Jour. Fac. Sci., Hokkaido Univ., Ser. IV,
vol. 22, no. 4, Aug., 1990, pp. 529-552.

PLEISTOCENE MOLLUSCAN FAUNAS IN CENTRAL AND SOUTHWESTERN HOKKAIDO

by

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(with 8 text-figures and 5 plates)

Abstract

The Pleistocene marine deposits bearing many molluscan fossils are widely distributed in the Ishikari Lowland and its surrounding hills, the Nopporo, Ishikari and Umaoi Hills. The abundant molluscan fossils in this area are divided into three major faunas in ascending order; the Early Pleistocene (ca. 1.8 to 0.8 Ma), the Middle Pleistocene (ca. 0.4 Ma) and the Late Pleistocene (ca. 0.13 to 0.026 Ma) faunas.

Judging from the faunal characteristics and the ratio of the extinct species, the Early Pleistocene fauna is mainly characterized by extralimital cold water species. This fauna is correlative with that of the Setana Formation in the Kuromatsunai Lowland, southwestern Hokkaido. It is noteworthy that the ratio of extinct species to the total number of species decreases from about 12.7% to about 5.6% during Early Pleistocene time. A significant feature of the Middle Pleistocene fauna is the large representation of extralimital warm water species of molluscs. About 20% of total species has modern distributional patterns that are entirely south of the fossil lacalities. Also extinct species has not yet usually been found. This fauna may be indicated a second climatic optimum event throughout the late Cenozoic time in Hokkaido. Such differences of faunal elements existing between the above-mentioned Early and Middle Pleistocene faunas are in close relation with changes of environmental conditions or resulted from changes through the lapse of time. The Late Pleistocene fauna is, as a whole, characterized by recent species which are now living in shallow water along the Japan Sea or Pacific Ocean in the vicinity of this Lowland. Such prosperity and decay in distribution of northern and southern molluscs are the characteristics of Pleistocene molluscan faunas in Hokkaido.

Introduction

Recently, much informations on the Neogene to Quaternary biostratigraphy in Hokkaido are obtained by the investigations of micropaleontology, molluscan paleontology, chrono-and magnetostratigraphy, etc., besides Uozumi's (1962) exhaustive study on the late Cenozoic molluscan faunas in Hokkaido (Tsuchi(ed.), 1981; Tanai(ed.), 1982; Yoshida, 1983; Uozumi et al., 1986a, 1986b; Koshimizu et al., 1986; Akamatsu, 1988b). As a result, the ideas concerning the classifications of formations as well as their distributions and correlations have been greatly modified. For example, the new stratigraphic sequences for the Ishikari Lowland (Text-fig. 2) have been established as described in the next chapter, and numerous

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1995
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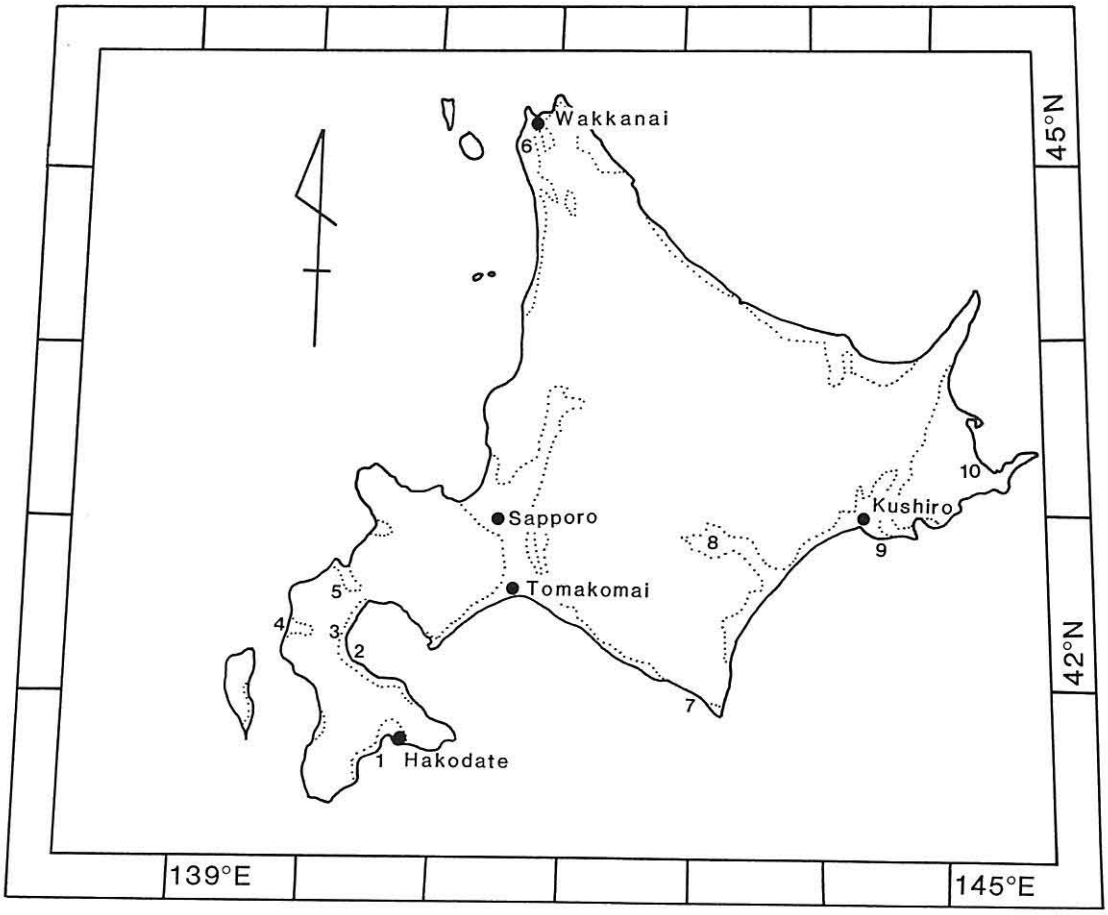
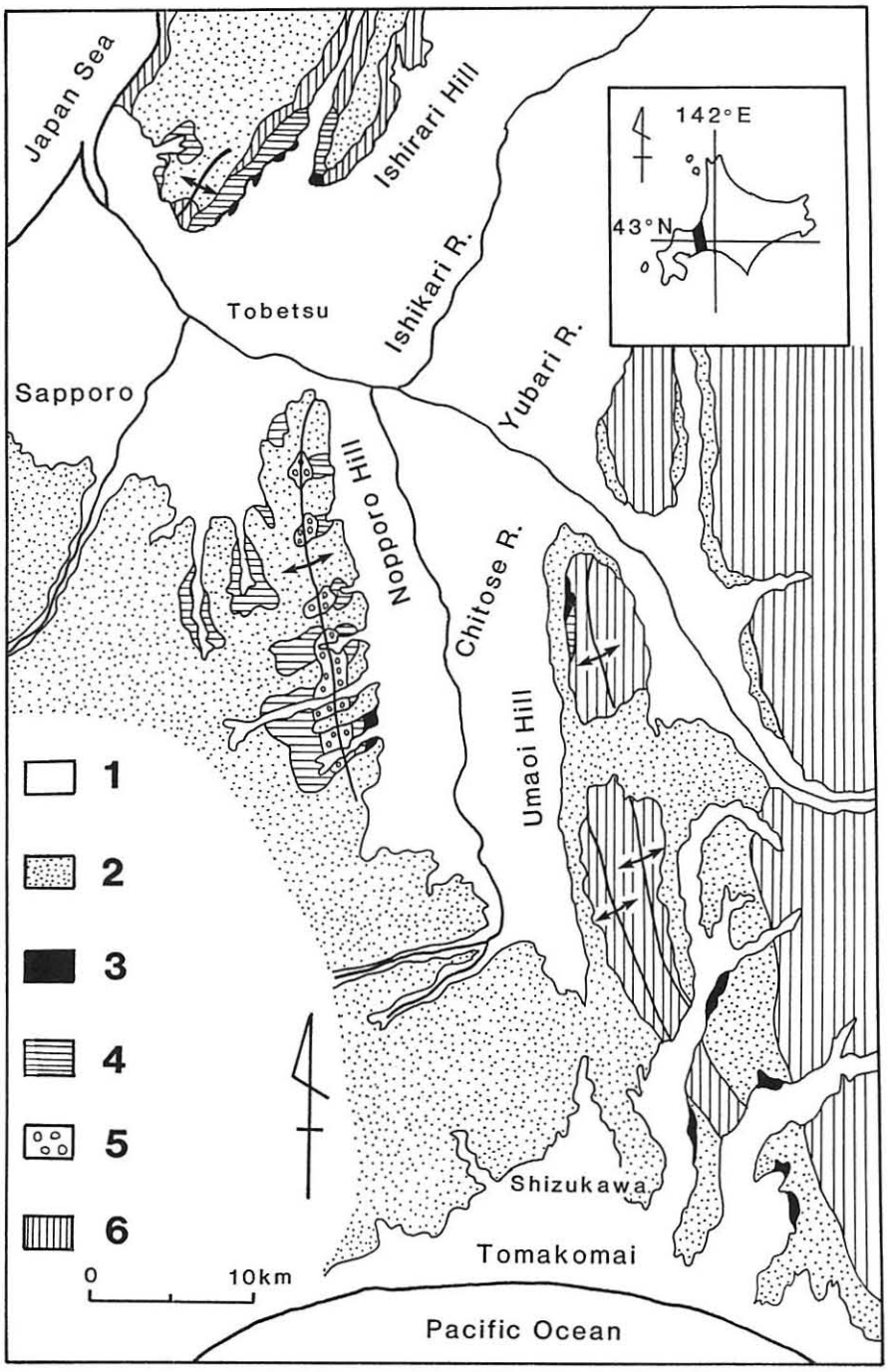


Text-fig. 1 Location map of the studied areas.
1. Tomikawa, 2. Yakumo, 3. Kunnui-Hanaishi, 4. Kitahiyama-Imagane, 5. Kuromatsunai, 6. Wakkanai-Teshio, 7. Samani, 8. Obihiro, 9. Kushiro, 10. Bekkai.

fossil remains have been yielded from each stratigraphic units. Also it has been generally accepted that the Setana Formation (Nagao and Sasa, 1933) is the Early Pleistocene in age (Maiya et al., 1981 ; Chitoku, 1983), although this formation has been previously regarded as a stratotype of the Late Pliocene in southwestern Hokkaido. Moreover, it has been poited out that this formation contains two essentially different molluscan faunas, proper Setana fauna in the lower part and younger one in the upper part (Suzuki, 1987, 1989).

In this paper we will briefly describe the stratigraphic sequence of the Pleistocene deposits in the Ishikari Lowland and its surrounding hills, and also discuss the characteristics of the Pleistocene molluscan faunas in comparison with those of the Setana Formation in the Kuromatsunai Lowland, southwestern Hokkaido.



Text-fig. 2 Geological map of the hills around the Ishikari Lowland. 1. Holocene, 2. Late Pleistocene deposits (including Shikotsu volcanic deposits), 3. Dateyama, Otoebetsugawa, Hayakita and Yamanegawa Formations, 4. Zaimokuzawa, Shimonopporo and Umaoi Formations, 5. Uranosawa Formation, 6. Pre-Zaimokuzawa, Hayakita and Umaoi Formations.

Stratigraphy——correlation and geologic age

The general stratigraphic succession and correlation of the Quaternary marine deposits in the Ishikari Lowland are shown in Text-fig. 3. The Pleistocene deposits are exposed typically in the Nopporo Hills, but the previous paleontological and stratigraphical investigations concerning the Pleistocene deposits in the Nopporo Hills have not always been fully satisfactory in their stratigraphic sequences and geologic times.

Recent studies have revealed that the Pleistocene deposits are chronologically divided into the following six formations in ascending order and are unconformable with each other (Akamatsu, 1987): the Uranosawa, Shimonopporo, Otoebetsugawa, "Takeyama" (Takeyama Gravel Bed), Momijidai and Konopporo Formations.

The Uranosawa Formation, more than 50 meters thick, is composed of siltstone bearing some molluscan fossils in the lower part and alternating beds of tuffaceous siltstone and sandstone in the upper part. Fission track age of a pumice bed which intercalates in its upper part indicates 1.46 ± 0.23 Ma (Koshimizu et al., 1988).

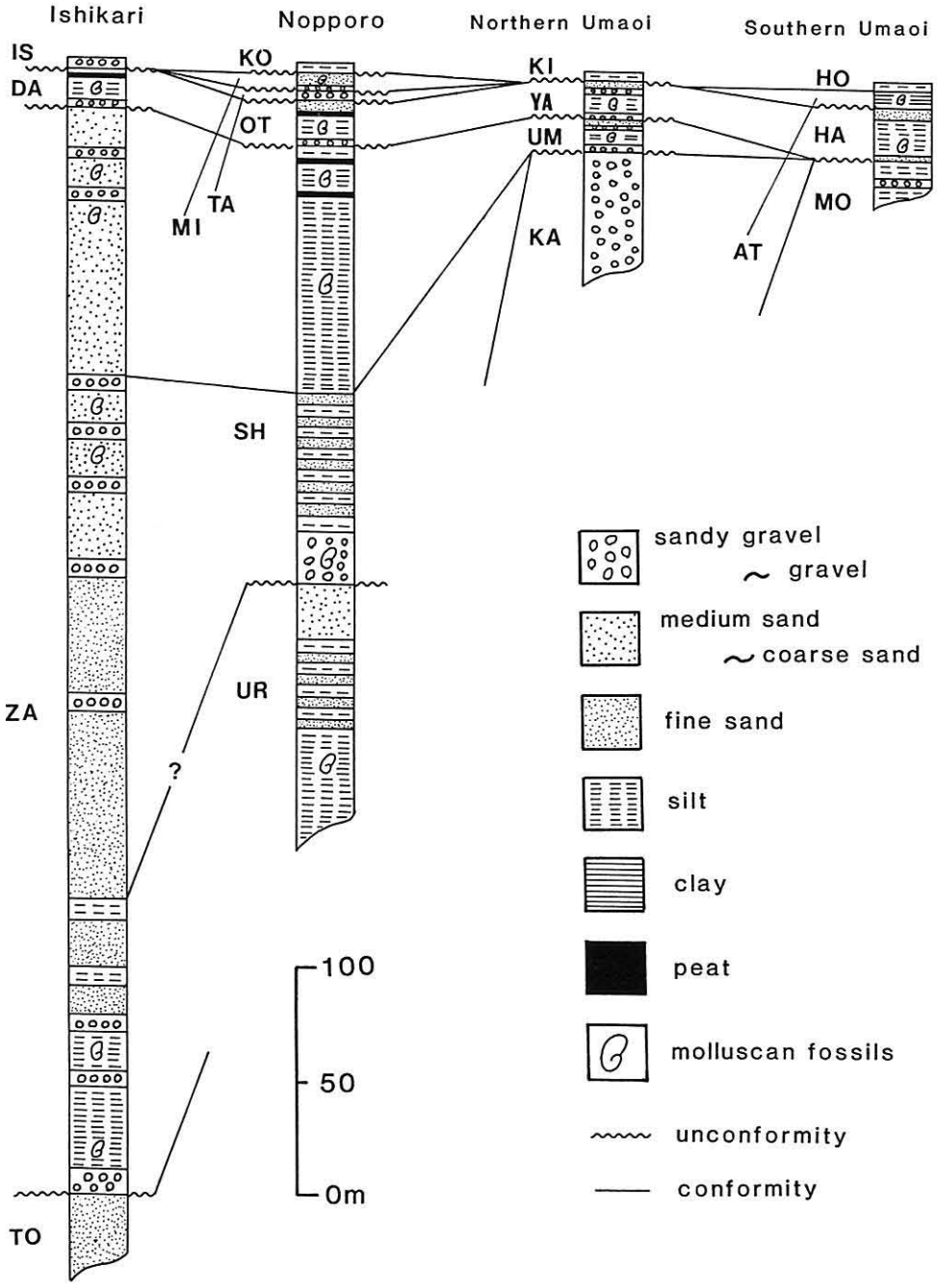
The Shimonopporo Formation, 200 m thick in the western wing of the Nopporo Anticline and 50 m thick in the eastern wing, is composed of gravel, sand and silt, and lithologically divided into three parts, lower, middle and upper. A basal sandy gravel bed, about one meter thick, yields abundant molluscan fossils. The upper part of this formation is made up largely of sand and contains two or three intercalated thin peat beds.

The Otoebetsugawa Formation, 10 meters thick, is composed mainly of massive silt bearing many molluscan fossils and is lithologically divided into three parts, lower, middle and upper. This formation occasionally contains gravels and medium sand in the lower and upper parts.

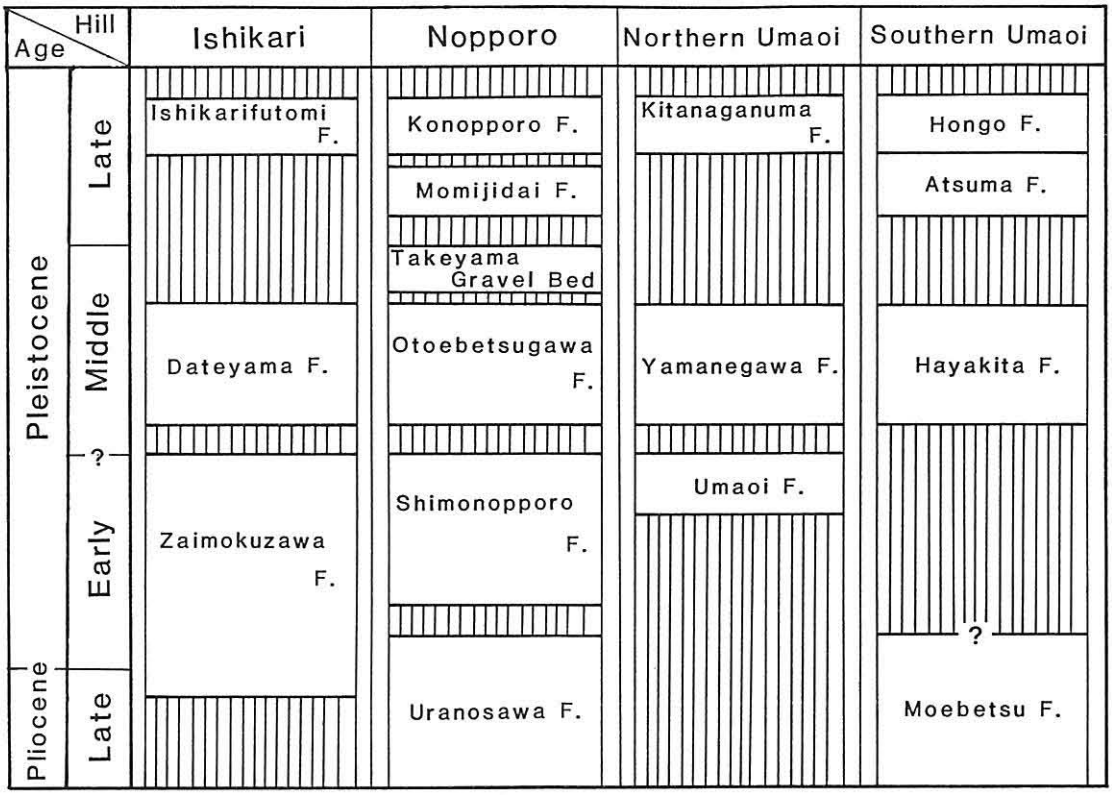
The Takeyama Gravel Bed, uppermost middle Pleistocene deposits, 1 meter thick, is composed mainly of andesite gravels. This bed is a high terrace sediment and forms geomorphic surface of 80 to 120 meters above sea level around the southern part of the Nopporo Hills.

The Momijidai Formation, 4 to 10 meters thick, is composed mainly of sand and andesite gravels and is divided into two parts on the basis of its lithology. Molluscan fossils are yielded from sandy gravel bed of the basal part of this formation. The upper part contains commonly two peat beds. The basal plane of this formation is constantly situated about 15 to 30 meters above sea level.

The Konopporo Formation is a terrestrial sediment and forms the present topography of the most part of the Nopporo Hills. This formation, about 2 to 4 meters thick, is mainly composed of alternating beds of silt and clay, but included by thin layers of sandy gravels and peaty clay. A thin tephra layer (Toya-ash) is found within the upper peaty clay, and is ca. 90 Ka in age (Machida et al., 1987).



Text-fig. 3 Columnar sections of the Pleistocene deposits in the hills around the Ishikari Lowland. IS: Ishikarifutomi Formation., DA: Dateyama F., ZA: Zaimokuzawa F., TO: Tobetsu F., KO: Konopporo F., MI: Momijidai F., TA: Takeyama Gravel Bed, OT: Otoebetsugawa F., SH: Shimonopporo F., UR: Uranosawa F., KI: Kitanaganuma F., YA: Yamanegawa F., UM: Umaoi F., KA: Kawabata F., HO: Hongo F., AT: Atsuma F., HA: Hayakita F., Mo: Moebetsu F.



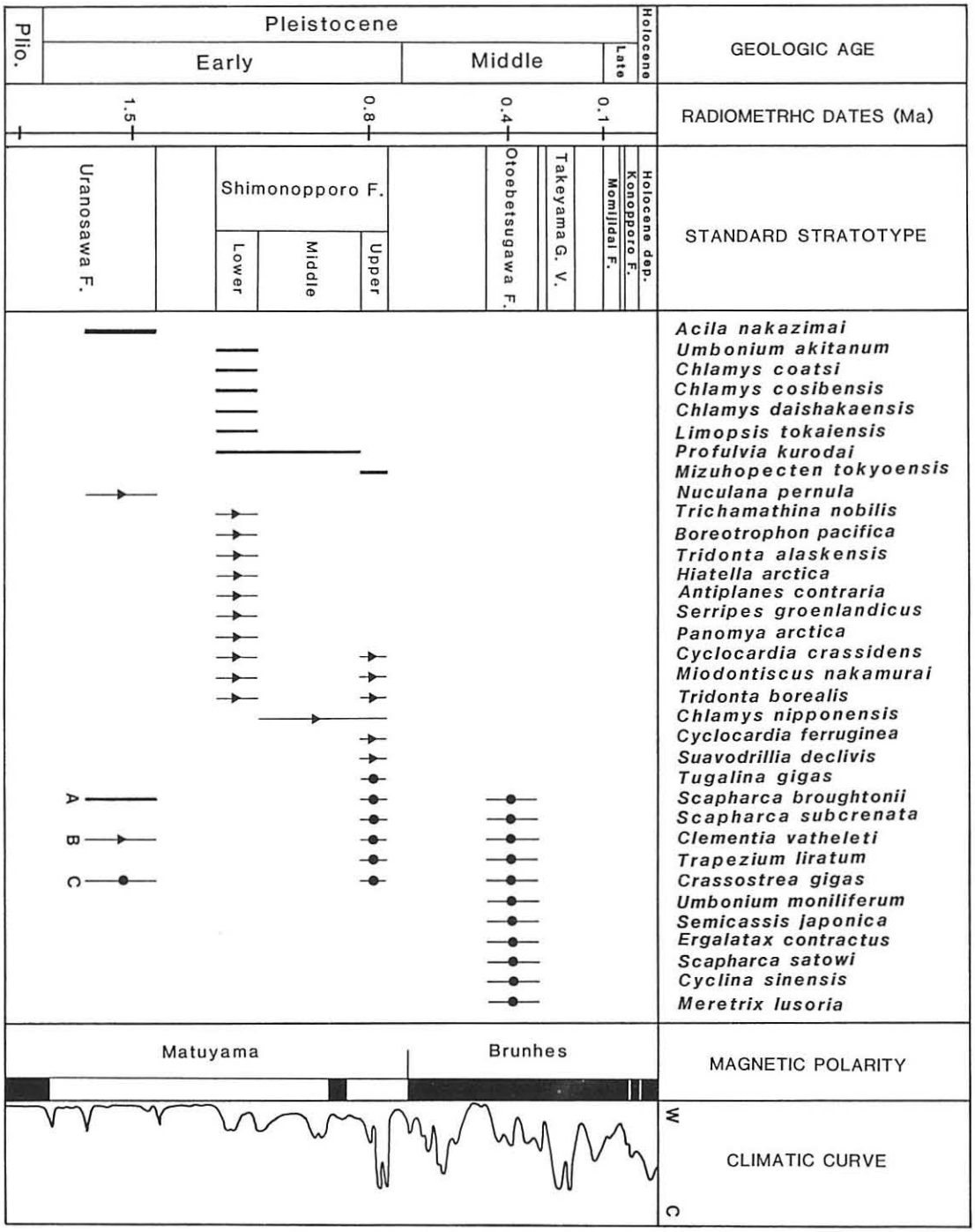
Text-fig. 4 Stratigraphic correlation of the Pleistocene deposits in the hills around the Ishikari Lowland.

As already reported by Akamatsu (1987), the above-mentioned Pleistocene deposits in the Nopproro Hills are tentatively correlated with equivalent strata in Ishikari and Umaoi Hills as shown in Text-fig. 4.

Meanwhile, the subsurface Pleistocene deposits of this Lowland uncomformably overlies the equivalent strata to the Shimonopporo Formation. This subsurface deposits may be coeval the latest Pleistocene deposits, and are divided into the Hachiken, Yamaguchi and Tarukawa Beds in ascending order. The Hachiken and Tarukawa Beds are considered to be cerrelated respectively to the Göttweiger and Päudorf Interstadials (Akamatsu and Matsushita, 1984).

Characteristics and history of molluscan faunas

From the above-mentioned stratigraphic sequence and correlation of the Pleistocene deposits in the Ishikari Lowland, the characteristics of the molluscan faunas throughout the Pleistocene time are as follows (Text-fig. 5):



Text-fig. 5 Geologic distributions of selected molluscan species of Pleistocene in the hills around the Ishikari Lowland. (Climatic curve is adopted from Kent et al. (1971)).
A. Extinct species, B. Extralimital cold water species, C. Extralimital warm water species.

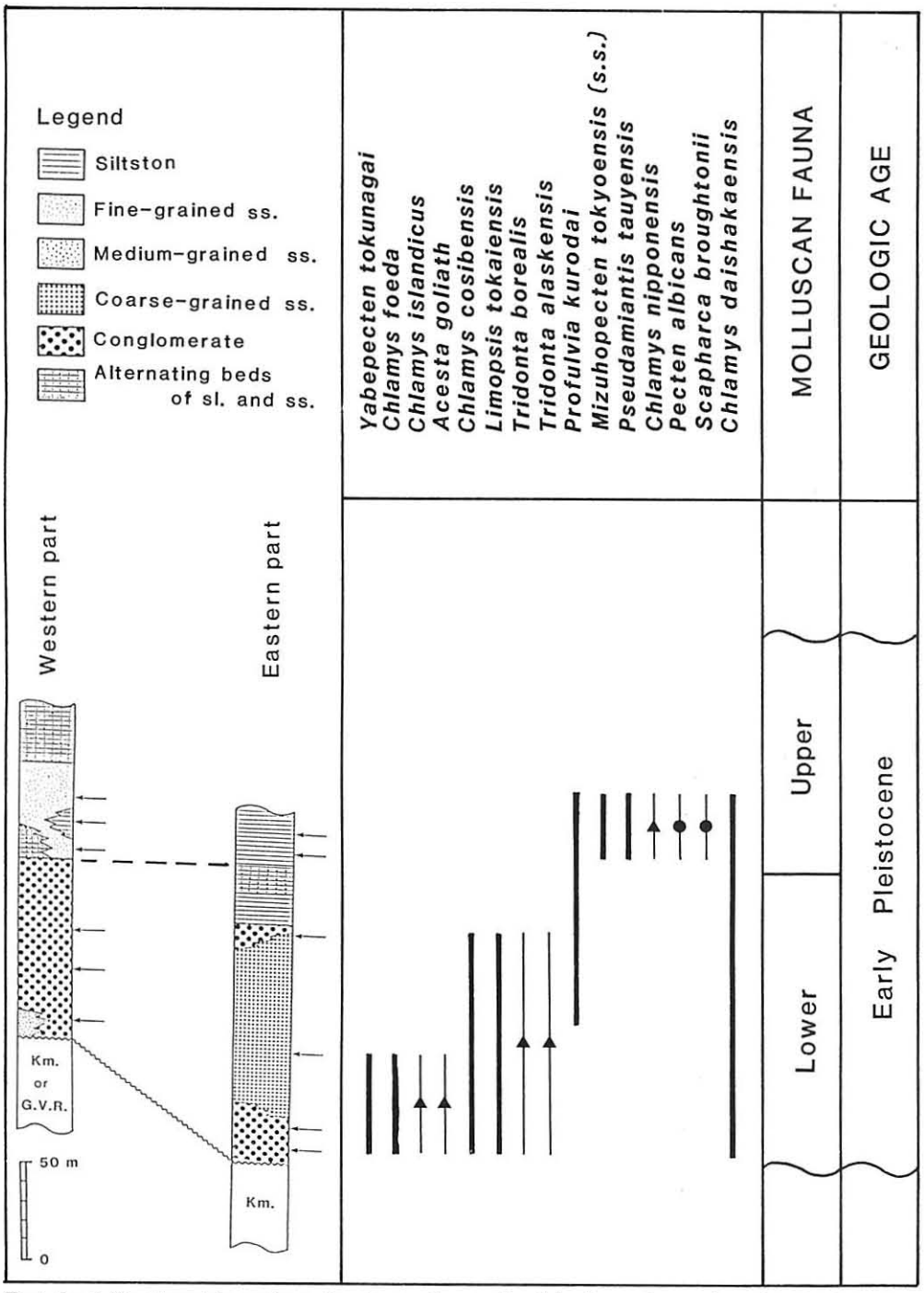
(1) Early Pleistocene time (ca. 1.8 to 0.8 Ma)

The molluscan fossils of this age are subdivided into three faunas; lower, middle and upper.

The lower fauna is commonly found in the Uranosawa Formation and the Lower Zaimokuzawa Formation. This fauna consists predominantly of the extralimital cold water species, such as *Nuculana pernula, Clinocardium* sp., *Cyclocardia* sp. and the extinct species *Acila nakazimai*. The geologic age of this fauna is considered to suggest the latest Pliocene to the earliest Pleistocene, ranging from about 1.8 to 1.5 Ma(Akamatsu, 1987, 1988b).

The middle fauna is obtained from the basal sandy gravel bed of the Shimonopporo Formation and is composed of 86 species. They are characterized by the extralimital cold water species which are associated with some extinct species, such as *Umbonium akitanum, Limopsis tokaiensis, Chlamys daishakaensis, Chlamys cosibensis* and *Profulvia kurodai*. The following are the representative extralimital cold water species in this fauna: *Trichamathina nobilis, Crepidula grandis, Cyclocardia crassidens, Tridonta borealis* and *Panomya arctica*. The above-mentioned species indicate the shallow water habitants in the open sea environment. From the large representation of extralimital cold water species of molluscs, the surface water temperature at that time has been estimated to be annual average temperature 7℃, about 2℃ lower than the present-day temperature of the modern Pacific Ocean coast in the southern Ishikari Lowland. Meanwhile, judging from ages demonstrated by the radiometric dates and diatom biostratigraphy, this fauna appears to be the Early Pleistocene, ranging from about 1.5 to 0.8 Ma (Akamatsu, 1987, 1988 b).

The upper fauna is found in the middle to upper part of the Shimonopporo Formation, the middle to upper part of the Zaimokuzawa Formation and the Umaoi Formation. The molluscan fauna from the upper part of the Shimonopporo Formation is composed of 22 living species, and it is remarkable that a large number of indivisuals of *Crassostrea gigas* make a particular shell-colony or "Oyster bank," which are associated with the following extralimital warm water species: *Scapharca broughtonii* and *Trapezium liratum*. The molluscan fauna of the middle Zaimokuzawa Formation is composed of 17 species including the extinct species *Profulvia kurodai*. The molluscan fauna of the upper Zaimokuzawa Formation which was previously called "Shishinai fauna" (Nagao, 1934; Oinomikado, 1937; Fujie, 1958) is composed of 80 living species(Akamatsu, 1984). They are characterized by an intermingled fauna of warm and cold water species. The representative extralimital cold water species in this fauna are *Acmaea pallida, Homalopoma amussitatum, Mitrella bicincta, Acila insignis, Glycymeris yessoensis, Crenomytilus grayanus, Mizuhopecten yessoensis, Swiftopecten swiftii, Cyclocardia isaotakii, Felaniella usta, Callista brevisiphonata, Saxidomus purpuratus, Spisula voyi* and *Myadora fluctuosa*. On the other hand, the extralimital warm water species are represented by *Tugalina gigas* and *Scapharca subcrenata*. The molluscan fauna of



Text-fig. 6 Stratigraphic sections showing molluscan fossil horizons (arrows) and geologic distributions of selected molluscan species of the Setana Formation in the Kuromatsunai Lowland, southwestern Hokkaido. Km: Kuromatsunai Formation, G. V. R.: Garogawa volcanic rocks. Other symbols are the same as in Text-fig. 5.

the Umaoi Formation is composed of 65 species which are characterized by the intermingled fauna of warm and cold water species which include the extinct species *Mizuhopecten tokyoensis* (*s. s.*). The following are the representative extralimital cold water species; *Homalopoma amussitatum, Mizuhopecten yessoensis, Chlamys nipponensis, Swiftopecten swiftii*, and *Clinocardium californiense*. The extralimital warm water species *Scapharca brougtonii* and *Clementia vatheleti* are noticeable. It must be firstly noticed that about 79% of this fauna are composed of species in common with the upper Zaimokuzawa fauna. The representative species are as follows: *Crepidula grandis, Mizuhopecten yessoensis, Swiftopecten swiftii, Crassostrea gigas, Clinocardium californiense* etc. Secondly, many species of this fauna are characterized by the taxa which are the tidal fine sand and/or sandy mud bottom habitants; they are widely inhabited in the embayment under the influence of open sea af the Pacific Ocean and Japan Sea coasts.

From the faunal and depositional analyses, the upper Zaimokuzawa Formation is seemed to have accumulated in or near bay-mouth or midbay, while the upper part of the Shimonopporo Formation and the Umaoi Formation in or near bay-head. The sea which left behind the Shimonopporo Formation invaded southernwards widely from the Japan Sea side, but was restricted in its southern expansion by a land mass. This sea had not connected with the Pacific coast as shown in Text-fig. 8. Moreover, the presence of the above-mentioned extralimital warm water species suggests the surface water annual average temperature about 12℃, about 3℃ higher than the present-day temperature of Japan Sea coast of the Ishikari Lowland. The geologic age of these faunas is considered to suggest about 0.8 Ma (Akamatsu, 1987, 1988b).

The marine molluscan fossils of the Early Pleistocene Setana Formation are found around the Kuromatsunai Lowland, southwestern Hokkaido, and consist of two faunas, lower and upper ones (Text-fig. 6; Suzuki, 1987, 1989). The lower fauna is characterized by the extralimital cold water species and includes some extinct species, such as *Yabepecten tokunagai, Chlamys cosibensis, Chlamys foeda, Limopsis tokaiensis*, etc. These extinct species are about 12.7% of the total number of species. The upper fauna is represented by an intermingled fauna of warm and cold water species and includes the following extinct species; *Mizuhopecten tokyoensis*(*s. s.*), *Profulvia kurodai, Pseudamiantis tauyensis*, etc. These extinct species are about 5.6% of the total number of species.

Compared with the Early Pleistocene molluscan faunas in the Ishikari and the Kuromatsunai Lowland, it is evident that the Setana molluscan fauna contains the considerable number of species which are in common with the species of that of Ishikari Lowland. They are about 80% of the total number of species. In addition, it is remarkable that the ratio of extinct species is almost the same with each others.

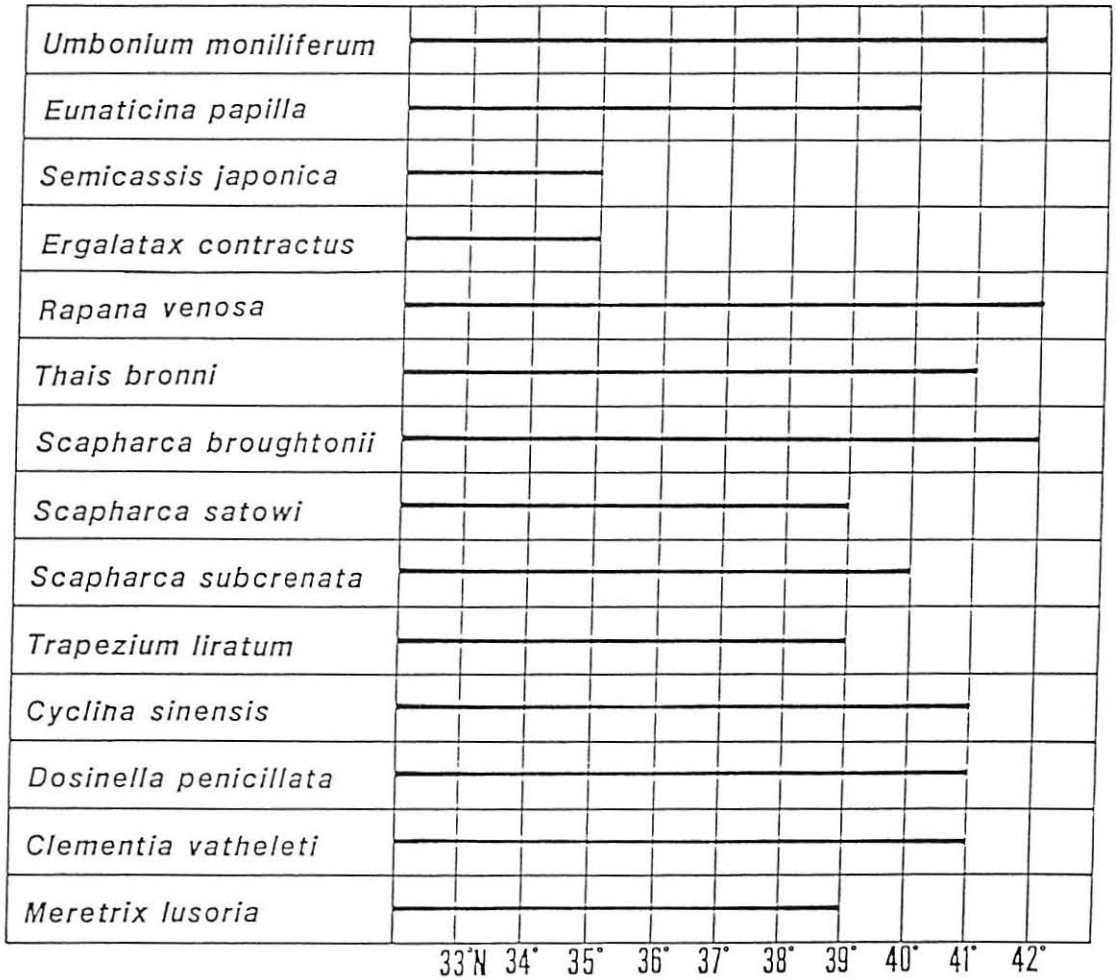
From the foregoing remarks concerning the constitution of those faunas, it may be suggested that the lower part of the Setana Formation is correlatable to

the lower part of the Shimonopporo Formation, and the upper one of the former is to the middle upper part of the latter.

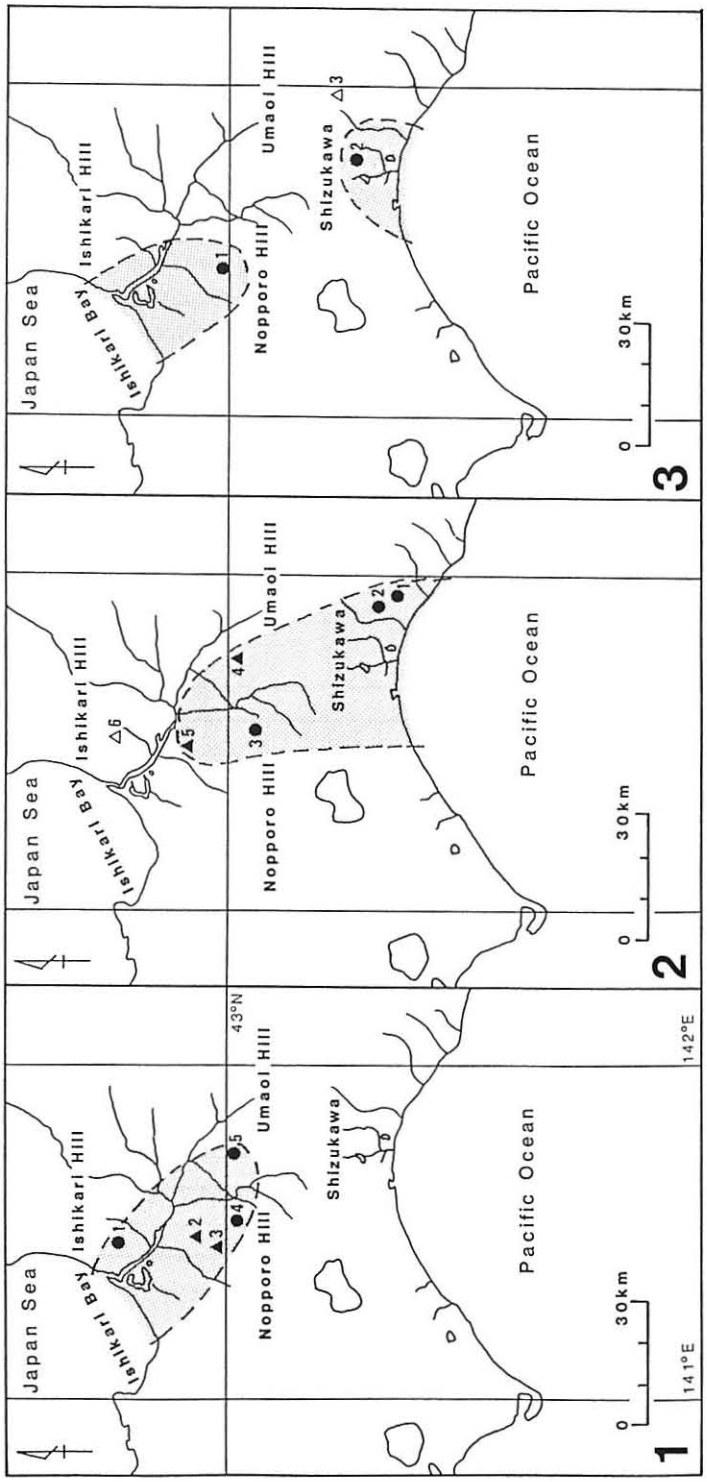
(2) Middle Pleistocene time (ca. 0.4 Ma)

The molluscan fossils of this time are yielded from the Otoebetsugawa Formation in the Nopporo Hills, the Hayakita Formation in the southern Umaoi Hills and the Yamanegawa Formation in the northern Umaoi Hills.

Those molluscan faunas are characterized by the living species including the extralimital warm water species of molluscs. The following are representative extralimital warm water species; *Umbonium moniliferum, Eunaticina papilla, Semicassis japonica, Ergaratax contractus, Scapharca brougtonii, Cyclina sinensis, Meretrix lusoria,* etc. These species exceed about 20% of the total number of



Text-fig. 7 Biogeographic distributions of some extralimital warm water species from the Ishikari Lowland and its surronding hills with respect to their modern northern end-points of range.



Text-fig. 8 Paleogeographical maps of Early Pleistocene (1., ca. 0.8 Ma), Middle Pleistocene (2., ca. 0.4 Ma) and Late Pleistocene (3., ca. 0.13 Ma) in the Ishikari Lowland.
Black circle: Localities of "Oyster bank" and the extrtalimital warm water species, Black triangle: Localities of "Oyster bank," White triangle: Lacalities of *Corbicula japonica*, Dotted line: Presumed coastline.

species and have modern distribution ranges that are entirely south of the fossil localities. These representative species and their modern northern end-points of range are listed in Text-fig. 7. *Semicassis japonica* and *Ergaratex contractus* are now living only south of the Choshi district (35° N). As metioned above, the large representation of extralimital warm water species is a significant feature of those faunas. The Dateyama Formation in the Ishikari Hills is represented by the terrestrial deposits bearing brackish-water speies *Corbicula japonica.* This formation may be equivalent to the above-mentioned marine strata from stratigraphic sequence and pollen analysis (Tonosaki and Uma-oi Collabolative Reserch Group, 1983). Akamatsu (1988a) has already reported from the data on modern distribution of shallow water molluscs along the Pacific Ocean coast of Japan that the surface water annual average temperature at that time was similar to that of the modern Pacific Ocean of 35° N in the vicinity of the Choshi district. In the context, the suggested annual average temperature 17℃ is about 8 ℃ higher than that of the present.

The middle Pleistocene sea which invaded the Ishikari Lowland was northernward from Pacific coast, but was restricted in expansion and graded to the land mass with a small terrestrial sedimentary basin (Text-fig. 8). This sea invasion left behind terrestrial deposits in a small area in the northern part of this Lowland, as seen in the Dateyama Formation. From the biogeographical viewpoint, it must be noticed that the sides of the Japan Sea and Pacific Ocean have not connected in that time, and the sea invasion from the Pacific Ocean formed a deep inner bay. Moreover, it may be generalized that the Ishikari Lowland at that time was under the warm water current which tended to be predominate over any others nearby in Early Pleistocene.

In the Eastern Hokkaido, the sea invasion of that time is represented by the Otanoshike Formation in the Kushiro district and by the Konsen Formation in the Bekkai district. These formations contain rich molluscan fossils, but were extremely limited in distribution. Zoogeographic criteria suggest the higher surface water annual average temperature during the Middle Pleistocene interval represented by these deposits. There is a moderately large element of extralimital warm water species that today range no further north than the latitude of the Sendai Bay (39° N). The suggested annnual average temperature about 13℃, are about 6℃ higher than the present-day temperature in same district. From the foregoing lines, it may be said, though somewhat venturesome, that such warm water transgression was related closely to a global oceanic event which was known in the whole of the Northern Hemisphere at that time.

(3) Late Pleistocene time (ca. 0.13 to 0.026 Ma)

(a) Last interglacial (ca. 0.13 Ma)

The molluscan fossils of this age are found in the Momijidai Formation in the Nopporo Hills, the Atsuma Formation in the Umaoi Hills and others. The Momijidai Formation contains marine molluscs such as *Crassostrea gigas, Chlamys*

nipponensis, Dosinia japonica and *Spisula sachalinensis*. They are flourishing in the modern Ishikari Bay. The Atsuma Formation has not yet yield marine molluscs but brackish-water species *Corbicula japonica*. In addition, the deposits which are coeval with the Atsuma Formation were recognized under the Shizukawa Hills around or in the southern Ishikari Lowland according to the boring data (Kondo et al., 1984). These subsurface deposits have not been known to be exposed on this area. They contain some marine molluscs, such as *Macoma* sp. and *Mercenaria* sp., or " Oyster bank " construted by the shells of *Crassostrea gigas*. Judging from the information concerning the distribution and depositional conditions of these deposits, it may be said that the Ishikari Lowland was invaded from both sides of the Japan Sea and the Pacific Ocean and left behind deposits in small areas(Text -fig. 8). In other words, some narrow encroachments of the sea might have taken place on the presnt Lowland from the sides of the Japan Sea and the Pacific Ocean, but were completely separated by a land mass.

(b) Last glacial (ca. 34 to 26 Ka)

Three molluscan faunas have been found in the subsurface deposits in the northern Ishikari Lowland.

The molluscan fauna of the Hachiken Bed is characterized by the extralimital warm water species such as *Scapharca subcrenata, Crassoetrea gigas* and *Ruditapes philippinarum*.. This deposit is dated 34, 420±1,170 years B. P. and may be correlatable to the Göttweiger Interstadial (Akamatsu and Matsushita, 1984).

The fauna of the Yamaguchi Bed is represented by a large number of individuals of *Glycymeris yessoensis, Mizuhopecten yessoensis* and *Callista brevisiphonata*. These species are flourishing in the modern Pacific Ocean along the southern end of the Ishikari Lowland. This deposit is dated 32,000 to 29,000 years B. P. (Akamatsu

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Explanation of Plate 1

Fig. 1 *Buccinum ochotense* (Middendorff), Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll. cat. no. 71339)

Fig. 2 *Profulvia kurodai* (Hatai and Nishiyama), Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll. cat 71668)

Fig. 3 *Limopsis tokaiensis* (Yokoyama), Shimonopporo Formation, Otoebetsugawa, Hisroshima Town (×2). (H. M. H. coll. cat. 71413)

Fig. 4 *Cyclocardia crebricostata* (Krause), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town (×2). (H. M. H. coll. cat. 95459)

Fig. 5 *Cyclocardia isaotakii* (Tiba), Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll. cat. no. 71634)

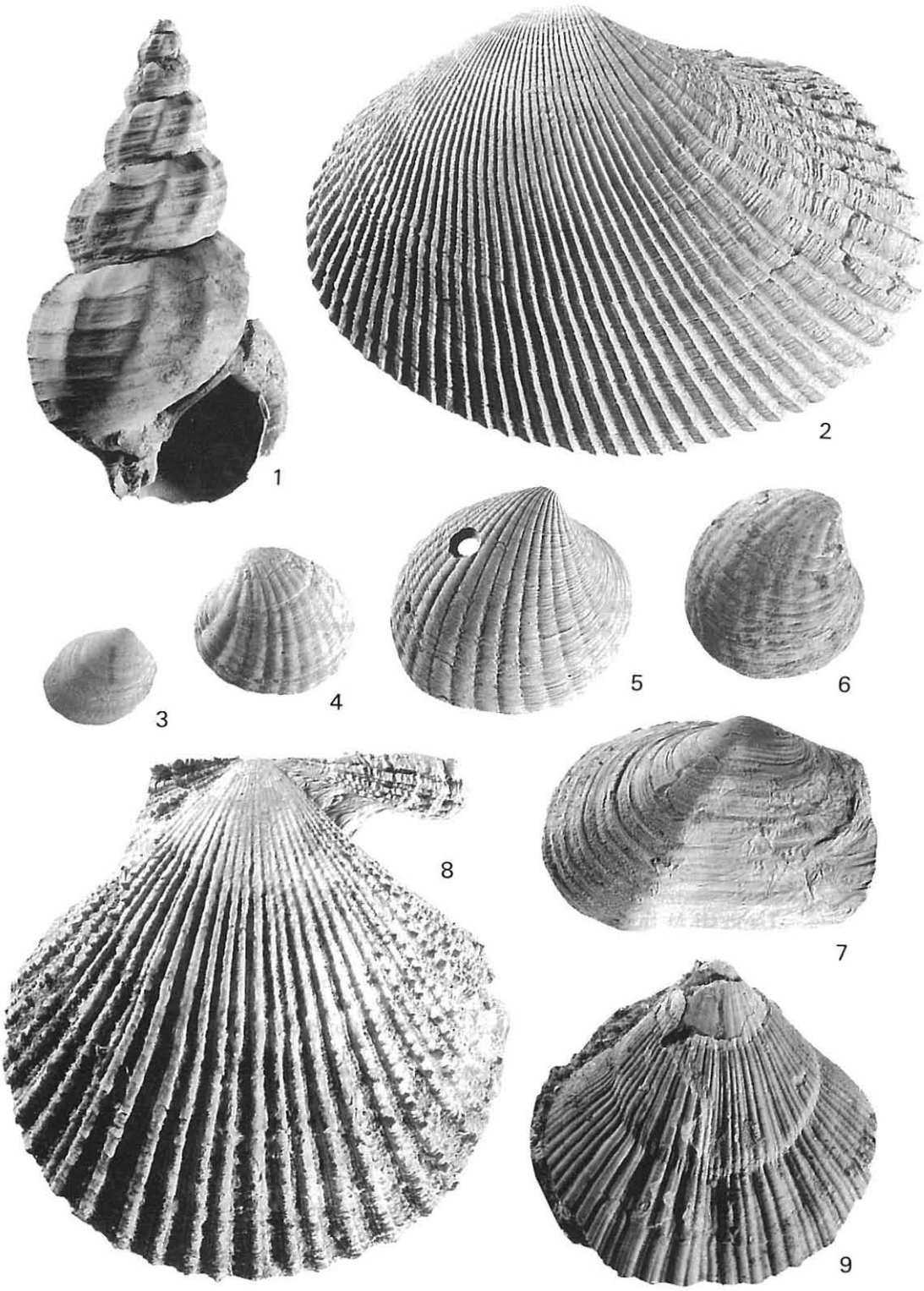
Fig. 6 *Cyclocardia crassidens* (Broderip and Sowerby), Shimonopporo Formation, Kitanosato, Hiroshima Town (×2). (H. M. H. coll. cat. no. 71604」

Fig. 7 *Mya truncata* Linné, Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71609)

Fig. 8 *Chlamys daishakaensis* Masuda and Sawada, Shimonopporo Formation, Kitanosato, Hiroshima Town (H. M. H. coll, cat. no. 71496)

Fig. 9 *Chlamys cosibensis* Yokoyama, Shimonopporo Formation, Nopporo, Ebetsu City. (H. M. H. coll. cat. no. 71531)

(H. M. H.: Historical Museum of Hokkaido)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and Matsushita, 1984).

The Tarukawa Bed is characterized by the high embayment species, *Raetellops pulchella* and *Glycymeris yessoensis*. This deposit is dated 26,320±1,170 years B. P. and may be correlatable to the Päudorf Interstadial.

The late glacial marine invasion was restricted extremely in expansion and only left behind deposits in a small area in the southern and the northern Ishikari Lowland. The faunas of the late Pleistocene age, as a whole, are characterized by predominant recent species which are now living in shallow water bordering the Ishikari Lowland. The data on modern distribution of shallow water molluscs in this fauna suggest that the surface water annual average temperatures are closely similar to that of the present.

Summary

1) The known Pleistocene molluscan faunas of Hokkaido are from the Ishikari Lowland, Kuromatsunai Lowland, Kushiro Plain and Konsen Plain. Additional occurrences are known from the subsurface deposits under the Ishikari Lowland.

Explanation of Plate 2

(All figures in natural size, unless otherwise stated)

Fig. 1 *Plicifusus plicatus* (A. Adams), Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71392)

Fig. 2 *Pyrulofusus dexius* Dall, Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll. cat. no. 71402)

Fig. 3 *Volutharpa perri* (Jay), Shimonopporo Formation, Kitanosato, Hiroshima Town (×2). (H. M. H. coll. cat. no. 71391)

Fig. 4 *Neptunea vinosa* (Dall), Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71407)

Fig. 5 *Tricamathina nobilis* (A. Adams), Shimonopporo Formation, Kitanosato, Hiroshima Town (×2). (H. M. H. coll. cat. no. 71320)

Fig. 6 *Hiatella arctica* (Lamarck), Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71685)

Fig. 7 *Antiplanes contraria* (Yokoyama), Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71409)

Fig. 8 *Trichotropis bicarinata* (Sowerby), Shimonopporo Formation, kitanosato, Hiroshima Town. (H. M. H. coll. cat. no. 71333)

Fig. 9 *Boreotrophon candelabrum* (Reeve), Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll. cat. no. 71387)

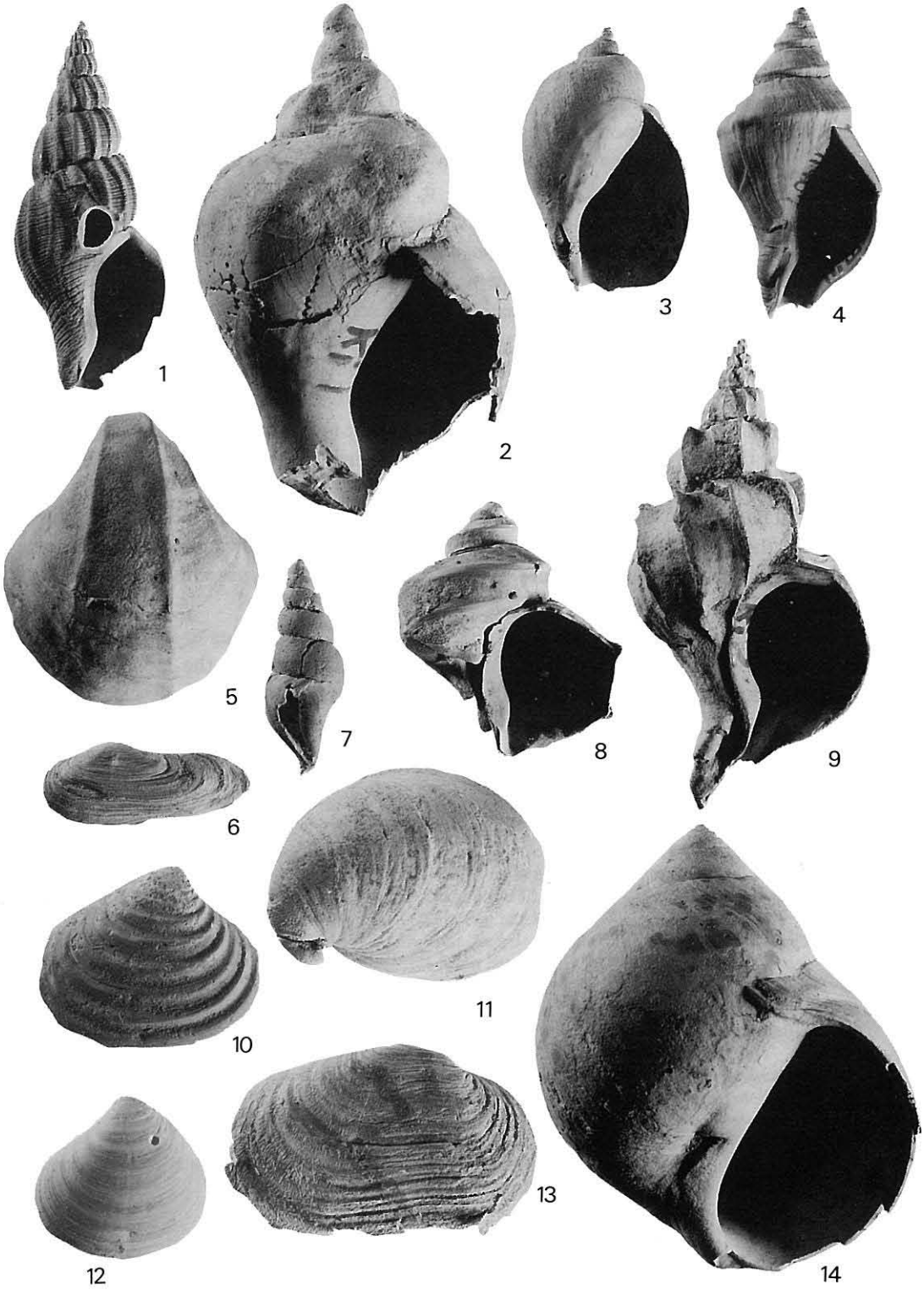
Fig. 10 *Tridonta alaskensis* Dall, Shimonopporo Formation, Otoebetsugawa, Hiroshima Town (×2). (H. M. H. coll. cat. no. 79697)

Fig. 11 *Crepidula grandis* Middendorff, Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. cool. cat. no. 71339)

Fig. 12 *Astarte hakodatensis* Yokoyama, Shimonopporo Formation, Kitanosato, Hiroshima Town (×2). (H. M. H. coll. cat. no. 71903)

Fig. 13 *Panomya arctica* (Lamarck), Shimonopporo Formation, Otoebetsugawa, Hiroshima Town. (H. M. H. coll. cat. no. 71695)

Fig. 14 *Lunatia pila* (Pilsbry), Shimonopporo Formation, Kitanosato, Hiroshima Town. (H. M. H. coll.cat. no. 71380)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2) The early Early Pleistocene fauna is mainly characterized by a persistent element of extralimital cold water species that now live far to the north from Hokkaido. This element amounting to as much as about 25% in early Early Pleistocene fauna is now entirely restricted to the Okhotsk Sea and southern Alaska. The zoogeographical aspects of faunal data suggest the surface water annual average temperature 7℃, about 2℃ lower than the present-day temperature. Approaching the close of late Early Pleistocene, it is remarkable that small number of extralimital warm water species are recognized in the molluscan fauna. The presence of extralimital warm water species suggests the surface water annual average temperature 12℃, about 3℃ higher than the present-day temperature.

3) The Middle Pleistocene fauna is characterized by the considerable number of extralimital warm water species of molluscs. They exceed about 20% of total number of species, and suggest the surface water annual average temperature 17℃, about 8℃ higher than the peresent-day temperature. Such high warm water marine climate may be said to a second climatic optimum event for molluscs throughout the late Cenozoic since the Middle Miocene *Vicarya* fauna (Uozumi and Fujie, 1966).

4) The Late Pleistocene fauna is characterized by recent species that is now living in the Japan Sea coasts in the vicinity of Ishikari Lowland. The surface water annual average temperature is closely similar to the present-day temperature.

5) Throughout Early Pleistocene, the ratio of extinct species to the total number of species decreases from about 12.7% to about 5.6% during the lapse of time. Moreover, extinct species is absent in the faunas since Middle Pleistocene time. This fact may be suggested that significant changes of environmental and evolutional conditions occurred in the duration between Early Pleistocene and Middle Pleistocene.

Explanation of Plate 3

(All figures in natural size, unless otherwise stated)

Figs. 1. a, b *Mizuhopecten tokyoensis* (Tokunaga), Umaoi Formation, Naganuma, Naganuma Town (×0.5). (H. M. H. coll. cat. no. 123237)

Fig. 2 *Crenomytilus grayanus* (Dunker), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95411)

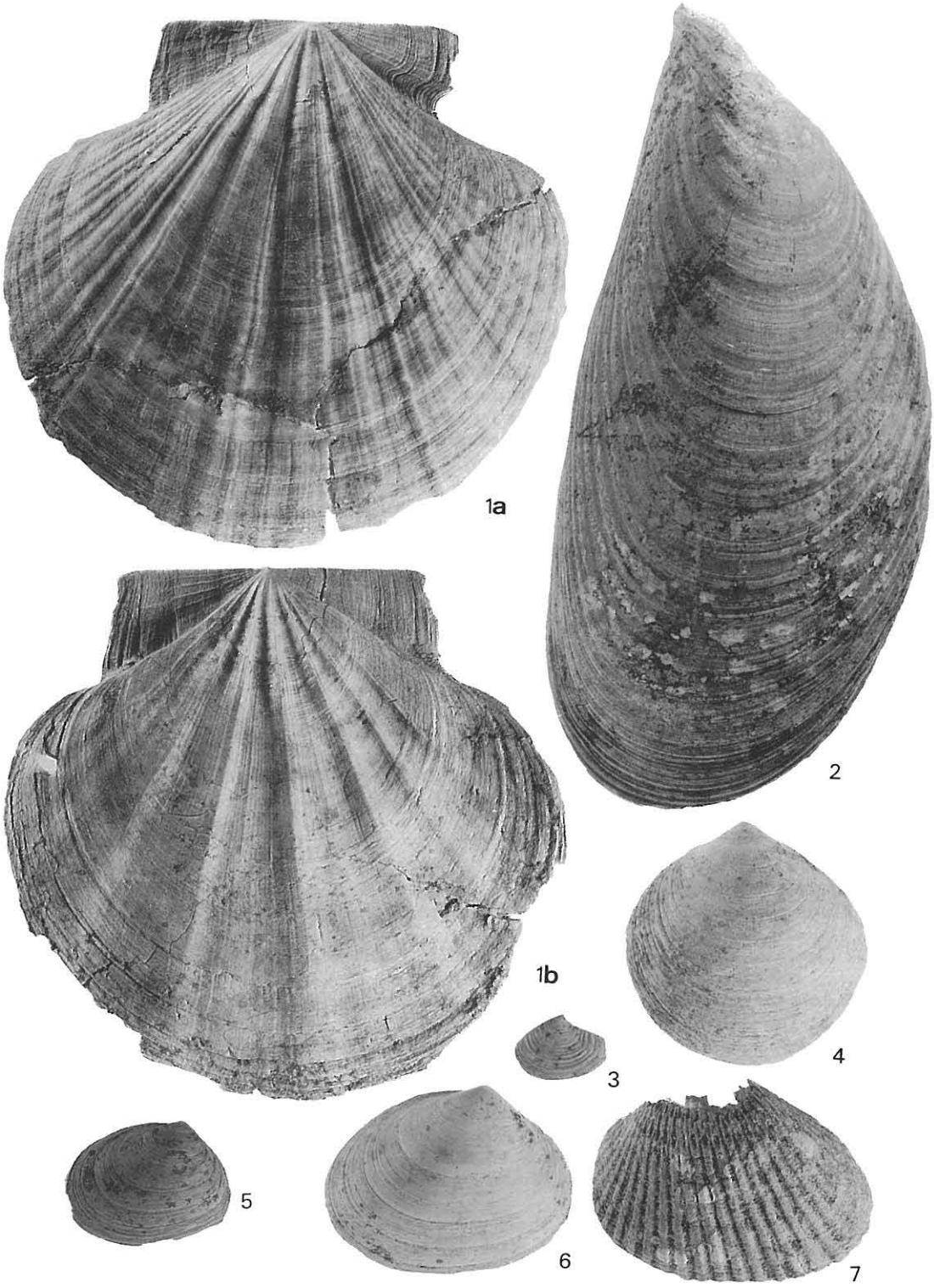
Fig. 3 *Myadora fluctuosa* Gould, Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95558)

Fig. 4 *Glycymeris yessoensis* (Sowerby), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95406)

Fig. 5 *Macoma nipponica* (Tokunaga), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll., cat. no. 95332)

Fig. 6 *Macoma calcarea* (Gmelin), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95526)

Fig. 7 *Scapharca subcrenata* (Lischke), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95398)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Ackowledgements

We express our deep gratitude to Prof. Satoru Uozumi of Hokkaido University for his continuous guidance during the present study and for critical reading of the manuscript. Gratitude is also due to Dr. Keiji Iwata of Hokkaido University and Dr. Yoshihiro Togo of Hokkaido University of Education, Iwamizawa College, for their suggestions and encouragements on this study. We are indebted to Mr. Susumu Tameoka of Historical Museum of Hokkaido for his photographic work.

References

Akamatsu, M., 1984. On the so-called Shishinai fauna from the Ishikari Hills, Hokkaido. *Ann. Rep. Hist. Museum of Hokkaido*, 12: 1-33. (in Japanese).

Akamatsu, M., 1987, Stratigraphic position and faunal characteristics of middle Pleistocene warm-water extralimital molluscan fossils from the hills around the Ishikari Lowland, Hokkaido. *Jour. Geol. Soc. Japan*, 93: 809-821. (in Japanese with English abstract).

Akamatsu, M., 1988a. Middle Pleistocene marine transgression and its significance in Hokkaido. *Jour. Geol. Soc. Japan*, 94: 173-186. (in Japanese with English abstract).

Akamatsu, M., 1988b. History and significance of the late Cenozoic molluscan faunas in Hokkaido. *Doctoral thesis, Hokkaido University*, 198 pp. (in Japanese with English abstract). (manuscript).

Akamatsu, M. and Matsushita, K., 1984. Molluscan faunal assemblage and geological sequence of the Pleistocene deposits under the west Ishikari Alluvial plain, Hokkaido. *Quat. Res.*, 23: 183-195. (in Japanese with English abstract).

Chitoku, T., 1983. Calcareous nannofossil assemblage from the Setana Formation, Southwestern Hokkaido, Japan (Part 1). *Earth Sci.*, 37: 90-97. (in Japanese with English abstract).

Fujie, T., 1958. Fossil molluscs from the Pleistocene Shishinai Formation. 1. Fossil Pelecypoda. *Cenoz. Res.*, 28: 663-679. (in Japanese).

Kent, D., Opdyke, N. D. and Ewing, M., 1971. Climate change in the North Pacific using ice-rafted detritus as a climatic indicator. *Geol. Soc. Amer. Bull.*, 82: 2741-2754.

Kondo, T., Igarashi, Y., Yoshida, M. and Akamatsu, M., 1984. Quaternary deposits in the borehole at Shizukawa, Tomakomai City, Hokkaido, Japan. *Quat. Res.*, 22: 313-325. (in Japanese with English abstract).

Koshimizu, S., Yamazaki, J. and Kato, M., 1986. Fission-track dating of the Cainozoic formations in the Oshima Peninsula, southwestern Hokkaido, Japan. *Jour. Geol. Soc. Japan*, 92:

Explanation of Plate 4

(All figures in natural size)

Fig. 1 *Swiftopecten swiftii* (Bernardi), Umaoi Formation, Naganuma, Naganuma Town. (H. M. H. coll. cat. no. 123238)

Fig. 2 *Clementia vatheleti* Mabile, Umaoi Formation, Naganuma, Naganuma Town. (H. M. H. coll. cat. no. 123239)

Fig. 3 *Acila insignis* (Gould), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95385)

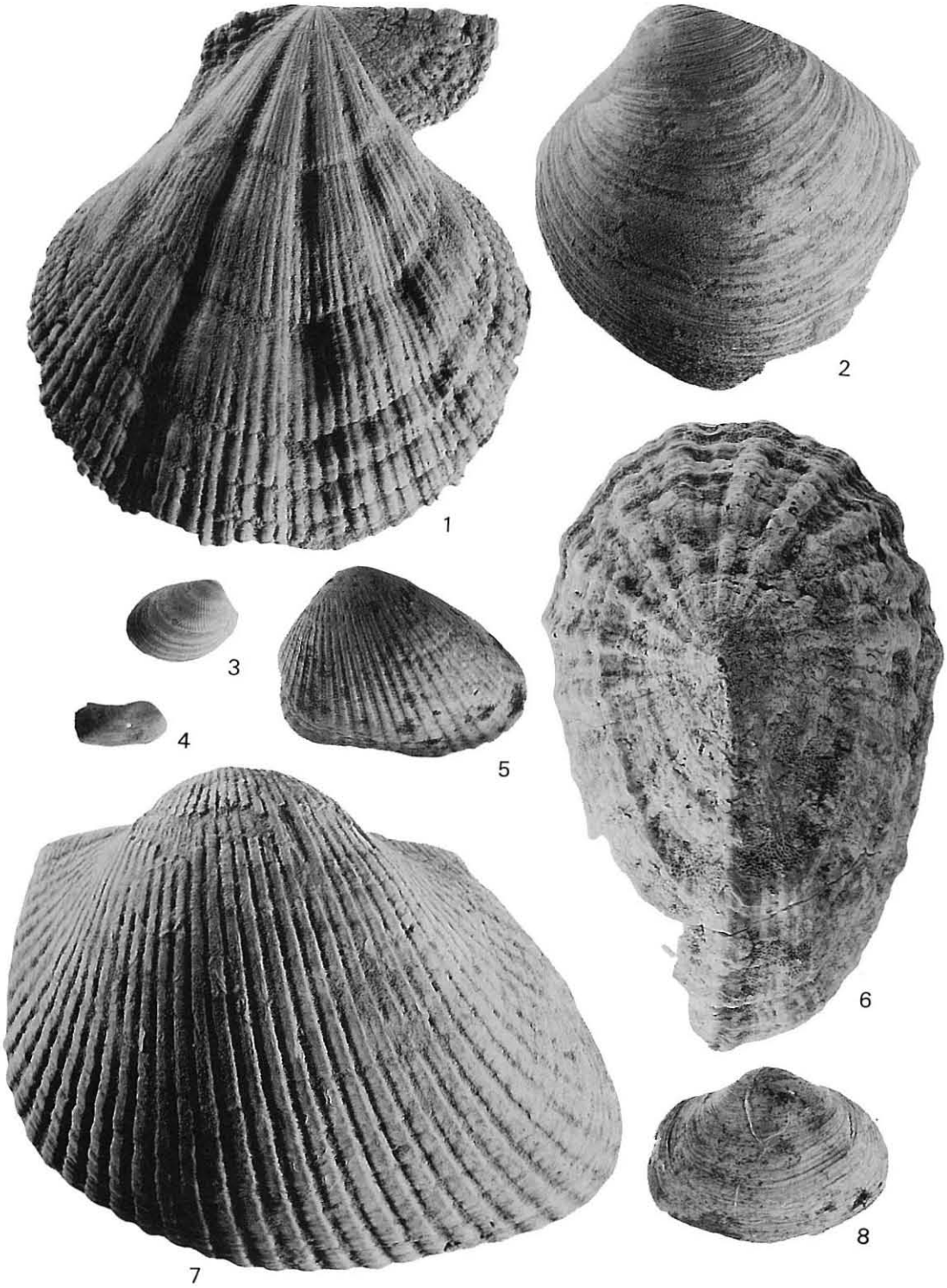
Fig. 4 *Hiatella flaccida* Gould, Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95550)

Fig. 5 *Scapharca subcrenata* (Lischke), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95397)

Fig. 6 *Tugalina gigas* (v. Martens), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95303)

Fig. 7 *Scapharca brougtonni* (Schrenck), Umaoi Formation, Naganuma, Naganuma Town. (H. M. H. coll. cat. no. 123240)

Fig. 8 *Thracia kakumana* (Yokoyama), Upper part of the Zaimokuzawa Formation, Ganpizawa, Tobetsu Town. (H. M. H. coll. cat. no. 95542)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771-780. (in Japanese with English abstract).

Koshimizu, S., Akamatsu, M. and Kitagawa, Y., 1988. Fission-track dating of the Pliocene -Pleistocene Uranosawa Formation in the Nopporo Hills, Hokkaido, Japan. *Jour. Geol. Soc. Japan*, 94: 461-463. (in Japanese).

Machida, H., Arai, F., Miyauchi, T. and Okumura, K., 1987. Toya ash -A widespread Late-Quaternary Time-Marker in Northern Japan-. *Quat. Res.*, 26: 129-145. (in Japanese with English abstract).

Maiya, S., Ichinoseki, T. and Akiba, F., 1981. Oshima Peninsula. In: R. Tsuchi, (Editor), *Neogene of Japan-Its biostratigraphy and chronology-*, Shizuoka, pp. 76-80.

Nagao, T., 1934. Marine fossil bearing strata of the post Setana stage in Hokkaido. *Jour. Geol. Soc. Japan*, 41: 205-207. (in Japanese).

Nagao, T. and Sasa, Y., 1933. The Cenozoic System of southwestern Hokkaido and its geological history. *Jour. Geol. Soc. Japan*, 40: 555-577. (in Japanese).

Oinomikado, 1937. Molluscan fossils from the Pleistocene deposits of Sisinai in Tobetsu-mura Ishikari-gun, Hokkaido. *Jour. Geo. Soc. Japan*, 44: 65-70.

Suzuki, A., 1987. Stratigraphy and molluscan fauna of the Setana Formation, Kuromatsunai district, southwestern Hokkaido, Japan. *Abstracts of Annual Meeting of Geol. Soc. Japan*, 215. (in Japanese).

Suzuki, A., 1989. Molluscan fauna from the Setana Formation in the Kuromatsunai district, southwestern Hokkaido, Japan. *Earth Sci*, 43: 277-289. (in Japanese with English abstract).

Tanai, T. (ed.), 1982. *Biostratigraphy of the Neogene deposits in Hokkaido*. Hokkaido University, 134 pp. (in Japanese).

Tonosaki, T. and Uma-oi Collaborative Research Group, 1983. Shimosueyoshi age in the Ishikari Lowland area. In: T. Shibazaki (Editor), *Study on correlation and geological age of marine middle terrace called Shimosueyoshi terrace in Japan*, Tokai University, pp. 13-18. (in Japanese).

Tsuchi, R.(ed.), 1981. *Neogene of Japan-Its biostratigraphy and chronology-*. IGCP-114, National Working Group of Japan, Shizuoka, 140 pp.

Uozumi, S., 1962. Neogene molluscan faunas in Hokkaido (part 1 Sequence and distribution of Neogene molluscan faunas). *Jour. Fac. Sci. Hokkaido Univ.*, [*IV*], 6: 507-544.

Uozumi, S. and Fujie, T., 1966. Neogene molluscan fauna in Hokkaido. Part II. Description of the Okushiri fauna associated with *Vicarya*, from Okushiri Island, Southwest Hokkaido. *Jour. Fac. Sci. Hokkaido Univ.*, [*IV*], 13: 139-163.

Explanation of Plate 5

(All figures in natural size)

Fig. 1 *Ergalatax contractus* (Reeve), (H. M. H. coll. cat. no. 71768)

Fig. 2 *Semicassis japonica* (Reeve), (H. M. H. coll. cat. no. 71767)

Figs. 3, 6 *Scapharca broughtonii* (Schrenck), (H. M. H. coll. cat. no. 71789, 71790)

Fig. 4 *Umbonium moniliferum* (Lamarck), (H. M. H. coll. cat. no. 32278)

Fig. 5 *Eunaticina papilla* (Gmelin), (H. M. H. coll. cat. no. 71765)

Fig. 7 *Scapharca subcrenata* (Lischke), (H. M. H. coll. cat. no. 71804)

Fig. 8 *Lingula unguis* (Linné), (H. M. H. coll. cat. no. 71896)

Figs. 9, 11 *Meretrix lusoria* (Röding), (H. M. H. coll. cat. no. 71886-1, 71886-2)

Fig. 10 *Trapezium liratum* (Reeve), (H. M. H. coll. cat. no. 71865)

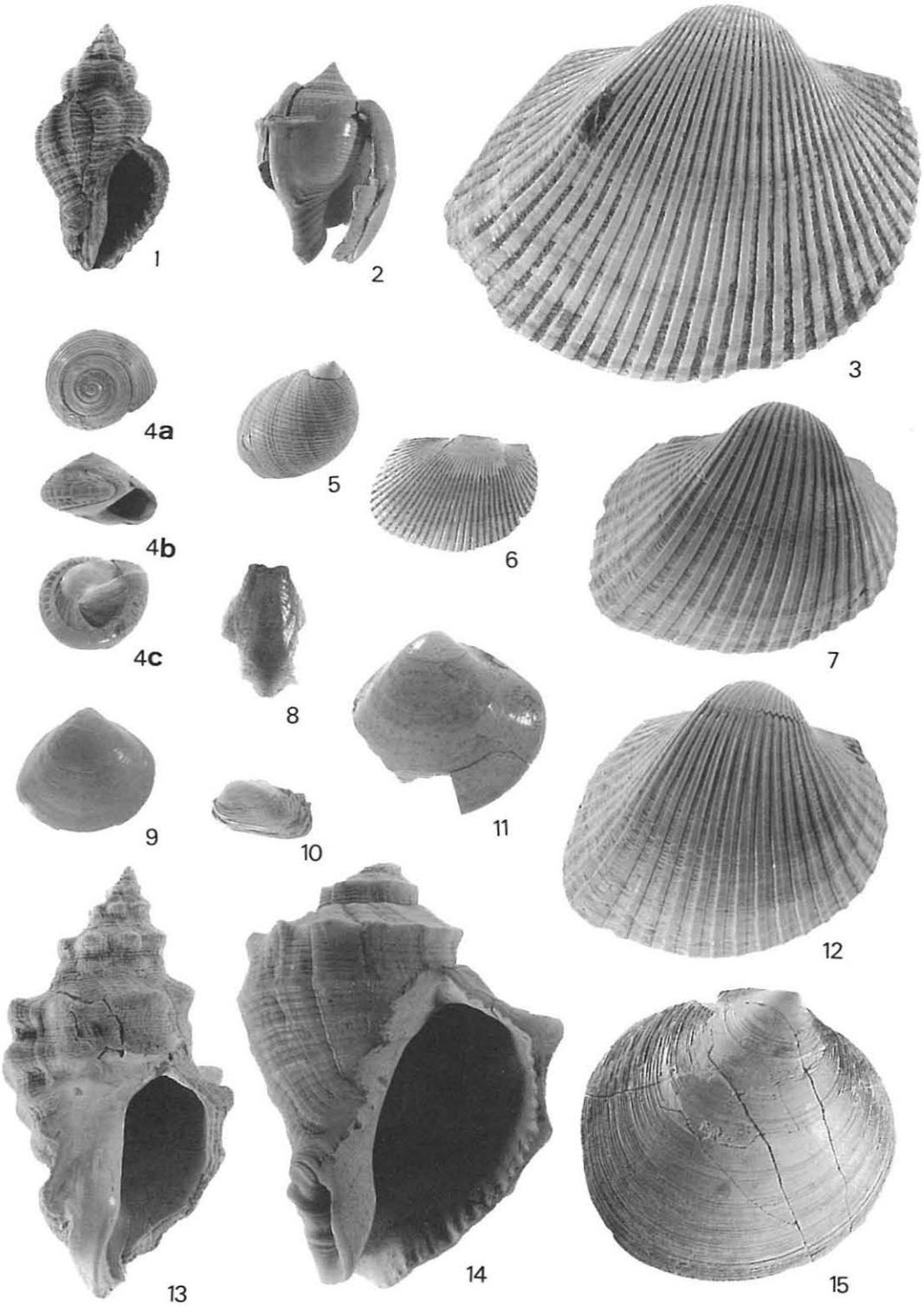
Fig. 12 *Scapharca inaequivalvis* (Bruguiére), (H. M. H. coll. cat. no. 71823)

Fig. 13 *Thais bronni* (Dunker), (H. M. H. coll. cat. no. 71777)

Fig. 14 *Rapana venosa* (Valencinnes), (H. M. H. coll. cat. no. 71774)

Fig. 15 *Dosinella penicillata* (Reeve), (H. M. H. coll. cat. no. 71884)

All specimens from the Otoebetsugawa Formation, Otoebetsugawa, Hiroshima Town.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Uozumi, S., Akamatsu, M. and Takagi, T., 1986a. Takikawa-Honbetsu and Tatsunokuchi faunas (*Fortipecten takahashii*-bearing Pliocene faunas). *Palaeont. Soc. Japan, Special Papers*, 26 : 211-226.

Uozumi, S., Takagi, T. and Suzuki, A., 1986b. *Yabepecten tokunagai* and *Mizuhopecten tokyoensis* of Hokkaido -Characteristics of boreal molluscs and paleobiogeographic position of Hokkaido-. *Monogr. Mizunami Fossil Mus.*, 6 : 75-89. (in Japanese with English abstract).

Yoshida, M., 1983. Plio-Pleistocene in the Tokachi province and the Ishikari Lowland, Hokkaido, Japan. *Monogr. Geol. Collab. Japan*, 25 : 105-113. (in Japanese with English abstract).

(Manuscript received on June 20, 1989 ; and accepted on Oct. 27, 1989).