Pearls from the lion's paw scallop

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In memory of Alexander E. Farn, former Director of the London Chamber of Commerce DPPS Laboratory, Vice President of the Gemmological Association and Gem Testing Laboratory of Great Britain, author and gentleman.

Abstract: *Pearls from the Lion's Paw scallops* Nodipecten (Lyropecten) nodosus *L. 1758 and* Nodipecten (Lyropecten) subnodosus *Sowerby 1835 are rare and have only recently come to the notice of the gemmological community. They are non-nacreous but differ in surface appearance and composition to other non-nacreous pearls such as the Conch and Melo varieties. The surface appearance is comprised of a patchwork of cells with each cell being formed from three sub-cells. The orientation of these sub-cells and the low magnification fibrous appearance of structures within them give the scallop pearl a peculiar surface sheen. SG and Raman data indicate that the perfectly round 5.91 ct scallop pearl described is composed in the main of calcite rather that being dominated by aragonite as is the case for the Melo and Conch pearls. In addition the chemistry, infrared, and UV/visible spectra for the 5.91 ct scallop pearl are described. These data are compared with similar data from lion's paw shells and detailed submicroscopic structures are described for the shells.*

Keywords: *lion's paw scallop,* Nodipecten magnificus, Nodipecten nodosus, Nodipecten subnodosus, *USA*

Introduction

Not frequently seen but relatively well known to gemmologists are those often quite valuable (Shigley *et al.*, 2000) natural pearls, formed within molluscs that do not produce nacre (Gutmannsbauer and Hänni, 1994; Hänni, 1999). Examples of these non-nacreous pearls are the Conch pearl from *Strombus gigas* (Farn, 1977; Fritsch and Misiorowski, 1987; Moses, 2001), the clam pearl from *Tridacna gigas* (Anderson, 1971), the horse-Conch pearl from *Pleuroploca gigantean* and the Melo pearl from any of the various Melo volutes (Brown and Kelly, 1990; Scarratt, 1992, 1996; Traub, 1999). The most

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Figure 1: *A* Nodipecten subnodosus *shell.*

common of these rare non-nacreous pearls is the spectacular variety produced by *Strombus gigas* or the Queen Conch, and the rarest being the spectacular Melo pearls. Of late another non-nacreous pearl variety, the scallop pearl has become known and thus far a very limited number recorded. The following briefly describes *Nodipecten (Lyropecten) nodosus* L. 1758 (Atlantic Lion's Paw) and *Nodipecten (Lyropecten) subnodosus* Sowerby 1835 (Pacific Lion's Paw) and one particular pearl that was produced by one of these colourful scallops. Another scallop pearl produced by the Atlantic Sea Scallop (Placopecten magellanicus) has also been recently described (Wight, 2004).

The lion's paw scallop: its description, distribution and habitats

The scallops or pectens are bivalves that have been a part of man's existence from the earliest of times, both as a source of food and adornment. The shapes of the shells and wide variety of colours and patterns have caused them to be a significant collector's item, to be the focus of scientific study, to serve as industrial symbols such as that of the oil company Shell, and to feature as the centre piece of art forms. A particularly impressive art form where the focal point is the lion's paw shell (*Figure 1*) (so called as the shell resembles a lion's paw (Anonymous, 2003)) may be seen in a brooch created by Cartier (Paris) *ca.* 1958 (*Figure 2*). The shell is accompanied by turquoise and sapphires and set in gold (Anonymous, 2004), the brooch being valued in the region of $28,000 (Fitzpatrick, 2002).

Of the many scallops there are three bearing the common name Lion's Paw. One of these is the exceedingly rare *Nodipecten magnificus* (Sowerby, 1835) which is largely restricted to the Galapagos Islands (although one was recently dredged off the coast of

Colombia (Hill and Carmihael, 2004)) and given this rarity is not a focus of this paper. The other two are *Nodipecten (Lyropecten) nodosus* L. 1758 (Atlantic Lion's Paw) and *Nodipecten (Lyropecten) subnodosus* Sowerby 1835 (Pacific Lion's Paw), the largest pectinid in tropical waters and the one described as the probable source of the scallop pearl portrayed herein. *N. nodosus* is found in the seas off the south-eastern USA to Brazil and *N. subnodosus* in the seas off western Central America at depths between 25 and 150 m. Together the shell colours are exceptional both in their variety and depth (Hill and Carmihael, 2004). The outer surface of the shell may be several shades of brown, sometimes described as chocolate brown (Norris, 2003) and yellow to orange while the interior varies from pearly white to shades of purple and brown (*Figure 1*). The outer surface of the *N. nodosus* shell most commonly displays several rows of rounded nodular protuberances located on about eight rounded ribs (although many from the southern Caribbean are smooth (Hill and Carmihael, 2004)) potentially differentiating it from shells of *N. subnodosus* which typically have no such protuberances. Both the Atlantic and Pacific Lion's Paws have fan-shaped (typical of scallops in general) equal valves with unequal ears (Wye, 1991).

Scanning electron microscope studies give some insight into the architecture of the lion's paw shell. Classical nacre consists of fine tabular aragonite which provides the typical nacreous lustre.

Non-nacreous shell material from *Strombus gigas* consists of aragonite fibres lying in bunches in crossed arrays (Kamat *et al.*, 2000). The scallop shell displays a different structure. A surface image shows fibres lying in bunches in different directions almost parallel to the surface (*Figure 3*).

The thickness of the fibres is around 0.5 μm. An image of a broken section shows that under the surface the bunches of fibres still have a crossed orientation (*Figure 4*). At higher magnifications the fibres can be seen as geometrically not very well defined rods with the width and depth almost equal (*Figure 5*). At a magnification of 10,000× there is no trace of organic material in or between the fibres.

From the SEM images of the shell (*Figures 3, 4 and 5*) it becomes clear that depending on the direction of light the fibres will be in either a 'conducting' (ends of the fibres towards the light) position and appear dark, or 'reflecting' (other directions towards the light) position and appear light. This phenomenon is also responsible for the shimmering silk-like appearance seen in other shells that have a similar construction, e.g. *Strombus gigas* and the Melo volutes. In these shells too, bunches of fibres are in crossed orientation (Kamat *et al.*, 2000) and either reflect or conduct incoming light but in this case producing the ubiquitous flame-like pattern (Farn, 1977) well known for these materials.

Barrios-Ruiz reports (Barrios-Ruiz *et al.*, 2003) that *N. subnodosus* was cultured in La Paz Bay (1995-1996) and noted that the culture is feasible. However, high water temperatures in La Paz Bay in summer reduced growth and survival rates.

Figure 2: *A brooch consisting of turquoise, sapphires and gold set on a lion's paw shell, created by Cartier (Paris) ca. 1958; courtesy of Primavera Gallery, New York, photo Noel Allum.*

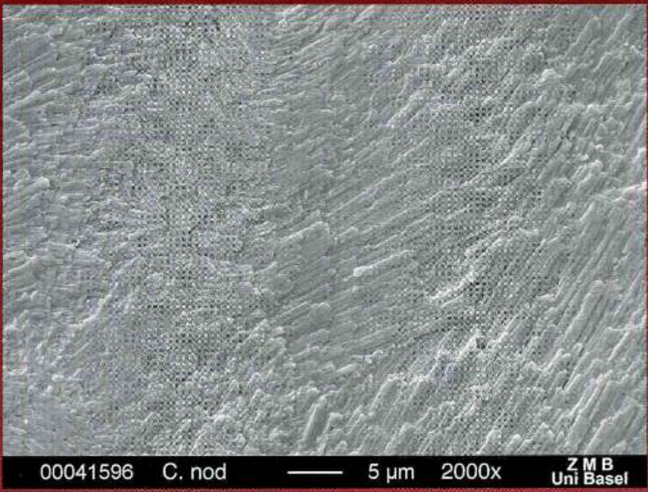

Figure 3: Fibres lying in bunches in different directions almost parallel to the surface of the scallop shell.

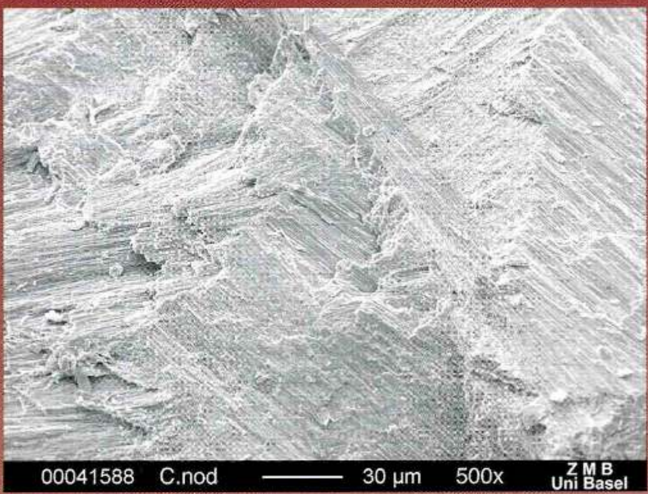

Figure 4: A broken section of a scallop shell shows that under the surface the bunches of fibres still have crossed orientations.

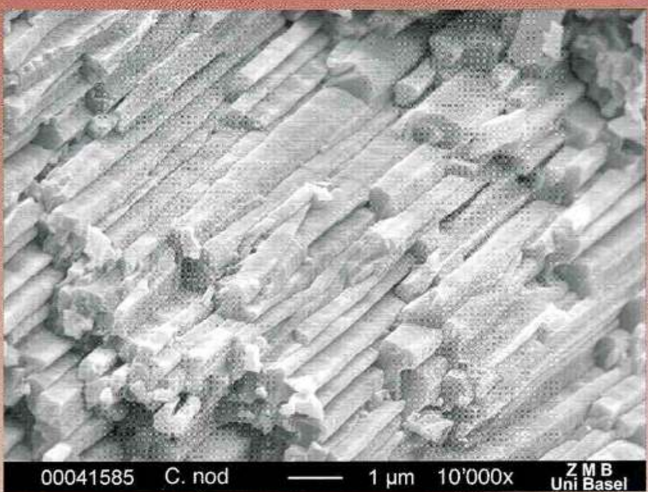

Figure 5: At higher magnifications the fibres in the scallop shell can be seen as rods with width and depth almost equal, but neither round nor square, and not geometrically well defined in cross section.

A natural pearl from the lion's paw scallop

Materials and methods

While the authors have been given the opportunity to view and perform limited examinations on several, they have had the opportunity to complete a detailed examination on only one scallop pearl which is said to be derived from *Nodipecten (Lyropecten) subnodosus*. The data included in this paper are gathered from that one pearl which is perfectly round and weighs 5.91 ct (*Figures* 6 and 7). Several shells of both the Atlantic and Pacific lion's paw types have also been examined and these data are compared with the pearl.

Analytical techniques employed by the authors include microscopy using gemmological microscopes at magnifications ranging from 15 to 60× and the Leica DMLM connected to a Raman microscope at magnifications of up to 1000×. Scanning electron microscopy of shell sections was performed at the University of Basel (ZMB SEM Laboratory) with a Philips ESEM XL 30 FEG with magnifications up to 10,000×; specific gravity (SG) determinations were determined hydrostatically using an appropriately fitted Mettler electronic balance with water at room temperature; UV/visible spectra were recorded in reflectance mode using a Zeiss MCS 500/501 spectrometer recording data for these purposes between 250 and 800 nm; infrared data were obtained using a Thermo-Nicolet Avatar 360 FTIR spectrophotometer utilizing a diffuse reflectance accessory (pearl) and a Thermo-Nicolet Magna 560 using a 4× beam condenser (shell), both at a resolution of 4 cm^{-1}; Raman data were recorded from a Renishaw Raman system 1000 spectrometer incorporating a 512 nm argon ion laser; and qualitative chemical compositions were measured using an Energy Dispersive X-ray Fluorescence Spectrometer (EDXRF) manufactured by EDAX (DX95) operating in vacuum at 35 kV and 450 μA. X-radiographs were produced using a Faxitron X-ray unit at 90 kV and 3 ma.

The LA ICPMS instrument used is a prototype excimer ArF laser (193 nm). Sample material is ablated (craters of 5 - 80 μm in diameter) and then flushed into an Elan 6000 quadrupole ICP mass spectrometer for 'simultaneous' multi-element analysis. The laser optics were developed in collaboration with Microlas (Göttingen). With this prototype instrument we can quantify as little as 0.01 ppm of trace elements in minerals, gemstones or archaeological samples from single spot ablations.

Figure 6: *The 5.91 ct scallop pearl on a scallop shell which shows the two colour zones at the rim and centre.*

Results

Appearance

Natural pearls from the lion's paw scallop, *N. subnodosus*, occur in a variety of shapes and colours and have been described as resembling high-fired pottery (Norris, 2003). They may be drop-shaped, oval, button, round, off-round or baroque, while the colour range has been variously described as white to deep royal purple with varying shades of oranges, pinks and plum (Hurwit, 1998; Anonymous, 2003). The surface of the pearls displays a shimmering sheen effect particularly when viewed under a bright light. The first short gemmological reports appeared on these rare pearls in 1998 and 1999 (Hurwit, 1998, 1999). A further general description appeared in 2004 (Federman, 2004).

The inside of the lion's paw shell shows two colour zones indicating different materials; a wide ruffle-like margin at the edge with a distinctive sheen which is an orange to purple colour (*Figures 6* and *8*) and a white interior. The external mantle tissue

Figure 7a: *A close-up of the 5.91 ct scallop pearl from the collection of Mr. Olivier Galibert and described in the text.*

Figure 7b: *A group of four scallop pearls of various qualities and shapes (from the collection of K.C. Bell)*

Figure 8: A wide ruffle-like margin with a distinctive sheen at the edge of a scallop shell.

produces two materials as a function of age (Gutmannsbauer and Hänni, 1994); the younger mantle tissue produces the pigmented purple material and at a genetically programmed moment in the life of the mantle tissue cell, this production changes and the cell precipitates the white material, with no pigment.

It thus depends upon the moment of a pearls harvest, whether it is purple (produced by the mantle tissue in the juvenile period) or white (produced by the epithelium that has shifted to the second stage) or a combination of the two. The purple margin on the shell is relatively wide when compared with the *Pinctada* or *Pteria* shells where the columnar growth produces smaller rims. We can thus expect a large number of lion's paw pearls to be of a plum colour with only the older pearls having a white coating.

Chemical composition

As is common with pearls of all varieties, scallop pearls are composed principally of calcium carbonate (Hurwit, 1998). An examination of the chemistry of the 5.91 ct scallop pearl using EDXRF confirmed Ca as being dominant with Sr also showing a significant presence. An examination of the lion's paw shells revealed similar data. In both the pearl and the shells examined, various trace elements were also recorded, but since some are possibly the result of contamination picked up since recovery, they are not reported here.

A few shell samples (see *Table I*) were analysed by LA ICPMS to compare their trace element composition with that of a Pacific lion's paw shell. LA ICPMS is a method that is increasingly used in gemmology for the detection of low concentrations and for light elements (Heinrich *et al.*, 2003). In *Table I* concentrations of some elements are shown, the figures (in microgram per gram – ppm) are mean values from three point analyses. The sample shell of the Pacific Lion's Paw shows the highest magnesium concentration compared to all other shells. With its low manganese content

Table I: Trace element contents in (ppm) of some shell materials identified by LA ICPMS.

	Lion's Paw (Pacific)	P. maxima (Australia)	P. margaritifera (Tahiti)	Hyriopsis schlegeli (China)	Unio (China)	A. plicata (China)
Na	2119	6674	8019	2092	1857	2369
Mg	813	185	508	20	31	20
B	18	20	22	4	4	4
P	311	34	35	188	113	137
K	54	62	113	12	65	13
Mn	0.6	3	0.7	760	658	733
Sr	924	1077	926	666	2588	384
Ba	0.4	0.4	0.1	253	509	137

it is in line with other saltwater shell material.

Structure

The structure at the surface of pearls produced by the lion's paw scallop is unique and upon sight is sufficient to identify the origin of such a pearl. The structure at the surface may be described as a segmented patchwork of cells, each cell comprising three differently oriented sub-segments. Within each sub-segment there is what appears to be at low magnifications a 'fibrous structure' (*Figures 9* and *10*) that is differently oriented for each sub-segment. Light reflecting from these 'fibrous structures' produces a shimmering effect similar to that produced by tiger's-eye and this is a unique feature of this type of pearl. Although the light shimmering effect is also seen in the shells of both *N. nodosus* and *N. subnodosus* (*Figure 8*) it is not in the segmented form as observed on the pearl.

SG and X-radiography

The SG of the 5.91 ct scallop pearl was determined to be 2.65 which is rather low for non-nacreous pearls. SGs determined for the Melo pearls have been found to be fairly consistent and are generally 2.84 to 2.85 (Traub *et al.*, 1999), although a few lower values down to 2.78 have been recorded. However, these lower values can be attributed to a greater amount of organic/less X-ray absorbent material contained within these pearls. For Conch pearls Webster (Webster, 1994) gave an SG range of 2.81 to 2.87. From this it has been suggested (Fritsch and Misiorowski, 1987) that a composition for Conch pearls of 40% calcite and 60% aragonite was likely, the individual specific gravities for calcite and aragonite being 2.71 and 2.93 to 2.95 respectively. The 2.65 SG recorded for the 5.91 ct scallop pearl suggests a higher content of calcite than aragonite. This conclusion is strengthened by the Raman data.

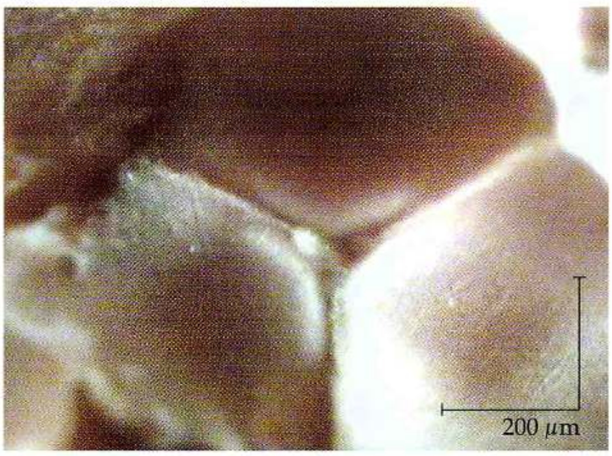

Figure 9: The structure at the surface of the scallop pearl may be described as a segmented patchwork of cells, each cell comprising three differently oriented sub-segments.

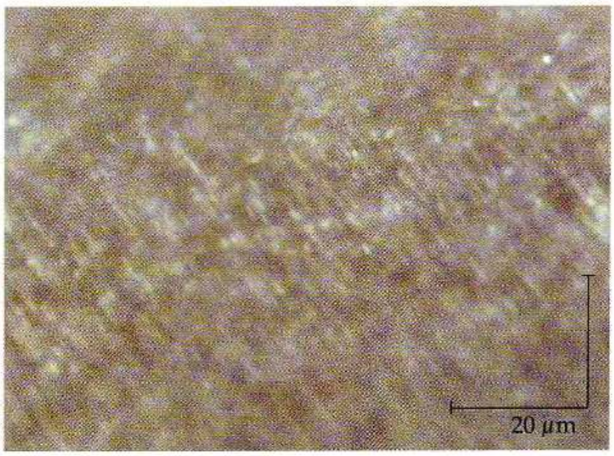

Figure 10: Within each sub-segment (see Figure 9) there is what appears to be at low magnifications a 'fibrous structure'.

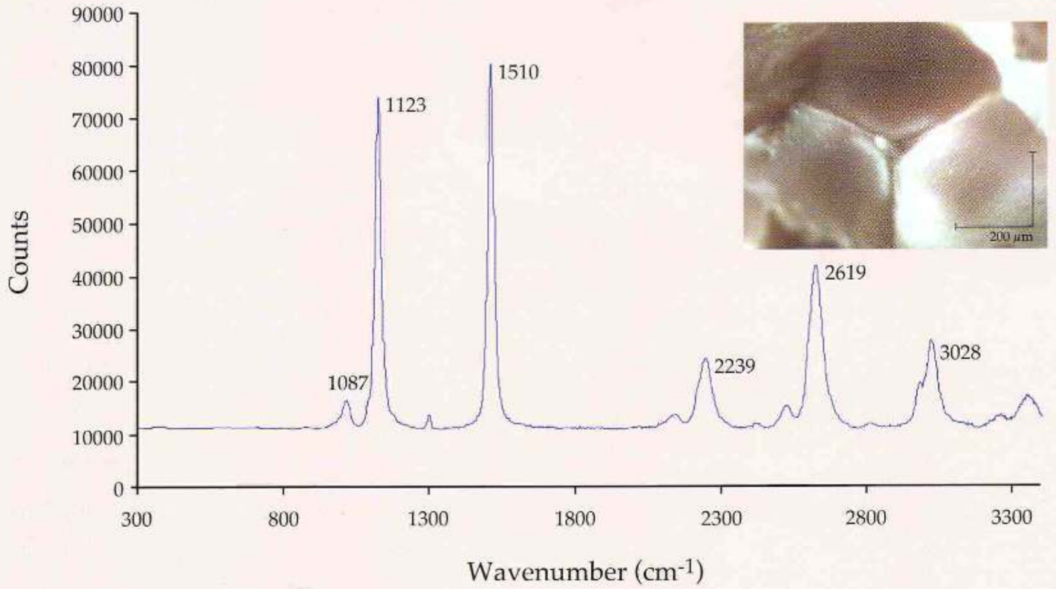

Figure 11: *The Raman spectrum of the 5.91 ct scallop pearl.*

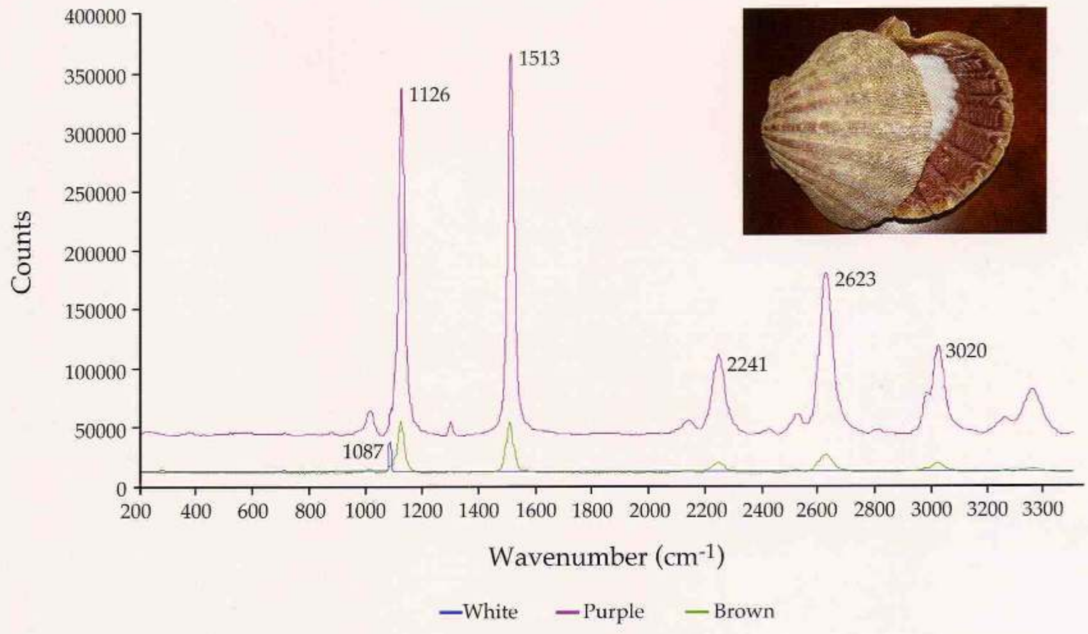

Figure 12: *Raman spectra of the purple, brown and white areas of the interior of a* N. subnodosus *shell.*

While being the most powerful technique in the arsenal of the gemmologist when distinguishing natural from cultured pearls, X-radiography relies upon the differences in X-ray absorbance between the alternating crystalline and organic layers that are generally present within a nacreous pearl (natural or cultured) (Kennedy, 1998; Akamatsu *et al.*, 2001) but these differences are not necessarily obvious in non-nacreous pearls. Non-nacreous pearls tend to have a structure that consists of dense closely packed crystal arrays without large amounts of organic material being present. Therefore,

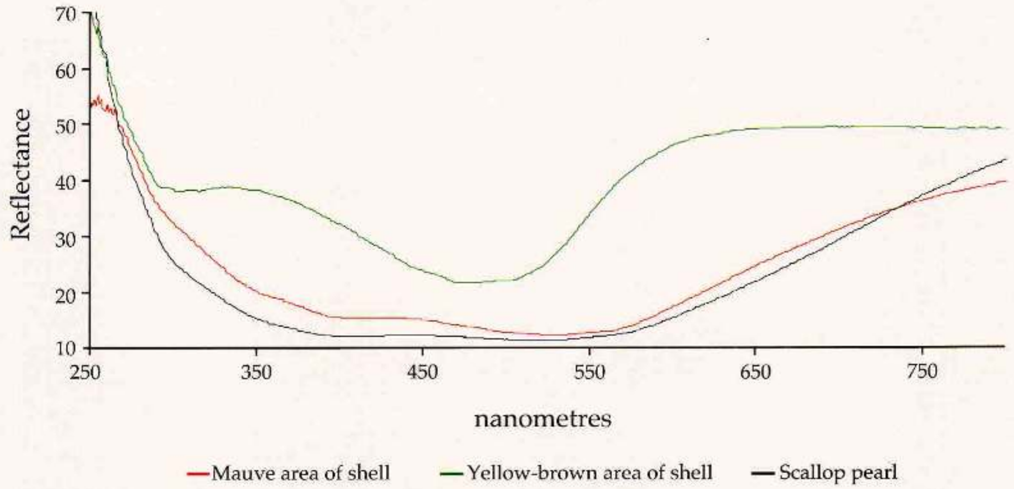

Figure 13: The UV/visible spectra recorded for the 5.91 ct scallop pearl and the yellow-brown and purple areas of the scallop shell.

in general non-nacreous pearls are opaque to X-rays and only occasionally show the presence of organic material by X-radiography. As was to be expected, radiographs taken of the 5.91 ct scallop pearl revealed only a small centrally placed dark arc partially surrounding a dark but extremely small central core, and a few very faint arcs towards the periphery of the pearl. While these structures were sufficient to confirm that it was a cyst-type pearl and of natural origin the apparent small amount of organic material present could not explain the low SG (Traub *et al.*, 1999) but rather supported the conclusion that calcite rather that aragonite is the main component of this scallop pearl.

Raman, UV/visible and infrared spectra

Raman spectra (Kiefert *et al.*, 2001) for the 5.91 ct pearl were collected from several different areas and compared. All areas examined produced the same spectrum with primary peaks located at 1123, 1510, 2239, 2619 and 3028 cm^{-1} (*Figure 11*). These peaks are due to the carotenoids (Fritsch and Misiorowski, 1987; Moses, 2001; Huang *et al.*, 2003; Withnall, *et al.*, 2003) present in the pearl. A peak of comparatively very weak intensity located at 1087 cm^{-1} and which we can attribute to calcite (Li and Chen., 2001; Huang *et al.*, 2003; Kiefert *et al.*, 2004) was also noted. The spectrum for this pearl differs from those recorded for other non-nacreous pearls such as those produced by *Strombus gigas* (the Conch pearl) and the Melo volutes (the Melo pearl). Both the Conch and Melo pearls show peaks normal for aragonite (rather than calcite) at 1085 cm^{-1} and 703 and these are also dominant over the carotenoid peaks. The Raman spectrum for the scallop pearl is similar to that shown by natural red coral.

The Raman spectrum of the 5.91 ct scallop pearl was compared with the spectra produced from the white, purple and brown areas on the interior of one *N. subnodosus* shell (*Figure 12*). The white area produced the complete Raman spectrum typical of calcite with peaks at 281, 713, 1087 and 1433 cm^{-1} and none indicating the presence of any carotenoids; the brown area showed relatively low intensity carotenoid peaks at

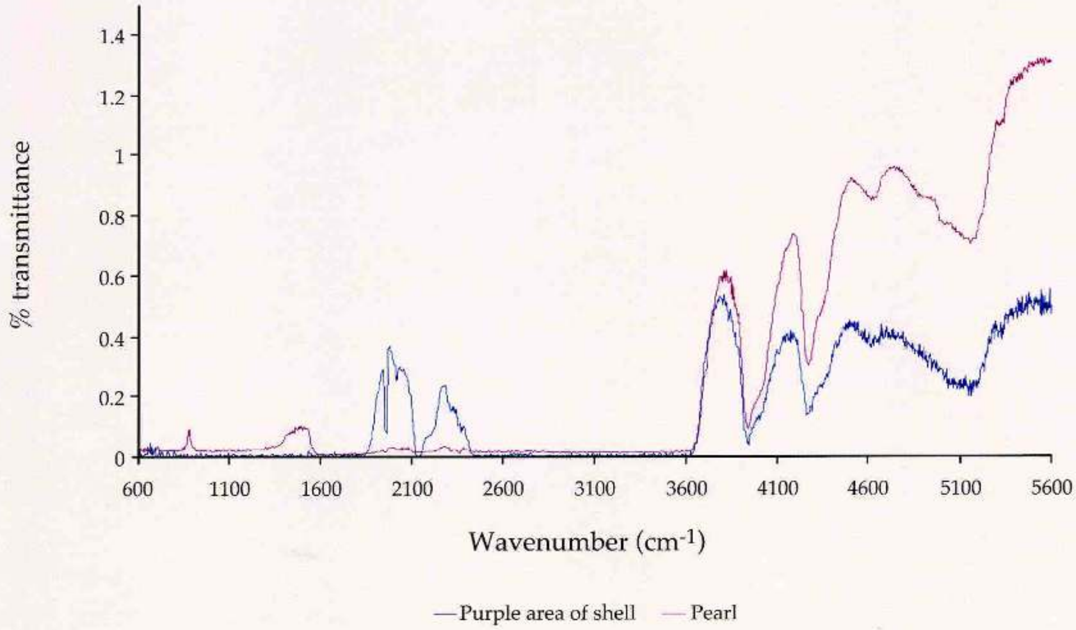

Figure 14: *The infrared spectra recorded for the scallop pearl and the purple area of a scallop shell.*

1126, 1513, 2241, 2623 and 3020 cm^{-1} that allowed the main calcite peak at 1087 cm^{-1} to be clearly recorded. In contrast, the spectra from the purple area showed carotenoid peaks of such intensity (about six times the count rate) as to completely obscure the strongest calcite peak.

UV/visible spectra were recorded in reflectance mode for the 5.91 ct pearl, and for white, purple and brown areas on the interior of one *N. subnodosus* shell (*Figure 13*). The spectra recorded for purple areas of the shell's interior and that for the pearl showed similar features. Broad but shallow absorption features were noted centred at 540 and 410 nm. For the yellow-brown areas on the shell two merging features were noted at approximately 510 and 460 nm; and for the white areas, as to be expected, only a flat line with no features was recorded.

The infrared spectra were obtained from both the 5.91 ct pearl and the purple area of a lion's paw shell *(N. nodosus) (Figure 14).* Above 1550 cm^{-1} both spectra were similar with features at 1960, 2018, 2140, 3932, 4264, 4593 and 5133 cm^{-1}. Below 1550 cm^{-1} the scallop pearl had additional features at 1508 and 1457 cm^{-1}.

Discussion

The shell of the lion's paw scallop is one of the most beautiful of all seashells (Hill and Carmihael, 2004) and it is therefore not surprising that any pearls produced by this mollusc should also be beautiful. However, it is surprising that given the beauty of the shells and their desirability to collectors, that knowledge of the scallop pearl has not reached gemmologists until recently.

Pearls from the lion's paw scallop are distinctive in so much as their surface structure is dissimilar to that of any other non-nacreous pearl. They are probably composed predominantly of calcite rather than aragonite and the strength of the carotenoid Raman peaks (in relation to the calcite peaks) is very distinctive. The combination of colour, structure and optical effects is unique among pearls and without doubt as a gem material they are exceedingly rare.

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