Fossil Pearl from the Pliocene Kakegawa Group, Central Japan

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静岡県掛川層群より産出した真珠化石

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(要　　旨)

静岡県掛川市本郷南東の切り通しに露出する鮮新統掛川層群大日砂層から，1981年2月に柄沢宏明は板鰓類化石，貝類化石に伴い，球形で単体の真珠を採集した．

真珠化石の報告は，1937年から地質時代をとおして海生・淡水貝類をとわず，広い分類群から報告されているが，たいていは貝付真珠化石である．今回の標本のように単体球形真珠は，世界的にみて極めて珍しいものである．この真珠化石は，1)大きさ：長径12.28 mm，短径11.98 mm，2)形態：球形，3)光沢：磁器質光沢，4)比重：2.8674，5)重量：2.6398 g，6)構成鉱物：アラレ石，7)構造：表面は多孔質，断面は複合交差板構造である．以上の真珠化石の特徴と，真珠化石と随伴した貝化石の貝殻構造との対照から，*Anadara* 属が真珠の母貝である可能性をもち，さらに類推すれば *A.* (*Scapharca*) *satowi castellata* (YOKOYAMA) であることも考えられる．しかし，天然真珠に於ても12mm 程度の大きさで，球形真珠形成の確率は非常に低いことから，この真珠形成過程についてさらに研究を進める必要性がある．

1. Introduction

In February of 1981, a small spherical fossil of calcareous matter was found by Hiroaki KARASAWA, a student of Nagoya-kita High School, from the Pliocene Dainichi Sand of the Kakegawa Group in Hongo, Kakegawa City, Shizuoka Prefecture, Japan. As a result of the study, it is confirmed by the various observations and analyses that the matter is a fossil pearl. Present day natural pearls which are the most spherical and large in their size are very rare. Considering this fossil pearl is very valuable and rare, a research into the structure is made keeping the original form as far as possible.

We can find readily a blister pearl on the inner surface of shell, for example, as that on the inner surface of the holotype specimen of *Barbatia minoensis* ITOIGAWA from the Miocene Mizunami Group in Japan (Pl. 15, fig. 1) and also commonly small spherical and ellipsoidal pearls (up to 3 mm in diameter). KOLESNIKOV (1973) reported the buried fossil pearl in the Cretaceous fresh-water bivalve found in the Gobi Desert in 1970, and referred to the fossil pearls found in deposits of late Silurian, Triassic, Jurassic, Cretaceous, Miocene and Pliocene age in Western Europe, America and New Zealand.

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Also TASNADI-KUBACSKA (1962) had been reported the fossil blister pearls as follows; that of 1 cm high on the inner surface of *Ostrea* sp. stored in the Hungarian National Museum and another one from Leithakalk of Nagymaros in Hungary, and the other of the fresh-water mollusc, *Congeria* sp. from the Pliocene (Pannonian stage) of Hungary deposited in Hungarian Geological Institute.

However the large and most spherical pearl is very rare among the present day natural pearls and, moreover, among the fossil pearls. And then, this is the first report on the fossil pearl from Japan.

2. Occurrence

Locality: Cutting, ca. 1 km to the ESE of the Haranoya Station, Hongo, Kakegawa City, Shizuoka Pref., Japan. Long. 137°58′2″E; lat. 34°48′5″N, *Horizon*: Dainichi Sand, Kakegawa Group. Pliocene Suchian Stage (MAKIYAMA, 1952), *Matrix*: yellowish-brown medium-fine sand

Finding: February of 1981, by Hiroaki KARASAWA

Depository: Mizunami Fossil Museum

Associated molluscs: *Suchium suchiense suchiense* (YOKOYAMA), *S. mysticum* (YOKOYAMA), *Turritella perterebra* YOKOYAMA, *Dolomena marginata robusta* (SOWERBY), *Polinices sagamiensis* PILSBRY, *Chicoreus totomiensis* MAKIYAMA, *Rapana venosa* (VALENCIENNES), *Thais nakamurai* MAKIYAMA, *Zeuxis caelatus dainitiensis* (MAKIYAMA), *Siphonalia cassidariaeformis declivis* (YOKOYAMA), *Babylonia elata* (YOKOYAMA), *Latirus* sp., *Hemifusus ternatanus* (GMELIN), *Baryspira rubiginosa albocallosa* (LISCHKE), *Cancellaria pristina* (YOKOYAMA), *Trigonostoma kurodai* (MAKIYAMA), *Solatia nodulifera* (SOWERBY), *Chelyconus* sp., *Olivella spretoides* (YOKOYAMA), *Turricula sobrina* (YOKOYAMA), *Clavatula dainitiensis* MAKIYAMA, *Pristiterebra bifrons ugariensis* (MAKIYAMA), *Diplomeriza yokoyamai* (MAKIYAMA), *Anadara* (*Scapharca*) *satowi castellata* (YOKOYAMA), *Glycymeris nakamurai* MAKIYAMA, *G. totomiensis* YOKOYAMA, *Amussiopecten praesignis* (YOKOYAMA), *Gloriopallium pallium* (LINNE), *Eucrassatella nanus* (ADAMS et REEVE), *Megacardita panda* (YOKOYAMA), *Callista chinensis* (HOLTEN), *Phacosoma troscheli* (LISCHKE), *Clementia papyracea* (GRAY), *Placamen tiara* (DILLWYN), *Macoma totomiensis* MAKIYAMA, *Panopea japonica* A. ADAMS, *Solidicorbula erythrodon* (LAMARCK), *etc.*

3. Observation and Analysis

Superficial observation and measurements:

form: the most spherical

color: light grayish-brown with pinkish-cream shade

luster: porcelain

size: 12.28 mm in major diameter, 11.98 mm in minor diameter

weight: 2.6398 g (13.199 ct)

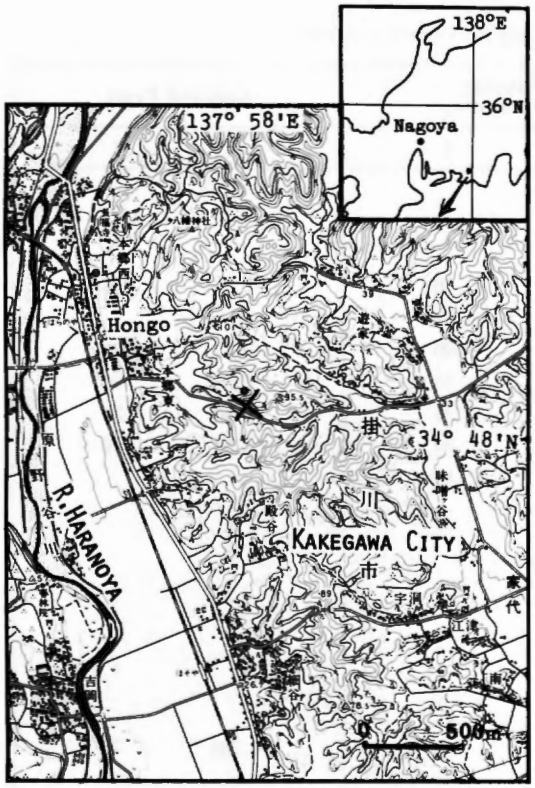


Fig. 1. Index map showing locality (Cited from the 1/25,000 Quadrangle Yamanashi).

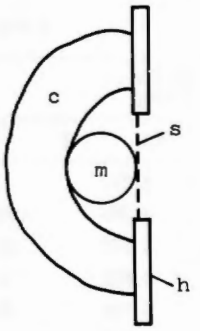


Fig. 2. Setting of the sample in X-ray diffraction analysis.
c. oil-clay, h. aluminum holder,
m. sample, s. surface for X-ray application.

specific gravity: 2.8674 (cf. aragonite 2.94, natural pearl 2.715±)

construction: The concentric circular construction is discernible at the surface come off partly the uppermost layer.

others: On the surface, it is observed minute holes like as pearl's one by the stereoscopic microscope (Pl. 14, figs. 1, 2). Some grains of sand adhered on the surface indicate long time burial of the specimen. The erosion of this fossil pearl is not so much that the luster has slightly remained on the only uppermost layer which is come off partly.

X-ray diffraction analysis:

In order to analyze by X-ray diffraction, the material was set in the case shown as Fig. 2 and analyzed after that, because we considered that the fossil pearl should not have been powdered. For the purpose of comparing we analyzed a cultured pearl by the same method with the material, and made into the diagram added to the datum of ASTM 5-0492 (aragonite) (Table 2). As a result of the comparison, it is confirmed that the material is made up of aragonite. The material is not identical completely with ASTM data, but it is able to recognize the crystal of aragonite in the material has a directionality whose character is almost similar to that of the cultured pearl. Moreover it is considered that the discrepancy on the numerical value of d(Å) is not attributable to the difference of setting the material, because we encounter practically with the discrepancy after resetting.

Ultraviolet rays analysis: long wave (3650 Å); reddish-orange, short wave (2536 Å); reddish-orange (week)

The reddish-orange color by the ultraviolet rays indicates that the material has the possibility of making up of aragonite. This fact was already proved by X-ray diffraction analysis, but still more emphasized being aragonite.

Table 1. Data of X-ray diffraction analysis

ASTM 5-0492			Material (the fossil pearl)		Cultured Pearl	
hkl	d(Å)	I	d(Å)	I	d(Å)	I
101	4.212	2				
110	3.396	100	3.38	5		
021	3.273	52				
002	2.871	4	2.88	10	2.88	15
121	2.730	9				
012	2.700	46	2.71	100	2.72	100
200	2.481	33	2.49	15	2.51	50
031	2.409	14	2.40	20	2.40	27
112	2.372	38	2.38	20	2.36	9
130	2.341	31	2.34	15		
022	2.328	6				
211	2.188	11				
220	2.106	23				
221	1.977	65				
041	1.882	32				
202	1.877	25				
132	1.814	23	1.824	10		
141	1.759	4	1.751	65	1.749	75
113	1.742	25				
231	1.728	15	1.732	40	1.728	24
222	1.698	3				
311	1.557	4	Cu (Ni), 40 KV 20 mA		Cu (Ni), 40 KV 20 mA	
232	1.535	2	1°−0.15− 1° full scale 500 ct'		1°−0.15−1° full scale 500 ct'	
241	1.499	4	time const. 2″		time const. 2″	
The rest is omitted.						

4. Observation by scanning electron microscope

Using Carter's (1980) sample preparation method 1 and 2, the microstructure of the fossil pearl from the Kakegawa Group is observed by scanning electron microscope (SEM). The depositional surface of the pearl is perforate (Pl. 14, fig. 3). This fossil pearl consists of concentric circular sheets parallel to the depositional surface (Pl. 14, figs. 4, 5). Thickness of the sheet is 60 to 90 μm. Little fracture of about perpendicular to the deposited surface has aragonitic complex crossed lamellar structure. In variation of complex crossed lamellar structure, this pearl is structurally similar to cone complex crossed lamellar structure (Pl. 14, figs. 6, 8). Aggregations of the elongate structural units dip in more directions relative to the depositional surface. This elongate structural unit is about 0.6 μm in diameter.

5. Discussion

The formation of natural pearl may be induced mainly by the introduction of some foreign particle into its connective tissue with a part of the epithelial manltle. And the body of mollusc forms the pearl sac for the regeneration to the trauma by the incentive of a foreign particle, and it forms calcite or aragonite layers secreted from the epithelial mantle. Therefore pearls have the similar to the structure of the shell layer of molluscs which form them. Based on the difference in their structure, cultured pearls are divided into the nacreous layer pearl, the prismatic layer pearl, the periostracal pearl, the hypostracal pearl and the compound pearl (KOBAYASHI and WATABE, 1959). It is common that pearls cultured in *pinctada fucata martensi* (DUNKER) and *Hyriopsis schlegeli* (v. MARTENS) have similar the nacreous layered structure to the nacreous structure of inner layers of their shells (Pl. 16, figs. 9, 10).

Indicating that the formation of a pearl is seen in various kinds of molluscs, there are many examples and some are under writers' collection. They are pearls formed in an upper area rather than near the pallial line of the inner surface of fresh-water bivalves as *Hyriopsis, Anodonta* and *Unio* (Pl. 16, figs. 1, 3, 4), the pearl existed near the posterior muscular scar of the inner side of the holotype specimen of *Barbatia minoensis* ITOIGAWA (Miocene bivalve), pearls formed in adductor muscles of *Glycymeris vestita* (DUNKER) (Pl. 16, figs. 5, 6) or pearls found in soft parts of *Turbo cornutus* SOLANDER (Pl. 16, figs. 2, 7, 8). Structures of these pearls are different in accordance with the kinds of the mother shell and their position in the shells on their occurrence.

The fossil pearl from the Kakegawa Group consists of aragonitic thin layers which structures are the complex crossed lamellar one (Pl. 14, figs. 6–8). Among molluscan fossils associated with the fossil pearl, *Anadara satowi castellata* (YOKOYAMA) and *Glycymeris nakamurai* MAKIYAMA have aragonitic shells with the complex crossed lamellar structure and are as large as possible to form the pearl of 12 mm in diameter.

In the bivalve group in which these two genera belong, the formation of a pearl is occasionally recognized. The shell structures of the two genera, *Anadara* and *Glycymeris,* have similar feature and are divided into the complex crossed lamellar structure of the inner layer and the crossed lamellar structure of the outer layer (Pl. 15, figs. 5–9). In comparison with the shell structure of these genera, the complex crossed lamellar structure of the fossil pearl is closely related to one of *Anadara satowi castellata* (YOKOYAMA). It is assumed that there is a possibility of the fossil pearl being formed in relation with a shell of the genus *Anadara,* especially *A. satowi castellata* (YOKOYAMA).

Concerning the formation of natural pearls, the size of the pearl should be in proportion to the shell thickness of the mother mollusc and its radius is nearly equal to the shell thickness. But it is not rare that the layers of pearl in the case of production by pearl sac are thicker than that of the shell.

Then, the thickness of the shell which produced this fossil pearl is estimated to be less than 6 mm. Also, if a large core existed in this fossil pearl, the core would be most

spherical.

6. Acknowledgements

We wish to express our hearty thanks to Mr. Hiroaki KARASAWA, a student of Nagoya-kita High School, for his offering the specimen. Thanks are also due to Dr. Iwao KOBAYASHI of Niigata University for his valuable comment on biomineralogy, to Mr. Takaki CHOSOKABE of Central Diamond Grading Center for his precious aid with the judgement of gemology, and to Mr. Hiroyuki NISHIMOTO of Toki High School, Mr. Haruo SAKAI and Dr. Hiroshi SHIBATA for supplying shell and pearl materials for this study.

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Plate

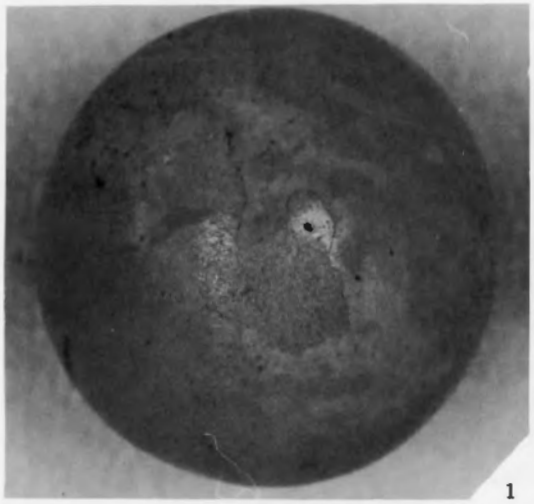
Plate 14

Figs. 1, 2. Exterior views of the fossil pearl by the stereoscopic microscope. Hongo, Kakegawa City, Shizuoka Pref., Dainichi Sand, Kakegawa Group. (×4.5)

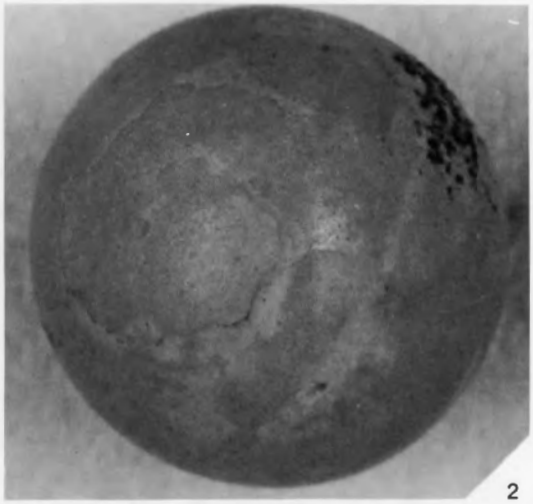
Fig. 3. SEM of gold-coated acetate peel, perforate-deposited surface of the fossil pearl from the Dainichi Sand, Kakegawa Group. Scale bar=10 μm.

Figs. 4–7. SEM of gold-coated acetate peel, oblique to the deposited surface of the fossil pearl from the Dainichi Sand, Kakegawa Group. Complex crossed lamellar structure. (Fig. 4, scale bar= 100 μm; Fig. 5, scale bar= 50 μm; Figs. 6, 7, scale bars= 25 μm)

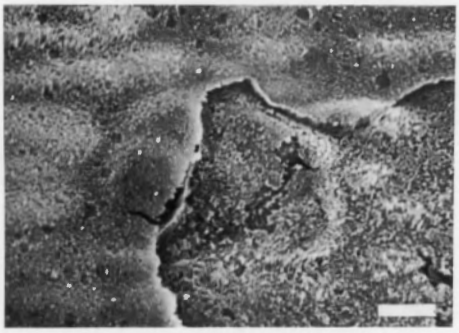
Fig. 8. SEM of gold-coated acetate peel, about parallel with the deposited surface of the fossil pearl from the Dainichi Sand, Kakegawa Group. Complex crossed lamellar structure. Scale bar= 10 μm.



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6



7



8

Plate 15

Fig. 1. Blister pearl on the inner surface of left valve, *Barbatia minoensis* ITOIGAWA from the Miocene Mizunami Group. After ITOIGAWA (1960). (× 1)

Figs. 2, 3. SEM of gold-coated acetate peel, about perpendicular to the deposited surface of the blister pearl in Fig. 1. Aragonitic pellucid structure.
(Fig. 2, scale bar=25 μm; Fig. 3, scale bar=10 μm)

Fig. 4. SEM of gold-coated acetate peel, about parallel with the deposited surface of the blister pearl in Fig. 1. Aragonitic complex crossed lamellar structure. Scale bar= 50 μm.

Fig. 5. SEM of gold-coated acetate peel, perpendicular to the deposited surface in *Anadara* (*Scapharca*) *satowi castellata* (YOKOYAMA) from the Dainichi Sand, Kakegawa Group. Aragonitic crossed lamellar structure. Specimen provided by Dr. Hiroshi SHIBATA. Scale bar=50 μm.

Fig. 6. SEM of gold-coated acetate peel, perpendicular to the deposited surface in *Anadara* (*Scapharca*) *satowi castellata* (YOKOYAMA) from the Dainich Sand, Kakegawa Group. Aragonitic complex crossed lamellar structure. Specimen provided by Dr. Hiroshi SHIBATA. Scale bar=50 μm.

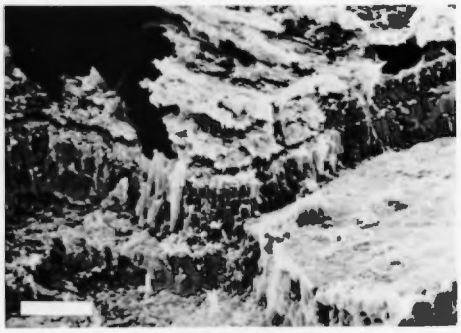
Fig. 7. Partly enlarged picture of Fig. 6. Scale bar= 25 μm.

Fig. 8. SEM of gold-coated acetate peel, perpendicular to the deposited surface in *Glycymeris nakamurai* MAKIYAMA from the Dainichi Sand, Kakegawa Group. Aragonitic crossed lamellar structure. Scale bar=50 μm. Specimen provided by Dr. Hiroshi SHIBATA.

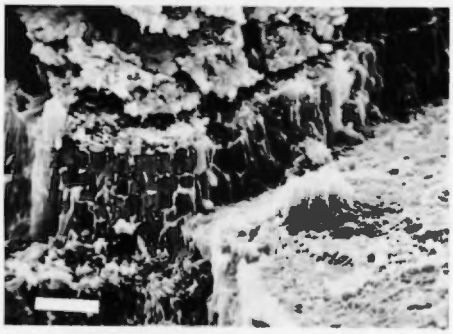
Fig. 9. Partly enlarged picture of Fig. 8. Scale bar= 25 μm.



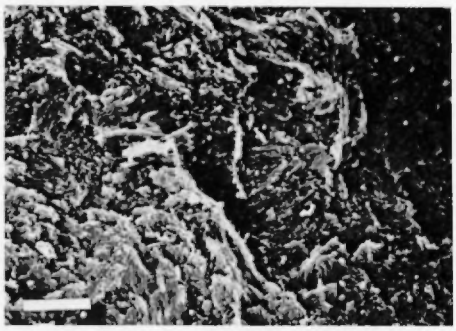
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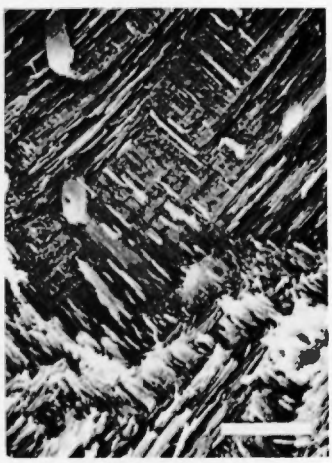
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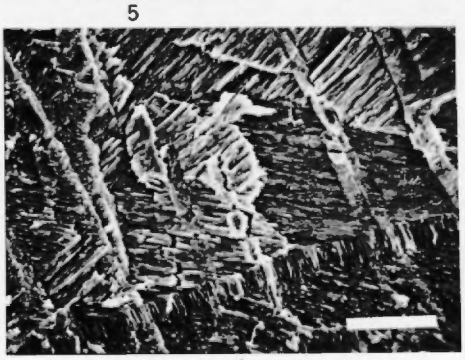
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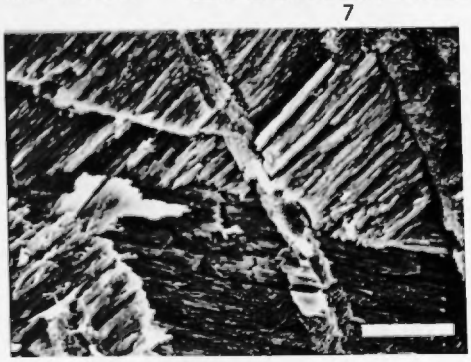
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Plate 16

Fig. 1. Cultured blister pearl on the inner surface of right valve, *Hyriopsis schlegeli* (v. MARTENS). Specimen provided by Mr. Haruo SAKAI. (× 2)

Fig. 2. Irregular pearl from the Recent *Turbo cornutus* SOLANDER. Specimen provided by Mr. Hiroyuki NISHIMOTO. (× 4)

Fig. 3. Blister pearl on the inner surface of left valve, *Anodonta lauta* v. MARTENS from Okubo, Shinano-machi, Kamiminochi-gun, Nagano Prefecture. (× 2)

Fig. 4. Blister pearl on the inner surface of right valve, *Unio* (*Nodularia*) *biwae* KOBELT from Lake Biwa, Shiga Prefecture. (× 2)

Fig. 5. SEM of gold-coated surface broken the irregular pearl of the Recent *Glycymeris vestita* (DUNKER). Aragonitic pellucid structure. Scale bar= 50 μm. Specimen provided by Mr. Hiroyuki NISHIMOTO.

Fig. 6. Partly enlarged picture of Fig. 5. Scale bar= 25μm.

Fig. 7. SEM of gold-coated surface broken the irregular pearl in Fig. 2. Aragonitic nacreous and prismatic structures. Scale bar= 50μm.

Fig. 8. Partly enlarged picture of Fig. 7. Scale bar= 10μm.

Fig. 9. SEM of gold-coated acetate peel, oblique to the deposited surface of the cultured pearl in *Pinctada fucata martensi* (DUNKER). Aragonitic nacreous structure. Scale bar= 10μm.

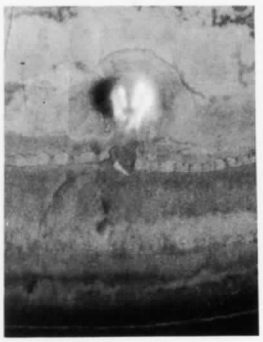
Fig. 10. SEM of gold-coated acetate peel, oblique to the deposited surface of the cultured pearl in *Hyriopsis schlegeli* (v. MARTENS). Aragonitic nacreous structure. Scale bar= 10μm.



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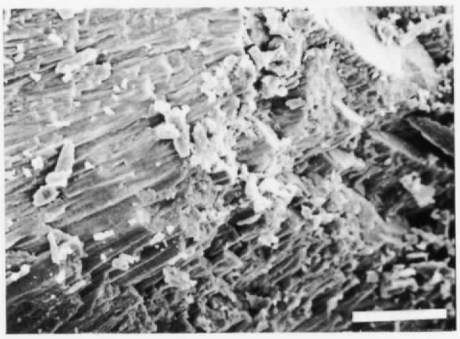
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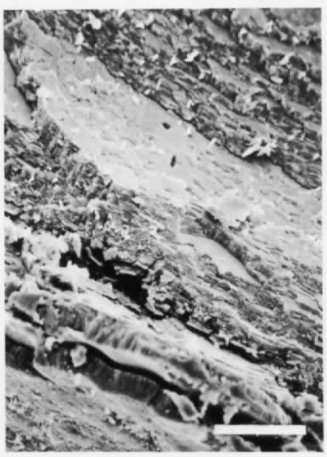
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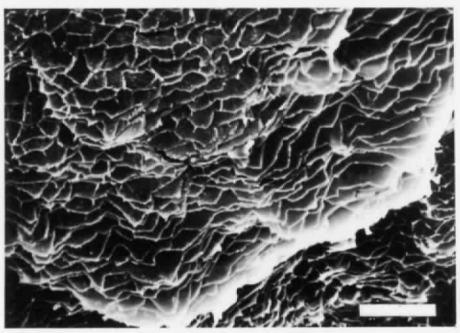
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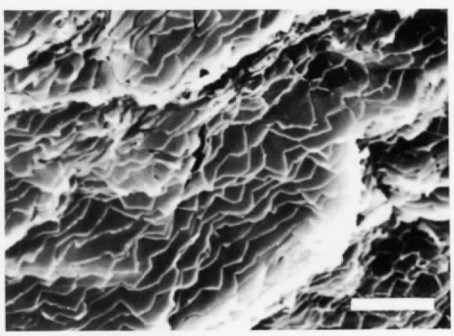
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