A description of pearl farming with Pinctada maxima in South East Asia

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Abstract: *This reports on a modern pearl farm in South East Asia which uses* Pinctada maxima *oysters. Marine biologists and geneticists supervise the pearling process. Culturing oysters from fertilized eggs has generally replaced wild oyster collection. In hatcheries larvae and spat are reared under scientifically controlled conditions. After around two years the oysters are about 12 cm in size and ready for the operation. Careful selection of donor oysters for the tissue graft and of host oysters to grow the pearls ensures optimum conditions for pearl formation. Excellent environmental conditions are sought to grow pearls of superior quality. High standards of working hygiene, X-ray checks and regular and frequent cleaning of the oysters and the holding nets are further steps to ensure high quality. Almost four years from the hatching of the larvae, the oysters are ready for a first pearl harvest. Most of the oysters are not re-beaded, and their muscle flesh is processed as seafood and the shells utilized for their nacre. The pearls are graded for quality and marketed mainly in Australia.*

Keywords: *pearl culturing process, pearl farming,* Pinctada maxima*, South Sea cultured pearls*

Introduction

In February 2006 the author had the opportunity to visit a pearl farm belonging to North Bali Pearls in Penyabangan, which is part of PT Cendana Indopearls, a company in the Atlas South Sea Pearls (Australia) group (*Figure 1*). In December 2006 a second trip was undertaken, this time to the West Papua area, for purposes of familiarization with the main pearl farming centre there. In both places, the author was afforded facilities at a state-of-the-art pearl farm to study the preparatory work that results eventually in the prized South Sea cultured pearls. The volume of scientific, technical and financial investment that has to go into a modern pearl farm is very impressive. The shares of these pearl forms are bought and sold on the stock exchange, and the success or otherwise of a harvest has a direct bearing on the share price.

The literature on oysters and cultured pearls is voluminous, and only a small selection can be listed here. On the biology of the *Pinctada maxima* oyster, see Dix, 1973 and Lowenstam and Weiner, 1989. On the farming of pearl oysters, see Jobbins and Scarratt, 1990; James, 1991; Müller, 1997. The microstructure of pearls is dealt with in Wise, 1970; Gauthier and Ajaques, 1989; Gutmannsbauer, 1993; Gutmannsbauer and Hänni, 1994. On issues of nomenclature, CIBJO, 1997, 2006,

ISSN: 1355-4565

Figure 1: *The pearl farm in North Bali, an aquacultural business with an ultra-modern approach to oyster production and pearl culturing in Penyabangan. Photo © H.A. Hänni.*

and Hänni, 2006a,b, are useful. For general information on pearls, see Hänni, 1995 and 1997; Schoeffel, 1996; Matlins, 1999; Hänni, 2001; Strack, 2006. Methods of identifying pearls are covered in Wada, 1981; Komatsu, 1987; Lorenz and Schmetzer, 1985.

Oysters used in cultured pearl production serve one of two distinct purposes. Some are used as mantle tissue donors, while others serve as host animals for the cultured pearls. Both halves of an oyster's shell have a layer of soft skin. This tissue, known as mantle tissue (or mantle epithelium), lines the whole shell and has produced both wings of the oyster.

A tiny piece of the outer surface of this mantle tissue is essential for transference of the nacre-forming ability to a different site for the purpose of growing a cultured pearl. The body of an oyster selected as a host animal has two sites where the transplanted mantle tissue can be accepted and will form a cultured pearl. One is the host's mantle tissue and the other is its gonad (reproductive organ). Pearls may be referred to accordingly as mantle-grown or gonad-grown. Located deep within the oyster shell, the gonad affords the room for one or two beads to be implanted in order to produce one or two beaded cultured pearls. In general, cultured pearls with beads will be the familiar saltwater-grown Akoya, South Sea and Tahiti varieties.

Cultured pearls without a bead usually derive from transplanted mantle tissue placed in the mantle of freshwater mussels, producing well-known varieties such as the Biwa or Chinese freshwater cultured pearls. Thus cultured pearls are always formed by the transfer of mantle tissue, regardless of whether the graft is into freshwater mussels or saltwater oysters, and regardless of the presence or absence of a bead. *Figure 2* provides an overview, illustrating sectioned cultured pearls of all types.

Pearl farmers who use *Pinctada maxima*,

Figure 2: *Cross-sections through different kinds of cultured pearls. Upper part: beadless pearls, e.g. South Sea 'keshi', Chinese freshwater cultured pearls. Lower part: cultured pearls with beads, e.g. Akoya, Tahiti and South Sea, and freshwater. Photo © H.A. Hänni.*

the large silver or gold lipped oyster (South Sea pearl oyster), insert a bead of nacre along with the mantle tissue (Japanese term: *saibo*). This is the practice followed at the farm in North Bali. Some of the grafted oysters expel this bead; however, the mantle tissue remains and forms a pouch inside which it produces a beadless cultured pearl, a variety marketed as a keshi cultured pearl (Hänni, 2006). But the great majority will retain the bead, form a pearl-sac round it and envelop the bead and deposit a good thick layer of nacre. This results in the classical South Sea cultured pearl.

Back in the 1960s, trading in cultured pearls was centred on Broome and Darwin in north-western Australia. Problems persisted over a long period in the rearing of oysters artificially from fertilized eggs, and therefore the animals required were harvested from the seabed by divers. They were then grafted and transported to warmer waters. As the harvesting of wild oysters in Australia is subject to quota, the production of cultured pearls is correspondingly limited.

The pearl farm in North Bali

The North Bali pearl farm is linked to other pearl farms in West Papua (Irian Jaya, Indonesia). The brief account provided here will indicate the complexity of modern production processes for cultured pearls with bead, and will refer for comparison to the production of beadless freshwater pearls. Thus, for example, a pearl oyster will produce a single cultured pearl, while as many as fifty may develop simultaneously inside freshwater mussels. The formation of beadless freshwater cultured pearls, however, may take several years when larger sizes are required.

In North Bali (Penyabangan) the author visited a farm which rears young oysters from fertilized eggs in a breeding facility. Carefully selected individuals are used to found a line of vigorous, handsome oysters, and the broodstock and subsequent generations will remain under genetic monitoring by scientists. With a view to minimizing disease and parasite infestation, the initial breeding and rearing stages take place in filtered seawater. The fertilized eggs and larvae are given the best possible conditions in which to grow into baby oysters (*Figure 3*).
The purified water is enriched by food in the form of specially cultivated micro algae. Once the juveniles reach a certain size, they lodge on special jute strings and continue to grow. At one month old they are transferred to ordinary seawater adjacent to the farm premises. By now they have grown to 1.5 or 2 mm in size. One net frame will accommodate up to 500 juvenile animals, and the hatchery as a whole has a population of several millions of larvae. Of these, about 20 per cent survive the transition from larva to oyster. When the young pearl oysters are 10 mm across, they are separated, and each tiny shell is re-housed in a net frame with

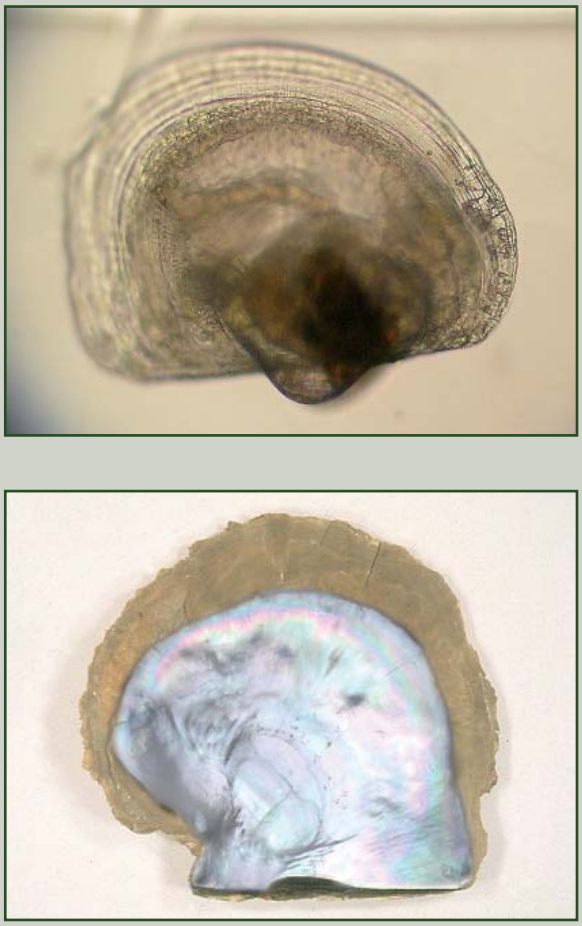

Figure 3: *A three-week-old* Pinctada maxima *oyster 2 mm across, photographed through the microscope, and a five-year-old shell half of the same species (18 cm). Photo © H.A. Hänni.*

64 others. These nets are suspended from horizontal longlines so that they hang at a depth of between 5 and 10 metres below the sea surface. From the shore the distinctive spherical black buoys supporting the hundreds of metres of line are clearly visible. The main activities involved in this phase of pearl oyster farming are regular removal of algae and also fouling organisms from nets and shells and monitoring of the growth rate of operated shells that have received their bead using X-rays (*Figure 4*). The work is carried out partly from ships or on shore.

The whole process of pearl formation could take place in Bali, but with a view to improving product quality, the North Bali Pearls management chose to ship most of the juvenile oysters at about eighteen months old to West Papua for depositing the nacre. In generous-sized ship-borne seawater tanks (*Figure 5*), as many as 40,000 *Pinctada maxima* at a time are freighted to clean waters remote from all civilization, and here they have almost two years to benefit from the ideal local growing conditions.

Figure 4: *X-ray monitoring after a cleaning process shows whether the bead has been retained in the oyster. Photo © H.A. Hänni*

Figure 5: *Workers handling nets with oysters ready for the tanks in the ship which will take them to Alyui Bay in West Papua (Irian Jaya). Photo © H.A. Hänni*

The ship takes a week to reach West Papua, the Indonesian part of New Guinea, also known as Irian Jaya. Ideal conditions are found in the Alyui Bay area (approximately 0 12'S, 130 14'E) where the coves between the islets are sheltered, and the water contains suitable minerals and plankton at the right temperature around 27 C.

The pearl farm in West Papua

The Alyui Bay base is not accessible overland but can be reached by sea from Sorong, a journey of 12 hours. Berthing facilities, office premises, production sheds, workshops, canteen and staff quarters are all on the shoreline and back directly onto jungle. The diving base essential for coping with the many and varied underwater tasks is also located by the pier. The company's board of management is Australian, the technical staff Indonesian. The pearling operations base and surrounding bays are under military guard as a precaution against theft of oysters.

Preparing the oysters for grafting

On reaching approximately 11-12 cm in size, the oysters undergo the surgery which enables production of the cultured pearls. They have to be conditioned for this operation, either by sinking the nets to the seafloor for 4-6 weeks or by covering

the nets for 4 weeks with fabric which has 1mm diameter holes. Either way the oysters are prevented from feeding and thus from producing gametes, which would cause problems during the surgical procedure (Taylor and Knauer, 2002). The food withdrawal slows down bodily processes and ensures empty gonads.

The operating table

The author's earlier visits to other pearl farms – in China, Australia and French Polynesia – had invariably made for extremely interesting observations with regard to work routines, technical provision and equipment. In contrast to some working conditions seen elsewhere by the author, the graft surgery conditions at PT Cendana Indopearls and Atlas South Sea Pearls in Indonesia (Bali and Irian Jaya) proved exemplary. The two most important innovations, in the author's assessment, have been the self-rinsing operating table with integral oyster-clamp and the cold-light fibre-optic lighting for the surgical procedures (*Figure 6*). The work-surface is continuously swilled clean by filtered seawater, and a spray device washes the instruments automatically as they are returned to their holders. The lighting used – from either a low-voltage lamp or a light pipe – affords the transplant technician a clear view of the operation site deep inside the barely opened oyster. This contrasts with some other farms visited in the past where the entire production shed had been lit by a small number of fluorescent tubes high in the ceiling.

Donor oysters and host oysters

The next step is to select which oysters will be tissue donors and which will be those that host the cultured pearls. Tissue donors provide pieces of mantle tissue for the graft. They must have nacre of the desired quality in terms of colour, lustre and 'orient' (iridescence). Young oysters are opened so that the quality of their nacre can be assessed.

Figure 6: *A clean workplace with good lighting for the operation site, hygienic surroundings and an instrument rack which is rinsed continuously characterizes the high standards at Atlas South Sea Pearls farms. Photo © H.A. Hänni*

Figure 7: *Two strips cut from the mantle tissue of a donor oyster are divided into tissue grafts (*saibo*) for transplantation. Photo © H.A. Hänni*

If the mantle tissue has grown on silvery, highly iridescent shell surfaces, the oyster is selected for tissue donation.

The remainder become potential host oysters which need to be large, vigorous specimens capable of providing optimal nurture for the transplant (Knauer and Taylor, 2002).

The mantle tissue graft

During subsequent preparation of the tissue pieces it is important not to lose track of which side had lain next to the shell, as only this outer mantle tissue is capable of secreting nacre. Two strips are cut out with scissors from the mantle tissue on each half of the shell and then cut into tiny grafting pieces (*Figure 7*). One tissue-donor oyster sacrificed for this purpose will yield about 30 *saibo*, each approximately 2.5 x 2.5 mm square. Next, these slivers of flesh containing

the complete genetic programme for the production of nacre are implanted one at a time in host oysters by a grafting technician. To make the transplant readily visible in the body of the oyster and ensure accurate positioning, the practice in many farms is to stain it red with eosin.

The bead

In Alyui, as also elsewhere, beads for the cultured pearls are derived from mussel-shell beads cut and shaped from thick-walled Pigtoe river mussels (Strack, 2006). These beads have a more or less parallel-layered structure. Even though the *Pinctada maxima* at Alyui deposit good thick coatings over the bead, care is taken to use beads that are white in colour. In Tahiti, where *Pinctada margaritifera* oysters produce dark-hued shells, it is possible to use nuclei that may be pale brown. Where snow-white beads are particularly important is for Akoya pearls, which have characteristically thin coatings. Here any brownish marbling of the beads would show conspicuously through the deposited nacre. The synthetic 'Bironite' type beads (Snow, 1999) and those made from the shell of the giant mussel *Tridacna maxima*, are not used at Alyui. The traditional Pigtoe beads are usually coated with the antibiotic tetracyclin as a prophylactic measure against disease and implant rejection.

The operation

The selected host oysters will still be young (11-12 cm), so the implanted beads must not exceed about 5.8-7.6 mm in diameter. Host oysters have to be vigorous, fast-growing specimens. Their own nacre does not need to be particularly fine, as the cultured pearl will acquire the quality characteristics introduced by the transplanted donor grafted tissue. The thickness of the deposit and the rate of growth, however, depend principally on the nurture, i.e. on the host oyster. Once the host has been slightly opened and secured in the operation clamp, the grafting technician makes a precisely performed incision in the gonad. The antibiotic-treated beads are then inserted and the tissue transplants added (*Figure 8*).

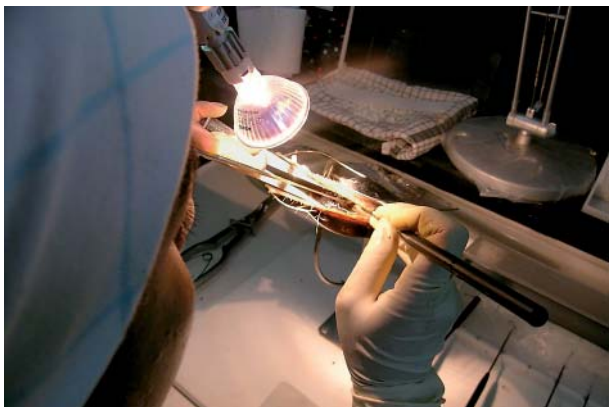

Figure 8: *A technician introduces a bead and a tissue graft into the gonad of a* Pinctada maxima. *On the excellently equipped workstation further tissue grafts and shell beads are waiting for transplantation. Photo © H.A. Hänni.*

The donor mantle tissue is accepted by the host oyster's gonad tissue, grows on in its new environment, and receives blood and minerals via the circulatory system.

The growth phase

Following the operation, the oyster is returned to seawater and allowed some time to recover. During this time, the mantle tissue graft in the gonad begins to fuse into its surroundings and also increases in size, growing concentrically around the bead and forming a closed sac. On its inner side, it gradually begins to secrete calcium carbonate in the form of aragonite platelets: the bead is acquiring its coating of mother-of-pearl. These thin aragonite platelets are what gives mother-of-pearl its unique characteristic orient.

Further checks carried out alongside routine cleaning permit the monitoring of growth and removal of casualties. Oysters that have rejected their bead are not re-seeded: they produce beadless cultured pearls, as the pearl-sac that has been formed fills up without a bead (Hänni, 2006). Oysters identified as bead-rejectors by X-ray are kept around three years in the water in order to produce substantial beadless cultured pearls, so-called South Sea keshi pearls.

It is during this growth phase that the quality of the cultured pearl will be determined. A number of factors are decisive. One important factor is the genetic makeup of the oyster concerned. This determines

its vigour and its growth rate. A second set of factors are the environmental conditions during the growth phase: light, available food, water temperature and salinity, etc. Other factors again are of human origin: hygiene during surgery, selection and condition of the transplant, and keeping feeding conditions at an optimum by regular net-cleaning (*Figure 9*).

When allowance is made for the condition of the mantle tissue, the formation of the pearl-sac follows a more or less routine course. Cleanly cut edges to the epithelium wound amply guarantee the formation of a fully functional pearl-sac. However, frayed edges will give rise to unsightly scar tissue which cannot produce problem-free nacre. Irregular shapes, dimples or rings may result.

As a rule, oysters that have undergone surgery at Alyui Bay will remain in the water for at least 18 months, sufficient time for an impressively thick coating of nacre to be secreted over the bead. Interestingly, pearl size is subject to major variation even when the maturing period inside the oyster is the same. Individual oysters will have nurtured their pearl-sacs to varying degrees, reflecting differences in their respective physical resources. 'Lazy' tissue or insufficient nourishment from the host will result in pearls that are smaller than those produced when all parts of the system have been working at their optimum. Where a nacre deposition period 'pregnancy' lasting nearly two years is involved, differences in the products from individual pearl-sacs will be more conspicuous than they would in thinly coated cultured pearls that have had only a short maturing period.

Figure 9: *Frequent cleaning with water jets and by hand is necessary to keep the nets and oyster shells free of parasitic animals and plants. A large number of boats are at work every day servicing the longlines. Photo © H.A. Hänni*

The harvest

The quality of day-to-day nacre deposition is affected by environmental influences, water temperature in particular. The shape of the cultured pearl is broadly speaking the product of the accumulated layers surrounding the bead. Irregularities may perpetuate themselves and lead to non-rounded shapes. However, surface characteristics such as colour, sheen and lustre are largely the outcome of the deposition of material over the few weeks preceding the harvest. Nacre formed at cooler temperatures is known to be made up of thinner platelets, which means that as nacre it is of finer quality. That in turn suggests that harvesting should take place just after a period during which thin platelets were being formed. Accordingly, the harvest proper is preceded by a number of oysters opened as small sample harvests. These give insight into the general condition and quality of the nacre formed up to that point. When the pearl is to be removed, the slightly opened oyster is held firmly in the clamp. A precisely executed incision opens up the gonad, and the cultured pearl can be lifted out with a specially designed tool (*Figure 10*). It is striking that a harvest of cultured pearls of uniform age yields a wide range of sizes and some variations in shape. Beadless (bead rejected) keshi pearls of the first generation are identified early on by X-ray checks when the shells undergo routine cleaning. These shells are separated and stay in separate nets, being allowed to grow for 12 months longer than the beaded cultured pearls in order to attain a marketable size. *Figure 11* shows a number of cultured pearls, all of the same age, from a sample harvest. However, the colours do not vary greatly, most of these pearls having either a clean silvery white colour or a gold tone. Half-tones are uncommon, as are pearls with constrictions (so-called 'circled' pearls).

Figure 10: *Removal of a cultured pearl from the gonad of a* Pinctada maxima. *The white part in the shell (to the left) is the powerful adductor muscle. Photo © H.A.Hänni.*

Figure 11: *A small trial harvest provides data on the present quality of the pearl surfaces. The picture shows a bead (yellow, width 6.5 mm) in comparison with pearls produced after 18 months in the shell. The mean diameter is about 12.5 mm. Photo © H.A.Hänni.*

Only those oysters that have formed top-quality pearls are beaded a second time; large beads are now used as the quality of the nacre that can be obtained diminishes as the pearl-sac grows older.

At Alyui Bay, the annual harvest in 2007 took place February. Most of the oysters were not re-beaded. Pearls from a first-harvest oyster range in size from 9 to 16 mm, with frequency peaking at 10 to 12 mm diameter (*Figure 12*). Pearls from re-beaded oysters yielded diameters of from 12 to 20 mm, with maximum frequency at 14 - 16 mm. Atlas South Sea Pearls open approximately 240,000 oysters annually. Oysters identified through X-ray monitoring during cleaning as having lost the implanted bead (10%) have been separated from the main population at an earlier stage. These oysters will have formed

Figure 12: *These beaded South Sea cultured pearls from Alyui Bay, West Papua (Irian Jaya) were harvested in February 2007. The diameters vary between 9 and 16 mm. Photo © H.A.Hänni.*

a beadless cultured pearl or keshi in their pearl-sac, and are allowed to grow for three years. About 15,000 keshi cultured pearls are produced annually in this way; they range from 5-15 mm in diameter with a mean of 8-9 mm.

About 90 per cent of the cultured pearls produced at Alyui Bay are put on the market in Australia, through the Pearlautore International Company. Eighty per cent are offered for purchase as loose pearls. The others, after being drilled through and graded for size, are traded as strings, along with pearls from other farms, and bought up in lots by wholesalers. A small number of pearls from the harvest go into jewellery manufactured in Atlas South Sea Pearls' own boutiques in Bali.

Acknowledgements

The author wishes to thank Dr Joseph Taylor for arranging access to North Bali Pearls und Atlas South Sea Pearls. The extremely interesting information provided by Dr Taylor was the stimulus for this paper. The author also had many absorbing discussions with Dr Taylor and Dr Jens Knauer. Warm thanks are also due to the

personnel of Atlas South Sea Pearls (Alyui Bay), in particular Mark Pieper and Kevin Smith. My gratitude is also expressed to Andy Müller of Hinata Trading, Kobe, Japan, for his many years of support for the SSEF in the form of information and materials for research and training in the field of cultured pearls and for introductions which greatly helped this study. My thanks finally go to Dr T. Gensheimer and Dr J. Knauer for their comments on the manuscript.

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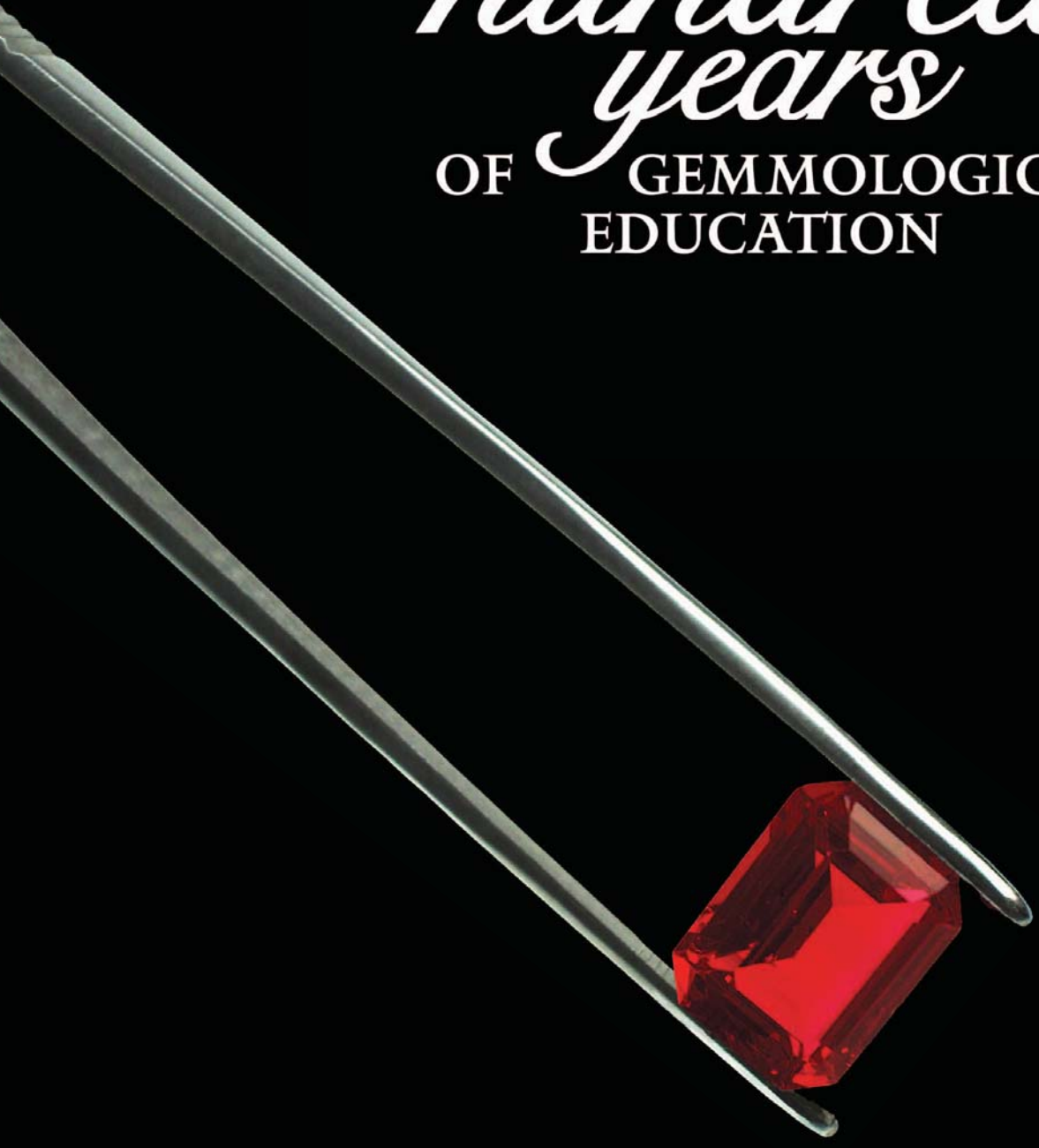

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