

THE VARIATION IN THE DEVELOPMENT OF PELAGE OF THE RIBBON SEAL WITH REFERENCE TO THE SYSTEMATICS

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ABSTRACT

More than four hundreds pelages of the ribbon seal (*Histriophoca fascita*) were examined to know the development of the patterns and their variation. To describe them, some terminology were devised. The formations of these bands pattern were closely related to the pigmentation. Concerning to the pigmentation, two types of the pigmentation were found such as basic pigmentation and secondary pigmentation. The former pigmentation was found in both sexes of all ages except pups (not white coat pups), and the later pigmentation was found in adult males and in some females. However, some adult males did not show secondary pigmentation exceptionary. From these formations of the pigmentation, the ancestral form of the ribbon seal was speculated. The small ringed pattern was also found, and systematic reverse or atavism was considered and discussed.

INTRODUCTION

The ribbon seal (*Histriophoca fascita*) is generally known for its ribbon mark. Their color pattern is much characterized by sex. The ribbon seal and harp seal are the only seals with banded pelage, and in these seals the color pattern has not been discussed and argued while the sexual dimorphism seen in polygamous form has been well noted from the point view of social biology, evolution and so on. In general, however, divergence in the pinnipeds from meaning of adaptation occurs in many directions. The less arguments and discussions on the color pattern of the ribbon seal may due to the less knowledge on this seal. When we consider the problems on color patterns, we have quite small knowledges on their distribution, movements, breeding, social behaviour and etc. Yet, it is still necessary to discribe the color pattern itself for the sake of future study of adaptation, evolution and systematics on this seal. The present

paper is written to introduce the color pattern itself of the ribbon seal, and variations are described with some new findings.

MATERIALS AND METHODS

All pelages of the ribbon seal dealt in the present study were collected from the area along the Sakhalin (south to 50°N) in the Sea of Okhotsk from the mid to the end of May 1975. The pelages of these seals were stocked in the fur companies after they were tentatively tanned. The authors had a chance to examine the pelages in October 1975 at Engaru Fur Company and Hakodate Fur Company. The pelages were recorded by photo to examine. The pelages size were measured from the nose tip to the root of the tail. The measurements, however, were sometimes rough because the pelages were broken in the measuring points. The sexes were also recorded by examining the genital openings (penis openings in males and teats openings in females). The total numbers examined in this study were 472 pelages (280 males and 192 females).

1. *The formation of the ribbon pattern*

It is widely known that the adult male ribbon seal has the characteristic white bands on their head to neck part, lateral body sides and lumber part which are so-called ribbon pattern. These white bands are also found in adult females, yet they are not so distinct. It is also generally recognized that these white bands are not seen in both sexes of young seals. Concerning the revelation of these bands, however, it is still uncertain when and how these bands are formed.

According to the Tikhomirov (1966), during the time from the moulting of the lanugo coat to the first moulting the seals have no pattern showing dark grey color in the dorsal side and bright grey in the belly side. After the first moulting at one year old they begin to show the distinct shield shaped pattern against the darker grey back, however there found no sexual dimorphism in the color pattern. After the second moulting at 2 years old, they first begin to show the peculiar ribbon pattern in males, and sexual dimorphism was found in the color pattern. The seals show the full adult type ribbon mark in males at 3 years old.

In our pelage study, we failed to get age informations from canine teeth, however, we got almost same results as Tikhomirov (1966) attained. As shown Table 1 and Plate I, all pelages were easily classified into four categories in males and three in females such as stage I, stage II, stage III, and stage IV in males by the developmental stages of the pattern, and each stages of both sexes well corresponded with the results by Tikhomirov (1966). The seals of both sexes of stage I have no ribbon pattern but showed grey or brownish grey back and creamy white or brownish yellow bellies. The seals of this stage were identified to be pups by the sealers and the pelage process workers. Actually these pelages corresponded with the pelages of 0 year old described

TABLE 1. PELAGE MATERIALS USED IN THIS STUDY. ALL PELAGES WERE CLASSIFIED IN EACH 10 CM BY THE LENGTH, AND THE DEVELOPMENTAL STAGES OF PELAGE PATTERN WERE EXAMINED. NUMBERS IN PARENTHESIS SHOW PERCENTAGE OF EACH STAGE IN EACH CLASS.

Class of pelage size in cm	Numbers	Developmental stage of pattern			
		stage I	stage II	stage III	stage IV
Males					
110-120	2	2 (100.0)			
120-130	10	9 (90.0)		1 (10)	
130-140	31	10 (32.2)	16 (51.6)	3 (9.7)	2 (6.4)
140-150	35	5 (14.3)	11 (31.4)	2 (5.7)	17 (48.6)
150-160	63	1 (1.6)	1 (1.6)	3 (4.8)	58 (92.0)
160-170	75		1 (1.3)	1 (1.3)	73 (97.4)
170-180	55				55 (100)
180-190	7				7 (100)
190-200	2				2 (100)
	280	27	29	10	214
Females					
110-120	6	6 (100.0)			
120-130	12	10 (83.3)	2 (16.7)		
130-140	28	6 (21.4)	20 (71.4)	2 (7.1)	
140-150	17	2 (11.8)	9 (52.9)	6 (35.3)	
150-160	45	1 (2.2)	22 (48.9)	22 (48.9)	
160-170	63		19 (30.2)	44 (69.8)	
170-180	18		3 (16.7)	15 (83.3)	
180-190	3		1 (33.3)	2 (66.7)	
	192	25	76	91	

by Tikhomirov (1966). From above the seals of stage I were supposed to be 0 year old. The seals of stage II still showed the same pattern between two sexes. They begin to show the peculiar shield pattern with narrow white line at its margin, and at the same time the initial pup dorsal dark color were still found. These seals of this stage were also estimated to be 1 year old by the sealers and the pelage process workers, and also the comparison with the results by Tikhomirov (1966) suggested these seals to be 1 year old. In stage III seals begin to show the sexual dimorphism. Being incomplete, male seal pelages of this stage showed the ribbon pattern with obscured white bands. These pelages did not show as strong contrast as seen in full adult type pelages as over all look, and shield pattern had developed extending four feet towards the belly side to connect each other from both sides making the ring patterns at each lateral sides. The margin of this developed shield pattern were relatively clear. On the contrary, the other margin of white bands were unclear, so that the ribbon pattern did not appear clearly at this stage. This may due to the time

duration of pigmentation between four feeted dorsal pigmentation (developed shield pattern) and other pigmentation, and also due to decolorization in white bands parts. As a matter of facts in this stage unclear radial thin dark lines were found in the white bands. In this stage initial pup dorsal dark color which were found in stages I and II were already lost. Concerning the age of this stage, the sealers and the pelage process workers do not classify the pelages by age, however, seals of this stage were supposed to be 2 years old in accordance with pelages of 2 years old seals described by Tikhomirov (1966). Pelage pattern of female seals of stage III were apparently different from these of males. Wide variation being found, seals generally showed indistinct ribbon pattern. The pigmentations did not develop as strongly as males of same stage. The peculiar shield pattern which were always found in stage II usually changed to have extended four feet. Over all look, however, was very bright, for the pigmentations at lateral body side and hip parts were dim. The decolorization at white bands developed to vanish the initial pup dorsal dark color which was still found at stage II. The ages of female seals of this stage III were supposed to be over 2 years old. Only in males stage IV was possibly classified. Seals of this stage showed complete adult type ribbon pattern. The ages of seals of this stage were supposed to be over 3 years old.

As already described, we do not have any age informations from the canine teeth in this study, yet we could know the formation of the ribbon pattern by the age in accordance with the results by Tikhomirov (1966). However it is considered that age variation may occur in the formation of the ribbon pattern. To make this problem much surer, we studied on the captured ribbon seals. Kamogawa Sea World well succeeded in keeping a male and a female ribbon seals. A male and a female pups were kept from 1973 and 1974 respectively. This male seal developed his pattern showing the same stages as described above after each moulting in May, and showed complete ribbon pattern of the final stage in this study at age 3 years old. On the other hand a female seal showed the same pattern as stages I and II at age 0 and 1. However, she had died at age 1 year old in 1974. From above all, stages I, II, III and IV well corresponded to the age 0, 1, 2, and over 3 years old in males, and stages I, II, III also to the age 0, 1, and over 2 years old in females.

2. *Analysis from schematic diagram*

As mentioned above, the ribbon pattern was formed age by age showing the peculiar age classes such as stages I, II, III, IV in males and stages I, II, III in females. We already described when these pattern appear, however, we still do not know how they appear. To analyze this problem, we made some schematic diagrams in each sex, and for the explanation convenience some terminology were used. Farther more in the former chapter, we used stage classes such as stages I, II, III, IV for the convenience, however, each stage corresponded to age classes such as 0 year old, 1 year old, 2 years old and over 3 years old respectively over all. Therefore we use age classes instead

of stage classes in this chapter and later chapters.

Male

Plate II shows the schematic peculiar pattern of each age classes, this plate also shows the degrees of pigmentation. Seals of 0 year old have their dorsal pattern which are named pup pattern (P. P.). At age one, the darker shield pattern (S. P.) appears in the center part of pup pattern, and at the same time decolorization occurs at the margin of shield pattern. As a result pup pattern are divided into four pattern such as initial neck pattern (I. N. P.), initial lateral patterns (I. L. P.) and initial hip pattern (I. H. P.). The pigmentations of these patterns are same degree as pup pattern at age 0. The pigmentation and decolorization develop quickly at age 2. The basic shield pattern developed having four feet which connect each other to make round circle at lateral side. This developed shield pattern (D. S. P.) is almost real black. The same degree of pigmentation appears in the head and neck parts forming the neck pattern (N. P.) which took place the initial neck pattern (I. N. P.). The decolorization at the outer margin of developed shield pattern occurs as fast as pigmentation forming the neck band (N. B.), lateral bands (La. B.) and lumber band (Lu. B.), so that the initial lateral pattern at age 0 do not appear at age 2. At the same time, however, the lesser new pigmentation begin to occur innerpart of the lateral bands and at hip part forming the lateral pattern (L. P.) and the hip pattern (H. P.). The developmental stage of pigmentation and the decolorization attains the final stage at age 3. The neck pattern and the developed shield pattern come to much more black, and the delayed pigmentation of the lateral pattern and the hip pattern develop to come as black as the pigmentation of other patterns. At the same time each bands appears whiter by the developed decolorization.

As mentioned above, we could find out that time duration of the pigmentation and the decolorization exist in forming the so-called ribbon pattern, and furthermore we can classify the pigmentation of each pattern by their developmental stages, while the decolorization of each bands is impossible to classify because of their same developmental stage. Fig. 1 shows this pigmentation stage of each pattern. The pigmentation of pup pattern is decreasing and took over by other pigmentation or disappear. We call this as the degenerative pigmentation. The pigmentation of the shield pattern is very stable and very actively increase, and the neck pattern pigmentation is relatively stable and increasing. These pigmentations are classified as the basic pigmentation. The latest pigmentations of the lateral pattern and the hip pattern are not stable, for these are much variable (explained in the later chapter). These are classified as the secondary pigmentation.

Female

Plate III shows the schematic diagrams of pattern of each age class in females. As shown in Plates II and III, females show the quite same pattern and the same

degrees of pigmentation and decolorization as males at age 0 and 1. At age 0 they possess the pup pattern, and at age 1 the shield pattern, initial neck pattern, lateral patterns and initial hip pattern appear as well. At age 2, the shield pattern develop its four feet at each corner making the round circles at lateral sides. This developed shield pattern is quite same as males not in the degrees of pigmentation but in form. The neck pattern, the lateral pattern, and the hip pattern also appear at this age, while the pigmentation of these pattern also not so strong as males. These pattern and pigmentation do not seem to change over 2 years old. Compared with males, overall look of female seems to be quite bright and no pattern seems to exist in females at first glance. However, these are due to the less pigmentation in females. They actually possess the each same pattern as males. These pigmentation stage of each pattern are also shown in Fig. 1. Concerning to the sexual dimorphism, it is generally believed that the male ribbon seal shows distinct ribbon pattern and the female seal does not show it. As already mentioned above, it was revealed that the sexual dimorphism are found not in the pattern itself but in the degrees of the pigmentation of the pattern. As seen in Fig. 1 and Plates II and III, the sexual dimorphism occurs after 2 years old, and completion of dimorphism is found at age 3. Probably, these are closely related to the sexual maturation. We do not know the age of sexual maturation of the ribbon seal. According to Tikhomirov (1966), however, it seems to mature after age 2 and 3 in females and males.

	ages	0	1	2	3	
Male	P.P.	+	+			degenerative pigmentation
	S.P.		++	+++	+++	basic pigmentation
	D.S.P.			+++	+++	
	N.P.			+++	+++	secondary pigmentation
	La.P.			++	+++	
	H.P.			++	+++	
Female	P.P.	+	+			degenerative pigmentation
	S.P.		++	++	++	basic pigmentation
	D.S.P.			+	+	
	N.P.			+	+	secondary pigmentation
	La.P.			+	+	
	H.P.			+	+	

Fig. 1. Development of the pigmentation of each pattern. Plus symbols show the degree of the pigmentation. Abbreviation shows as follows. P.P., Pup Pattern; S.P., Shield Pattern; D.S.P., Developed Shield pattern; N.P., Neck Pattern; La.P., Lateral Pattern; H.P., Hip Pattern.

3. *The variations of bands, pigmentations and other charactor*

As already introduced, three types of distinct white bands are seen on the pelage such as head band and two lateral bands which encircle the fore flippers, and lumber band. Of all three type bands, head band showed the least variation. This band circulate the neck and the throat slightly prolonged anterior at the head, so that it shows the chevron when we saw the tanned sheet of pelage (Plate V). Being slight variation in this band, these are no individuals in our materials which never form the chevron. The lateral bands which form the large ringed patterns in the sheet of tanned pelages show much more variation than the head band. Some variation being found in the size of the ring itself and width of the band as well, and rather wide variations were found in the connection or the combination to other bands. Concerning to the way of connection three basic types were derived such as type 1, no connection to other bands; type 2, connection with lumber band (including the case of one side band connecting to the lumber band); type 3, connection to both head band and lumber band (including the case of one side band connecting to other band (Plate IV). The appearance frequency of each type were shown in Table 2. Type 1 is the most popular with 51.7% frequency, and 34.4% for type 2 and 13.9% for type 3 respectively. However, there seemed no pelages which showed the connection between the lateral bands and the head band. It also seemed that each lateral band never connect at dorsal side while they usually connect at belly side. The widest variation was apparently found in the lumber band. The variation found in this band was so much wide that it seemed quite difficult to describe or classify into some categories precisely. For the convenience in this study the lumber band variations were only shown in Plate V showing from simple form to complicated form.

The variation seen in the bands was described already from the understanding that these bands are peculiarly specialized in this species. The pattern of these bands, however, have never been interpreted from the point of view of its origin, for these white bands are too much distinct and attractive to draw the attention to the dark pigmented counter pattern against the white bands. The darker the pigmented counter parts the more remarkably the white bands appears. On the other hand, the less pigmentation makes the bands be

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 TABLE 2. APPEARANCE FREQUENCY OF EACH VARIATION TYPE OF THE LUMBER BANDS. NUMBERS IN PARENTHESIS SHOW THE NUMBER OF CASES THAT ONE SIDE OF TWO LUMBER BANDS CONNECTED TO OTER BANDS.

Type	Numbers	%
Type 1.	108 (0)	51.7
Type 2.	72 (18)	34.4
Type 3.	29 (9)	13.9
Total	209	100

more obscure. In the present study such above mentioned obscure bands were found. As shown Plate VI, the less pigmentation were found in the lateral pattern and the hip pattern. We found six examples of this less pigmentation pelages out of 214 pelages of over 3 years old male seals, and the frequency was 2.8%. These less pigmentations make the lateral bands and lumber band obscure as if those bands do not exist. On the other hand the pigmentation at the neck pattern and the developed shield pattern were very strong and stable, and such less pigmentation were not found. This may relate to the less variation of the head band mentioned already. The less pigmentations in lateral parts and hip parts may relate to wider variation of the lateral bands and the lumber band already mentioned. With regards to the female pattern, the contrast being obscure, female shows the distinct dorsal pigmentation which form the same developed shield pattern as the males, while the pigmentation in the lateral pattern and hip pattern are not strong as much as in the developed shield pattern. Therefore in the females no lateral bands and lumber bands were often found. From above as already mentioned in the former chapter, the pigmentation of the ribbon seal were possibly classified into two stages from the phylogenetic aspects, basic pigmentation and secondary pigmentation, indicating speculately that the ribbon seal in its ancestral form had the pigmentation in smaller area such face-head parts and shoulder-dorsal parts showing the brighter phase as over all look (Plate VII), and secondary pigmentation had occurred in the lateral and hip parts resulted the formation of the peculiar bands so-called ribbon marks. Of course sexual dimorphism by the pigmentation degrees might existed even if it was not distinct as much as today's ribbon seal.

The variation of the bands and pigmentation were described above, and the formation of the ribbon pattern were explained. In the present study farther variation were found. As shown Plate VI, the small ringed pattern or spotted pattern was found in some of pelages. The appearance frequency was as shown in Table 3. According to the numbers of rings or spotted patterns they were classified into three degrees. Males showed higher frequency (8.8%) and in females these patterns are not distinct and they showed lower frequency (5.6%). This difference between sexes may due to that these small white ringed or spotted patterns are embossed against darker pelages of males and are easily found. This ringed or spotted patterns well resembles to those of the harbour seal (*Phoca vitulina*; both ice-breeding and land-breeding types) which were mentioned Belkin *et al.* (1969), and Naito (1973). On these ringed pattern of the harbour seal, McLaren (1966) pointed out to be atavism related to the ringed seal. In this study it is quite difficult to deny that these small ringed patterns are nothing but the only simple variation, because they appeared pretty high frequency (8.8%) in adult males. The present stage of study on this problem cannot settle the arguments, however, this finding in the ribbon seal may support that these small ringed patterns are the pretty stable systematic or phylogenetic character which appears in some taxonomic groups.

TABLE 3. APPEARANCE FREQUENCY OF THE PELAGES ON WHICH THE SMALL RINGED OR SPOTTED PATTERN WAS OBSERVED. THE PELAGES WERE CLASSIFIED INTO THREE DEGREES BY NUMBERS OF THE RINGS AND SPOTS.

	Males	Females	Total
Numerous	2	0	2
Medium	4	0	4
Rare	14	5	19
Total	20	5	25
Numbers examined	226	90	316
Total ratio for examined numbers	8.8%	5.6%	7.9%

DISCUSSION

The pelage color pattern of the ribbon seal were studied, and revelation of the color pattern according to ages, sexual difference, the bands variation, the formation of the bands, and the small ringed patterns were examined as systematic character.

Concerning to the sexual segregation in the pinnipeds, the divergence occurred in many ways. The remarkable sexual segregation are well known in the land-breeding polygamous seals such as the fur seals, the elephant seals and etc. In these seals, sexual dimorphism seen in body size, size of canine teeth and etc. seem to be derived from the possession of territory and mating females through the struggles between males. On the contrary sexual dimorphism seen in the pelage pattern are only found in the ribbon seal and harp seal. The ribbon seal occurs in the unstable dispersed pack ice area in the breeding season (Burns, 1970; Fay, 1972). This seal does not aggregate but appears alone on the ice floes. Each individual occupies each ice floe (Naito, unpublished). Therefore these remarkable pelage pattern may have some effects to increase a chance to mate, or may effect on females as display from a distance even on ice floes or darker under water where the surface is covered by ice floes. The breeding behaviours of this seal, however, are not known at the present stage of our study, therefore explanation on some significance of this pelage pattern seemed to be quite difficult from the aspects of breeding or social behaviour.

As to phylogenetic problems, some findings were made in the present study. The peculiar pelage pattern of this seal were formed by the two stages of pigmentation such as the basic pigmentation and the secondary pigmentation. The basic pigmentation was found in all of adult males and females even in immature seals of both sexes, and the secondary pigmentation was not always occurred in some adult females and even in some of adult males. When we consider that the secondary pigmentation are the acquired character in their pathway of evolution, it is supposedly considered that the ancestral form of the ribbon seal would not have the lateral and lumber bands pattern, but showed dark patterns around the face and shoulder-dorsal area against the bright ground

color. This speculated ancestral form would much resemble to the harp seal in the Atlantic, because this seal shows smaller pigmentation parts and brighter color over all. However, to attain some conclusion on the relation between the ribbon seal and the harp seal, it is essential to examine the variation of the pelage pattern of the harp seal as well as the ribbon seal.

The small ringed patterns were also found in this study, and estimated to have some systematic characters. This may support the hypothesis that ringed patterns occur as atavism (McLaren, 1966). Burns and Fay (1970) showed the systematic relationship among the four smaller seals of the tribe Phocini (*Histiophoca*, *Pagophilus*, *Phoca*, *Pusa*) by the osteological study. They indicated the stronger interrelationship between *Histiophoca* and *Pagophilus*, and also suggested the stronger interrelationships between *Pagophilus* and *Pusa-Phoca* group than those between *Histiophoca* and *Pusa-Phoca* group. From above relationships we can expect to find the some ringed patterns from the harp seal, too.

ACKNOWLEDGMENT

This work were performed by examining the larger number of pelages, and we are very much indebted to Mr. Y. Suzuki, the president of Engaru Fur Company and Mr. Kodama, the Hakodate Fur Company. They were kindly permitted us to examine and take photographs their pelages. We also would like extend our sincere thanks to them for their kindness to permitted us to use their facilities.

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EXPLANATION OF THE PLATES

PLATE I

The developmental stages of the color pattern. From top stage I (pup), stage II (1 year old), stage III (2 years old), stage IV (3 years old). Left, males; right, females.

PLATE II

The schematic diagrams of male pelage pattern. From top to below 0 year old, 1 year old, 2 years old and 3 years old.

PLATE III

The schematic diagrams of female pelage patterns. From top 0 year old, 1 year old and 2 years old.

PLATE IV

The variation of lateral bands. From top, Type 1 (no connection to other bands), Type 2 (connection to lumber band), Type 3 (connection to both lumber and head bands).

PLATE V

The variation of the lumber band. Arranged from simple form to more complicated form from left top to right bottom.

PLATE VI

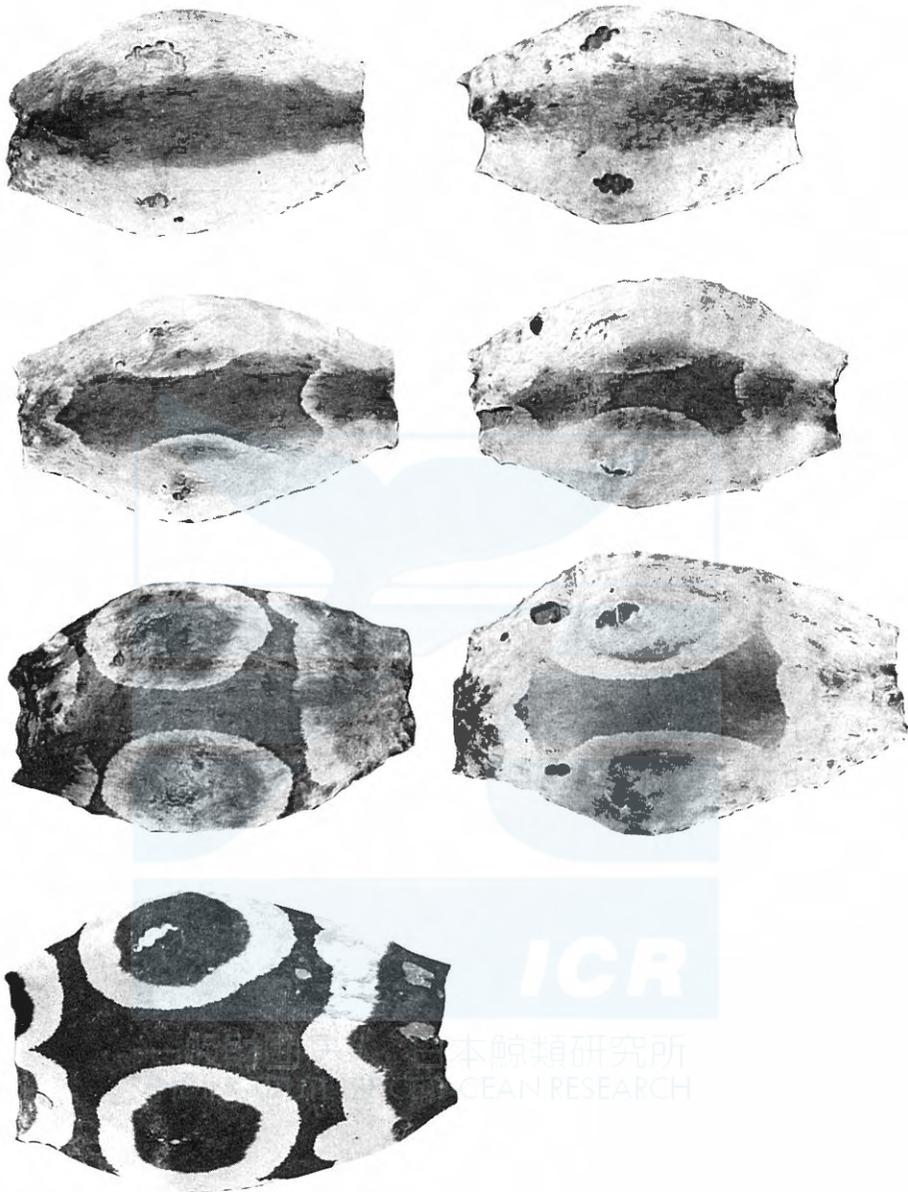
Examples of adult males which did not show the complete secondary pigmentation.

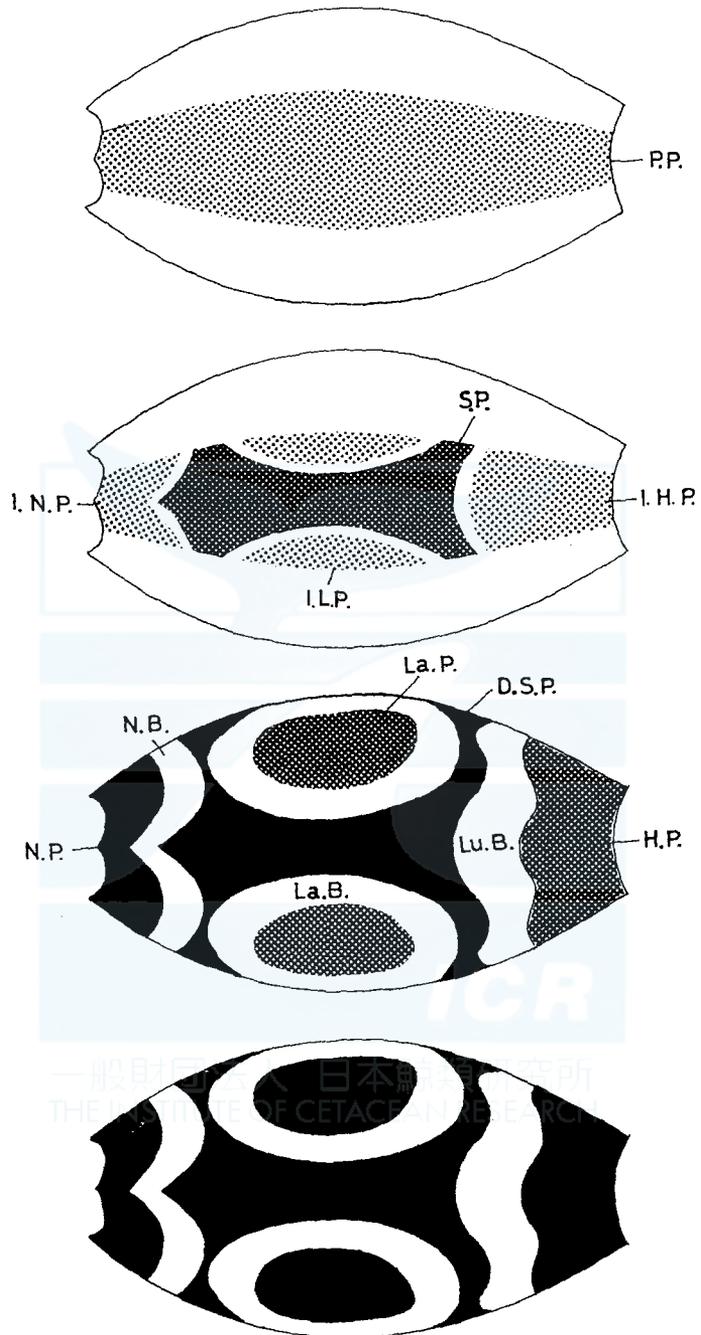
PLATE VII

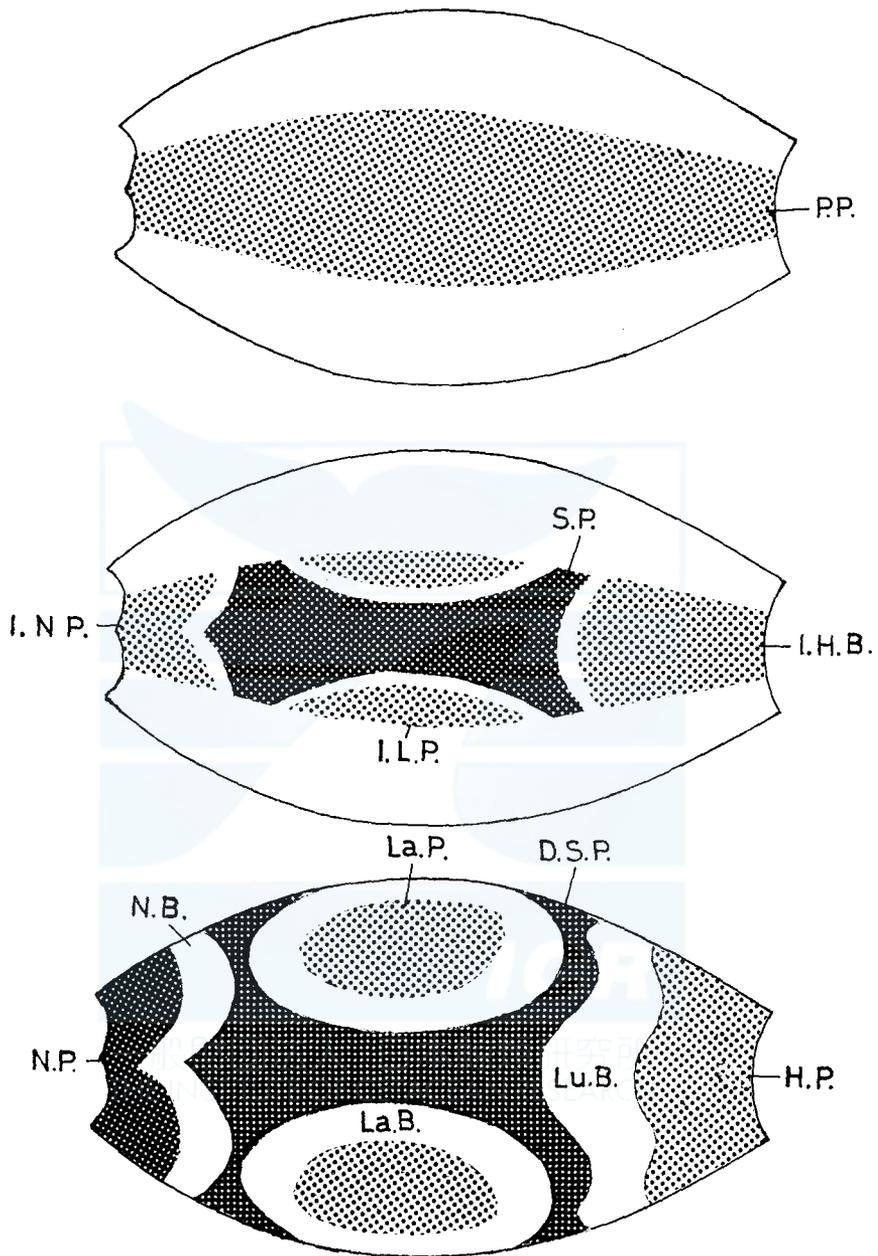
The schematic diagrams of the speculated ancestral form, which were devised from the developmental process of the pigmentation.

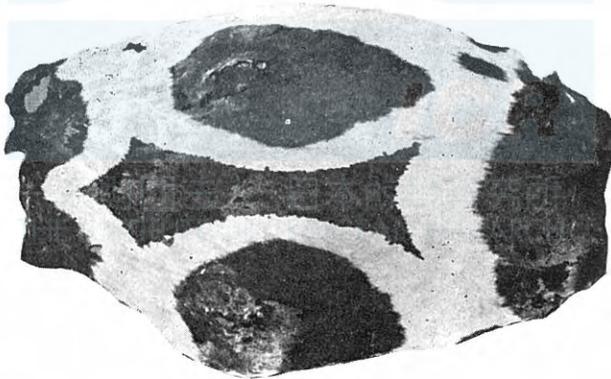
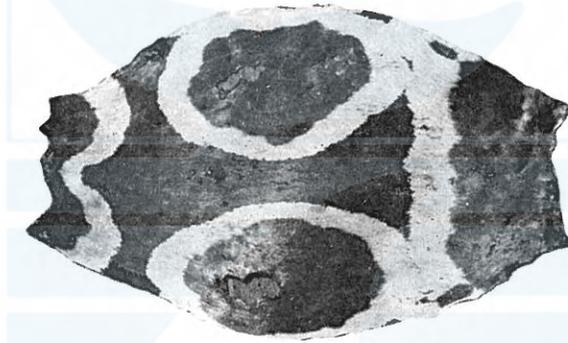
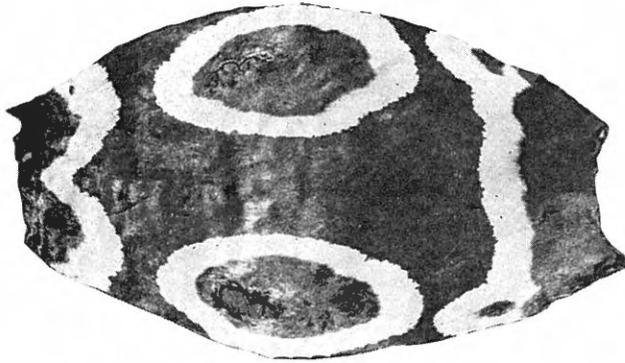
PLATE VIII

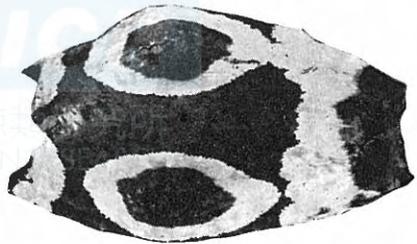
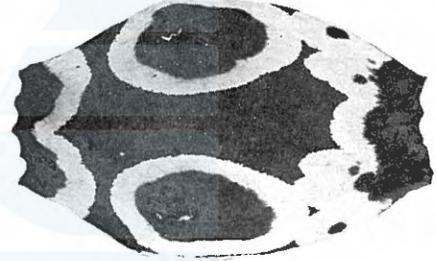
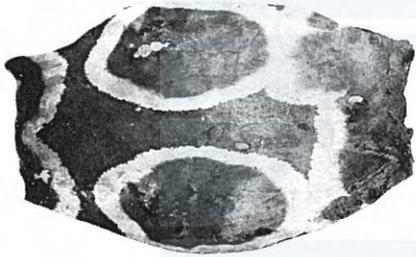
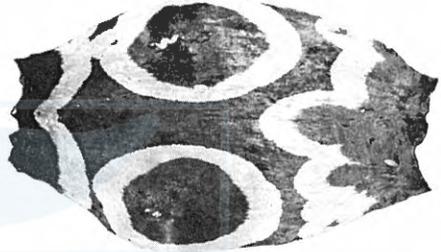
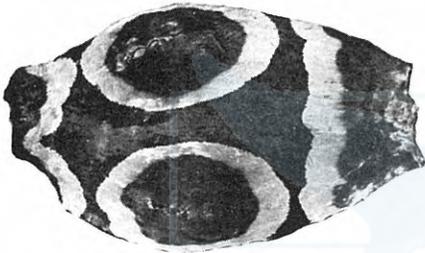
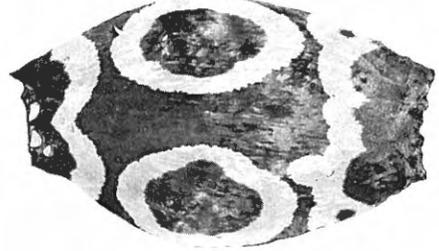
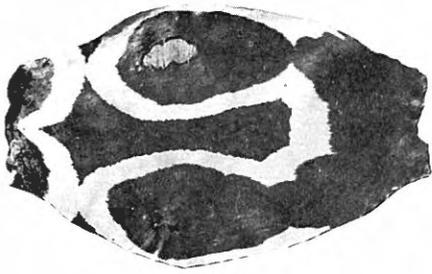
The examples of the small ringed or spotted patterns. The pelages were classified into three degrees A, B and C according to the numbers of ringed patterns.



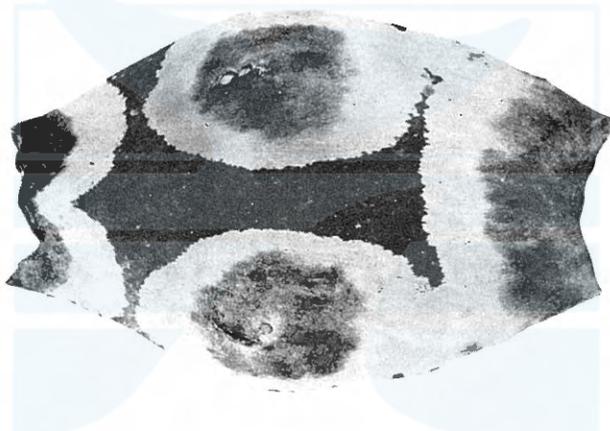
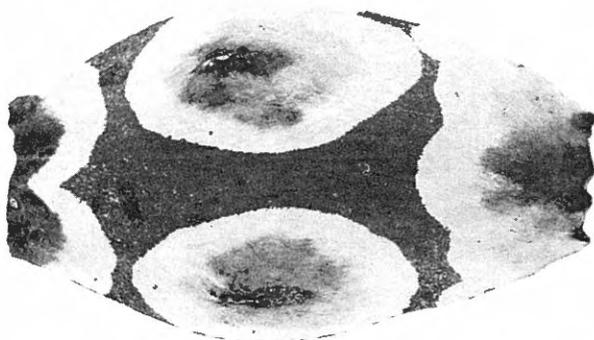








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