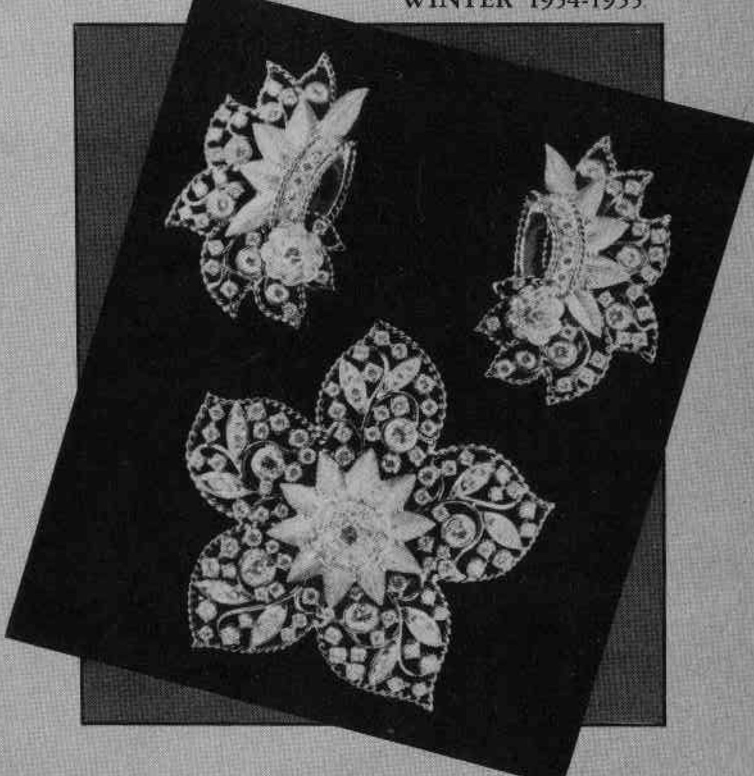
Gems and Gemology

WINTER 1954-1955



See Inside Cover

Gems & Gemology

VOLUME VIII | WINTER 1954-1955 | NUMBER 4

IN THIS ISSUE

On the Cover

Reminiscent of foliage spattered with dew is this lovely matched set of diamond and gold ear-clips and brooch from B. D. Howes of Los Angeles. The ensemble was picked by the Selection Committee for one of the Diamonds U.S.A., Awards.

Photo GIA

WEIGHT ESTIMATION
OF
PEARLS

WITH ACCOMPANYING CHART
and formula with derivation

by

JAMES SMALL

For some time it has been the writer's thought that weight estimation tables be made available for all gems, no matter what their style of fashioning, and for all pearls. The following article develops such a weight estimation procedure for pearls. The weight estimation of drilled and undrilled spherical pearls is given as a formula. The weight estimation for drilled pearls is also given as a chart and in the form of tables. All measurements are given in terms of millimeters and the computed weights are in terms of pearl grains unless otherwise indicated.

On the assumption that a pearl is merely a sphere minus a cylinder (drill hole), a formula can be derived whereby the pearl's weight may be estimated by referring to its diameter and inserting this figure in the formula. The formula also can be computed and presented in the form of tables or shown as a graph.

Derivation of the formula. The volume of a sphere is given as:

$$\text{Volume} = \frac{4}{3} \pi r^3$$

Since it is practical to measure the diameter rather than the radius the formula should be stated in terms of that dimension.

By definition:

$$\text{Diameter} = 2\text{x radius}$$

or

$$\text{Radius} = \frac{\text{Diameter}}{2}$$

Substitute this in the formula:

$$\text{Volume} = \frac{4}{3} \pi \frac{(D)^3}{(2)}$$

$$= \frac{4}{3} \pi \frac{D^3}{8}$$

$$= \frac{4 \pi D^3}{24} = \frac{\pi D^3}{6}$$

But $\pi = 3.1416$

Therefore,

$$\text{Volume} = \frac{\pi D^3}{6} = \frac{3.1416 D^3}{6}$$

$$= .5236 D^3$$

This formula is valid for materials with a specific gravity of 1.0. However, our needs are such that the formula should be expressed for pearl weight.

The specific gravity of natural pearls varies from 2.66 to 2.76 and the specific gravity of cultured pearls ranges from 2.70 to 2.78. For the purposes of the formula a specific gravity of 2.72 was taken. This figure should satisfy the conditions for both natural and cultured pearls since their specific gravities vary so much. For comparison a natural pearl of 2.72 specific gravity and a 10 millimeters diameter would weigh 28.37 pearl grains; a cultured pearl of 2.75 specific gravity and a diameter of 10 millimeters would weigh 28.69 pearl grains. In another example, the weight of a natural pearl of 2.72 specific gravity and 5 millimeters diameter, was computed to be 3.51 pearl grains as compared to 3.54 pearl grains for a cultured pearl of the same size but a specific gravity of 2.75.

These differences in computed weights rarely exceed 1%. Such a small difference confirms the practicability of using an average specific gravity of 2.72 for the formula.

In cases of pearls which are not spherical but irregular in shape, an average of the several diameters will give satisfactory results.

By multiplying by 2.72 the formula is adjusted for pearl's gravity:

$$\text{Volume} = .5236\ D^3 \times 2.72$$

$$= 1.424\ D^3$$

However, the above answer would be in terms of grams and *D* would be in terms of centimeters. For utility, the formula should read in pearl grains and the measurements should be made in millimeters. This adjustment is easily made since (a) 1 gram = 20 pearl grains and (b) a gram is equal to 1 cubic centimeter; since there are 10 millimeters in a centimeter it follows that 1 cubic centimeter =10x10x10=1000 millimeters.

By substituting these factors the formula will read in pearl grains rather than volume.

$$\text{Volume} = 1.424\ D^3 \ (\text{grams})$$

Estimated pearl weight =

$$1.424\ D^3 \times 20 \times \frac{1}{1000}$$

$$= \frac{28.48}{1000}\ D^3$$

$$= .02848\ D^3 \qquad (1)$$

This formula is valid for solid spherical pearls. However, for drilled pearls the amount of pearl material removed when the pearl was drilled must be subtracted. The drill hole is really in the form of a cylinder. The volume of a cylinder = $\pi r^2 h$

The radius of an average drill hole is approximately .025 centimeters. Therefore

$$\text{Volume} = \pi\ (.025)^2\ h$$

But the *h* (length of the drill hole) is equal to the diameter (D) of the whole pearl and $\pi = 3.1416$.

$$\text{Volume (drill hole)} = 3.1416 \times (.025)^2 \times D$$

$$= .0019635\ D$$

Again our answer is in terms of grams when centimeter measurements and material of specific gravity = 1 is used.

The weight of cylinder

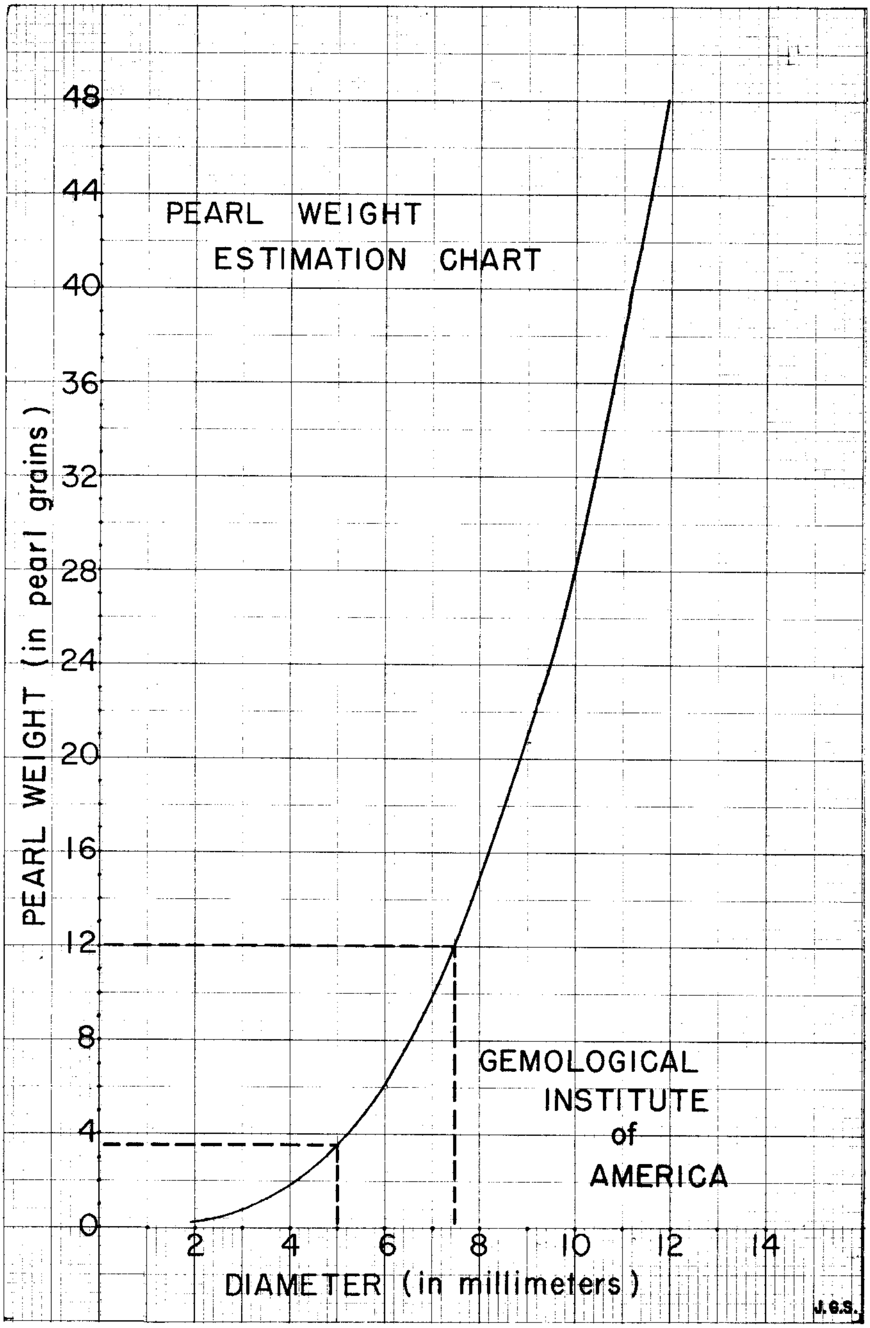
$$= .19635\ D \times 20 \times \frac{1}{1000} \times 2.72$$

$$= .0107\ D \qquad (2)$$

The weight of a drilled pearl is the total weight of a sphere of pearl material minus the weight of the cylinder of pearl removed in drilling, or formula (1) minus formula (2) or

Estimated weight in pearl grains = .02848 D^3 minus .0107 D. Using this formula, a pearl weight estimation chart can be computed. By reference to such a chart, the pearl weight in grains is read opposite the proper number in the "Diameter" column. Thus if a pearl of unknown weight was found to have a diameter of 7.0 millimeters, by reference to the chart opposite 7.0 we find a weight of 9.70 pearl grains. For comparison and reference a column each for pearl

(Continued to page 124)


PEARL WEIGHT
ESTIMATION CHART
PEARL WEIGHT (in pearl grains)
48
44
40
36
32
28
24
20
16
12
8
4
0
2
4
6
8
10
12
14
DIAMETER (in millimeters)
GEMOLOGICAL
INSTITUTE
of
AMERICA
J.e.S.

ESTIMATED WEIGHTS FOR DRILLED PEARLS

DIAMETER	PEARL GRAINS	MOMME	CARATS	GRAMS
1.0	.02	.003	.005	.001
1.1	.03	.004	.008	.0015
1.2	.04	.005	.010	.002
1.3	.05	.007	.013	.0025
1.4	.06	.008	.015	.003
1.5	.08	.011	.020	.004
1.6	.10	.013	.025	.005
1.7	.12	.016	.030	.006
1.8	.15	.020	.038	.008
1.9	.18	.024	.045	.009
2.0	.21	.028	.053	.011
2.1	.24	.032	.060	.012
2.2	.28	.037	.070	.014
2.3	.32	.043	.080	.016
2.4	.37	.049	.093	.019
2.5	.42	.056	.105	.021
2.6	.47	.063	.118	.024
2.7	.53	.070	.138	.028
2.8	.60	.080	.150	.030
2.9	.67	.089	.169	.034
3.0	.74	.098	.185	.037
3.1	.82	.109	.205	.041
3.2	.90	.120	.225	.045
3.3	.99	.129	.248	.050
3.4	1.08	.144	.270	.054
3.5	1.18	.157	.295	.059
3.6	1.29	.172	.323	.061
3.7	1.40	.187	.350	.070
3.8	1.52	.202	.380	.076
3.9	1.65	.219	.413	.083
4.0	1.78	.237	.45	.089
4.1	1.92	.255	.48	.096
4.2	2.06	.274	.52	.103
4.3	2.22	.295	.56	.111
4.4	2.38	.318	.58	.115
4.5	2.55	.339	.64	.127
4.6	2.72	.362	.68	.136
4.7	2.91	.387	.73	.145
4.8	3.10	.413	.78	.155
4.9	3.30	.438	.83	.165
5.0	3.51	.467	.88	.175
5.1	3.73	.497	.93	.186

ESTIMATED WEIGHTS FOR DRILLED PEARLS

DIAMETER	PEARL GRAINS	MOMME	CARATS	GRAMS
5.2	3.95	.527	.99	.197
5.3	4.18	.558	1.05	.209
5.4	4.43	.592	1.11	.221
5.5	4.68	.622	1.17	.234
5.6	4.95	.661	1.24	.247
5.7	5.21	.693	1.30	.260
5.8	5.49	.730	1.38	.275
5.9	5.79	.772	1.45	.249
6.0	6.09	.810	1.52	.304
6.1	6.40	.852	1.60	.320
6.2	6.72	.895	1.68	.335
6.3	7.05	.938	1.76	.352
6.4	7.40	.987	1.85	.370
6.5	7.75	1.03	1.94	.387
6.6	8.11	1.07	2.03	.405
6.7	8.49	1.13	2.13	.425
6.8	8.88	1.18	2.22	.444
6.9	9.28	1.24	2.32	.464
7.0	9.70	1.29	2.42	.48
7.1	10.12	1.34	2.53	.51
7.2	10.55	1.42	2.64	.53
7.3	11.00	1.46	2.75	.55
7.4	11.46	1.53	2.87	.57
7.5	11.94	1.59	2.99	.60
7.6	12.42	1.65	3.11	.62
7.7	12.92	1.72	3.23	.65
7.8	13.43	1.78	3.33	.67
7.9	13.95	1.86	3.49	.70
8.0	14.50	1.93	3.63	.73
8.1	15.05	2.00	3.76	.75
8.2	15.61	2.05	3.90	.78
8.3	16.20	2.16	4.05	.81
8.4	16.79	2.23	4.20	.84
8.5	17.40	2.32	4.35	.87
8.6	18.02	2.39	4.51	.90
8.7	18.66	2.47	4.67	.93
8.8	19.32	2.57	4.83	.97
8.9	19.98	2.66	5.00	1.00
9.0	20.67	2.74	5.17	1.03
9.1	21.36	2.83	5.34	1.07
9.2	22.08	2.94	5.52	1.10
9.3	22.81	3.03	5.70	1.14

ESTIMATED WEIGHTS FOR DRILLED PEARLS

DIAMETER	PEARL GRAINS	MOMME	CARATS	GRAMS
9.4	23.25	3.13	5.89	1.18
9.5	24.31	3.23	6.08	1.22
9.6	25.10	3.34	6.28	1.26
9.7	25.89	3.44	6.47	1.29
9.8	26.70	3.55	6.68	1.34
9.9	27.52	3.66	6.88	1.38
10.0	28.37	3.77	7.09	1.42
10.1	29.23	3.89	7.31	1.46
10.2	30.11	4.02	7.53	1.51
10.3	31.00	4.13	7.75	1.55
10.4	31.92	4.24	7.98	1.60
10.5	32.86	4.36	8.22	1.64
10.6	33.80	4.49	8.45	1.69
10.7	34.78	4.63	8.70	1.74
10.8	35.75	4.75	8.94	1.79
10.9	36.76	4.88	9.19	1.85
11.0	37.79	5.03	9.45	1.89
11.1	38.82	5.17	9.71	1.94
11.2	39.88	5.32	9.97	2.00
11.3	40.98	5.47	10.25	2.05
11.4	42.07	5.62	10.52	2.10
11.5	43.19	5.76	10.80	2.16
11.6	44.34	5.89	11.09	2.22
11.7	45.49	6.07	11.37	2.27
11.8	46.67	6.22	11.67	2.33
11.9	47.85	6.37	11.96	2.39
12.0	49.08	6.52	12.27	2.45
12.1	50.33	6.72	12.58	2.52
12.2	51.59	6.86	12.90	2.58
12.3	52.86	7.03	13.22	2.64
12.4	54.16	7.22	13.54	2.71
12.5	55.48	7.38	13.87	2.77
12.6	56.84	7.57	14.21	2.84
12.7	58.19	7.77	14.55	2.91
12.8	59.58	7.93	14.90	2.98
12.9	61.00	8.13	15.25	3.05
13.0	62.40	8.30	15.60	3.12
13.1	63.89	8.50	15.97	3.19
13.2	65.37	8.70	16.34	3.27
13.3	66.87	8.89	16.72	3.34
13.4	68.37	9.09	17.09	3.42
13.5	69.91	9.30	17.48	3.50

ESTIMATED WEIGHTS FOR DRILLED PEARLS

DIAMETER	PEARL GRAINS	MOMME	CARATS	GRAMS
13.6	71.47	9.50	17.87	3.51
13.7	73.07	9.76	18.27	3.65
13.8	74.70	9.94	18.68	3.74
13.9	76.32	10.15	19.08	3.82
14.0	77.97	10.37	19.50	3.90
14.1	79.67	10.60	19.92	3.98
14.2	81.39	10.82	20.35	4.07
14.3	83.11	11.05	20.78	4.16
14.4	84.91	11.29	21.23	4.25
14.5	86.69	11.52	21.67	4.33
14.6	88.50	11.77	22.13	4.43
14.7	90.29	12.01	22.57	4.51
14.8	92.18	12.26	23.05	4.61
14.9	94.04	12.51	23.51	4.70
15.0	95.96	12.76	23.99	4.80
15.1	97.90	13.02	24.48	4.90
15.2	99.81	13.28	24.96	4.99
15.3	101.54	13.54	25.46	5.09
15.4	103.84	13.81	25.96	5.19
15.5	105.86	14.08	26.47	5.29
15.6	107.93	14.35	26.98	5.40
15.7	110.04	14.64	27.51	5.50
15.8	112.19	14.92	28.05	5.61
15.9	114.30	15.20	28.58	5.72
16.0	116.45	15.49	29.11	5.82
16.1	118.66	15.78	29.67	5.93
16.2	120.88	16.08	30.22	6.04
16.3	123.17	16.38	30.79	6.16
16.4	125.40	16.68	31.35	6.27
16.5	127.76	16.99	31.94	6.39
16.6	130.09	17.30	32.52	6.50
16.7	132.43	17.61	33.11	6.62
16.8	134.85	17.94	33.71	6.74
16.9	137.29	18.26	34.32	6.86
17.0	139.69	18.56	34.92	6.98
17.1	142.22	18.92	35.55	7.11
17.2	144.68	19.24	36.17	7.23
17.3	147.22	19.58	36.81	7.38
17.4	149.78	19.92	37.45	7.49
17.5	152.40	20.27	38.10	7.62
17.6	155.06	20.62	38.77	7.75
17.7	157.74	20.98	39.44	7.89

X-RAY STUDY OF FIBROUS QUARTZ CHALCEDONY IRIDESCENT AGATE

by SIR C. V. RAMAN
and A. JAYARMAN

Editor's note: *This article was abstracted from three articles appearing in the "Proceedings of the Indian Academy of Sciences."* Volume XXXVIII, Numbers 4 and 10 Volume XL, Number 3

Mineralogists designate a mineral as fibrous when it consists of visibly distinct rods or threads, irrespective of whether these are separable from each other. Many gradations between a coarsely columnar and a finely fibrous structure are to be observed, the finely fibrous materials often exhibiting a silky lustre. In his *Handbuch der Mineralogie,* Hintze[1] reports that secondary quartz often appears as pseudomorphs of the original minerals which it has replaced, and that when such minerals had a fibrous structure, the secondary quartz formed therefrom is also fibrous.

The material examined in the present investigation was very kindly placed at our disposal by the Director of the Geological Survey of Mysore. It had been collected by Dr. Pichamuthu many years ago and the following description of the circumstances in which it had been found is quoted from his monograph on the iron formation of the Eastern Bababudan Hills in Mysore.

"The writer has collected from various parts of the Bababudans specimens of fibrous quartz. In some of the siliceous layers which are formed of fibrous aggregates of quartz crystals, the fibres are disposed at right angles to the plane of bedding and are separable in some cases. The fibres are not always straight, but often bent. These layers frequently exhibit a chatoyant lustre. In micro-sections, these quartz layers are seen to contain fibrous amphiboles. (Ed. Note: Actinolite, of which nephrite is a variety, is an amphibole.) Though in no one place was it possible to trace a layer of fibrous amphibole passing into a layer of quartz, the collections made by the writer show that the quartz has replaced amphibole. Similar fibrous quartz (Ed. Note: Tiger-eye) has long been known to occur associated with the banded ironstones of South Africa. The prevalent view in South Africa is that fibrous asbestos has been pseudomorphosed by Silica."

The specimen of fibrous quartz consisted of small rods each a few millimetres long and less than a millimetre thick. They were practically colorless. On the stage of the polarising microscope and immersed in liquid of suitable index, the material appears transparent. When the vibration direction of the polariser is parallel to the length of the specimen, the refractive index is nearly equal to the extraordinary index of quartz as judged by the Becke line test. Between crossed Nicols, the extinction is almost perfect when the longer dimension of the specimen is either parallel or perpendicular to their vibration directions. When a quartz wedge is introduced parallel to the length of the specimen, the interference color rises in the Newtonian scale, thereby revealing that the *c*-axis of quartz is parallel to the length of the specimen.

The foregoing inference from the optical observation is generally confirmed by the results of the X-ray diffraction studies which show that the axis of the fibre is nearly parallel to the *c*-axis of quartz which is set horizontal in the figures.

Other X-ray studies suggest that it would seem correct to describe the material as polycrystalline quartz with a strongly preferred orientation for the crystallographic *c*-axis along the length of the fibres rather than as truly fibrous quartz. Micro sections of the original formation prepared by Dr. Pichamuthu and seen by us showed no break in continuity of the individual fibres along their length under the polarising microscope, thereby supporting the view of the structure indicated by the X-ray diagrams.

CHALCEDONY

Chalcedony is a crypto-crystalline variety of silica occurring in a massive form and exhibiting a waxy lustre. It is only slightly inferior to quartz in hardness and has a density lying between 2.60 to 2.64. A small percentage of water may often be found in the material. The refractive index averages at 1.537 and is thus not very different from quartz. Thin sections exhibit a fibrous character under the microscope and the material shows a distinct birefringence which is of the same order of magnitude as that of quartz. (Ed. Note: Gemological Institute studies on chalcedony indicate a birefringence of approximately one half that of crystalline quartz.)

Mineralogists formerly regarded chalcedony as a distinct crystalline species of silica and classed it under the orthorhombic system. But the X-ray pattern of powdered chalcedony is identical with that of quartz, as was first reported by Washburne and Navias[3] and later confirmed by Rinne[4], thus demonstrating that chalcedony is composed of crystallites of quartz. The fibrous character of the material and the birefringence exhibited by it indicate that the crystallites have preferred orientations. Correns and Nagelschmidt[5] showed that such orientation is actually observable in the X-ray patterns of unpowdered chalcedony.

The fibrous structure of chalcedony in which the *a*-axis of the crystallites of quartz are parallel to the fibre length is often, if not invariably, accompanied by a lamellar structure with its planes running everywhere transverse to the fibres. Such a structure is most clearly seen through a magnifier when the area under observation lies on the boundary between light and darkness, when the plate is held and viewed against a source of light. (It is seen very clearly in Fig. 5 in the lower parts of the figure.) A remarkable characteristic of this fine lamellar structure is the appearance of numerous ripples or waves running approximately parallel to the area of the specimen. From past observations we are entitled to infer that lamellar structure and the fine ripples seen accompanying it are a consequence of a variation in the orientation of the *c*-axes of the crystallites in the successive layers which are perpendicular to the length of the fibres.

When X-ray patterns of chalcedony were recorded for different regions and interpreted, confirmation of the ideas regarding the structure were deduced from its optical behaviour. The X-ray pattern reproduced demonstrated that the crystallites of quartz composing the material were orientated with their *a*-axes common along the fibre length.

IRIDESCENT AGATE

It is well known that agate exhibits a banded structure. One explanation of the banding which has been put forward is that the agate is the result of the deposition of

(Continued to page 125)

KOKICHI MIKIMOTO

A TRIBUTE

by

JEANNE G. M. MARTIN

The recent death of Kokichi Mikimoto ended an era in the history of cultured pearls that began in the latter part of the nineteenth century, when Mr. Mikimoto produced his first blister pearl. His influence on the pearl culture industry continued for more than six decades with his numerous developments and contributions to its growth.

Deservedly he was often called the father of the industry, and the name of Mikimoto has come to be almost synonymous with cultured pearls. However, other names already almost lost, should be recognized as important in the early history of pearl culture. As a consequence, the time seems appropriate for an evaluation of Mikimoto's important contributions as well as those of some of his early contemporaries.

The excellent report, "Pearl Culture in Japan" by Dr. A. R. Cahn, issued October 31, 1949 provides the major source for this analysis. The evaluation of the relative importance of various developments is largely Dr. Cahn's.

Mikimoto spent his youth on the shores of Ago-wan, a bay long famous for the production of the Japanese pearl oyster, *Pinctada martensii.* Because of overfishing and lack of conservation measures, the output of these shellfish had decreased rapidly during his youth, but the world demand for pearls had constantly increased.

Mikimoto established his first pearl farm at Shimenoura in Ago-wan in 1889 and at the national exposition in Tokyo in 1890 he exhibited a collection of natural pearls from Ago Bay. Among the members of the jury of awards was Dr. Mitsurkuri, a well known Japanese biologist, who showed to Mr. Mikimoto the inside of a Chinese fresh water mussel shell with Buddha images which had been coated with nacre. He suggested that similar growths could be produced in Japanese oysters. Mikimoto was impressed by this suggestion and soon after began his experiments in the culture of blister pearls at Ago Bay.

Mikimoto established the first experimental station on a small island off Toba in 1890. For several years he groped blindly, trying to find the answer to the riddle of pearl formation. In 1893, the red tide* wiped out his oyster crop at Shimenoura and he withdrew to Toba. Here on July 11, 1893 he gained his first success, a semi-spherical blister pearl. In 1896 he obtained a patent on his method of producing blister pearls. This was the first patent issued in Japan on pearl culture. In time, this patent was interpreted to include any insertion of a nucleus into the pearl oyster from the exterior, thus apparently protecting Mikimoto from infringement by anyone introducing a nucleus of any kind by any method, even though at the time he had not the slightest idea of how to produce a spherical pearl.

In 1905, the red tide again practically destroyed his crop, killing about 800,000 oysters under cultivation in bamboo baskets. Examination of this lot showed five spherical pearls, located near the adductor muscle. The pearl-muscle relationship of the five pearls gave him the idea how spherical pearls could be produced, by inserting the nucleus within the tissue of the oyster. In the meantime both Mise and Nishikawa had discovered the secret.

Apparently the first person to develop a spherical cultured pearl was a carpenter by the name of Tatsuhei Mise. He became interested in pearls through his step-father who had been sent on an inspection trip through the Australian oyster fisheries. He had no scientific training but he did have a keen interest and a wealth of ideas. He developed one of his ideas successfully and produced his first spherical pearls very early in the century. Cahn states, "The exact date can not be established, but it was before 1904, as in that year he showed his culture spherical pearl to Dr. Kishinoye, a leader among Japanese marine scientists. The pearl was developed in *Pinctada martensii* by a tissue-graft around a tiny lead nucleus."

Although a patent was not granted Mise on his spherical culture pearl, he did receive a patent on the instrument used in his method in April, 1907. Apparently this was the first patent issued relative to actual spherical pearl culture. The first mention of the deliberate introduction into the oyster of mantle epithelium in order to produce a pearl is found in this application for a patent. The needle was used to insert a nucleus and pieces of epithelium from the mantle into the connective tissue and leave it inside the body of the oyster. It seems reasonable to believe that Mise now understood the basic requirements for producing spherical cultured pearls; a spherical nucleus, and a piece of mantle epithelium to be introduced into the connective tissue of the oyster.

The mantle is a connective tissue membrane that enwraps the visceral mass of the oyster. The right and left lobes of the mantle are continuous with each other along the mid-dorsal line and hang like flaps on either side of the oyster's body. The mantle is protected on the outside by a single layer of epithelial cells. The portion of the epithelium which is in contact with the inner surface of the shell is called the outer epithelium and secretes the substance from which the calcareous shell is made.

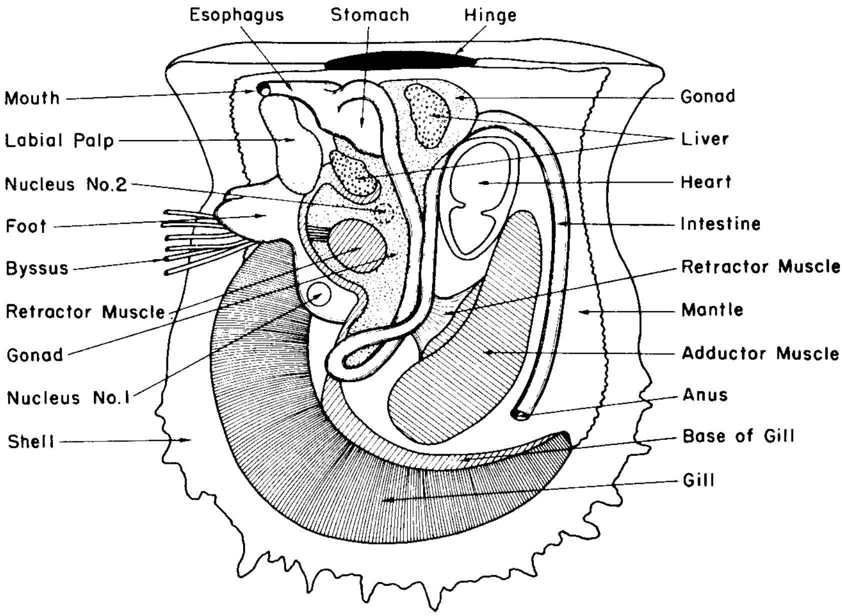
An inner epithelium which is ciliated and performs no shell or nacre-secreting functions, lines the free inner surface of the mantle in the rear of the mantle cavity.

Finely crystalline calcium carbonate is secreted by the outer epithelium cells, in the form of aragonite crystals, better known as

*A "red tide" has been known to occur several time since the sixteenth century, but not until 1856 did an investigation show the basic cause to be plankton organisms, During a "red tide," one of the dinoflagellates occurs in sufficient numbers to color the water red. The "red tide" is fatal to fish, molluscs and other forms of marine life which breathe by gills or in which respiration is controlled by pores or small body openings, as in the sponge.

The actual cause of death due to these micro-organisms is not entirely clear but it is suggested that due to the enormous numbers and the oxygen consumed by them, the marine life dies from suffocation or that their gills become clogged with the masses of organisms and prevent the proper aeration of the blood within.

Other suggestions are that the marine life is poisoned by the toxic substances secreted by these living organisms or toxic substances released by the decomposition of the dead organisms.



• Anatomy of Japanese Pearl Oyster *Pinctada martensii* from *Pearl Culture in Japan by Dr. A. R. Cahn.*

nacre or mother-of-pearl and hexagonal calcite crystals which form the prismatic layer of the shell. These cells also secrete conchiolin, the organic substance, with which the calcareous crystals are cemented. The outer epithelium, if transplanted under favorable conditions into the body of another oyster, can produce new cells and will continue to develope and to secrete calcareous material. This characteristic of the outer epithelium is of major importance in the formation of a pearl.

Tokichi Nishikawa is credited with the production of the first spherical pearl produced from scientifically planned experiments. Nishikawa, a technologist with the Japanese Bureau of Fisheries had been deeply interested in the marine products, and especially the oyster fishing grounds in Australia, while stationed there.

After returning to Japan, he resigned from the Bureau and devoted his time to research on pearls at the Marine Biological Laboratory of Tokyo University at Nisake. He produced his first spherical pearl during his stay at the University but the exact date is not known. Nishikawa applied for a patent on his pearl culture method in 1907, five months after Mise had applied for his patent.

One of the most interesting facets of the whole patent picture was in the Japanese Patent Office judgments. In 1908, only a year after both patent applications were filed, but eight years before a patent was finally granted, Mise's application was ruled as an infringement of Nishikawa's.

This remarkable judgment not only called the original application an "infringement" on one filed months later, but ruled that a key point on which Mise had been specific and Nishikawa too general made little difference. Mise's application called for insertion of the nucleus into "connective tissue" and Nishikawa's only into "a tissue." In Cahn's judgment as a biologist, "Unfortunately for Mise, the judge was not a biologist, for that one word "connective" in the Mise application is the key to the success or failure of the entire operation."

Apparently the basis for the judgment was a claim by Nishikawa that he made the discovery in 1899 for which there is no known supporting evidence. On this Cahn says "Although these decisions may be in full accord with the existing Japanese patent laws, the judgment of history is not bound by these laws, and the reader can decide for himself who actually discovered the method for the culture of the spherical pearl. All he need do is answer this question. Is it likely that Nishikawa, knowing he had in his hands the key to a fabulous fortune, would have delayed for nine years, eight months, and three days in safeguarding his invention?"

The Mise and Nishikawa methods were approximately the same, consequently, Mise and Nishikawa signed an agreement in September 1908 making the use of their methods common property between them. Mise had already received a patent on the instrument used in the operation in which the nucleus and mantle epithelium was inserted in the oyster but Nishikawa's heirs finally received the patent on the pearl culture method itself.

Nishikawa was married to K. Mikimoto's eldest daughter but he and his father-in-law were not on the friendliest of terms. Nishikawa died in 1909 prematurely at the age of 35, shortly after applying for the patent on his method of culturing spherical pearls. According to Cahn, ". . . his rights reverted to his son Shinkichi, and his able assistants, the Fujita brothers." They successfully completed Nishikawa's experiments and long after his death obtained the "Nishikawa patent" in 1916. The method used tiny gold and silver nuclei.

Mikimoto produced his first spherical cultured pearls with his more complicated system which consisted of enclosing a nucleus in a tissue sac made from the mantle and tied with a fine silk thread prior to its insertion in the body of the oyster. A patent was applied for in 1914 but was not granted at that time.

Cahn States "The actual inventor of the 'Mikimoto method,' according to Dr. Matsui, was Otokichi Kuwabara, formerly a dentist and later a very valuable employee and also a close friend of Mikimoto." Kuwabara, being very feeble and now in his eighties, does not recall this early history.

Unfortunately, Mise's and Nishikawa's applications for patents were overlooked for nine years and in 1916 Nishikawa was finally granted a patent but Mikimoto's patent, which had been applied for in 1914 was granted just seven weeks prior to the granting of Nishikawa's.

Through relatives and friends a reconciliation was effected between Shinkichi Nishikawa and Mikimoto and eventually Mikimoto was granted permission to use the Nishikawa-Mise method, which is used to produce spherical cultured pearls at the Mikimoto pearl farms today. The Mikimoto method proved too delicate and difficult and the Nishikawa-Mise technique was much simpler.

Mikimoto, realizing that pearl culture depended on a plentiful supply of pearl oysters, undertook extensive experiments to increase his supply. The Japanese pearl oyster *Pinctada martensii* is by far the most important pearl producing mollusc and produces some of the finest although not the largest pearls. The naturally grown oyster was originally the sole source of supply for pearl culture. It is in the field of pearl mollusc culture that some of Mikimoto's most important contributions were made.

The naturally grown oysters are still gathered each year in the early autumn from the small bays and inlets along the coast of Ago-wan. During World War II this operation was discontinued and the supply of available oysters gradually diminished. Gathering was resumed in 1946, and due to successfully planned large scale operations, about 945,000 oysters were collected.

COLLECTING NATIVE OYSTERS

According to Cahn, more than 300 small fishing skiffs and launches, each carrying several persons, two or more being divers, participated in this collection of oysters. About 300 tenders employing another 1,000 divers were active in gathering the oysters. The oysters were weighed and sorted at the shore bases and the records taken by an additional 100 persons who then loaded the tallied shells into large barges.

The divers, most of whom are women wear simple long-sleeved, white cotton dresses which cover them from throat to knees. On their heads they wear white cotton cloths, and the diving masks which are necessary for protection cover all except their mouth and chin.

Each diver is provided with a small hand net of about 8 inches diameter and 16 inches deep made of 1 inch cotton netting. When diving in water 18 feet or less, a large wooden bucket, about 12 inches in diameter and 16 inches deep is attached to the diver's waist by a stout cord. The oysters gathered from the bottom are brought to the surface in the hand net and transferred to the floating bucket which is emptied periodically into the tender boats. The diving time is dependent on the skill and experience of the diver, sometimes lasting as long as 40 seconds for the most experienced. The catch usually runs from 1 to 10 shells for each dive.

In water 16 to 25 feet deep, the divers operate directly from the side of the tender boat. A stout rope supporting a heavy weight and operated with a pulley from the gunwale of the boat, is grasped by the diver close to the weight. The tender releases the rope and clears it from the pulley and the diver takes a deep breath and is slowly lowered to the water and submerges. At a signal from the diver, by the cotton life-line which is fastened to her waist, the tender passes the life-line over the pulley and hauls the diver to the surface. After emptying her hand net the diver rests while the weight is raised to the surface by the tender.

The main vertical distribution of the pearl oyster ranges from 3 to 35 feet. In water 25 feet in depth or over, the dives last 20 to 25 seconds. The diving is done at low tide and as the water rises the divers move into more shallow water.

The divers work 5 hours each day which consists of 2 periods of 2½ hours each. At the close of each period the collected oysters are taken to the shore base where there is a sorting table. The 2-year old oysters are identified by their size and are separated from the older individuals, and the unsatisfactory shells are discarded. The 2 year old oysters are purchased by the fishing association, to be sown in shallow water. The older oysters which are collected by the divers are taken to the oyster farms and are distributed in shallow water that has a moderately rough bottom. These areas have all been cleaned of oysters during the time divers were busy gathering the crop for the culture operations. The new oysters remain undisturbed until late in the spring of the following year, at which time the divers begin collecting them to be taken to the laboratory for the operation and nucleus insertion.

COLLECTING SPAT

As early as 1885 the gathering of spat (very young oysters) was widespread throughout Japan but it was devised for culturing the edible oysters and no thought had been given to the possibility of using similar methods in collecting spat for culturing pearl oysters. The expansion of the cultured pearl industry resulted in a shortage of naturally grown oysters and demanded a newer and more efficient type of spat collector. Although the native oysters are still collected, the totally new type of spat collector invented by Mikimoto in 1924, has assumed much greater importance. Until it attaches itself to some object at the age of 25 days, the young mollusc is able to move about. Experiments demonstrated that the spat developed a light sensitivity just before settling, so Mikimoto devised and patented in 1924 a small cage, 27 x 18 x 7 inches, formed by covering a heavy wire frame with wire mesh, fitted with shelves of wire mesh and suspended vertically. A large door comprises the front of the cage. The cage, which is made of galvanized wire, is dipped into hot coal tar to prevent corrosion and then dipped in a thin sand and cement mixture. This mixture after drying forms a rough coating about 2 to 5 millimeters thick all over the cage and provides an excellent surface which permits the larvae to cling. The bottom and sides of the cage are covered with black painted boards creating a darkened area which is very attractive to the light sensitive spat. The spat collecting cages are suspended from large frame rafts which are anchored in the most productive spat collecting areas, at a depth of about 20 feet.

The rafts measure about 15 x 18 feet and are constructed of an open framework of poles about 3 inches in diameter, with the longitudal and tranverse poles fastened together about 3 feet apart. Each raft is supported by fifty gallon drums or barrels with 5 or more to each raft. These rafts are anchored in series of 5 to 10 and lashed together end to end. Approximately 50 spat collecting cages are suspended from each raft. These spat collecting cages are set out early in July as the Japanese oyster spawns from July to September. Late in November, when the young oysters are about one-half inch or over in size, they are collected and transferred to rearing cages. The catch per cage varies from 1,000 to 160,000 but the range is usually around 7,000 to 10,000.

• **Protective Cages for Rearing Oysters.**

REARING CAGES

The rearing cages developed by Mikimoto are flat wire baskets and resemble the collecting cages but they are divided into 4 to 6 compartments. They are covered with wire mesh or cotton netting. The young oysters are well protected against their natural enemies and survival rate is high. Another of Mikimoto's ingenius ideas was to place pieces of either charcoal or pumice in the rearing cages on the shelves to protect the oysters from the parasites. In May or June, when adhering parasites abound in the waters, they are attracted to the little fragments of substances instead of the oysters.

A different tvpe of rearing cage, also developed by Mikimoto, consisted of two baskets, one smaller than the other, the smaller one fitting inside of the larger with shelves between the two baskets, on which the ovsters were placed. Inside of the smaller basket was fitted a propeller which stirred up the water and stimulated the growth of the oyster.

The cages are either distributed over the sea bottom in sheltered areas or are suspended again from rafts, and they remain undisturbed until the following June or July. The oysters then approximately one year old and averaging 1 inch in diameter, are sown in water from 10 to 16 feet and over a fairly rough bottom. They remain here for 2 years.

During June, July and August of the third year, the oysters are collected by women divers and brought to the cleaning barges. These barges are fully decked rafts with platforms of 30 x 18 feet, with a sloping roof. They are towed to the collecting areas by motor launches. A group of workers, mainly girls, sort and clean the collected shells as they are brought to the barges. The distorted and old shells are discarded and the undersized shells are returned to the growing beds for another year. All encrusting organisms such as anemones are scraped from these shells as well as seaweed. The cleaned shells are placed in culture cages and distributed in shallow water again, suspended from the rafts. They are left here for a period of about ten days for acclimatization. This period allows the oyster to recover from the shock of collection and cleaning and to become adjusted to the conditions of the shallow water.

PREPARATION FOR THE OPERATION

Before the nucleus insertion can begin the host oysters have to be prepared for the insertion. This means they have to be partially open. The insertion of the bamboo plug is used among all operators but the methods used to induce the oysters to open vary. There are three general systems in use.

Stagnant water will sometimes cause them to gape. The oysters are placed in a shallow metal tray with the hinge down and are covered with sea water, and in a few minutes the two valves will open a small amount then the opening forceps are inserted between the valves which are gently forced apart to permit the insertion of the bevelled edge of the bamboo wedge. The water is changed frequently because the oysters consume the oxygen so rapidly, but even so the oysters are often weakened considerably by the lack of oxygen. Therefore, this method has certain disadvantages due to the high mortality rate.

Another method used is approximately like the last with the exception that running water covers the oysters while they await the insertion of the key.

The method used by the larger commercial operators is to bring their oysters to the operating station about 24 hours prior to the insertion time and hang the baskets of oysters in the water directly from the rafts. Approximately one-half hour before the technicians are ready for them, the operators pull in the baskets and unload the oysters on the wharf. This has a tendency to cause the oysters to gape and possibly 35 percent will open in a few minutes. The ones already opened are selected for the operation and the balance are returned to their baskets and to the water to rest. The ones selected are pegged immediately and then after the others have been in the water around 4 hours, they are again lifted and the same procedure is repeated. The 4 hour resting period in the water enables the weaker oysters to regain strength to withstand the nucleus insertion operation. Experience has indicated that only the healthy, and most vigorous oysters open their valves in the air.

Pinctada martensii will close in about 2 hours naturally, therefore the insertion of the nucleus is performed only by the most highly experienced operators with speed and accuracy. Under no circumstances should an oyster stay pegged more than 2 hours. The oyster becomes fatigued from a prolonged forced opening and is then unable to withstand the shock of the operation and does not survive. The wedge-shaped key is placed between the valves at the posterio-ventral region at an angle of about 45° to the hinge line. The more experienced operators rarely key their oysters more than twenty minutes prior to the insertion of the nucleus. Thus the keyers and the technicians have to be in close coordination.

A weakened condition brought on by careless or inexperienced handling of the oysters during keying materially contributes to the high mortality rate of the oysters at the time of the nucleus insertion.

Negligence in handling the shell which may result in breaking of the edge or fracturing the shell is definitely harmful to the oyster. It is the habit of the oyster to withdraw the edges of the mantle lobe to the innermost limit of any such fracture or damage and to rebuild that section first before extending the mantle to the periphery for normal activities. Therefore, damage to the shell results in a suspension of its normal development while the repairs are being made and the vitality of the oyster is reduced; this affects the quality of the pearl sac and the pearl within the tissue of the oyster's body.

LABORATORY EQUIPMENT

The technicians arrange their equipment in the laboratory for the nucleus insertion at the same time the keyers are pegging the oysters on the wharf. The technicians are in the majority women and each one has her own individual desk, located by a large window and equipped with a set of specialized instruments.

These instruments have been devised for the insertion of the nucleus. All instruments used by the technicians at the Mikimoto Farm are made there and are the result of many years of experience and research by Mikimoto and his technicians.

There are certain instruments used for the preparation of the tissue graft and others specialized for the operation of the nucleus insertion. A specially designed *brass clamp* which holds the oyster in position for the operation without danger of crushing the delicate shell, consists of a plate against which a spring clamp plate closes. The front edge of these two plates are slightly curved and follow the curve of the oyster shell and prevents movement of the oyster during the operation. The entire apparatus is supported on a telescopic column which measures one-half inch in diameter and is inserted in a heavy wooden block base of about 5 x 4 x 2 inches. The oyster is placed in this clamp in exactly the correct position needed and is then ready for the operation.

PREPARATION OF THE GRAFT TISSUE

The same extreme care and precision that would accompany a delicate surgical operation must be exercized when preparing the graft tissue and when inserting it as this governs the production of the pearl.

The frilled mantle edge of a living oyster is used to prepare the graft tissue. The blade of a sharp knife is inserted between the valves and the adductor muscles of the oyster, and the adductor muscle is cut from its attachment to one shell. This must be done carefully so as not to injure the mantle tissues in any way. A surgical scalpel, using the blunt edge is needed here to clean off the extraneous matter and a strip about 2¾ inches long and 3/10 inches wide is cut from the edge of this piece of mantle. This strip is smoothed out carefully on a wet graft trimming block, and the adhering mucous is wiped off with a sponge.

The dark and discolored areas of the thickened outer edge of the mantle are cut away with the sharp edge of the scalpel. The remaining tissue is trimmed to form a long strip 2 to 3 millimeters wide which is then cut into squares. The size of these squares is determined by the size of the nucleus which is to be introduced. At least ⅓ of the nucleus should be covered. The entire block with the tissue is then dipped in a beaker of sea water to await the insertion. The graft tissue will live for approximately 2 hours if kept wet with sea water and at cool temperature.

To produce the best pearls, the nacre-producing mantle cells on the little squares of tissue must be in contact with the nucleus. As these cells are located on the outer surface of the mantle, the position of these cells must be definitely known.

Also both graft tissue and nucleus must be inserted adjacent to tissues on which the graft will take hold and grow, when inserted in the oyster. When grafts are inserted into the organs or other specialized tissue they usually degenerate and the action of the body fluids of the oyster eject the nucleus.

PREPARATION OF THE NUCLEUS

Almost any object used as a nucleus may be coated with nacre and form a pearl of sorts, but experience has proven that a calcareous nucleus has several advantages over other substances; the nacre seems to bind to a calcareous substance more satisfactorily; when the pearls are drilled for stringing there is less possibility of their fracturing; and the specfic gravity of the material is nearly identical to that of the nacre.

Most nuclei are prepared from the shells of fresh-water molluscs, which answers the requirements for the heavy solid shell necessary, as the diameter of the usual nuclei range up to 6 millimeters or more. Since Japan does not have a source of bivalves with shell thick enough to produce the nuclei of the larger diameters, a search for material led to the United States, where shell material of desired thickness was found in large quantities in the species *Amblema, Quadrula, Pleurobema and Magalonais,* which are indigenous to the waters of the Mississippi and its major tributaries. These molluscs also have massive shells and yielded a high proportion of satisfactory nuclei similar in hardness and specific gravity to the superimposed nacre. Mikimoto shipped these molluscs by dozens of carloads to Japan, where he manufactured his own nuclei at his Pearl Farms.

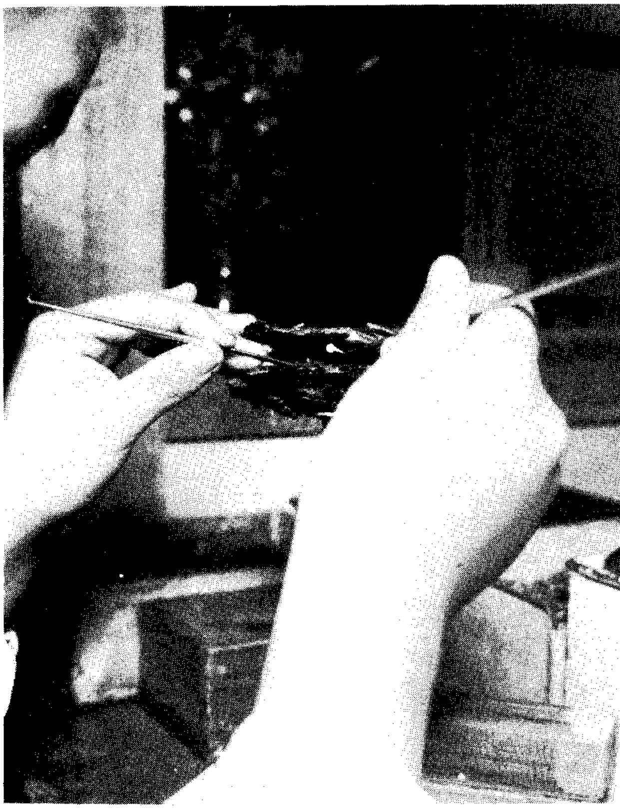
The preparation of the nuclei is quite simple. The shells are cut into small cubes of the required size then placed between two sheets of iron. The upper sheet revolves and the resulting grinding of the cubes, between the plates and against one another, chips off the edges and produces rough spheres. The rough spheres are placed in cotton bags and subjected to a further grinding treatment which brings the surface to a fair polish. A high polish is not really necessary.

The finished nuclei are graded according to size. The nuclei used in *Pinctada martensii* are sized from 1.2 to 6.6 millimeters in diameter, each size grading to 1.3 millimeters larger than the former.

Although a substitute material has been searched for at various times when the nucleus shell supply became increasingly low (as during the World War II), results were disappointing and the best known nucleus material remains the thick shelled bivalves from the Mississippi valley.

INSERTION OF THE NUCLEUS

When the pegged oyster is placed in the *clamp* in just the right position and the tissue graft has been prepared, the operator smooths back the mantle with the *spatula,* exposing the body mass. The *retractor hook* is used to hold the foot down and extend it slightly to prevent muscular action. A *flat probe* makes an incision into the epithelium of the foot and a slender channel is opened into the main mass of the tissue. The prepared piece of graft tissue is passed down this channel to the place selected as the best resting place for the nucleus. The *moistened cup* of the *nucleus lifter* picks up the nucleus and it is inserted into the oyster so it will lie immediately above the already introduced graft tissue. The *probe* is used to gently



• Inserting the Nucleus in the Oyster.

smooth the mass and close the channel, the mucous helping to keep it closed. As the *retractor hook* releases the foot and the plug is removed from between the valves, the oyster closes immediately and is deposited in a receptacle for holding the processed oysters and another oyster is selected for the operation. About 25 to 40 oysters can be processed in an hour by a well trained technician.

At least one year of apprenticeship is required to attain sufficient skill for the first nucleus insertion operation. The practice of inserting glass beads into various operational areas and the cutting and preparing of graft tissue is part of the training.

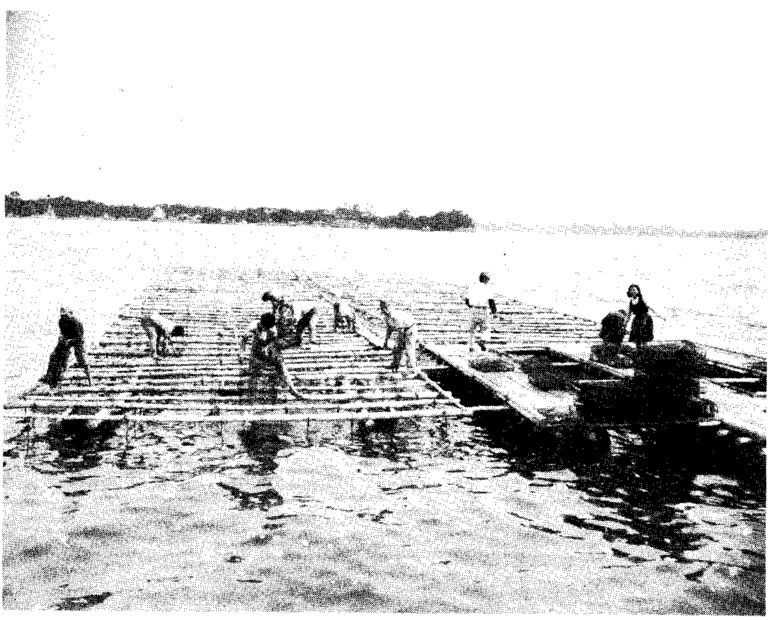
Rarely a second nucleus is desired. If so, the wooden plug is left in position and the oyster is turned over to a new position in the clamp. In this position the left valve is uppermost and when the insertion is made into the epithelium covering the viscera, the graft tissue is introduced and the nucleus is inserted into the gonad. Extreme care must be taken in this operation to avoid puncturing or injuring the vital organs.

A third insertion can be accomplished in this second position but—only by a highly skilled technician. The technique is so delicate that most technicians will not attempt it.

When the live piece of mantle tissue and the nucleus is inserted into the connective tissue of an oyster, a capsule of tissue developes around the solid matter within a few days. While this is forming, the epithelium of the inserted mantle begins to reproduce through cell division and in a week or two the regenerated epithelium completely encloses the foreign substance, developing a pearl sac. The pearl sac then begins to secrete and to deposit calcareous matter around the nucleus within it as soon as the cell division begins. As the deposition of nacre increases, the pearl sac grows larger through the action of cell division. The growth of the pearl starts immediately after the graft tissue takes hold and begins to grow by cell division. The rate of nacre deposition is either fast or slow depending on the temperature and conditions of the environment.

CONVALESCENCE

Freshly tarred culture cages are prepared for the convalescing oysters. They consist of heavy wire frames of about 2 feet square and 1 foot high covered with a 1 inch mesh wire netting. One side of the cage is hinged to form a door. Each cage is divided into 4 compartments and will hold approximately 50 to 60 oysters. These filled cages of newly operated oysters are suspended from a group of rafts anchored in sheltered areas near the laboratory. They are submerged in water of 7 to 10 feet and remain undisturbed for a period of 4 to 6 weeks, during which time they undergo a period of convalescing necessary after the delicate nucleus operation. During this period the oysters recover from the shock of the operation and have time to repair any injuries sustained while being processed. One of Mikimoto's patents covered the use of ultraviolet rays to heal the wound quickly after the nucleus was inserted.



• Rafts from which the Cages of Oysters are Suspended.

At the end of this period the cages are lifted and the oysters are inspected, the dead shells are removed and the cages cleaned. The cages are then transferred to permanent culture rafts by barges or towed by motor boats.

The cages are suspended from the permanent culture rafts at a depth of 7 to 10 feet. There are generally 60 cages to a raft, each cage containing 3,000 or more oysters. Here they remain undisturbed for approximately 3 to 4 years. At least 3 times a year the cages are lifted and all encrusting marine growths are scraped from the oysters. This cleaning process requires roughly 40 days out of the year. At this time all dead shells are removed and a few living oysters are checked to determine the rate of growth of the pearls. The cleaned oysters are placed in freshly tarred cages, and the used cages are returned to the shore bases for renovating, cleaning and eventual retarring. In a few of the stations, the oysters are cleaned 5 to 8 times a year.

Mikimoto developed the system of coating the shell with a gelatin solution to make it smooth after the shell was cleaned of the parasites. Then the shell was coated with a paint based on drying oil and other substances. This possibly helped to keep the shells free of parasites.

The harvesting operations begin in October and continue until the middle of January. Some operators who specialize in producing pearls of high luster believe that the oyster deposits only a thin translucent layer of nacre over the thicker more colorful layers at the start of cold weather and therefore do not begin their harvest until after December. They contend this translucent layer, deposited during the last month before the harvest, adds materially to the quality of the pearl.

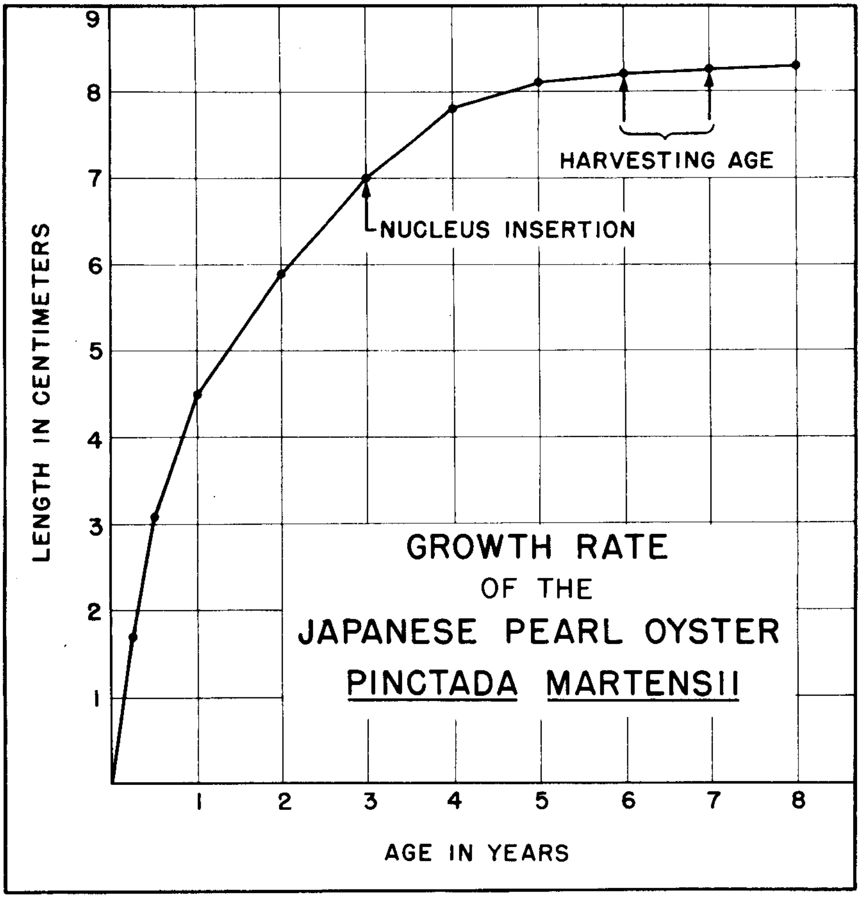
Mr. Oda, the chief research biologist for Mikimoto, inserted a nucleus 6.9 millimeters in diameter into each of a number of oysters, to determine the relation between water temperature and the nacre-secreting activities of *Pinctada martensii*. At regular intervals throughout the year, the nacre-coated nuclei were examined to determine the amount of nacre deposited. The results of his observation showed that in the months of September and October when the water temperature was around 20° C the accretion of nacre was at its maximum. The nacre secretion apparently ceases when the water temperature fell below 14° C indicating a definite relationship between secretion and water temperature.

In areas where the water temperature does not fall below the critical minimum for nacre deposition, as in Shizuoka Prefecture, nacre is produced every month of the year.

The factors which cause the biochemical reaction determining the structure and character of the secretion are not fully understood, but it has been established that the desposition of the prismatic layer becomes very marked when the oyster is subjected to strong sunlight. A series of experiments to determine the reaction of pearl-forming molluscs held at varying depths and under various colored lights indicated that *Pinctada martensii* becomes most active in the deposition of nacre when exposed to intensely blue light for a long period. In these tests the nacre examined showed a high luster with an excellent coloration.

One of Mikimoto's patents covered the use of reflectors for the formation of iridescent pearls. Colored plates, colored wire netting, or transparent colored plates were placed at the top and bottom of the basket containing operated oysters. The object was to produce a rich iridescence in the pearl and was based on the theory that light waves influence color.

Mikimoto's Research Laboratory has compared pearls of various colors. The results of the investigation show that the grains are finest in pearls of a greenish color and they have the most surface lines. If structural quality alone were considered, the green



• From *Pearl Culture in Japan*, by Dr. A. R. Cahn.

pearls would be considered superior, because of the greater smoothness of their surface owing to the closeness of the componant layers.

Silver pearls have the least surface lines and the coarsest grains, while the pink pearls rank next to the green in finest of grains and also shows less occurrence of aragonite and the layers are regular in outline. The pink pearl is considered the most valuable. The yellow pearl has more calcite crystals in its structural composition and the componant layers of the yellow pearl are wavy in outline.

The color of pearls does not seem to be an accidental property but rather the result of a definite physical basis: not a chemical one.

SIZE

The size of the pearl produced is influenced by the size of the nucleus, the duration of the growing period, and the health and age of the oyster. Oysters between 3 and 7 years of age produce the best growth.

After the age of 7 years the oyster's vitality apparently decreases and the deposition of nacre is of poor quality and the resultant pearl of inferior grade.

Although nacre is deposited on the pearl as long as it remains in the oyster the best pearls are those produced in a 3 to 4 year period. The deposition of nacre increases the diameter of a cultured pearl about .3 of a millimeter each year. Therefore, the ultimate size of the pearl is chiefly dependent on the size of the nucleus inserted and not the length of time it remains in the oyster.

Cahn states "The largest pearl of good quality produced by culture methods in *Pinctada martensii* at the Mikimoto Pearl Farm, was 10.6 millimeters in diameter. The nucleus introduced was 9.0 millimeters in diameter and the pearl was formed over a period of 4 years."

RECOVERY

The cages are lifted at the end of a designated period, averaging 3 to 4 years and the oysters are brought to the laboratory for the removal of the pearls.

A laboratory technician opens the shells and extricates the culture pearls and any natural pearls which may have developed. The pearls are carefully washed to remove any slime or dirt and then dried carefully by gently rubbing between 2 soft pieces of cloth using a rotary motion and done by

• **Removing the Cultured Pearl**

• **Sorting Cultured Pearls**

hand to reduce any possibility of marring the pearls.

The Mikimoto Pearl Farm is reported to have the most complete system, so far devised, for keeping all records of their operations. A record for each technician is kept separately on the total number of oysters operated on; the number of oysters surviving the operation; at each successive cleaning, the number still living; and at the end of the culture period, the yield of pearls. By keeping these precise records the skill and production of each technician is maintained and at any time may be accurately checked.

SUMMARY

A pearl can be formed when a small piece of live mantle tissue, together with suitable nucleus is inserted into the visceral connective tissue of another oyster and through the regeneration of the inserted epithelium cells forms a pearl sac which in turn secretes narce and grows by cell division. The relationship of the pearl sac epithelium and the nucleus is essentially the same as the outer epithelium of mantle and the shell. The only difference is, that the pearl sac secretes nacre within the connective tissue of the body of the oyster but the formation of the shell and the formation of the pearl is the same. This is the basic principle of pearl culture.

The equivalent of a surgical operation must be performed when inserting the nucleus and graft tissue, therefore, only highly skilled technicians are given this responsibility.

Both before and after the processing, the oysters are kept under close observation. They are kept in cages suspended from rafts in water and repeatedly inspected by women divers. Periodically they are cleaned, and dead shells removed. Complete records are kept on all phases of the culturing process.

Mikimoto was granted the first patent in the history of pearl culture on his method of producing the semi-spherical or blister pearl and he was the first to receive a patent dealing with the method of producing spherical pearls by deposition of nacre from graft tissue.

Although he cannot be credited with having produced the first spherical culture pearl nor with originating the method he has used so successfully to produce them, his contributions to the culture pearl industry and his great business acumen have resulted in his often being called the father of the industry.

To increase the supply of oysters Mikimoto undertook extensive experiments in spat collecting and rearing. He invented and patented many devices which eventually became the basis of pearl oyster culture.

During World War II, the pearl industry declined rapidly and not until after hostilities ceased did the industry slowly begin to regain some of its lost ground. It was chiefly through Mikimoto's ingenuity that it was revived and placed on a productive and highly profitable basis.

The Mikimoto Pearl Farms represent the results of 60 years systematic management. Mikimoto was granted 30 patents on his pearl developments during a period of 50 years; only 60 were granted in all, in Japan, during this period.

Nature has been ably encouraged in her work of producing pearls by scientists and pearl culturists, therefore, the cultured pearl cannot be called a natural pearl; however, it is a genuine pearl. On each occasion when a cultured pearl is being admired for its beautiful luster, iridescence and its remarkable occurrence, a tribute is being paid to those scientists who have made it possible.

REFERENCE:
Dr. A. R. Cahn, "Pearl Culture in Japan," published by General Headquarters, Supreme Commander for the Allied Powers, Natural Resources Section, Report No. 122, Tokyo, 1949.

WHAT PRICE CONVENIENCE?

by

GEORGE R. KAPLAN

If you mention "convenience" to a diamond buyer, just back from an overseas trip, chances are he will wince, or perhaps cringe. To him the word has become synonymous with the really "intricate currency structure" of his trade. How did it get that way? It's the story of a few Belgian merchants who, trying to make their business life a little easier, erected a diamond price structure which frightens even the most ardent mathematician. First, let's look at the end result.

Let's take the case of an American who seeks to buy Belgian diamonds for resale in the United States. We would logically expect prices to be quoted to him in either Belgian francs or American dollars. Instead, to his amazement he finds quotations for the gems in £ (pounds sterling) or guilders. To make things still more confusing, the required £ and guilder are not respective currencies of England and Holland, but *totally artificial currencies* set up and used by the diamond trade only to "facilitate" business.

Today, the English pound is pegged at $2.80, yet the "diamond" £ is worth $3.53 to the American polished diamond purchaser. Today's Dutch guilder is equivalent to $.26, but when diamond men use it to quote prices, it is worth $.40.

Well, how did it happen? Oddly enough, this muddled price structure arose from attempts by Belgian diamond merchants to simplify their currency transactions.

Prior to 1936, European currencies were based on the "gold standard." Diamond prices were quoted in almost any currency, but the Dutch guilder was usually employed. This guilder was equivalent to 20 Belgian francs, 1/12th £, or approximately $.40 in American money. However, in 1936, the entire sterling area (including Holland and Belgium) abandoned the gold standard, and currencies began to fluctuate independently.

At this point the Belgian diamond dealers stepped into the picture. Accustomed to dealing with the old Dutch guilder, worth 20 Belgian francs, the Belgian merchants maintained this value. To the American of that time this "gold" guilder was worth $.40 whereas the actual Dutch guilder was worth only 80% as much.

During World War II, trade between the low countries and the U. S. was completely cut off. Our only large scale importations of European diamonds during this period were in rough — from England — with prices quoted in £. When the war ended, we resumed importations of polished diamonds from Belgium with prices still quoted in £, at $3.53, as neither the guilder nor the Belgian franc were pegged to the dollar at that time.

For a brief period (1945-1948) diamond prices were being quoted in real currency and buyers breathed easier, but in September 1948 the £ was devalued to $2.80. The Belgian diamond merchants again seeking to "ease" business transactions invented the "diamond £," equivalent to the old £'s value of $3.53. Matters were made even simpler when American buyers added our import duties and expenses thus recognizing the "diamond £" as equivalent to $4.00.

And so today, we have the following mud-clear situation: If a London merchant sets a diamond's value at £ 100, he means $280.00. The Belgian merchant might offer a finer gem for seemingly the same price (100 £). Actually he means $353.00 or $400.00 including import duties.

I sincerely hope my readers see the great time-saving feature of inventing one's own currency; your author does not.

Ironically enough, whereas confusion used to be sole property of the buyer, the "diamond" £ and "gold" guilder have boomeranged on their inventors. Those who complain of the complexities of American business will take comfort in the plight of the Belgian diamond cutters, who these days live in a sort of accountants' paradise.

The typical European cutter buys his rough diamonds in England with pounds sterling worth $2.80, and pays his workers in Belgian francs. He may then sell part of his production in Dutch guilders worth $.26, and part in "gold" guilders worth $.40, a third part of his sales might be in £ worth $2.80, and a fourth part in "diamond pounds" worth $3.53, and the American purchaser buys the remainder in £ equaling $4.00. What is worse, neither he nor his customers understand the "convenience" of such a system.

So, if you're on friendly terms with an international diamond buyer, *don't* talk shop. His trade makes him just a little nervous, not only because of the currency clearness but also the honest competition he meets from others in his own country and from abroad.

Pearl Weight Estimation

(Continued from page 100)

weight in momme*, carats, and grams is also given.

The formula is also adapted for ready reference in graph form. The vertical reference is given in pearl grains and the horizontal reference is diameter. To solve a problem by use of the graph, draw a perpendicular line from the diameter in which you are concerned, until it intersects the curve. At the point of intersection on the curve draw a line parallel to the bottom of the graph until it intersects the vertical reference line where you will read your answer in pearl grains. Such an example is shown on the graph. A pearl of 5 millimeter in diameter is found to have a weight of 3.5 grains.

The graph may also be used in a reverse manner. For example, if you wish to know the diameter of a pearl of given weight, the graph can be used to solve this. For example, what is the diameter of a pearl which weighs 12 pearl grains? By projecting a line from 12 (on the side of the graph) to a curve, we locate a point of intersection. From this point we drop a perpendicular line until it intersects the diameter at the bottom of the graph. At this intersection we read 7.5. Therefore the diameter of a pearl which weighs 12 pearl grains is 7.5 millimeters.

---

* *Momme* is a Japanese weight term used in cultured pearl wholesaling. The Japanese measure large quantities of pearls in *Kans* (1 Kan = 8.267 pounds). Smaller quantities are measured in *Momme* (1 momme = .0132 ounces). By converting ounces to the metric system, we find that

1 pearl grain = .133 momme

Other conversion factors used for these tabulations are:

1 gram = 5 carats = 20 pearl grains

X-Ray Studies

(*Continued from page 107*)

silica in an intermittent manner from liquids containing the material in solution. The assumed manner of formation is, however, clearly hypothetical and it leaves the question of the physical nature of the banding resulting therefrom unanswered. A different explanation that has been suggested and received with some favor is the so-called silica-gel theory. This regards the banded structure of agate as analogeous in its nature to the periodic precipitates formed in gelatinous substances in certain circumstances. We may remark, however, that the characteristic structure of agate is observed even in the absence of any material other than silica in its composition. Further, it is to be noted that the microscope shows agate to be a coarsely crystalline material and not a colloid.

The question of the nature of the banded structure of agate presents itself in a particularly interesting form when we consider the case of the specimens exhibiting iridescence. It has long been known that the stratifications in agate may be so close and so regularly spaced as to enable a polished plate of the material to function as a diffraction grating when traversed by a beam of light. It is natural to suppose that a structure exhibiting such a high degree of regularity with strata following each other some 10,000 times in a centimetre is a consequence of some special feature in the aggregation of the crystallites of quartz of which agate is composed. The fact that we had at our disposal two examples of iridescent agate encouraged us to undertake a careful study of this question by optical and X-ray methods. The investigation has revealed several interesting facts, and besides elucidating the particular problem under consideration has also thrown fresh light on the structure and optical behaviour of non-iridescent agate and chalcedony.

A detailed study was made by optical and X-ray methods of the two plates of banded agate which displayed iridescence over part of their areas. The light transmitted by the banded areas was found to be completely polarised with the vector normal to the planes of banding. On the other hand, the wavy supposition patterns exhibited by the iridescent areas disappear for the same vibration direction. From these facts and the observed optical characters of the diffusion and diffraction phenomena it is deduced that the crystallites of quartz form fibres elongated in the direction of a crystallographic *a*-axis, while their principal or *c*-axes lie in the planes of banding but are orientated in a periodic manner in these planes so as to build up a structure which functions as a diffraction grating. The X-ray results support these findings. More generally also, they indicate that the banding of agate is a consequence of the presence in it of groups of crystallites of quartz having a common specific orientation.

It is known that quartz exhibits a type of twinning in which the principal axis in the two components of the twin are nearly at right angles to each other — more exactly make an angle of 84°33′ with each other. It seems that the fibres of quartz in iridescent agate may be described as polysynthetic twins in which the alternate elements are related to each other presumably in the same manner as in the twins of the kind referred to.

REFERENCES

1. Hintze, Carl., Hanbuch der Mineralogie, Erster Band, Zweite lung, 1915, p. 1348.
2. Pichamuthu, C. S., Mys. Univ. Jour., 1935, 8, 1-48.
3. Washburne and Navias Proc. Nat. Acad., Washington, 1921, 1,8.
4. Rinne Z. Krist., 1924, 60, 55.
5. Correns and Nagelschmidt Zeit. F. Krist., 1933, 85, 199.

Gemological Digests

IS BORNEO BECOMING AN IMPORTANT DIAMOND SOURCE?

The September 1954 issue of "Mineral Trade Notes" (published by the U. S. Bureau of Mines) carried an interesting note by an embassy officer in Djakarta, Indonesia, which suggests that Borneo, the earliest known source of gem diamonds, may again become important.

The report states:

"Although accurate records on diamond production in Indonesia are lacking, news from the field continues to confirm that activities are by no means insignificant. A century ago the chief producing area was the Landak and the Kapuas river valleys of western Kalimantan on the island of Borneo. However, in August 1953 a 31½-carat stone was found near Ngabang in this region, for which a dealer offered Rp. (rupiahs) 90,000. (U.S. $1 equals about 11.40 rupiahs). The stone, believed to be worth Rp. 200,000 after polishing to about 25 carats, was the second largest on record from that area. (During the Japanese occupation stones of 18 and 28 carats were found).

"The Barito valley region in southeast Kalimantan, in which 5,000 diamond hunters work around Halung, reported the find of a diamond worth half a million rupiahs (size unspecified) in September 1953. In December 1953 the largest diamond on record in Indonesia was reported (350 carats) found at Puruktjahu in Barito Kabupaten county. It had tentatively been valued at 3 million rupiahs. No confirmation of these reports has been received. Chinese diamond-grinders in Bandjarmasin and Djakarta make most of the profit on the diamonds."

The size of the diamonds seems much less significant than the reported figure of 5,000 diamond miners said to be working in the Barito valley. If this is true, the total weight of diamonds mined must be great. The fact that they have not appeared in any quantity on the market suggests that the Chinese who purchased them are shipping them to Red China rather than to the West. Of course this may be little more than a rumor but it is possible that Borneo will assume a world importance in diamond production.

273½ CARAT DIAMOND FOUND AT JAGERSFONTEIN MINE

It is reported that a 273½ carat diamond was recently found at the Jagersfontein Mine.

This mine has the reputation of producing occasionally some very fine large stones, an instance of which was the discovery of the "Excelsior" in June, 1893, by a native mineworker, who received a reward of £500 in cash and a horse equipped with saddle and bridle.

An exquisite blue-white, the "Excelsior" weighed 971½ carats, which made it then the world's largest authenticated diamond, a distinction it enjoyed till 1905 when the fabulous Cullinan diamond took pride of place.

From the "Excelsior" were cut 21 gems, 10 of which ranged between 10 and 70 carats. De Beers Company exhibited one weighing 18 carats at the New York World Fair in 1939.

The Jubilee, another fine diamond, was found in the Jagersfontein mine, in 1895. In the rough, it was a flattened octahedron weighing 650.8 carats. It was entirely flawless and perfect in color, transparency, and brilliancy. The gem was shown at the Paris Exhibition of 1900. It is generally conceded that at the present time the Jubilee is the third largest cut diamond in existence.

Book Review

FOUR CENTURIES OF EUROPEAN JEWELLERY

by Ernle Bradford. 219 pages: 48 pages of illustrations: a Glossary, Bibliography and Index: published by the Philosophical Library Inc., New York. London: $12.00. Reviewed by Jeanne G. M. Martin.

This well illustrated book on European Jewelry from the Renaissance to the present day cannot fail to interest students and collectors.

Beginning with a survey of the jewelry of the ancient world and a chapter on the brilliant craftsmen of the Italian Renaissance, the author discusses the fashions and products of each succeeding century. The following chapters deal with the historical background and growth of the jewelry craft in Europe, as well as specialized aspects of the subject. The aim has not been so much to catalogue the outstanding examples of jewelry still in existence, as to indicate the course and changes of fashion.

The processes by which jewelry was made and the changes which have occurred in techniques is stressed.

There are chapters on diamonds, rings, enameling, cameos, intaglios, paste, marcasite and the precious metals; also pearls, amber, jet and coral. One chapter is given to the history and properties of precious stones. In the chapter on the craft of gem cutting some of the most important styles which have been used since the sixteenth century are described briefly. In addition, Bradford outlines developments in the methods employed by the lapidaries. A glossary of six pages and a selected Bibliography is included which will be welcomed by those wishing to do further research on the subject.

The preparation involved for this book and the assimilation of the material, required a keen insight and appreciation of jewelry on the part of the author as well as a great deal of effort and research. It will be welcomed by libraries, designers, students and all connoisseurs of jewelry, particularly those who are beginning to build their own collections.

DIAMOND PRODUCTION AT THE WILLIAMSON MINE INCREASES

According to the annual report of the Tanganyika Department of Mines for 1953, as reported in The Diamond News, the production of cuttable and industrial diamonds increased by 29,281 carats or 20 per cent over that of the previous year. The whole of this increase came from the Mwadui Mine of Williamson Diamond Mines Ltd., in the Shinyanga district. At the neighboring mine of Alamasi Ltd., the only other diamond producer, production was slightly less than in 1952.

Exports were estimated at £1,834,761. Some of the final valuations had not been received at the end of the year.

Williamson Diamond Mines, Ltd., continued the installation of the new plant at Mwadui Mine to increase the quantity of diamondiferous gravel treated to 7,500 tons a day. The plant was scheduled to come into production toward the end of 1954. To provide an additional water supply the Du Toit Dam was constructed with a capacity of 1,800 million gallons. The principal mining unit will be a six cubic yard electrically-driven walking dragline. A third 900 k.v.a. diesel generator set was installed and foundations poured for three further sets. It is estimated that by the time the new plants put into production it will have cost £3½ million, all of which will have been found from revenue.

The largest diamond yet to be found in Tanganyika was recovered at this mine during the year. The stone weighed 181 carats. Details regarding classification and value are not yet available.