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Age Determination of Cod from Otoliths Collected in Divisions 2J, 3K and 3L

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Introduction

Except for laboratory-reared specimens, it is perhaps impossible to determine with certainty the age in years of individual cod, *Gadus morhua*, particularly those comprising the adult population. Cod taken in the commercial fisheries in the Northwest Atlantic are usually age 4 and older, and the catches may consist of 10 or more age groups as are evident from reported age-length keys (e.g. ICNAF, 1974). As cod become older and the average length-at-age tends to a maximum, the overlap in the length range of adjacent age-groups becomes more pronounced. The proportion of cod of a particular age at a given length varies because of such factors as changes in growth rate and fluctuations in year-class strength. Therefore, the lengths of specimens taken in the commercial fisheries canot provide reliable indications of age.

Ages of cod have been determined from various skeletal elements, but interpretation of age from otoliths is the usual procedure. Comparison of length and age frequencies, reported by various laboratories as being representative of cod catches from particular stocks, indicated considerable variation in age determination of cod from otoliths by ageing experts of these laboratories. In an attempt to resolve these discrepancies and to provide guidelines for interpretation of cod otoliths, the Standing Committee on Research and Statistics of ICNAF (International Commission for the Northwest Atlantic Fisheries) organized workshops at Vigo, Spain, in October 1975 (Lopez-Veiga *et al.*, 1977) and at St. John's, Newfoundland, Canada, in Feburary 1977 (ICNAF, MS 1977). From the workshop held at St. John's, photographs were available of 224 otolith sections for which the ages had been agreed by the participants. A selection of these photographs is presented here together with comments on how the various zones in the sections were interpreted.

Procedure for Age Interpretation

Although more sophisticated methods of preparing and examining otolith sections for age determination are available, the procedure outlined below has been found acceptable in some laboratories.

Preparation of otoliths

The otoliths after removal from the fish are washed and then stored in a dry condition. Preparatory to examination, the otolith is broken across the *sulcus acousticus* with the aid of a scalpel, and the halves partially embedded in modeling clay with the broken surfaces upward. Care should be taken in making the fracture, because, if the cut is not made correctly, the aspect of the annuli on the cut surface changes and an error in ageing may result.

Microscopic examination

The fractured surfaces of the otolith halves are examined by transmitted light under low power (about 15×) of a binocular microscope. The angle and amount of illumination should be such that the relevant details can be distinguished. A scalpel blade held on the distal edge of the cut surface will shade the surface from direct illumination. A drop of alcohol on the cut surface will enhance the examination. The accompanying photographs were made from otoliths prepared by this simple method.

Interpretation of age

Opaque and hyaline zones are distinguishable in the otolith section. The opaque zones are associated with periods of fast growth and are usually formed during the summer and autumn. Hyaline zones represent periods of slow growth and are usually formed in the winter and spring. Therefore, over a period of 1 year, an opaque zone and a hyaline zone would be expected to be added to those already existing in the otolith. In practical terms, if all hyaline zones are annuli, the number of hyaline zones can be considered as the age if the fish's assumed birthday has been reached.

The fish's birthday. Because the actual birthday of the sampled specimen is unknown, it is usual to assume an arbitrary birthdate and January 1 is convenient for this purpose. The relationship between the

number of opaque and hyaline zones and the fish's age at capture might be as follows:

Period	No. of opaque zones	No. of hyaline zones	Edge of otolith	Fish age (years)
Jan-Apr	4	4	Hyaline	4
May-Aug	5	4	Opaque	4
Sep -Dec	5	5	Narrow hyaline	4

It is usual that otoliths of younger cod show new opaque growth earlier in the summer and new hyaline growth earlier in the autumn than older cod. As noted in the above example, it is in the autumn that difficulties arise in determining the age from the number of hyaline zones. If the hyaline zone at the edge of the otolith was formed in the previous winter, the age is equal to the number of hyaline zones. If, on the other hand, the hyaline zone at the edge was recently formed, it is not counted in determining the age.

Checks and splits. Because of variable environmental and feeding conditions, narrow hyaline zones may sometimes be formed during the period when growth is normally fast and narrow opaque zones may occur in the winter when growth is expected to be negligible. Consequently, not all hyaline zones are annuli. A check is a hyaline zone in the middle of an opaque zone and should not be interpreted as a winter zone or annulus. A split is a composite hyaline zone consisting of two or more closely spaced hyaline zones of the same pattern which comprise one annulus. Also, some hyaline zones may not be well defined, and it may be difficult to determine if these are in fact annuli.

Annuli patterns. Although the past history of the fish from which the otolith was taken is unknown, it is reasonable to assume that its growth occurred in accord with the von Bertalanffy growth pattern, i.e. a series of decreasing increments following the first 2 or 3 years of rapid growth. Therefore, if a relationship between fish length and otolith radius is accepted, the pattern of the annuli along a line from the center of the otolith section toward the periphery should appear as a series of progressively declining increments. If such a pattern is clearly discernable, the problem of distinguishing checks and splits will be very much lessened.

Use of otolith size and fish length. In the east Newfoundland-south Labrador cod stock (Div. 2J, 3K and 3L), the size ranges by age-group taken in the commerical fishery overlap to such an extent (Appendix Table 1) that the use of fish length or otolith radius is not a reliable indicator of age, and, if used in conjunction with an interpretation of the otolith pattern, may in fact be a source of bias.

Use of constant magnification. Despite the overlap in the otolith radius for different age-groups of cod, it is clear that, on the average, the otolith radius increases with age. The fact that many expert otolith readers not only maintain a fixed magnification but also prefer a particular microscope when interpreting otolith sections implies that otolith size assists the reader in determining the age.

Age validation. While the ageing of juvenile cod may be validated by the occurrence of relatively distinct modal groups in length frequencies from catches in small-mesh research trawls, the method cannot be used directly for older cod of commercial sizes. However, the experience gained in observing the annuli patterns in otoliths of juvenile cod (ages 1-4) is extremely useful in interpreting the patterns in otoliths of older fish. The occurrence of dominant year-classes and the similarity of growth patterns from the results of ageing would lead to confidence that otoliths are being consistently interpreted. Comparison of age composition and mean length-at-age data reported by different laboratories for the same cod stock would indicate whether there were substantial discrepancies or biases. The occasional exchange of otoliths within and between laboratories may act as a safeguard against overconfidence in age determination.

Selected Photographs of Otolith Sections

Details relevant to interpretation of the 95 otolith sections illustrated in the Appendix are given in Table 1. The first 18 speciments with numbers prefaced by J or K were collected in these divisions during November and December 1975, and each would have been aged 1 year older if it had been taken on or after 1 January 1976. The specimens with numbers prefaced by 2J, 3K and 3L were collected in these divisions in February 1975, April 1976 and June 1976 respectively. Examples of symbols used to designate the type of zone at the edge of the otolith and the various checks and splits are as follows:

H = hyaline zone
0 = opaque zone
D_1 = diffuse first hyaline zone
W_2 = wide second hyaline zone
C_2 = check in second opaque zone
S_2 = second hyaline zone split.

The illustrated sections, photographed under constant magnification, are considered typical of annuli patterns, at least for age-groups 2 to 8, found in otoliths of cod from the stock complex off eastern Newfoundland and southern Labrador, and are presented with a view to their potential use as aids to cod otolith interpretation by other workers.

References

ICNAF. 1974. Age-length keys for cod. *ICNAF Sampl. Yearb.*, Vol. 17: 179–211.

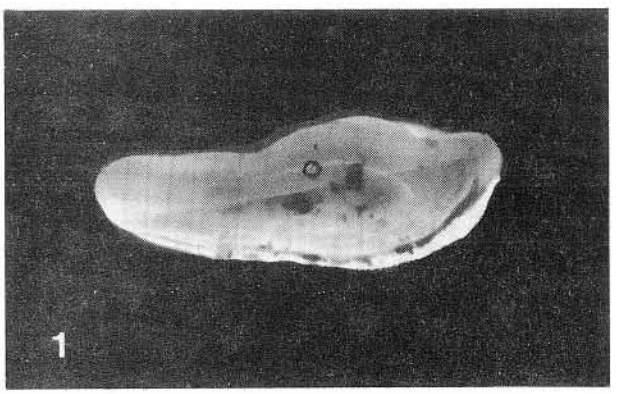
ICNAF. MS 1977. Preliminary report of Ageing Workshop on Cod held at St. John's, Canada, 31 January–5 February 1977 (R. Wells, convener). *ICNAF Sum. Doc.*., No. 77/12, Serial No. 5048.

LOPEZ-VEIGA, E. C., R. WELLS, and V. M. HODDER (Eds.) 1977. Report of Ageing Workshop on Cod held at Vigo, Spain, October 1975. *ICNAF Sel. Papers*, No. 2: 155–204.

APPENDIX

APPENDIX TABLE 1. Ages and comments relative to the photographs of otoliths on the following pages.

Photo. No. .	Spec. No.	Fish length (cm)	Fish age (yr)	Edge of otolith	Comments
1	K-1	17	1	H	S_2
2	K-4	20	1	H	C_2
3	K-6	20	2	H	C_2
4	K-7	20	2	H	S_2
5	K-9	21	2	H	D_1
6	K-17	24	2	H	C_1
7	J-5	24	2	H	S_1
8	K-18	25	2	H	—
9	K-19	25	2	H	S_1
10	J-7	25	2	H	C_1, S_2
11	J-8	25	2	H	C_1, S_1
12	J-9	26	2	H	C_2
13	J-10	26	2	H	—
14	J-14	27	2	H	S_1
15	K-23	28	2	H	C_1, S
16	J-20	30	2	H	—
17	K-25	31	2	H	S_3
18	J-22	31	3	H	W_2
19	3L-1	31	3	H	—
20	3K-1	37	3	H	S_1
21	3K-2	40	3	H	W_1, S_2
22	3L-8	40	3	H	—
23	3L-12	40	3	H	S_1, S_2
24	2J-1	34	4	H	C_2, S_2, S_4
25	2J-2	37	4	H	D_2, S_3
26	2J-3	40	4	H	S_3
27	3L-11	40	4	H	—
28	3K-3	43	4	H	S_2, S_3
29	3K-4	43	4	0	S_3, S_4
30	3L-16	43	4	H	S_3
31	3L-17	43	4	H	D_1, C_3
32	3L-24	43	4	H	S_1, C_2
33	3K-6	46	4	H	S_2, S_3, S_4
34	3K-9	46	4	H	S_2, cut off center
35	3L-29	46	4	0	S_1, W_2, S_3
36	3K-10	49	4	H	C_3, S_4
37	3K-14	49	4	H	C_1, S_3
38	3L-40	49	4	H	S_3
39	3L-42	49	4	H	C_2, S_2, S_4
40	3L-50	52	4	0	S_1, S_3, S_4
41	3K-38	55	4	0	C_1, S_2
42	2J-5	43	5	H	C_4
43	2J-6	45	5	H	C_1, C_2, S_3
44	2J-8	46	5	H	S_2, S_3
45	2J-9	47	5	H	S_3, C_4
46	3K-12	49	5	H	S_2, C_5, S_5
47	3K-15	49	5	H	S_2, C_5
48	3K-16	49	5	H	S_3, S_5
49	2J-23	50	5	H	C_2, C_3
50	3K-28	52	5	H	S_4, S_5
51	3L-56	52	5	H	S_2, S_3, S_4
52	3K-32	55	5	0	S_2, S_4
53	3L-63	55	5	H	S_1, S_2, S_3, S_4, S_5
54	3L-66	55	5	H	C_3, S_4
55	3K-48	58	5	0	C_4, S_4, C_5
56	3L-68	58	5	0	C_1, S_2, S_3, S_4
57	3L-77	61	5	H	S_3, S_5
58	3L-83	64	5	H	S_2
59	2J-16	48	6	H	S_1, S_2
60	2J-30	51	6	H	W_2
61	2J-38	51	6	H	C_2, S_2, S_3
62	2J-25	52	6	H	C_2, S_2, S_3, C_4, S_6
63	3K-18	52	6	H	W_2, S_4, S_6
64	3K-30	52	6	H	W_2, S_2, S_3
65	2J-48	54	6	H	W_3, C_4
66	2J-49	54	6	H	C_2
67	3K-34	55	6	H	S_3
68	3K-41	55	6	H	S_2, S_4
69	3K-42	55	6	H	S_1, C_4
70	3K-65	61	6	H	S_2, S_4
71	3L-85	67	6	H	S_2, S_3
72	3L-97	73	6	H	C_4, C_5
73	3L-98	76	6	0	S_1, C_2
74	2J-12	48	7	H	S_3, S_4, S_5
75	2J-20	49	7	H	C_4, S_5, S_6
76	2J-34	52	7	H	S_2, S_5
77	2J-37	52	7	H	S_2, C_6
78	2J-39	52	7	H	C_2, C_3
79	2J-45	55	7	H	C_2, S_2, C_4, S_5
80	3K-35	55	7	H	S_1, C_3, C_4, S_5
81	3K-36	55	7	H	S_3, S_6
82	3K-39	55	7	H	C_2
83	3L-81	64	7	H	S_4, S_6
84	3L-94	73	7	H	S_4, S_5, S_6
85	2J-18	49	8	H	C_2, C_7
86	3K-43	55	8	H	C_2, S_3, S_4, S_5
87	2J-47	56	8	H	C_2, S_3, S_5, S_6
88	3L-90	70	8	H	S_3, S_7
89	3L-91	70	8	H	S_2, S_4, S_6, S_7
90	3L-95	73	8	H	C_2, C_4, C_5, S_7, S_8
91	3L-100	76	8	H	S_1, S_2, S_3
92	2J-27	53	9	H	W_1, S_2, S_3
93	3K-44	55	9	H	S_4
94	3K-45	55	9	H	S_3, S_4, S_5, S_6
95	3K-49	58	9	H	C_2, C_5, C_8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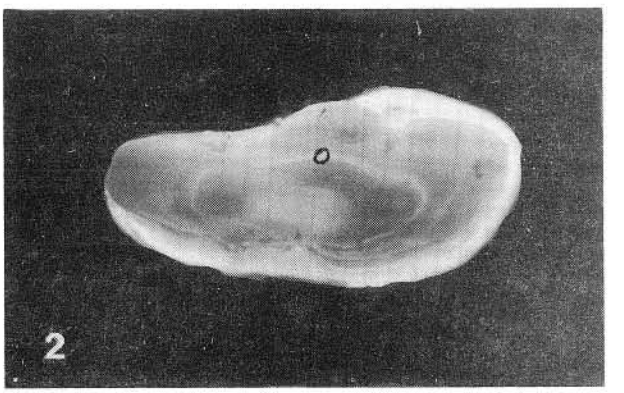
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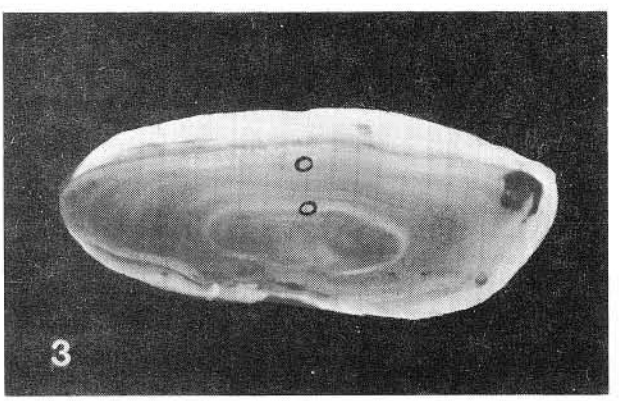
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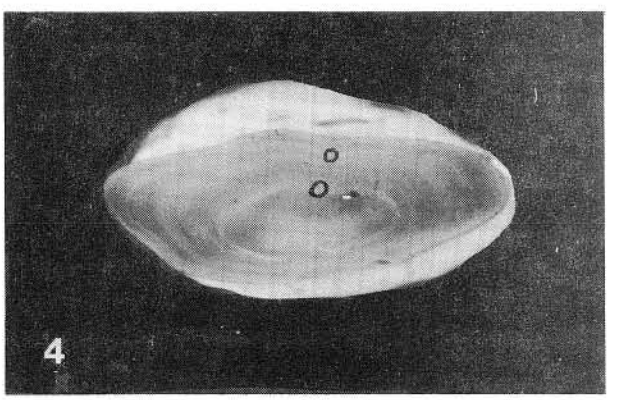
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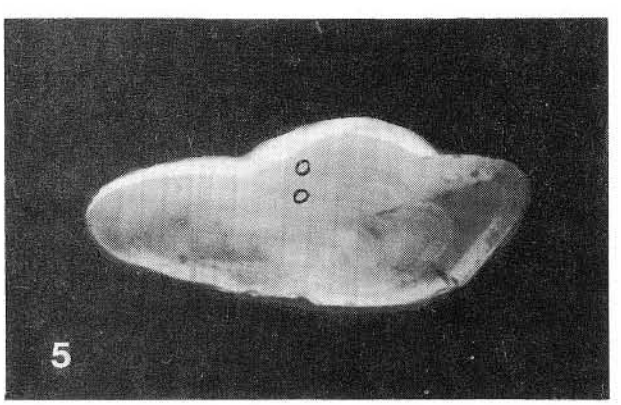
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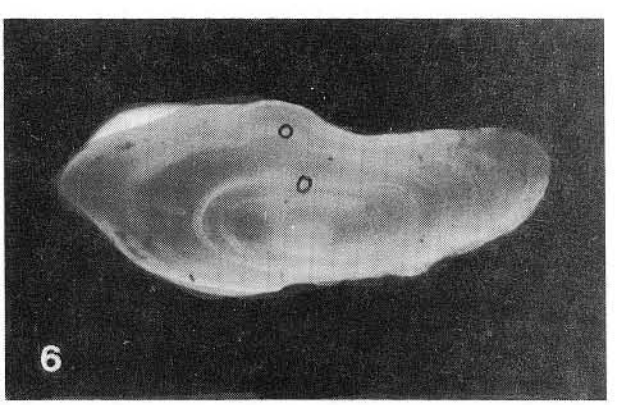
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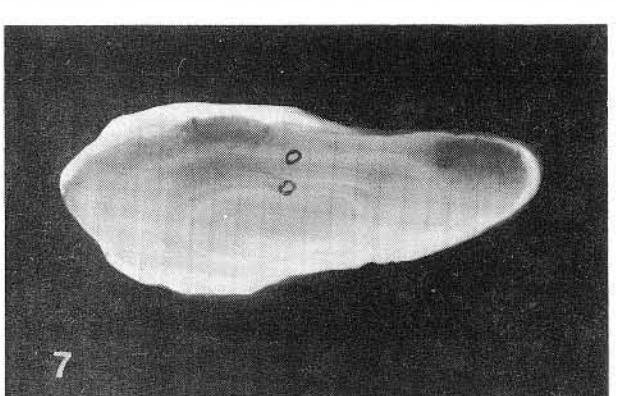
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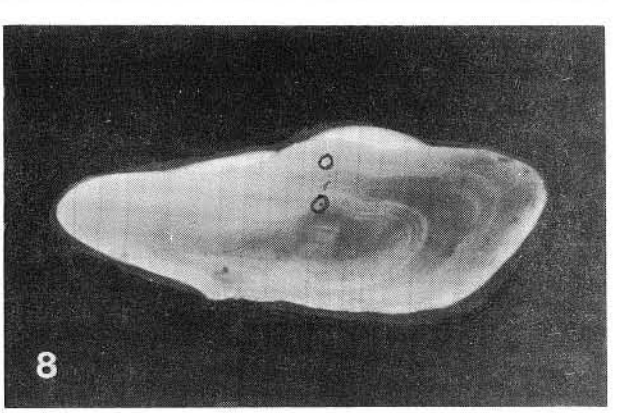
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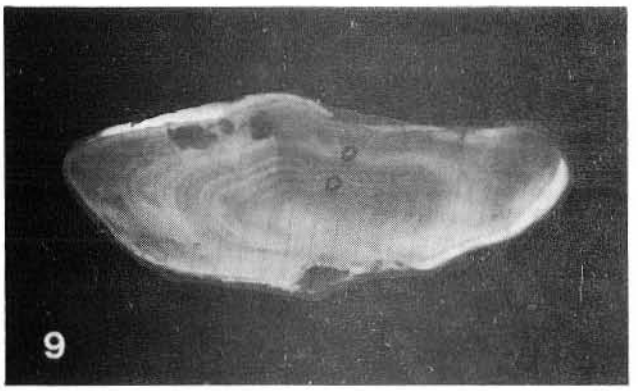
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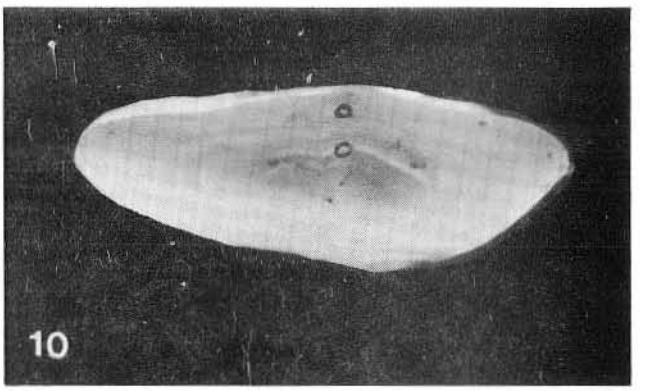
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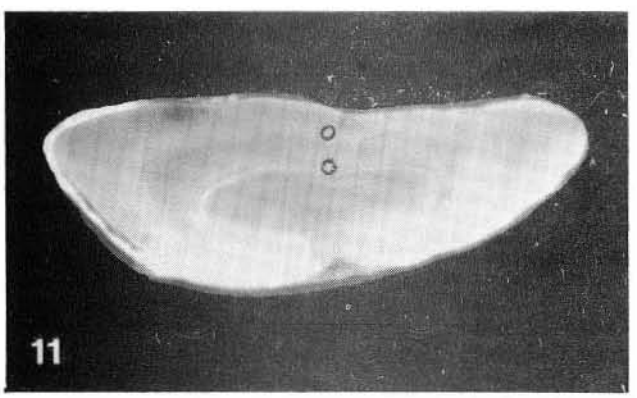
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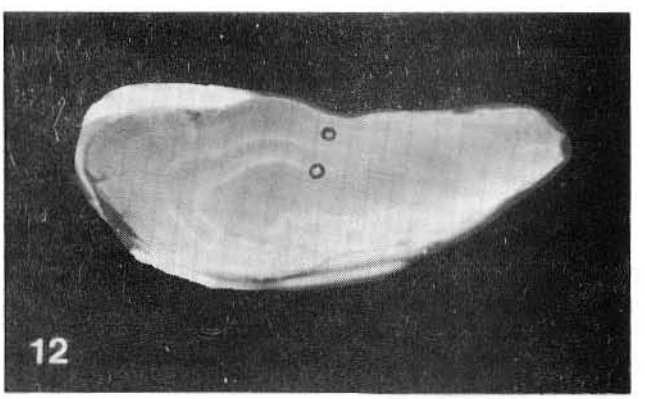
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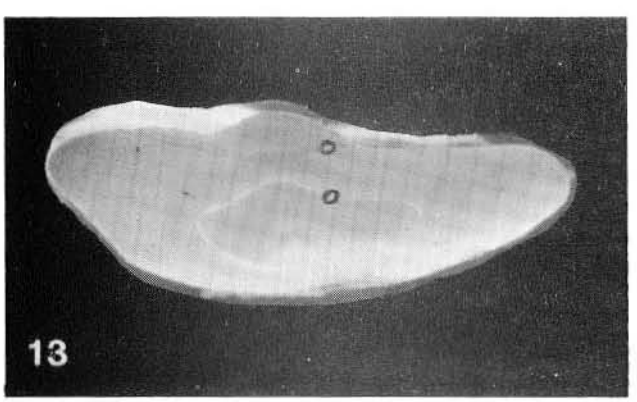
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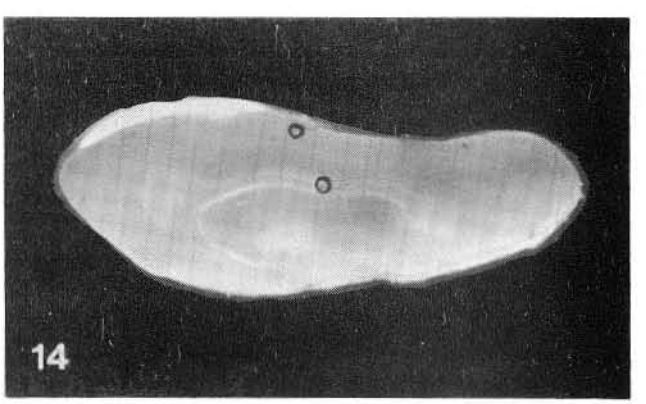
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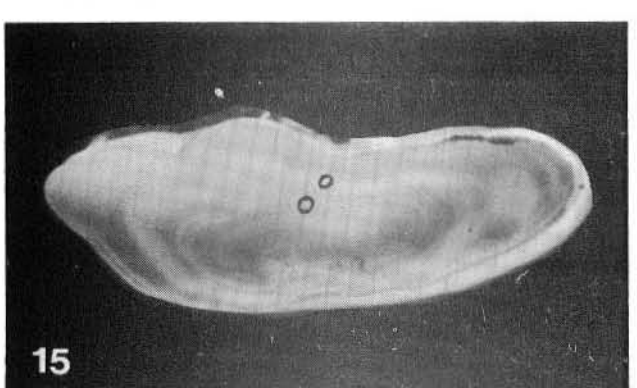
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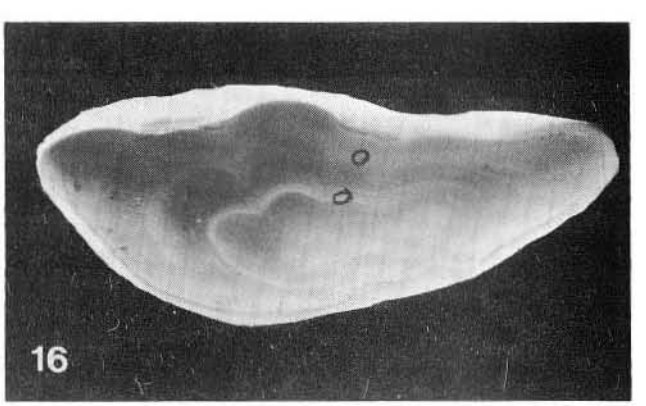
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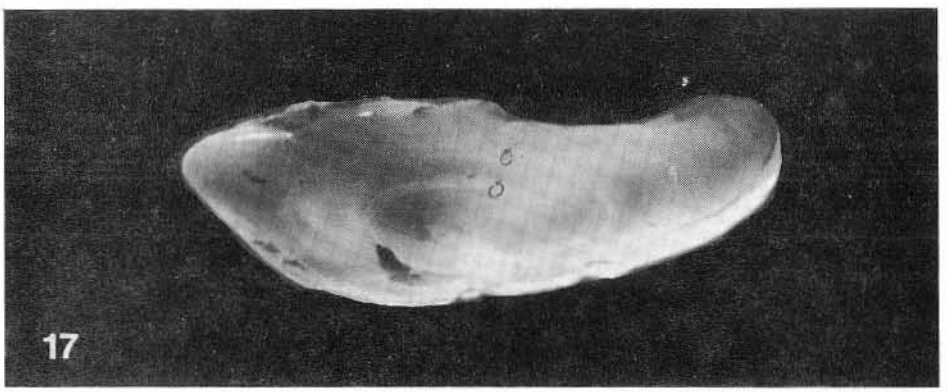

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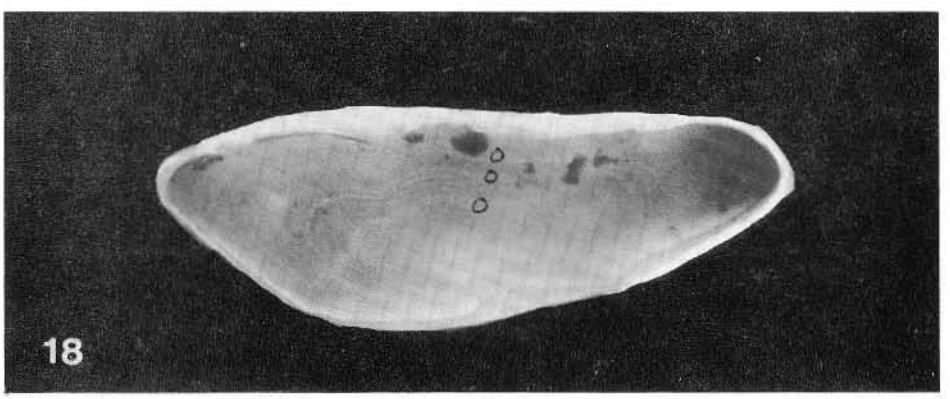

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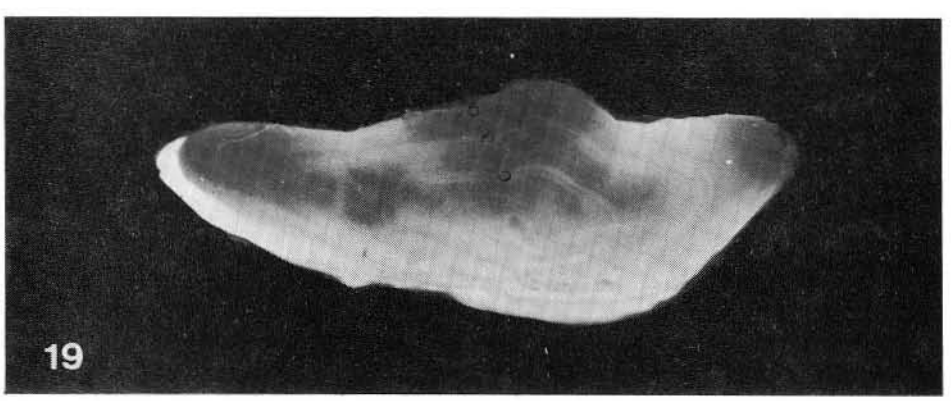

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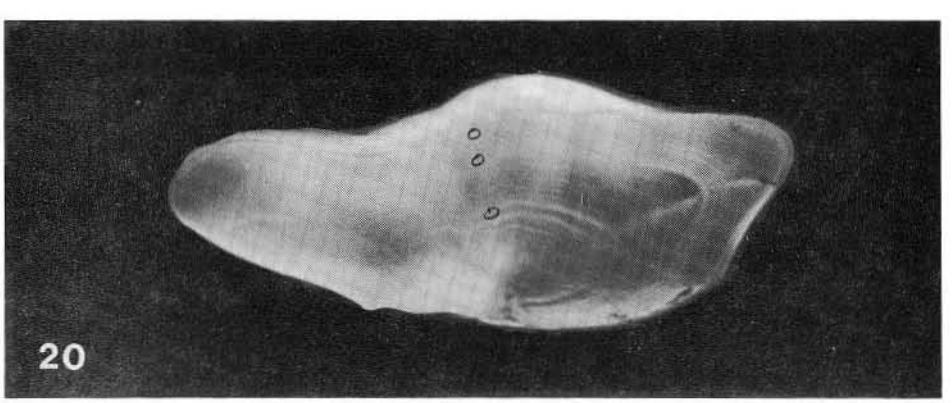

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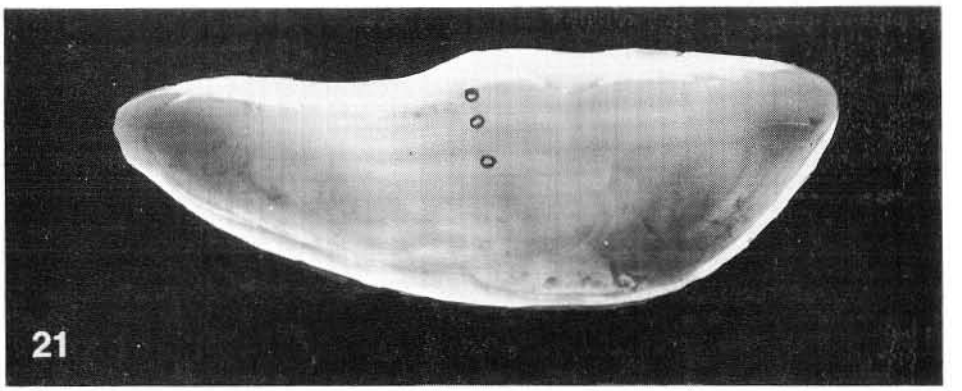
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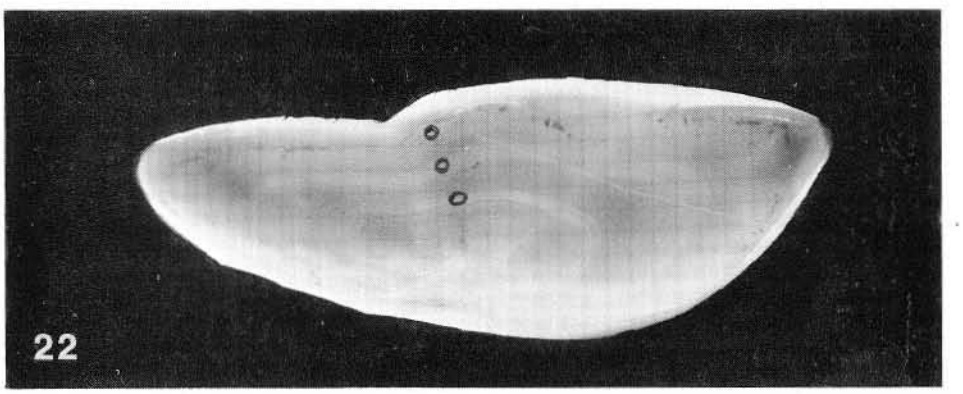
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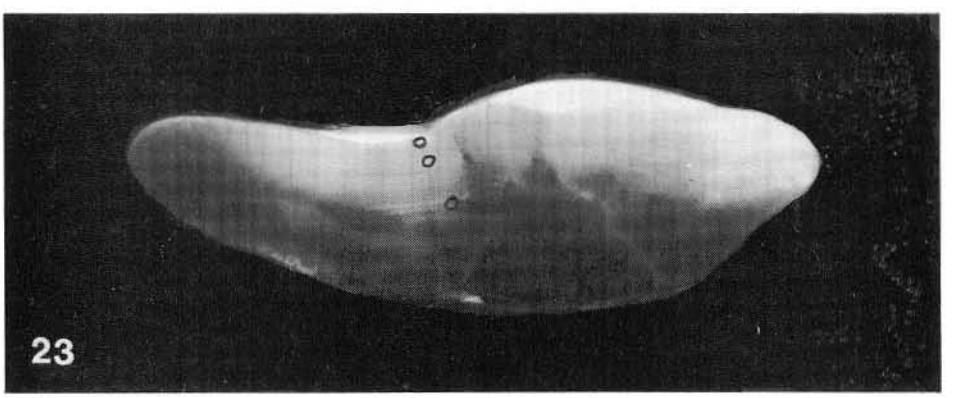
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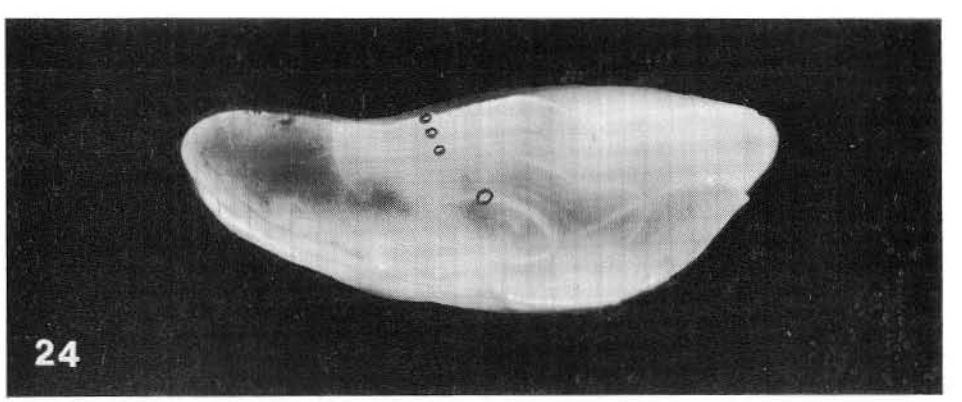
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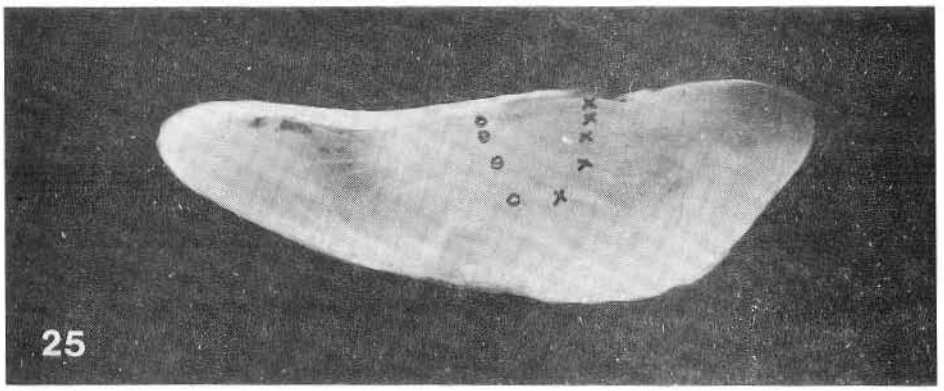
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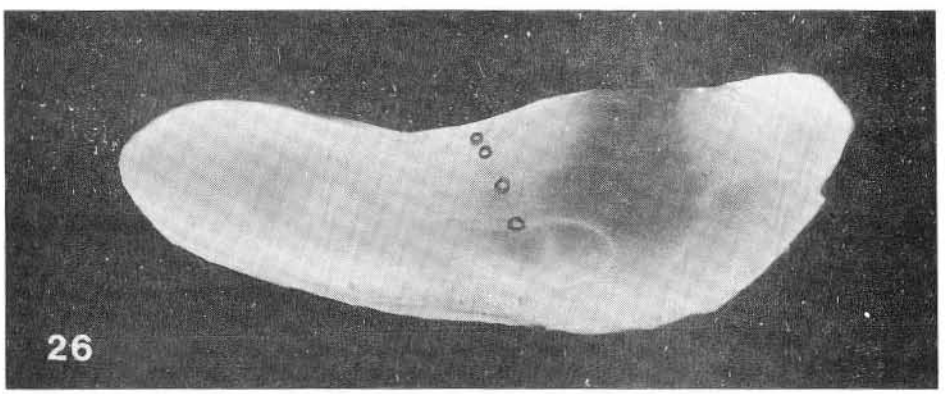
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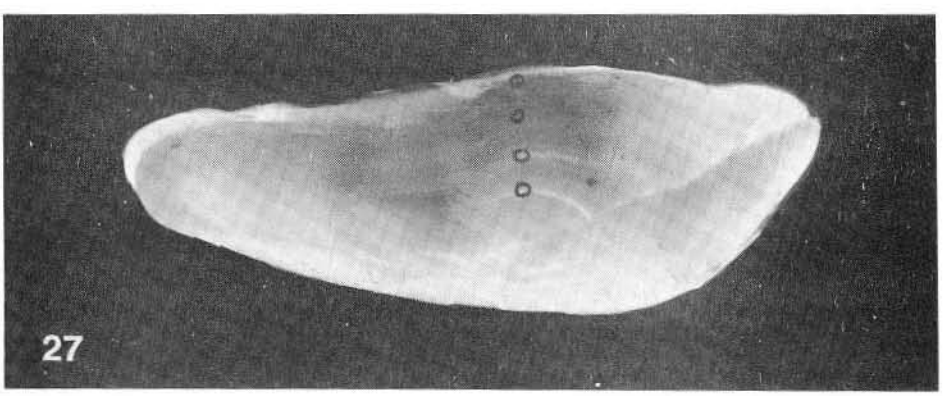
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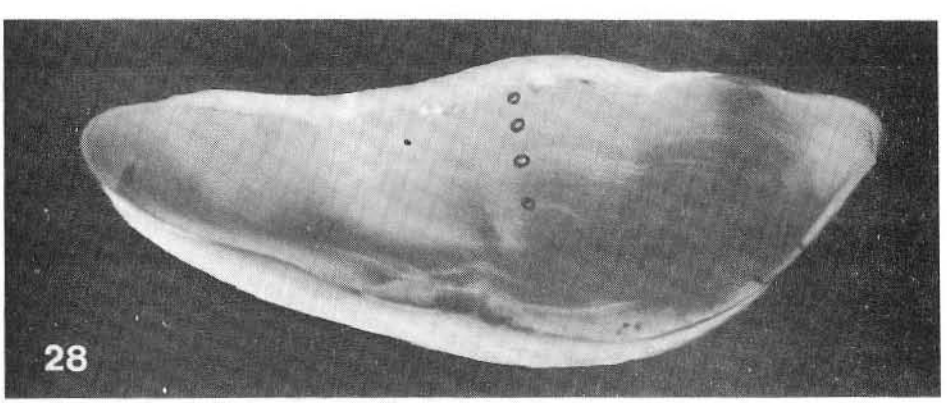
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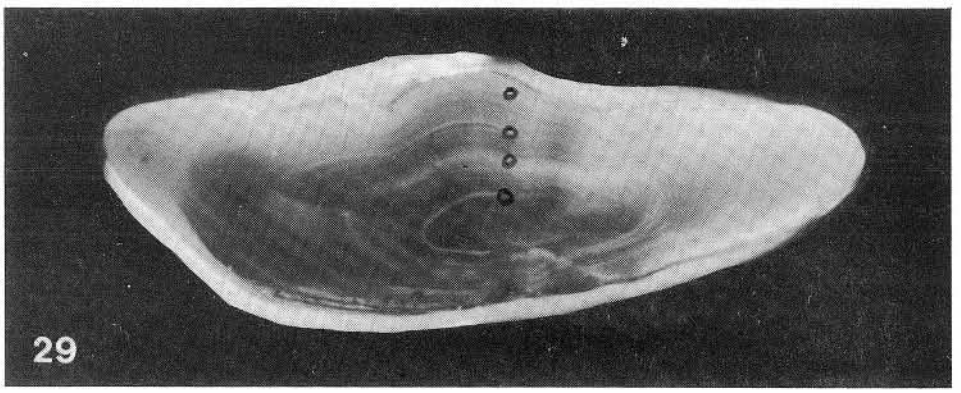
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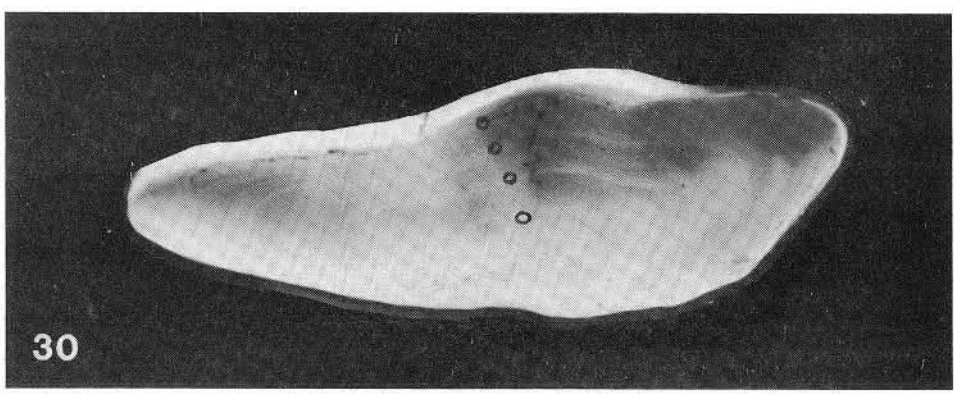
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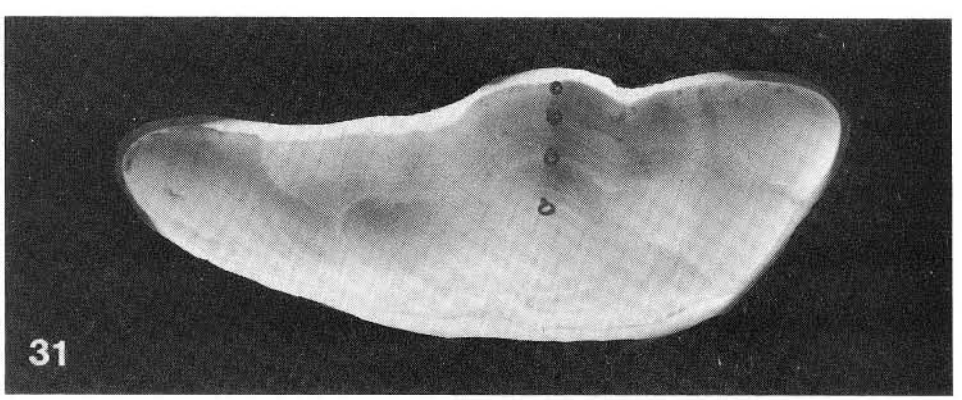
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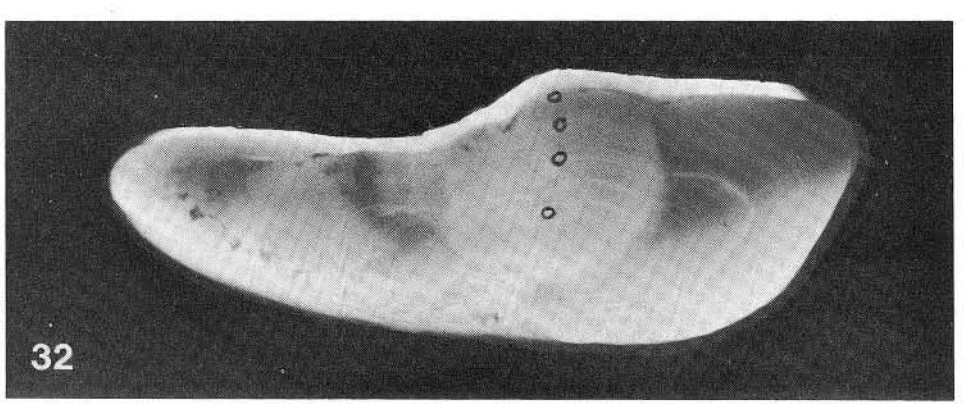
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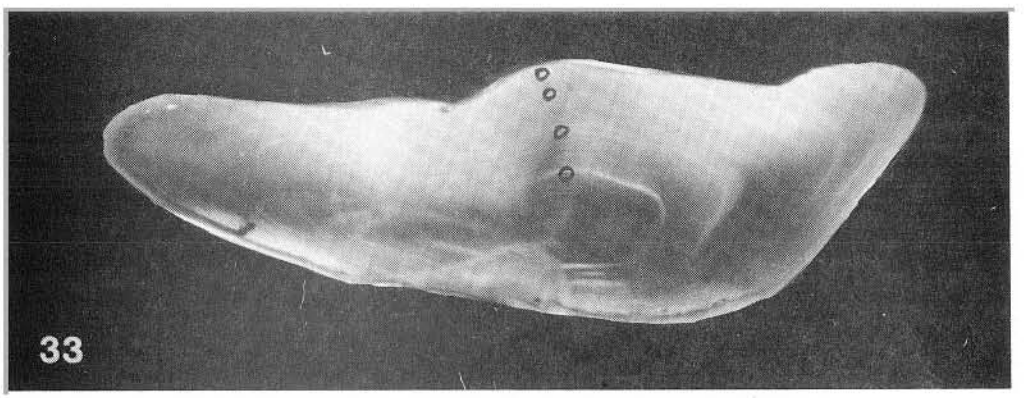
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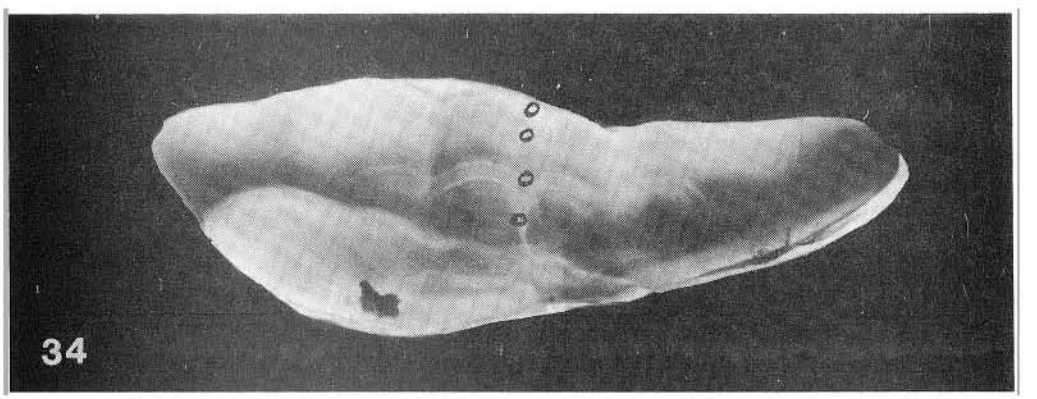
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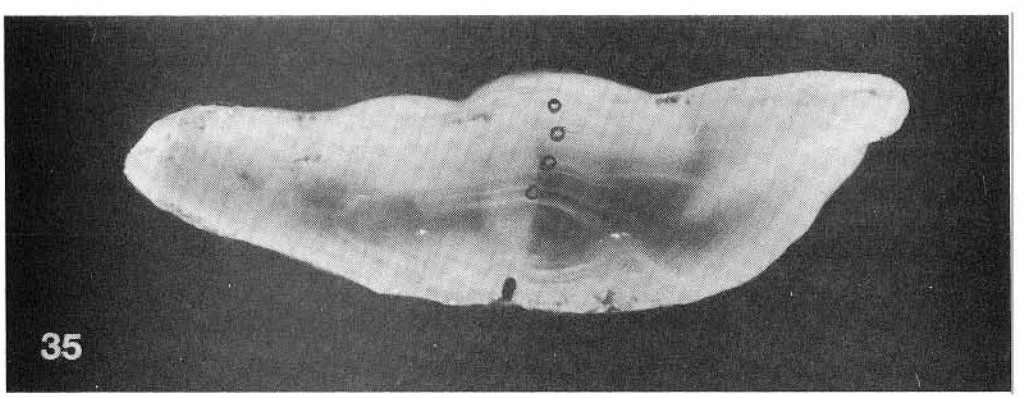
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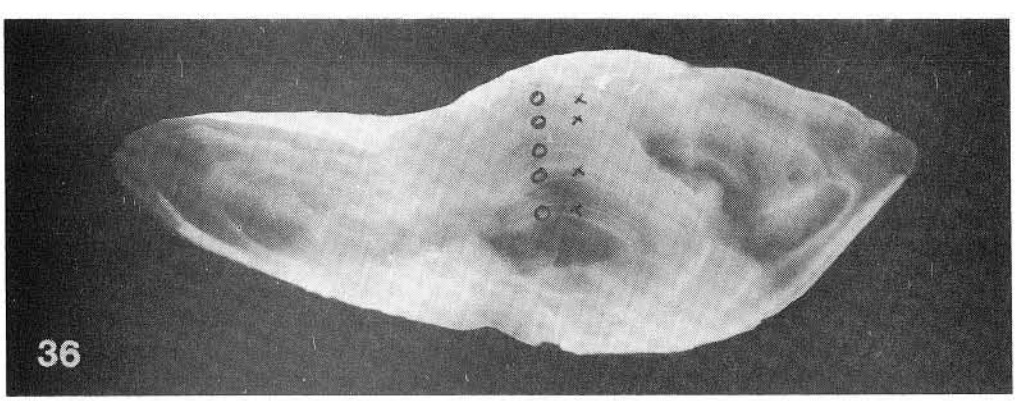
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