AGE DETERMINATION, REPRODUCTION, AND GROWTH OF THE FRANCISCANA DOLPHIN, *PONTOPORIA BLAINVILLEI*

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ABSTRACT

An examination was made of 260 Franciscana dolphins taken off the Uruguayan coast. Deposition of dentinal and cemental layers is annual with the formation of an unstainable layer between August and November. Cementum deposition continues after the probable cessation of dentine deposition at four to seven years. Females usually have a 2-year reproductive cycle. Calves are born at a length from 70 to 75 cm after a gestation of about 10.5 months, and weaned before one year of age. Sexual maturity is attained in both sexes at an age between two and three years, which corresponds to the length of 131 cm and weight of 25 to 29 kg in males, and to 140 cm and 33 to 34 kg in females. Physical maturity is attained soon after the onset of sexual maturity. Sex ratio is at parity in immature individuals.

INTRODUCTION

The Franciscana dolphin *Pontoporia blainvillei* (Gervais and d'Orbigny, 1844) inhabits the coastal waters off eastern South America from Valdes Peninsula (42°30′S), Argentina, north to the Tropic of Capricorn near Ubatuba, Brazil (Ximenez, Langguth, and Praderi, 1972).

The purpose of this study was to investigate reproductive parameters and growth in this species. Specific objectives included collection and analysis of information on age of sexual maturity, frequency and timing of calving, growth, and sex and age composition.

MATERIALS AND METHODS

The dolphins examined in this study, 123 females and 137 males, were collected dead, offshore from Punta del Diablo, Uruguay, by local fishermen in gillnets set for sharks. Details on the fishing methods used at Punta del Diablo are given by Van Erp (1969), Brownell and Ness (1970), Pilleri (1971), and Brownell (1975).

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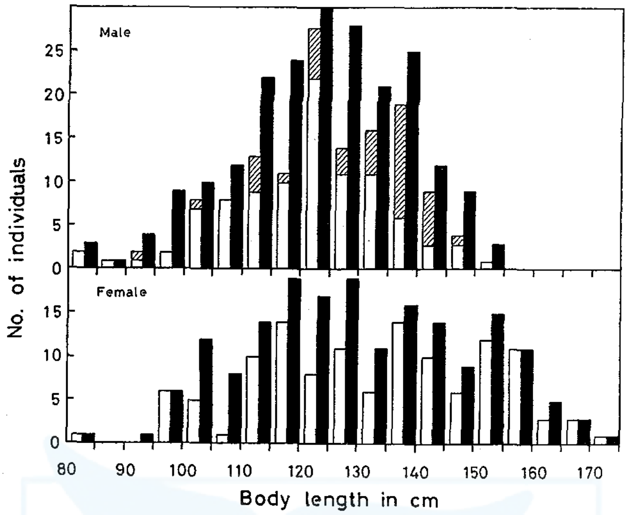

Fig. 1. Body length frequency of *Pontoporia blainvillei*. Right column (black) represents the random sample cited from Brownell (1975), left column the present material, and shaded area individuals of unknown age.

TABLE 1. MATERIALS OF *PONTOPORIA BLAINVILLEI* USED IN THIS STUDY

Month	I	II	III	VI	VII	VIII	IX	X	XI	XII	Total
Male[1]	79[3]	3	2	3	1	3	1	1	0	33	126
" [2]	0	0	0	0	7	1	1	0	1	1	11
Female[1]	57[3]	7	3	3	0	1	2	2	2	21	98
" [2]	0	0	0	0	0	4	3	6	6	6	25
Female, %[1]	41.9	70.0	60.0	50.0	0.0	25.0	66.7	66.7	100.0	38.9	43.8
" , %[2]	—	—	—	—	0.0	80.0	75.0	100.0	85.7	85.7	69.4

[1] : Random sample, [2] : Nonrandom sample, [3] : One aged individual of unknown length included.

Over 400 dolphins were collected by us or a local fisherman Amilcar Olivera (AO) between December 1970 and December 1973. The sample was heavily biased toward December and January (austral summer), because of the seasonal nature of the shark fishery, with minimal coverage during the rest of the year. The body weight and external proportion data were obtained from specimens taken between December 1972 and January 1973. The standard total length of each specimen was measured in a straight line from the tip of the rostrum to the notch in the flukes. The material we collected was a random sample of the catch, but the AO specimens are biased towards adult females exceeding 135 cm in total length. Olivera only agreed to collect a limited number of specimens. Therefore, we asked him, in our absence, to collect all adult females landed.

Tooth preparation

Although the anterior teeth are slightly longer than the others, the difference is not as extreme as in *Platanista*. Three to five contiguous mandibular teeth, starting at approximately the tenth from the front and moving posteriorly, were collected and fixed in 10% formalin solution or 70% ethanol.

The principle of the preparation is to decalcify and stain a thin longitudinal ground section glued with cyanoacrylate monomer on a clear plastic plate (Kasuya, 1978). The tooth was ground down to a thickness of 20 to 30 μm. The decalcification was done with 5% formic acid for several hours at about 25°C. The slide was then rinsed in running water for two hours or longer, stained with Mayer's haematoxylin for 30 minutes, and finally mounted with Canadian balsam. Both anterio-posterior and lingual-buccal sections were prepared for most individuals; they were not significantly different in readability. However, since the teeth are compressed anterior-posteriorly, the chance of missing the pulp cavity is less in the anterio-posterior section.

Reading of growth layers

The age determination was based on the growth layers in the dentine and cementum. Observations of growth layers were made with a compound microscope (40 to 120×), without referring to the biological data. At first, about 20 slides, probably representing new born individuals and very old individuals, were selected, and the standard of reading was established by comparing the growth stage and layer counts of the slides. Then all the slides were read by the same standard. If the number of cemental layers exceeded significantly that in dentine, the former was taken as the age. This only occurred when teeth had narrow pulp cavities. In cases where the counts of dentine and of cemental layers differed only by a fraction of a layer, the dentine count was taken as the age because it is clearer and more reliable than the cemental layer. If the independent readings of the growth layers in the same tissue of two slides from one individual were different, they were carefully compared including the difference of the finish, and then a final decision was made without referring to the biological data. When there was no choice in the interpretation of the fraction of the last incomplete layer, the mean of the two counts was used.

One complete growth cycle was considered to be composed of one broad stainable layer and a narrow unstainable layer. The final fractional layer was estimated by eye to the nearest 0.1 layer. Although this is not highly accurate, it gives a better result when the sample is seasonally biased.

AGE DETERMINATION

Morphology and number of teeth

The number of teeth ranges from 48 to 61 on each tooth row (Table 2). There are no consistent sexual or bilateral differences. However, the number of teeth is significantly different between the upper and lower jaws ($p<0.001$). The excess of upper teeth over the lower varies from −1 to +11 with a mean of 3.3 in females, and from −1 to +9 with a mean of 2.7 in males. This is related to the downward curving of the rostrum. In *Platanista gangetica*, the rostrum is curved upward and the number of lower teeth exceeds the upper (Kasuya, 1973).

The straight length of a tooth is approximately 7 to 10 mm. The pointed crown is compressed anterio-posteriorly and the tip is curved mesially. The root is flattened lingual-buccally and the proximal tip is usually curved, through the growth, towards the posterior direction. The cementum forms a thick cingulum at the cervix of the tooth. In old individuals the root is covered by the cementum leaving small branching canals connecting the narrow pulp cavity and external surface of cementum. (Pl. IV, Fig. 1).

TABLE 2. TOOTH COUNT OF *PONTOPORIA BLAINVILLEI*

Position	Sample	Range	Mean	SD	SE
Male					
Up. left	33	51-60	54.6	2.25	0.39
Up. right	33	51-60	55.0	2.24	0.39
Lo. left	33	48-61	53.3	2.54	0.44
Lo. right	32	49-59	53.4	2.33	0.41
Female					
Up. left	39	50-60	55.4	2.62	0.42
Up. right	39	50-61	55.3	2.67	0.43
Lo. left	38	49-58	53.7	2.26	0.37
Lo. right	38	49-59	53.6	2.40	0.39

Growth layers

When a thin ground section is observed under transmitted light, the growth layers are seen as the alternation of optical density. The decalcification and staining of a thin ground section partially masked with wax indicates that the opaque layer in the cementum and dentine corresponds to the stainable layer (Pl. IV, Fig. 2). The minute layer in dentine is detected more clearly on decalcified and stained slides.

The fetal dentine has a thick, uniform, moderately stainable layer, and the neonatal line is an unstainable layer of about 5 μm width deposited on the inner wall of fetal dentine. Three kinds of layers and presumably cycles are found in the postnatal dentine. The first is the coarse layer and is the most conspicuous. As discussed later, we believe that this layer represents the annual cycle. One cycle of this layer is composed of a thin (about 10 to 20 μm in the first layer) conspicuous unstainable layer and a wide stainable layer. The unstainable layer is clearer near the cusp than at the root. The stainability in the stainable zone is not uniform, but consists of finer layers ranging from 10 to 17 in number with a mode at 12 or 13. This is the second kind of layer, which may correspond to the short cycle cemental layers in the teeth of the Baird's beaked whale, *Berardius bairdii*, suspected by Kasuya (1977) to represent a lunar cycle or an endogenous rhythm of about one month. Some of these fine layers deposited just prior to the unstainable layer of the annual cycle are always stained more strongly than the preceeding stainable dentine which forms the stainable layer of the annual cycle. In other words, the annual cycle of dentine deposition is formed by the enhancement of some of the shorter cycle layers. This cycle is inconspicuous in the third and successive annual layers. There are often observed several narrow layers (third layer) in some of the second kind of layers, but it is almost impossible to count them.

In the cementum, the alternation of narrow stainable layers and wide weakly stainable layers is the only way to read layers. From comparison with the dentinal layers, it appears that the stainable cementum corresponds to the strongly stainable dentine deposited just prior to the unstainable layer of the annual cycle. This cemental cycle is clearest usually on the cusp side of the cingulum.

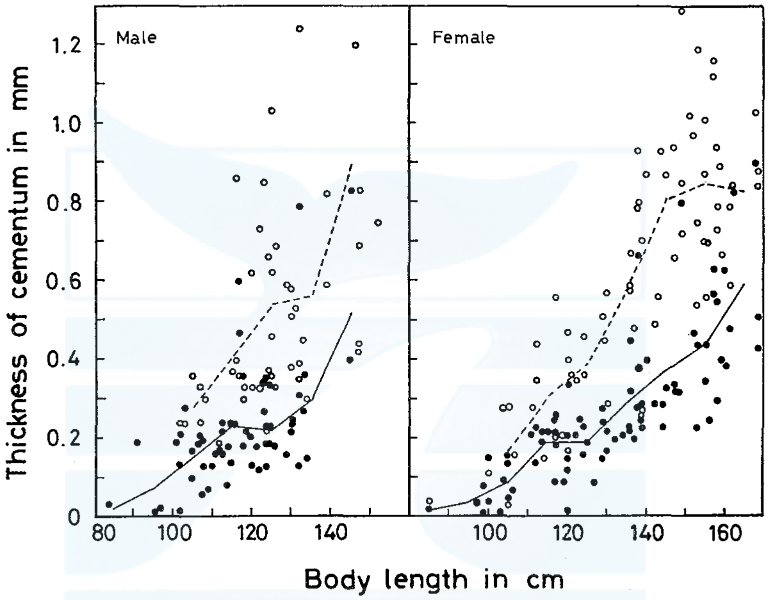

Fig. 2. Scatter plots of thickness of cementum at cingulum on body length. Open circle and dotted line indicate anterio-posterior thickness, and closed circle and solid line ligual-buccal thickness.

Thickness of cemental layers

Figure 2 shows the maximum thickness of cementum at the cingulum plotted against the body length. The cementum was present on all the individuals, which had at least some teeth erupted. There were three juveniles, one female (98.5 cm) and two males (84.5 and 96.0 cm), where 20 to 30 teeth on each jaw were left unerupted. The teeth of these individuals had cementum of 5 to 12 μm in thickness. Their postnatal dentine ranged from 65 to 110 μm in thickness, or 14 to 24% of the mean thickness of the first postnatal dentine shown in Table 3. These data indicate that tooth eruption and cemental deposition starts as early as one or two months after birth.

These is a great deal of individual variation in cementum thickness. This would, in some degree, have been caused by technical problem with preparation.

However, it is clear that the cementum is thicker on the anterio-posterior direction, and that there is no sexual dimorphism of the thickness if compared between individuals of the same body length.

The relationship between the thickness of cementum and age is shown in Fig. 3. The deposition is faster in the first 3 years, and then changes to a slower growth phase which seems to continue until at least 9 years of age. The difference between sexes is not significant.

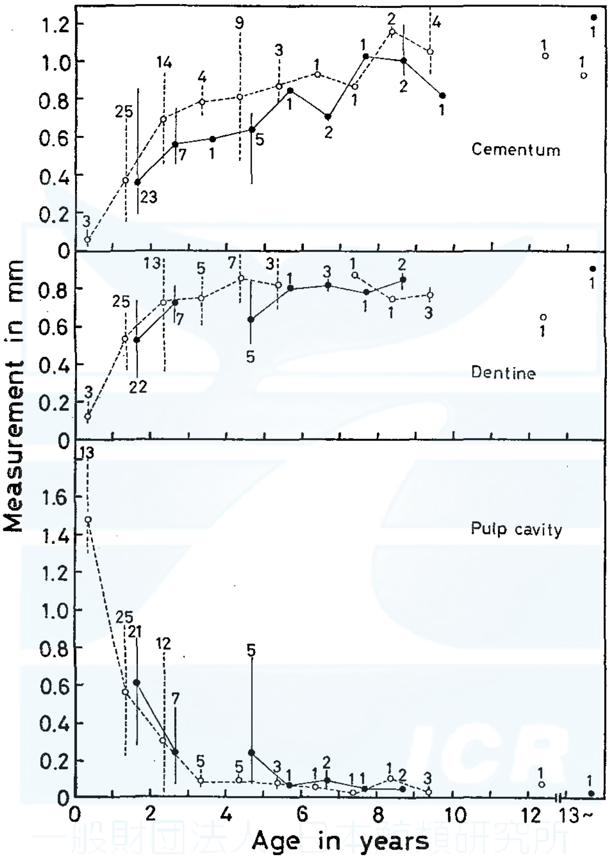

Fig. 3. Relationship between anterio-posterior dimensions of the tooth and age. Closed circle and solid line indicate mean value in males, open circle and dotted line that in females, vertical line observed range, and numerals the number of samples. For further explanations see text.

Thickness of dentinal layers

Figure 4 shows the relationship between body length and thickness of dentine measured at the level corresponding to the proximal end of the prenatal dentine. There was no sexual dimorphism in the thickness nor any difference related to the direction of the preparation. Although the dentine deposition is slow in juveniles under 100 cm in body length, there is a sudden increase in the thickness at lengths

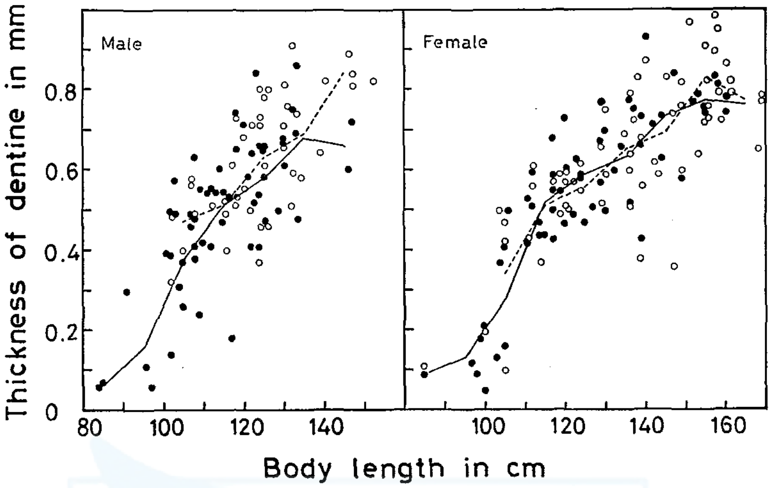

Fig. 4. Scatter plots of the thickness of dentine on body length. For key see Fig. 2.

TABLE 3. THICKNESS OF DENTINAL LAYERS OF *PONTOPORIA BLAINVILLEI* (in μm)

	Lingual-buccal			Anterio-posterior		
	No.	Mean	SD	No.	Mean	SD
Male						
1st	53	432	88.3	36	458	95.6
2nd	28	206	55.7	18	204	57.4
3rd	4	133	10.4	4	100	24.5
Female						
1st	56	462	81.3	55	469	88.8
2nd	27	214	66.4	34	202	71.8
3rd	4	95	32.4	14	102	40.6

of 100 cm in males and 105 cm in females, which is again followed by a slower increase. The body length of rapid dentine deposition coincides with an age of 0.5 to 1.0 years (Fig. 7). The increase of dentine thickness is almost negligible after the age of 4 years, and this is reflected by the change of the diameter of pulp cavity (Fig. 3). The diameter of the pulp cavity attains the minimum of 40 to 100 μm at about 4 years of age. This stage nearly coincides, as mentioned below, with the age when the number of cemental layers exceeds that of dentinal layers of the same individual. Furthermore, in these individuals, the pulp wall is covered by strongly stainable structureless thin dentine. We consider that this is an indication of the cessation of dentine deposition or of the deposition of such a thin dentine that the growth layers in it cannot be counted by the present method.

Accumulation rate of the layer

Figure 5 shows the relationship between the number of layers of dentine and cementum in the same individual. When there are less than four dentine layers, the difference between these two figures is usually less than a fraction of a layer. The number of dentine layers usually exceeds the number of cemental layers by a small fraction because of the difficulty of distinguishing a thin incomplete layer in the cementum. The two figures often disagree after the age of 4 layers in males or 5 layers in females. This suggests that the accumulation rate of the layers in the two tissues is the same up to an age of approximately 4 to 5 layers (=years). After this age, it appears that only the cemental layer retains the same deposition rate. It must be noted, however, that age determination by means of cemental layers is less accurate than by dentinal layers.

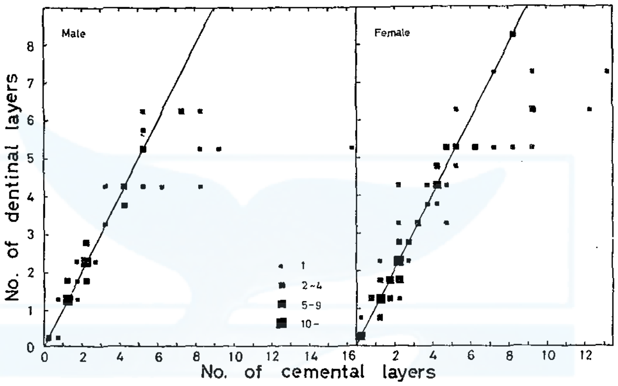

Fig. 5. Relationship between number of growth layers in dentine and that in cementum.

TABLE 4. NATURE OF THE LAST INCOMPLETE DENTINAL LAYER

Month	I	II	III	VI	VIII	IX	X	XI	XII
Unstainable									
Male	7	0	0	0	1	0	0	0	10
Female	10	1	0	0	1	0	2	2	2
Total, no.	17	1	0	0	2	0	2	2	12
„ , %	18.5	14.3	0.0	0.0	66.7	0.0	100.0	40.0	27.3
Stainable									
Male	40	0	1	1	0	0	0	0	13
Female	35	6	3	1	1	2	0	3	19
Total, no.	75	6	4	2	1	2	0	3	32
„ , %	81.5	85.7	100.0	100.0	33.3	100.0	0.0	60.0	71.1

The seasonal frequency of the condition of the last incomplete layer was studied only on the dentinal layers, because the observation is more difficult on cemental layers. Only individuals with less than three growth layers were used. These results are shown in Table 4. There is some difficulty in determining the nature of the last incomplete layer, because of the presence of finer structures in the dentine. This will increase the apparent individual variatiod in the seasonal formation of a certain kind of layer. A sufficient number of samples was available only in December and January, when most of individuals (70 to 80%) were forming the stainable type of dentine. The ratio seems to be higher in January through June, but decreases from August to November when only half of 12 individuals are forming the stainable dentine. These data, together with the fact that the thickness of unstainable layer is less than 5% of the total thickness of one dentinal layer, suggests that the period of the formation of unstainable dentine is rather short in each individual and that it occurs at various times between August and November.

Figure 6 shows the seasonal change of the fractional part of the dentinal layer count. This is estimated by eye at the time of age determination without referring to the biological data or the date of death. The graph indicates that the thickness of incomplete layer increases linearly from November to September of the next year, when the deposition of unstainable layer seems to occur in most of individuals, to complete one deposition cycle.

From the above analyses it is concluded that the coarse dentinal layer is deposited annually. The cemental layer deposition also follows the same cycle.

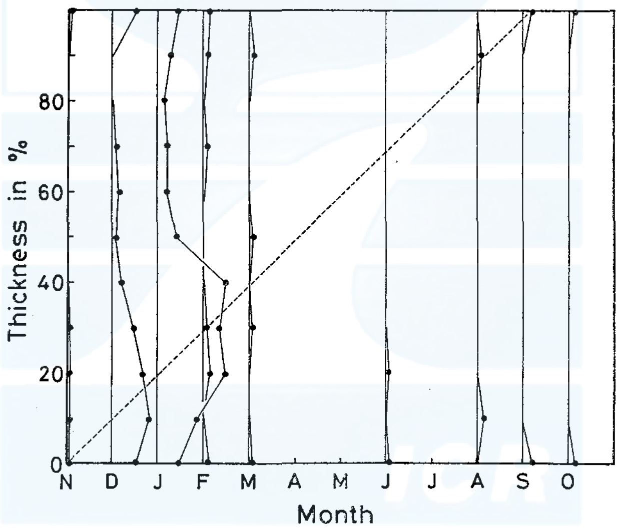

Fig. 6. Seasonal change of the thickness of the last incomplete layers in dentine. For explanations see text.

GROWTH

Length at birth

The largest fetuses encountered were a male and female 68 and 70 cm long, respectively. The three next largest fetuses were 66, 65, and 63 cm. The smallest neonatal animals were two males 84 and 84.5 cm long. The two next smallest dolphins were a male and female, both 85 cm in length. The next was a male 92 cm long. The age of the 84.5 cm neonate was estimated at 0.2 years. Therefore, we conclude that the body length at birth is greater than 70 cm and less than

85 cm, probably in the low 70 cm range.

Postnatal growth in body length

The calves which are born at a length between 70 and 75 cm attain a mean length of 96.2 cm (13 individuals, sexes combined) at the age of about 0.5 year. Although the sexual dimorphism in the body length might be present at the age below 1 year (Table 5), the observed difference is not significant ($p=0.2$). The growth is slower in males and the mean body lengths are significantly smaller than those of females after the age of 1 year ($p<0.001$). No secondary growth spurt is observed in either sex. The present materials indicate that the growth ceases at the age of 4 years (Fig. 7). The mean asymptotic length of 133.3 cm for males and 153.0 cm for females are estimated as the mean body length of individuals 4 years or older.

If the Gompertz equation (Zweifel and Perrin, in press) is fitted for three mean lengths below 3 years by forcing to have the asymptotic length of 133.3 cm, the least squares calculation gives following equation for males:

TABLE 5. AGE AND BODY LENGTH (cm) IN *PONTOPORIA BLAINVILLEI*

Age (yr.)	Mean age	No.	Range	Mean	S.D.
Male					
0≦, <1	0.3	5	84.0-102.0	92.7	8.04
1≦, <2	1.2	48	90.5-134.0	115.7	9.72
2≦, <3	2.2	21	110.0-152.0	128.8	10.59
3≦, <4	3.3	2	118.0-129.0	123.5	—
4≦, ≦16	6.2	21	122.0-147.0	133.3	8.58
Female					
0≦, <1	0.5	8	85.0-105.0	98.4	6.02
1≦, <2	1.3	54	100.0-143.0	122.6	10.64
2≦, <3	2.2	25	120.0-169.0	141.2	14.41
3≦, <4	3.2	6	145.0-160.0	152.2	5.46
4≦, ≦13	6.4	28	137.0-171.0	152.8	9.23

TABLE 6. AGE AND BODY WEIGHT (kg) IN *PONTOPORIA BLAINVILLEI*

Age (yr.)	Mean age	No.	Range	Mean	S.D.
Male					
0≦, <1	0.3	4	10.9-17.2	14.2	2.74
1≦, <2	1.2	21	11.8-24.5	18.6	4.35
2≦, <3	2.2	10	16.3-35.7	24.0	6.40
3≦, <4	3.0	1	17.2	17.2	
5≦, ≦16	8.5	4	19.9-32.2	28.2	5.66
Female[1]					
0≦, <1	0.3	3	11.8-14.9	13.1	1.59
1≦, <2	1.2	26	14.5-30.8	22.9	4.72
2≦, <3	2.3	9	17.7-34.9	26.3	6.76
3≦, <4	3.0	1	34.4	34.4	
4≦, ≦8	5.6	5	29.9-52.1	40.3	8.55

[1] No pregnant female included.

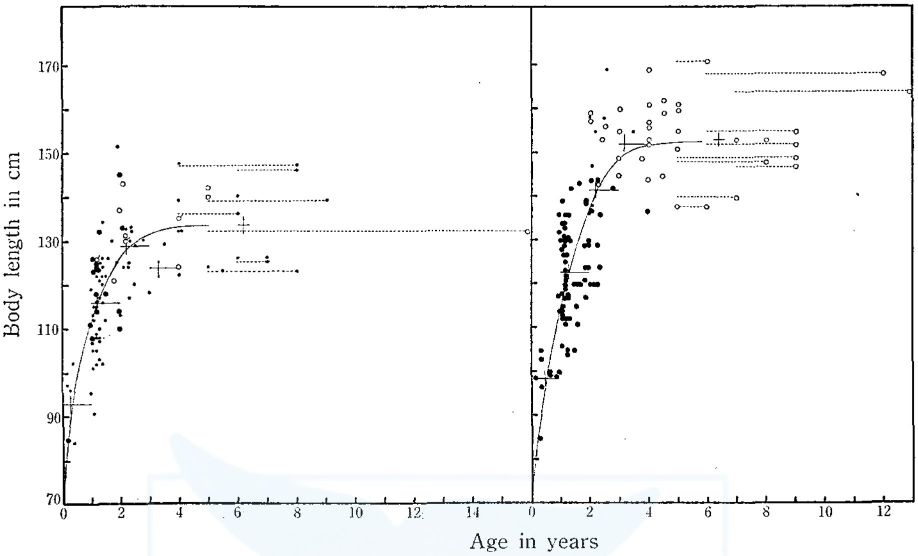

Fig. 7. Scatter plots of body length vs. age, males at the left and females at the right. Immature individuals are indicated by the larger closed circles, mature individuals by open circles, and those of unknown maturity by the smaller closed circles. Dotted line indicates an individual where number of cemental layers (circle at the right end) is used instead of dentinal layers (left end of dotted line). Growth curves are drawn by eye.

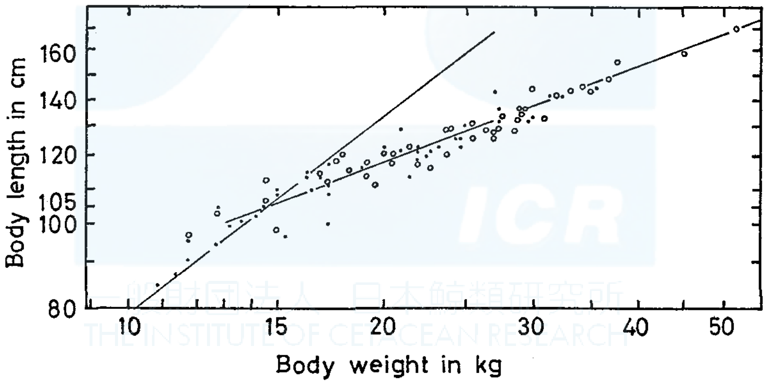

Fig. 8. Scatter plots of body weight vs. body length (the x and y axes are reversed in this graph). Closed circles indicate males and open circle females. For further explanations see text.

$$Y_t = 133.3 \exp(-0.5611 \exp(-1.2447t))$$

where Y_t indicates the body length (cm) at age t years. Although this equation fits well to the male data, the analogous equation for females does not fit the data. This may be due to the fact that the growth of females is more specialized, that is, females grow at a faster rate for a longer period.

Postnatal growth in body weight

The sexual dimorphism of body length suggests the presence of sexual dimorphism of body weight in all the age classes above 1 year of age. However, the observed difference of mean body weight is significant only in the age group from 1 to 2 years and that above 4 years ($p<0.05$). This is because of the large individual variation of body weight and small sample size.

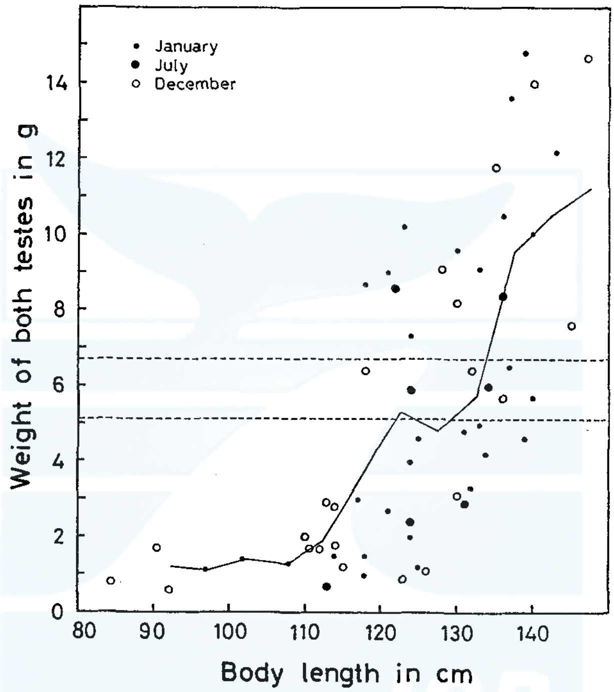

Fig. 9. Scatter plots of combined weight of both testes on body length. Horizontal lines indicate the mean weight at the attainment of puberty or of sexual maturity calculated in this study.

In Fig. 8, the body weights are plotted against the body length. No sexual dimorphism is observed in the relationship. This is reasonably expected from the fact that there is no observed secondary sexual dimorphism in the external proportions of the species (Kasuya, 1974). The correlation seems to change at a body length 105 cm. The relationship of the body weight to body length is expressed by the following equations calculated by least squares,

$$y = 3.459\times10^{-2}\cdot x^{1.2993}, \quad x\leqq105$$
$$y = 6.902\times10^{-5}\cdot x^{2.6347}, \quad x\geqq105$$

where y indicates body weight in kg and x indicates body length in cm. A body length of 105 cm corresponds, on the mean growth curve, to an age between 0.5 and 1.0 year, or probable weaning period as discussed below. If the growth of the body in the longitudinal and transverse directions is the same, the coefficient must be close to 3.0. However, it is much smaller in this species. This indicates that the body of the species becomes slender with the increase of body length and the tendency is more exaggerated during the suckling stage.

Weaning

The stomach contents of only four juveniles were studied. The smallest, male, 84.5 cm, 0.2 years of age, had milk in the stomach. Also present were numerous small unidentified discs of a diameter of about 0.3 mm. Although the origin of these substances is unknown, they may have been derived from some solid food. More than half of the teeth had erupted in this individual. Three other juveniles, 90.5 cm to 104.5 cm in body length and 0.3 to 1.1 years of age, had fish otoliths, squid beaks or shrimps in their stomachs. The presence of milk was not noted.

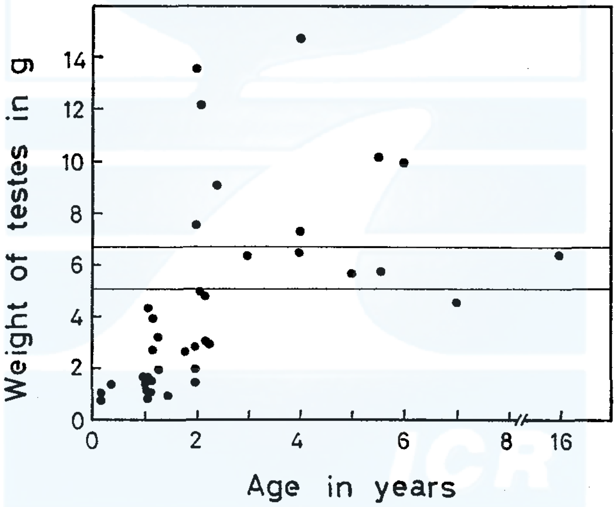

Fig. 10. Scatter plots of combined weight of both testes on age. For horizontal lines see Fig. 9.

These data suggest that the species starts to take solid food at about 3 months after birth. The length of the suckling was not determind. The rapid increase of the dentine thickness at a length of 100 to 105 cm, which corresponds to an age of 0.5 to 1.0 year, possibly coincide with the period when the diet changes from milk to solid food as suggested in *Stenella attenuata* by Kasuya, Miyazaki and Dawbin (1974).

Attainment of sexual maturity in male

Figure 9 shows the relationship between body length and combined weight of both testes. The weight is below 2 g in juveniles, but shows a rapid increase at a length of 120 to 130 cm, which will correspond with the approach of sexual maturity. The present data on the testes weight are limited mainly to the months of January, July and December. The seasonal change of the testes weight was examined between these three months. Since the mating peak of the species is estimated to be in December to February (Harrison *et al.*, Ms.) there is expected a difference of the weight between the winter and summer months. However, as shown in Fig. 9, there is no observed seasonal change in the present materials. This is probably because the sample contains so few adult animals. In case of *Stenella coeruleoalba*, the seasonal change of testes weight is observed clearly only in adults (Miyazaki, 1977).

Figure 10 shows the relationship between age and weight of testes based on 13 males in December, 25 in January and one in February. The increase of the weight is rapid between 2 and 2.5 years of age.

TABLE 7. SEXUAL MATURITY AND WEIGHT OF TESTES IN *PONTOPORIA BLAINVILLEI*

Weight[1] (g)	Immature		Puberty		Mature		Total no.
	no.	%	no.	%	no.	%	
0–2	9	100.0	0	0.0	0	0.0	9
2–4	7	87.5	1	12.5	0	0.0	8
4–6	4	50.0	0	0.0	4	50.0	8
6–8	1	16.7	2	33.3	3	50.0	6
8–10	0	0.0	2	28.6	5	71.4	7
10–12	0	0.0	0	0.0	0	—	0
12–14	0	0.0	0	0.0	2	100.0	2

[1] Lower limit included.

The determination of sexual maturity in males is less accurate than that in females. In the present study it was done based on the histological examination of testis. The epididymal development was used only for a reference. By examining all the available seminiferous tubules in a slide which is usually a cross section of the entire testis, an individual was classified as mature if all tubules contained spermatids or spermatocytes, as immature if no tubules contained them, and as pubertal if some of the tubules contained them. The spermatid and spermatocyte are always observed together and often accompanied by spermatozoa, but the presence of only spermatozoon was not observed. This criterion is similar to that used for *Phocoenoides* by Kasuya (1978), and is not based on direct data if the individual participate in the reproduction.

The development of the ductus epididymis seems to be completed before that of the testis. This is indicated by the facts that the pubertal testis is usually accompanied by an epididymis with a fully developed ductus, and some immature testis by an epididymis with a partially developed ductus.

The relationship between the combined weight of both testes and the maturity is shown in Table 7. The largest immature testes appeared at the weight of 7.6 g and the smallest mature at 4.6 g. Pubertal stage testes at a weighed between 3.1 and 8.7 g. The least squares regression gives 5.1 g as the weight where the frequency of " immature " individuals is 50%, and 6.7 g as that where half of the individuals are " mature ". The former value corresponds to the mean weight of the testes when males reach the pubertal stage (see Fig. 9). In the following analyses of the growth of the male, the identification of maturity is based on the result of the histological examination of the testis. Weight criteria were not used because they did not improve the accuracy of the analyses.

TABLE 8. AGE AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Age (range)	Female					Male				
	Age (mean)	Im no.	Pu no.	M no.	M %	Age (mean)	Im no.	Pu no.	M no.	M %
1≦, <2	1.2	48	0	0	0.0	1.2	12	1	0	0.0
2≦, <3	2.2	10	3	5	27.8	2.1	4	1	3	37.5
3≦, <4	3.2	0	0	5	100.0	—	0	0	0	—
4≦, <5	4.1	1	0	10	90.9	4.0	0	1	1	50.0
5≦, <6	5.0	0	0	4	100.0	5.0	0	0	2	100.0

Im: Immature, Pu: Pubertal, M: Mature.

TABLE 9. BODY LENGTH AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Body length (cm)	Female				Male			
	Im no.	Pu no.	M no.	M %	Im no.	Pu no.	M no.	M %
115–119	—	—	—	—	2	1	0	0.0
120–124	—	—	—	—	5	0	4	44.4
125–129	8	0	0	0.0	2	1	1	25.0
130–134	10	0	0	0.0	4	1	5	50.0
135–139	4	1	2	28.6	1	3	6	60.0
140–144	2	2	4	50.0	0	1	7	87.5
145–149	0	0	7	100.0	1	1	2	50.0

Im: Immature, Pu: Pubertal, M: Mature.

Table 8 shows the relationship between age and maturity. The age of the oldest immature male is 2.1 years, and that of the youngest adult male 2.0 years. The pubertals male appeared between the age of 1.2 and 4.0 years. These data, gether with the principal uncertainty of the definition of sexual maturity of the male, allow us to say with certainty only that the mean age of the male at the attainment of sexual maturity is between 2 and 4 years. However, the scatter plot of testes weight againt age shown in Fig. 10 strongly suggests that the males attain maturity at an age between 2 and 3 years as in the case of the females.

Table 9 shows the relationship between body length and the growth stage. If the unusually large immature male (RLB 835, 145 cm, 35.7 kg, and 2.0 years of age) is excluded, body lengths of the smallest mature male and of the largest immature are 121 cm and 137 cm, respectively. The pubertal males are found between 118 cm and 145 cm. The least squares regression fitted for the data in Table 9 gives 124.8 cm as the length where half of the individuals are immature. The corresponding figure calculated for the ratio of mature males is 131.4 cm. The former corresponds to the mean length at the onset of the pubertal stage defined in this study and the latter to that at the onset of the mature stage. Possibly the mean length at the start of actual adult stage lies between the two values.

If the large immature male (RLB 835) is excluded, the weight of the heaviest immature male is 24.5 kg and that of the lightest mature males 29.0 kg. One pubertal male weighed 24.9 kg (Table 10). Accordingly, the weight of male at the onset of sexual maturity is estimated to be between 25 and 29 kg.

TABLE 10. BODY WEIGHT AND MATURITY IN *PONTOPORIA BLAINVILLEI*

Body weight (kg)	Male			Female		
	Im	Pu	M	Im	Pu	M
21.0-23.9	3	0	0	5	0	0
24.0-26.9	2	1	0	6	0	0
27.0-29.9	0	0	2	6	1	1
30.0-32.9	0	0	2	1	1	0
33.0-35.9	1	0	0	0	1	2
36.0-38.9	0	0	0	0	0	2
39.0≦	0	0	0	0	0	2

Attainment of sexual maturity in female

The sexual maturity of the female was determined by the presence of at least one corpus luteum or albicans in the ovaries. Some immature females with developed Graafian follicles were considered as being at the pubertal stage. The youngest mature female appeared at the age of 2.0 years and the oldest immature at 4.0 years. The pubertal females ranged in an age between 2.1 and 2.8 years. The mean age at the attainment of sexual maturity is calculated from the ratio of adult females in each age group shown in Table 8. The least squares equation is expressed as follows:

$$y = 28.52x - 26.39, \quad 1 \leqq x \leqq 6$$

where x indicates the age in years and y the ratio of adult females in percentage. The age where half of the females are sexually mature, or the mean age at the attainment of sexual maturity, is 2.7 years.

The smallest mature and the largest immature female were 137 cm and 146 cm in length, respectively. The pubertal females were found between 136 cm and 144 cm in body length. The least squares regression of the data in Table 9 gives 140.3 cm as the body length where half of the females are sexually mature. This value is significantly smaller than the approximate length of 147 cm read on the mean growth curve corresponding to the mean age at the attainment of sexual maturity. This difference is caused by the cessation of growth in body length soon after the onset of sexual maturity.

The body weight of the largest non-pubertal immature female was 30.8 kg (1.2 years of age), and pubertal females were found in the range between 29.0 kg (2.4 years) and 33.1 kg (2.1 years). The smallest adult appeared at the body weight of 29.9 kg (4.0 years). All the females were sexually mature above the weight of 34 kg. Accordingly, it is expected that the female attains maturity at a body weight of 33 to 34 kg. The weight calculated for the mean body length at the age at sexual maturity of 2.7 years is about 35 kg, which is close to the above figure.

Attainment of physical maturity

The fusion of vertebral epiphyses to the centrum was examined on a limited number of individuals. The sexually immature individuals were, even if the epiphysis was not examined, reasonably considered in this study as physically immature.

In the present sample only one male was physically mature. It was 132 cm in body length and 16 years of age. The age of the oldest physically immature males was 5 years, represented by two sexually mature males. Their body lengths were 140 and 142 cm, respectively. Because of the scarcity of materials, it was impossible to determine the difference of the age at physical maturity of males and the corresponding value of females below.

The age of the oldest physically immature females was 4.0 years, and the age range of five physically mature females was from 4.0 to 8.0 years. This indicates that females attain physical maturity at the age of about 4 years or about 1 year after the attainment of sexual maturity. The mean length of the female at the attainment of physical maturity will be very close to the asymptotic length of 153.0 cm estimated in the former section. The largest physically immature female was 145 cm in body length, and the length of physically mature females ranged from 148 to 171 cm.

DISCUSSION

Scott (1949) found in cetaceans the following linear relationship between the maximum length of the adult, x in cm, and the neonatal length, y in cm:

$$y = 0.2441x + 44.3 \qquad (1)$$

Later, Ohsumi (1966) obtained for several species of odontocetes the following allometric relationship between the mean length of female at the attainment of sexual maturity, x in m, and neonatal length, y in m:

$$y = 0.532x^{0.916} \qquad (2)$$

If the asymptotic length of females 153.0 cm, and the mean length at the attainment of sexual maturity, 147 cm, estimated in this study for *P. blainvillei* are put in these equations, neonatal lengths of 81.6 cm and 72.6 cm are obtained from equations (1) and (2), respectively. The extraporation of the growth equation (page 55) gives a neonatal length of 76.1 cm. These, figures, especially the second, are close to the value estimaetd in the former section of this study.

The fetal growth rate and length of gestation can be deduced by the method of Kasuya (1977) or of Perrin *et al.* (1977). When x indicates the neonatal length in cm and y the fetal growth rate in cm/day at the linear part of the growth curve, the following equation was obtained from eight species of odontocetes (Kasuya, 1977).

$$y = 0.001802x + 0.1234$$

Accordingly, the length of time from the date when the extended straight fetal growth line cuts the axis of time to the mean date of birth is calculated by $x/(0.001802x+0.1234)$. If the neonatal lengths 81.6 cm and 72.6 cm are put in the equation, the duration is calculated as 291 and 275 days, respectively. The estimation of length of time from the start of gestation to the date when the extended linear growth line cuts the axis of time has some uncertainty. Hugget and Widdas (1951) estimated for the growth curve indicated by the cube root of the fetal weight that the length of time is $0.2 \times$(gestation time) for the gestation over 400 days. Laws (1959) indicated that the value will be 90% of the value estimated by Huggett and Widdas (1951), if the growth curve is based on the length. After repeated calculations beginning with a gestation of 350 days (for details see Perrin, Coe and Zweifel, 1976), the values obtained for species ***P. blainvillei*** were 0.130 (for linear growth period of 291 days) or 0.139 (275 days). These figures give a total gestation time of 334 days or 11.0 months (neonatal length of 81.6 cm) and 319 days or 10.5 months (neonatal length of 72.6 cm).

Perrin *et al.* (1977) found the following relationship between length of gestation in months (Y) and length at birth in cm (X).

$$\mathrm{Log}Y = 0.4586\,\mathrm{Log}X + 0.1659$$

This equation and the neonatal lengths of 81.6 cm and 72.6 cm calculated above give gestation lengths of 11.0 and 10.5 months respectively. Presumably the latter figure, 10.5 months, will be closer to the true value. These estimates show a good agreement with the range of 10.5 to 12 months obtained by Harrison *et al.* (Ms.). Further improvement of the estimate will depend on a better calculation of the neonatal length.

The age at the attainment of sexual maturity, 2.7 years, obtained for female *P. blainvillei* is the lowest in any cetacean which has been studied. This may be related to the small body size of the species. The only comparable species is *Phocoena phocoena*, which in the western North Atlantic attains sexual maturity at the age of 4 years (Gaskin and Blair, 1977). The same species in the North Sea is considered to attain maturity at 5 years in males and 6 years in females (Utrecht, 1978).

The age frequency of the present materials is shown in Fig. 11, where only the data of random collection are listed. A mode exists between 1 and 2 years. The frequency of the calves below 1 year of age is only 13 individuals, and the

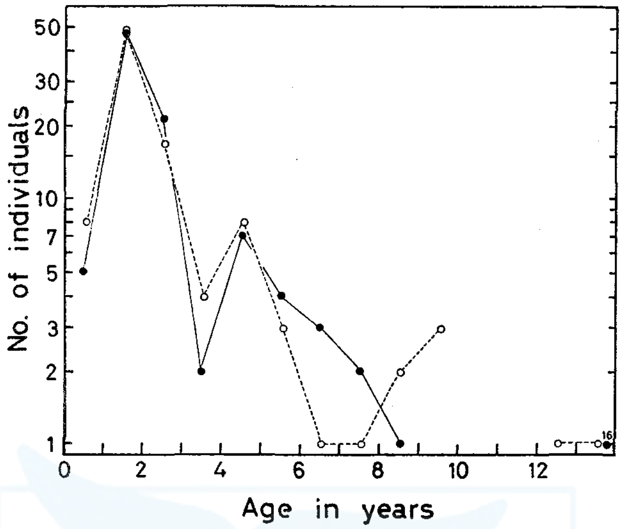

Fig. 11. Age frequency of *P. blainvillei*. Closed circle and solid line indicate males, and open circle and dotted line females. Only the random catch samples are included.

presence of bias in the sample is suggested. According to Harrison *et al.* (Ms.) the parturition peak of the species is in the second half of November to the second half of December (depending on the estimation of the mean neonatal length). Since most of the present materials were obtained in December and January, there should have been more newborn calves if the materials were not biased. The number of pregnant females, namely the number of calves which would have been born in the next year, is close to the number of calves below 1 year of age. This is again an indication of the under representation of pregnant females, and presumably that of other adult individuals of both sexes. This bias may cause an error in the estimation of the mean age at the attainment of sexual maturity, the mean growth curve after this age, and the maximum length of life-span. However, since the correlation between age and sexual maturity is very high in the present species, the bias in the estimation of the first two figures will be slight. Samples bias related to the method of fishing is known in *Stenella coeruleoalba* and *Phocoenoides dalli* (Kasuya, 1978).

Though catchability might be different between the sexes, the difference was negligible in the immature individuals. The ratio of females in the total of 148 individuals below 3 years of age is 50.0%. This is considered to be close to the real sex ratio at the immature stage.

Among 27 adult females dealt with here, the reproductive stage is known in 15 individuals. They are seven pregnant, two pregnant and simultaneously lactating, three lactating, and three resting females. The last category indicates adult females neither pregnant nor lactating. The lactating or resting females are limited to December and January, the parturition season of the species. The data from other months are one pregnant in August, two in October, and two in November. These data suggest that lactation usually lasts a short period, presumably not longer than eight or nine months. This figure is in good agreement with the length of nursing period estimated in the former section. Females which weaned a calf before August or September will become pregnant in the next mating season in January. Accordingly we suspect that a two years cycle of breeding will be most frequent in this species.

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EXPLANATION OF PLATES

PLATE I

Fig. 1. Immature testis. RLB809, body length 111 cm, weight of testes 1.7 g, age 2.0 years. 19 Dec. 1972. Scale indicates 0.1 mm.

Fig. 2. Pubertal testis. RLB821, body length 130 cm, weight of testes 3.1 g, age 2.2 years. 24 Dec. 1972. Same magnification with Fig. 1.

Fig. 3. Mature testis. AO1972–4, body length 124 cm, weight of testes 5.8 g. 29 July 1972. Same magnification with Fig. 1.

Fig. 4. Mature epididymis. AO1972–4. Same magnification with Fig. 1.

PLATE II

Decalified and stained thin sections of teeth. Scale indicates 2 mm, all figures in same magnification. C, cementum. Open circle, neonatal line in dentine.

Fig. 1. RLB600, 0.2 dentinal layers, 84 cm male, 14 Jan. 1971. Immature.

Fig. 2. RLB861, 0.4 dentinal layers, 103 cm female, 4 Jan. 1973. Immature.

Fig. 3. RLB648, 1.5 dentinal layers and 1.8 cemental layers, 105 cm female, 27 Jan. 1971. Immature.

Fig. 4. RLB698, 2.5 dentinal layers and 2.3 cemental layers, 120 cm male, 18 March 1971.

PLATE III

Decalcified and stained thin sections of teeth. Scale indicates 2 mm, all the figures in same magnification. C, cementum. Open circle, neonatal line in dentine.

Fig. 1. AO1971–54, 4.0 dentinal layers and 4.5 cemental layers, 157 cm female, 24 Dec. 1971.

Fig. 2. AO1971–57, 6 dentinal layers and 8 cemental layers, 153 cm female, 30 Dec. 1971. Sexually mature.

Fig. 3. RLB592, 7 dentinal layers and 13 cemental layers, 144 cm female, 14 Jan. 1971. Sexually mature.

PLATE IV

Fig. 1. Decalcified and stained thin section of a tooth. RLB577, 6 dentinal layers and 7 cemental layers, 125 cm male, 5 Jan. 1971. Sexually mature. Scale indicates 2 mm. For other marks see Plate III.

Fig. 2. Decalcified and stained preparation of partially masked tooth. Left half, undecalcified thin section; right half decalcified and stained part. RLB878, 133 cm male, 16 Jan. 1972. Immature. Scale indicates 1 mm. Photographed under transmitted light. For marks see Fig. 1.

PLATE V

Comparison of annual layers in dentine and cementum Scale indicates 0.5 mm, all figures in same magnification. Bar, boundary of prenatal and postnatal dentine. C, cementum. Closed circle, annual growth layers.

Fig. 1. RLB600. Same tooth with Plate II, Fig. 1.

Fig. 2. RLB861. Same tooth with Plate II, Fig. 2.

Fig. 3. RLB648. Same tooth with Plate II, Fig. 3.

Fig. 4. RLB698. Same tooth with Plate II, Fig. 4.

PLATE VI

For explanations see Plate V.

Fig. 1. AO1971–54. Same tooth with Plate III, Fig. 1. Deposition of osteoden-

tine started.

Fig. 2. AO1971-57. Same tooth with Plate III, Fig. 2. Osteodentine nearly fills most of pulp cavity leaving narrow canals.

PLATE VII

For explanations see Plate V.

Fig. 1. RLB592. Same tooth with Plate III, Fig. 3. Deposition of osteodentine started on some part of pulp wall.

Fig. 2. RLB577. Same tooth with Plate VI, Fig. 1. Central part of pulp cavity is almost filled by osteodentine.


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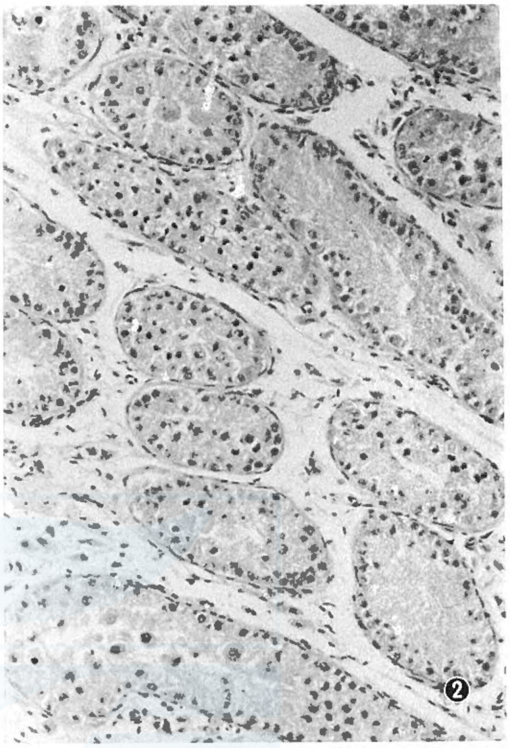
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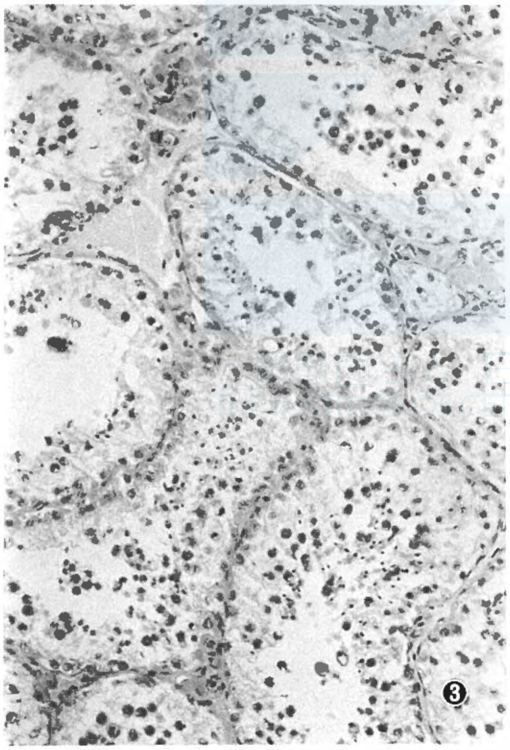
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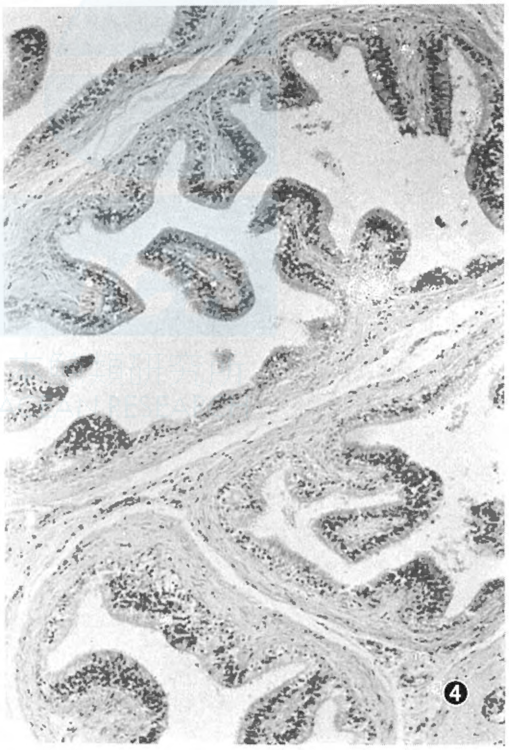
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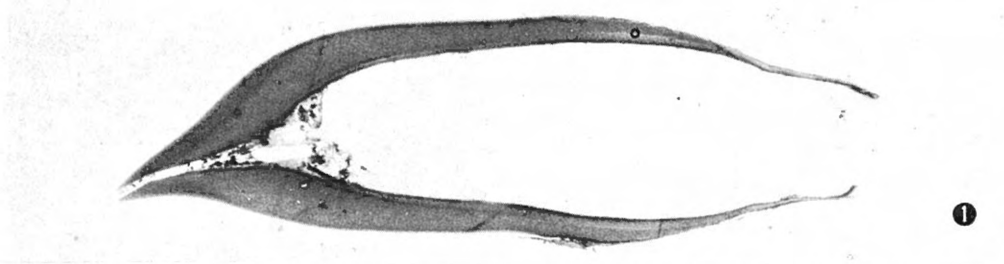

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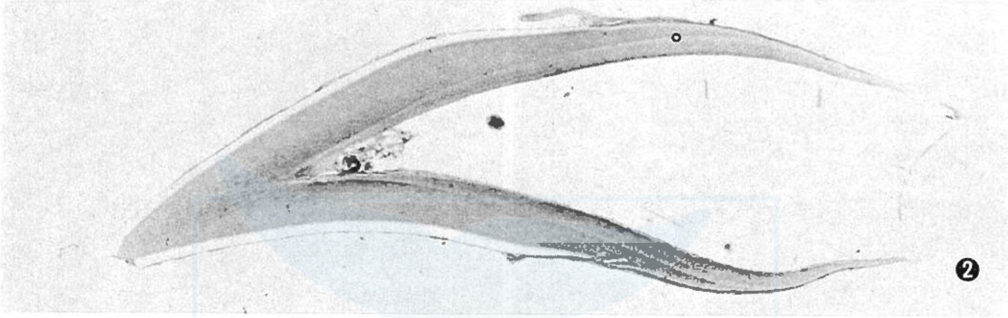

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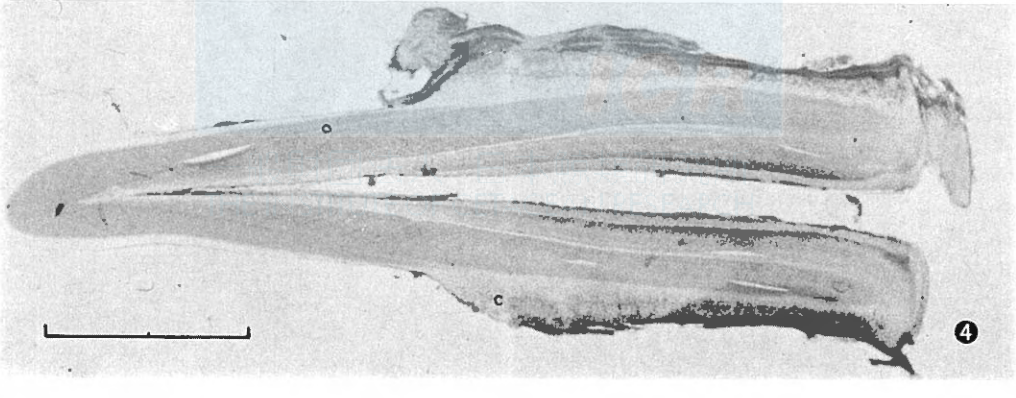

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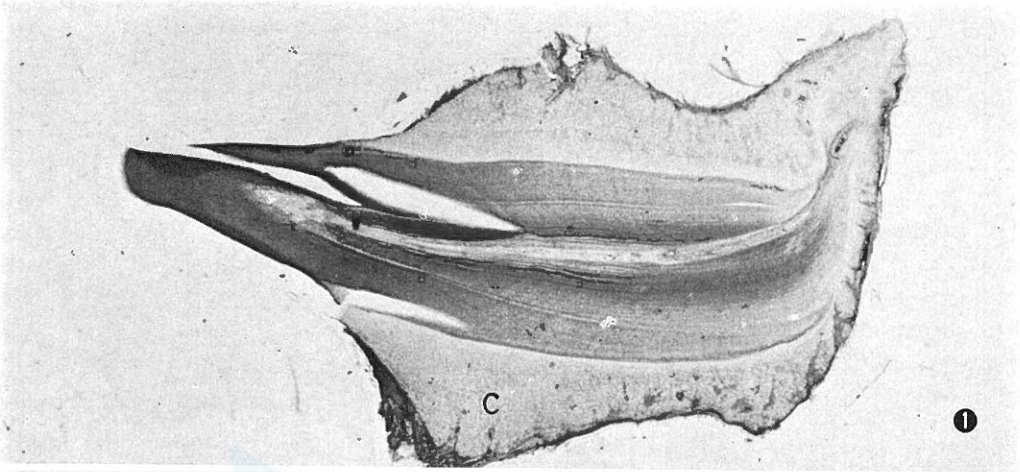

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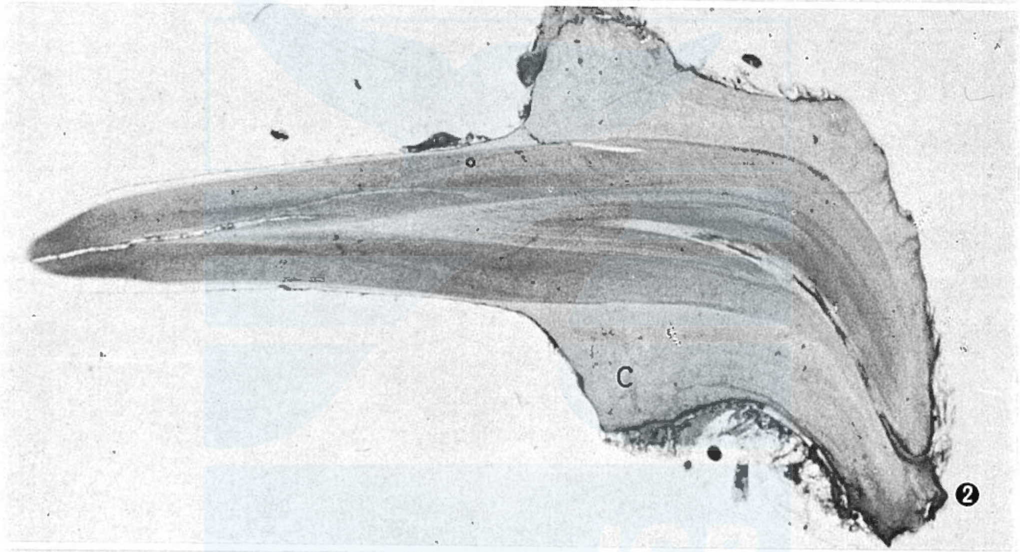

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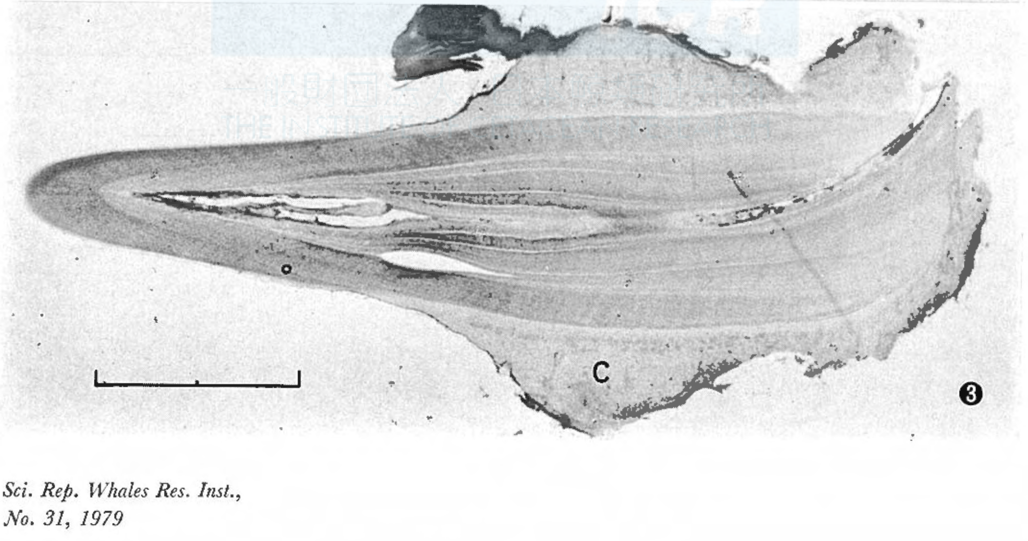

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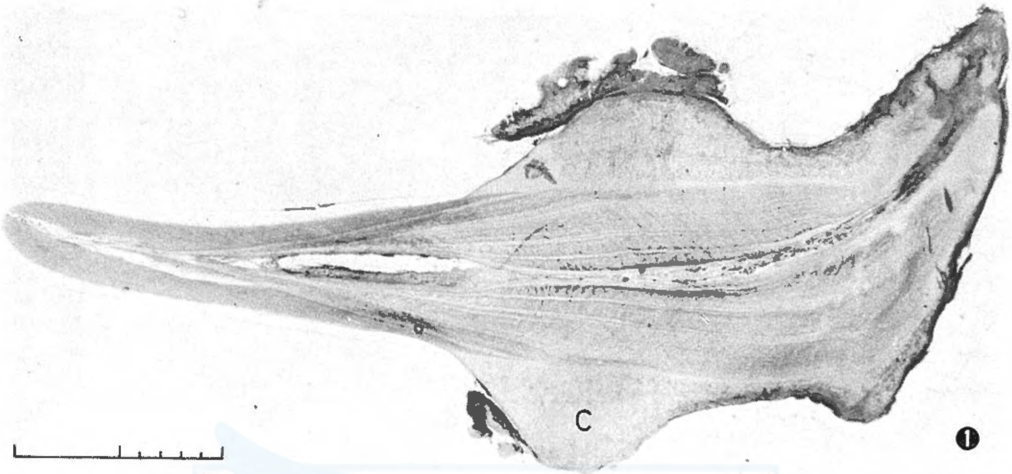

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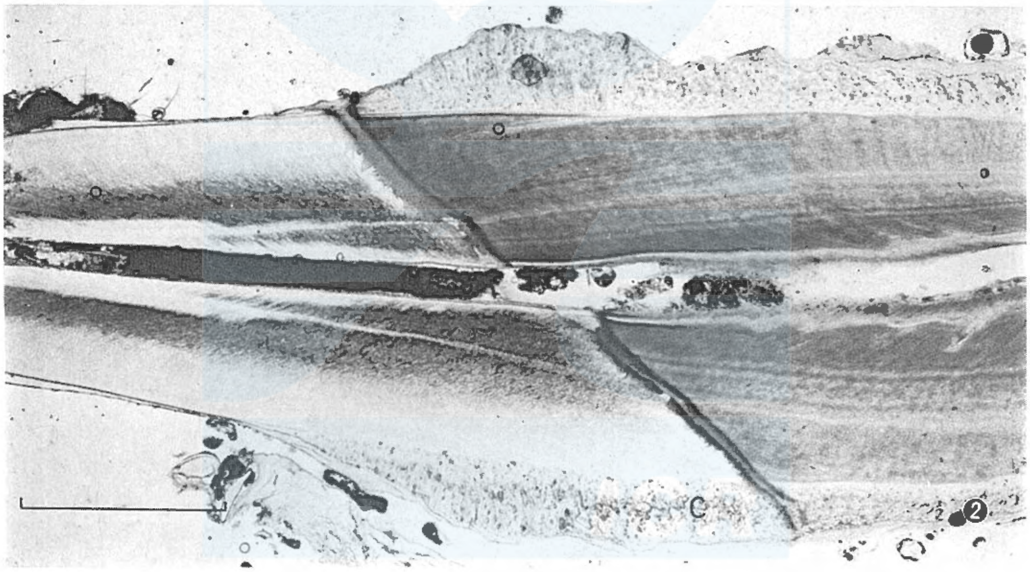

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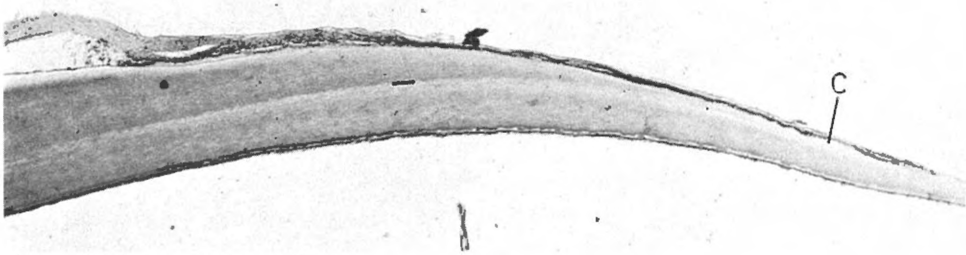

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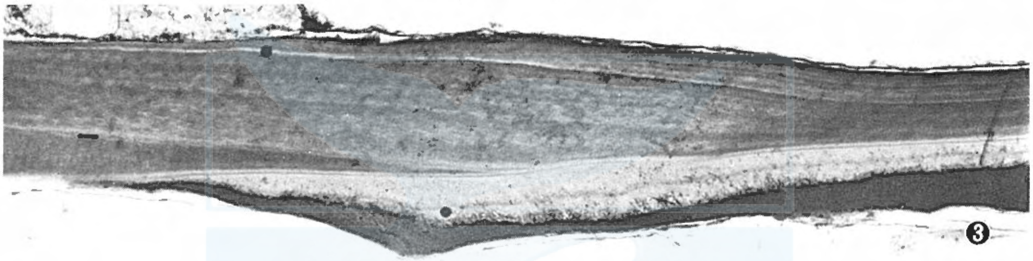

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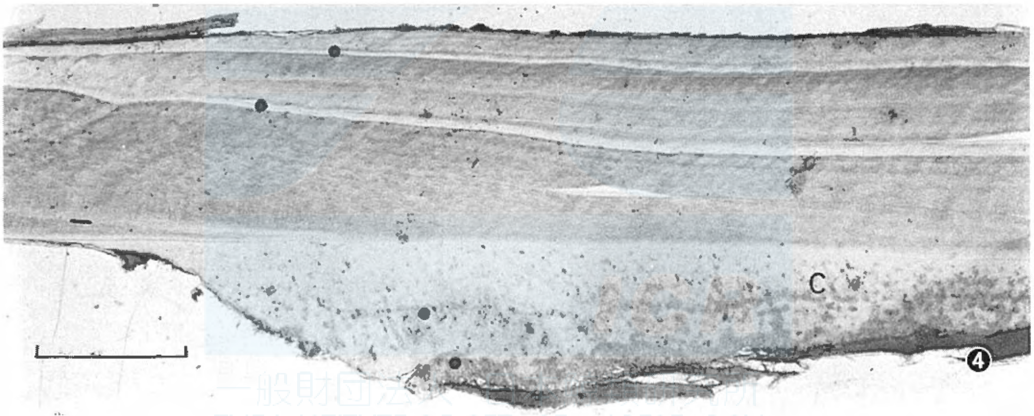

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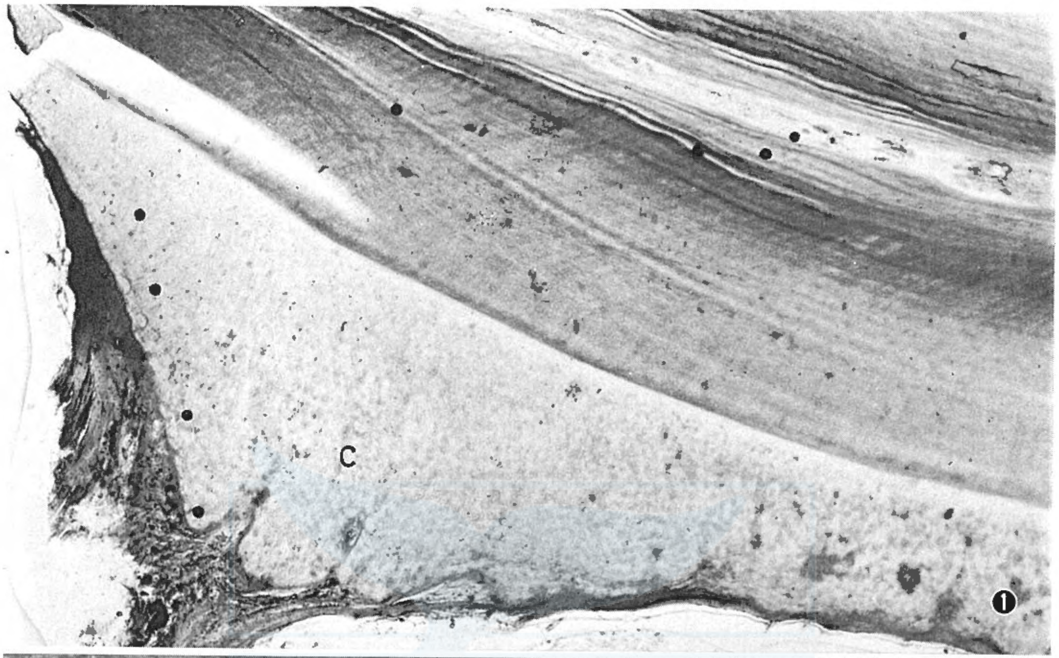
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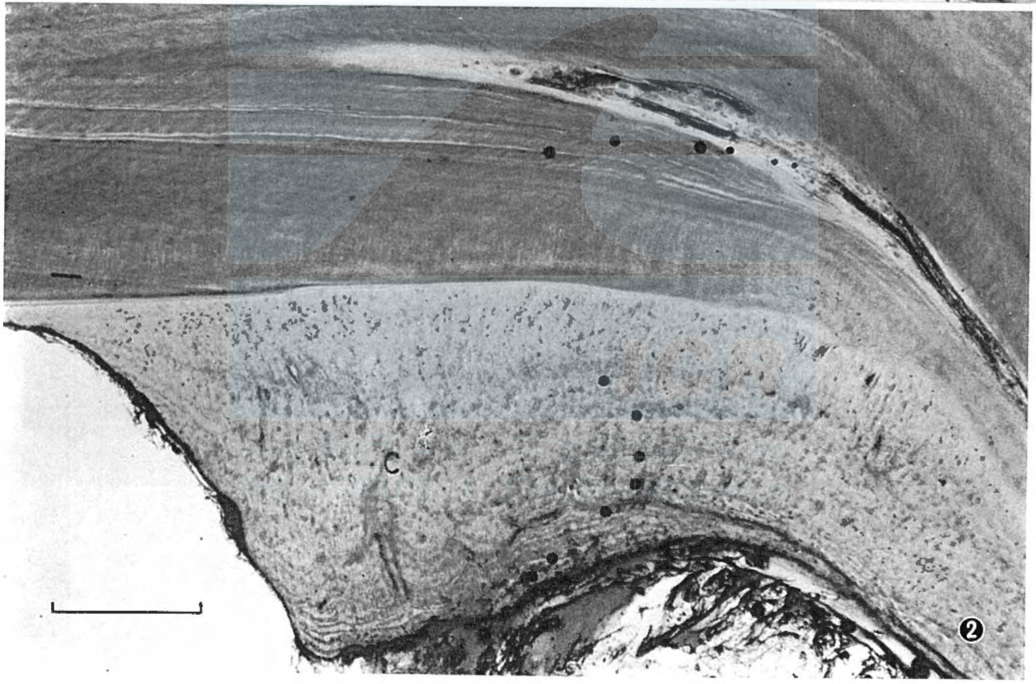
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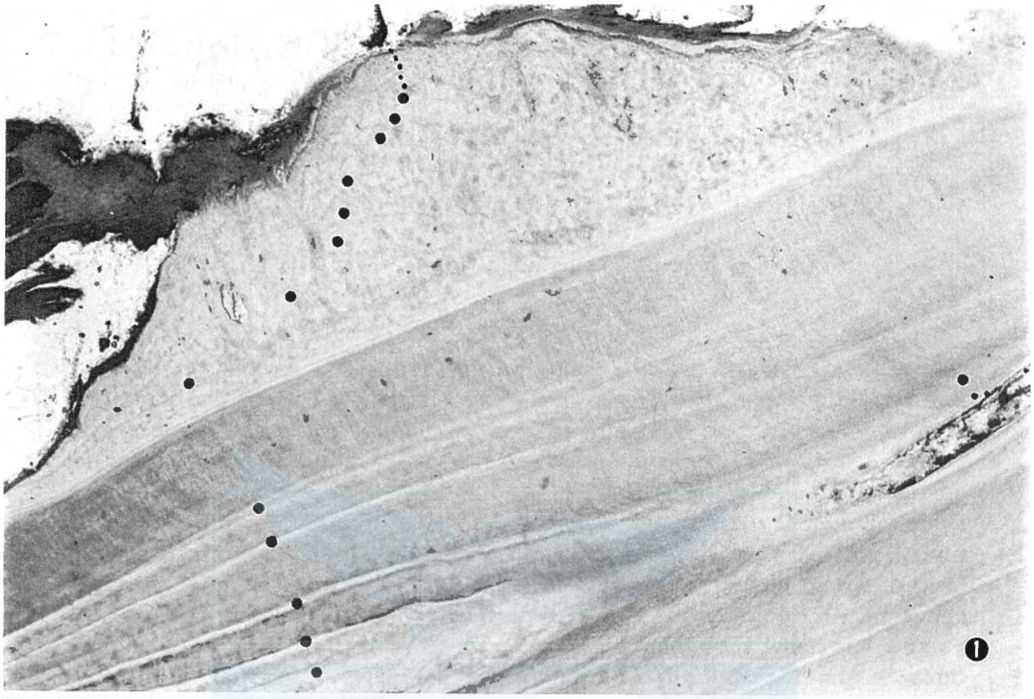

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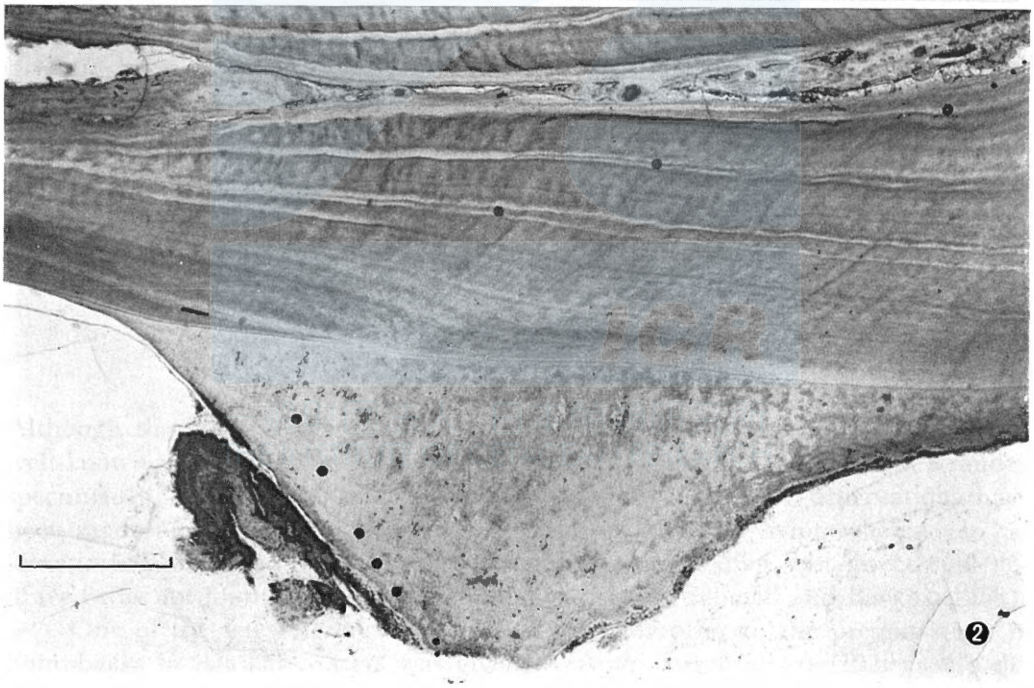

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