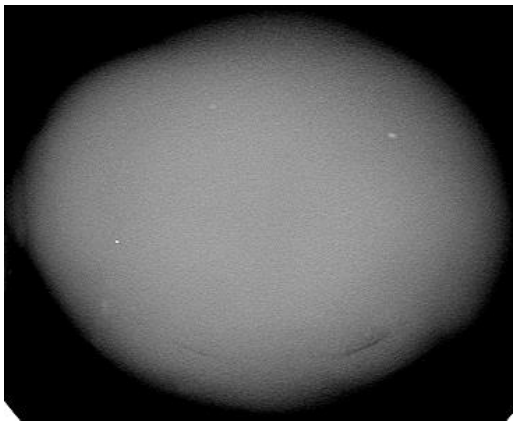


Figure 115: An RTX image of the natural scallop pearl seen in Figure 116, Figure 118 and Figure 117, now overgrown with nacre following atypical beading experiments. Note that the demarcation between the natural pearl 'bead' and the new cultured nacre growth is unclear

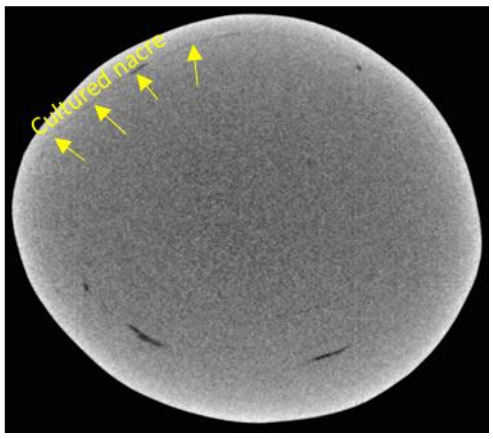


Figure 117: A slice from a µCT scan of the natural scallop pearl seen in Figure 116, Figure 118 and Figure 115, now overgrown with nacre following atypical beading experiments. Note the demarcation between the cultured nacre growth and the natural pearl 'bead' is visible but unclear.

Figure 119: The resulting aBCP, using the 'bead' seen in Figure 116, weighing 5.338ct and measuring 10.04 x 9.57 x 8.32mm., a small NBCP was also found along with the aBCP in the gonad Photo by Lhapsin Nillapat.

The use of non-bead freshwater cultured pearls as atypical 'beads' with clear non-bead cultured x-ray imaging characteristics may not lead an examiner to think that the pearl is of natural origin, but there may be a 'hick-up' in the identification process if the chemistry of the new cultured nacre is determined and found to be of saltwater origin. However, as the x-ray induced florescence of these samples is still strong this should allow for a proper identification to take place.

If, as in these experiments, a long period is allowed to deposit cultured nacre on to a natural pearl substrate the subsequent identification process is simplified (although still challenging in some cases), particularly if the structures within the natural pearl 'bead' differ greatly from the cultured nacre overgrowth and there is a clear organic tail at the interface between the 'bead' and the cultured nacre. However, if the growth period is shortened to a period that allows just enough time for a thin cultured nacre coating or even if the time allowed is significant but the coating is still thin (as in 100306144554 above) identification may prove exceedingly challenging and this seems to be the aim of the present perpetrators of these processes.

A full commercialization of the production for this kind of product seems unlikely given that farmers desire large volumes with predicable outcomes in this high risk business. The use of readily available shell beads that are in calibrated sizes eases the operations and increases the eventual success factor. In these experiments neither the sizes or the shapes of the 'beads' were anywhere near the 'ideal', and while accepting that this was only a single experiment with no follow through or re-run based on what was learned, the failure rate was notably high at near 70%, despite the services of one of the most experienced technicians in the business, and much too high for any serious pearl culturing to be based. Nevertheless, as noted above a relatively small number of these aBCPs are circulating in the market place and the trade as well as those responsible for pearl testing should be wary of their presence despite the low numbers.

In ending this report it is worth noting the lack of any whole pearl produced by the "coaxing" of the mantle itself. Despite the various methods applied (see Table 2) these actions resulted in no end products which to some extent runs contrary to other reports of keshi pearls being produced by damage to the mantle during the seeding process (Hänni H. , 2006) (Hänni H. , 2012).

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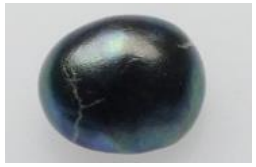
Tables

Table 1: Atypical 'bead' culturing experiments.

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
	Natural Abalone Pearls (2 pieces)									
1	E	1641	100306144539	0.489	0.266	2.19	dark grayish Green	Semi-baroque		
2	E	1642	100306144540	0.442	0.265	2.50	light bluish Green	Baroque		Failed experiment, shell died, plus tag missing, likely temporary tag E2

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
	Natural Scallop Pearls (10 pieces)									
3	E	1620	100306144541	1.720	1.075	2.67	Brown	Circled-Oval		
4	E	1619	100306144542	1.593	0.991	2.65	purplish Brown	Circled-Drop		
5	E	1618	100306144543	1.157	0.716	2.62	purplish Pink	Circled-Drop		Failed experiment, shell died, plus tag missing, likely temporary tag E3

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
15	D	1617	100306144554	3.950	2.466	2.66	purplish Pink & White	Baroque		  Keshi also in gonad
16	D	1612	100306144555	3.496	2.209	2.72	White	Semi-baroque		 
17	D	1615	100306144556	1.948	1.213	2.65	White & purplish Pink	Semi-baroque Drop		  No pearl in gonad adductor pearls present.

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
18	D	1616	100306144557	1.446	0.928	2.79	Pink & Orange	Drop		 
19	D	1611	100306144558	1.445	0.902	2.66	White	Near-round		 
20	D	1613	100306144559	1.387	0.860	2.63	White	Button		Failed experiment, shell dead, tag 1613 present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
21	D	1614	100306144560	0.701	0.427	2.56	purplish Pink	Oval		Failed experiment, shell dead, tag 1614 present
	Natural *Pteria sterna* Pearls (9 pieces)									
6	D	1610	100306144544	3.516	2.224	2.72	White	Baroque		Failed experiment, shell alive but no pearl present.
7	C	1602	100306144545	2.818	1.762	2.67	light Brown	Semi-Baroque		Failed experiment, shell alive but no pearl present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
8	C	1603	100306144546	1.468	0.932	2.74	light Brown	Semi-Baroque		Failed experiment, shell died, tag 1603 present
9	C	1604	100306144547	1.432	0.883	2.61	White	Baroque		Failed experiment, shell died, tag 1604 present
10	C	1605	100306144548	1.253	0.749	2.49	light Brown	Baroque		Failed, shell dead, tag 1605 present
11	C	1606	100306144549	1.006	0.617	2.59	White	Semi-baroque		Failed, shell dead, tag 1606 present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
12	C	1607	100306144550	0.854	0.532	2.65	White	Semi-baroque		
13	C	1608	100306144551	0.827	0.521	2.70	light Brown	Baroque		Failed experiment, Tag 1608 not found likely temporary tag C1 dead shell
14	C	1609	100306144552	0.399	0.242	2.54	White	Baroque		Failed experiment, shell dead, tag 1609 present
	Natural Pinna Pearl (1 pieces)									
22	I	1664	100306144561	2.110	1.221	2.37	Brown	Baroque		Failed experiment

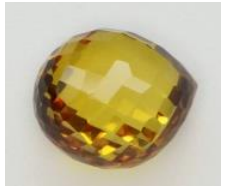
Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
	Partially drilled Coral (8 pieces)									
23	H	1626	100306144562	2.137	1.326	2.64	orangey Pink	Round		Failed experiment
24	H	1627	100306144563	1.897	1.183	2.66	orangey Pink	Round		
25	I	1628	100306144564	1.890	1.175	2.64	orangey Pink	Round		Failed experiment

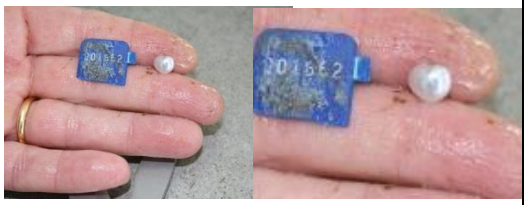
Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
26	K	1709	100306144565	3.119	1.942	2.65	orangey Pink	Round		
27	K	1710	100306144566	3.021	1.883	2.65	orangey Pink	Round		Failed experiment
28	K	1631	100306144567	2.990	1.867	2.66	orangey Pink	Round		Failed experiment
29	J	1669	100306144568	4.376	2.465	2.29	orangey Pink	Round		Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
30	J	1668	100306144569	3.964	2.735	3.23	orangey Pink	Round		Failed experiment
	Natural *Caracol panocha* Pearls (9 pieces)									
31	H	1660	100306144570	1.374	0.773	2.29	Cream	Baroque		 Likely a keshi
32	H	1621	100306144571	1.364	0.883	2.84	White	Baroque		Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
33	J	1704	100306144572	0.962	0.602	2.67	Cream	Button		 
34	J	1703	100306144573	0.778	0.507	2.87	White	Near-round		 
35	H	1622	100306144574	0.770	0.471	2.58	White	Baroque		 
36	H	1623	100306144575	0.697	0.437	2.68	Orange	Semi-baroque Button		Failed experiment, shell died, tag 1623 present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
37	K	1705	100306144576	0.674	0.423	2.69	Cream	Near-round		Failed experiment
38	H	1624	100306144577	0.488	0.308	2.71	Cream	Semi-baroque Button		Failed experiment
39	H	1625	100306144578	0.364	0.231	2.74	Cream	Semi-baroque Drop		Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
	Natural Sapphire (8 pieces)									
40	K	1632	100306144788	1.250	0.928	3.88	Yellow	Briolette Drop		Failed experiment, shell alive but no pearl present
41	I	1629	100306144789	1.149	0.862	4.00	orangey Yellow	Briolette Drop		Failed experiment, shell died, tag 1629 present
41	I	1630	100306144790	1.048	0.784	3.97	greenish Blue	Briolette Drop		Failed experiment, shell died, tag 1630 present

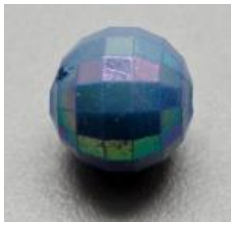
Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
43	I	1661	100306144791	1.043	0.779	3.95	Orange	Briolette Drop		Failed experiment
44	I	1662	100306144792	0.971	0.726	3.96	bluish Violet	Briolette Drop		
45	L	1633	100306144793	0.909	0.680	3.97	grayish green	Briolette Drop		Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
46	I	1663	100306144794	0.841	0.631	4.00	Purple	Briolette Oval		Failed, shell dead, tag 1663 present
47	L	1634	100306144795	0.800	0.600	4.00	Colorless	Briolette Drop		Failed experiment
	Freshwater non-bead Cultured Pearls (2 pieces)									
48	E	1644	100306144579	2.918	1.826	2.67	White	Baroque		Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
49	E	1643	100306144580	1.417	0.882	2.65	White	Semi-baroque		 
	Glass (1 piece)									
50	E	1645	100306144581	2.975	1.784	2.50	Dark Brown & Black & White	Bead		Failed experiment

	Assorted - Plastic, quartz, agate (8 pieces)									
51	J	1701	100306144642	7.630	4.700	2.60	Black	Sphere		Failed experiment, shell dead, tag 1701 present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
52	J	1670	100306144643	7.909	4.926	2.65	Colorless	Sphere		Failed experiment, shell alive but no pearl present
53	F	1651	100306144644	1.486	0.238	1.19	yellowish Green	Pear		Failed experiment, shell alive but no pearl present
54	F	1649	100306144645	1.427	0.228	1.19	yellowish Green	Pear		Failed, shell alive but no pearl present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
55	F	1650	100306144648	2.272	0.281	1.14	Blue	Bead		Failed experiment, shell alive but no pearl present
56	F	1646	100306144650	1.143	float	-	White	Bead		
57	F	1647	100306144651	1.099	0.045	1.04	White	Bead		Failed experiment, shell alive but no pearl present

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
58	F	1648	100306144654	3.201	float	-	White	Bead		Failed experiment
Shells – various (11 pieces)										
59	G	1652	100306144668	0.752						 No aBCP produced only one keshi.
60	G	1653	100306144669	0.414						

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
61	G	1654	100306144670	0.375						 
63	G	1656	100306144672	0.145						Failed experiment, shell died, tag 1656 present
64	G	1657	100306144673	0.083						Failed experiment

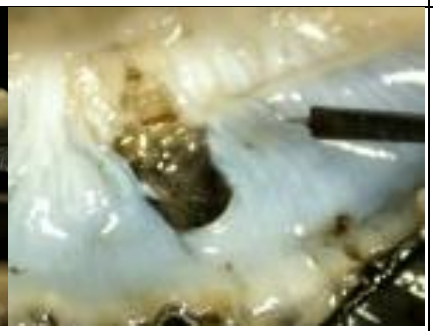
Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
65	G	1658	100306144674	0.078						Failed experiment
66	G	1659	100306144675	0.073						
67	I	1665	100306144662	0.262						

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
68	J	1666	100306144663	0.275						Failed experiment, shell died, tag 1666 present
69	J	1667	100306144677	0.030						Failed experiment, shell died tag 1667 present
75	L	1637	100306144676	0.058						Failed experiment

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
Coral (6 pieces)										
62	G	1655	100306144671	2.653						Failed experiment
70	K	1706	100306144658	2.287						Failed experiment, shell alive but no pearl present
71	K	1707	100306144659	1.193					  	

Experiment #	Panel Tag	Shell Tag	Control number	Carat weight		SG	Colour	Shape	Image	Results
				Air	Water					
72	K	1708	100306144664	3.205						Failed experiment
73	L	1635	100306144660	0.460						Failed experiment
74	L	1636	100306144667	0.914						Failed experiment

Table 2: Experiments involving the irritation of the mantle of Pinctada maxima.

Experiment #	Panel Tag	Shell Tag	process	Image of process	Results
76	A	1586	Cut and fold mantle no bead. Photos 3633 and 3634.	  	Failed to produce pearls but several blisters were produced shell alive

Experiment #	Panel Tag	Shell Tag	process	Image of process	Results
77	A	1587	Cut and fold mantle no bead. Photos 3635 and 3636.		Failed experiment
78	A	1588	Cut and fold mantle no bead. Photos 3637 and 3638		Failed experiment
79	A	1589	Cut and fold mantle no bead but with glue added to stabilize. Photos 3639 and 3640		Failed experiment

Experiment #	Panel Tag	Shell Tag	process	Image of process	Results
80	A	1590	Cut and fold mantle no bead but with glue added to stabilize. Photos 3641 and 3642		Failed experiment
81	A	1591	Cut and fold mantle no bead but with glue added to stabilize. Photos 3643 and 3544		Failed experiment
82	A	1592	10 pricks made to the upper and another 10 to lower mantle no bead. Photos 3645 and 3646		Failed experiment

Experiment #	Panel Tag	Shell Tag	process	Image of process	Results
83	A	1593	10 pricks made to the upper and another 10 to lower mantle no bead. photos none same process as above		Failed experiment
84	B	1594	10 pricks made to the upper and another 10 to lower mantle no bead. photos none same process as above		Failed experiment
85	B	1595	Scarify and smear only no bead. Photos 3649 and 3650		Failed experiment shell died tag present
86	B	1596	Scarify and smear only no bead. Photos none same process as above		Failed experiment shell died tag present
87	B	1597	Scarify and smear only no bead. Photos none same process as above		Failed experiment shell alive but no pearls

Experiment #	Panel Tag	Shell Tag	process	Image of process	Results
88	B	1598	Mantle sandwich (flat side under) no bead. Photos 3651 and 3652		Failed shell died tag present
89	B	1599	Mantle sandwich (flat side under) no bead. Photos none but same process as above		Failed shell alive but no pearls
90	B	1600	Mantle sandwich (flat side under) no bead. Photos none but same process as above		Failed shell alive no pearls but blisters on shell
91	B	1601	Insert mantle tissue into the mantle only, inserted on inner side of mantle. Photo shows the shell side and that the insert did not fall through. Photos 3655 and 3656		Failed shell alive but no pearls

Acknowledgements

With numerous examples of these deceptive products already on the market in 2011, the authors were grateful for the cooperation of Umit Koruturk of Australian Pure Pearls, based in Sharjah, UAE. Initially only nondestructive examinations of the 100 samples Mr. Koruturk provided were carried out but after he gave permission six of these were subject to destructive tests for which the authors are again grateful.

The examinations, experiments and results described here began with conceptual thoughts in 2011 when the authors discovered on the market and were later presented with 100 samples that were reported as aBCPs. In 2012 the first stage of the actual experiments (the operations) were realized and the shell placed in a holding area in the ocean off Australia's North West coast. In 2014 the shell were retrieved with successes (atypical bead cultured pearls [aBCPs] being produced) and failures being noted. These strictly non-commercial experiments were made possible only through the good offices of the Paspaley Pearling Company of Darwin, NT, Australia, the availability of their fleet, specialist staff and the donation of 100 live *Pinctada maxima*, as well as the husbandry of these molluscs over the two year growth period used to maximize results. The authors are truly appreciative of their assistance during the whole experiment period, their support both beforehand and ongoing.

In concluding the authors wish to thank all of their colleagues in the Pearl Department of the GIA laboratory in Bangkok and the entire team in the Gem and Pearl Testing Laboratory of Bahrain for their support during this process. Importantly, thanks should be recorded for Mr. Thomas Moses, the Executive Vice President at GIA for his continued support of Pearl Research within GIA and his readily available advice.

Endnotes

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[i] Beaded Nacreous Cultured Pearl (from the CIBJO Pearl Book)
Beaded cultured pearls are usually nacreous formations secreted in the interior of a various saltwater and freshwater molluscs. A bead is inserted into the mollusc along with a piece of mantle tissue which eventually forms the cultured pearl sac around the bead which is in turn responsible for the secretion of nacreous layers. The outer layers of beaded nacreous cultured pearls are concentric and composed of a complex scleroprotein named conchiolin and of calcium carbonate (usually in the form of aragonite).

[ii] Keshi Cultured Pearl (from the CIBJO Pearl Book)
a trade term that designates a non-beaded cultured pearl formed accidentally or intentionally by human intervention in marine pearl oysters such as the Akoya oyster (*Pinctada fucata*, Silver/Gold lipped oyster (*Pinctada maxima*) and Black lipped oyster (*Pinctada margaritifera cumingii*) and is a by-product of the culturing process. The creation results from the formation of a pearl sac either following injury of the mantle rim upon human handling, from a partial piece of the inserted (grafted) mantle tissue or the whole inserted piece following the rejection of a bead. See also South Sea Keshi Cultured Pearl. Alternative name; Lagniappe (or Bonus) cultured pearl.