Golden South Sea Cultured Pearls: Cultivation Steps & Gemmological Investigations
金色南洋珍珠：養殖步驟及寶石學鑑定

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作者詳細描述了在菲律賓巴拉望水域的金色南洋珍珠養殖場：由尋找合適的稀有大珠母貝（台灣稱為白蝶真珠蛤）的金唇貝，至適合養殖珍珠，到首批珍珠產出的養殖流程。另外，作者簡述如何利用紫外—可見光和拉曼光譜分辨大珠母貝、黑蝶珍珠母貝（台灣稱為黑蝶真珠蛤）和斑珠母貝（台灣稱為白斑珍珠蛤）的金色南洋珍珠，並利用對照實驗檢測其染色和熱處理。

Fig. 1 Untreated golden South Sea pearls from the Jewelmer pearl farms in Palawan (Philippines).
Photo: Laurent Cartier

Introduction

The South Sea pearl oyster *Pinctada maxima* is known to produce white, cream and golden pearls. Such pearls are cultured mainly in Australia, Burma (Myanmar), Indonesia and the Philippines. Interestingly, 2016 marks the 60th anniversary of the first harvest of South Sea cultured pearls at the Kuri Bay farm (Australia), established by Tokuichi Kuribayashi of Nippo Pearls in 1954 (Müller, 1997). In the past few decades, South Sea cultured pearls have become some of the most desired and expensive cultured pearls in the market. This article will focus on the production of cultured golden pearls from *Pinctada maxima* and the gemmological investigation of such pearls.

Farming golden South Sea pearls: a Philippino case study

At present, golden South Sea cultured pearls are harvested mainly in Burma, the Philippines and Indonesia. Pearl farmers have targeted traits and oysters that can enable them to focus on specific nacre colours and thus pearl colours. In February 2016 one of the authors (LC) had the opportunity of visiting Jewelmer pearl farms near Palawan Island in the Philippines and observing the different culturing techniques required to harvest golden South Sea pearls.

The Jewelmer company was co-founded in 1979 by Jacques Branellec and Manuel Cojuangco with the aim of producing high-end golden South Sea cultured pearls. The South Sea pearl has a rich connection with the history of the Philippines, so much so that in October 1996 President Fidel V. Ramos named it the National Gem of the Philippines (through Proclamation 905). The South Sea pearl is also featured on the latest 1000 Peso bill printed by the Bangko Sentral ng Pilipinas.

Fig. 2 The tropical waters of Palawan (Philippines) seen here offer the pristine waters necessary for South Sea pearl production.
Photo: Laurent Cartier

Fig. 3 Approaching the Terramar Four pearl farm. The mangrove and coral-rich environment is a good source of nutrients for pearl oysters.
Photo: Laurent Cartier

Sourcing oysters and finding gold colours

Due to the overfishing of natural pearl oysters in past decades, natural stocks of oysters were low in the Philippines when the decision was made to establish a pearl farm on Palawan and produce golden South Sea cultured pearls, so the sourcing of suitable spats (baby oysters) was critical. Unlike in Australia where oysters for pearl production are largely fished in the wild (Scarratt et al., 2012), in the Philippines Jewelmer and other companies had to focus on developing suitable hatchery technology. Finding, rearing and crossing appropriate oyster broodstock to prioritize the golden colour in these *Pinctada maxima* oysters has been a long process.

From juvenile to pearl

Oyster spawn is kept in the hatchery and fed different types of plankton before the juvenile oysters are large enough and strong enough to be transferred to the nursery. Kept in sheltered waters, they are cleaned regularly to promote optimal growth conditions until they reach a size suitable for mantle tissue and nucleus insertion. Grafting and nucleus seeding procedures are proprietary but we can say that donor mantle tissue ("saibo") is taken from oysters that show especially nice golden colours and fine lustre. As with other pearl farming operations, host oysters are chosen for their vigour and vitality (Southgate and Lucas, 2008). After a period of two years or more, pearls are harvested by pearl operating technicians. From the spat and juvenile stages all the way to the pearl harvest of a first generation cultured pearl typically takes 4-5 years in total. Then, if the pearl is deemed to be beautiful and of sufficiently high quality, and the pearl oyster is in good health, the pearl technician may choose to implant another nucleus into the oyster which will produce a second generation cultured pearl of larger size after a further two years of growth.

Fig. 4 A Jewelmer farm in northern Palawan that was heavily damaged by Typhoon Haiyan in 2013 but is being rebuilt. Pearl farmers are especially vulnerable to storms and climate change.
Photo: Laurent Cartier

Fig. 5 Water levels at the Terramar Four farm show increasing levels of sea water that pose a long-term threat to pearl farmers.
Photo: Laurent Cartier

Fig. 6 Jewelmer is an innovator in hatchery techniques, spawning and rearing oysters that are more likely to exhibit the much sought-after golden colours of nacre.
Photo: Laurent Cartier

Fig. 7 Regular cleaning of oyster nets and baskets is vital, as seen here. The thriving Palawan ecosystem means that numerous algae and other organisms grow on the nets. To ensure optimum conditions for the oysters, bio-fouling needs to be removed regularly.
Photo: Laurent Cartier

Jewelmer has about 1200 employees, highlighting the commitment required to produce high-quality cultured pearls today. Continuous research into optimizing pearl production, reducing risks for pearl oysters, improving harvests and increasing understanding of pearl formation are all vital aspects to ensuring that high-quality cultured pearls can continue to be cultivated in the long term. Environmental issues such as rising sea levels, climate change, and pollution through mining or slash-and-burn activities are all potential risks to pearl farming.

Harvested golden South Sea cultured pearls from the Jewelmer farms are flown to Manila where they are sorted and matched into numerous different categories. A share of high-quality golden South Sea pearls from these farms goes into Jewelmer jewellery collections that are sold internationally. Other cultured pearls are sold through auctions or wholesale to the trade. The appreciation of untreated golden pearls has grown considerably in recent years, and their rarity, due to the difficulty in cultivating them, has also contributed to impressive price increases. Asia, especially China, is currently the most important market for golden South Sea cultured pearls.

Fig. 8 Harvesting a golden South Sea cultured pearl after several years of work.
Photo: Laurent Cartier

Gold colour in pearls from *Pinctada maxima*

As already mentioned, *Pinctada maxima* oysters produce pearls in a range of colours from pure white (silver-lipped pearl oyster) to cream and moderately yellow (gold-lipped pearl oyster). Careful breeding selection has resulted in cultured pearls of a saturated yellow - known and highly appreciated in the trade as golden cultured pearls (Fig. 9).

The cause of colour of *Pinctada maxima* nacre is not fully understood (Karampelas, 2008; Scarratt, 2012), but it is not only linked to the presence of natural colour pigments but also, due to optical effects such as reflection and refraction, (Dakin, 1913; Snow et al., 2004) at the surface and within the sub-surface nacre layer. It is however most unlikely that the colour of *Pinctada maxima* is related to the presence of polyenes, as characteristic Raman peaks for these colour pigments at approx. 1135 cm^{-1} and 1530 cm^{-1} are absent in *Pinctada maxima* (Fig. 13). This is very much in contrast to pearls from freshwater mussels (e.g. *Hyriopsis schlegeli*) and many other marine molluscs coloured by polyenes, such as Queen Conch (*Strombus Gigas*), Horse Conch (*Triplofusus giganteus*), Melo, Quahog (*Mercenaria Mercenaria*) and Scallops.

Fig. 9 Impressive necklace of 29 cultured South Sea pearls (beaded) from Pinctada maxima of large size and perfectly matching golden (natural) colour. Maximum pearl diameter approximately 16.5 mm.
Photo: L. Phan, SSEF

Apart from grading the colour of *Pinctada maxima* pearls into different categories of hue, saturation, and overtones, the main question remains the authenticity of colour. This is commonly tested in laboratories by a combination of UV-Vis-NIR reflectance, Raman spectroscopy, photoluminescence, and trace element analysis. These analyses provide complementary information about the nature of the colouration and its authenticity as has been well documented in literature (Elen 2001 & 2002; Karampelas 2008; Mamangkey 2009; Strack & Krzemnicki 2011; Scaratt et al., 2012).

Distinguishing golden South Sea pearls from pearls from other species

Pinctada maxima (South Sea pearl oyster) is not the only oyster that can produce cream, yellow and golden pearls. The *Pinctada margaritifera* pearl oyster (the Tahitian and Fijian pearl producing oyster) can also produce yellow and golden pearls. Spectra of these pearls reveal a “dip” in reflectivity at about 700 nm, which is characteristic for the colour pigments (porphyrins) present in these shells and pearls (Miyoshi et al., 1987; Karampelas et al. 2011). Interestingly, even the yellow and golden pearls of *Pinctada margaritifera* show this feature in the reflectivity spectrum (Fig. 10). This is in contrast to yellow pearls from the golden-lip pearl oyster (*Pinctada maxima*), which may be visually very similar, but which do not show such a dip.

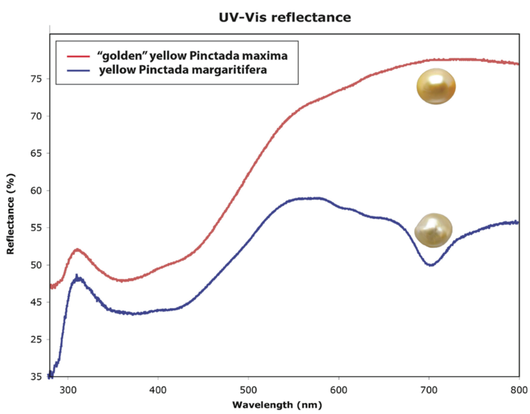


Fig. 10 UV-Vis reflectometry spectra of a yellow *Pinctada margaritifera* cultured pearl and a golden yellow *Pinctada maxima* cultured pearl.

Raman spectroscopy offers another means of distinguishing pearls from *Pinctada maxima* from *Pinctada margaritifera*. Apart from vibrational peaks of the aragonite nacre (mainly group of bands between 100-300 cm^{-1}, a doublet at 701 and 705 cm^{-1}, and the main peak at 1084 cm^{-1}) (Karampelas 2008), these spectra generally show multiple weak and broad Raman bands mostly in the range of 1000 – 1800 cm^{-1} related to their colour pigments. As these broad bands are hidden in the distinct increase of luminescence emitted due to excitation with a 514 nm laser, they are best revealed after applying a programme-integrated baseline correction. As Fig. 13 shows, the yellow *Pinctada maxima* are characterised by two broad Raman bands at about 1385 cm^{-1} and 1540 cm^{-1}, not found in *Pinctada margaritifera* or the many mollusc species coloured by polyenes, such as freshwater pearls from *Unio*.

Finally, DNA fingerprinting is another method that can be used to separate golden *Pinctada maxima* pearls from those from other species. Meyer et al. (2013) describe a pearl that was submitted for testing as a yellow South Sea cultured pearl but based on DNA fingerprinting could be conclusively identified as a Tahitian cultured pearl (*Pinctada margaritifera*).

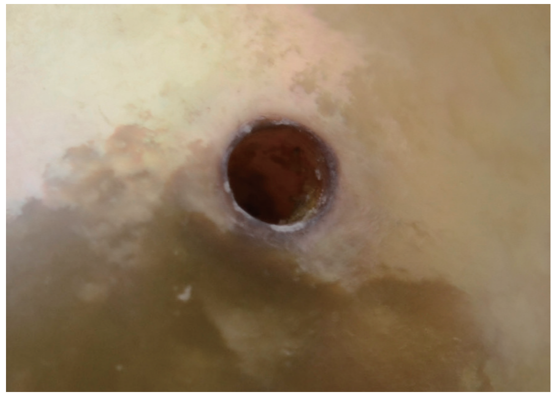
Treatment of golden South Sea pearls

Given the high appreciation of golden South Sea pearls and the difficulty with harvesting intense colours, it is no surprise that lower-quality South Sea pearls have been treated to achieve a golden colour (Elen, 2001 & 2002).

There are basically two treatments applied to cultured pearls from *Pinctada maxima* to intensify their yellow colour: dyeing and heating. By using various organic or chemical colouring agents, it is possible to change the colour of the pearls into any colour desired - the most deceptive being colours that also occur in nature.

The detection of colour treatments in pearls is generally possible through a combination of microscopy (e.g. observation of suspicious colour concentrations around the drill-hole), UV-Vis-NIR reflectance, Raman spectroscopy and chemical trace element analyses.

In the last few years, we, at SSEF, have analysed a number of treated yellow to golden cultured pearls of the variety *Pinctada maxima*. Of those, many have revealed artificial colour concentrations around the drill hole (Figs. 11a & 11b) and in surface pits, which strongly indicate a dyeing process applied to the pearls after drilling (Hargett, 1989; Komatsu, 1999; Elen, 2001).



Figs. 11a and 11b Colour treated pearl of *Pinctada maxima* and detail thereof, showing the distinct brownish artificial colour concentration around the drill-hole.
Photos: M.S. Krzemnicki

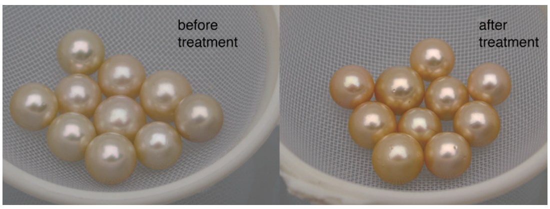


Fig. 12 Cream coloured *Pinctada maxima* pearls (undrilled) and their treated counterparts showing a distinctly more saturated treated colour.
Photos: M.S. Krzemnicki

Apart from this, we have also analysed batches of treated yellow to orangey yellow pearls from *Pinctada maxima* that had not yet been drilled (Fig. 12). These treated pearls, when viewed microscopically, showed only a few brownish spots on the surface. Although the specific treatment was not disclosed, we concluded that a heat treatment, possibly supported by a chemical process, had been applied to these treated pearls, similar to the process assumed by Vock (1997) and Elen (2001).

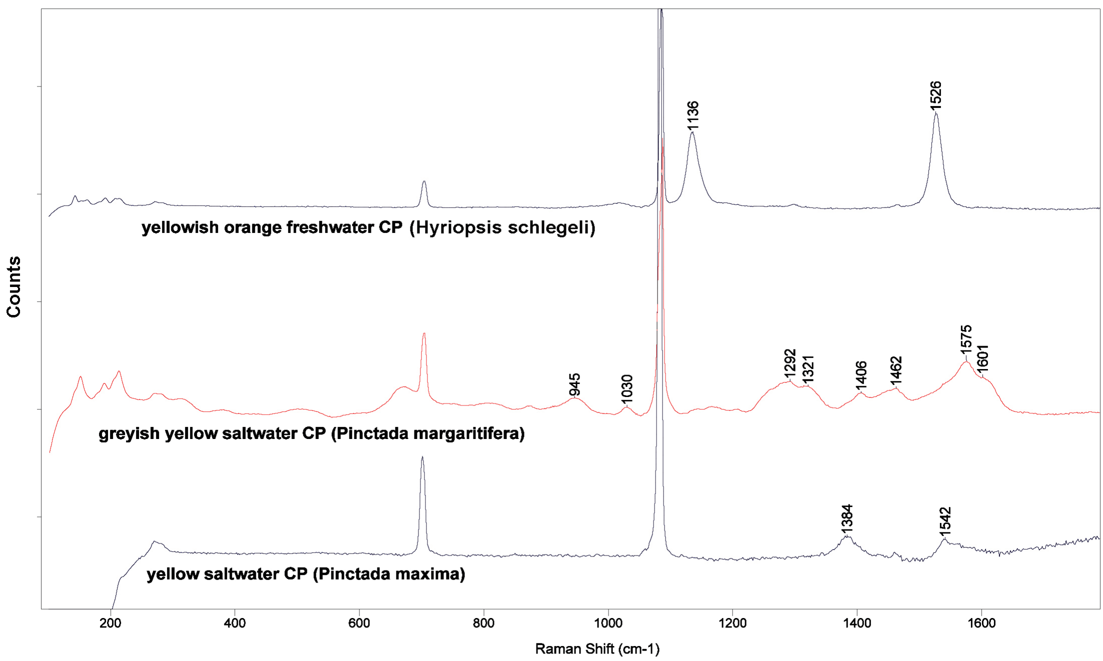


Fig. 13 Comparison of the Raman spectra (baseline corrected) of three different "golden" yellow cultured pearls; *Pinctada maxima*, *Pinctada margaritifera*, and *Hyriopsis schlegeli (Unio)*.

All of these treated pearls could be identified positively by a combination of UV-Vis-NIR reflectance and Raman spectra. A few, harvested from *Pinctada maxima* oysters, showed a flat reflectance spectrum in the range of 330 nm to 460 nm as described by Elen (2001 & 2002) as being characteristic for treated pearls of this species. All of the treated pearls – even the ones with a non-specific reflectance spectrum – showed a distinctly stronger luminescence in Raman spectra when compared to their untreated yellow counterparts and, in addition to this, were lacking the small and broad Raman bands at about 1385 cm^{-1} and 1540 cm^{-1} characteristic for the natural yellow colour pigment of *Pinctada maxima*.

Conclusion

Untreated high-quality golden South Sea cultured pearls from the *Pinctada maxima* oyster continue to be rare and highly sought after on the international market. This complexity (both ecologically and technically) associated with cultivating these pearls is a limiting factor in offering the market larger quantities of such high quality cultured pearls. Treatments to attain and imitate such pearl colours and qualities will continue to exist. So it is important that both gemmological research, as presented in this article, and correct disclosure (see CIBJO Pearl Book) are followed. In order to continue to brand and market South Sea cultured pearls from *Pinctada maxima* as such it is important to be able to distinguish, at a gemmological level, between them and pearls of similar colour from other species. The appreciation of golden South Sea cultured pearls - such as those from Jewelmer in Palawan - will continue to rise as this relatively new resource in the jewellery industry gains wider attention and embodies a golden future.

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