OSTEOLOGICAL STUDY OF THE BRYDE'S WHALE FROM THE CENTRAL SOUTH PACIFIC AND EASTERN INDIAN OCEAN

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ABSTRACT

A complete set of skeleton of the Bryde's whale was obtained in the 1977–78 season and a skull and mandibles of the same species in the following season, from central South Pacific and eastern Indian Ocean respectively, based on a special permit for scientific researches. In addition nasal bones were collected from five animals in both seasons. All of these whales belonged to the offshore form of the Bryde's whale. Study of these bones has confirmed the reliability of the osteological characters of the Bryde's whale hitherto obtained in the past study, especially the shape of nasal bones.

INTRODUCTION

The osteological study of the Bryde's whale, *Balaenoptera edeni* has been very limited, though it is now well known that this species is widely distributed in the both hemispheres, in tropical and subtropical waters between 40°N and 40°S Latitudes.

Lönnberg (1931) studied a skeleton of *Balaenoptera brydei* (=*edeni*) which was presented from Captain C. O. Johnson, a female specimen caught on 10 March 1929 from the coast of South Africa. He compared this skeleton with skeletons of the sei whale, *Balaenoptera borealis* from the coast of Norway and from South Georgia, both kept in his museum, R. Natural History Museum at Stockholm, in addition to statements in the literature (Andrews, 1916: Miller, 1924 etc).

Junge (1950) studied a skeleton of fin whale that was cast ashore on the coast of Pulu Sugi, one of the smaller islands of the Rhio Archipelago between Singapore and the Smatran coast in July 1936 and concluded that this whale is identical with *B. edeni* Anderson 1879. He also examined a skeleton of *B. brydei* from Saldanha Bay, South Africa and an incomplete skelton of *B. edeni* both preserved at the British Museum and got to a conclusion that *B. edeni* and *B. brydei* are to be considered conspecific, which makes the name *Balaenoptera brydei* Olsen a junior synonym of *Balaenoptera edeni* Anderson.

Anderson (1879) made studies of the Sittang whale, stranded on 18 June 1871 in a creek named Thyabu Choung, which runs into the Gulf of Martaban, Burma. He has studied the skeleton of this whale and named it *Balaenoptera edeni*, in re-

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cognition of the Hon'ble Ashley Eden, the Chief Commissioner of British Burma, having been the means of saving this whale to science. He also reports "six pieces of short balene (=baleen) accompanied the other remains of this whale, they were all of one size, or nearly so, with the exception of one small white piece, evidently only a portion of a flake. The five remaining pieces are triangular, with about 12 inches (30.48 cm) of length and a maximum breadth at the base of 6 inches (15.24 cm). Their basal margins are uninjured, as the plates had evidently been drawn out of the decaying mucous membrane. The long curved free border is deeply fringed." He did not compare these baleen plates to those of *B. borealis*, but these proportions would place the animal as an offshore form of Bryde's whale (Omura and Fujino, 1954; Best, 1977).

Omura (1959) also made a study of skeleton of the Bryde's whale, comparing to that of the sei whale, both taken in the waters off Ayukawa, Japan. His conclusion was that the Bryde's whale from the coast of Japan is identical with *B. edeni* Anderson. He further assumed that *B. edeni* is distributed in tropical and subtropical waters of the world between 40°N and 40°S Latitudes.

Soot-Ryen (1961) studied an incomplete skeleton of Bryde's whale stranded on Curacao in 1959. He referred the specimen to *B. brydei* Olsen. He found pronounced differences in various ratios of the skeleton between *brydei* Olsen and *edeni* Anderson than between the two and *borealis* Lesson. His opinion is that untill the external characters and the baleen plates of *edeni* are described, there are reasons to keep the two nominal taxa separate. As already noted, however, baleen plate of *B. edeni* was already described by Anderson (1879).

Mead (1977) found, in several specimens, some of the characters generally used to separate *B. borealis* from *B. edeni* either intermediate or contradictory, particularly the shape of the nasal bones. He examined records of sei whales from the Atlantic coast of the United States and identified the specimen of the pollack whale reported by Miller (1924) as *B. edeni*. He describes that this was confirmed by an examination of the baleen, which is clearly that of *B. edeni*. This Miller's pollack (=sei) whale was used for the comparison of *B. brydei* and *B. edeni* by Lönnberg (1931) and Junge (1950). The re-examination of skeleton of the Bryde's whale, therefore, is needed.

A total of 459 Bryde's whales were taken by Japanese whaling expeditions in the Coral Sea, South Pacific and Indian Ocean during three successive seasons from 1976–77 to 1978–79 by a special permit from the Japanese government for purposes of scientific research. Reports on these whales taken were already published (Ohsumi, 1978; Ohsumi, 1979; Ohsumi, 1981; Kawamura, 1977; Kawamura, 1978; Kawamura, 1980). A complete set of skeleton was obtained in the 1977–78 season and a skull in the 1978–79 season. In addition to these a part of skull near nasal bones was obtained from five individuals in each of these two seasons for the comparison of the form of the nasals.

Whale specimens taken in the 1977–78 season belong to the offshore form of the Bryde's whale of Best (1977). This was confirmed by the measurements of baleen plates. The length: breadth quotients of the largest plates of these whales were ranged 1.47–2.05, and the mean was 1.81 (FSFRL unpublished data). For whales taken in the 1978–79 season no baleen plate was measured, but the skull has very flat rostrum which suggests that this group of whales too belong to the offshore form.

MATERIAL

Materials used in this study are shown in Table 1. Bones obtained in November 1977 or in the 1977–78 Antarctic season were landed at the Port of Chiba, towards the end of April 1978. Most of the bones of the sample no. 77N62 or the skull, mandibles, ribs and most of the vertebrae were then transported by a truck to Hakodate, Hokkaido, and burried in the earth in the campus of Hokkaido University, Faculty of Fisheries, for extraction of oils contained in them. Tendon or other soft parts attached to bones had already been cleaned on the factory ship.

Flippers, chevron bones and so-called " Mitsuya " in Japanese or the hindmost part of the vertebral column where tail flukes attaches, were brought frozen and these were transported to WRI, where they were also burried in the earth, after enclosed in mosquito nets made of synthetic fibre, in order to prevent from missing of small bones. Most of chevron bones, and nasals and their surrounding bones, were also transported to WRI where they were also burried in the earth, but without using mosquito nets.

The bones which were burried in the campus of the Hokkaido University were dug out from the earth on 7–8 May 1980, after about two years, and the observation, measurements and photography of bones were made on the following days.

The bones which were burried in WRI were dug out in November 1979. Some of the vertebrae were still attached to blubber and it was removed by boiling.

The skull and mandibles taken in the 1978–79 season were burried in the sand of the Kamogawa Sea World, an aquarium in Kamogawa, Chiba. These

TABLE 1. CATCH PARTICULARS OF WHALES FROM WHICH MATERIALS FOR THIS STUDY WERE OBTAINED

Whale no.	Date of catch	Position of catch		Body length	Sex	Material obtained
		Lat.	Long.			
77N06	1 Nov. 1977	25°12′S	177°44′W	13.5 m	M	Nasals
77N07	1 Nov. 1977	25°08′S	177°55′W	13.4	M	Nasals
77N09	8 Nov. 1977	26°30′S	170°58′W	13.8	M	Nasals
77N10	8 Nov. 1977	26°57′S	171°26′W	11.9	M	Nasals
77N11	9 Nov. 1977	27°52′S	175°03′W	14.6	M	Nasals
77N62	14 Nov. 1977	28°32′S	179°41′W	14.7	F	Complete set of skeleton
78N29	7 Nov. 1978	12°49′S	114°47′E	10.9	M	Nasals
78N31	7 Nov. 1978	12°46′S	114°50′E	12.8	M	Nasals
78N32	7 Nov. 1978	12°42′S	114°39′E	12.3	M	Nasals
78N33	7 Nov. 1978	12°31′S	114°18′E	14.2	F	Skull and mandibles
78N41	7 Nov. 1978	12°07′S	113°57′E	12.6	F	Nasals
78N49	7 Nov. 1978	10°54′S	112°30′E	13.9	F	Nasals

bones were dug out in October 1980, after about one and a half years. Observation and measurements of these bones were made successively.

Nasal bones, taken with surrounding bones from five individuals in that season were sent to WRI, where they were burried in the earth for about two years and then dug out.

All of these whales belonged to offshore form of the Bryde's whale of Best (1977),as stated already.

SKULL
(Plates I-IV)

The most conspicuous characters of the skull of *B. edeni* compared with *B. borealis* are the following: (1) In the lateral view the rostrum is very flat and pointing straight forward. The ventral surface of the maxillaries is less concave. (2) In the dorsal view outer margin of the rostrum is convex in *B. edeni* whereas more straight in *B. borealis*, hence rostrum at its middle is broader in *B. edeni*. The front margin of nasals is concave or straight and bent forward on the outer side in *B. edeni*, but convex and never bending forward on the outer side in *B. borealis*. It is situated strikingly posterior to the anterior border of the posterior maxillary concavity in *B. edeni*, whereas nearly at the same level of the concavity in *B. borealis*. (3) In the inferior view the palatines do not extend so far back in *B. edeni* and the basicranial part of the skull exposed behind the palatines is much longer than broad in *B. edeni*.

Our specimen of 77N62, obtained from central South Pacific and 78N33, obtained from eastern Indian Ocean show above characters in general. In both specimens the rostrum is very flat. The premaxillaries, especially their posterior ends, are sunk in between the maxillaries, which together with the little downward curving of the maxillaries cause the flat appearance in profile. In the specimens reported by Anderson (1879), Lönnberg (1931), Junge (1950), Omura (1959), and Soot-Ryen (1961) the rostrum is flat and they all agree in this respect. The flat rostrum of these specimens would place the animal as offshore form as stated below. Junge (1950) reports on the specimen in the British Museum the rostrum is curved downwards. Straight or curved rostrums are thought to be related to the shape of the baleen plates. Best (1977) reports that two distinct forms of the Bryde's whale occur on the west coast of South Africa, termed 'inshore' and 'offshore' forms. A morphological difference between the two forms is in the shape of the baleen plates. The shape of baleen plates of inshore whales is similar to those of the sei whale, but those from offshore whales are shorter and broader. The long baleen plates similar to those of the sei whale were also reported from the coast of Brazil (Omura, 1962) and from the west coast of Kyushu, Japan (Omura, 1977). Omura (1962) showed a drawing of cross section of the rostrum, just cranial to blowholes in the Bryde's and sei whales and showed correlation between the shapes of baleen plates and rostrum. The Bryde's whale with long baleen plates *i.e.* inshore form whales of Best are thought to have downward curving rostrum as in the case of the sei whale, though this has not been confirmed yet.

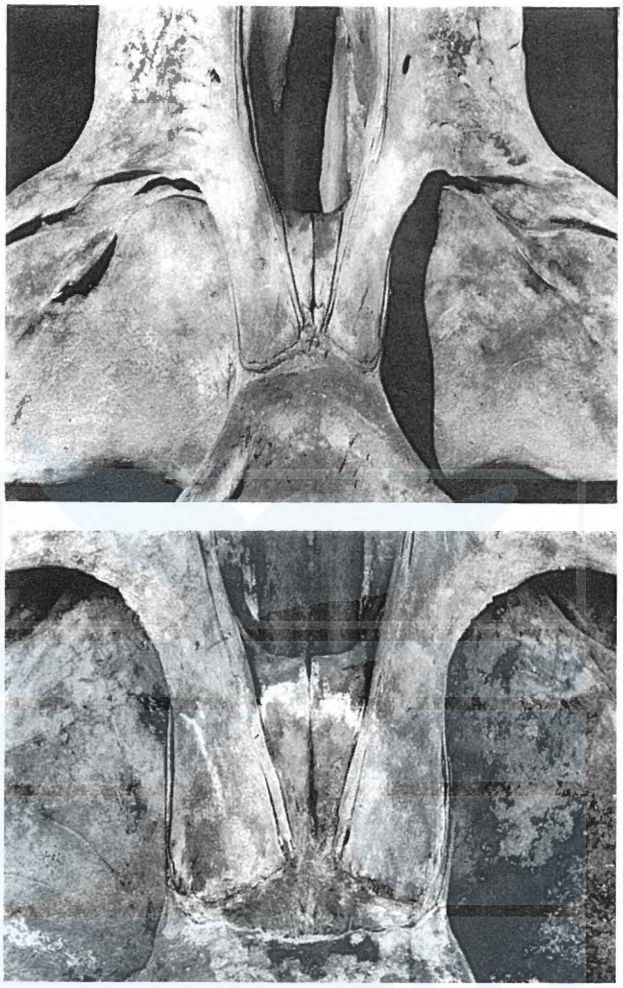

Fig. 1. Nasals of the Bryde's whale.
Upper: Specimen 77N62.
Lower: Specimen 78N33.

In the dorsal aspect, the rostrum of our specimens is long and slender. Anderson (1879) pointed out the long and slender beak of his specimen and thought this is a character which differs materially from *B. schlegeli* (=*borealis*). In the Lönnberg's (1931) specimen of the Bryde's whale, however, the rostrum is shorter and broader than in the sei whale, and Junge (1950) found large individual variations in this character. Position of nasals of our specimens are well behind the anterior border of the posterior maxillary concavity (Plate I, Fig. 1; Plate II, Fig. 1; Fig. 1).

Lönnberg (1931) reported that the flat area formed by the nasals and the posterior ends of the maxillaries is longer than broad in the Bryde's whale, whereas in the sei whale it is square or even broader than long. The Pulu Sugi specimen of

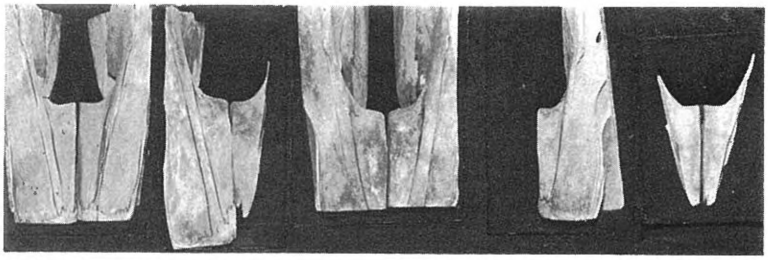

Fig. 2. Nasals of five Bryde's whales from the central South Pacific. From left to right: 77N06, 77N07, 77N09, 77N10, 77N11.

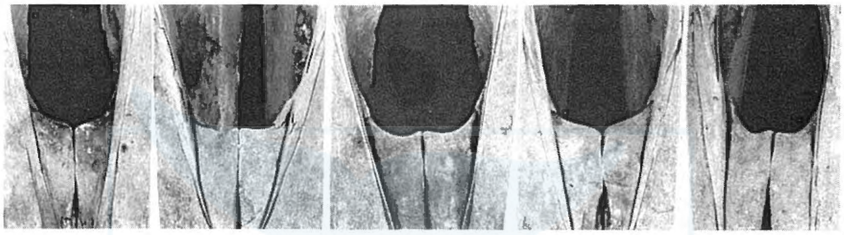

Fig. 3. Nasals of five Bryde's whales from the eastern Indian Ocean. From left to right: 78N29, 78N31, 78N32, 78N41, 78N49.

Junge (1950) also agrees in this respect to Bryde's whale and according to him this is also true in the specimen of *edeni* from Thyabu Choung. In our specimens of 77N62 and 78N33 this area is longer than broad. Junge (1950) described, however, on the London specimen of *brydei* (=*edeni*) this area is broader than long as in the case of Lönnberg's specimen of the sei whale. This character, therefore, is of little value for taxonomic purpose.

The front margin of nasals is concave and bent forward on the outer side in all of our specimens (Figs 1, 2 and 3). This is a striking character which separates *B. edeni* from *B. borealis* in which it is convex or straight and never bending forward on the outer side. This is true in all of the specimens of *B. edeni* reported before, *i.e.* the Sittang whale of Anderson (1879), South African specimen of Lönnberg, Pulu Sugi specimen of Junge (1950), Ayukawa specimen of Omura (1959), and Curacao specimen of Soot-Ryen (1961). Mead (1977) doubted, however, the reliability of this character. This is why we asked the Japanese expeditions to collect a part of skull of the Bryde's whale, around nasals, in the two seasons of 1977–78 and 1978–79, as shown in Table 1. Nasals thus collected are shown in Figs 2 and 3.

As seen in these photographs the front margin of the nasals of *B. edeni* are concave, straight or somewhat convex towards the center, but more important is the fact that they always bending forward on the outer side. We have confirmed that the nasal bone itself is of a light and spongy structure, but it covers completely a thin and subtle membrane of bone which coming up from the maxillary, lying beneath the premaxillary. Thus in *B. edeni* nasals are more firmly fixed than in *B.*

TABLE 2. MEASUREMENTS OF SKULL OF THE SPECIMENS 77N62 FROM THE CENTRAL SOUTH PACIFIC AND 78N33 FROM THE EASTERN INDIAN OCEAN, COMPARING TO THAT FROM THE NORTH PACIFIC

Measurements		Length in mm			Percent of skull length	
	S. Pacific 77N62	Indian O. 78N33	N. Pacific Omura, 1959	S. Pacific 77N62	Indian O. 78N33	N. Pacific Omura, 1959
1. Condylo-premaxillary length	3,792	3,422	3,480	100	100	100
2. Length of beak	2,524	2,137	2,230	66.6	62.4	64.1
3. Length of premaxillary, along upper surface R	2,973	2,590	2,640	78.4	75.7	75.9
L	2,962	2,595		78.1	75.8	
4. Length of maxillary along upper surface R	2,846	2,518	2,495	75.1	73.6	71.7
L	2,812	2,525	2,500	74.2	73.8	71.8
5. Tip of premax. to post. end of maxillary	3,021	2,719	2,670	79.7	79.5	76.7
6. Tip of premax. to vertex	2,978	2,635	2,695	78.5	77.0	77.4
7. Tip of premax. to nasals, mesial	2,699	2,360	2,440	71.2	68.9	70.1
8. Tip of premax. to ant. end of maxillaries	212	121	183	5.6	3.6	5.3
9. Tip of premax. to ant. end of vomer	484	251	439	12.8	7.3	12.6
10. Tip of premax. to ant. end of palatines	2,756	2,292	2,445	72.7	67.0	70.3
11. Tip of premax. to post. end of palatines, mesial	3,165	2,785	2,909	83.5	81.4	83.6
12. Tip of premax. to post. end of pterygoid	3,357	3,127	3,225	88.5	91.4	92.7
13. Greatest breadth of skull at zygomatic process	1,665	1,592	1,615	43.9	46.5	46.4
14. Breadth of skull at maxillaries	1,565	1,508	1,445	41.3	44.1	41.5
15. Breadth of skull at frontal plane, post. to premaxillaries	327		217	8.6		6.2
16. Breadth of skull at orbital process of frontal, center	1,508	1,466		39.8	42.8	
17. Breadth of beak at base	1,105	961	955	29.1	28.1	27.4
18. Breadth of beak at middle	664	687	645	17.5	20.1	18.5
19. Breadth across premaxillaries, greatest	296	301	330	7.8	8.8	9.5
20. Breadth across premaxillaries, at base of beak	269	270	302	7.1	7.9	8.7
21. Breadth across premaxillaries, at middle of beak	209	220	219	5.5	6.4	6.3
22. Length of nasals, mesial	266	229	198	7·0	6.7	5.7
23. Breadth of nasals at mesial tip	155	165	137	4.1	4.8	3.9
24. Breadth of nasals at posterior end	45	36	49	1.2	1.1	1.4
25. Breadth of orbit R	250	241	234	6.6	7.0	6.7
L	248	241		6.5	7.0	
26. Length of supraoccipital from foramen magnum	818	838	835	21.6	24.5	24.0
27. Breadth of occiput between squamosal sutures	1,148	1,091	1,118	30.3	31.9	32.1
28. Breadth across occipital condyles	288	285	266	7.6	8.3	7.6
29. Height of occipital condyle R	194	196	174	5.1	5.7	5.0
L	193	193		5.1	5.6	
30. Breadth of foramen magnum	70	64	53	1.8	1.9	1.5
31. Height of foramen magnum	86	79	45	2.8	2.3	1.3
32. Length of mandible, straigth R	3,500	3,252	3,305	92.3	95.0	95.0
L	3,516	3,215	3,315	92.7	94.0	95.3

Continued . . .

TABLE 2. Continued.

Measurements		Length in mm			Percent of skull length		
		S. Pacific 77N62	Indian O. 78N33	N. Pacific Omura, 1959	S. Pacific 77N62	Indian O. 78N33	N. Pacific Omura, 1959
33. Length of mandible, on curve	R	3,649	3,385	3,540	96.2	98.9	101.7
	L	2,646	3,380	3,645	96.1	98.8	104.7
34. Height of mandible at coronoid	R	441+	405+	397	10.8+	11.8+	11.4
	L	450	411	392	11.9	12.0	11.3
35. Height of mandible at proc. articularis	R	288	312	302	7.6	9.1	8.7
	L	287	308	301	7.6	9.0	8.6
36. Height of mandible at middle	R	240	245	214	6.3	7.2	6.1
	L	234	242	217	6.2	7.1	6.2
37. Breadth of mandible at middle	R	160	168		4.2	4.9	
	L	153	168		4.0	4.9	
38. Length of tympanic bulla	R		122			3.6	
	L		124			3.6	

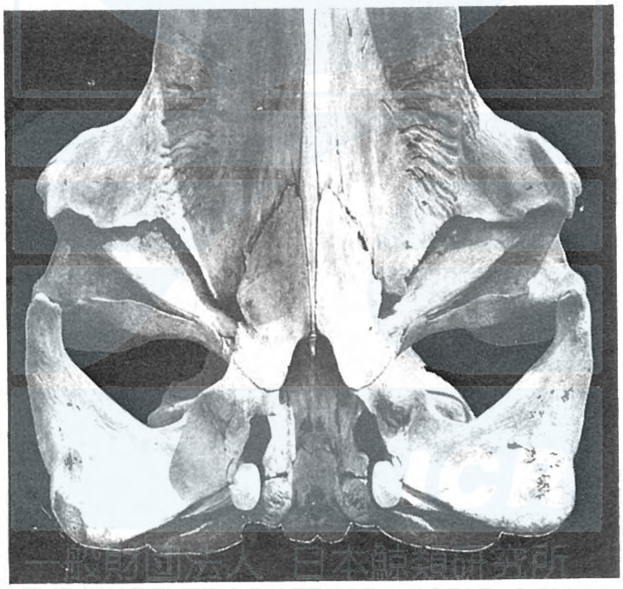

Fig. 4. Inferior view of the skull of the specimen 77N62, showing the basicranial part of the skull exposed behind the palatines.

borealis. In the minke whale, *B. acutorostrata*, those from the North Pacific have sei-whale-type nasals and those from the Antarctic have Bryde's-whale-type nasals (Omura, 1975).

In the inferior view of the skull of *B. edeni* the palatines do not extend so far back and the basicranial part of the skull exposed behind the palatines is much longer than broad (Lönnberg, 1931; Junge, 1950; Omura, 1959). This is true in our specimens of 77N62 (Fig. 4) and 78N33. In the sei whale the extension of the palatine bones so far backward that the position of the basicranial region exposed behind them is squarish in outline instead of longer than broad (Miller, 1924).

Miller (1924) considers the deep and narrow sulcus between the articular and squamosal parts of the squamosal in *B. borealis* as a specific character of the sei whale. Junge (1950) and Omura (1959) found the sulcus is not so deep and narrow in *B. edeni*. In our present specimens too this is true, but it is difficult to conclude whether or not this is an important character which separates *B. edeni* from *B. borealis*.

In Table 2 the measurements of skull of our specimens of 77N62 and 78N33 are shown in actual length of millimeter and percentage figures against the skull length. The corresponding figures of *B. edeni* from the North Pacific are also shown in the table, cited from Omura (1959). There are some differences in the percentage figures of the three specimens, but they are rather small and possibly due to individual variation, rather than racial difference. Junge (1950) gives a table showing proportional distance from nasals to tip of premaxillaries, and breadth of rostrum basally as well as at its middle for each six specimens of *B. borealis* and *B. edeni*, including those reported as *B. brydei*. Much wider differences are observed in this table even in the same species.

MANDIBLES

(Plate III, Figs 1 and 2, Plate IV, Figs 1 and 2)

There are some characters in mandible which are said to separate *B. edeni* from *B. borealis*. One of these is the groove between the angular and articular parts of the mandible in the posterior region. This groove is much deeper in *B. borealis*, but less developed or shallower in *B. edeni*. In this respect our present specimens of *B. edeni* from the southern hemisphere do not differ from that from the North Pacific.

Another difference between *B. borealis* and *B. edeni* is the relation between the articular and angular portions. In *B. borealis* angular portion ends before the hind edge of the articular portion, whereas in *B. edeni* the angular portion is at equal level or projects behind the articular parts (Junge, 1950; Omura, 1959). This is

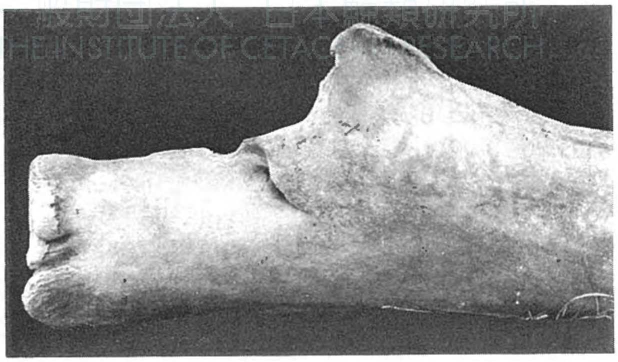

Fig. 5. Posterior part of the left mandible of the specimen 77N62. Inner view.

true in our present specimens too, and in these two specimens angular portion is projecting behind articular portion. This is clearly shown in Fig. 5.

Omura (1959) describes that the mandible of the Bryde's whale on the coast of Japan is much robust than that of the sei whale, and its cross section at the middle of the mandible is more rounded. Percentages of the breadth against the height of mandible at its middle is about 64% in *B. edeni*, whereas the corresponding figure is about 54% in *B. borealis* in specimens preserved at the National Science Museum in Tokyo. From Table 2 we calculate the percentages in the mandibles from the central South Pacific and from the eastern Indian Ocean and got the figures of 66.7% and 68.6% respectively, in both the right and left mandibles. This shows that mandibles of the Bryde's whales in these oceans are more robust than in those in the North Pacific, but we are not able to compare these with corresponding figures of the sei whale in these oceans.

VERTEBRAE
(Plates VI and VII)

The vertebral formula of our specimen of 77N62 from the central South Pacific is C 7, D 13, L 12, Ca 22, which makes the total number of vertebrae 54. This number of 54 is exactly the same with the number in the Ayukawa specimen of *B. edeni* reported by Omura (1959) from the North Pacific, though the formula is slightly different, or one lumbar less and one more caudal present in the present specimen. All of the epiphyses are completely fused to their centra, and accordingly the whale was physically mature.

The total number of vertebrae of *B. edeni* was reported as 52 or 53 (Andrews, 1879; Lönnberg, 1931; Junge, 1950). In all of these specimens, however, all of the vertebrae were not saved and some numbers were added in estimation. Omura (1959) had an opportunity to observe the Pulu Sugi specimens of *B. edeni* kept at the Rijksmuseum van Natuurlijke Historie in Leiden in 1958 by the courtesy of Dr G.C.A. Junge and measured some of the last caudals. He compared sizes of these vertebrae to those of the Ayukawa specimen and got to a conclusion that the total number of the Pulu Sugi specimen should be 54, instead of 52 or 53. Omura (1966) expressed, however, the need of the exact counting of the number of vertebrae of *B. edeni* from other localities. And this was done in the present specimen from the central South Pacific. Omura and Fujino (1954) report that they counted the number of vertebrae of then so-called sei whales processed at landstations on the coast of Japan in 1953. In these days they separated so-called sei whales into two categories of northern and southern types. Later it was proved that the northern type is nothing but *B. borealis* and the southern type *B. edeni*. They found that in *B. borealis* the total number of vertebrae is 56 (2 individuals), but in *B. edeni* they were 54 (5 individuals) and 55 (8 individuals). The total number of vertebrae in *B. borealis* has been well established as 56–57, and it is proved that the number in *B. edeni* is 54–55.

The front view of the cervicals are given in Plate VII. In this specimen the 3rd and 4th cervicals are fused together completely and they can not be separated.

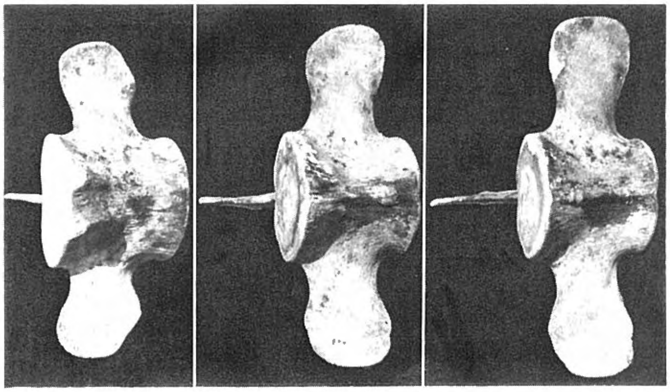

Fig. 6. Inferior view of some of vertebrae of the specimen 77N62.
Left: 34th vertebra.
Center: 33rd vertebra.
Right: 32nd vertebra.

The shapes of each cervicals are similar in general to the Ayukawa specimen reported by Omura (1959). In the 6th cervicals, however, complete rings are not formed by dia- and parapophyses and narrow spaces are present between these processes, whereas in the South African specimen of Lönnberg (1931) and in Ayukawa specimen of Omura (1959) complete rings are formed. These differences are thought, however, subject to individual as well as age variations and may have very little taxonomic value. In the Pulu Sugi specimen of Junge (1950) rings are not formed in the 4th and 6th cervicals. In the 7th cervical parapophyses are reduced to a small notch on the vertebral body. This is so in other specimens of *B. edeni* ever reported.

The number of dorsal (thoracic) vertebrae counts 13. This corresponds to the number of pairs of ribs. In the 20th vertebra or 13th dorsal the distal ends of the transverse processes are somewhat thickened and have no clear articulating facet for ribs. In the succeeding vertebrae no such thickning of transverse processes present.

The last lumbar vertebra is separated from the 1st caudal by absence of chevron bone at its ventro-posterior end. The first chevron bone is usually small and in this case the right and left laminae are not united into a mass but separated. The articulating facet on the ventro-posterior end of the preceding vertebra is, therefore, not always clear. In the succeeding vertebra, however, this articulating facet is very clear, because of the 2nd chevron is quite big and united into a mass.

In Fig. 6 are shown the inferior and posterior ends of the 32nd, 33rd and 34th vertebrae. As clearly seen in these potographs no articulating facet is present in the 32nd vertebra, small facet in the 33rd, and very clear one in the 34th vertebra. Accordingly we assigned the 33rd vertebra as the 1st caudal vertebra. De Smet (1977) raised some problems in the regions of the cetacean vertebral column and proposed a new method of expressing the number of vertebrae.

He describes, however, that in ' most of the reports of Japanese cetologists ' ' the slightest indication as to how the categories are distinguished.' We like to refer here, therefore, some description on this point from Omura (1959). He described that ' The first 12 dorsal (=thoracic) vertebrae have more or less well marked facets at the distal ends of the transverse processes for the articulation of the ribs. The 13th dorsal vertebra has a well marked facet at the distal end of the right transverse process, but on the left no such facet present, though the distal end of the process is somewhat thickened.

He further described that " The 1st caudal vertebra is detected by the presence of bifurcated median carina on the inferior side of the vertebral body." These are the basis that he determined the vertebral formula of this specimen is C 7, D 13, L 13, Ca 21, Total 54. In the present specimen of *B. edeni* from the central South Pacific the formula is similarly decided as C 7, D 13, L 12, Ca 22, Total 54, as stated already.

De Smet (1977) proposing new formula dividing the cetacean vertebrae into following 6 regions.

1. *Cervical vertebrae* (vertebrae cervicales: Cv.): the seven vertebrae which are found between the skull and the first vertebra which possesses a complete rib; if there is a coalescence between several vertebrae it is shown in brackets or with a+sign; *e.g.* Cv. 7, or Cv. (7) or Cv. (2)+5.
2. *True thoracic vertebrae* (vertebrae thoracicae verae: Th. v.): the vertebrae which exhibit on their transverse process an articular facet for the tuberculum or for the capitulo-tuberculum of the corresponding rib (even if such a facet is not present for both ribs).
3. *Intermediary thoracolumbar vertebrae* (vertebrae intermediate thoracolumbales: I. Thl.): the vertebrae which are accompanied by a rib or the rudiment of a rib (whether on one side or on both sides) but which have no articular facets on the two transverse processes or which are joined to a rib by a ligament.
4. *X Vertebrae* (vertebrae X: X): well-developed vertebrae, placed within the trunk, which are neither a relationship with a rib nor carry a chevron bone on their cranio-ventral border: this series is homologous with the lumbar vertebrae, with the sacral vertebrae and with some others such as the postsacral vertebrae of Slijper and the first caudal of Knauff.
5. *Y Vertebrae* (vertebrae Y: Y): those vertebrae which are preceded by a chevron bone; this is attached to their cranio-ventral border, but in fact it articulates better with the vertebra in front; in reality the bone can be incomplete or much reduce or coalesced with another.
6. *Z Vertebrae* (vertebrae Z: Z): these are the small vertebrae of the terminal part of the column, they have no chevron bones and they are found in the flukes.

If we adopt the new system of formula proposed by him then the formula for our specimen 77N62 are the following:

Cv.=(2)+5, Th.v.=12, I.Thl.=1, X=13, Y=17, Z=4, Total=54

There are some doubt, however, in adopting this formula. One is the distinction between Th.v. and I.Thl. Th.v. is defined as ' which exhibit on their transverse process an articular facet '. In our specimen of 77N62 no clear articulating facet for ribs is present in the 20th vertebra, but the distal ends of the transverse processes are somewhat thickened, contrally to the succeeding one, as already stated. In the Ayukawa specimen (Omura, 1959) the 13th dorsal vertebra had a well marked articulating facet on the right side, but no such facet was present on the left side, though the distal end of the process was somewhat thickened. It is thought better to include the 20th vertebra into the category of Th.v. and making this number 13, instead of 12, and I.Thl.=0. It is true that in some specimens the last rib or ribs are very small, compared with the preceding ribs. Omura *et al.* (1971) report an unpaired and very short rib in the black right whale from the coast of Japan. It is possible that such rib or ribs are floating. They also reported that in one specimen of the black right whale the first dorsal vertebra is completely fused to a fused mass of the cervicals, or the first 8 vertebrae are fused into a mass. In these cases the expression is very difficult.

We like to raise here some other difficulties in adopting the new formula. In practice it is very difficult to count the exact number of the chevron bones, especially in the larger cetaceans. In our case of the specimen 77N62 a special care was taken, in order to secure very small bones, as already stated. Thus we got 17 (or pairs of) chevron bones. Among these 5 (pairs) were obtained from the region of tail flukes. In the usual practice these can not be collected. In the former reports of the Bryde's whale the total number of chevron bones are reported: 11 (Lönnberg, 1931), 11 (Junge, 1950), and 12 (Omura, 1959). These are all incomplete and it is possible that none of those in the region of tail flukes was collected. Separation of Y and Z vertebrae, therefore, may lead to a confusion.

Lastly the definition of Y vertebrae is those vertebrae which are preceded by a chevron bone. The chevron bone, however, articulates to the ventro-posterior end of the preceding vertebra, as he mentioned, and it is thought that the change of definition might not be needed. There exist very clear articulating facet both in the vertebral body and superior margin of the chevron bone, as shown in Figs 6 and 8.

The most remarkable difference in vertebrae other than total number which separate *B. edeni* from *B. borealis* is the strong backward inclination of the spinous processes in the former species (Anderson, 1879; Lönnberg, 1931; Junge, 1950; Omura, 1959). This inclination begins towards the middle of the dorsal vertebrae and increases till it reaches the maximum at about 27th vertebra (or the 7th lumbar) and then decreases. This is clearly shown in Pl. VI, Figs 1 and 2. In general the degree of inclination and its tendency are similar to the Ayukawa specimen of *B. edeni* (Omura, 1959).

In Table 3 the measurements of vertebrae of the specimen 77N62 are shown. In this table also included the degree of the inclination of spinous processes of the lumbar vertebrae. These were measured as the distance at which the vertical plane along the posterior surface of the vertebral body reaches the upper margin of the spinous process reckoned from the posterior upper angle of the process.

TABLE 3. MEASUREMENTS OF VERTEBRAE OF THE SPECIMEN 77N62 (IN MM)

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum			Note
				Breadth	Height	Length	
1	C 1	487	323	276	195	121	
2	2	861	326	288	172	81	
3	3	707	323	229	172	127	Completely fused
4	4	739	325	225	177		
5	5	716	323	219	175	66	
6	6	653	345	217	180	72	
7	7	636	379	220	180	78	
8	D 1	623	368	222	176	93	
9	2	635	390	228	172	117	
10	3	636	456	240	174	139	
11	4	694	503	239	172	159	
12	5	758	526	240	169	175	
13	6	845	573	237	172	189	
14	7	895	600	236	167	198	
15	8	928	626	233	167	209	
16	9	963	628	238	176	215	
17	10	1,003	646	240	176	223	
18	11	1,042	665	247	179	227	
19	12	1,079	666	246	179	232	
20	13	1,100	680	251	182	241	Backward inclination of S.P.*
21	L 1	1,064	695	254	180	244	141
22	2	1,068	697	256	185	251	195
23	3	1,070	697	251	198	256	213
24	4	1,069	711	258	204	262	250
25	5	1,053	757	258	217	265	249
26	6	1,034	749	256	215	270	259
27	7	1,003	737	260	215	274	256
28	8	972	720	264	214	278	246
29	9	953	721	264	212	282	246
30	10	911	719	267	214	288	244
31	11	870	714	273	219	294	192
32	12	860	714	281	226	294	123
33	Ca 1	796	714	288	234	295	
34	2	734	697	291	241	294	
35	3	710	638	289	244	293	
36	4	647	556	294	244	289	
37	5	576	460	306	243	284	Transverse processes perforated
38	6	497	437	308	241	280	”
39	7	427	392	304	236	271	”
40	8	374	385	297	234	263	”
41	9	336	351	286	230	256	”
42	10	298	330	271	225	238	”
43	11	262	278	245	227	220	”
44	12	237	235	224	208	178	
45	13	206	218	195	175	127	

Continued . . .

TABLE 3. Continued.

Serial No.	Vertebral No.	Greatest breadth	Greatest height	Centrum			Note
				Breadth	Height	Length	
46	14	181	174	173	145	103	
47	15	—	151	152	125	96	
48	16	—	134	122	113	87	
49	17	—	116	102	100	78	
50	18	—	94	84	81	69	
51	19	—	67	70	62	59	
52	20	—	—	56	47	52	
53	21	—	—	42	32	45	
54	22	—	—	27	18	27	

* See text.

These figures are quite similar to those reported by Omura (1959) to his Ayukawa specimen.

RIBS
(Plate V)

The specimen 77N62 has thirteen pairs of ribs. The first pair of ribs are deeply bifurcated at the head by narrow cleft, and broadly expanded at the distal end (Fig. 7). The anterior head ariculates with the diapophyse of the seventh cervical and the posterior head with the first thoracic vertebra which indicates that possibly the cervical and the first thoracic ribs have ankylosed into one body.

Anderson (1879) reports that in his type specimen of *B. edeni* only a fragment of the first rib of the left side and the entire sixth rib of the same side were saved. As the former he describes that it is single headed, and the head and tubercle are well-developed. Other specimen of *B. edeni* ever reported, however, all have bifurcated first rib. In *B. borealis* also the first rib is double-headed and the separation of the two species by this character is not possible. This may serve, however, to separate these two species from other species of baleen whales.

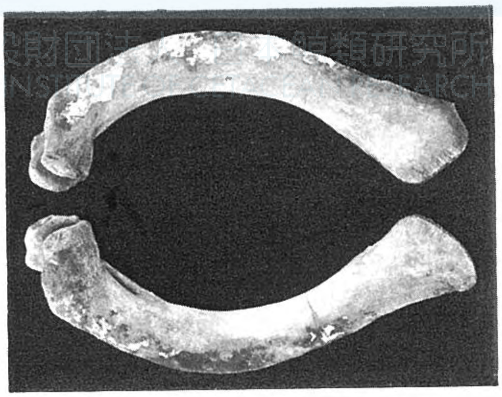

Fig. 7. First ribs of the specimen 77N62, showing bifurcated head. Posterior view.

In other specimens of *B. edeni* also thirteen pairs of ribs were present. Among them the thirteenth rib has length nearly same with that of the twelfth in the Pulu Sugi specimen of Junge (1950) and the Ayukawa specimen of Omura (1950), but in the South African specimen of Lönnberg (1931) the thirteenth rib was rudimental and short and slender. In the present specimen of 77N62 the thirteenth is shorter than any of the proceeding one except the first, but it can not be said as rudimental as shown in Plate V, Fig. 1.

In some of the ribs there is a rudiment of a capitulum and collum as in the most cases of the baleen whales, and these are thought to be of less importance in the taxonomic study. In the baleen whales ribs and sternum are less developed compared with the toothed whales. In the former the thoracic structure is more flexible than in the latter that allow the thorax to collapse more easily as the hydrostatic pressure increases, an adaptation for aquatic life and in particular for deep diving.

The measurements of ribs of the present specimen are shown in Table 4.

TABLE 4. MEASUREMENTS OF RIBS OF THE SPECIMEN 77N62 (IN MM)

Rib No.	Right*	Left*
1	950	968
2	1,358	1,370
3	1,530	1,555
4	1,652	1,637
5	1,736	1,718
6	1,772	1,760
7	1,750	1,740
8	1,681	1,672
9	1,611	1,590
10	1,550	1,530
11	1,455	1,454
12	1,435	1,240+ (tip broken)
13	1,039	1,025

* Straight length.

CHEVRON BONES
(Fig. 8)

As already stated sixteen chevron bones were collected. It is thought, however, one was missed at the time of dismembering the whale carcass. Among them eleven were collected on the factory ship when treating the whale body, but in a state of long strip of meat and tendon which surrounds these bones, and not separately. These were sent to WRI as frozen. Five chevrons were obtained from a mass of posterior caudal vertebrae and connective tissue called ' Mitsuya ' in Japanese, as stated already. Thus chevron bones were collected divided into two parts. The last of the first group or the eleventh was broken. Comparing the sizes of this bone and the chevron found at the anterior most part of ' Mitsuya ' we think that one was lost at the time of treating the whale body, which makes the total number of chevron bones seventeen.

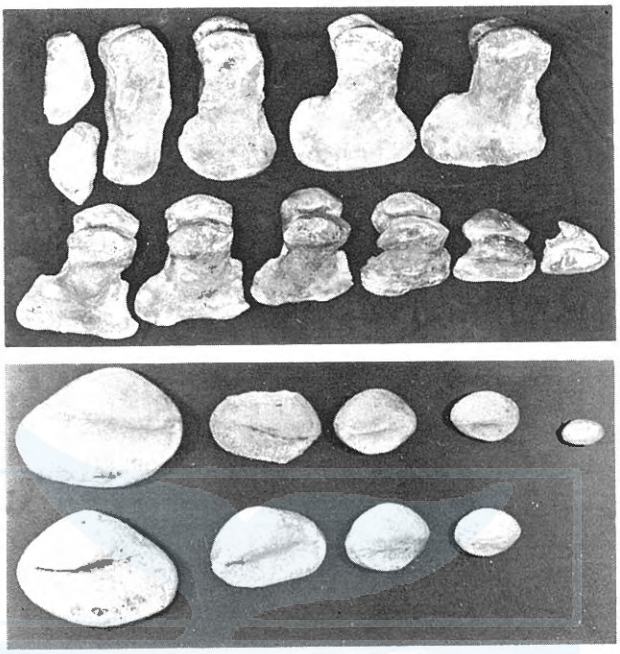

Fig. 8. Chevron bones of the specimen 77N62.
Upper: 1st-11th chevrons. In 1st chevron right and left laminae are not united into a mass, but separated. Others all united.
Lower: 13th-17th. These chevrons were obtained from the region of tail flukes. All are not united. One lamina of the last was missed?

TABLE 5. MEASUREMENTS OF CHEVRON BONES OF THE SPECIMEN 77N62 (IN MM)

No.	Height	Breadth	Distance*	Note
1	157	86	71	Two laminae are not united
	138	81		
2	267	101	137	
3	266	165	143	
4	259	210	148	
5	242	212	136	
6	212	203	130	
7	198	183	132	
8	184	170	118	
9	152	151	117	
10	110	141	110	
11	69	114+	97	Partly broken
12				See text
13	48	71	57	Two laminae are not united
14	32	51	44	"
15	26	38	38	"
16	22	30	27	"
17	11	19	?	Only one lamina saved

* Distance of right and left laminae at their superior margin (outside).

Measurements of chevron bones are shown in Table 5.

SCAPULLAE
(Plate V, Fig. 2)

Both scapullae were preserved. They are quite similar to that of the Ayukawa specimen of Omura (1959). The greatest breadth of the right and left scapullae are 1,021 and 1,013 mm respectively and the height is 57–58% of the breadth, not differing greatly from the Ayukawa specimen. Acromion is well developed and the coracoid is also developed, but the latter is a little shorter than that in the Ayukawa specimen. In general no special feature is observed from other specimens of *B. edeni*.

Measurements of scapullae are shown in Table 6.

TABLE 6. MEASUREMENTS OF SCAPULLAE OF THE SPECIMEN 77N62 (IN MM)

Measurements	Right	Left
Greatest breadth, straight	1,021	1,013
Greatest height	593	581
Length of acromion	279	279
Breadth of acromin at middle	100	101
Length of coracoid	123	126
Length of glenoid fossa	184	188
Breadth of glenoid fossa	138	136

HUMERUS, RADIUS, AND ULNA
(Plate VIII, Figs 1 and 2)

These bones are quite similar to those of the Ayukawa specimen of *B. edeni* reported by Omura (1959), but somewhat larger in general, due to larger size of the whale body. Epiphyses of humerus and proximal epiphyses of radius and ulna are all completely fused to their main body, but distal epiphyses of the latter two are not fused. No special feature was observed in these bones. Measurements of these bones are shown in Table 7.

TABLE 7. MEASUREMENTS OF HUMERUS, RADIUS AND ULNA OF THE SPECIMEN 77N62 (IN MM)

Measurements	Right	Left
Humerus		
Greatest length	396	386
Width at middle	159	158
Radius		
Greatest length	672	676
Width at middle	111	116
Ulna		
Length at middle*	624	628
Width at middle	70	65

* Excluding olecranon

CARPALS AND PHALANGES
(Plate VIII, Figs 3 and 4)

These bones are of no special feature and their measurements are shown in Table 8.

TABLE 8. MEASUREMENTS OF PHALANGES OF THE SPECIMEN 77N62 (IN MM)

Measurements	Right				Left			
	I	II	III	IV	I	II	III	IV
Length								
1st phalanx	135	141	132	112	136	144	131	110
2nd phalanx	131	137	122	85	132	136	122	92
3rd phalanx	104	109	105	77	106	107	105	75
4th phalanx	77	84	85	missed	76	83	80	42
5th phalanx	53	64	63	—	53	63	57	—
6th phalanx	—	48	44	—	—	47	42	—
7th phalanx	—	37	27	—	—	missed	24	—
Width at middle								
1st phalanx	50	48	44	42	52	47	42	43
2nd phalanx	31	47	43	30	31	48	43	28
3rd phalanx	23	38	31	18	23	37	30	17
4th phalanx	17	34	26	missed	19	34	24	10
5th phalanx	12	32	22		14	30	21	—
6th phalanx	—	30	20		—	29	19	—
7th phalanx	—	27	19		—	missed	18	—

PELVIC BONES

Pelvic bones of our specimen 77N62 are shown in Fig. 9. These are slender and flat bone, but widened at promontories. Remnants of the femur are attached. The length of these pelvic bones are 276 and 275 mm respectively.

Lönnberg (1931) reports the pelvic bones of the Bryde's whale. His main

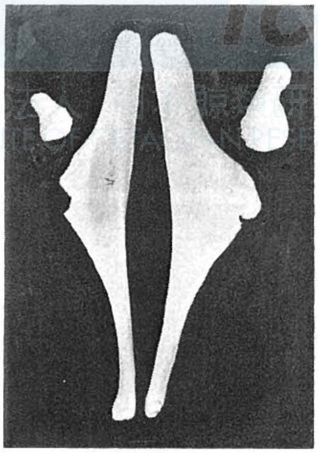

Fig. 9. Pelvic bone of the specimen 77N62.

specimen of skeleton was not accompanied by any pelvic bone and later these bones were sent to him from another specimen. These pelvic bones are well developed and furnished with well developed remnant of femur. He describes these bones in detail. In the minke whale, *Balaenoptera acutorostrata*, from the Antarctic the pelvic bone subjects to very wide individual variation (Omura, 1980). It is thought, therefore, these bones have less taxonomic values.

OTHER BONES

The sternum is a ' cross-shaped ' small bone (Fig. 10). Its breadth is 327 mm and the length is 231 mm. In the other specimens too the sternum is cross-shaped in general (Lönnberg, 1931; Junge, 1950; Omura, 1959), but there are slight difference in the proportion of length and breadth. Also in the sei whale the sternum is similar in shape and possibly this bone has no special importance from the standpoint view of taxonomy.

The hyoid bones (Fig. 11) were also secured. The overall length of the combined bone of basihyal and thyrohyals is 904 mm on curve. And the heights at promontory and at middle are 247 and 153 mm respectively. The lengths of stylohyals are 451 and 460 mm and their breadths are 140 and 139 mm respectively. In general the shape of stylohyals is broad and much curved forwards in *B. borealis*, whereas less broad and less curved in *B. edeni* (Omura, 1964). There are, how-

Fig. 10. Sternum of the specimen 77N62.

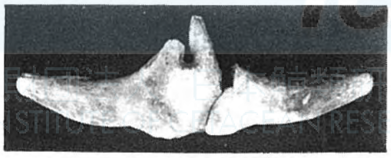

Fig. 11. Hyoid bone of the specimen 77N62.
Upper: Combined bone of basi- and thyrohyals. Partly broken.
Lower: Stylohyals

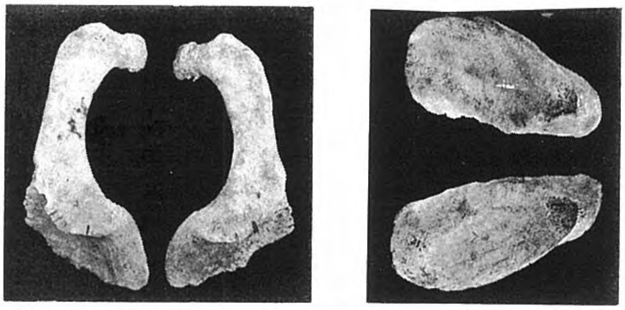

Fig. 12. Malars (left) and lachrymals (right) of the specimen 78N33.

ever, very wide range of variation and these two species can not be separated by this character alone.

In Fig. 12 are shown the malars and lachrymals. These bones are of no special importance in the present study.

DISCUSSION

As stated in the foregoing chapters there are some charcters of skeleton which separate the offshore form of *B. edeni* from *B. borealis*. These have been already recognized in the past study, but it is now confirmed by the present study on new specimens obtained from other localities than ever reported. These are as follows:

A. skull

1. In the lateral view the rostrum is very flat. It is possible, however, in whales which have narrow and long baleen plates, *e.g.* inshore form of Bryde's whales by Best (1977), that the rostrum may be curved downwards as in the case of *B. borealis*.
2. In the dorsal view outer margin of the rostrum is more or less convex, whereas more straight in *B. borealis*.
3. The front margin of nasals is concave or straight and bent forward on the outer side, but convex in *B. borealis* and never bent forward on the outer side.
4. The front margin of nasals is situated strikingly posterior to the anterior border of the posterior maxillary concavity, whereas nearly at the same level in *B. borealis*.
5. In the inferior view palatines do not extend so far back and the basicranial part of the skull exposed behind the palatines is much longer than broad. In *B. borealis* this area is squarish or broader than long.

B. Mandible

6. The groove between the angular and articular parts is shallow, whereas much deeper in *B. borealis*.
7. The posterior end of the angular portion is at equal level or projects behind the articular portion, but it ends before the posterior end of the articular portion in *B. borealis*.

8. The cross section of the mandible at its middle is much rounded than in *B. borealis*.

C. Vertebrae

9. The number of vertebrae is 54–55, whereas 56–57 in *B. borealis*.

10. Spinous processes of the vertebrae in the region from the middle of the dorsals to the beginning of caudals show strong backward inclination, whereas no such inclination is observed in *B. borealis.*

D. Ribs

11. The first rib is deply bifurcated at the head by a narrow cleft, both in *B. edeni* and *B. borealis*. This character may serve, however, to separate the two species from other species of baleen whales.

We consider that above characters are well established, especially the shape of the nasal bone is very important. Mead (1977), however, have not relied upon skeletal characters, as several of his specimens appear to be either intermediate or contradictory in some of the characters, particularly the shape of the nasal bones. He identified the whale which was reported as *B. borealis* by Miller (1924) as *B. edeni* and described that ' This is confirmed by an examination of the baleen, which is clearly that of *B. edeni* '.

We like to discuss about this whale based on the paper by Miller (1924). This is a 13.7 m male *Balaenoptera* stranded at Pablo Beach (now Jacksonville Beach), Florida (No. 236680, U.S. National Museum). The baleen plate of this whale is narrow and long and show typical sei-whale-type (Pl. 21, Fig. 3 of Miller). According to Miller this plate is taken from near middle of series and ' whalebone plates uniformly blackish horn color, the extremely fine and hairlike bristles a very pale horn color appearing conspicuously whitish by contrast '. The front margin of nasals is convex and not bent forward on the outer side, and is situated nearly at the same level of the anterior border of the posterior maxillary concavity (Pl. 1). The rostrum is bending downwards (Pl. 3) and its outer margin is nearly straight (Pls 1 and 2). The angular portion of the mandible ends before the end of the articular portion (Pl. 3, Figs 2 and 3). The breadth of mandible at its middle is about 55% of the height (estimated from Pl. 3, Figs 2 and 4). The strong backward inclination of the spinous processes of lumbar vertebrae is not observed (Pls 12 and 13).

All of these suggest strongly that the Pablo Beach whale is in fact a sei whale *B. borealis*. Our conclusion on this whale is, therefore, re-examination of the baleen plate of this whale is needed.

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We are much indebted to crew of the *Nisshin Maru No. 3* and staff of the Kyodo Hogei K. K. for securing and transporting the skeleton used in this study.

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EXPLANATION OF PLATES

PLATE I

Skull of the specimen 77N62 of the Bryde's whale from the central South Pacific.

Fig. 1. Dorsal view.
Fig. 2. Ventral view.
Fig. 3. Lateral view.

PLATE II

Skull of the specimen 78N33 of the Bryde's whale from the eastern Indian Ocean.

Fig. 1. Dorsal view.
Fig. 2. Ventral view.
Fig. 3. Lateral view.

PLATE III

Skull and mandibles of the specimen 77N62 of the Bryde's whale from the central South Pacific.

Fig. 1. Right mandible. Lateral and inner view.
Fig. 2. Left mandible. Lateral and outer view.
Fig. 3. Skull. Posterior view.

PLATE IV

Skull and mandibles of the specimen 78N33 of the Bryde's whale from the eastern Indian Ocean.

Fig. 1. Right mandible. Lateral and inner view.
Fig. 2. Left mandible. Lateral and inner view.
Fig. 3. Skull. Posterior view.

PLATE V

Ribs and scapullae of the specimen 77N62 of the Bryde's whale from the central South Pacific.

Fig. 1. Right and left ribs.
Fig. 2. Right and left scapullae.

PLATE VI

Vertebrae of the specimen 77N62 of the Bryde's whale from the central South Pacific.

Fig. 1. Cervical and dorsal vertebrae.
Fig. 2. Lumbar vertebrae.
Fig. 3. Caudal vertebrae.
Fig. 4. Caudal vertebrae obtained from the region of the tail flukes.

PLATE VII

Cervical vertebrae of the specimen 77N62 of the Bryde's whale from the central South Pacific. Anterior views.

Fig. 1. Atlas.
Fig. 2. Axis.
Fig. 3. Combined bone of Nos 3 and 4.
Fig. 4. No. 5.
Fig. 5. No. 6.
Fig. 6. No. 7.

PLATE VIII

Bones in flipper of the specimen 77N62 of the Bryde's whale from the central South Pacific.

Fig. 1. Humerus, radius and ulna in the right flipper.
Fig. 2. Humerus, radius and ulna in the left flipper.
Fig. 3. Carpals and phalanges in the right flipper.
Fig. 4. Carpals and phalanges in the left flipper.


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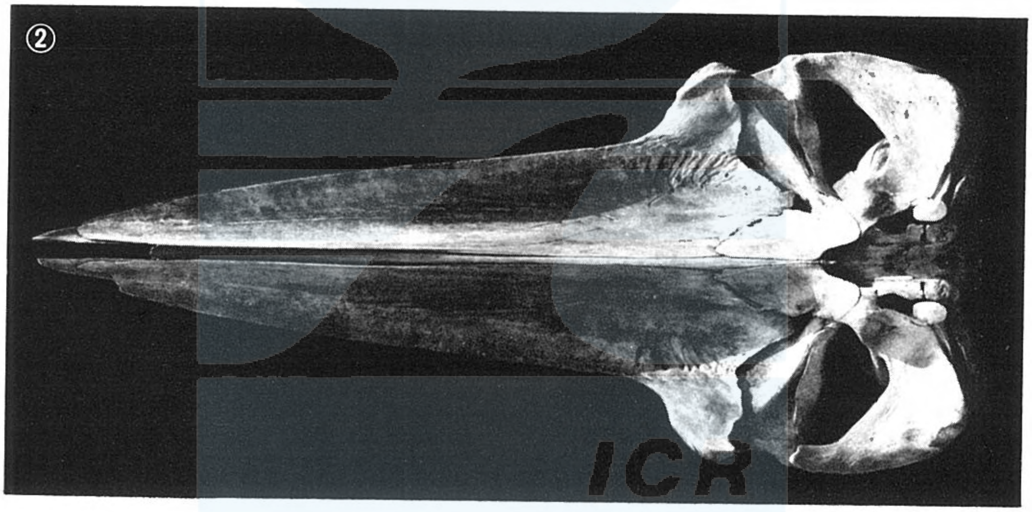
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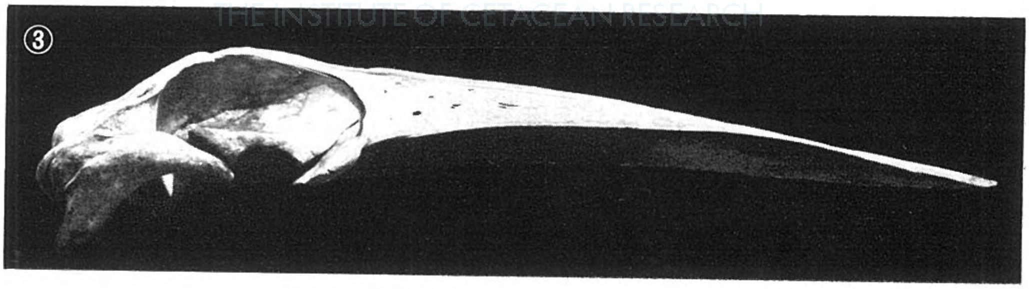
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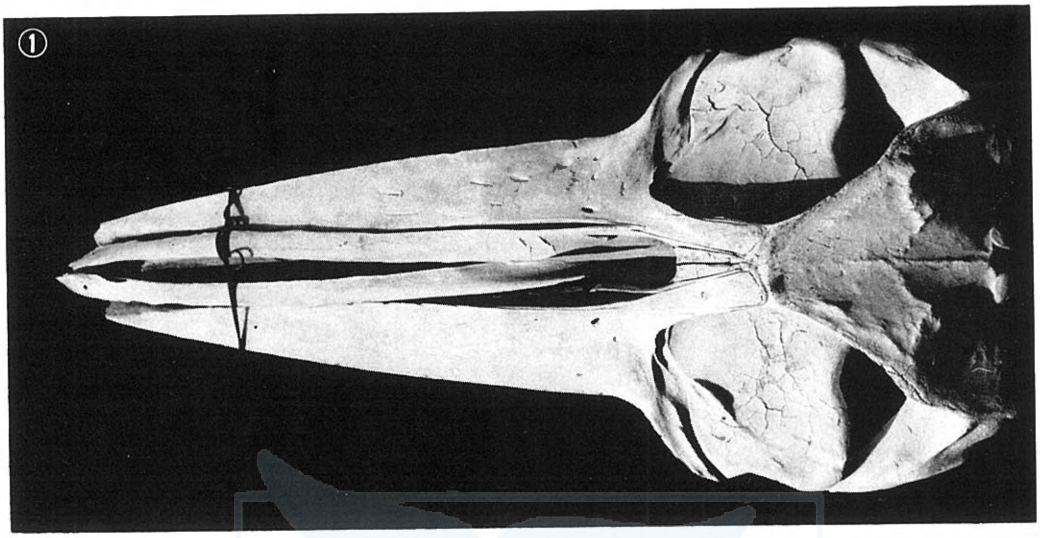
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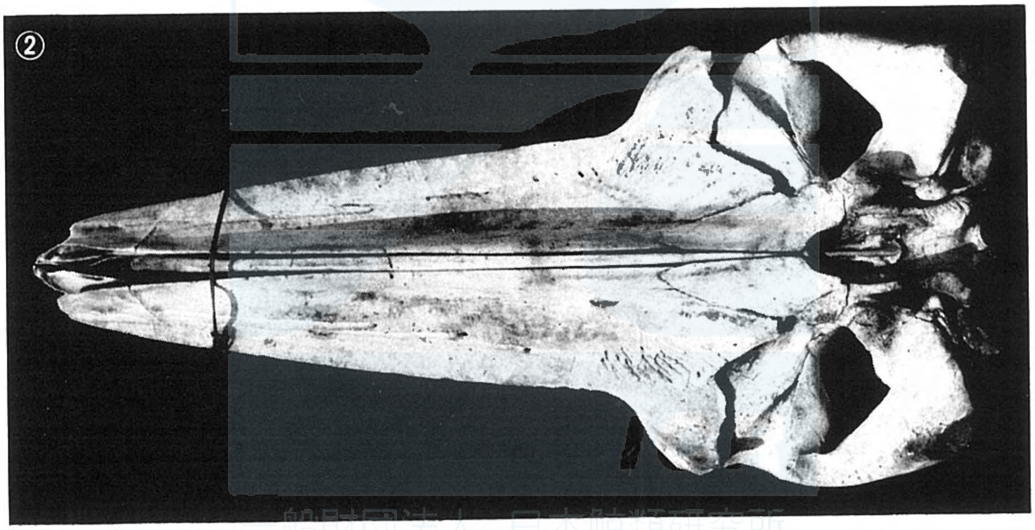
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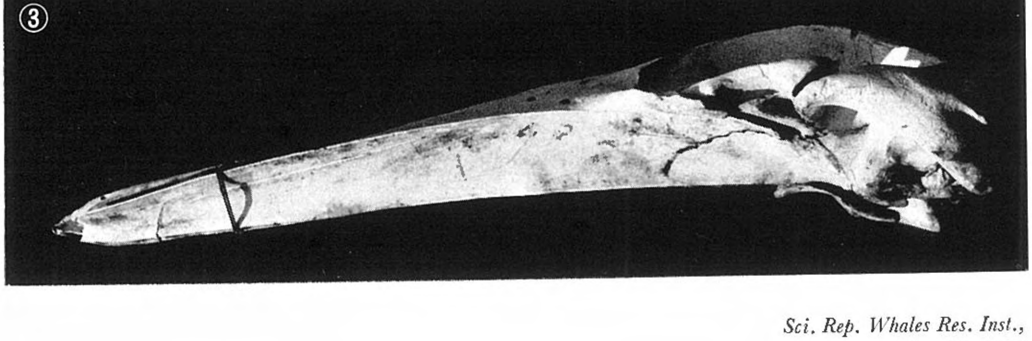
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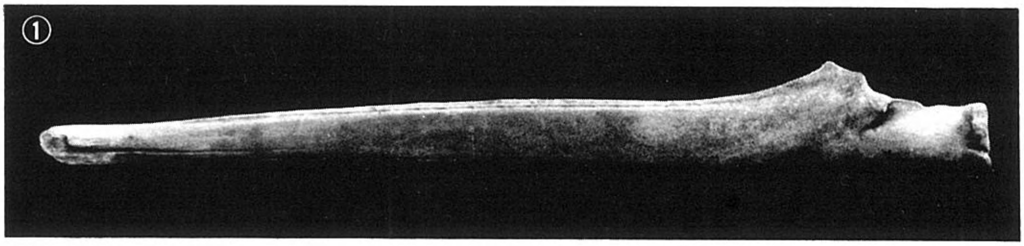
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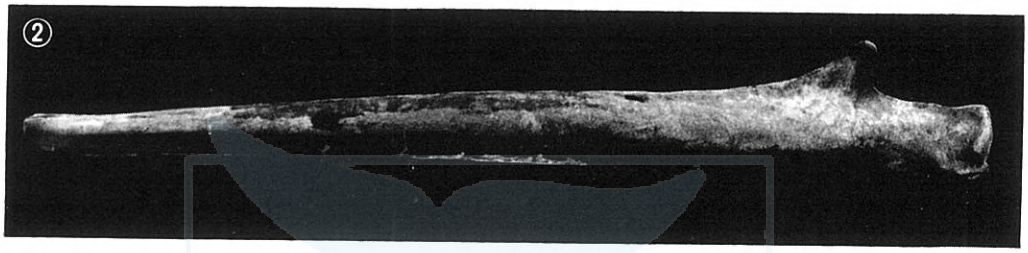
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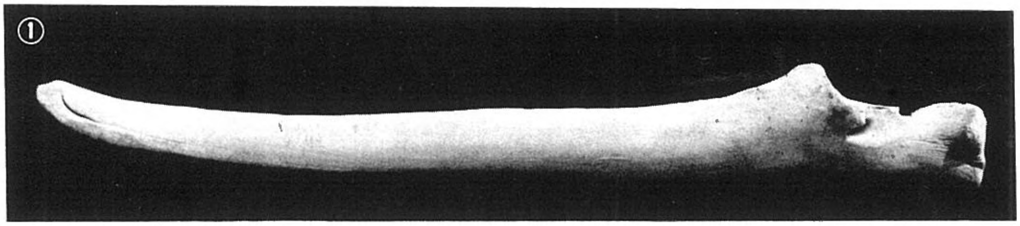

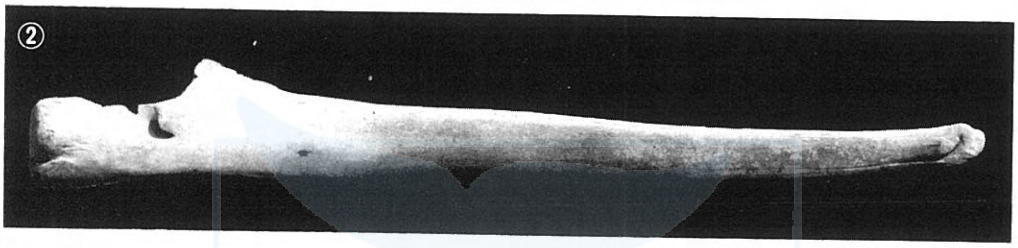

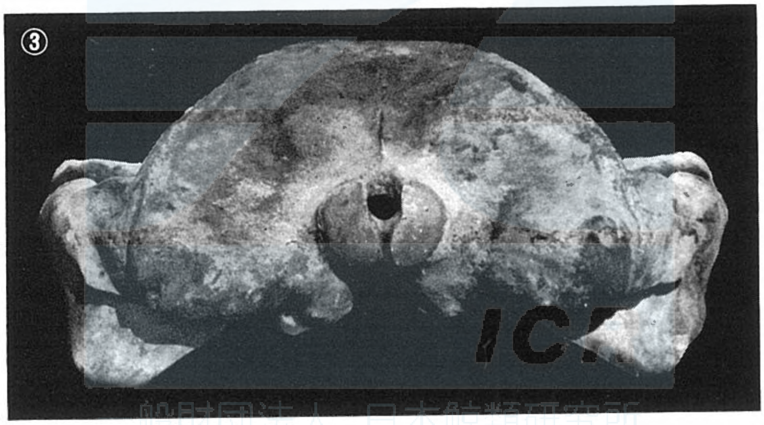

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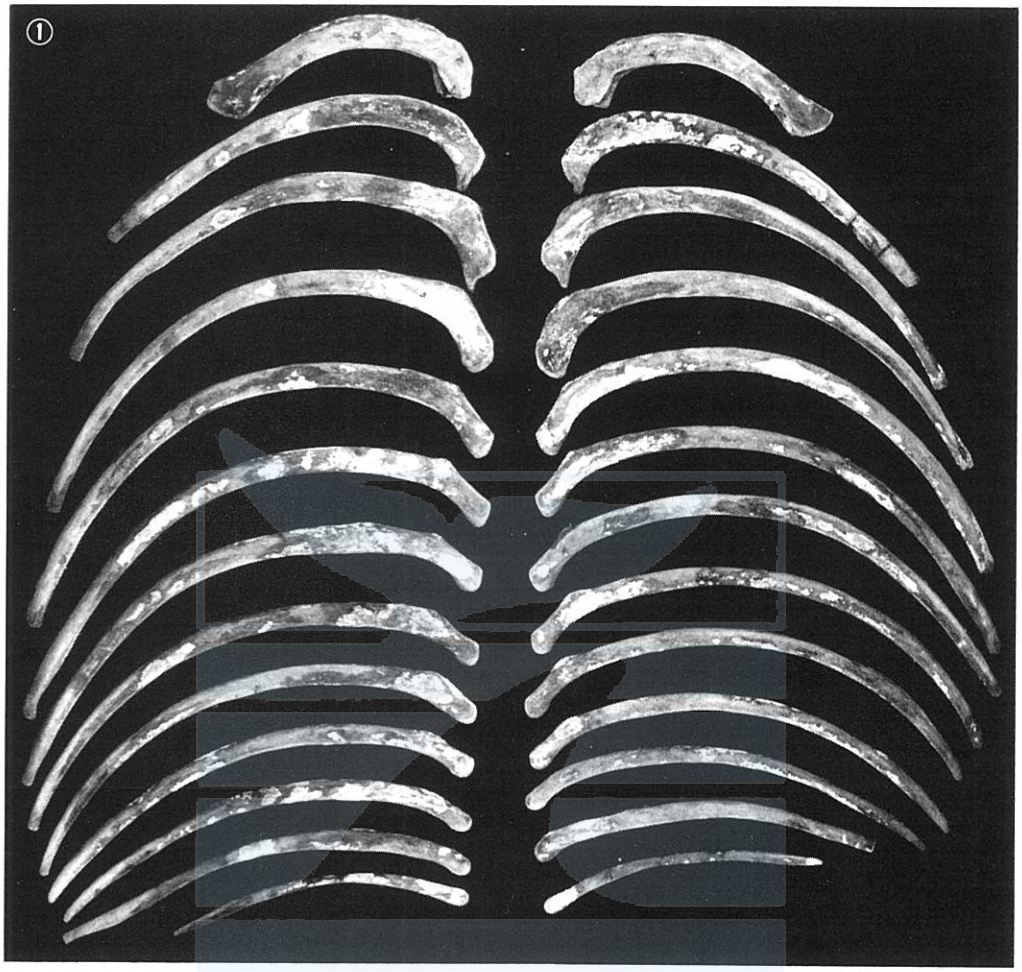

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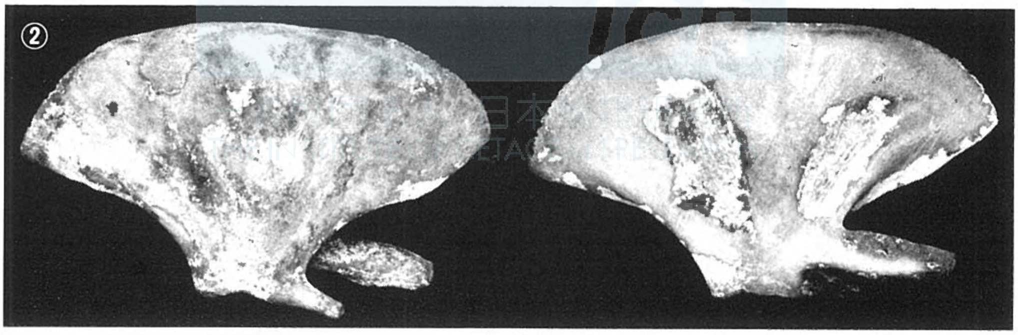

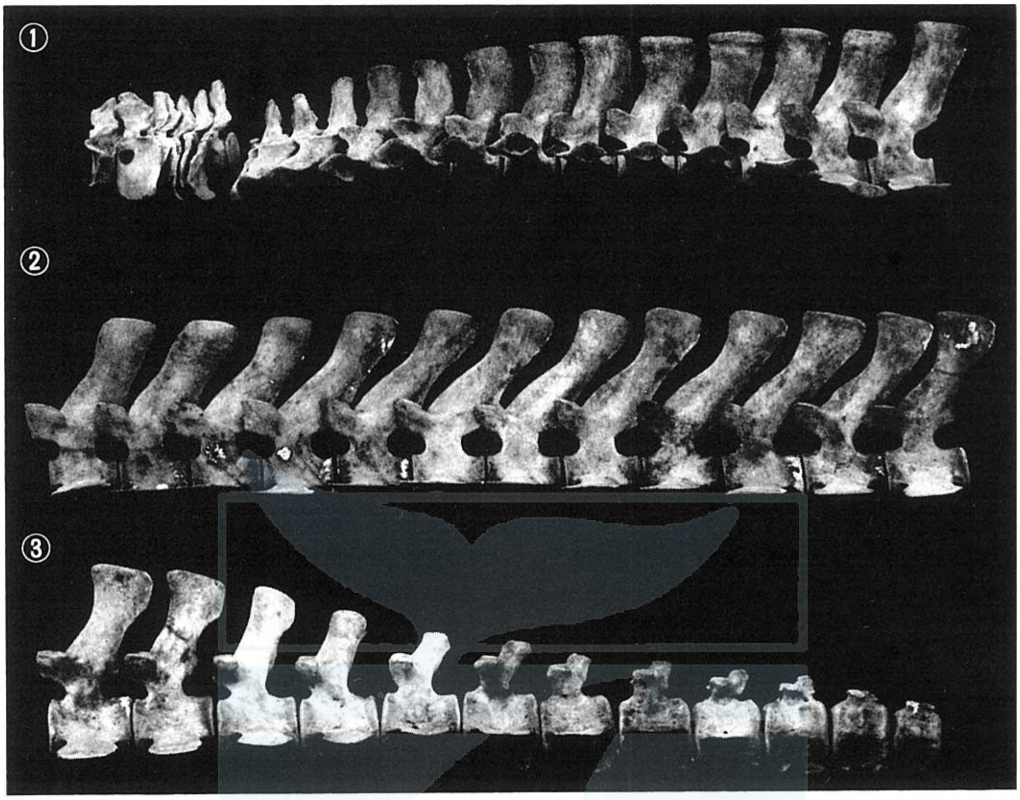
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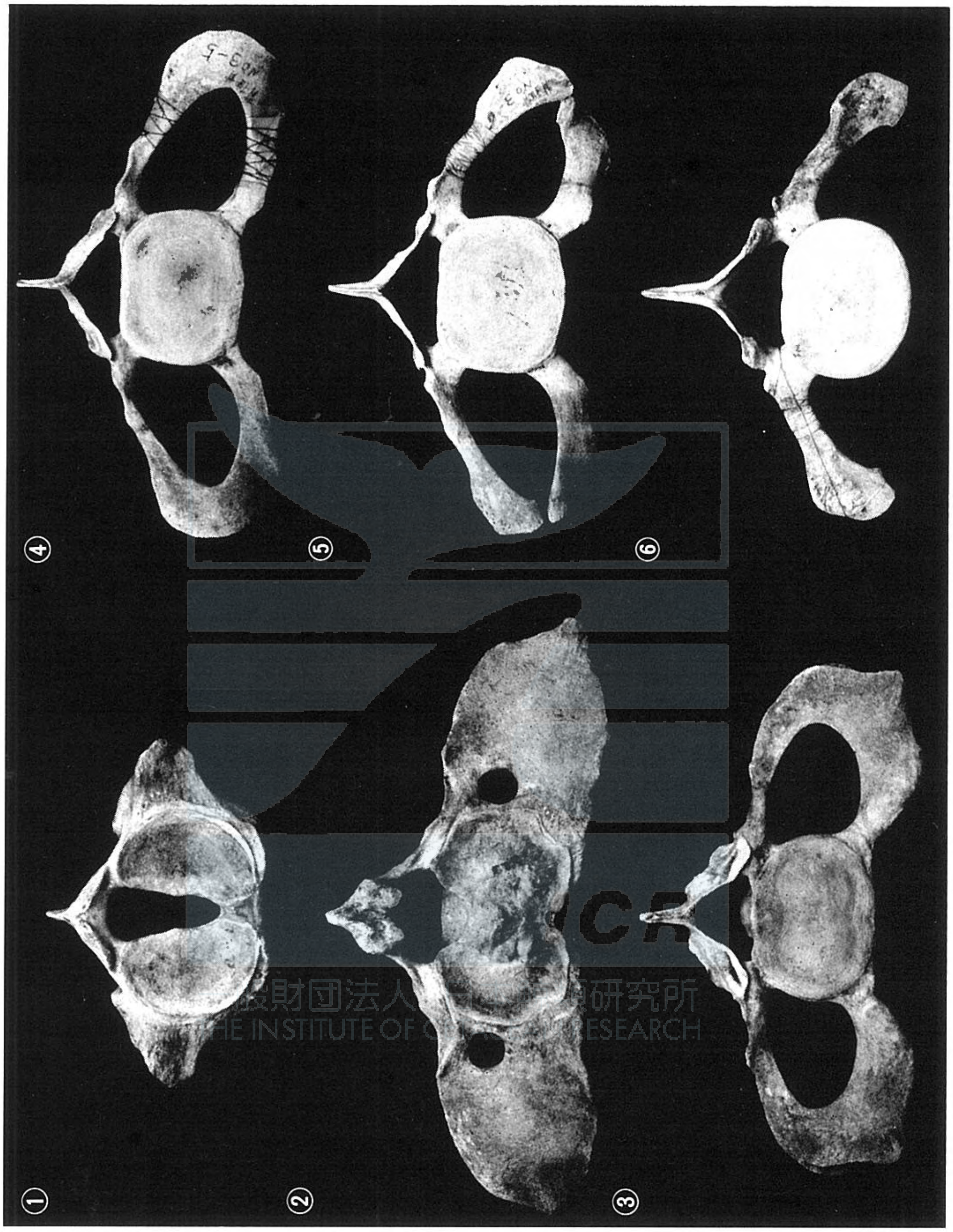
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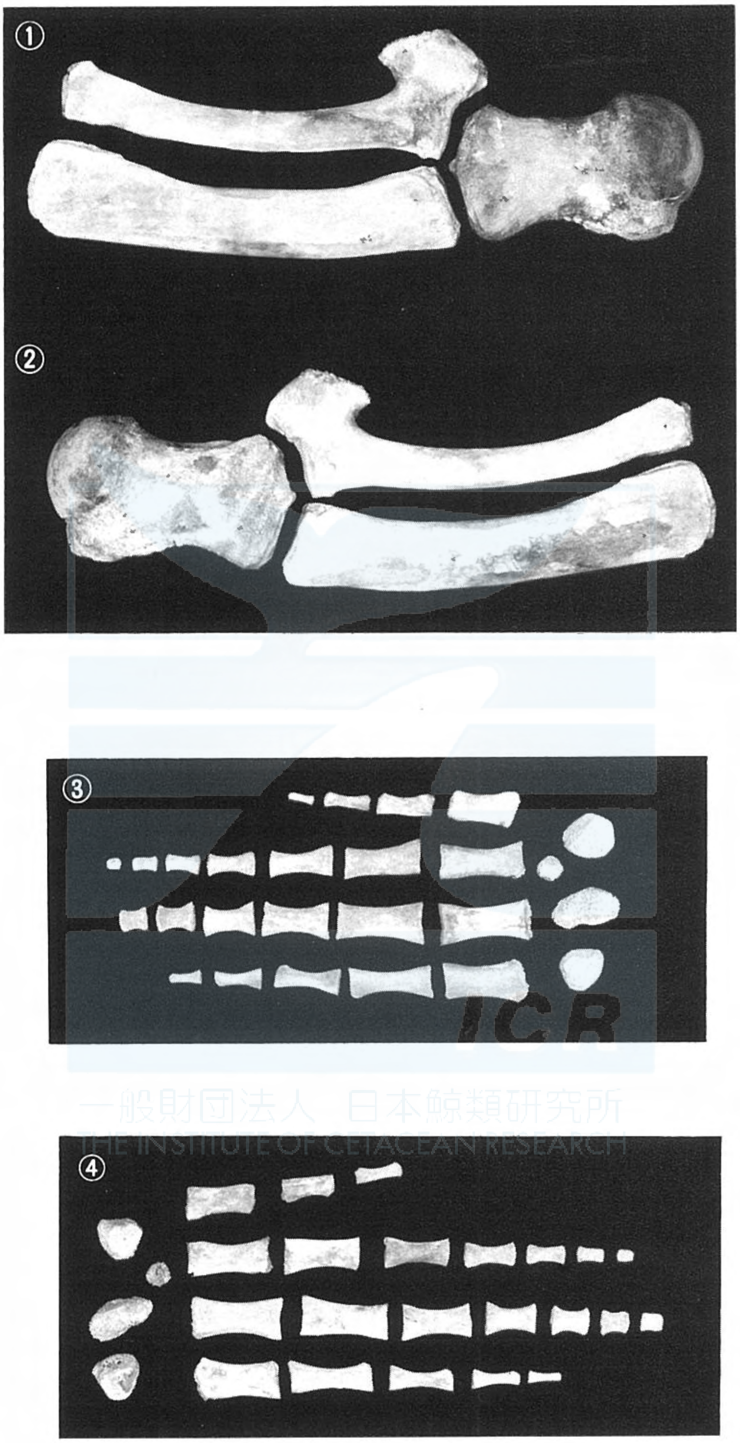
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