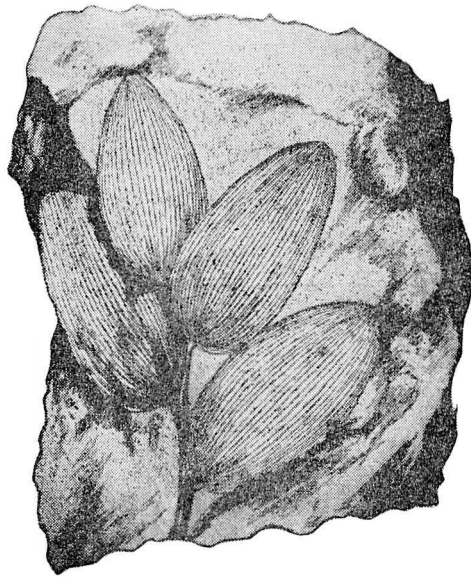日本古生物学會
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The fossil on the cover: Original figure of *Podozamites Reinii* GEYLER, 1877, from the Tetori group. GEYLER's description marked the onset of modern palaeontology in Japan.

682. TAXONOMIC STUDIES ON SOME FOSSIL AND RECENT JAPANESE BALANOIDEA (PART 2)*

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日本のいくつかの化石 および 現生フジツボ類の分類学的研究 （その 2）：この論文では日本の主要な化石 および 現生フジツボ類のうち *Balanus rostratus*, *B. crenatus*, *Megabalanus rosa*, *M. volcano* および *Solidobalanus* (*Hesperibalanus*) *hesperius* を記載する。*B. rostratus* および *S.* (*H.*) *hesperius* の 2 種は従来いくつかの種以下の分類群に細分されていた。しかしそれらの種以下の分類群の標徴とされた形態的特徴は日本の現生および化石の 1 つの地方個体群の標本中に見られる。従ってそれらの種以下の従来の分類は認められない。しかしこの結論は別の形態的特徴によって両種がそれぞれさらに地理的に細分される可能性を否定はしない。*M. volcano* の化石がはじめて沖縄本島の更新世に発見された。この化石には *M. rosa* が付着しており，更新世には両者の生殖的隔離が完了していたことを暗示する。*B. crenatus* および *S.* (*H.*) *hesperius* は最古の化石記録が日本では中新世初期まで溯られる。両種とも現在までの時間経過の間に種を特徴づける形質にほとんど変化が認められない。フジツボ類のこのような形態の長期間にわたる安定性は表現型がその状態を維持する機構を考えあわせる時古生物学的に興味深い素材を提供する。 　　　　　　　　　山口寿之

6. Revision of *Balanus rostratus*

Historical Review

Balanus rostratus HOEK was originally described by HOEK (1883) from Kobe, Japan. PILSBRY (1911, 1916) proposed, beside *B. rostratus* s. s., five subspecies: *B. r. apertus*, *B. r. alaskensis*, *B. r. dalli*, *B. r. heteropus* and *B. r. suturalis*. He divided *B. rostratus* into two groups. One has transverse septa of longitudinal tubes extending near to the base, and the other has transverse septa confined to the upper half of longitudinal tubes. *B. rostratus* s. s., *B. r. alaskensis* and *B. r. heteropus* were included in the former

group, while *B. r. apertus*, *B. r. dalli* and *B. r. suturalis* in the latter group. The former group is further subdivided into two subgroups by the nature of radii and rostrum: one is *B. rostratus* s. s. which has conspicuously sunken radii and at the same time has about 14 tubes in the rostrum. The other subgroup was characterized by the slightly sunken radii and about 18 or more tubes in the rostrum, and includes *B. r. alaskensis* and *B. r. heteropus*. *B. r. alaskensis* was defined by the larger size with diameter of 60-70 mm and with four or five pairs of spines on each segment of the posterior cirri, while *B. r. heteropus* was smaller in size with diameter of about 18 mm and with four pairs of spines on segments of posterior cirri.

BROCH (1922) described *B. r.* forma *eurostratus* from Departure Bay, Van-

couver Island. NILSSON-CANTELL (1932) described *B. r.* var. *spiniferus* from Kobe, Japan, an area roughly corresponds to the HOEK's type-locality of *B. rostratus*.

Taxonomic treatment proposed by PILSBRY (1911, 1916) has been adopted by many authors, CORNWALL (1925), HIRO (1935, 1939b), HENRY (1940, 1942), TARA-SOV and ZEVINA (1957) and UTINOMI (1958). HENRY (1940) pointed out that *B. r. heteropus* and *B. r. spiniferus* are synonyms of *B. r. alaskensis*, without giving taxonomic remarks. Thus, the current classification of *B. rostratus* seems to be an intact application or a slight modification of PILSBRY's old classification explained in the preceding lines.
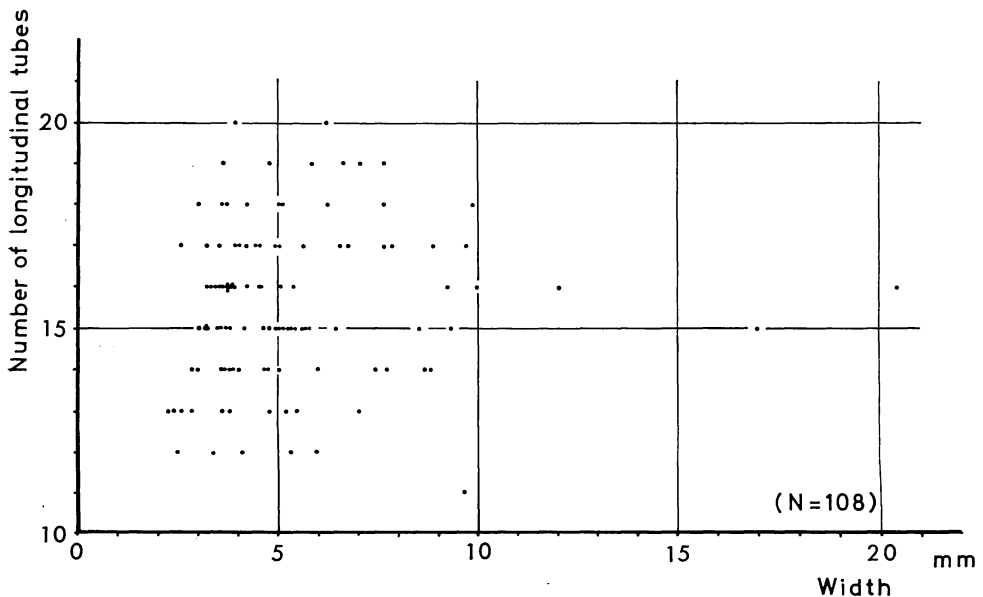
Morphological Examination of Recent and Fossil Japanese B. rostratus

Transverse septa: The distribution pattern of transverse septa in the longitudinal tubes was regarded by PILSBRY as one of the criteria for the subspecific division of *B. rostratus*. This character will be examined on Recent Japanese materials collected from Loc. C1 (Mutsu Bay). They are composed of living specimens and fragmental skeletal elements derived apparently from one population. The distribution pattern of transverse in the longitudinal tubes varies between two extremes. In one extreme the distribution of transverse septa covers entirely from orifice to base, but the other confined to the upper part of longitudinal tubes (pl. 24, figs. 7a–g).

Radii: Even in the specimens from the same population, variably sunken radii are found among compartments which are of uniform size. Thus the degree of sinking of radii does not related to the shell size, that is perhaps to growth age.
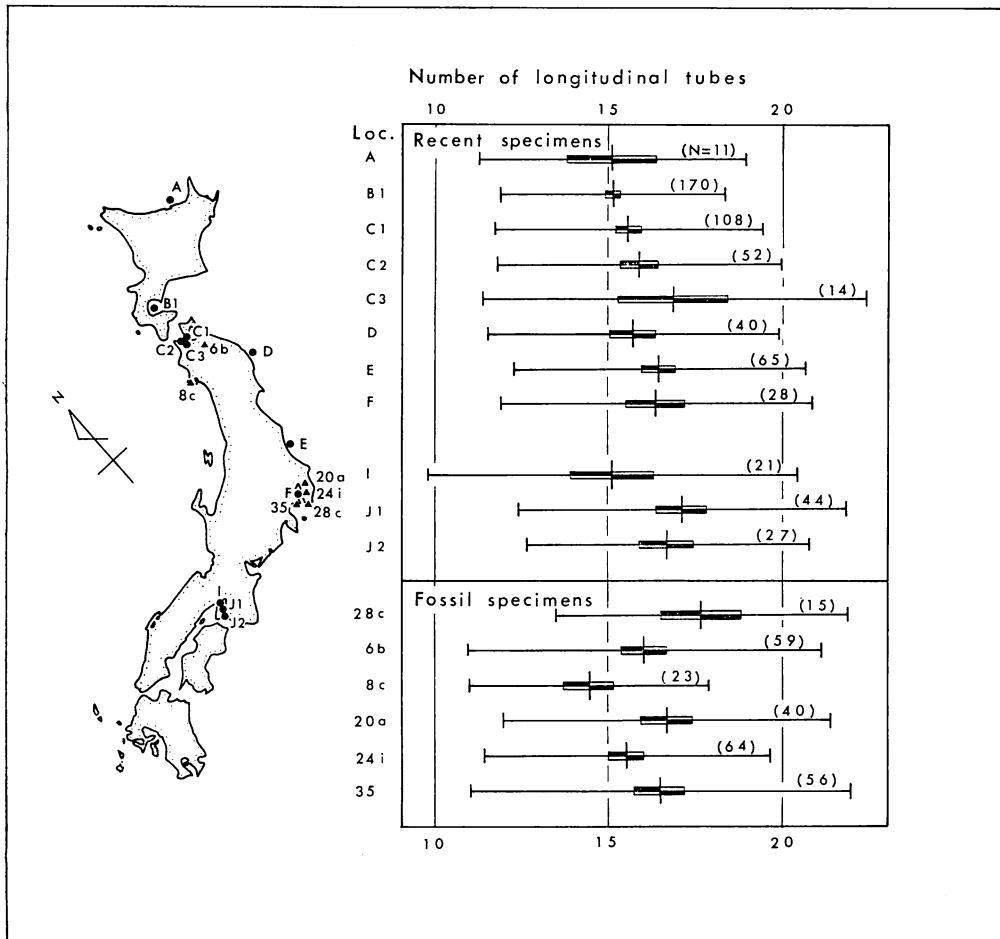
Longitudinal tubes: The number of longitudinal tubes in rostrum compartment of *B. rostratus* are compared with the

Text-fig. 6. Relation between shell size (width) and number of longitudinal tubes in rostrum of *B. rostratus* from Loc. C1.

shell size (width) of the compartment in text-fig. 6. The number of longitudinal tubes seems to be a character which is not much influenced by width of the compartment. It is also observable in x-ray photograph that the number does not change during shell growth, though an increase or a decrease in number is detectable in some traumatized specimens. In order to ascertain the number of the tubes in topotype specimens of *B. rostratus*, the writer made dredge

sampling of bottom sediments at the type-locality (Kobe, Japan; St. 233 of Voyage of Challenger). It is found that this species is no more alive in the area of the type-locality off Kobe harbor because of the polution of sea in the present time. Therefore, three samples from the neighborhood of the type-locality, that is Locs. I and J1-2 were examined. In these three samples, the 95% confidence limits of means ($\bar{x} \pm t \cdot \sigma_{\bar{x}}$) for the number of longitudinal tubes

Text-fig. 7. Mean, 95% confidence limits of the mean ($\bar{x} \pm t \cdot \sigma_{\bar{x}}$) and twice standard deviation of the mean for number of longitudinal tubes in rostrum of living and fossil *B. rostratus* of Japan.

Table 4. Statistic values of number of longitudinal tubes in rostrum of living and
fossil *B. rostratus* HOEK. N: number of individuals examined, OR: ob-
served range, $\bar{x}$: mean, s: standard deviation, $\sigma_{\bar{x}}$: standard error.

	Loc.	N	OR	$\bar{x}$	s	$\sigma_{\bar{x}}$
Living specimens	A	11	12–18	15.09	1.92	0.58
	B1	170	10–20	15.12	1.62	0.12
	C1	108	11–20	15.56	1.93	0.19
	C2	52	11–20	15.88	2.05	0.28
	C3	14	11–21	16.86	2.77	0.74
	D	40	11–23	15.70	2.10	0.33
	E	65	12–22	16.44	2.09	0.26
	F	28	13–22	16.36	2.24	0.42
	I	21	11–22	15.10	2.66	0.58
	J1	44	14–25	17.11	2.36	0.36
	J2	27	14–21	16.68	2.03	0.39
Fossil specimens	28c	15	14–21	17.67	2.09	0.54
	6c	59	11–24	16.02	2.54	0.33
	8c	23	11–17	14.43	1.73	0.36
	20a	40	12–23	16.68	2.35	0.37
	24i	64	12–21	15.53	2.06	0.26
	35	56	13–25	16.52	2.72	0.36

overlap with one another (Text-fig. 7). Thus these three samples are not essentially different in number of longitudinal tubes, and are derived from the same population.

In the same way, the means and the 95% confidence limits for the number of longitudinal tubes in various Recent specimens from several mutually distant Japanese localities were examined (Text-fig. 7, Tab. 4). The sample means range from 15.09 (Loc. A) to 17.11 (Loc. J1). Three samples from the different environments in the Mutsu Bay, that is, from the sea bottom (Loc. C1), on cultivated scallops hanging from a raft (Loc. C2) and on the rocky shore (Loc. C3), are compared. The 95% confidence limits of the means among three samples from Mutsu Bay overlap with one another (Text-fig. 7). Therefore, so far as this character is concerned, geo-graphical and ecophenotypic effects are regarded as insignificant.

The observed ranges and twice the standard deviation of the mean, for the number of longitudinal tubes in Recent samples from various localities of Japan, greatly overlap and include 14 and 18 which were regarded by PILSBRY (1911, 1916) as a subspecies criterion. In conclusion, it is not possible to separate *B. rostratus* into subspecies or any other infraspecific taxa by this character.

The number of longitudinal tubes in fossil specimens was also examined. The result is shown in text-figure 7. The same conclusion can be ascertained by the Pleistocene and the Holocene specimens.

Distribution

The distributions of *B. rostratus* so far known are summarized in text-figures 8

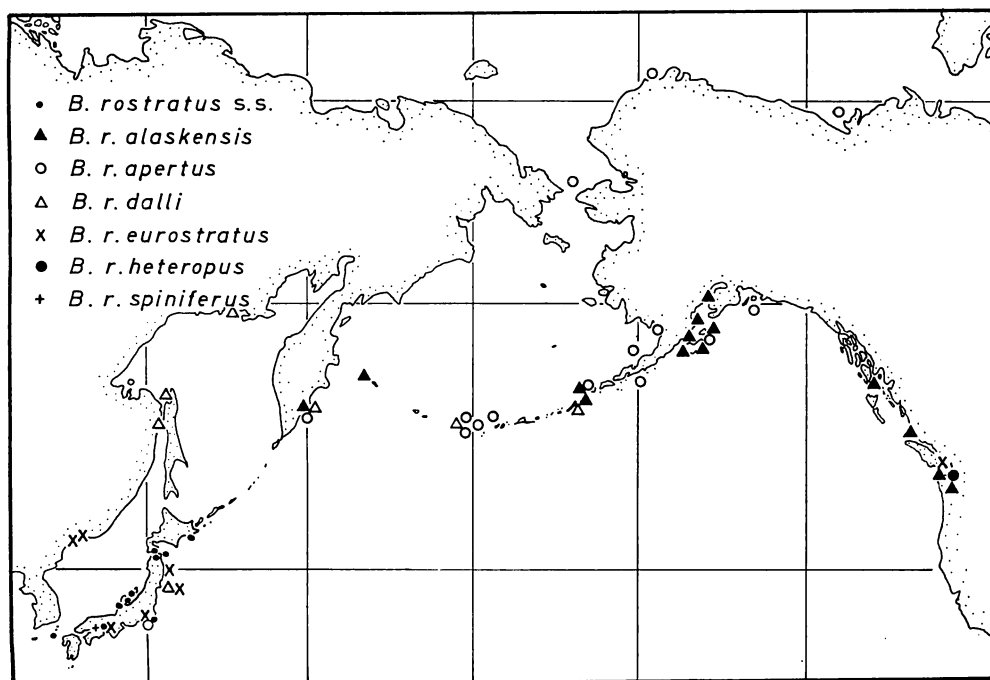and 9. Depth distribution ranges from 0 m to 168 m.

From the text-figure 9, it is seen that, in Japanese waters, *B. rostratus* s. s. and *B. r. eurostratus* are distributed in a macrogeographically sympatric relationship. The distribution extends to Sagami Bay on the Pacific side and to the Tsushima Straits on the Japan Sea side, a branch further extends into the Inland Sea of Japan through the Kanmon Straits.

B. rostratus forma *eurostratus* was originally described by BROCH (1922) from Depature Bay, Nanaimo, Vancouver Is. He mentioned that his specimens "quite agree with the Japanese variants which PILSBRY (1916) takes to be the typical *B. rostratus* i. e. the forma *eurostratus*".
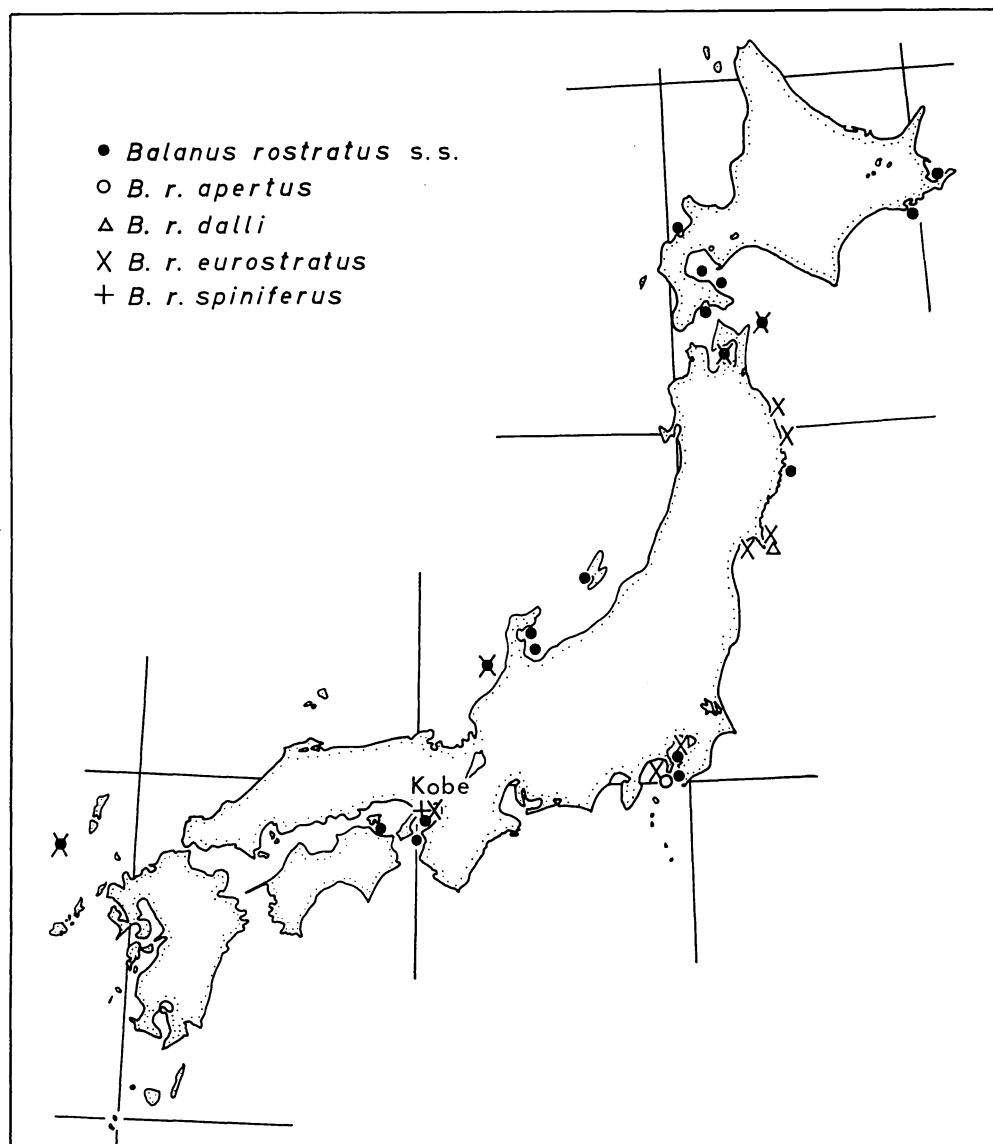
Therefore, *B. r. eurostratus* seems to be coincided with *B. rostratus* s. s.

NILSSON-CANTELL (1932) has described *B. r.* var. *spiniferus* from Kobe, the type-locality of *B. rostratus* s. s. This variety is embedded in sponges and characterized by a few downwardly projecting spines, and thus coincides with the PILSBRY's *B. r. apertus* (UTINOMI, 1958).

B. r. rostratus and *B. r. apertus* are found by UTINOMI in the different dredges at the same locality in Sagami Bay, central Japan. In fact. *B. r. rostratus* with the smooth surface and with the spinose surface are found together in the same dredged sample in Mutsu Bay (Loc. C1). Thus *B. r.* var. *spiniferus* which does not differ very much from *B. rostratus* s. s. in morphology other

Text-fig. 8. Distribution of *B. rostratus* and its "subspecies" in the Recent sea. [Compiled from CORNWALL; 1925, 1955, HENRY; 1940, 1942, HIRO; 1932b, 1933, 1935, 1939b, HOEK; 1883, NILSSON-CANTELL; 1932, 1958, PILSBRY; 1911, 1916, TARASOV and ZEVINA; 1957, UTINOMI; 1955, 1970, YAMAGUCHI; 1972MS, 1974MS].

• *Balanus rostratus* s.s.
○ *B. r. apertus*
△ *B. r. dalli*
X *B. r. eurostratus*
+ *B. r. spiniferus*

Kobe

Text-fig. 9. Distribution of *B. rostratus* and its "subspecies" in the Recent sea of Japan. [Compiled from HIRO; 1932b, HOEK; 1883, KRÜGER; 1911b, NILSSON-CANTELL; 1932, 1958, UTINOMI; 1955, 1970, YAMAGUCHI; 1972MS, 1974MS].

than spines, seems to be a mere phenotypic variation of *B. rostratus*.

Three subspecies, *B. r. alaskensis, B. r. apertus* and *B. r. dalli*, has been found in Puget Sound, west coast of British Columbia, Alaska, Bering Sea, Aleutian Islands, south coast of east Siberia, Kamchatka, the Sea of Okhotsk and Sakhalin. The localities of *B. rostratus* and its subspecies described by PILSBRY (1911, 1916) are shown in text-figure 10. The vertical distribution of three sub-

Text-fig. 10. Type and sampling localities of *B. rostratus* and its "subspecies" described by PILSBRY (1911, 1916). a, b, c, d, and e: type localities of *B. rostratus* s. s., *B. r. apertus*, *B. r. dalli*, *B. r. alaskensis B. r. heteropus.*

species is similarly restricted to shallow seas less than 100 m in depth. They are found in many places in macrogeographically sympatric relation. In fact, there are records of the coexistence of certain subspecies, such as *B. r. alaskensis*, *B. r. apertus*, and *B. r. dalli* in Abachinsky Bay, Kamchatka Peninsula (TARASOV and ZEVINA, 1957).

Further, *B. r. dalli* and *B. r. eurostratus* occur together in Onagawa Bay, northern Honshu (HIRO, 1939b). *B. r. rostratus* and *B. r. apertus* coexist in Sagami Bay (UTINOMI, 1958). And *B. r. eurostratus* lives amidst the range of *B. r. alaskensis* in the British Columbia area.

HENRY (1942) pointed out that the number of longitudinal tubes in *B. r. alaskensis* from Seymour Inlet, British Columbia ranges from 15 to 20. This range

of variation of *B. r. alaskensis* from Seymour Inlet fall in that of Recent Japanese *B. rostratus* s. s. HENRY also synonymized *B. r. heteropus* and *B. r. spiniferus* with *B. r. alaskensis.*

In conclusion, all the subspecies which have been proposed in *B. rostratus* do not fit the current geographical definition of subspecies at least from the macrogeographical point of view.

Summary on Taxonomic Revision

The PILSBRY's (1911, 1916) proposal of five subspecies *B. r. alaskensis*, *B. r. apertus*, *B. r. dalli*, *B. r. heteropus* and *B. r. suturalis* were not accompanied by any biogeographical study of this species, but based only on morphological differences. However, diagnostic characters he employed for defining these sub-
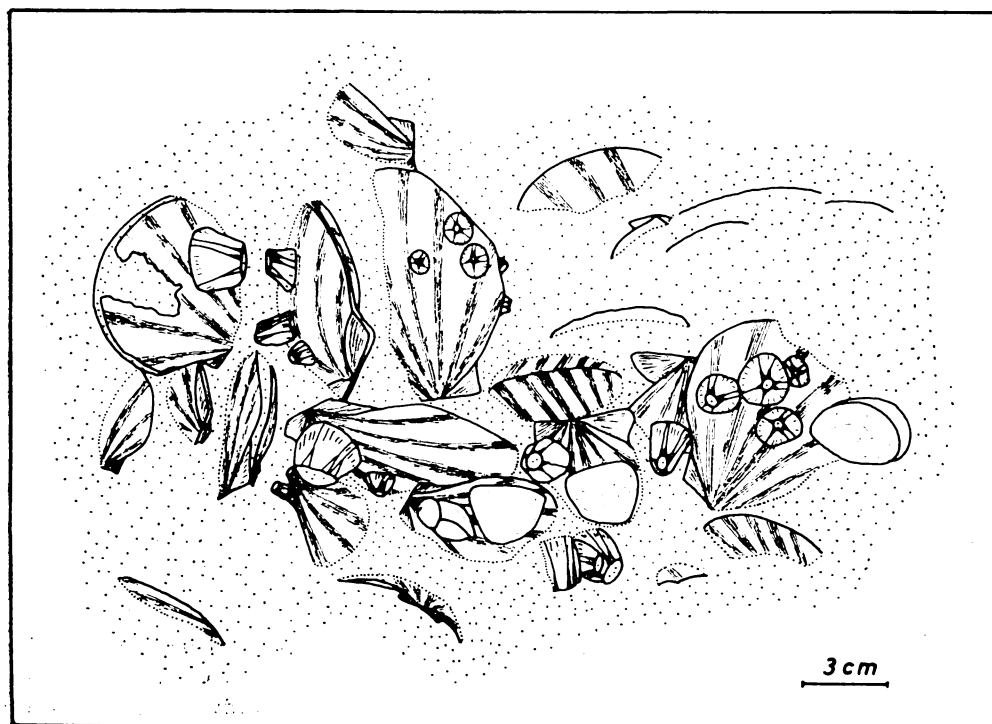
species, such as the distribution pattern of transverse septa, the nature of radii and the number of longitudinal tubes in rostrum are found to be within the range of intrapopulational variation of Recent Japanese *B. rostratus* s. s. An analysis of distribution demonstrated that these subspecies do not fit current geographical criteria for subspecies. Therefore these subspecies are here regarded as synonymous with *B. rostratus* s. s. Although further study may prove the existence of geographical subspecies in *B. rostratus*, the proof needs an extensive biogeographical as well as morphological study on the material from outside of Japan.

Fossil Occurrence

Generally, fossil *B. rostratus* is found as fragmental skeletal elements which show allochthonous occurrence. But autochthonous occurrence is often met with in certain localities, such as Locs. 6b, 20a, 25b, 28c and 29. Three types of autochthonous barnacle occurrences can be recognized. 1) Barnacles which are found on fossil bank-forming oysters (*Crassostrea gigas* at Locs. 6b and 25b; *Crassostrea nipponina* at Loc. 28c). 2) Barnacles which are embedded in massive mud as colonial aggregations in growth position (Loc. 29). 3) Barnacles which are found in coarse sand (Loc. 20a).

Most of fossil barnacles found from Loc. 20a are embedded in sand and attach to the external surface of *Chlamys nipponensis*. Articulate valves of *Chlamys* are occasionally found in the sand, in growth position with umbones directed
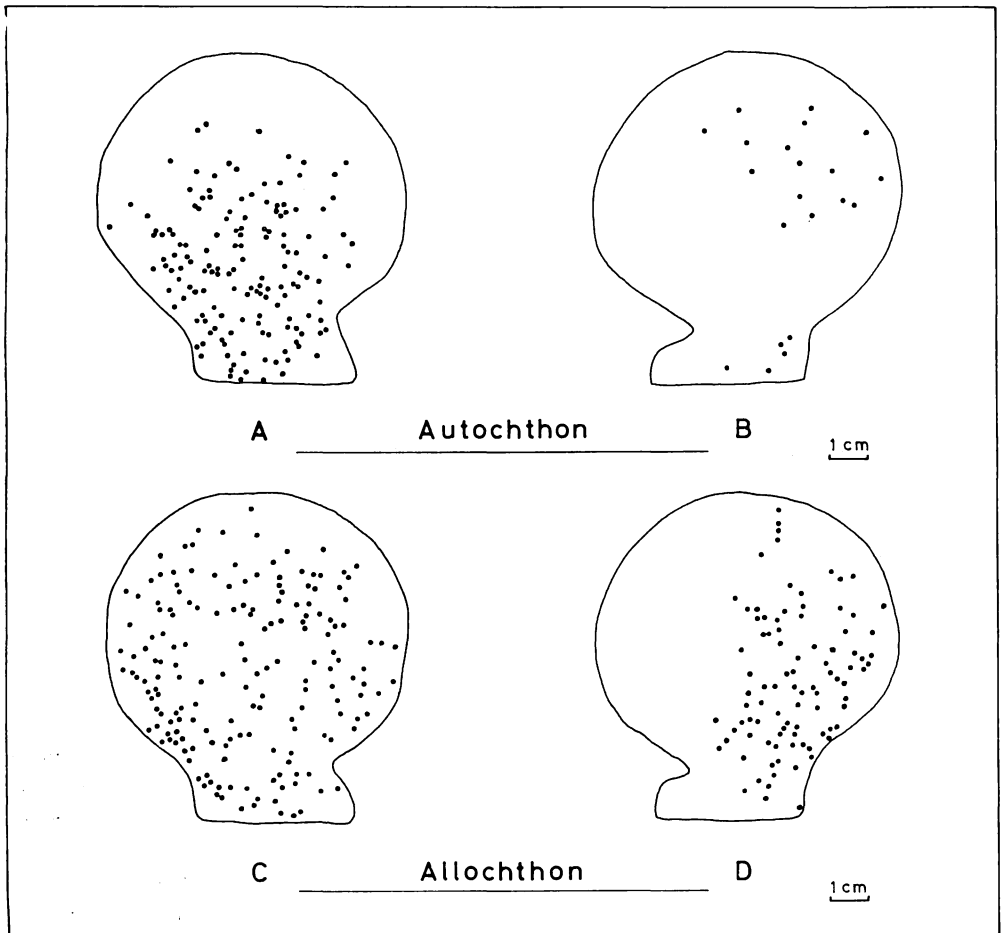

Text-fig. 11. Mode of occurrence of fossil *B. rostratus* growing on autochthonous *Chlamys nipponensis* (Loc. 20a, Pleistocene Semata Fm.).

downward and attached to other individuals or objects by byssus (Text-fig. 11; Pl. 24, fig. 8; cf. Pl. 24, fig. 9). In such cases, fossil barnacles are found on the external surface of both valves, often with a set of opercular valves preserved in the shell cavity. Some individuals may have been transported, but the distance must not have been great.

The examination of 22 individuals of *Chlamys*, revealed that the number and mode of distribution of barnacles on them was remarkably different between left and right valves (Text-fig. 12; Pl. 24, figs. 1-3). Namely, left-valve barnacles are distributed on the entire surface, while right-valve barnacles are restricted to the posterior half of the external surface.

A similar trend was also observed on the disarticulate valves of allochthonous

Text-fig. 12. Mode of distribution of fossil *B. rostratus* growing on *Chlamys nipponensis* (Loc. 20a, Pleistocene Semata Fm.). A, B: left and right valves of 22 individuals of autochthonous *Chlamys*. C, D: left and right valves (11 specimens in each valve) of allochthonous *Chlamys*.

Text-fig. 13. Mode of distribution of living *B. trigonus* growing on *Chlamys nip-ponensis* (Loc. C2). E, F: left and right valves of 10 individuals of living *Chlamys*. × : *B. rostratus*, △ : *Megabalanus rosa*. [Positions of barnacles on 10 individuals of *Chlamys* are plotted on the figure.]

Chlamys (Text-fig. 12). Thus, barnacles found on disarticulate valves had grown there during the life time of *Chlamys*.

Recent barnacles on living specimens of *Chlamys nipponensis* were examined from Loc. C2. Most, on the 10 individuals of *Chlamys*, were *Balanus trigonus* DARWIN, only a few individuals being referable to *B. rostratus* and *Megabalanus rosa*. None the less, the mode of distribution of these barnacles is very similar to that of the fossil barnacles from Loc. 20a (Text-fig. 13). Therefore, the distribution must be controlled by the living position of *Chlamys* (pl. 24, figs. 1-6, 8, 9).

Fossil barnacles at Loc. 20a are generally attached to *Chlamys nipponensis*, but some of them are found on *Anomia lisckei*, *Arca miyatensis*, *Patinopecten tokyoensis* and *Granulifusus musashiensis*.

7. Revision of *Solidobalanus* (*Hesperibalanus*) *hesperius*

Solidobalanus (*Hesperibalanus*) *hesperius* and its Subdivision

PILSBRY (1916) described *S.* (*H.*) *hesperius*, the forma *laevidomus* and the subspecies *nipponensis*. The type specimen of *S.* (*H.*) *hesperius* s. s. is from the Bering Sea (Albatros St. 3483). *S.* (*H.*) *h. nipponensis* was described from off Daikoku-saki, northern Japan (Albatros St. 3768), while *S.* (*H.*) *h.* forma *laevidomus* are based on the specimens from San Juan Is., Puget Sound.

The following characters were considered diagnostic by PILSBRY (1916). 1) The external surface of *S.* (*H.*) *hesperius* s. s. is typically ribbed but in some cases smooth; in *S.* (*H.*) *h.* forma *laevidomus* it is typically smooth but in a few cases ribbed near the base; in *S.* (*H.*) *h. nip-*

ponensis it is always smooth. 2) The scutum of *S.* (*H.*) *hesperius* s. s. has close and sharp growth ridges; in *S.* (*H.*) *h.* forma *laevidomus*, the ridges are very low and more widely spaced growth ridges; in *S.* (*H.*) *h. nipponensis*, they are closely spaced. 3) The tergal margin of scutum is longer than that of basal margin in *S.* (*H.*) *hesperius* s. s., but shorter in *S.* (*H.*) *h.* forma *laevidomus; in S.* (*H.*) *h. nipponensis* the margin are nearly equal in length. 4) The segment of posterior cirri has three or four paired spines, the lower pair being minute in *S.* (*H.*) *hesperius* s. s.; on the other hand *S.* (*H.*) *h. nipponensis* has three paired spines, the lower pair being very minute or absent in some cases. PILSBRY did not described this character for *S.* (*H.*) *h.* forma *laevidomus.*

PILSBRY (1916) mentioned that these morphological characters were variable (p. 200), but thought it "desirable to signalize by name the presence of a modified form" and proposed the new subspecies, *S.* (*H.*) *h. nipponensis.*

Japanese Living and Fossil S. (*H.*) *hesperius*

Many specimens of living *S.* (*H.*) *hesperius* were collected from Funka Bay, Hokkaido, northern Japan (Loc. B2), attach to *Turritella fortilirate* SOWERBY (pl. 27, fig. 5), *Macoma calcarea* (GMELIN) (pl. 27, fig. 4), *Panomya arctica* (LAMARCK), *Mya truncata* LAMARCK, *Eunatica pila* (PILSBRY), *Neptunea arthritica* (BERNARDI), etc.

1) The external surface of shell wall (pl. 27, figs. 1-5) show a wide range of variation from smooth type (*nipponensis* type) (pl. 27, figs. 2e-f, 4, 5) to strongly ribbed type (*hesperius* s. s. type) (pl. 27, figs. 3e-i, 4, 5). In the samples from Funka Bay, large individuals (larger than about 5 mm in basal diameter) are generally ribbed, small individuals (smaller than 3 mm in basal diameter) are usually smooth, and many of medium sized individuals are intermediate, having ribs only near the base (*laevidomus* type). Sometimes, however, a smooth external surface is observed in large individuals, and ribbed surface are found in small individuals.

2) The external surface of scutum in Japanese living specimens shows a wide range of variation, having either widely spaced growth ridges (*laevidomus* type) (pl. 27, fig. 2a) or closely spaced growth ridges (*hesperius* s. s. and *nipponensis* types) (pl. 27, fig. 1a).

3) The proportion between basal and tergal length of scutum, in Japanese living specimens, shows intrapopulational variation covering both the *nipponensis* (pl. 27, figs. 2a-b) and the *hesperius* s. s. type (pl. 27, figs. 1a-b, 3a-b), with the *laevidomus* type in between.

4) The median segments of cirri IV to VI have two large paired spines and one to three short paired spines on the anterior face.

In the shell wall and scutum, two extreme forms are found in living specimens of Funka Bay. However, no significant difference can be detected in the morphology of animal parts between two extreme forms. There are some specimens showing mosaic characters of *hesperius* s. s. and *nipponensis* in which the shell wall possesses strong ribs but the basal length of scutum is longer than the tergal length. In fossil specimens of *S.* (*H.*) *hesperius*, smooth and ribbed individuals (pl. 27, figs. 10a-11b) are associated.

In conclusion, intermediate forms with various combinations of characters between three types which are morphologically comparable with *S.* (*H.*) *hesperius* s. s., *S.* (*H.*) *h.* forma *laevidomus*, and *S.* (*H.*) *h. nipponensis* of PILSBRY's sense

are found in living population of Funka Bay. Therefore, it seems taxonomically irrational to classify *S. (H.) hesperius* into these subspecies or formae by these morphological characters.

8. Additional observation on *Megabalanus tintinnabulum* group

Living *M. rosa* and *M. volcano*, treated as subspecies of *M. tintinnabulum* by PILSBRY (1916) and later authors, are distinct both in morphology, habitat and biochemistry (composition of isozymes). They are largely overlapping geographic ranges. Where the ranges overlap, they occupy similar but in detail different habitat; in general *M. volcano* lives on rocky shores at the lower tide zone, while bulk of *M. rosa* on floating objects. However, it is occasionally observable the physical attachment between the two species. Therefore, they are sympatric in macro- and microgeographical sense. Breeding season between these two phena is completely separable. These facts seems to furnish important proof that two phena are regarded as distinct at the species level (YAMAGUCHI, 1973).

In fossil specimens, macrogeographical sympatry may be assumed, if two or more phena occur at the same horizon. For example, fossils of *M. volcano* were recently obtained together with *M. rosa* from the same horizon of the same outcrop of the Pleistocene Nakoshi Sandstone of Okinawa Is. (Loc. 44). An individual of fossil *M. rosa* is attached to the colony of *M. volcano* (pl. 26, fig. 13). This observation strongly suggests the microgeographical sympatry between the two species. Thus the speciation seems to have been accomplished already in the Pleistocene.

9. Stratigraphical distribution of Japanese Balanoidea

Information on the stratigraphical distribution of Japanese Balanoidea is scarce. Text-figure 14 summarizes the present knowledge on the distribution in Japan. Many species are found living around Japan. However, number of species found in the Pleistocene is half of that of living species. The species limited to the Recent seem to belong either to the rare species with limited distribution or the immigrant species. *Chirona (Striatobalanus) krügeri*, Ogasawara Is.; *Solidobalanus (S.) pseudauricoma*, Ogasawara Is. and off Nagasaki provide examples of species with restricted distributions. Most of symbiotic species are too rare to be encountered as fossils. *B. eburneus, B. improvisus* and *B. amphitrite* are immigrant species. The first two species arrived in the Japanese region after World War II, while *B. amphitrite* arrived but in historical times, as explained in the preceding pages.

Around the Plio-Pleistocene boundary, the occurrence of many warm water species is noticable. It is interesting to note, however, such warm water species as *B. concavus* withdrew from Japan at end of the Pliocene. On the other hand, cold water species such as *Chirona (Chirona) evermanni* disappeared from the Japanese region at the end of Pliocene or sometime in the Pleistocene, but still persists in the northern part of the Okhotsk Sea.

Not many species of Balanoidea can be traced back into the Pliocene and Miocene. This is perhaps because of the incompleteness of fossil record. Yet, microgeographical sympatry can be detected between *Megabalanus rosa* and *M. volcano* even in the Pleistocene.

			Living	Holocene	Pleistocene	Pliocene	Late Miocene	E.-M. Miocene
symbiotic species	W	Armatobalanus (A.) cepa						
	W	Armatobalanus (A.) quadrivittatus						
	W	Armatobalanus (A.) allium						
	W	Conopea calceola						
	W	Conopea cymbiformis						
	W	Conopea navicula						
	W	Conopea cornuta						
	W	Conopea granulata						
	W	Balanus poecilotheca						
	W	Membranobalanus cuneiformis						
embayment species	W	Balanus eburneus						
	W	Balanus improvisus						
	W	Balanus amphitrite						
	W	Balanus albicostatus						
	W	Balanus reticulatus						
	W	Balanus kondakovi						
open sea species	W	Megabalanus volcano						
	W	Megabalanus rosa						
	W	Balanus trigonus						
	W	Chirona (Striatobalanus) tenuis						
	W	Chirona (Striatobalanus) amaryllis						
	W	Chirona (Striatobalanus) krugeri						
	W	Solidobalanus (S.) hawaiensis						
	W	Solidobalanus (S.) socialis						
	W	Solidobalanus (S.) pseudauricoma						
	W	Solidobalanus (S.) compressus						
	W	Balanus concavus						
open	C	Balanus rostratus						
	C	Balanus crenatus						
	C	Chirona (C.) evermanni						
	C	Semibalanus cariosus						
	C	Solidobalanus (Hesperibalanus) hesperius						
fossil species		Balanus sp. aff. "amphitrite"						
		Chirona sp. A						
		Chirona sp. B						
		Solidobalanus? sp.						
		Megabalanus sp. A						
		Megabalanus sp. B						

Text-fig. 14. Stratigraphical distribution of Japanese Balanoidea. W: warm water species, C: cold water species.

Morphological stability of some species (*B. crenatus* and *Solidobalanus* (*Hesperibalanus*) *hesperius*) can trace back to the early or middle Miocene.

B. crenatus is known from a few stations in northern Japan. Where extant individuals are usually found attached to the gastropod shells (*Neptunea*, *Pugilina* and *Phalium*) and the carapace of a crab (*Paralithodes*). Fossil occurrence are also restricted to the northern Japan, where usually fragmental skeletal elements are found in shelly sandstone of Miocene age. When the compartments,

scutum and tergum are recovered from the sediments, they clearly show the diagnostic characters as defined by the living specimens. These characters include the nature of the external surface and cavity between sheath and inner lamina of the compartments, growth ridges, articular ridge, adductor ridge and pit for adductor muscle of the scutum, and nature of spur fasciole, spur and basal margin of tergum. Thus, it is evident that this species has survived from the early or middle Miocene in northern Japan without notable modification in morphology. Long-term stability in morphology may furnish interesting problems in paleobiology concerning the mechanisms maintaining the *status quo* of a phenotype.

Present article is based on YAMAGUCHI (1974, MS) which was submitted to the Geological Institute, University of Tokyo as a partial fulfilment of the requirements for doctorate degree in December 25, 1974. YAMAGUCHI (1974, MS) has re-examined classification of Japanese *B. amphitrite* group in a part of his taxonomic studies on Japanese fossil and Recent Balanoidea. The result is based primarily on a taxonomic evaluation of morphological diversity of the group, but is also supplemented by observations on macro- and microgeographic distribution and on seasons of larval settlements.

Shortly after my work, HENRY and McLAUGHLIN published a paper on the *B. amphitrite* complex in October, 1975. Their work (1975) is based on extensive

collections from various localities of the world, and on thorough analysis of morphological characters of *B. amphitrite* complex.

Although the works have been done independently by HENRY and McLAUGHLIN (1975) and YAMAGUCHI (1974, MS), the classifications resemble strikingly each other both in evaluation of morphological characters and in the conclusion. Therefore, to avoid overlapping of systematic descriptions, only a few supplementary descriptions are appended to this paper. For full synonymies, diagnoses and detailed descriptions, refer to the comprehensive work by HENRY and McLAUGHLIN (1975).

10. Systematic Descriptions

Superfamily Balanoidea LEACH, 1817

Family Balanidae LEACH, 1817

Genus *Balanus* DA COSTA, 1778

Balanus amphitrite DARWIN, 1854

Pl. 19, figs. 1-2; pl. 20, figs. 1, 5, 9; pl. 21, fig. 1; text-fig. 15

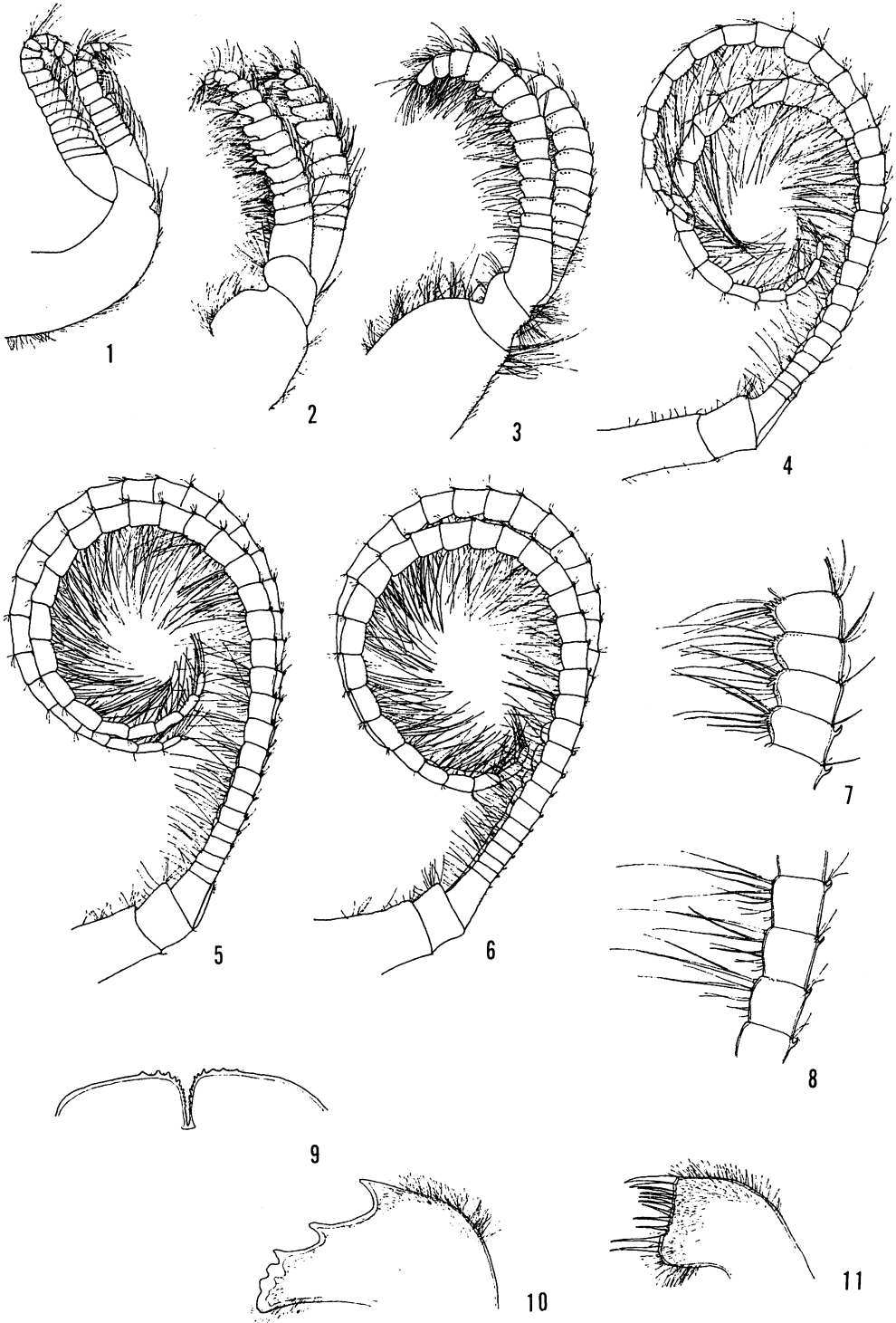*B. amphitrite hawaiiensis* BROCH, ROSELL, 1973, p. 82, figs. 5a-f and 6g-k.
B. amphitrite amphitrite DARWIN, SOUTHWARD, 1975, p. 6, figs. 1-3; HENRY and McLAUGHLIN, 1975, p. 30, text-figs. 10, 11, 13; pl. 1; pl. 5, fig. 9, upper row right; pl. 9, figs. b, c; NEWMAN and ROSS, 1976, p. 62.

Supplementary descriptions.—Shell smooth and with several colored longitudinal stripes. Generally, central trapezoidal area of rostrum and lateral compartment

Text-fig. 15. *Balanus amphitrite* DARWIN from Tanabe Bay (Loc. H), Shirahama, Wakayama Pref. 1-11: UMUT-RA8274. 1-6. right cirri I to VI, lv., ×23.3., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI. 7. 6th to 9th segments of exopodite of right cirrus III, lv., ×46.5. 8. 8th to 12th segments of exopodite of right cirrus V, lv., ×46.5. 9. labrum, av., ×46.5. 10. right mandible, lv., ×46.5. 11. right maxilla I, lv., ×46.5.

white and without colored longitudinal stripe. Adductor ridge sloping toward occludent margin. Exopodite of cirrus III with many conic teeth and denticles on anterior face of each intermediate segment, but exopodite of cirrus IV without conic tooth, but with a few denticles.

Fossil record.—None in Japan.

Balanus albicostatus PILSBRY, 1916

Pl. 19, figs. 3-4; pl. 20, figs. 2, 6, 10; pl. 21, fig. 2; pl. 22, figs. 1-5; text-fig. 16

B. albicostatus PILSBRY, HENRY and Mc-LAUGHLIN, 1975, p. 108, text-figs. 20, 22a; pl. 10, figs. h-k; pl. 11, figs. m, n.
B. albicostatus albicostatus PILSBRY, NEWMAN and ROSS, 1976, p. 62.

Supplementary descriptions. — Shell with white longitudinal ribs. Longitudinal tubes with transverse septa. Adductor ridge vertically projecting on the inner surface of scutum. Short spinules on anterior face of exopodite of cirri III and IV obscure.

Fossil record.—Pleistocene to Holocene. Pleistocene: Loc. 30b., Holocene: Locs. 21, 28a, b., 30g and 33d. With human remains: Locs. 19a-c.

Balanus reticulatus UTINOMI, 1967

Pl. 19, fig. 5; pl. 20, figs. 3, 7, 11; pl. 21, fig. 3; pl. 22, figs. 6-12; text-fig. 17

B. amphitrite amphitrite DARWIN, HARDING (in part), 1962, p. 274; ROSELL, 1973, p. 79, figs. 4a-g.
B. reticulatus UTINOMI, SOUTHWARD, 1975, p. 11, pl. 1, figs. 4-15; HENRY and Mc-LAUGHLIN, 1975, p. 88, text-figs. 11, 18; pl. 7, fig. d; pl. 8; pl. 9, figs. a, d, e; NEWMAN and ROSS, 1976, p. 64.

Supplementary descriptions.—Shell smooth with numerous longitudinal narrow stripes which are intersected by white and colored horizontal stripes. Adductor ridge sloping toward occludent margin.

Fossil record.—Pleistocene to Holocene. Pleistocene: Loc. 33a., Holocene: Locs. 21, 28, 30e, g, 32a-b, 33d and 38.

Balanus kondakovi TARASOV and ZEVINA, 1957

Pl. 19, figs. 6-7; pl. 20, figs. 4, 8, 12; pl. 21, fig. 4; pl. 22, figs. 13-18; text-fig. 18

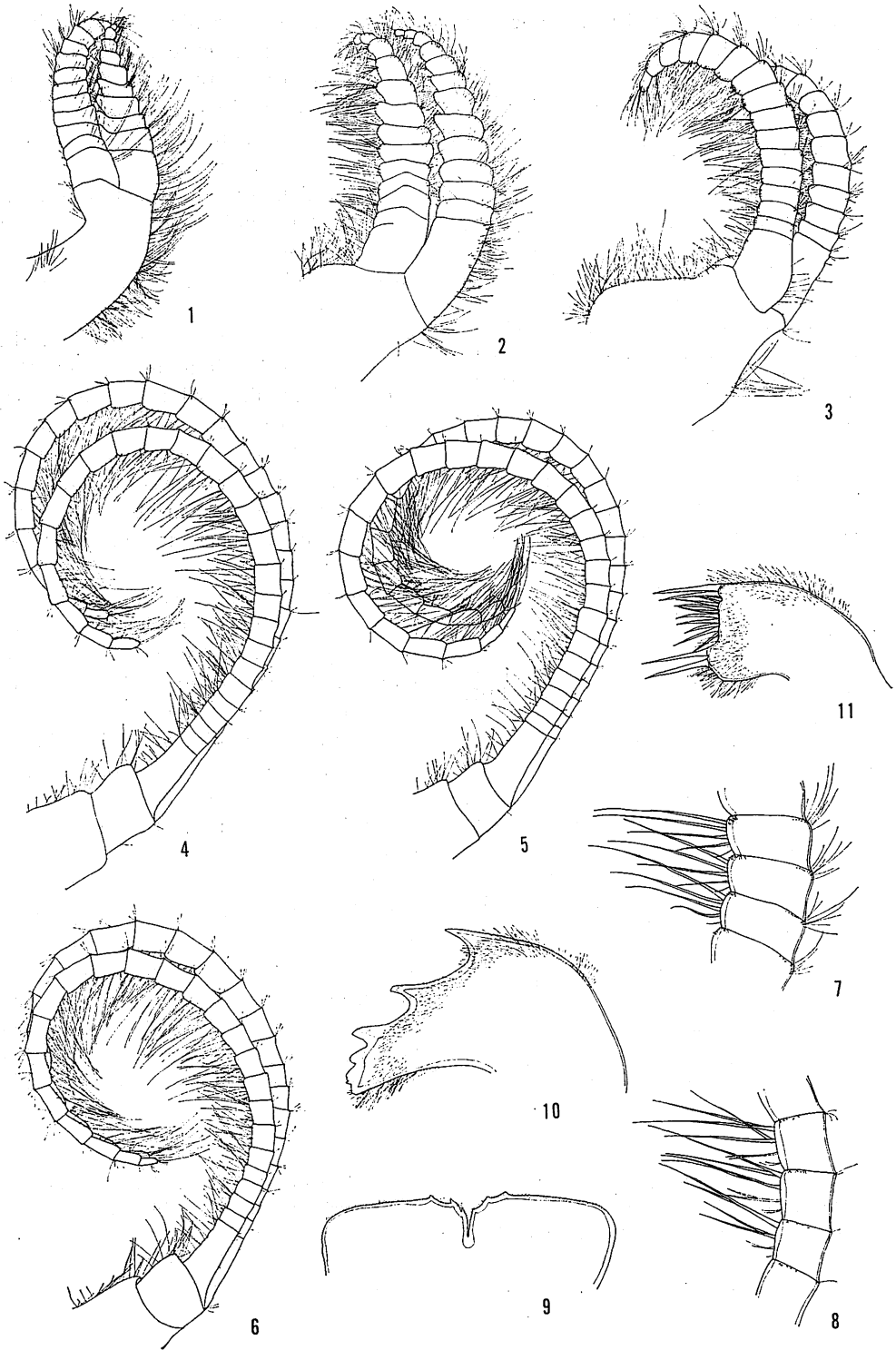*B. amphitrite kondakovi* TARASOV and ZEVINA, NEWMAN and ROSS, 1976, p. 63.
B. kondakovi TARASOV and ZEVINA, HENRY and McLAUGHLIN, 1975, text-figs. 21, 22b, c, f; pl. 11, figs. a-m.

Supplementary descriptions.—Shell smooth with many longitudinal narrow stripes which are often intersected by white horizontal stripes. Parietal tubes of Japanese specimens in single row. Adductor ridge sloping toward the occludent margin. Exopodite of cirri III and IV with a few denticles on anterior face of each segment.

Fossil record.—Pleistocene and Holocene.

Text-fig. 16. *Balanus albicostatus* PILSBRY from Tanabe Bay (Loc. H), Shirahama, Wakayama Pref. 1-11: UMUT-RA8366. 1-6. right cirri I to VI, lv., ×19.3., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI., 7. 6th to 10th segments of exopodite of right cirrus III, lv., ×38.6. 8. 9th to 13th segments of exopodite of right cirrus V, lv., ×38.6. 9. labrum, av., ×38.6. 10. right mandible, lv., ×38.6. 11. right maxilla I, lv., ×38.6.

Pleistocene: Locs. 30d and 42a., Holocene: Locs. 33e and 34.

Balanus rostratus HOEK, 1883

Pl. 23, figs. 1-13; pl. 24, figs. 1-3, 7-8; text-fig. 19

Balanus rostratus HOEK, 1883, p. 152, pl. 13, figs. 16-22; GRUVEL, 1905, p. 239, fig. 267; PILSBRY, 1911, p. 73, pl. 12, fig. 6; PILSBRY, 1916, p. 138, pl. 36, figs. 1-2a; HIRO, 1933, p. 71; HIRO, 1935, p. 217, pl. 10, figs. 1-2; HATAI, 1938, p. 97; CORNWALL, 1955, p. 38, figs. 30-31; OZAKI, 1958, p. 175, pl. 10, figs. 15-16; ŌHARA, 1969, p. 126; IWAI and SIOBARA, 1969, p. 5, pl. 3, fig. 21; UTINOMI, 1970, p. 357; YAMAGUCHI, 1971, p. 125, pl. 5, figs. 8-13; NEWMAN and ROSS, 1976, p. 61.

Balanus rostratus rostratus HOEK, UTINOMI, 1958, p. 294.

Balanus rostratus alaskensis PILSBRY 1916, p. 141, pl. 38, figs. 4-5; CORNWALL, 1925, p. 484, pl. 5, fig. 5; HENRY, 1940, p. 21, pl. 2, figs. 9-12; HENRY, 1942, p. 117, pl. 3, figs. 13-14; TARASOV and ZEVINA, 1957, p. 200, fig. 79.

Balanus rostratus apertus PILSBRY, UTINOMI, 1958, p. 295, text-fig. 5.

Balanus rostratus dalli PILSBRY, HIRO, 1935, p. 218, pl. 10, figs. 1-2; HIRO, 1939, p. 211; KOLOSVÁRY, 1943, p. 89.

Balanus rostratus forma eurostratus BROCH 1922, p. 320; HIRO, 1932b, p. 550, text-fig. 4; HIRO, 1939b, p. 210; TARASOV and ZEVINA, 1957, p. 200.

Balanus rostratus heteropus PILSBRY 1916, p. 142, pl. 36, figs. 7-8.

Balanus rostratus var. spiniferus NILSSON-CANTELL, 1932, p. 20, text-figs. 8-9.

Balanus sp. OZAKI, 1958, p. 176, pl. 22, fig. 23.

Diagnosis.—Shell conical to subcylindrical, with smooth external surface and white to dirty white in color. Carinolateral narrow. Rostrum well developed. Radii narrow, their summits oblique to the base. Scutum with prominent growth ridges which are divided into squarish beads by longitudinal striations. Pit for adductor muscle weakly developed or hardly visible. Tergum with wide and blunt spur.

Descriptions.—General appearances: Shell conical to subcylindrical, rather thick and white to dirty white in color, with smooth external surface. Radii narrow, generally deeply sunken below surface of parietes, their summits oblique to the base. Orifice ovate, variable in diameter, often same as base in diameter, and slightly toothed.

Compartments: Parietes conical, smooth, with longitudinal tubes having transverse septa. Carinolateral narrow. Rostrum well developed. Radii narrow, generally deeply sunken below surface of parietes. Summits of radii oblique to the base. Alae very narrow, and their summits oblique to the base. Sheath extending lower than the half of the wall.

Opercular valves: Scutum concave externally, color white to dirty white, external surface with very prominent growth ridges, superimposed over very fine growth lines; growth ridges imbricating downwardly, divided into squarish beads by longitudinal striations, depression between ridges deepen toward basal margin; articular ridge long, but not so

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Text-fig. 17. *Balanus reticulatus* UTINOMI from Tanabe Bay (Loc. H), Shirahama, Wakayama Pref. 1-11: UMUT-RA8367. 1-6. right cirri I to VI, lv., ×10., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI., 7. 7th to 9th segments of exopodite of right cirrus III, lv., ×32.6. 8. 10th to 12th segments of exopodite of right cirrus V, lv., ×32.6. 9. labrum, av., ×32.6. 10. right mandible, lv., ×32.6. 11. right maxilla, lv., ×32.6.
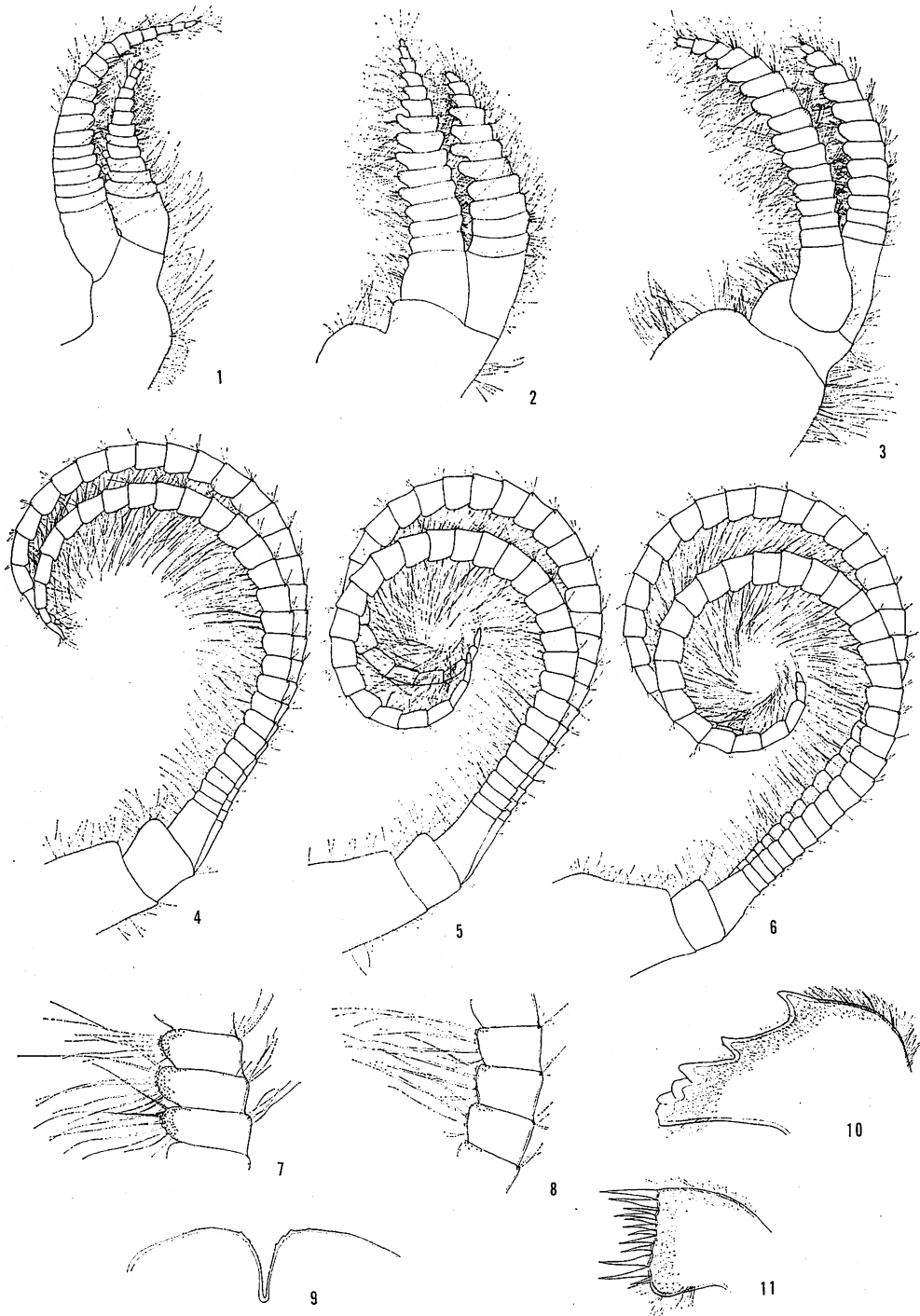
Table 5. Number of segments in each right cirrus of *B. rostratus* HOEK from Loc. C3 (Mutsu Bay). N: number of individuals examined, OR: observed range, $\bar{x}$: mean, exo: exopodite, end: endopodite.

		rCI		rCII		rCIII		rCIV		rCV		rCVI	
		exo	end	exo	end	exo	end	exo	end	exo	end	exo	end
1	RA8277	28	14	19	16	19	16	34	34	37	37	38	38
2	RA8278	25	14	16	15	19	15	18+	22+	27+	18+	18+	22+
3	RA8373	27	14	15	16	20	15	18+	16+	18+	20+	11+	8+
4	RA8374	26	13	15	14	18	15	23+	31	31	21+	35	31
5	RA8375	28	13	15	14	18	15	32	33	29	35	20+	27+
6	RA8375	24	12	16	14	16	14	28	29	33	31	35	31
N		6	6	6	6	6	6	3	4	4	3	3	3
OR		24-28	12-14	15-19	14-16	16-20	14-16	28-34	29-34	29-37	31-37	35-38	31-38
$\bar{x}$		26.3	15.0	16.0	14.8	18.3	15.0	31.3	31.8	32.5	34.3	36.0	33.3

prominent; articular furrow narrow and shallow; adductor ridge low, in some cases weak; adductor muscle pit weakly developed or hardly visible; lateral depressor muscle pit rather deep, in some cases shallow. Tergum flat, white to dirty white in color, with weak growth ridges and lines and faint longitudinal striae; spur wide at base and obliquely truncated at end; spur furrow absent; articular ridge moderately developed; ridge running from apex toward basiscutal angle; scutal margin concave; crests for depressor muscle weak or difficult to observe.
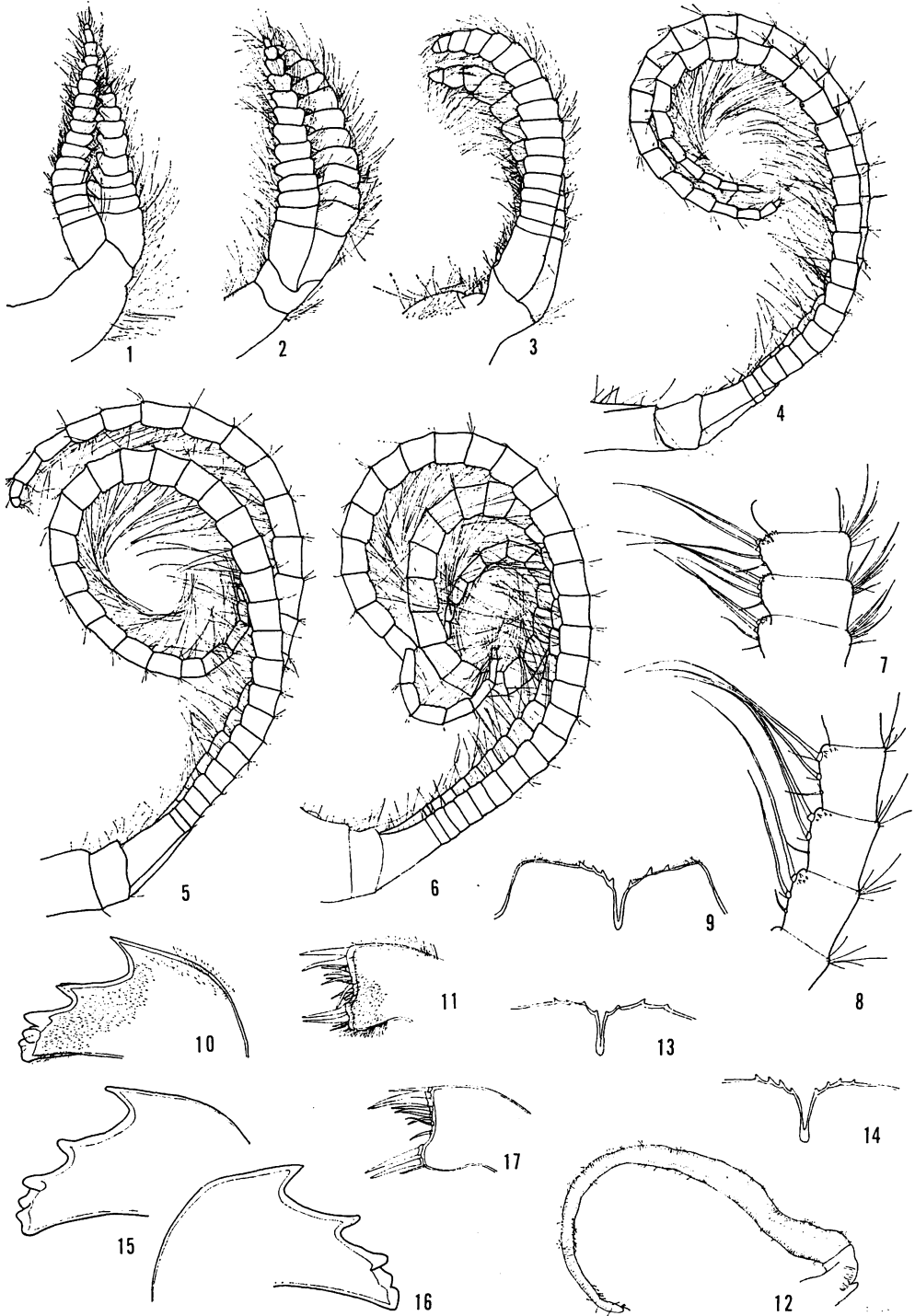
Base: Calcareous, thin and with radiating tubes.

Mouth parts: Labrum with two or three minute teeth on both sides of notch and with numerous very fine setules. Mandi-

ble with three large acute teeth and a minute but blunt fourth tooth, and with closely set setae convering the narrow stripe between the main part of mandible and tooth edge. Mandiblar palp oval, with closely set setae. Maxilla I with two large spines near upper distal angle; an another large spine near lower distal angle; one to three medium sized spines at upper distal angle; five to eight medium sized spines between upper and lower large spines; small, narrow and shallowly concave notch just below two upper large spines; and with closely set setae between upper and lower edges. Maxilla II oval with closely set setae.

Cirri: Number of segments in each cirrus is shown in table 5. Exopodite of cirrus I approximately one and a half times as long as endopodite; number of segments

Text-fig. 18. *Balanus kondakovi* TARASOV and ZEVINA from Kasaoka Bay, Okayama Pref. Coll. Dr. S. FUSE. 1-11: UMUT-RA8362. 12, 13, 15 & 17: UMUT-RA8363. 14 & 16: UMUT-RA8364. 1-6. right cirri I to VI, lv., ×16.3., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI., 7: 7th to 9th segments of exopodite of right cirrus III, lv., ×45.8. 8: 16th to 18th segments of exopodite of right cirrus IV, lv., ×45.8. 9. labrum, av., ×33.8. 10. right mandible, lv., ×33.8. 11. right maxilla I, lv., ×33.8. 12. penis, lv., ×10.8. 13. labrum, av., ×33.8. 14. labrum, av., ×33.8. 15. right mandible, lv., ×33.8. 16. left mandible, lv., ×33.8. 17. right maxilla I, lv., ×33.8.

nearly twice of that of endopodite. Anterior face of each segment in endopodite of cirrus I and both rami of cirrus II remarkably protuberant. Exopodite of cirri II, and of III, nearly equal to the endopodite in length, but exopodites have a few more segments. In cirri IV to VI with slender segments, expodites nearly equal to endopodites in length, and in number of segments; median segments with three to five paired spines, generally four, which gradually shorten from distal to proximal side. Cirri IV and V with many fine spinules in a row at distal border of each segment.

Penis: Long, with slender dorsal point and with very fine setae.

Fossil record.—Pliocene to Holocene. Pliocene: Locs. 2c; 3a, b, d, f; 4a-c; 5a, b; 13a-c; 31 and 40a-e., Pleistocene: Locs. 6a-c; 8a-c; 16; 17a-c; 18a; 20a, b; 22a-c; 23a, b; 24a, c-f, h-m; 25a, b; 26; 35 and 43.. Holocene: Locs. 28c and 29.

Balanus crenatus BRUGUIÈRE, 1789

Pl. 25, figs. 1-19; text-fig. 20

Balanus crenatus BRUGUIÈRE, 1789, p. 168; DARWIN, 1854a, p. 261, pl. 6, figs. 6a-g; GRUVEL, 1905, p. 240, figs. 268-269; PILSBRY, 1911, p. 75, pl. 14, figs. 1-9; PILSBRY, 1916, p. 165, pl. 39, figs. 1-5, pl. 40, figs. 1-6; NILSSON-CANTELL, 1921, p. 326; BROCH, 1924, p. 78, fig. 27, pl. 1, figs. 3-6, pl. 2, fig. 14; CORNWALL, 1925, p. 476, fig. 2, pl. 4, figs. A-h; HIRO, 1935, p. 219, figs. 2a-f, pl. 10, fig. 4; HENRY, 1940, p. 19, pl. 1, figs. 9-11, pl. 2, figs. 1-2; HENRY, 1942, p. 105, pl. 2, figs. 5-11; CORNWALL, 1951, p. 329, pl. 4, fig. F, pl. 5, fig. A;

CORNWALL, 1955, p. 28, figs. 21-22; TARASOV and ZEVINA, 1957, p. 205, figs. 22, 82, 83; DAVADIE, 1968, p. 63, pl. 34, figs. 1-7, pl. 36, figs. 4-5; NEWMAN and ROSS, 1976, p. 60.

Diagnosis. — Shell white and smooth. Parietes with longitudinal tubes. Radii narrow with denticulated sutural edges; summits steeply oblique to the base. Alae well developed, with denticulated sutural edges and summits slightly oblique to the base. Calcareous vesicules develop in the cavity between sheath and inner lamina. Scutum warped externally, with widely spaced and very weak growth ridges; articular ridge very prominent and reflexed; adductor ridge very weak or hardly visible; pit for adductor muscle deep. Basal margin of tergum comes near to the tip of the spur on both sides.

Descriptions.—General appearances: Shell conial to tubuloconical, rather thick and smooth in general; color white. Radii narrow, summit steeply oblique to the base. Orifice large, rhombodial and irregularly toothed.

Compartments: Parietes smooth in general, but in rare cases slightly ribbed near the base. Longitudinal tubes large at base, and with transverse septa. Calcareous vesicles develop in the cavity between sheath and inner lamina. Sutural edges of radii slightly oblique and denticulated. Alae well developed, and their summit slightly oblique to the base. Sutural edges of alae rather thick and slightly denticulated.

Opercular valves: Scutum warped exter-

Text-fig. 19. *Balanus rostratus* HOEK from Asamushi (Loc. C3), Aomori Pref. 1-10: UMUT-RA8376. 1-6. right cirri I to VI, lv., ×10., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI., 7. 13th to 17th segments of exopodite of right cirrus VI, lv., ×25. 8. labrum, av., ×25. 9. right mandible, lv., ×25. 10. right maxilla I, lv., ×25.
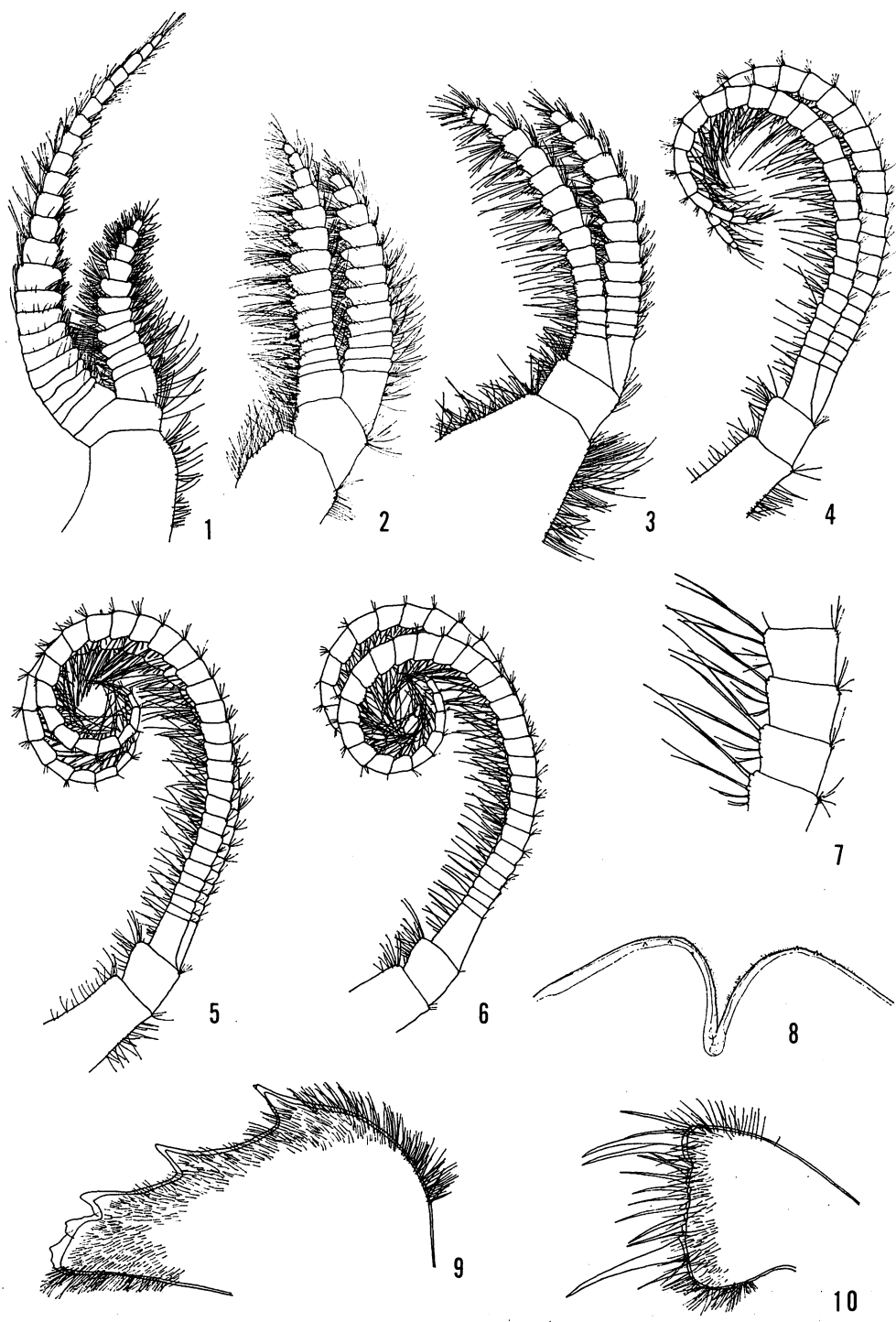
Table 6.　Number of segments of each right cirrus of *B. crenatus* BRUGUIÈRE.

	rCI		rCII		rCIII		rCIV		rCV		rCVI	
	exo	end	exo	end	exo	end	exo	end	exo	end	exo	end
RA8330	18	19	12	12	15	12	27	32	33	31	34	34

A specimen from Paramushir Is., Kurile Islands; Coll. Mr. K. KOBA.

nally, with widely spaced very weak growth ridges and faint longitudinal striae; color white; articular ridge very prominent and reflexed; articular furrow narrow and deep; adductor ridge very weak or hardly visible; adductor muscle pit deep and narrow; lateral depressor muscle pit small and shallow, but in some cases variable in size and depth. Tergum flat with weak growth lines and faint longitudinal striae; color white; spur fasciole wide; spur wide, short and rounded at end; width of spur approximately equal to one-third of basal margin of tergum; distance between basiscutal angle and anterior face of spur nearly equal to width of spur; crests of depressor muscle well developed; basal margin near tip of the spur on scutal side and away from on carinal side.

Base: Calcareous, thin and solid.

Mouth parts: Labrum with three teeth on both sides of notch. Mandible with three acute and large teeth and minute but bluntly rounded fourth and fifth teeth. Mandiblar palp oval, with closely set setae. Maxilla I with two large spines at distal angle; five medium sized spines between upper and lower large spines; a small, narrow and slightly concave notch just below the two upper large spines; and with closely set setae between upper and lower edges. Maxilla II oval with closely set setae.

Cirri: Number of segments in each cirri is shown in table 6. Exopodite of cirrus I approximately one and a half times as long as endopodite, having twice as many segments as endopodite; anterior face of both rami protuberant. Cirri II to VI, exopodites nearly equal to endopodites in length and number of segments. Median segments of cirri IV to VI with two paired long and three or four paired short spines on anterior face.

Penis: Nearly equal to or longer than cirri; with short a blunt dorsal point and very fine setae.

Fossil record.—Early or middle Miocene to Holocene. Early or middle Miocene: Locs. 9a-d; 10; 12b and 39., Late Miocene: Locs. 7a, c-e, g-n; 11; 14; 15 and 41a, c-e, g., Pliocene: Locs. 2b; 3a, e-f; 4b-c; 5a-b; 7f and 12a., Pleistocene: Locs. 7f; 8a-c and 23b.

Recent distribution.—This species is widely distributed in the northern Pacific and Atlantic Oceans, and the Arctic Ocean, as shown in text-figure 21.
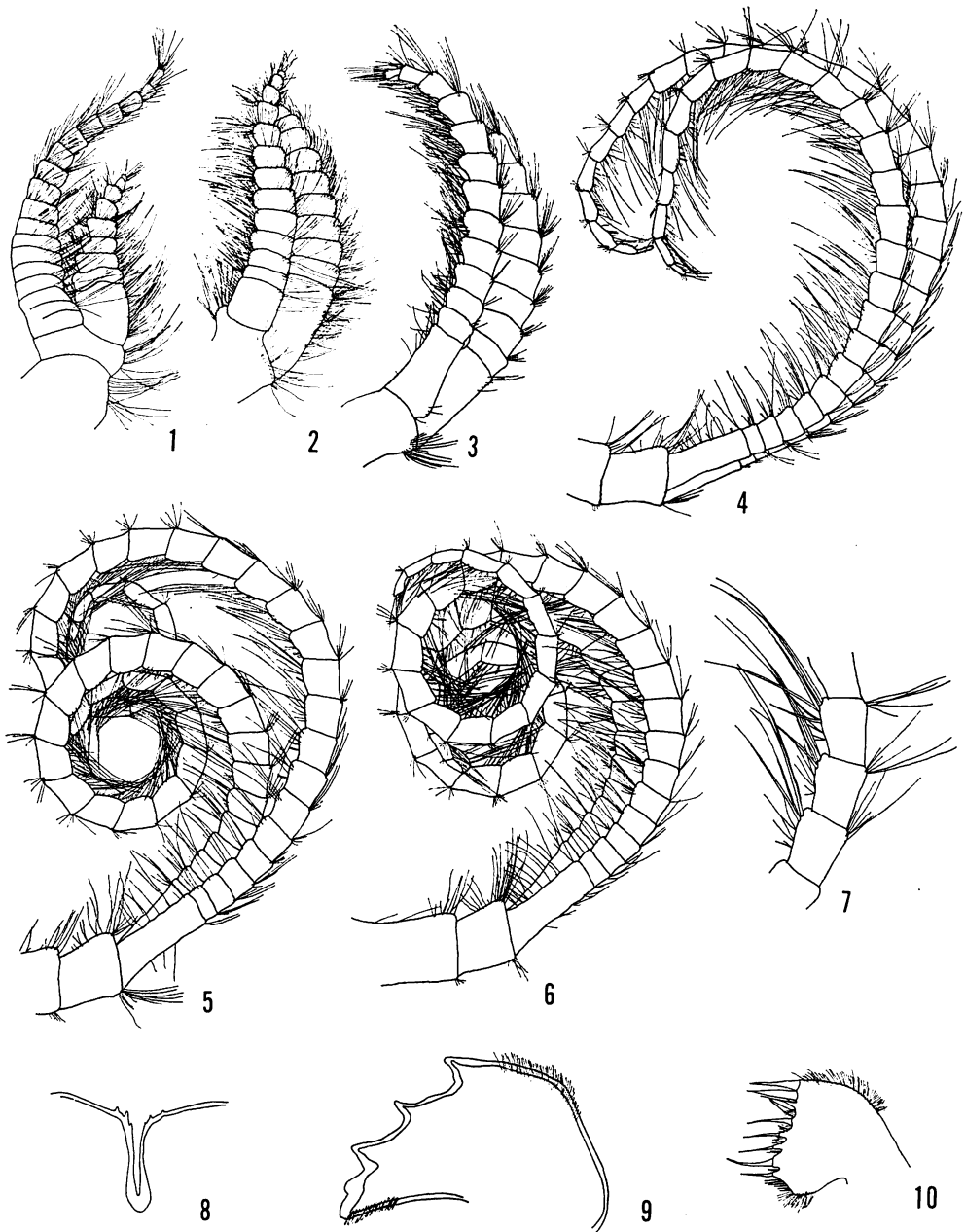
Genus *Megabalanus* HOEK, 1913
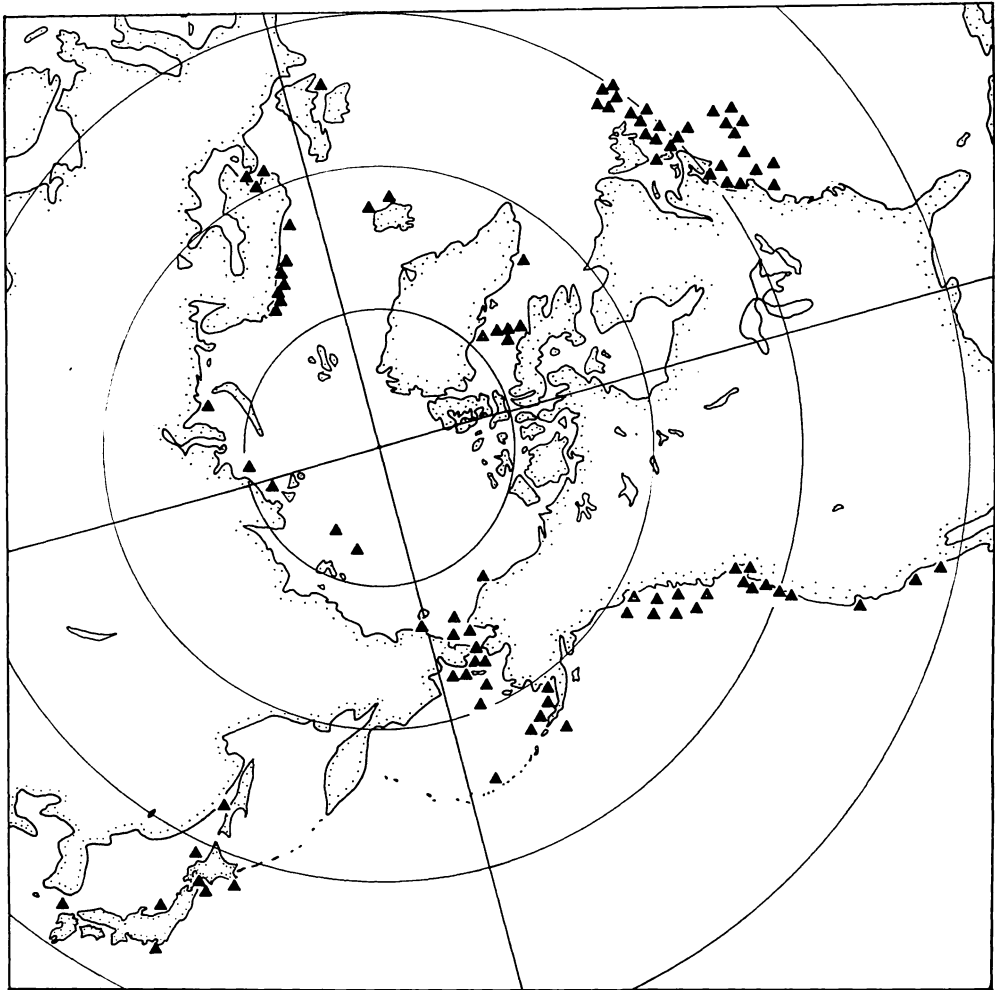
Megabalanus rosa (PILSBRY, 1916)

Pl. 26, figs. 11-13

Balanus (Megabalanus) rosa PILSBRY, YAMA-
　GUCHI, 1973, p. 130, pl. 6, figs. 1a-j, 3, 6,
　7; pl. 7, figs. 3a-4b; pl. 8, figs. 1-2b; text-
　fig. 10.
Megabalanus rosa (PILSBRY), NEWMAN and
　ROSS, 1976, p. 68.

Additional remarks.—For synonymy, description and fossil localities see YAMA-GUCHI (1973). The following localities of

Text-fig. 20. *Balanus crenatus* BRUGUIÈRE from Murakami Bay, Paramushir Is., Kurile Isls. Coll. Mr. K. KOBA.   1-10: UMUT-RA8330.   1-6. right cirri I to VI, lv., ×20., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI., 7. 15th to 17th segments of expodite of right cirrus IV, lv., ×33.4. 8. labrum, av., ×33.4. 9. right mandible, lv., ×33.4. 10. right maxilla I, lv., ×33.4.

Text-fig. 21. Distribution of *B. crenatus* in the Recent sea. [Compiled from BROCH; 1924, CORNWALL; 1925, 1951, 1955, DARWIN; 1854a, HENRY; 1940, 1942, HIRO; 1935, NILSSON-CANTELL; 1921, PILSBRY; 1911, 1916, 1921, STEPHENSEN; 1938, TARASOV; 1936, 1937, TARASOV and ZEVINA; 1957, UTINOMI; 1955, 1968, 1970, YAMAGUCHI; 1972MS, 1974MS].

fossils are newly added: Locs. 13a-b; 17a-c; 23-a-e, l, m; 25b; 28a-c; 30g; 31; 33c; 37a-b and 44. The writer found some errors in the previous description of *M. rosa* (YAMAGUCHI, 1973). One of the errors arose from misidentification: the fossil specimens from Loc. 16 is not *M. rosa*. Therefore, Loc. 16 should be excluded from the fossil localities of this species. The geological age of the Misaki Formation at Loc. 27 (YAMAGUCHI, 1973) is not Miocene but probably Pliocene. Thus, the straigraphical range of *M. rosa* is rectified from Pliocene to Recent.

Megabalanus volcano (PILSBRY, 1916)

Pl. 26, figs. 1-10, 13

Balanus (Megabalanus) volcano PILSBRY, YA-
MAGUCHI, 1973, p. 133, pl. 6, figs. 2a-j, 4,
5; pl. 7, figs. 1a-2b; pl. 8, figs. 1-2b; text-
fig. 2.
Megabalanus volcano (PILSBRY), NEWMAN and
ROSS, 1976, p. 69.

Additional remarks.—For synonymy and
description see YAMAGUCHI (1973). Noth-
ing had been known about the fossil
record of this species. However, un-
doubted specimens of *M. volcano* were
newly obtained from the Pleistocene
Nakoshi Sandstone of Okinawa Is. (Loc.
44). Thus, the Pleistocene should be
added to the stratigraphical range of
M. volcano.

Family Archaeobalanidae NEWMAN
and ROSS, 1976

Genus *Solidobalanus* HOEK, 1913

Subgenus *Hesperibalanus* PILSBRY,
1913

Solidobalanus (Hesperibalanus)
hesperius (PILSBRY, 1916)

Pl. 27, figs. 1-18; text-fig. 22

Balanus (Hesperibalanus) hesperius PILSBRY,
1916, p. 193, figs. 1-1d, 7-8; HIRO, 1935,
p. 225, fig. 5; TARASOV and ZEVINA, 1957,
p. 228, fig. 89.
Balanus (Hesperibalanus) hesperius forma
laevidomus PILSBRY, 1916, p. 196, pl. 49,
figs. 2-5; pl. 50, figs. 12b.
Balanus (Hesperibalanus) hesperius nipponensis
PILSBRY, 1916, p. 199, pl. 49, fig. 6.
Balanus hesperius PILSBRY, HIRO, 1939b, p.
212; CORNWALL, 1955, p. 35, fig. 27.
Balanus hesperius laevidomus PILSBRY, HENRY,
1940, p. 31, pl. 3, figs. 1-4.
Balanus (Solidobalanus) hesperius PILSBRY,

HENRY and McLAUGHLIN, 1967, p. 47.
Balanus (Solidobalanus) hesperius laevidomus
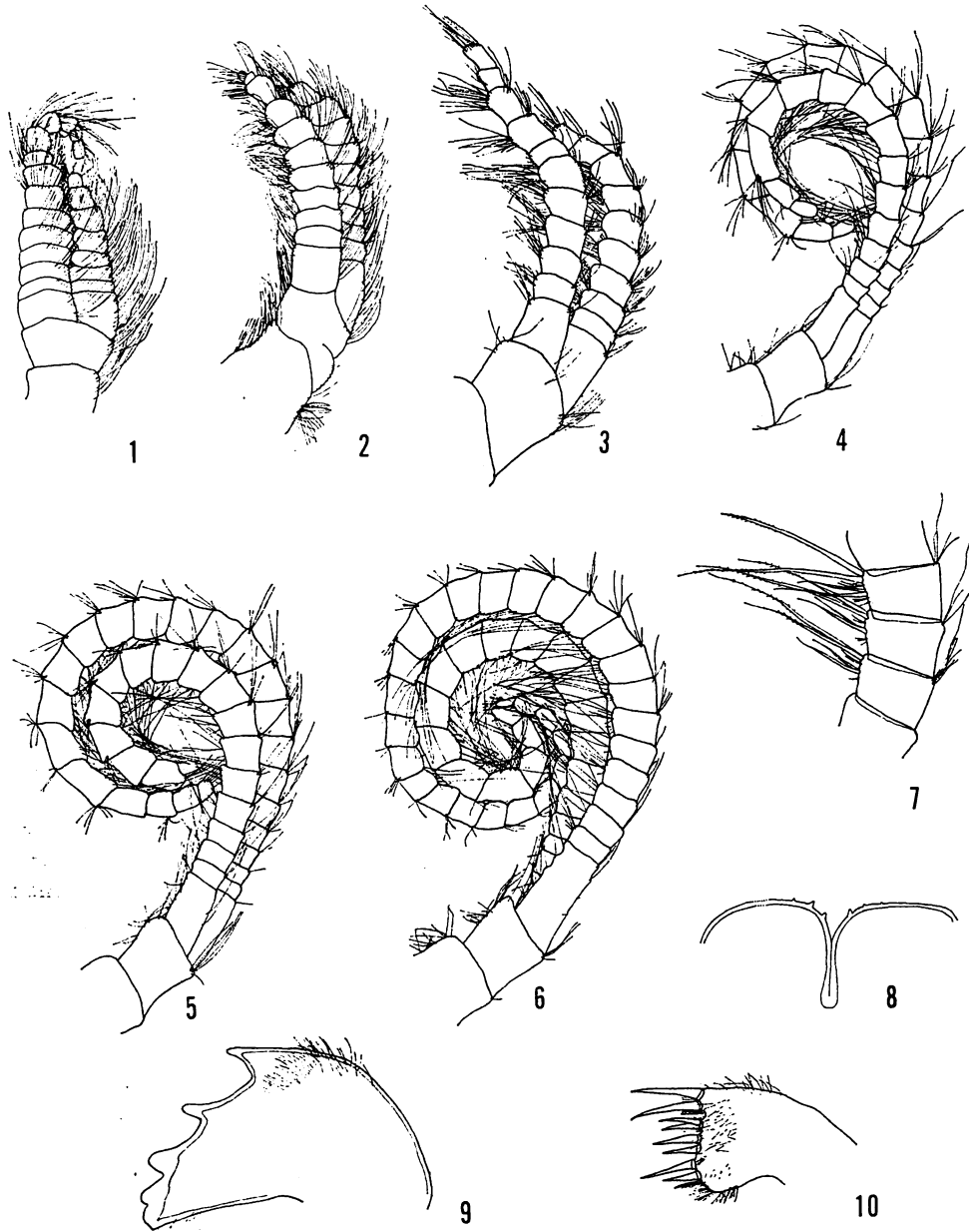PILSBRY, HENRY and McLAUGHLIN, 1967,
p. 47.
Balanus (Solidobalanus) hesperius nipponensis
PILSBRY, HENRY and McLAUGHLIN, 1967,
p. 47.
Solidobalanus (Hesperibalanus) hesperius hes-
perius (PILSBRY), NEWMAN and ROSS, 1976,
p. 51.

Diagnosis.—Shell white and smooth to
strongly ribbed. Parietes without longi-
tudinal tube. Radii narrow with denti-
culated sutural edge, summits slightly
oblique to the base. Alae wide and
nearly parallel to the base. Orifice
slightly toothed. Scutum flat, with weak
and closely spaced growth ridges in
general; articular ridge very short; faint
callus-like projections observable between
articular and adductor ridges in some
individuals; articular furrow wide and
deep. Tergum with wide spur; crests
for depressor muscle strongly developed.
Descriptions.—*General appearances:* Shell
conical to subcylindrical, smooth to
strongly ribbed, and white in color. Radii
commonly narrow, but fairly wide in
some subcylindrical individuals, summits
oblique to the base. Orifice rhomboidal
and slightly toothed.
Compartments: Parietes smooth to strong-
ly ribbed, without longitudinal tube. Alae
rather wide and their summits approxi-
mately parallel to the base. Sutural
edges of radii slightly denticulated, but
those of alae simple.
Opercular valves: Scutum flat, with close-
ly to widely spaced weak growth ridges
and faint longitudinal striations on ex-
ternal surface; occludent and tergal
margins straight; articular ridge very
short, very prominent, reflexed and
pointed at end; articular furrow wide
and deep; adductor ridge very short and
prominently to weakly projected; faint

Text-fig. 22. *Solidobalanus* (*Hesperibalanus*) *hesperius* (PILSBRY) off Kafuran, west Kamchatka. Coll. Mr. K. KOBA. 1-10: UMUT-RA8368. 1-6. right cirri I to VI, lv., ×30., 1: cirrus I, 2: cirrus II, 3: cirrus III, 4: cirrus IV, 5: cirrus V, 6: cirrus VI. 7. 8th to 10th segments of exopodite of right cirrus VI, lv., ×50. 8. labrum, av., ×50. 9. right mandible, lv., ×50. 10. right maxilla I, lv., ×50.

callus-like projections observable between articular and adductor ridges in some individuals; adductor muscle pit narrow and deep. Tergum flat, with weak growth lines and faint longitudinal striations; spur short, broad and rounded at end; width of spur approximately equal to one third length of basal margin of tergum; distance between basiscutal angle and anterior face of spur extremely short; spur faciole wide; articular ridge very prominent, and running from apex toward basiscutal angle; articular furrow wide and deep; crests for depressor muscle well developed.

Base: Base calcareous, thin and solid.

Mouth parts: Labrum with three teeth on both sides of notch. Mandible with three large teeth, minute but bluntly rounded fourth and fifth teeth, and with closely set setae between upper and lower edges. Mandibular palp oval with closely set setae. Maxilla I with two large spines at upper distal angle; one or two large spines near lower distal angle; three to six medium sized spines between upper and lower large spines; small, narrow and shallow concave notch just below two upper large spines; and with closely set setae between upper and lower edges. Maxilla II oval with closely set setae.

Cirri: Number of segments in each cirrus is shown in table 7. Exopodite of cirrus I slightly longer than endopodite, and segments slightly protuberant. Exopodite

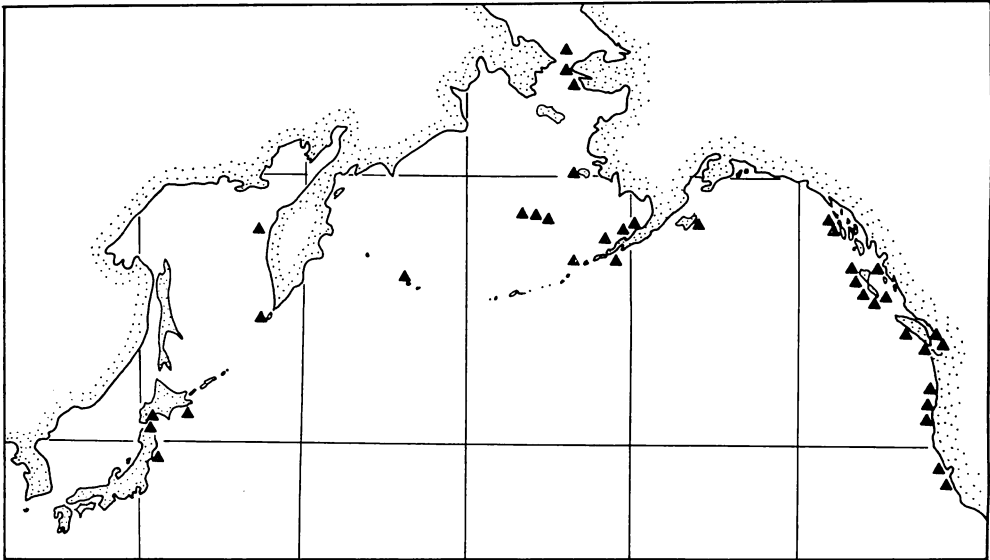Table 7. Number of segments in each right cirrus of *Solidobalanus* (*Hesperibalanus*) *hesperius* (PILSBRY).

		rCI		rCII		rCIII		rCIV		rCV		rCVI	
		exo	end	exo	end	exo	end	exo	end	exo	end	exo	end
	*RA8368	13	9	11	10	11	10	15	19	17	23	32	21+
1	RA8295	17	9	9	12	12	11	19	20	22	25	26	25
2	RA8296	12	7	9	9	10	9	15	18	24	23	17+	25
3	RA8297	9	6	8	8	8	7	13	15	18	22	22	23
4	RA8377	14	9	10	11	10	10	17	21	26	27	25	23
5	RA8378	12	8	8	9	9	9	15+	14+	20+	19+	23	23
6	RA8379	12	7	10	9	10	9	22	21	13+	19	19	24
7	RA8380	13	8	10	10	10	10	15+	23	25	13+	14+	14+
8	RA8381	13	7	8	9	9	8	14	17	20	20	20	22
9	RA8382	9	7	7	8	8	9	13	17	19	21	14	16
10	RA8383	16	8	12	12	12	13	19	21	26	25	30	29
11	RA8384	17	8	10+	12	11	11	24	23	28	30	28	30
	N	11	11	10	11	11	11	9	10	9	9	9	10
	OR	9–17	6–9	7–12	8–12	8–12	7–13	13–24	15–23	18–28	19–30	14–30	16–30
	x	13.1	7.7	9.1	9.9	9.9	9.7	17.3	19.6	23.1	23.6	23.0	24.0

* A specimen (RA8368) from off Kafuran, west Kamchatka; Coll. Mr. K. KOBA. Other specimens (1–11) from Funka Bay (Loc. B3). 3, 4, 7, 9 & 10: Shell wall is ribbed. 1, 5, 6 & 8: Shell wall is smooth. 2 & 11: Shell wall is entirely smooth, having ribs only near the base.

N: number of individuals examined, OR: observed range, x: mean.

Text-fig. 23. Distribution of *Solidobalanus* (*Hesperibalanus*) *hesperius* in the Recent sea. [Compiled from CORNWALL; 1955, HIRO; 1935, 1939b, HENRY; 1940, 1942, KOLOS-VÁRY; 1943, KOLOSVÁRY and WAGNER; 1941, NILSSON-CANTELL; 1927, PILSBRY; 1916, 1921, TARASOV and ZEVINA; 1957, UTINOMI; 1955, 1970, YAMAGUCHI; 1972MS, 1974MS].

of cirri II, and of III, nearly equal to endopodite in length and in number of segments. Each ramus of cirri IV to VI elongate; exopodite smaller than endopodite in length and in number of segments; median segments with two large paired spines and one to three short paired spines on anterior face.

Penis: Longer than cirri with a short and blunt dorsal point and with very fine setae.

Fossil record: Early or middle Miocene to Holocene. Early or middle Miocene: Locs. 9b-c and 10., Late Miocene: Locs. 2d; 7a, d, g, i, k, n and 14., Pliocene: Locs. 1; 2a; 3a, d-e; 4a-c; 5a; 7f and 40a, c-f., Pleistocene: Locs. 8a-c; 23b; 24a-c, e, i-j, 1; 26 and 31.

Recent distribution.—Records of this species are so far restricted to the northern part of the Pacific as shown in text-figures 23.

11. Conclusion

The following species and species groups of the fossil and Recent Balanoidea of Japan are studied taxonomically; *B. amphitrite* group, *B. rostratus*, *Solidobalanus* (*Hesperibalanus*) *hesperius*, *Megabalanus tintinnabulum* group and *B. crenatus*.

In the previous works *B. amphitrite* was subdivided into various infraspecific taxa according to the degree of morphological differences. In this articles, however, they are treated as distinct species, for the following reasons. The morphological differences between them are clearly recognizable. Their macrogeographical distributions overlap. Where the ranges overlap, they occupy similar but in detail different habitats. *B. amphitrite* and *B. albicostatus* usually live side by side in the mid-intertidal zone of rocky shore. *B. reticulatus* is, in gen-

eral, found attached to the floating objects, but sometimes found on the lower intertidal zone of rocky shore. *B. kondakovi* is not commonly encountered, but lives on the brushwoods or the stems of marine plants, etc. in the innermost area of the embayments. Yet, these differences in habitats are not mutually exclusive. Where the habitats overlap, the barnacles are found to live side by side in several localities of Japan. The breeding seasons of both *B. amphitrite* and *B. albicostatus* are almost all the year round, and coincide with each other. Therefore, some other isolating mechanisms other than displacement of breeding season and/or habitat must be operative.

Fossil *B. albicostatus*, *B. reticulatus* and *B. kondakovi* were found from the Pleistocene and from shell mounds of historical age, but *B. amphitrite* has never been found as fossil or even semifossil. The absence of *B. amphitrite* in the fossil record supports HIRO's (1938) prediction that this species may have arrived on the Japanese coasts during historical age. Comparisons of descriptions and illustrations of DARWIN (1854a) and HARDING (1962) strongly indicates that *B. amphitrite* var. *communis* of DARWIN (1854a) includes two distinct species, *B. amphitrite* DARWIN sensu HARDING and *B. reticulatus* UTINOMI, as noted by UTINOMI (1967).

B. rostratus had been previously subdivided into five subspecies, *B. r. alaskensis*, *B. r. apertus*, *B. r. dalli*, *B. r. heteropus* and *B. r. suturalis*, based solely on the morphological characters. The diagnostic characters include the distribution pattern of transverse septa in longitudinal tubes, number of longitudinal tubes in rostrum compartment, and degree of sinking of radii (PILSBRY, 1911, 1916). However, the morphological dif-

ferences employed to discriminate these subspecies seems to fall within the limits of individual variation of one sample from one population. Therefore, it is unreasonable to classify *B. rostratus* into subspecies by using these morphological characters, but this does not deny a possibility of presence of subspecies in *B. rostratus*. However, the subspecific name hitherto proposed are presently placed in synonymy with *B. rostratus* s. s. until the specimens from entire range of distribution are studied in detail. *B. r.* forma *eurostratus* described from Vancover Is. by BROCH (1922) and *B. r.* var. *spiniferus* from Kobe by NILSSON-CANTELL (1932) are definitely synonyms of *B. rostratus* s. s.

Megabalanus tintinnabulum group was studied in detail by the writer. Living *M. rosa* and *M. volcano* are distinct both in morphology and biochemistry (composition of isozymes), are sympatric in macro- as well as microgeopraphical sense, and they are reproductively isolated (YAMAGUCHI, 1973). Occurrence of fossil *M. volcano* together with *M. rosa* from the Nakoshi Sandstone indicates that the speciation had been completed and then the microgeographical sympatry had also been established before the Pleistocene. The two species had been distinct also in morphology since that times.

Solidobalanus (Hesperibalanus) hesperius had been divided into forma *laevidomus* and subspecies *nipponensis* by morphological characters such as nature of external surface of shell wall, proportion between basal and tergal length of scutum, number and nature of spines on anterior face of segments of cirri IV to VI, etc. (PILSBRY, 1916). However, the morphological characters separating these two taxa are to be found within the limits of the individual variation of

of living or fossil populations. Therefore, for the same reasons utilized in synonymizing the subspecies of *B. rostratus*, it seems appropriate to do so here.

B. crenatus as well as *S. (H.) hesperius* can be traced back to the early or middle Miocene without any detectable changes in morphology. The stability of morphology extending over such a long stratigraphical range may become one of the interesting subjects of paleobiological studies.

Acknowledgements

Explanation of Plate 23

Fig. 1. *Balanus rostratus* HOEK (UMUT-RA8277) from Asamushi, Mutsu Bay (Loc. C3). 1a-b. whole wall, ×1., 1c-d. exterior and interior views of rostrum, ×1., 1e-f. exterior and interior views of right lateral, ×1., 1g-h. exterior and interior views of right carinolateral, ×1., 1i-j. exterior and interior views of carina, ×1.

Fig. 2. *Balanus rostratus* HOEK (UMUT-RA8278) from Asamushi, Mutsu Bay (Loc. C3). 2a-b. exterior and interior views of right scutum, ×2., 2c-d. exterior and interior views of right tergum, ×2.

Fig. 3. *Balanus rostratus* HOEK (UMUT-CA8279) from the Holocene Numa Formation (Loc. 28c). 3a. whole wall, ×1.5., 3b-c. exterior and interior views of left scutum, ×3.5., 3d-e. exterior and interior views of left tergum, ×3.5.

Fig. 4. *Balanus rostratus* HOEK (UMUT-CA8280) on *Crassostrea nipponina* from the Holocene Numa Formation (Loc. 28c), ×0.6.

Fig. 5. *Balanus rostratus* HOEK (UMUT-CA8290) from the Pleistocene Semata Formation (Loc. 20a). 5a-b. exterior and interior views of right scutum, ×2., 5c-d. exterior and interior views of right tergum, ×2.

Fig. 6. *Balanus rostratus* HOEK (UMUT-CA8281) on *Granulifusus musashiensis* from the Pleistocene Semata Formation (Loc. 20a), ×1.5.

Fig. 7. *Balanus rostratus* HOEK (UMUT-CA8282) on *Arca miyatensis* from the Pleistocene Semata Formation (Loc. 20a), ×1.

Figs. 8-13. *Balanus rostratus* HOEK from the Pliocene Hamada Formation (Loc. 3d). 8a-b. exterior and interior views of right scutum (UMUT-CA8283), ×4., 9a-b. exterior and interior views of right tergum (UMUT-CA8284), ×4., 10a-b. exterior and interior views of rostrum (UMUT-CA8285), ×1.5., 11a-b. exterior and interior views of left lateral (UMUT-CA8286), ×1.5., 12a-b. exterior and interior views of left carinolateral (UMUT-CA8287), ×1.5., 13a-b. exterior and interior views of carina (UMUT-CA8288), ×1.5.

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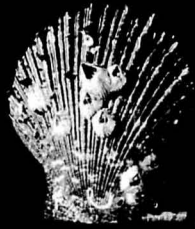
Explanation of Plate 24

Figs. 1-3. *Balanus rostratus* HOEK on *Chlamys nipponensis* from the Pleistocene Semata Formation (Loc. 20a). Autochthon. 1a-b. *B. rostratus* (UMUT-CA8289) on left and right valves of *Chlamys*, ×0.6, 2a-b. *B. rostratus* (UMUT-CA8290) on left and right valves of *Chlamys*, ×0.6., 3a-b. *B. rostratus* (UMUT-CA8291) on left and right valves of *Chlamys*, ×0.6.

Figs. 4-6. *Balanus trigonus* DARWIN on living *Chlamys nipponensis* from Kanita, Mutsu Bay (Loc. C2). 4a-b. *B. trigonus* (UMUT-RA8292) on left and right valves of *Chlamys*, ×0.6., 5a-b. *B. trigonus* (UMUT-RA8293) on left and right valves of *Chlamys*, ×0.6., 6a-b. *B. trigonus* (UMUT-RA8294) on left and right valves of *Chlamys*, ×0.6.

Fig. 7. *Balanus rostratus* HOEK from Mutsu Bay (Loc. C1). living. Photo by soft x-ray. 7a-g. rostrum, ×1.5.

Fig. 8. Mode of occurrence of *Balanus rostratus* HOEK on autochthonous *Chlamys nipponensis* from the Pleistocene Semata Formation (Loc. 20a).

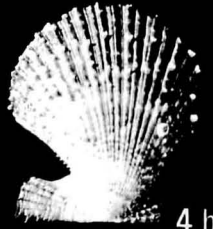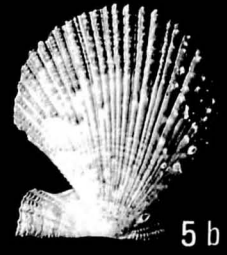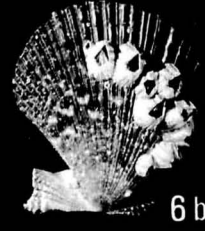Fig. 9. Mode of life of living *Chlamys nipponensis* on gravel at Asamushi, Mutsu Bay.

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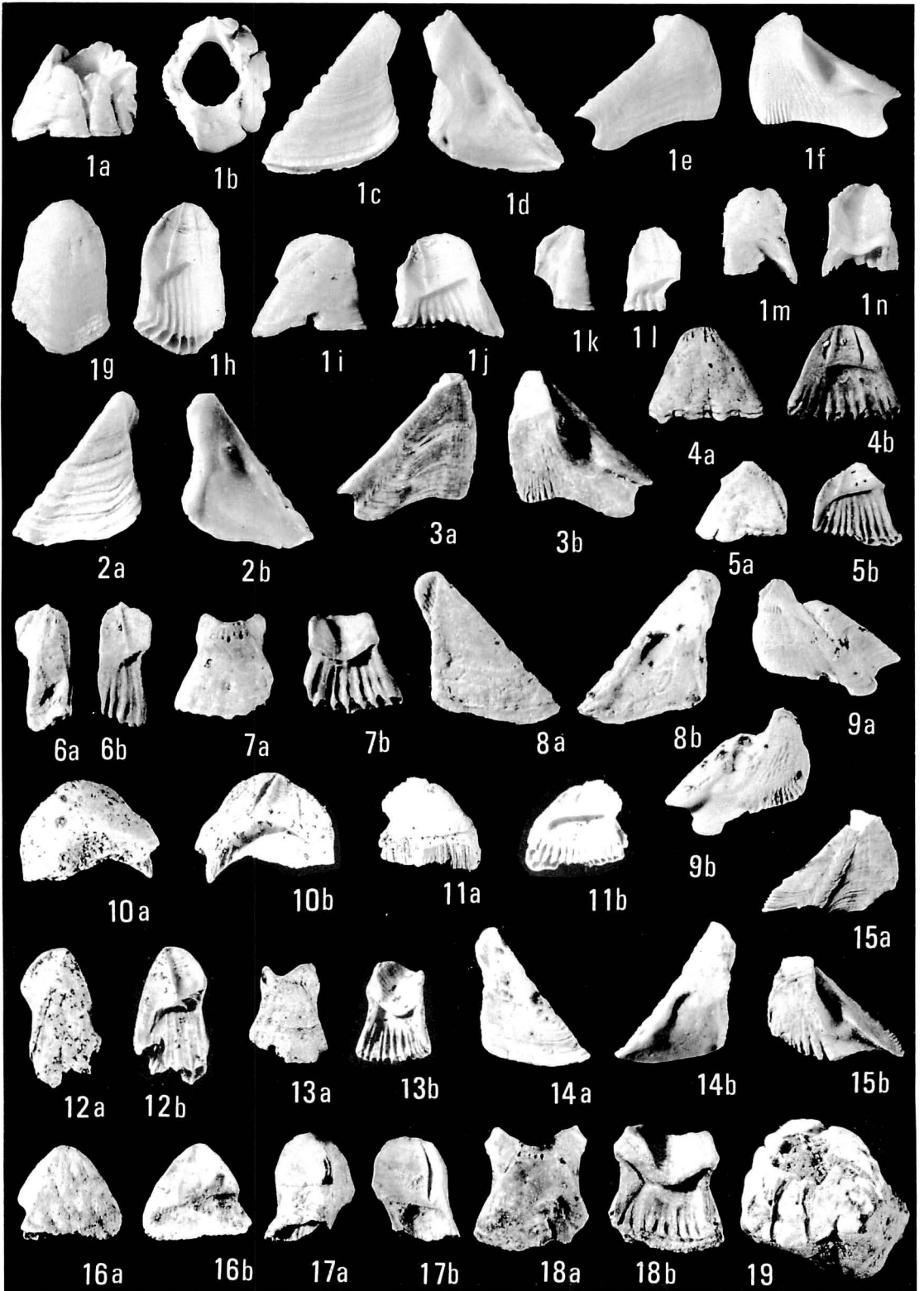
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Explanation of Plate 25

Fig. 1. *Balanus crenatus* BRUGUIÈRE (UMUT-RA8330) from Paramushir Is., Kurile Isls. Coll. Mr. K. KOBA. 1a-b. whole wall, ×1.5., 1c-d. exterior and interior views of right scutum, ×5., 1e-f. exterior and interior views of tergum, ×5., 1g-h. exterior and interior views of rostrum, ×2., 1i-j. exterior and interior views of right lateral, ×2., 1k-l. exterior and interior views of right carinolateral, ×2., 1m-n. exterior and interior views of carina, ×2.

Figs. 2-7. *Balanus crenatus* BRUGUIÈRE from the Pliocene Daishaka Formation (Loc. 5b). 2a-b. exterior and interior views of right scutum (UMUT-CA8311), ×5., 3a-b. exterior and interior views of right tergum (UMUT-CA8332), ×5., 4a-b. exterior and interior views of rostrum (UMUT-CA8333), ×2., 5a-b. exterior and interior views of right lateral (UMUT-CA8334), ×2., 6a-b. exterior and interior views of right carinolateral (UMUT-CA8335), ×2., 7a-b. exterior and interior views of carina (UMUT-CA8336), ×2.

Figs. 8-13. *Balanus crenatus* BRUGUIÈRE from the late Miocene Oidawara Formation (Loc. 41e). 8a-b. exterior and interior views of left scutum (UMUT-CA8337), ×5., 9a-b. exterior and interior views of left tergum (UMUT-CA8338), ×5., 10a-b. exterior and interior views of rostrum (UMUT-CA8339), ×2., 11a-b. exterior and interior views of right lateral (UMUT-CA8340), ×2., 12a-b. exterior and interior views of right carinolateral (UMUT-CA8341), ×2., 13a-b. exterior and interior views of carina (UMUT-CA8342), ×2.

Figs. 14-18. *Balanus crenatus* BRUGUIÈRE from the early to middle Miocene Moniwa Formation (Loc. 12b). 14a-b. exterior and interior views of left scutum (UMUT-CA8343), ×4., 15a-b. exterior and interior views of right tergum (UMUT-CA8344), ×4., 16a-b. exterior and interior views of right lateral (UMUT-CA8345), ×2., 17a-b. exterior and interior views of left carinolateral (UMUT-CA8346), ×2., 18a-b. exterior and interior views of carina (UMUT-CA8347), ×2.

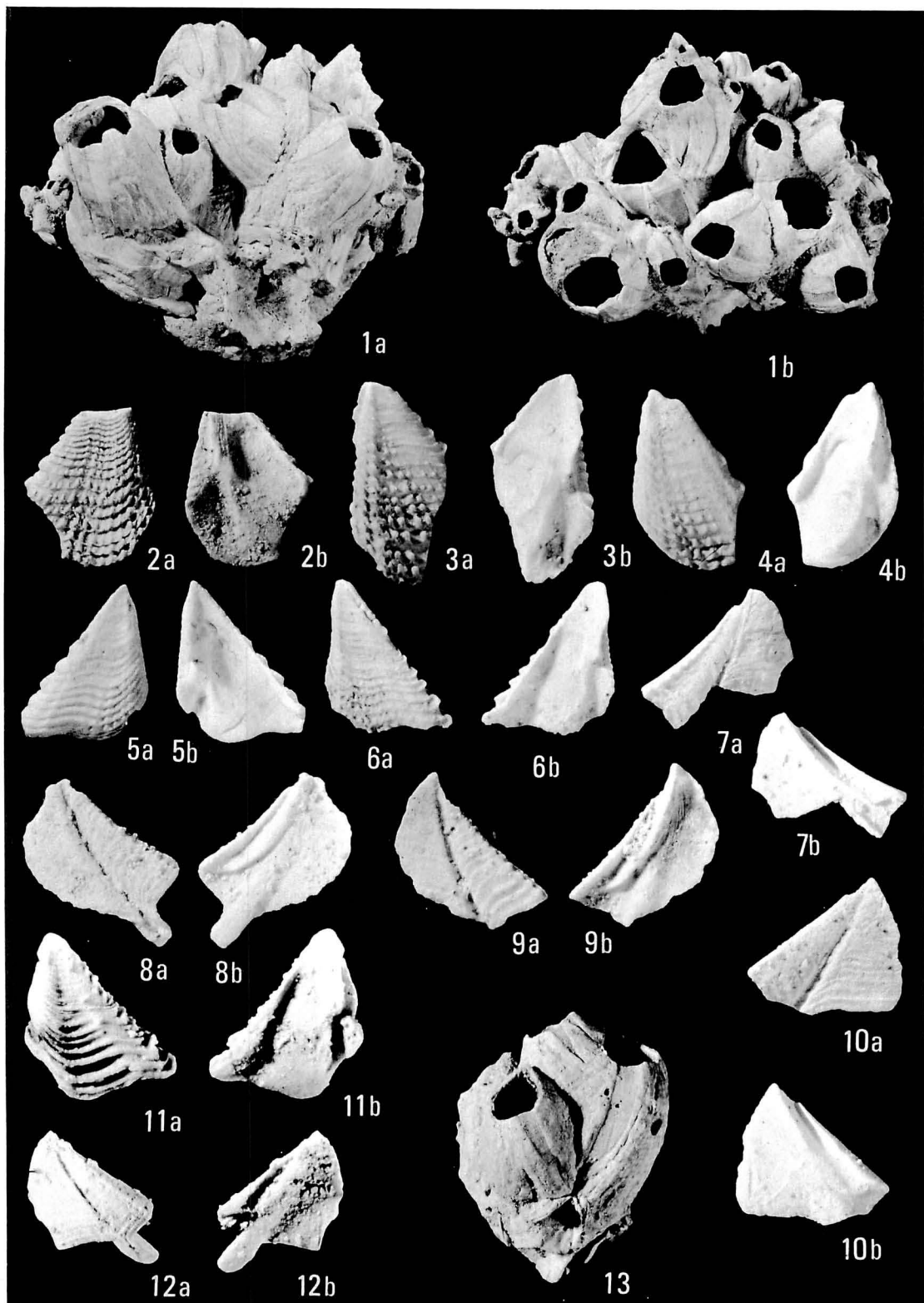Fig. 19. *Balanus crenatus* BRUGUIÈRE (UMUT-CA8348) from the late Miocene Shimokurosawa Formation (Loc. 11), ×1.5.

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Fig. 1. *Megabalanus volcano* (PILSBRY) (UMUT-CA8349) from the Pleistocene Nakoshi Sandstone (Loc. 44). 1a-b. crowded individuals, ×0.8.

Figs. 2-10. *Megabalanus volcano* (PILSBRY) from the Pleistocene Nakoshi Sandstone (Loc. 44). 2a-b. exterior and interior views of right scutum (UMUT-CA8350), ×3., 3a-b. exterior and interior views of left scutum (UMUT-CA8351), ×5., 4a-b. exterior and interior views of left scutum (UMUT-CA8352), ×5., 5a-b. exterior and interior views of right scutum (UMUT-CA8353), ×5., 6a-b. exterior and interior views of left scutum (UMUT-CA8354), ×5., 7a-b. exterior and interior views of right tergum (UMUT-CA8355), ×5., 8a-b. exterior and interior views of left tergum (UMUT-CA8356), ×5., 9a-b. exterior and interior views of left tergum (UMUT-CA8357), ×5., 10a-b. exterior and interior views of right tergum (UMUT-CA8358), ×5.

Figs. 11-12. *Megabalanus rosa* (PILSBRY) from the Pleistocene Nakoshi Sandstone (Loc. 44). 11a-b. exterior and interior views of left scutum (UMUT-CA8359), ×5., 12a-b. exterior and interior views of left tergum (UMUT-CA8360), ×5.

Fig. 13. Association of *Megabalanus volcano* (PILSBRY) and *M. rosa* (PILSBRY) from the Pleistocene Nakoshi Sandstone (Loc. 44). (UMUT-CA8361). ×1. v: *volcano*, r: *rosa*.

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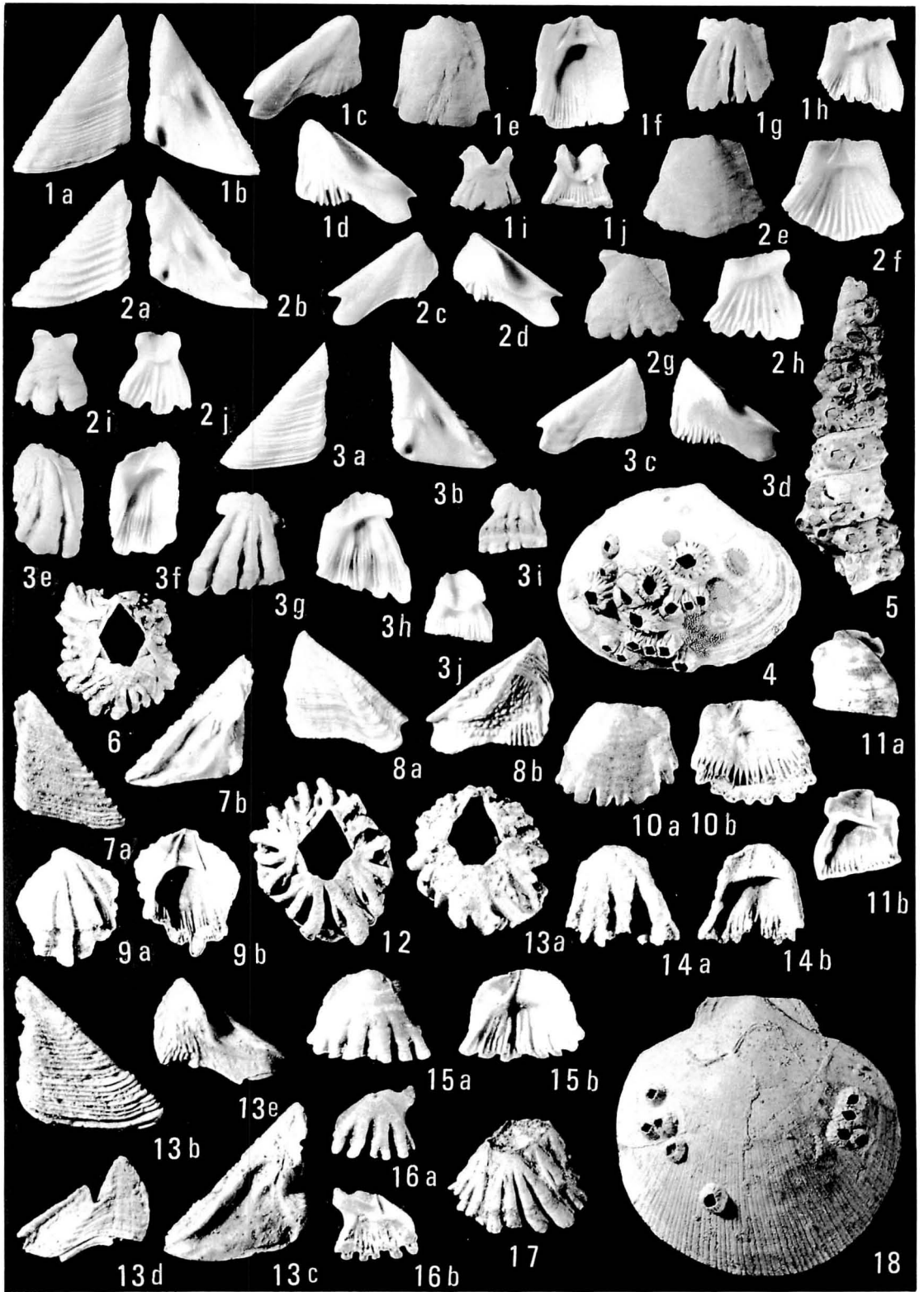*Biol. Lab.*, vol. 17, p. 339–372.
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Fig. 1. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-RA8295) from Funka Bay (Loc. B3). 1a–b. exterior and interior views of right scutum, ×4., 2a–b. exterior and interior views of right tergum, ×4., 1e–f. exterior and interior views of rostrum, ×1.5., 1g–h. exterior and interior views of right lateral, ×1.5., 1i–j. exterior and interior views of carina, ×1.5.

Fig. 2. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-RA8296) from Funka Bay (Loc. B3). 2a–b. exterior and interior views of right scutum, ×8., 2c–d. exterior and interior views of right tergum, ×8., 2e–f. exterior and interior views of rostrum, ×3., 2g–h. exterior and interior views of right lateral, ×3., 2i–j. exterior and interior views of carina, ×3.

Fig. 3. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-RA8297) from Funka Bay (Loc. B3). 3a–b. exterior and interior views of right scutum, ×5., 3c–d. exterior and interior views of right tergum, ×5., 3e–f. exterior and interior views of rostrum, ×2., 3g–h. exterior and interior views of right lateral, ×2., 3i–j. exterior and interior views of carina, ×2.

Fig. 4. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-RA8298) on *Macoma tokyoensis* from Funka Bay (Loc. B2), ×0.75 (smooth and ribbed forms).

Fig. 5. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-RA8299) on *Turritella fortilirata* from Funka Bay (Loc. B3), ×0.75.

Fig. 6. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-CA8300) from the Pleistocene Nishiyatsu Formation (Loc. 26), ×2.

Figs. 7–9. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) from the Pleistocene Narita Formation (Loc. 24i). 7a–b. exterior and interior views of left scutum (UMUT-CA8301), ×7., 8a–b. exterior and interior views of left tergum (UMUT-CA8302), ×7., 9a–b. exterior and interior views of rostrum (UMUT-CA8303), ×3.

Figs. 10–11. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) from the Pleistocene Shibikawa Formation (Loc. 8c). 10a–b. exterior and interior views of rostrum (UMUT-CA8304), ×3., 11a–b. exterior and interior views of left lateral (UMUT-CA8305), ×3.

Figs. 12–14. *Solidabalanus (Hesperibalanus) hesperius* (PILSBRY) from the Pliocene Horoshintachibetsu Formation (Loc. 1). 12. whole wall (UMUT-CA8306), ×2.5., 13. (UMUT-CA8307) ; 13a. whole wall, ×2.5, 13b–c. exterior and interior views of left scutum, ×7, 13d–e. exterior and interior views of right tergum, ×7., 14a–b. exterior and interior views of rostrum (UMUT-CA8308), ×2.

Figs. 15–16. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) from the early to middle Miocene Sugota Tuffaceous Silty Sand (Loc. 9b). 15a–b. exterior and interior views of rostrum (UMUT-CA8309), ×3., 16a–b. exterior and interior views of left lateral (UMUT-CA8310), ×3.

Fig. 17. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-CA8311) from the late Miocene Maisawa sandstone of the Suenomatsuyama Formation (Loc. 7k), ×2.

Fig. 18. *Solidobalanus (Hesperibalanus) hesperius* (PILSBRY) (UMUT-CA8312) on *Placopecten setanensis* from the late Miocene Yakumo Formation (Loc. 2d), ×0.6.

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683. SOME LATE TRIASSIC BIVALVIA AND GASTROPODA FROM THE DOMEYKO RANGE OF NORTH CHILE*

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チリー北部ドメイコ山地の三畳紀後期二枚貝および腹足類：1970年に千葉大学とチリー地質調査所の協力で行なわれたドメイコ山地の地質古生物合同調査の採集品を検討した結果，アントファアガスタの約 180 km 南東の砂質石灰岩から得られた化石群中に Limidae の 2 新種を含む二枚貝13種と腹足類 3 種を識別，鑑定したので記載する。このうち *Antiquilima ataca-mensis* はジュラ紀に世界的に繁栄した *Ctenostreon* の特徴をも備え，同属の起源を考察する上に興味ある種である。この化石群はペルー中部のセロ・ド・パスコ地域から知られている三畳紀後期（ノリアン）の軟体動物群に共通する種を多く含み，母岩の性質も類似するので，ペルーに広く分布する Pucará 層群の南縁がこの山地に達していることを示している。二枚貝の外層は一般によく保存されているが，がんらいアラレ石でできていたと思われる内層はしばしば消失していて，殻の構造や鉱物組成のちがいによって差別的な化石化がみられる。化石は多少とも珪化作用を受け，酸処理によって基質を除去できる場合がある。珪化は差別的な化石化の後で残された殻の内外の表層から内部に向って進行したと考えられる。

速水　格・前田四郎・C. R. FULLER

Introduction

In October and November, 1970, a geological and paleontological reconnaissance survey on the Mesozoic terrain of the Domeyko Range of Chile was carried out in cooperation between the members of the Chiba University Palaeontological Expedition to the Andes and the staff of the Instituto de Investiga-cions Geologicas (Santiago and Antofagasta) with the support of the Overseas Scientific Research Funds, Ministry of Education, Government of Japan. The present article is a part of its outcome, particularly about the newly discovered Triassic molluscan fossils from this area.

The Domeyko Range is located in the arid area of northern Chile (Provinces of Antofagasta and Copiapo), extending meridionally, ranging from 3,800 m to 4,900 m in altitude. Between this range

and the still higher Andean Cordillera on the east there are several salt lakes, namely, Salar de Atacama, Salar de Imilac and Salar de Punta Negra from north to south.

The fossils described in the present article were obtained at two localities (GCH 26 and GCH 85), both of which are situated on the eastern slope of this range near Salar de Punta Negra, about 180 km southeast of Antofagasta (Text-figs. 1, 2). The stratigraphy and geologic structure of the Mesozoic terrain in this range have not been sufficiently clarified, although, as shown in the geologic map of Chile (published from the Instituto de Investigacions Geologicas in 1968), it has generally been regarded as Jurassic and partly as Cretaceous. Actually, undoubt-

Text-fig. 1. Index map.
C: Cerro de Pasco area, D: Domeyko Range (locality of the present material)
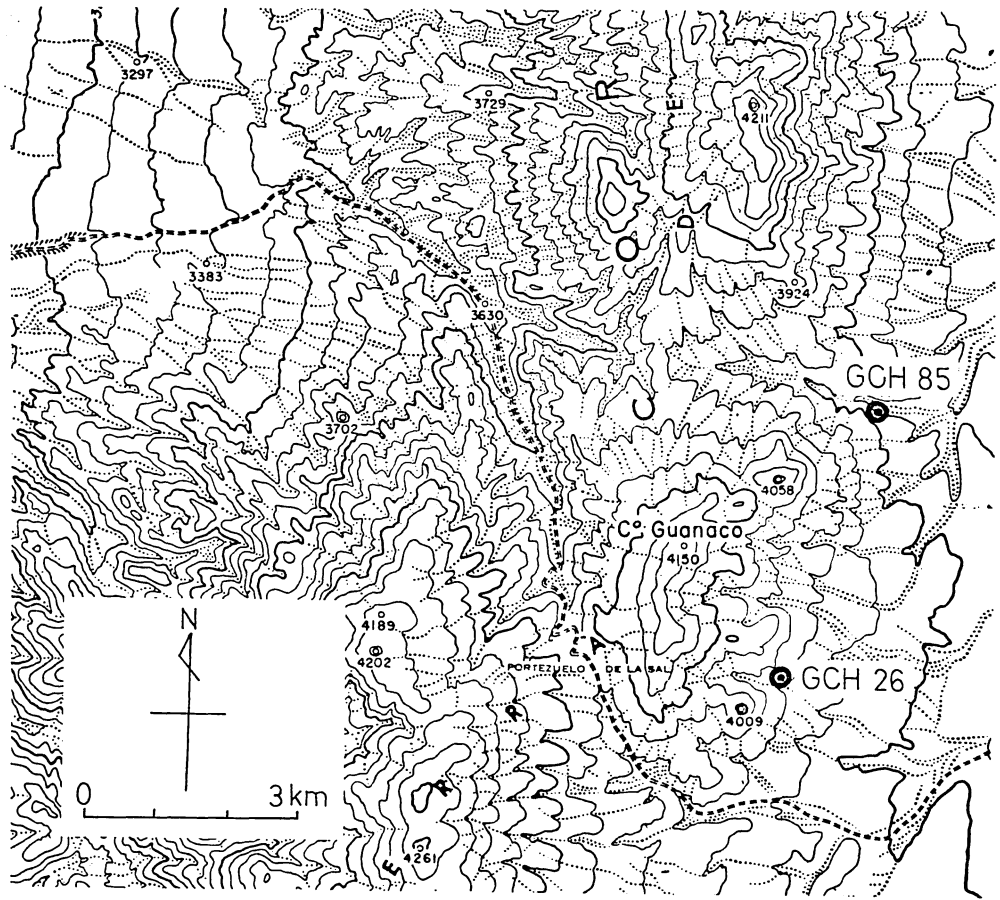
ed Lower Jurassic fossils occur at several localities on the western slope of this range. The occurrence of various fossils at the present localities was first found by Dr. CHONG, but they remain underscribed except for a species of *Thecosmilia* (hexacoral) in another paper related to the same expedition (MAEDA, YAMAGIWA, FULLER and CHONG, 1974). The fossiliferous beds are greyish (brownish if weathered) impure limestones of 1-3 meters' thickness which alternate with black shales. They contain abundant molluscan shells which are mostly fragmentary but sometimes well preserved. The strata near the two localities dip steeply to the east or are nearly vertical, being strongly folded. Because of the much flattened topography and insufficient exposure, it is difficult to recognize the detailed stratigraphic sequence in this area, but the various molluscan fossils, as described here, clearly indicate an upper Triassic age instead of Jurassic. Actually this fauna has a marked resemblance to the Upper Triassic ones of northern and central Peru, which were described by JAWORSKI (1922), KÖRNER (1937), COX (1949) and HAAS (1953). Like the fossils from the Pucará Group of Peru, the molluscan shells are considerably silicified, offering interesting material not only for the taxonomic studies but also for the consideration of fossilization and silification.

Text-fig. 2. Fossil localities in the Domeyko Range (GCH 26 and GCH 85)

Chiba Prefecture) for their close cooper-
ation in collecting the material, to Dr.
Hideo KATSUKI (President of the Chiba
University), Professor Emeritus Teiichi
KOBAYASHI (Japan Academy) and the
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Trade Organization for their kind as-
sistance in the actual field survey.
Thanks are also due to Professor Tetsuro
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fessor Kenji KONISHI (Kanazawa Uni-
versity) for their discussion about the
fossilization of this material.

Presesvation and silicification of fossils

Most of the fossils here studied were
obtained from the weathered surface of
impure limestone *in situ* at the two
localities. The calcium carbonate of
original shells have been commonly re-
placed by silica, and the fossils seem to
be more resistant to chemical and me-
chanical weathering than the matrix. The

actual extent of silicification, however, is considerably variable among species and individuals. Because selective fossilization of particular shell layers is occasionally seen, careful observation and adequate interpretation on the state of preservation are required for the taxonomic study on this material.

Chemical preparation of fossils by acid is really effective to take out the silicified shells from the limestone blocks. If the calcareous cement is completely dissolved, the rock becomes quite loose, looking as if it were Neogene or Quaternary sediment. The residue is wholly composed of fine to medium-grained sand and numerous fragments of silicified fossils, occupying 15 to 40 percent of the original block in weight. It may be, therefore, the best way for preparation of material to remove mechanically the loose residue after soaking the blocks in diluted HCl for several days. For large blocks we repeated the combination of the chemical and mechanical procedures for several times. The silicified shells are, however, quite fragile and apt to be damaged, especially in thin-shelled species. In some bivalves the silification is not completed or only the outer layer is selectively preserved, and, even if they had originally thick tests, this method is hardly applicable. In such cases it is partically effective to coat some part of the surface with paraffin before soaking the blocks in acid.

As the result of this preparatory work, 13 species of the Bivalvia and 2 species of the Gastropoda came to our knowledge as listed in Table 1. In the same table the actual state of preservation is shown in contrast with the presumed original shell structure and mineralogy which are, though not directly evidenced, generally inferable from the data by

TAYLOR, KENNEDY and HALL (1969, 1973) and others.

Although the process and cause of the selective fossilization and silicification still remain unsolved, we tentatively summarize the result of our observation and interpretation in the following items:

1) In most species of the Bivalvia the outer layer is better preserved than the inner. The detailed ornaments and growth increments on the external surface are generally well preserved, whereas the hinge teeth and musculature are observable only in a few species.

2) Regardless of the difference of shell fabrics, fossils originally composed of calcite seem to be well preserved. The outer layers of the shells of *Modiolus* sp., *Pinna* sp., *Pseudolimea chongi* sp. nov. and *Antiquilima atacamensis* sp. nov. and also the almost whole shells of *Plicatula* sp. and *Gryphaea* sp. are these examples. They are generally silicified, but the silicification is often incomplete in the interior of the foliated layers of *Plicatula* sp. and *Gryphaea* sp. In every specimen of *Pinna* sp. original simple prismatic structure is well preserved, notwithstanding that each prism has been completely replaced by pseudomorphous silica (see Plate 28, Fig. 1b). The preserved shells of *Antiquilima atakamensis* are very thin (less than 0.4 mm in maximum thickness) and probably produced by silicification after selective fossilization (see Text-fig. 3).

3) The inner layer of crossed-lamellar or nacreous aragonite in many of above mentioned species was dissolved at all without any trace. The space originally occupied by the inner layer seems to have been closed by compaction. This state of preservation is apparently similar to that of European Chalk which was studied by KENNEDY (1969), CARTER

Table 1. Late Triassic Bivalvia and Gastropoda from the Demeyko
Range of north Chile and the state of preservation

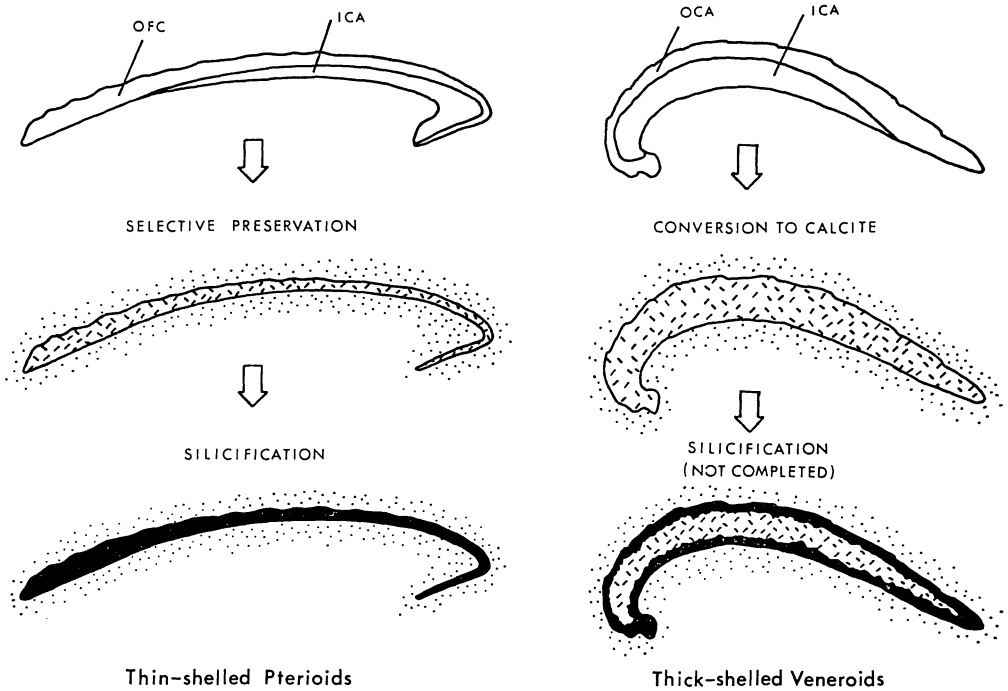| Species	Presumed original shell structure and mineralogy	Actual state of preservation and silicification
Modiolus sp.	O : finely prismatic, calcite I : nacreous, aragonite	O : finely prismatic, silicified I : not preserved
Pinna sp.	O : simply prismatic, calcite I : sheet nacreous, aragonite	O : simply prismatic, silicified I : apparently not preserved
Eopecten sp.	O : foliated?, calcite I : not inferable	O : apparently structureless, silicified I : not preserved
Plicatula sp.	O : foliated, calcite I : crossed-lamellar, aragonite	O : foliated, not completely silicified I : apparently structureless, silicified
Pseudolimea chongi sp. nov.	O : finely foliated, calcite I : crossed-lamellar, aragonite	O : apparently structureless, silicified I : not preserved
Antiquilima atacamensis sp. nov.	O : finely foliated, calcite I : crossed-lamellar, aragonite	O : apparently structureless, silicified I : not preserved
Gryphaea sp.	O : foliated, calcite I : foliated, calcite	O : foliated, not completely silicified I : foliated, not completely silicified
Unionites sp.	not inferable	probably only outer layer preserved, structureless, silicified
Myophorigonia sp. aff. *M. paucicostata* (JAWORSKI)	O : prismatic, aragonite I : lenticular, nacreous, aragonite	O : apparently structureless, silicified I : not preserved
Schafhaeutlia americana COX	O composite prismatic, aragonite M : crossed-lamellar, aragonite I : complex crossed-lamellar, aragonite	O : apparently structureless, silicified M : apparently not preserved I : not preserved
Palaeocardita peruviana COX	O : crossed-lamellar, aragonite I : complex crossed-lamellar, aragonite	O : apparently structureless, silicified I : apparently structureless, incompletely silicified
Septocardia peruviana (COX)	O : crossed-lamellar, aragonite I : complex crossed-lamellar, aragonite	O : apparently structureless, silicified I : apparently structureless, silicified
Isopristes sp.	O : crossed-lamellar, aragonite I : homogeneous or complex crossed-lamellar, aragonite	O : apparently structureless, incompletely silicified I : apparently structureless, incompletely silicified
Planospirina sp.	not inferable	Preserved shell apparently structureless, silicified
Chartronella pacifica (JAWORSKI)	not inferable	" Outer layer " : silicified " Middle layer " : not silicified but for small quartz crystals " Inner layer " : silicified

O : outer layer, M : middle layer, I : inner layer

(1972) and some others. However, the vanishing of aragonitic shells in the present material is not so exhaustive. The shells of the Trigonioida and Veneroida, which are believed to have been originally aragonitic, are often well preserved and silicified, though the original shell fabrics are hardly observable. The inner layer is generally silicified as well as the outer in *Septocardia peruviana* and sometimes also in *Palaeocardita peruviana*. In such a case the hinge structure and other internal characteristics are clearly observable by etching. Judging from the deeply excavated adductor muscle scars, the myostracum aragonite probably vanished before the silicification. On the other hand, the inner layer seems almost totally absent in the specimens of *Myophorigonia* sp. aff. *M. paucicostata* and *Schafhaeutlia americana*. In some specimens of *Palaeocardita peruviana* and *Isopristes* sp. only the external and internal surface is silicified like sandwich, and, when etched, the middle " layer" of shell commonly becomes hollow, indicating incomplete silicification. In this case the preservation does not seem to be controlled by the original nature of shell. If the actual state of preservation is compared with the presumed original shell structure, it may be said the prismatic aragonite is commonly preserved and that crossed-lamellar and complex crossed-lamellar aragonite may or may not have been fossilized. Nacre seems to be totally absent in the present material without any trace.

4) In a large number of specimens of *Chartronella pacifica* the outer and inner surface of shell is well silicified, while the middle " layer " is quite incompletely. By etching the middle " layer " becomes a cavity in which many microscopic crystals of druse-fashioned quartz are

observed. This state of preservation seems quite similar to the case of the gastropod fossils from the Pucará group in the Cerro de Pasco area of central Peru (HAAS, 1953, p. 9). Since the gastropod belongs to an extinct group, their original shell structure and mineralogy are hardly inferable. HAAS (1953) appears to have regarded the three " layers " of gastropod shells as original. We do not think, however, they represent any original shell structure, because the thickness of the cavity corresponding to the middle " layer " is quite irregular. Moreover, as noted before, essentially similar phenomena are also observed in some etched specimens of *Gryphaea* sp., *Palaeocardita peruviana* and *Isopristes* sp. It is here suggested that the silicification proceeded from the external and internal surface and has not been completed in the middle part of thick shells (see Text-fig. 3).

5) Generally speaking, the selective preservation of fossils at the present localities is believed to be primarily controlled by the structure and composition of original shells, while the extent of silicification seems to vary in accordance with local environmental condition. Prismatic and foliated structures of calcite, regardless of the extent of silicification, are commonly well exhibited, but such microscopic original shell structures of aragonite as crossed-lamellar are obliterated, even if the shells are preserved. Since skeletal aragonite in permeable carbonate rocks is said to have been vanished or more commonly converted to calcite (HALL and KENNEDY, 1967; etc.), the obliteration may have occurred at the time of the conversion before the silicification. The sandwich-like layered structure of silicification in some molluscan shells are decidedly regarded as having nothing to do with the original

Text-fig. 3. Inferred process of preservation for the bivalve fossils from the Domeyko Range. Left: complete silicification after the vanishing of inner layer [OFC: outer foliated (or prismatic) layer of calcite, ICA: inner crossed-lamellar (or nacreous) layer of aragonite]. Right: incomplete silicification after the recrystallization of total shell [OCA: outer crossed-lamellar layer of aragonite, ICA: inner complex crossed-lamellar layer of aragonite]. These are not sketches but based on the actual state of preservation in the shells of *Antiquilima atacamensis* and *Isopristes* sp.

shell structure and mineralogy.

Repository

All the specimens described in this paper are preserved in the Department of Earth Sciences, Faculty of Science, Chiba University.

Systematic description

[by Itaru HAYAMI and Shiro MAEDA]

Class Bivalvia

Order Mytiloida

Family Mytilidae RAFINESQUE, 1815

Genus *Modiolus* LAMARCK, 1799

Modiolus sp. indet.

Plate 28, Figure 2

This species is represented by two specimens: one is a left valve (GC. 1001, 64.9 mm long, 42.3 mm high, 13.6 mm thick), and the other is a broken conjoined specimen (GC. 1002). The nearly smooth surface is divided into two subequal areas by a distinct diagonal carina. The umbo is not terminal, the anterior lobe being wide but not much inflated. Judging from the general external characters, the present specimen is better referred to *Modiolus* than to *Falcimytilus*, though specifically indeterminable.

Occurrence.—Limestone at loc. GCH 85.

Family Pinnidae LEACH, 1819

Genus *Pinna* LINNÉ, 1758

Subgenus *Pinna* LINNÉ, 1758

Pinna (*Pinna*) sp. indet.

Plate 28, Figures 1a, b

Six specimens (GC. 1003–GC. 1008) are available for the present study. All of them are conjoined but fragmentary. The shells are completely silicified but show simple prismatic structure along the fracture, which is essentially the same as that of the living species of *Pinna*. The apical angle is as small as 30 degrees. The median ridge is distinct but becomes somewhat rounded in the adult stage. The transverse sections of conjoined specimens, therefore, are sub-rhomboidal near the umbo and thickly lenticular near the postero-ventral periphery. The largest specimen (GC. 1003) exceeding 85 mm in width, provided with some 20 flexuous weak radial riblets on the dorsal slope of surface. The ventral slope is nearly smooth except for fine incremental lines, which indicate rectangularly truncated and widely gaped postero-ventral margin. The present species is undoubtedly referable to *Pinna* (s. str.), but the incomplete material prevents us from determining its specific name.

Occurrence.—Limestone at Loc. GCH 85.

Order Pterioida

? Family Pectinidae RAFINESQUE, 1815

Genus *Eopecten* DOUVILLÉ, 1897

Eopecten sp. indet.

Plate 28, Figure 3

The present species is represented only by an incomplete specimen (GC. 1009). It is probably a left valve of an un-named species of *Eopecten*, judging from the indistinctly differentiated anterior auricle and mode of radial ribbing. The radial ribs on the disk are as numerous as 90 and irregular in prominence and breadth, often increasing their number by irregular insertion. The preserved test is extremely thin.

COX (1952) is of the opinion that some Triassic species hitherto referred to *Eopecten* [= *Velata*, *Velopecten* auct.] should be assigned to *Leptochondria* BITTNER, 1891. In fact, the present species is somewhat similar to *Leptochondria pascoensis* COX, 1949, from the Upper Triassic of Peru, but the shell-size is much larger and the radial ribs are more numerous in the present species. In Europe *Eopecten* seems to have first appeared in the Lower Jurassic, but in Japan an undoubted species of this genus has been known from the Upper Triassic. *Eopecten* has been tradi-tionally regarded as belonging to the Pectinidae, but actually there is some doubt as to the family reference. In fact, the radial ornamentation and deep byssal notch with distinct ctenolium in some Jurassic species may remind ones those of the Chlamydinae. Yet, the radial ribs of two orders in the left valve of some other species, as well as the plano-convex outline and indistinct-ly demarcated anterior wing of left valve, seem to suggest some relationship to the Aviculopectinidae and the Oxytomidae. Therefore, this genus together with *Leptochondria* may be an important group for the consideration on the an-cestry of the Pectinidae. Since the pre-served shell of the present specimen is unusually thin and may represent only the outer layer, its original inner layer

was possibly composed of other material than foliated calcite. Incidentally, the inner layer of a left valve is said to be composed of nacre in the Aviculopectinidae and of crossed-lamellar "calcite" in the Oxytomidae (COX *et al.*, 1969; ICHIKAWA, 1958). Because the present species may be more or less deviated from the type-species of *Eopecten* from the Jurassic, further studies on typical species of this genus, especially on their shell structure, are needed to solve this taxonomic problem.

Occurrence.—Limestone at Loc. GCH 85.

Family Plicatulidae WATSON, 1930

Genus *Plicatula* LAMARCK, 1801

Plicatula sp. indet.

Plate 28, Figure 4

An incomplete specimen (GC. 1010, 29.2 mm long, 31.8 mm+ high) is regarded as a left valve of *Plicatula* owing to the characteristic hinge structure and muscle impression. Although its external surface was damaged during the etching, radial ribbing seems to be inconspicuous.

Occurrence.—Limestone at Loc. GCH 85.

Family Limidae RAFINESQUE, 1815

Genus *Pseudolimea* ARKELL *in* DOUGLAS and ARKELL, 1932

Pseudolimea chongi HAYAMI and MAEDA, sp. nov.

Plate 28, Figures 5-8, 9a-c

Material. — Holotype : GC. 1011, left valve. Paratypes : GC. 1012, conjoined specimen ; GC. 1013 – GC. 1016, right valves ; GC. 1017-GC. 1019, left valves. Some other fragmentary specimens.

Diagnosis. — Medium-sized species of *Pseudolimea* characterized by the non-carinate, gibbose and obliquely ovate outline, not clearly demarcated auricles and about 19 angular radial ribs with one riblet of secondary strength on each interspace.

Description. — Shell equivalve, inequilateral, obliquely ovate, higher than long, strongly inflated ; preserved test thin ; anterior umbonal ridge undeveloped ; no lunule ; umbo highly protruded above the dorsal margin ; both auricles moderate in size, not much flattened, not clearly demarcated ; byssal gape, is present, narrow ; primary radial ribs as many as 18 to 20, commonly roof-shaped but sometimes bi-angulated ; their interspaces provided with one much weaker riblet respectively, though such riblets are very weak or invisible on the anterior auricle ; internal structure unknown.

Remarks.—More than ten specimens are available for the study. Their outer layer is well silicified, but the peripheral part is more or less broken in all the specimens. The characteristic ornamentation composed of radial ribs of two orders is well observable in every specimen, and the almost closed anterior

Table 2. Measurements in mm [*Pseudolimea chongi* sp. nov.]

Specimen	Length	Height	Thickness
Left valve (GC. 1011), holotype	24. 3	27. 2	9. 8
Conjoined valves (GC. 1012), paratype	17. 8	20. 1	13. 3
Right valve (GC. 1013), paratype	20. 0+	26. 2	8. 4
Left valve (GC. 1017), paratype	29. 6	31. 1	9. 9

commissure and the ornamentation on the anterior wing are recognized in the paratype (GC. 1012). The inner layer is not preserved at all. Though the hinge structure is not revealed, the present species seems to be an early representative of *Pseudolimea*. It is in fact similar to *Pseudolimea hettangiensis* (TERQUEM, 1855) from the lower Lias of western Europe (DECHASEAUX, 1936; COX, 1944), but the present species has weaker secondary riblets and more obliquely elongated shell. Some Carnian limids from the St. Cassian beds of Alps described by BITTNER (1895) seem also to belong to *Pseudolimea*, as were treated by COX (1944), but the present species is probably distinct from them, because the shell-size is much larger.

Occurrence.—Limestone at Loc. GCH 85.

Genus *Antiquilima* COX, 1943

Antiquilima atacamensis HAYAMI and MAEDA, sp. nov.

Plate 28, Figures 10–12

Material. — Holotype: GC. 1020, left valve. Paratypes: GC. 1021, conjoined specimen; GC. 1022, GC. 1023, left valves; GC. 1024, GC. 1025, right valves. Some other fragmentary specimens.

Diagnosis. — Medium-sized species of *Antiquilima* characterized by the strong incremental lines on the acutely triangular right anterior auricle, wide byssal gape and about 18 radial ribs which bear numerous fine radial threads and become squamose or knotty towards the ventral periphery.

Description.—Shell of medium-sized for the genus, slightly inequivalve, inequilateral, subovate, much higher than long, not strongly inflated; preserved test very thin; anterior umbonal ridge undeveloped, observed only near the umbo; lunule not delimitted; umbo low, situated near the mid-point of hinge-line; anterior auricle comparatively large, obtuse-triangular and rather flattened in the left valve, whereas it is acutely triangular, well inflated and marked with erect incremental lamellae in the right; byssal gape wide in the right valve but almost absent in the left; posterior auricle moderate in breadth, obtusely truncated in each valve; surface of disc ornamented with about 18 round-topped radial ribs, which are simple on the umbonal and middle part but become squamose or even knotty near the ventral margin of adult shell; radial ribs and interspaces marked with numerous fine radial threads and fine incremental lines, looking cancellate; fine radial ribs observable also on the posterior auricle; ligament and internal structure unknown, because the inner layer is not preserved at all.

Remarks.—The holotype reveals nearly complete outline, but other specimens are not complete or even fragmentary. The knotty radial are observed in the holotype and some of the paratypes and remind us strongly of the ornamentation of *Ctenostreon*, but other essential characters are similar to those of *Antiquilima*. The inequality of anterior auricles between two valves is recognized in the paratype (GC. 1021). In the an-

Table 3. Measurements in mm [*Antiquilima atacamensis* sp. nov.]

Specimen	Length	Height	Thickness
Left valve (GC. 1020), holotype	45. 7	59. 1	7. 6
Right valve (GC. 1021), paratype	40. 4+	54. 8+	9. 2

terior view of this specimen the byssal gape is quite asymmetrical, that is to say, the anterior margin is profoundly concave in the right valve but only slightly in the left. Although such a feature has not been recorded in any described species of *Antiquilima*, we presume that it may be a common tendency in this genus, because the anterior auricle is acute-angled only in the right valve also in *Antiquilima cubiferens* (WHIDBORNE, 1883), as figured by Cox (1943). Acutely triangular anterior auricle with similarly erect incremental lamellae is known in the right valves of early representatives of *Ctenostreon* such as *C. japonicum* HAYAMI, 1959, from the Lower Jurassic of west Japan.

The present species is anyhow morphologically transitional between *Antiquilima* and *Ctenostreon*. Although the data are not necessarily sufficient to reconstruct the evolutionary lineage, it is possible to consider that the species of Jurassic *Ctenostreon* are actually descendants from some Upper Triassic species of *Antiquilima*. Although Cox HERTLEIN *in* Cox *et al.* (1969) noted that *Antiquilima* ranges from Lias to Bajocian, KIPARISOVA *et al.* (1966) recorded an undoubted species of this genus from the Norian—Rhaetian of east Siberia. BITTNER (1900, p. 207) suggested the possible derivation of *Ctenostreon* from *Mysidioptera*, but the former seems to be more closely related to *Antiquilima* than to the latter.

The unequality of the anterior auricles of the present species suggests a byssate sedentary life and subparallel or oblique living position to the surface of stable substrate.

Occurrence.—Limestone at Locs. GCH 85 and GCH 26.

Family Gryphaeidae VYALOV, 1936

Genus *Gryphaea* LAMARCK, 1801

Gryphaea sp. indet.

Plate 29, Figures 1, 2

This species is represented by three specimens (GC. 1026–GC. 1028). They are incompletely silicified, showing foliated shell structure. One of them (GC. 1026, 34.0 mm long, 51.8 mm high, 24.5 mm thick) is conjoined and better preserved than the other specimens. The left valve of this specimen is strongly inflated, provided with incoiled umbo, fairly wide attachment area truncating the umbonal region and a distinct posterior lobe which is delimitted by a deep sulcus. However, such a sulcus is undevelopped in other left valves. No radial ornament is seen on the surface of two valves. This is probably an undescribed species of *Gryphaea*, but it is no difficult to find any definite specific criterion, because of the great morphological variability. In South America *Gryphaea darwini* FORBES and a few other species of *Gryphaea* have been known from the Lower Jurassic, but, so far as we are aware, there is no Triassic gryphaeid comparable with the present species in this continent. It has been said that the homeland of *Gryphaea* was the Arctic region, because the occurrence of Triassic species was scarcely known from other regions (STENZEL *in* Cox *et al.*, 1971, p. N1070; etc.). If the present species is a true early representative of *Gryphaea*, it may bear something informative to the long-pending question about the origin and migration route of this genus.

Occurrence.—Limestone at Loc. GCH 85 and GCH 26.

Order Unionoida

Family Pachycardiidae Cox, 1961

Genus *Unionites* Wissmann, 1841

Unionites sp. indet.

Plate 29, Figures 3a, b, 4

There are four conjoined specimens (GC. 1029-GC. 1032), the tests of which are partly preserved but commonly weathered or broken. Two specimens show oblong and weakly carinate outline and closed posterior margin (GC. 1029, 53.6 mm long, 29.5 mm high, 24.0 mm thick; GC. 1030, 55.2 mm+ long, 34.6 mm high, 23.6 mm thick). In an incomplete specimen (GC. 1031) the ventral margin is slightly sinuated at the middle and the test (only the outer layer) with fine incremental lines is well preserved. Two specimens (GC. 1029, GC. 1032) shows the opisthodetic and external position of ligament. The umbo is placed at about one-fifth of total length from the anterior end. Because of the absence of inner layer, the hinge and muscle structures are unknown. Although the general outline may remind one of some species of *Pachymya* and certain pholadomyid genera, the completely closed posterior margin, absence of radially disposed pustules, the position of ligament and smooth surface indicate that the present species should be referred to the Pachycardiidae. The anterior located umbo and moderately large shell-size may be comparable with those of some species of *Trigonodus*, but the oblong and weakly carinated outline and other external features seem to indicate that the present species belongs to *Unionites*.

Occurrence.— Limestone at Loc. GCH 85.

Order Trigonioida

Family Trigoniidae Lamarck, 1819

Genus *Myophorigonia* Cox, 1952

Myophorigonia sp. aff. *M. paucicostata* (Jaworski)

Plate 29, Figures 5, 6

Compare.—
1922. *Myophoria paucicostata* Jaworski, *Neues Jahrb. f. Min. usw.*, Beil.-Bd. 47, p. 126, pl. 5, figs. 9–11.
1929. *Myophoria paucicostata* Jaworski: Steinmann, Geologie von Perú, p. 63, figs. 69A-E.
1937. *Myophoria paucicostata* Jaworski: Körner, *Paleontographica*, Bd. 86, Abt. A, p. 184, pl. 12, fig. 4.
1949. *Myophoria paucicostata* Jaworski: Cox, *Bol. Inst. Geol. Peru*, no. 12, p. 25, pl. 1, fig. 11.
1952. *Myophorigonia paucicostata* (Jaworski): Cox, *Proc. Malac. Soc. London*, vol. 29, pts. 2-3, p. 52, pl. 3, fig. 3.
1969. *Myophorigonia paucicostata* (Jaworski): Cox *in* Cox *et al.*, Treatise on Invertebrate Paleontology, Part N, p. N485, fig. D71-3.

The present species is represented by three fragmentary specimens (GC. 1033-GC. 1035): one is a left valve and two are right. They show similarly eight or so tuberculated and highly elevated radial ribs on the anterior slope of disc as typical specimens of *Myophorigonia paucicostata* from the Upper Triassic of Peru. In comparison with the Peruvian specimens illustrated by Jaworski (1922) and Cox (1949), however, the marginal sulcus is narrower and merely as wide as the interspaces between other radial ribs, and the shell size seems to be much larger. The height of those Peruvian specimens scarcely exceeds 20 mm in length and height, whereas the largest

specimen (GC. 1033) in the present collection, though its original outline cannot be reconstructed, is evidently taller than 45 mm. In these respects the present specimens are more similar to another Peruvian specimen figured by KÖRNER (1937) and probably specifically distinct from JAWORSKI's. The material is, however, too insufficient to propose a new taxon.

Occurrence.—Limestone at Loc. GCH 85.

Order Veneroida

Family Fimbriidae NICOL, 1950

Genus *Schafhaeutlia* COSSMANN, 1897

Schafhaeutlia americana COX

Plate 29, Figure 7

1949. *Schafhaeutlia americana* COX, *Bol. Inst. Geol. Peru*, no. 12, p. 31, pl. 2, figs. 1, 2.

This species is represented only by a left valve (GC. 1036, 49.1 mm long, 48.2 mm high, 20.2 mm thick). The preserved test is unusually thin and probably represents only the outer layer. In view of the rounded outline, concentric ornamentation and strong convexity the present specimen is assignable to *Schafhaeutlia americana* COX 1949, which was originally described from the Upper Triassic of Peru, though the hinge and other internal structures are unknown at all.

Occurrence.—Limestone at Loc. GCH 85.

Family Carditidae FLEMING, 1828

Genus *Palaeocardita* CONRAD, 1868

Palaeocardita peruviana COX

Plate 30, Figures 1a, b, 2–4, 5a–c

?1937. *Cardita* aff. *beneckei* BITTNER : KÖRNER, *Palaeontographica*, Bd. 86, Abt. A, p. 192,

pl. 12, fig. 7.
1949. *Palaeocardita peruviana* COX, *Bol. Inst. Geol. Peru*, no. 12, p. 31, pl. 2, fig. 4.

Material. — GC. 1037–GC. 1039, right valves. GC. 1040–GC. 1042, left valves. Many other incomplete specimens.

Description.—Shell of medium or large size for the genus, sometimes exceeding 45 mm in length, equivalve, highly inequilateral, trapezoidal to oblong, about 1.4 times longer than high, strongly inflated; test moderate in thickness; antero-dorsal margin short, never concave, sloping down into the rounded anterior margin; postero-dorsal margin long, nearly straight or feebly convex, passing gradually into the posterior; posterior carina extending from the umbo to the postero-ventral corner where the posterior margin forms a nearly right angle with the ventral; maximum convexity lying on the carina; umbo prominent, angular, slightly opisthogyrous, placed at about one-fourth of shell from the anterior end; lunule and escutcheon not discriminated; surface ornamented with 20–22 roof-shaped radial ribs; one of which coincides with the carina and about eight of which are distributed on the posterior area behind the carina; interspaces of radials also angular, never flattened; somewhat scaly incremental lines crossing the radials; hinge plate moderate in breadth, provided with carditid-type teeth as formulated: 3a 3b PI/ 2 4b PII; 3a elongated and curved along the pre-umbonal margin; 2 very opisthocline, narrow; 3b acline, triangular, never bifid, massive and highly elevated; 4b rather thin; PI and PII strong but short, remote from the cardinals; anterior adductor scar deeply impressed, bordered posteriorly by a buttress; inner ventral margin coarsely crenulated in accordance with the external radial ribs.

Table 4. Measurements in mm [*Palaeocardita peruviana* Cox]

Specimen	Length	Height	Thickness
Right valve (GC. 1037)	26.6+	21.8	9.6
Right valve (GC. 1038)	28.1	19.9	9.5
Right valve (GC. 1039)	46.0	33.9	16.8
Left valve (GC. 1040)	30.1	21.9	9.7
Left valve (GC. 1041)	30.0	20.1+	9.6

Remarks.—More than 20 silicified specimens are available for the study, but few of them are complete. In every specimen the surface ornaments are well observable, but the inner layer may or may not be preserved. The hinge structure is best revealed in two specimens (GC. 1037, GC. 1040), which were taken out from blocks of limestone by diluted HCl. The present specimens seem to be referable to *Palaeocardita peruviana* Cox, 1949, originally described from the Upper Triassic of Peru, because all the essential characters are the same. Although the radial ribs are apparently more widely spaced on the posterior area in the Peruvian specimen (Cox, 1949, pl. 2, fig. 4), the difference may to due to variation within one and the same species. KÖRNER (1937) figured a similar carditid specimen also from Peru under the name of *Cardita* aff. *beneckei*. Cox (1949) suggested that it is conspecific with *P. peruviana*, but the number of radial ribs, 29 according to KÖRNER, is too numerous and the umbo is placed very anteriorly for this species, judging from the individual variation of the present material. KÖRNER (1937) proposed at the same time the genus *Schizocardita* for an aberrant carditid also from the Upper Triassic of Peru, which possesses a rostrum-like acuminate postero-ventral projection. Although the taxonomic evaluation of this character is not yet clear, it is interesting that the hinge and other essential characters of the type-species of

that genus: *Schizocardita cristata* KÖRNER, 1937, are fairly similar to those of the present species. Such a projection is, however, not recognized from the incremental lines of any specimen in the present collection.

Occurrence.—Limestone at Loc. GCH 85 and GCH 26.

Family Cardiidae LAMARCK, 1809

Genus *Septocardia* HALL and WHITFIELD, 1887

Septocardia peruviana (Cox)

Plate 29, Figures 8a, b, 9a–c, 10

1949. *Pascoella peruviana* Cox, *Bol. Inst. Geol. Peru*, no. 12, p. 35, pl. 1, figs. 9, 12–15, ?pl. 2, fig. 5.
1969. *Septocardia typica* HALL and WHITFIELD: KEEN *in* Cox *et al.*, Treatise on Invertebrate Paleontology, Part N, p. N586, figs. E85–1a–f (non 1g, h) [non *S. typica* HALL and WHITFIELD, 1877].

Material.—GC.1043–GC.1045, left valves.
Description.—Shell inequilateral, suborbicular to gibbose, nearly as long as high, strongly inflated; test heavy; antero- and postero-dorsal margins short, gently arcuate, passing gradually into venter; umbo subcentral, highly salient, slightly but distinctly opisthogyrous; lunule and escutcheon not delimitted; surface ornamented with about 19 roof-shaped scaly radial ribs which are comparatively wide on the anterior-middle

Table 5. Measurements in mm [*Septocardia peruviana* (Cox)]

Specimen	Length	Height	Thickness
Left valve (GC. 1043)	24.3	24.7	12.6
Left valve (GC. 1044)	22.2	21.1	10.5

surface and densely spaced on the posterior area; bottom of the interspace also angular and never flattened; ligament short, inserted in an oblique furrow bordered by the nymph, hinge plate wide, provided with two cardinal teeth (2, 4b) and one posterior lateral tooth (PII) in the left valve; cardinal 2 very opisthocline, elongated, highly elevated; 4b also stout, prosocline; 3a and 3b probably connected below the umbo, judging from the shape of their sockets in the left valve; PII tusk-like, well developed; no anterior lateral tooth; anterior adductor scar subovate, deeply excavated, bordered posteriorly by a prominent buttress, while the posterior one is obscure; inner ventral margin strongly crenulated in accordance with the external radials.

Remarks.—In this collection the present species is represented by three silicified left valves which were obtained by etching. Two of them (GC. 1043, GC. 1044) are well preserved and nearly complete, showing both the external and internal characters. The other specimen (GC. 1045) is incompletely silicified, and its hinge plate and inner layer were mostly dissolved. They are quite similar in every essential character to the specimens from the Norian at several localities in central Peru, which were described by Cox (1949) under the name

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Explanation of Plate 28

Fig. 1. *Pinna* sp. indet.
    1a: Right valve of a conjoined specimen (GC. 1003) ×1; 1b: part of fracture profile in the postero-dorsal area of the same specimen, revealing simple prismatic structure, ×4.
Fig. 2. *Modiolus* sp. indet.
    2: Left valve (GC. 1001) ×1.
Fig. 3. *Eopecten* sp. indet.
    3: Left valve (GC. 1009) ×1.
Fig. 4. *Plicatula* sp. indet.
    4: Internal view of a left valve (etched specimen) (GC. 1010) ×1.
Figs. 5-9. *Pseudolimea chongi* HAYAMI and MAEDA, sp. nov.
    5: Right valve (GC. 1014), paratype, ×1.5.
    6: Left valve (GC. 1011), holotype, ×1.5.
    7: Right valve (GC. 1016), paratype, ×1.5.
    8: Right valve (GC. 1013), paratype, ×1.5.
    9: Conjoined valves (GC. 1012), paratype, ×1.5. 9a: right view, 9b: left view, 9c: anterior view.
Figs. 10-12. *Antiquilima atacamensis* HAYAMI and MAEDA, sp. nov.
    10: Right valve of a conjoined specimen (GC. 1021), paratype, ×1.
    11: Left valve (GC. 1022), paratype, ×1.
    12: Left valve (GC. 1020), holotype, ×1.
All specimens from Loc. GCH 85. Photo by HAYAMI with whitening.

of *Pascoella peruviana.* Although the average shell-size may be somewhat smaller than in Cox' specimens, the hinge structure, outline and mode of radial ribbing are quite identical. Keen *in* Cox *et al.* (1969) refigured Cox's specimens under the specific name of *Septocardia typica* HALL and WHITFIELD, which was originally based on the material from the Upper Triassic of Nevada. This treatment, however, does not go down with us, because the original specimens of *S. typica,* as illustrated by HALL and WHITFIELD, show more inequilateral and rectangular outline, thinner test and less angular radial ribs and interspaces. We regard here *Pascoella peruviana* as a distinct species of *Septocardia. Cardita* n. sp. ex aff. *gümbeli* Pichler—*pichleri* BITTNER described by KÖRNER (1937) may be also another representative of this genus, though the shell-size is much smaller than the present species.

Occurrence.—Limestone at Loc. GCH 85.

Family Cardiniidae ZITTEL, 1881

Genus *Isopristes* NICOL and ALLEN, 1953

Isopristes sp. indet.

Plate 29, Figures 11a-c, 12

This species is represented by four specimens; two (GC. 1046, 35.0 mm long, 35.2 mm high, 26.1 mm thick; GC. 1047, 35.3 mm long, 32.6 mm high, 26.3 mm thick) are conjoined valves, one (GC. 1047) is a left valve and one (GC. 1048) is a fragmentary right valve. They are incompletely silicified and generally poorly preserved, but equidistantly spaced and somewhat imbricated concentric lamellae are clearly observed on the anterior part of a conjoined specimen (GC. 1046). Small radial ribs of *Isopristes* type are actually invisible on the surface, but numerous fine crenules on the

ventral rim of each imbrication suggest the presence of such radial ornaments. The hinge structure and wide *Cardinia*-like pseudolunule are, though obscurely, exposed in an incomplete right valve (GC. 1048), which was obtained by etching. Judging from these characteristics, the present species is certainly referable to the genus *Isopristes*, which was orignally founded on a species from the Upper Triassic of Peru. In comparison with *Isopristes crassus* NICOL and ALLEN, 1953, however, the shell of the present species seems to be more globose, and the concentric lamellae are more densely spaced.

Occurrence.—Limestone at Loc. GCH 85.

Glass Gastropoda

Order Archaeogastropoda

Family Neritopsidae GRAY, 1847

Genus *Planospirina* KITTL, 1899

Planospirina sp. indet.

Plate 30, Figures 8a, b

Only a single silicified specimen (GC. 1050, 29.4 mm in max. diameter, 20.8 mm in min. diameter, 22.1 mm in height) was obtained by etching. It shows low spire, descending suture near the aperture, somewhat irregularly undulated surface of upper whorl and gibbose aperture with feebly concave inner lip and inductura of moderate breadth, although the external surface and the marginal part of outer lip are incomplete. These characteristics seem to indicate that the present species belongs to the Naticopsinae, probably the genus *Planospirina.* In comparison with *Nerita esinensis* STOPPANI, 1858, from the Ladinian of Tyrol, the type-species of *Planospirina,* many characters are quite similar, but

the aperture is semicircular and higher than broad in the present specimen.

Occurrence.—Limestone at Loc. GCH 85.

Family Paraturbinidae COSSMANN, 1916

Genus *Chartronella* COSSMANN, 1902

Chartronella pacifica (JAWORSKI)

Plate 30, Figures 9-11

1922. *Eucyclus pacificus* JAWORSKI, *Neues Jahrb. f. Min. usw.*, Beil.-Bd. 47, p. 140, pl. 4, fig. 11.
1949. *Eucyclus hartisoni* COX, *Bol. Inst. Geol. Peru*, no. 12, p. 37, pl. 2, figs. 17, 18.
1953. *Chartroniella pacifica* (JAWORSKI) [sic]: HAAS, *Bull. Amer. Mus. Nat. Hist.* vol. 101, p. 81, pl. 5, figs. 31-41, 45-47, 54.

Several incomplete specimens are available for the study. Two of the illustrated specimens (GC. 1051, 28.6 mm in max. diameter, 26.1 mm in min. diameter, 40.3 mm in height; GC. 1052, 28.0 mm in max. diameter, 27.1 mm in min. diameter, 38.2 mm in height) show nearly complete outline, though their outer lips are partly broken. They are incompletely silicified and were obtained by partial etching from limestone blocks. Judging from the high-turbinate shell, obliquely growing last whorl with unusually deep suture near the aperture, gradually weakened and sometimes obscurely serrated keel, well marked growth lamellae on the base, obscure spiral ribs on the upper whorl and very prosoclinal outer margin of aperture seem to be essentially the same with those of *Chartronella pacifica* (JAWORSKI) from the Upper Triassic of Peru. If compared with many silicified specimens of various ontogenetic stages, which were fully described by HAAS (1953) on the material from the Cerro de Pasco area, the mode of allometric growth, especially the weakened keel with growth and obliquely descending suture of the last whorl, is quite similar, endorsing the present specific identification.

Explanation of Plate 29

Figs. 1, 2. *Gryphaea* sp. indet.
　　1: Left valve of a conjoined specimen (GC. 1026) ×1.
　　2: Left valve (GC. 1027) ×1.
Figs. 3, 4. *Unionites* sp. indet.
　　3: Conjoined valves (GC. 1029) ×1. 3a: left view, 3b: right view.
　　4: Right valve of a conjoined specimen (GC. 1031) ×1.
Figs. 5, 6. *Myophorigonia* sp. aff. *M. paucicostata* (JAWORSKI)
　　5: Left valve (GC. 1034) ×1.
　　6: Right valve (GC. 1033) ×1.
Fig. 7. *Schafhaeutlia americana* COX
　　7: Left valve (GC. 1036) ×1.
Figs. 8-10. *Septocardia peruviana* (COX)
　　8: Left valve (etched specimen) (GC. 1044) ×1.5. 8a: external view, 8b: internal view.
　　9: Left valve (etched specimen) (GC. 1043) ×1.5. 9a: external view, 9b: internal view, 9c: upper view.
　　10: Left valve (etched specimen) (GC. 1045) ×1.5.
Figs. 11, 12. *Isopristes* sp. indet.
　　11: Conjoined valves (GC. 1046) ×1. 11a: left view, 11b: right view, 11c: anterior view.
　　12: Internal view of a fragmentary right valve (GC. 1048) ×1.5.
All specimens from Loc. GCH 85. Photo by HAYAMI with whitening.

Occurrence.—Limestone at Loc. GCH 85.

Incertae sedis

Gastropod genus and species indet.

Plate 30, Figures 6, 7a, b

Two incomplete specimens of a gastropod (GC. 1059, 1060) are at a glance similar to the specimens of the preceding species, but the spire seems to be much lower and the base is much flatter. In the trochiform outline they resemble some specimens of *Chartronella wortheniaeformis* (COX, 1949) from the Upper Triassic of central Peru (HAAS, 1953), but the spiral ribs on the upper whorl and base are much stronger.

Occurrence.—Limestone at Loc. GCH 85.

Concluding remarks

1) As a result of the geological and paleontological survey to the south Andes performed in 1970, a molluscan faunule, which was found in the limestones exposed on the eastern slope of the Domeyko range about 180 km southeast of Antofagasta, was described in this paper. The bivalves consisting 13 species include two new limids: *Pseudolimea chongi* sp. nov. and *Antiquilima atacamensis* sp. nov. The latter species appears to foretell some characteristics of *Ctenostreon*. The internal characters of *Palaeocardita peruviana* and *Septocardia peruviana* were well observed on the basis of some silicified specimens taken out from limestone blocks by etching.

2) In some bivalve specimens, particularly in the Pteroida, the outer layer (originally composed of calcite) is well preserved, whereas the inner layer (originally composed of aragonite) is totally absent without any trace. The vanishing of originally aragonitic layer is,

however, not exhaustive, since the tests of the Veneroida and the outer layer of the Trigonioida are often well preserved. The secondary silicification of molluscan fossils does not seem to be related to the selective fossilization, because the middle "layer" of some bivalve and gastropod shells becomes hollow by etching regardless of the difference of inferred original shell structure and mineralogy.

3) The present molluscan faunule shows marked similarity to the Upper Triassic (mainly Norian) fauna of the Pucará Group in Cerro de Pasco area of Central Peru. In addition to the above mentioned Peruvian species, *Schafhaeutlia americana* and *Chartronella pacifica* are certainly common elements, and there are some species belonging to *Myophorigonia* and *Isopristes* which were also originally proposed on Peruvian materials. In Chile some Middle Triassic (mainly Anisian) molluscs were described from the environs of Alto de Carmen in Province of Atacama (ZEIL, 1958; BARTHEL, 1958) and some Anisian and Norian-Rhaetian sequences were known in the coastal region of Province of Coquimbo and Aconcagua (CECIONI and WESTERMANN, 1968), but the occurrence of Pucará type fauna has not been recorded. Taking also the resemblance of lithology into consideration, it is reasonable to regard the present fossiliferous limestones as belonging to the southern extension of the Pucará Group.
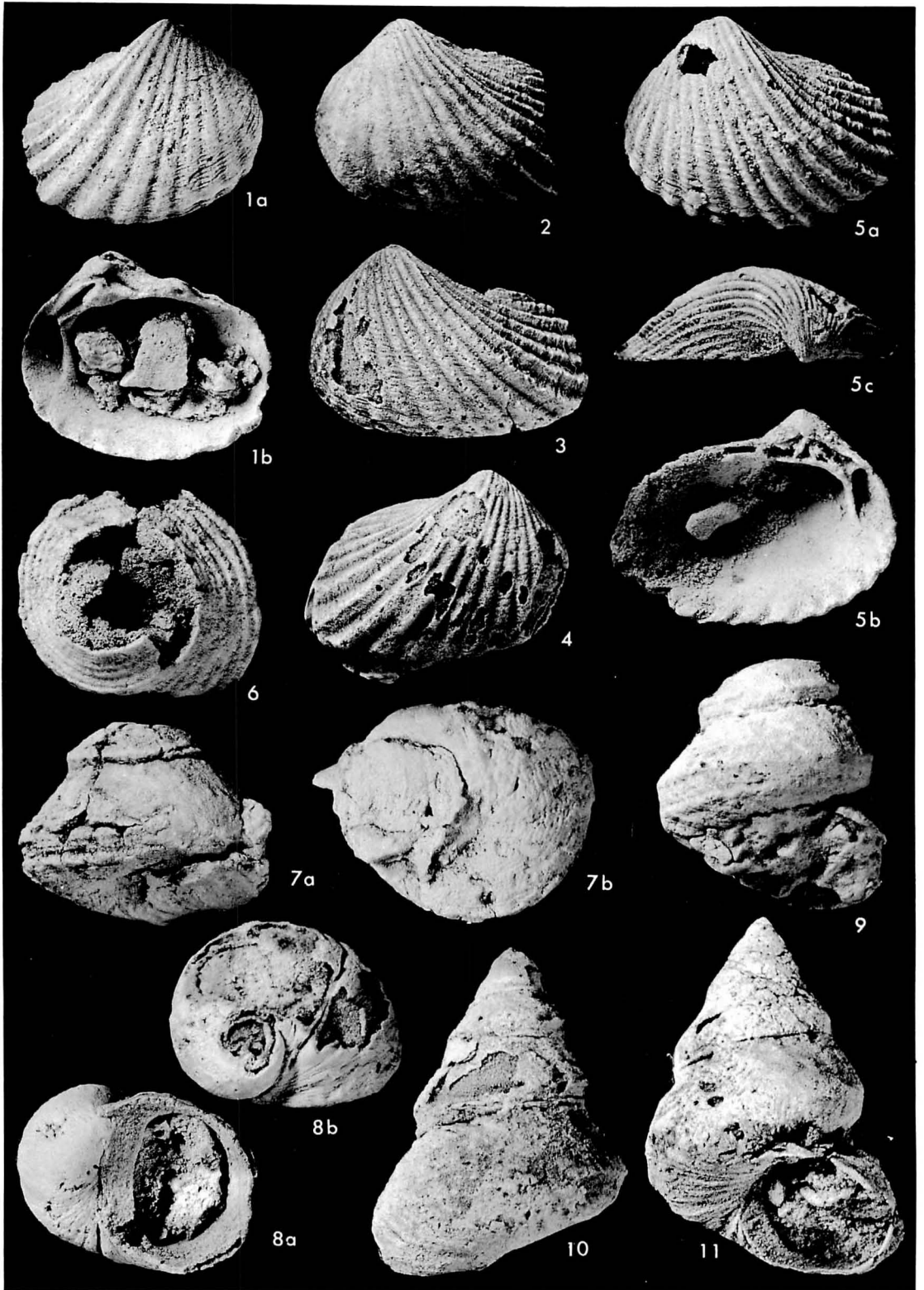
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Explanation of Plate 30

Figs. 1–5. *Palaeocardita peruviana* COX
    1 : Right valve (etched specimen) (GC. 1037) ×1.5. 1a : external view, 1b : internal view.
    2 : Left valve (GC. 1042) ×1.5.
    3 : Left valve (etched specimen) (GC. 1041) ×1.5.
    4 : Right valve (GC. 1038) ×1.5.
    5 : Left valve (etched specimen) (GC. 1040) ×1.5. 5a : external view, 5b : internal view, 5c : upper view.
Figs. 6, 7. Gastropod genus and species indet.
    6 : Upper view of an incomplete etched specimen (GC. 1060) ×1.5.
    7 : Apertural view of an incomplete specimen (GC. 1059) ×1.5.
Fig. 8. *Planospirina* sp. indet.
    8 : Partly etched specimen (GC. 1050) ×1.5. 8a : apertural view, 8b : upper view.
Figs. 9–11. *Chartronella pacifica* (JAWORSKI)
    9 : Apertural view of an incomplete specimen (GC. 1053) ×1.5.
    10 : Adapertural view of a partly etched specimen (GC. 1052) ×1.5.
    11 : Apertural view of a partly etched specimen (GC. 1051) ×1.5
All specimens from Loc. GCH 85. Photo by HAYAMI with whitening.

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PROCEEDINGS OF THE PALAEONTOLOGICAL
SOCIETY OF JAPAN

日本古生物学会第 120 回例会は昭和 52 年 10 月 16 日（日）熊本大学理学部で開催された。（参会者 47 名）

一 般 講 演

行 事 予 定

	開　催　地	開　催　日	講演申込締切
1978年総会・年会	京　都　大　学	1978年1月20・21日	1977年11月15日
第 121 回　例　会	筑　波　大　学	1978年6月3日	1978年3月31日

講演申込先：〒113 東京都文京区弥生 2-4-16　日本学会事務センター　日本古生物学会行事係

お 知 ら せ

○本会名誉会員の今野円蔵君は昭和52年10月3日に逝去されました。ここにつつしんで哀悼の意を表します。　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　日本古生物学会
○日本学術会議第11期会員選挙の第4部全国区候補として本会より特別会員大森昌衛君を推薦した。
○North American Paleontological Convention II および Mid-Cretaceous Events (IGCP ワーキンググループ) の研究集会が昭和52年8月7日〜12日にカンサス大学で開催され，日本から蟹江康光君が参加した。

編 集 係 よ り

○1978年度発行予定の本誌 No. 109 より，短報を除く各原著論文に内容を簡潔に示す英文アブストラクトをつけることになりました。今後投稿される方は原稿に添えて従来の和文要約とは別に，300語以内の英文アブストラクト原稿をお送り下さい。

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