Evidence of Subtropical Environments in the Miocene of Japan

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日本の中新世における亜熱帯性環境の証拠

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(要　旨)

日本の中新世には，Potamid-Arcid 群集（津田，1965），Potamid 群集が広い分布をもち，汽水性の暖海の環境を指示するものといわれる．これらのうちには，*Geloina*（ヒルギシジミ）を含む群集があり，以前から知られていたが，最近各地の古瀬戸内中新統から報告があり，亜熱帯性環境を示すものとして注目されている．*Geloina* の産出と関連して，中新世前期の終り（15.5～16－ m. y. 前）の，古瀬戸内海を中心とした西南日本の古環境・古地理について綜合した．

日本の中新世における，*Geloina* 化石の最初の発見は大山（1950）で，富山県八尾層群の黒瀬谷累層からであった．大山はその群集を *Geloina-Telescopium* 群集とよび，マングローブ沼の群集として位置づけた．その後，岩船層（新潟県村上），上郷層群大山層（山形県西田川炭田），鳥取層群（鳥取県春米）などから報告され，古瀬戸内中新統では広島県庄原市の備北層群下部層よりの発見につづき，現在では9カ所から知られ，さらに増加する可能性がある．

その時代の，暖い環境を示す化石の資料として，造礁サンゴ，軟体動物，石灰藻，*Aturia*，浮遊性軟体動物，海亀，くそこがね虫，赤色層，植物などがある．これは，多くの資料を使って組立てられた対比表（第1表）において 15.5～16－ m. y. B. P. 前後の層準に集中する．

以上を綜合し，現生生物の分布，生息環境と対比して考えると，15.5～16－ m. y. 前頃，日本列島とくにその西南部は少くとも亜熱帯的な海洋条件下にあったことが推定される．

サンゴ礁の発達が見られないこと，太平洋側に証拠が少ないことなど，問題は今後に残されている．当時の古地理図に，古環境，古海流の一部をくわえて第6図に示した．

(**Abstract**)

Geloina-bearing molluscan assemblages which indicate warm, shallow and brackish bay environments are found in late Early Miocene formations in Southwest Japan. There is other evidence of subtropical environments in that horizon (15.5 to 16－ m. y. B. P.). They are occurrences of some kind of benthonic and planktonic mollusks, *Aturia*, reef corals, a chelonia, some plants, an insect and others. Synthesized the data, paleoenvironment, paleogeography and paleobiogeography are discussed.

Introduction

The Potamid-Arcid fauna designated by TSUDA (1965) is the well-known

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Miocene molluscan fauna in Japan, especially in the Japan Sea coast region. It mainly consists of *Anadara, Crassostrea, Vicarya, Vicaryella, Tateiwaia* and so on. It has wide distribution from the Tané-ga-shima (Lat. 30° 30′ N) to the Okushiri-shima (Lat. 42° N) indicating warm, shallow and brackish environments.

In the Pacific Ocean coast region and the Setouchi region, the Potamid fauna seems to be equivalent to the Potamid-Arcid fauna though the species of *Anadara* and *Crassostrea* etc. are wanting in it.

OYAMA (1950) described the *Telescopium-Geloina* assemblage in the Potamid-

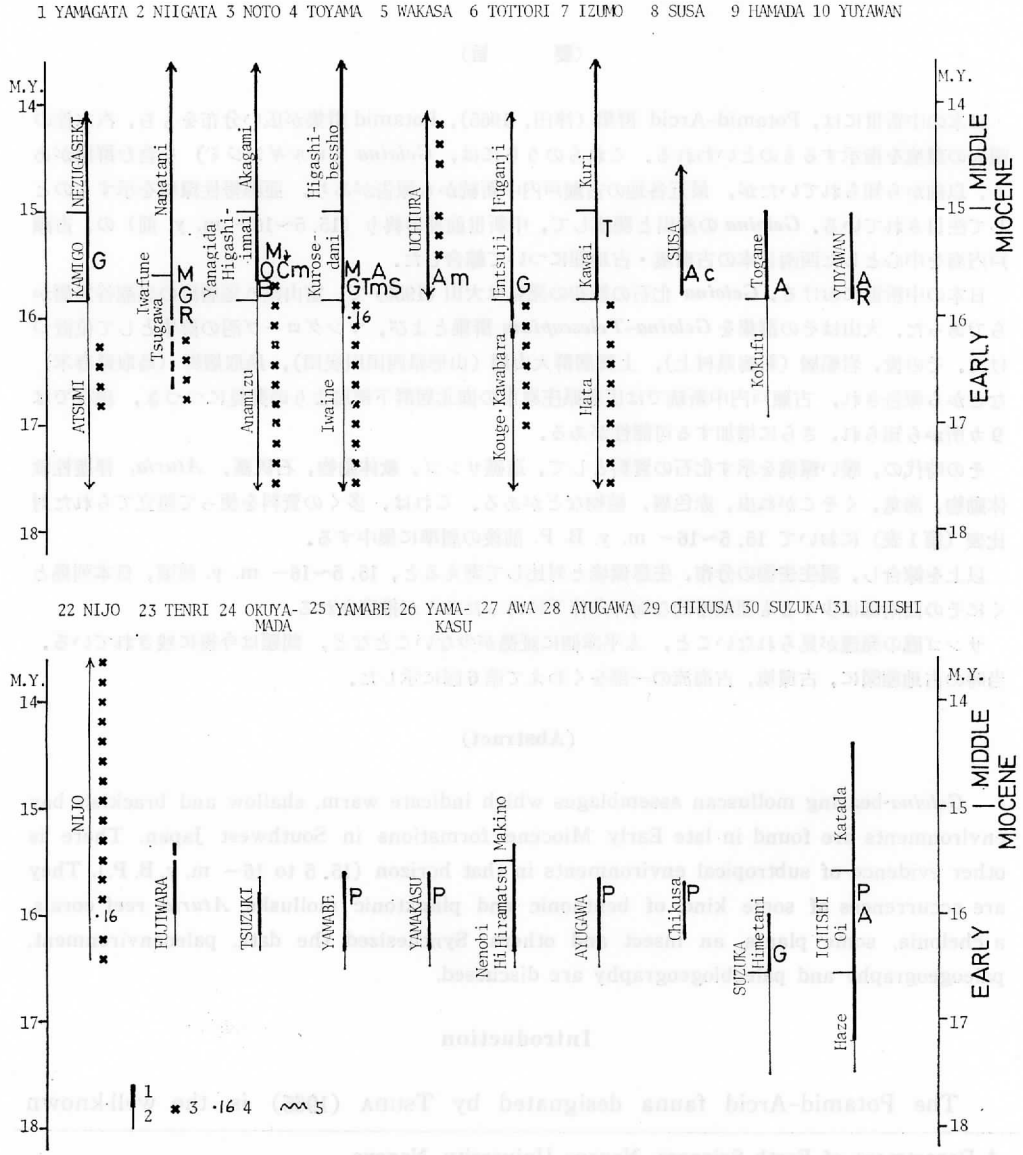
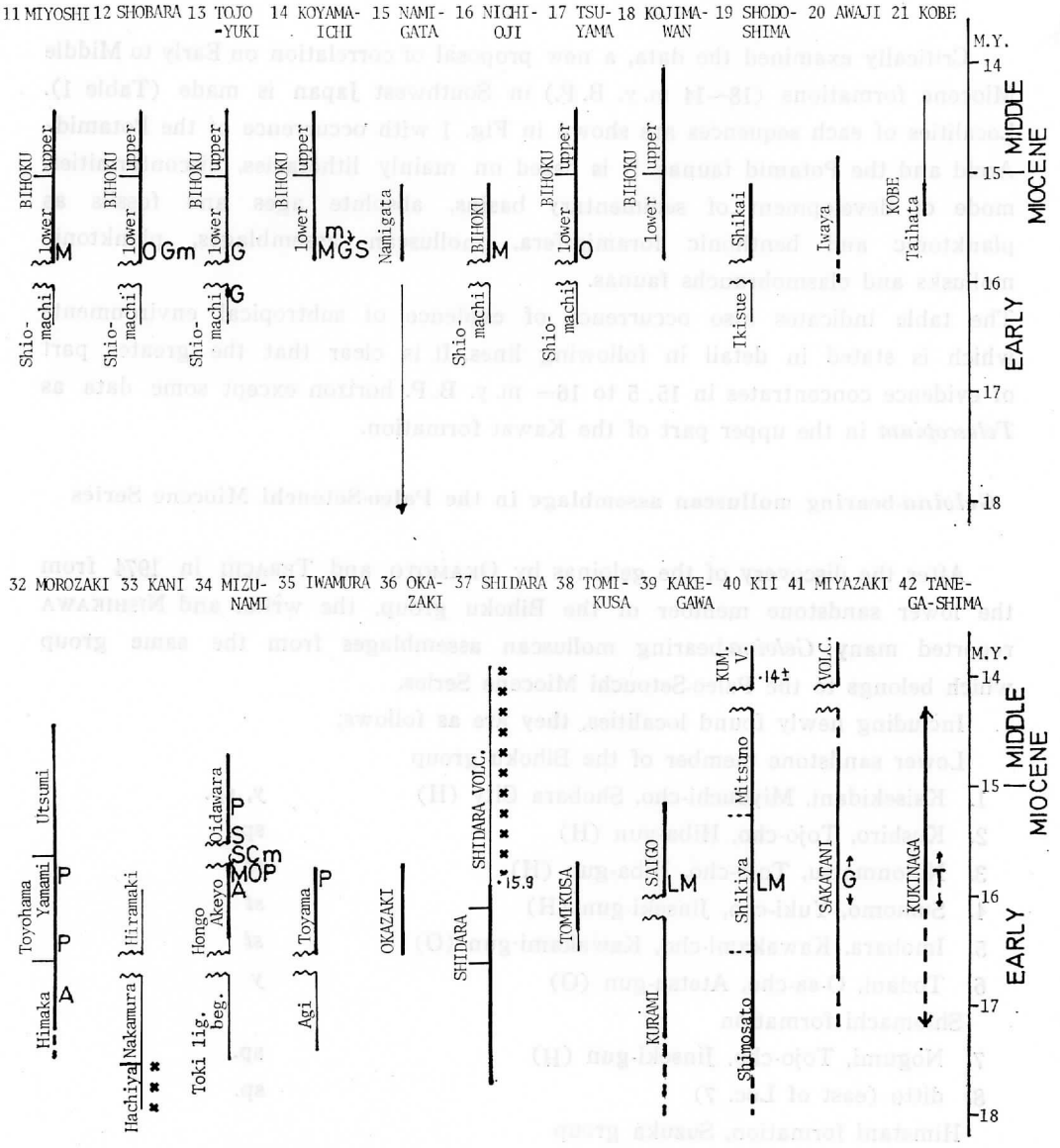


Table 1. Correlation table. 1: marine sediments, 2: lacustrine sediments, 3: volcanics, A: *Aturia*, B: dung beetle, C: reef coral, c: calcareous algae, G: *Geloina*, R: red bed, S: shark, T: *Telescopium*

Arcid fauna of the Yatsuo group, Toyama Prefecture suggesting it is a mangrove swamp biocoenosis.

After him, occurrences of *Geloina* or *Telescopium* are reported by several authors from various formations as the Sakatani subgroup of the Nichinan group of Miyazaki (SHUTO, 1963), the Iwafune formation of Niigata (TSUDA, 1965), the Kamigo group of Yamagata (NISHIDA and CHIHARA, 1966), the Kukinaga group of the Tané-ga-shima (IWASAKI, 1970), the Kawai formation of Shimane (OKAMOTO, TAKAHASHI and TERACHI, 1971), the Bihoku group of Okayama and Hiroshima



4: absolute age, 5: disconformity

L: *Lepidocyclina*, M: *Miogypsina*, m: mollusca, O: *Operculina*, P: pteropoda,

OKAMOTO and TERACHI, 1974, ITOIGAWA and NISHIKAWA, 1976), and the Tottori group of Tottori (YAMANA, 1977).

Synthesizing data on *Geloina*- or *Telescopium*-bearing assemblages and on yielding formation of them with other evidence of subtropical environments as occurrences of reef-building corals, *Aturia*, red colored beds and so on, paleoenvironment, paleogeography and paleobiogeography in late Early Miocene (15.5 to 16— m.y. B.P.) of Japan are discussed.

Correlation

Critically examined the data, a new proposal of correlation on Early to Middle Miocene formations (18~14 m.y. B.P.) in Southwest Japan is made (Table 1). Localities of each sequences are shown in Fig. 1 with occurrence of the Potamid-Arcid and the Potamid faunas. It is based on mainly lithofacies, disconformities, mode of development of sedimentary basins, absolute ages and fossils as planktonic and benthonic foraminifera, molluscan assemblages, planktonic mollusks and elasmobranchs faunas.

The table indicates also occurrence of evidence of subtropical environments which is stated in detail in following lines. It is clear that the greater part of evidence concentrates in 15.5 to 16— m.y. B.P. horizon except some data as *Telescopium* in the upper part of the Kawai formation.

Geloina-bearing molluscan assemblage in the Paleo-Setouchi Miocene Series

After the discovery of the geloinas by OKAMOTO and TERACHI in 1974 from the lower sandstone member of the Bihoku group, the writer and NISHIKAWA reported many *Geloina*-bearing molluscan assemblages from the same group which belongs to the Paleo-Setouchi Miocene Series.

Including newly found localities, they are as follows;

Lower sandstone member of the Bihoku group

1. Kaisekidani, Miyauchi-cho, Shobara City (H) — *y*, sp.
2. Kushiro, Tojo-cho, Hiba-gun (H) — sp.
3. Nihonmatsu, Tojo-cho, Hiba-gun (H) — *st*
4. Sumomo, Yuki-cho, Jinseki-gun (H) — *st*
5. Imobara, Kawakami-cho, Kawakami-gun (O) — *st*
6. Todani, O-sa-cho, Atetsu-gun (O) — *y*

Shiomachi formation

7. Nogumi, Tojo-cho, Jinseki-gun (H) — sp.
8. ditto (east of Loc. 7) — sp.

Himetani formation, Suzuka group

9. West of Ishiyama Kan-non, Geino-cho, Age-gun (M) — sp.

y: *yamanei*, *st*: *stachi*, sp.: species indet. H: Hiroshima Prefecture, O: Okayama P., M: Mié P.

1: OKAMOTO and TERACHI (1974), 2-6: ITOIGAWA and NISHIKAWA (1976), 7, 8: ITOIGAWA and NISHIKAWA (MS), 9: SHIBATA (MS)

These are divided into two groups in horizon. Localities 1 to 6 are in horizon of 15.5 to 16− m.y. B.P. and upper than 7, 8 and 9 which are 16 to 16+ m.y. B.P. But there is a question on the horizon of localities 7 and 8 because the strata are deposits under brackish environment differing the common facies of the Shiomachi formation which consists of lacustrine sediments.

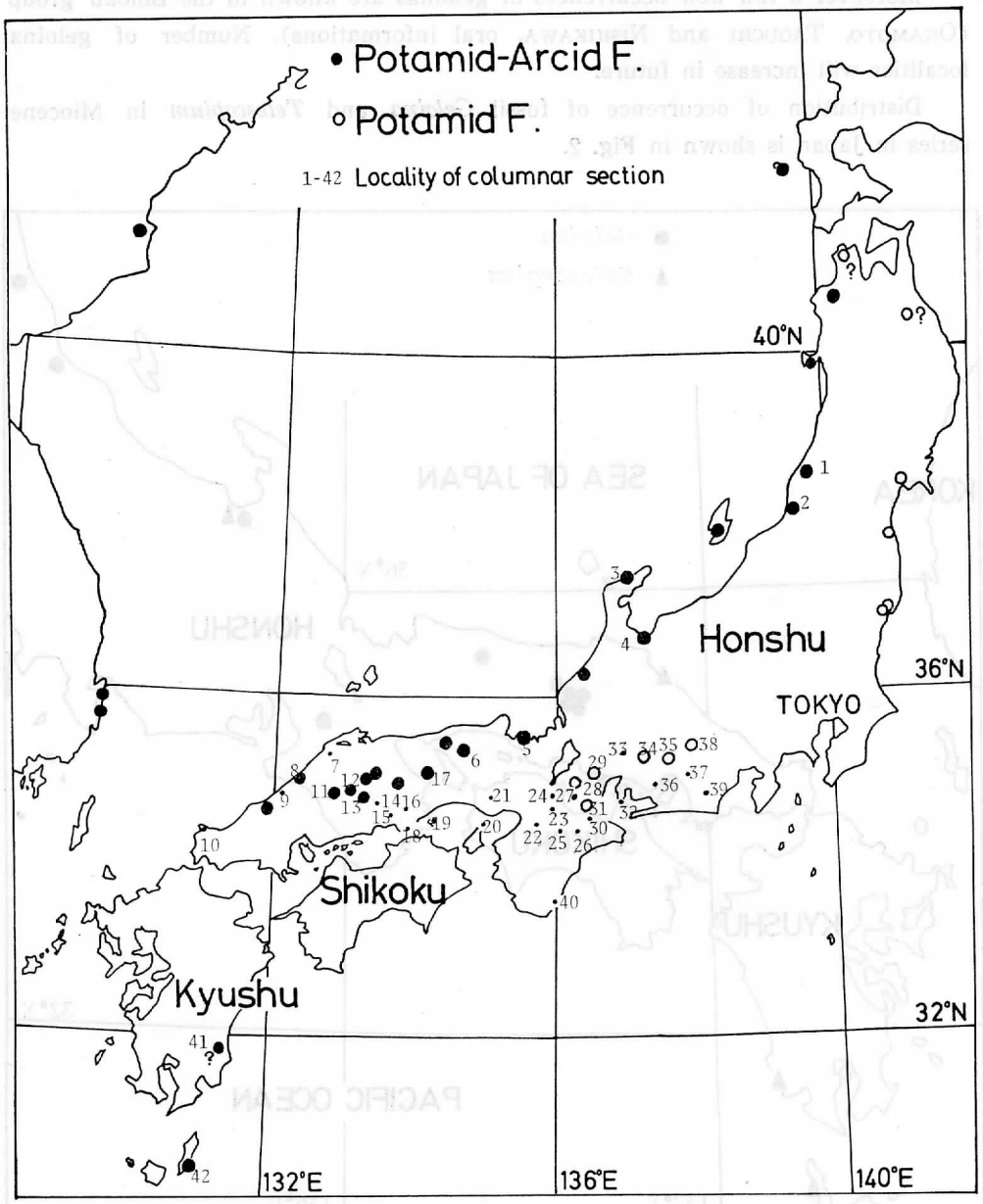


Fig. 1. Map showing localities of columnar sections in correlation table (Table 1), and occurrence of the Arcid-Potamid and the Potamid faunas

They have possibility to belong to the lower sandstone member of the Bihoku group.

Geloina-bearing molluscan assemblages of above mentioned are divided into two types in occurrence, *i. e.* one is autochthonous and another is semi-autochthonous. In the former case, geloinas occur without or with few numbers of species of other mollusks. The latter coexists with *Crassostrea, Anadara, Tateiwaia* and *Cyclina* in general.

Moreover a few new occurrences of geloinas are known in the Bihoku group (OKAMOTO, TAGUCHI and NISHIKAWA, oral informations). Number of geloina localities will increase in future.

Distribution of occurrence of fossil *Geloina* and *Telescopium* in Miocene series in Japan is shown in Fig. 2.

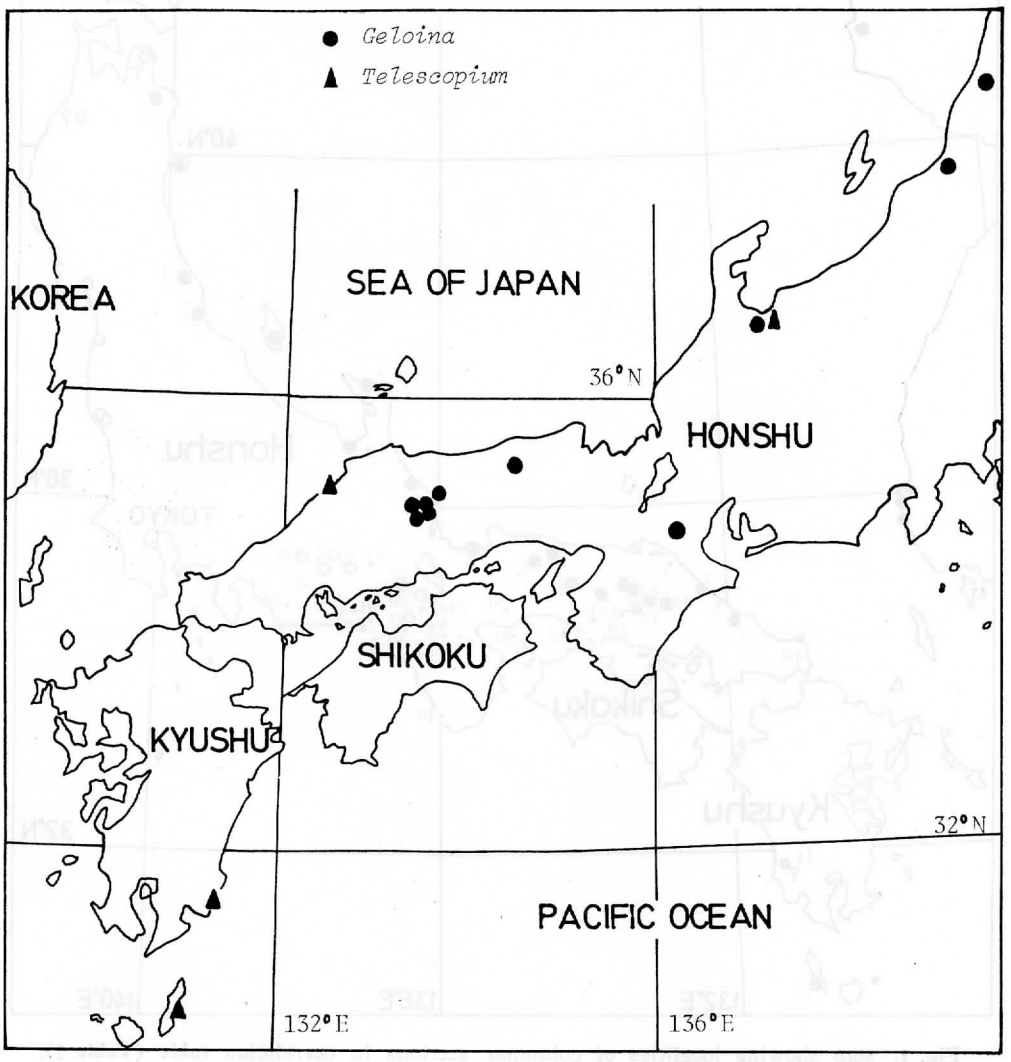


Fig. 2. Distribution of occurrence of fossil *Geloina* and *Telescopium*

Other evidence on subtropical condition in late Early Miocene of Japan

There is a large number of evidence which indicates subtropical condition in late Early Miocene of Japan. They are explained in following lines.

a. Benthos

1) Mollusca

Important assemblages are cited.

i. The *Cavilucina-Glycymeris* assemblage of the Shukunohora facies of the Mizunami group, Gifu includes *Isognomon*, *Maoricardium*, "*Cypraea*", "*Conus*" and "*Terebra*" (ITOIGAWA, 1960).

ii. The Uchiura group, Kyoto (KOBAYASHI and HORIKOSHI, 1958) includes *Tectus*, *Globularia* and "*Conus*".

iii. The Yatsuo group of Toyama (TSUDA, 1960) has species of subtropical-tropical Genus as *Tibia*, *Canarium*, *Rimella*, "*Terebra*", "*Conus*", and Turridae in addition to the *Geloina-Telescopium* assemblage.

iv. Higashi-innai fauna of Noto, Ishikawa (MASUDA, 1966) comprises subtropical forms as "*Cypraea*", *Mitra*, *Oliva* and "*Conus*" with reef-building corals.

v. A few subtropical forms are known from the Bihoku group of Okayama and Hiroshima. They are *Globularia*, "*Conus*", *Periglypta* and so on (ITOIGAWA and NISHIKAWA, 1976).

2) Reef coral

Occurrence of reef-building corals is not so common in late Early Miocene of Japan. *Porites*, *Plesiastrea*, *Cynaria*, *Lobophyllia* and *Turbinaria* are found in the Shukunohora facies (EGUCHI, 1974), but they do not form coral reefs. *Oculina* makes colonies but it is not a reef-building coral. In addition to them, some corals are reported from the Higashi-innai formation (MASUDA, 1966).

3) Calcareous algae

Limestones in the Kawashiri formation of the Yuyawan group bear calcareous algae as *Dermatolithon* cf. *saipanensis*, *Lithophyllum Iwamurai*, *L. yuyashimaensis*, *Mesophyllum yuyashimaensis* with *Crassostrea* cf. *sakitoensis* (mollusca), *Echinolampas yoshiwarai* (echinoid) and Cf. *Cellepora formosensis* (bryozoa) (ISHIJIMA, 1962, OKAMOTO and IMAMURA, 1964). It is assumed these limestones are reef sediments in a horizon and are deposited under environments with strong water movement in tropical to subtropical conditions.

b. Nekton

1) Elasmobrachia assemblage in the 15.5 to 16— m.y. B.P. horizon is the *Carcharhinus-Odontaspis-Negaprion* assemblage (NISHIMOTO and ITOIGAWA, 1977). It is found in many localities as Kushimoto (Wakayama), Mizunami (Gifu), Yatsuo (Toyama), Ichishi (Mié), Bihoku (Okayama) etc. in Southwest Japan. The assemblage consists of warm and oceanic species and indicates nearly equal conditions with the Jomon transgression 6000 y. B.P.) which is seemed to

show 2—3℃ higher mean sea-surface temperature in February than at present.
2) A fossil chelonia, *Procolpochelys* (?) *susensis* SHIKAMA and SUYAMA, 1976 from the Maeji sandstone, Susa group of Yamaguchi resembles *Chelonia mydas japonica* (THUNBERG), one of the recent marine chelonia living in the Southwestern Pacific Ocean and *Procolpochelys grandaeva* (LEIDY) from the upper Miocene of East U. S. A. SHIKAMA and SUYAMA concluded it had lived in both the Pacific and Atlantic Oceans.

Distribution of benthonic and nektonic fossil biota is shown in Fig. 3.

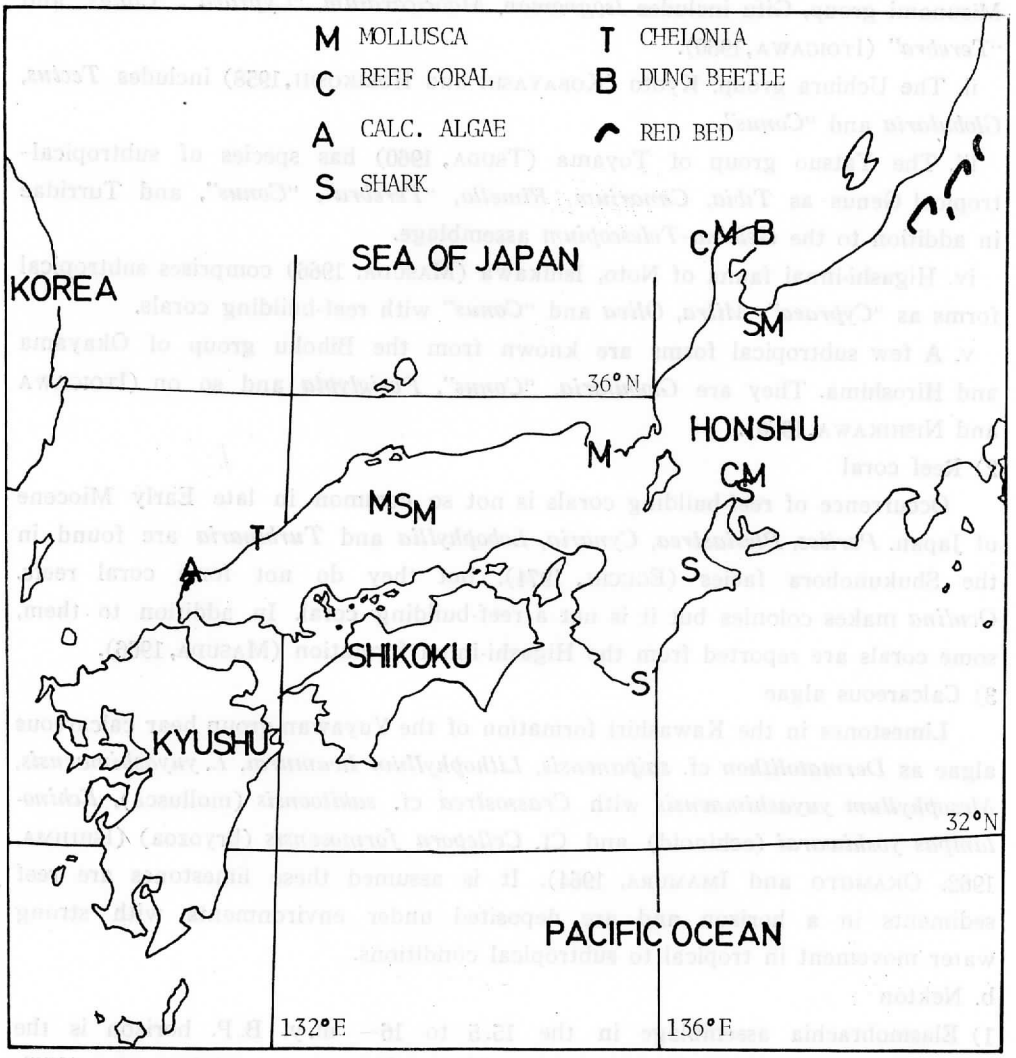


Fig. 3. Distribution of evidence of benthonic, nektonic and terrestrial materials in 15.5 to 16— m. y. B. P.

c. Macroplankton

1) Distribution of *Aturia minoensis* KOBAYASHI and its allies are shown in Fig. 4

with that of planktonic gastropods. Most of them are exotic floating from southern seas transported by strong warm currents but the case of the Uchiura group (Kyoto) is assumed it will be indigenous being collected five specimens together and including an immature specimen (KOBAYASHI and HORIKOSHI, 1958). It seems to be needed to examine this conclusion more in detail in connection with other data.

2) SHIBATA (1977) reported ten pteropodous species (*Euclio, Vaginella, Bowdenstheca, Cavolinia* etc.) and one heteropodous one (*Atlanta*) from the Miocene Paleo-Setouchi Series. He concluded that they are epipelagically distributing and are mainly in warm oceanic water regions. Excellent conditions of preservation in spite of their fragile tests show the specimens were not transported from remote places after death. They occur in very limited stratigraphic horizons which is included in the horizon presently concerned in *sensu lato.*

Fig. 4 shows distribution of evidence of planktonic fossils (including necroplanktonic one).

d. Terrestrial evidence

1) Dung beetle

Heliocopris antiquus FUJIYAMA is described in 1968 from the Yanagida formation of Noto (Ishikawa).

The habitat of living *Heliocopris* is further limited to the tropical regions namely, South China, Indonesia, Malaya, Sudan Island, Burma, Central Africa and its south.

Inferring from the distribution in the present day, FUJIYAMA concluded that this fossil dung beetle is a tropical one. It is afraid that the Yanagida is a little lower in horizon than 15.5 to 16— m.y. B.P. one.

2) Red colored bed

Two occurrences of red colored beds are reported in the subjected horizon. One is in the Tsugawa formation of Niigata described by TSUDA *et al.* (1977) from 12 places. TSUDA *et al.* pointed out that the red colored beds mainly are developing at the horizon just on basement rocks and it is considered to be possible that laterization, or weathering similar thereto, was taking places at temperatures higher than those of the present. Chocolate colored sediments found at the base horizon of the Igami formation of the Yuyawan group of Yamaguchi by OKAMOTO (1975) will be also the same origin in the same horizon.

Distribution of the dung beeele and the red colored bed is shown in Fig. 3.

3) Plant

According to TANAI (1967, 1972), floras in the 15.5 to 16— m.y. B.P. horizon is composed of mixedly deciduous and ever green broad-leafed trees such as *Comptonia, Carya, Carpinus, Castanopsis, Liquidambar* and *Cinnamonum* accompanied by conifer. They show a warm-temperate forest on the lowlands. Especially in Honshu it includes a northward extension of the Paleotropical Tertiary Geoflora to about 40° N according to him.

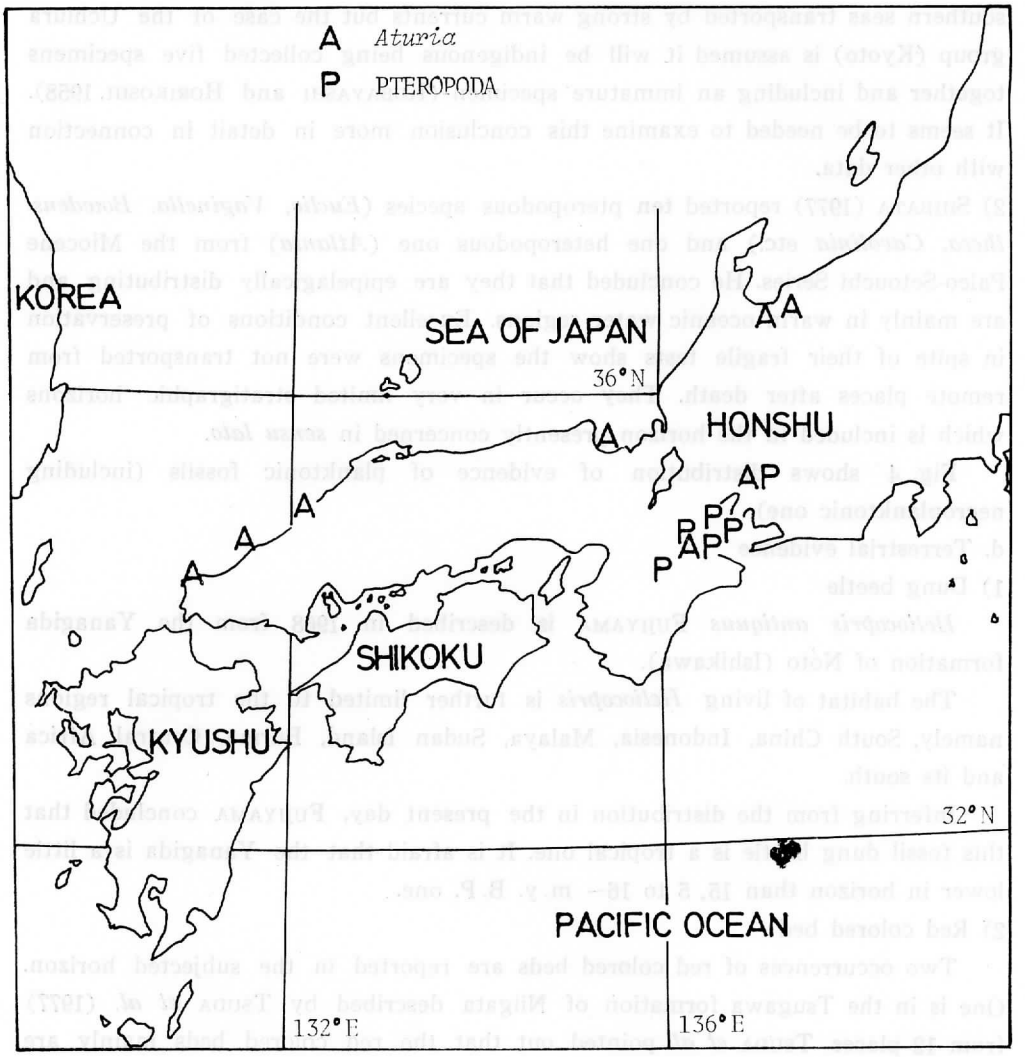


Fig. 4. Distribution of evidence of planktonic materials in 15.5 to 16— m. y. B. P.

d. Microfossil

It needs to note various kind of microfossils. In the mentioned horizon in Japan, the following zones are recognized on planktonic foraminifera and radioralia and compiled as biostratigraphical data (IKEBE, 1977, 1978).

	Pacific Ocean side	Japan Sea side
planktonic foraminifera	*Praeorbulina glomerosa* /*Orbulina sutularis* zone	*Globigerinoides sicanus* /*Praeorbulina glomerosa*
radiolaira	*Melittosphaera magnaporulosa* zone	

Most of species are extinct and it is very difficult to detect paleotemperatures of currents predominated at that time by them.

Pollen analytical data are also important. Dr. YAMANOI is working on pollen analysis of rock specimens from the *Geloina*-bearing Shiomachi formation in Yuki-Tojo area. The preliminary information by him shows occurrence of pollens of Rhizoporaceae and *Avicennia*.

Discussion

Living geloina is a representative of a mangrove swamp molluscan assemblage coexisting with *Telescopium*, *Littorinopsis*, *Ellobium* and so on. This assemblage is simple in constitution but individual of each species is large in number. Mangrove swamp environment is in tropical to subtropical seas and is represented by a shallow embayment having high temperature, low salinity and a muddy bottom, and clearly contrasts with coral reef environment which indicates high salinity under strong influence of oceanic currents.

Mangrove swamps and coral reefs are widely developed in the Southwestern Islands of Japan as the Amami and the Okinawa. Northern limit of mangrove swamps is situated at Kiiré, Kagoshima (Lat. 31° 20′ N) and geloinas distribute to the Amami-o-shima (Lat. ca. 28° 20′ N). Coral reefs in tidal zone also develop around the Amami Islands in their northern limit and subsurface reef corals are seen from the Yaku-shima (Lat. 30° 20′ N) to Boso Peninsula (Lat. 35° N) (Fig. 5). These facts indicate influence of the warm Kuroshio current from the southern seas to the Japanese Islands. 20° C isothermal line of mean sea-surface temperature in February limits the north of the Amami Islands. It is said the Amami and the Okinawa Islands belong to the subtropical region.

Synthesized the above mentioned data on fossil and living biota, it is made sure the followings.

1. Mangrove swamps existed in the proto-Japan Sea and the Paleo-Seto Inland Sea areas in late Early Miocene.
2. Evidence on coral reefs in that age is rather scanty.
3. Subtropical evidence is abundant in the Japan Sea side region and rare in the Pacific Ocean side.

Above-cited facts show the proto-Japan Sea was strongly influenced by the proto-Tsushima current with about 10° C higher mean sea-surface temperature in winter having nearly equal conditions in subtropical region as the Amami and Okinawa Islands. It is also assumed existence of mangrove swamps and coral reefs were rare in the Pacific Ocean side of the Japanese Islands.

A paleogeographic map in age of 15.5 to 16— m.y. B.P. (late Early Miocene) is shown in Fig. 6 indicating paleoenvironments as brackish, sublittoral and bathyal conditions in part, and direction of paleocurrents.

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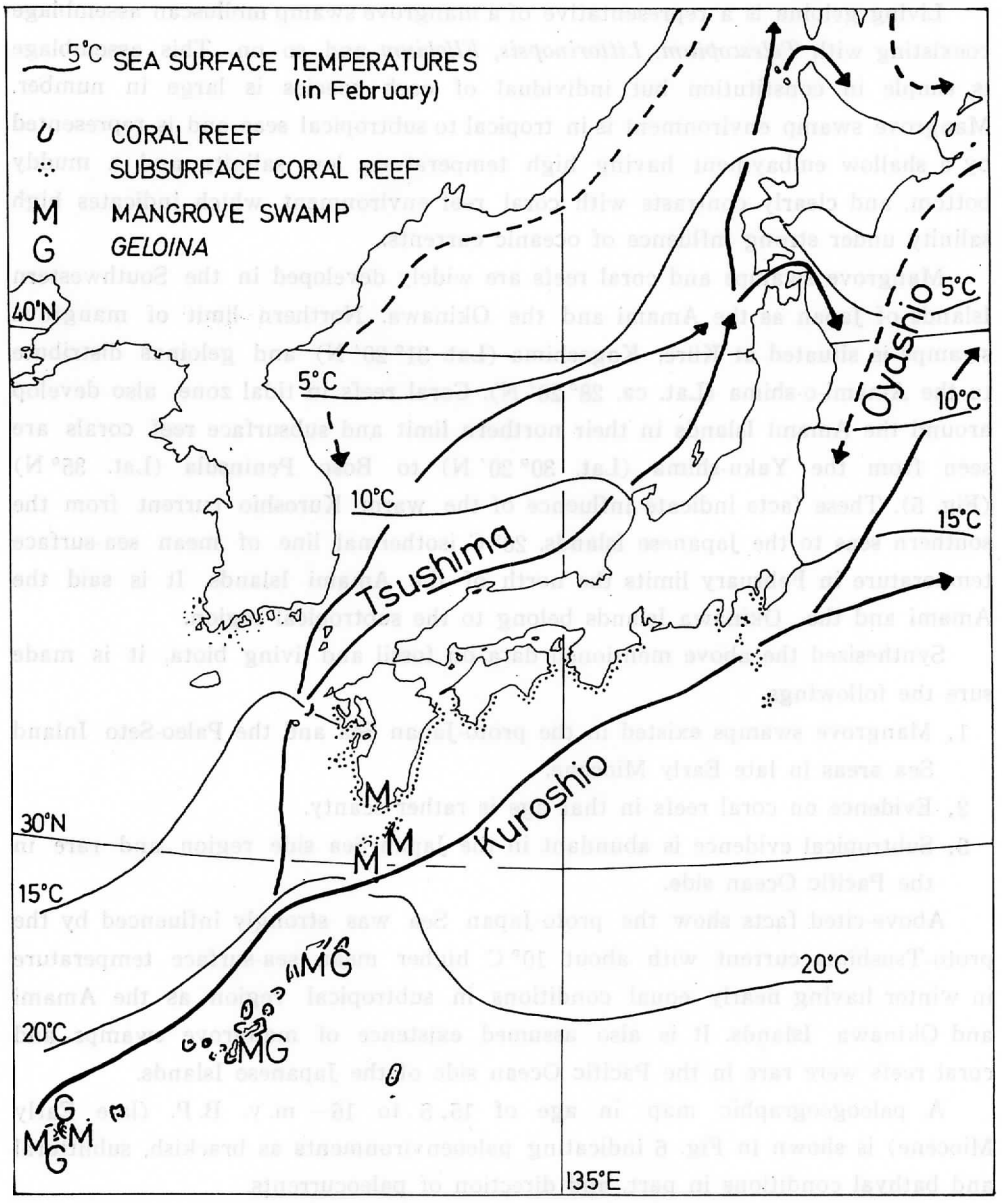

Fig. 5. Distribution of geloinas, mangrove swamps and coral reefs with some data on hydrographic condition in seas around the Japanese Islands

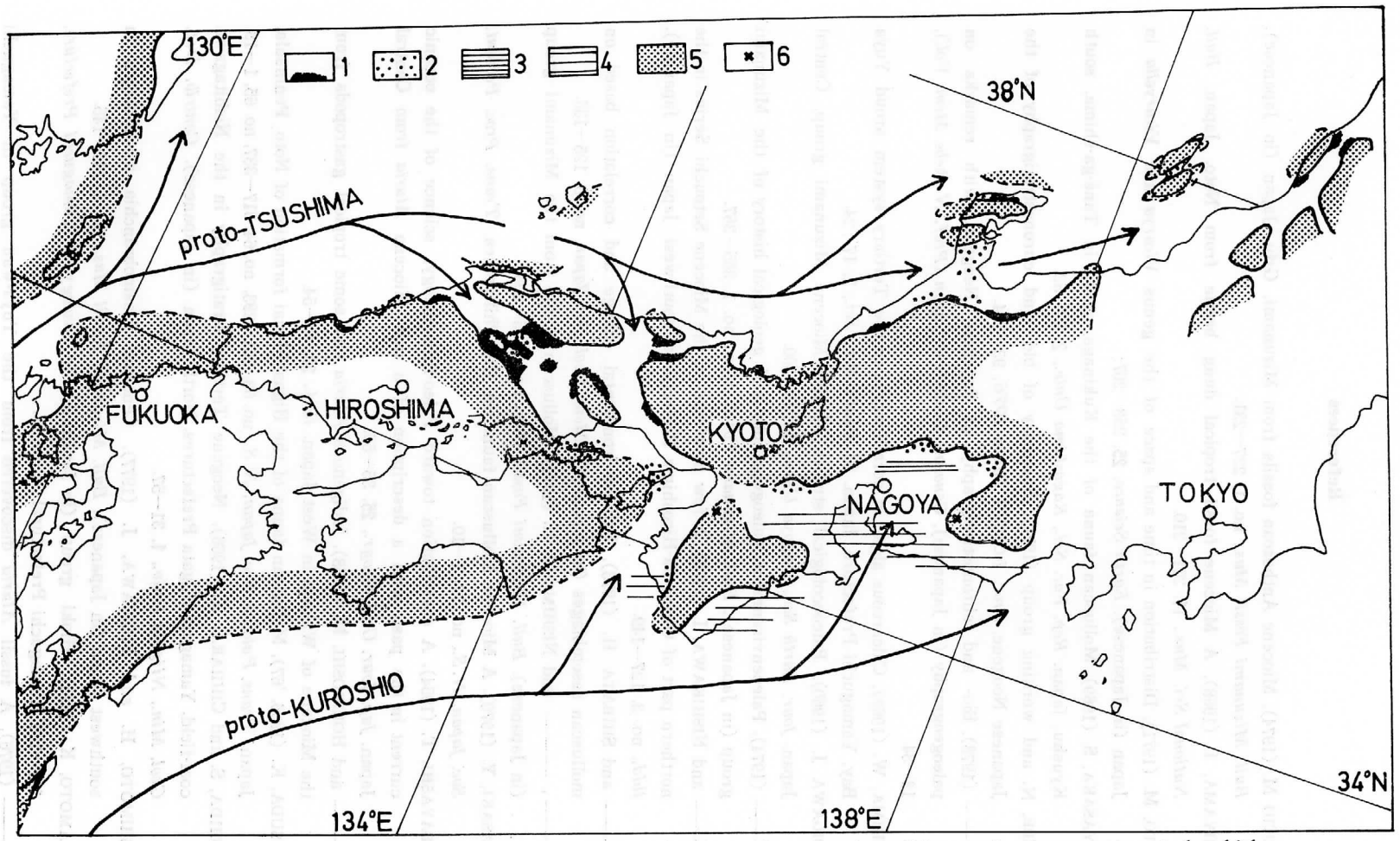

Fig. 6. Paleogeographic map in 15.5 to 16— m. y. B. P. with paleoenvironmental conditions and paleocurrents. 1: brackish – upper sublittoral, 2: upper sublittoral, 3: lower sublittoral, 4: lower sublittoral – bathyal, 5: land, 6: volcanic area

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Plate 2

Fig. 1. *Vicaryella* cfr. *notoensis* MASUDA ×1.5
Fig. 2. *Vicaryella bacula* (YOKOYAMA) ×1
Fig. 3. *Vicarya japonica* YABE and HATAI ×1
Fig. 4. *Tateiwaia yamanarii* MAKIYAMA ×1.4
Fig. 5. *Tateiwaia tateiwai* MAKIYAMA ×1.6
Fig. 6. *Anadara daitokudoensis* MAKIYAMA ×1
Fig. 7. *Crassostrea gravitesta* (YOKOYAMA) ×0.4
Figs. 8a, b. *Geloina stachi* OYAMA ×1
(Specimens from the lower member of the Bihoku group)

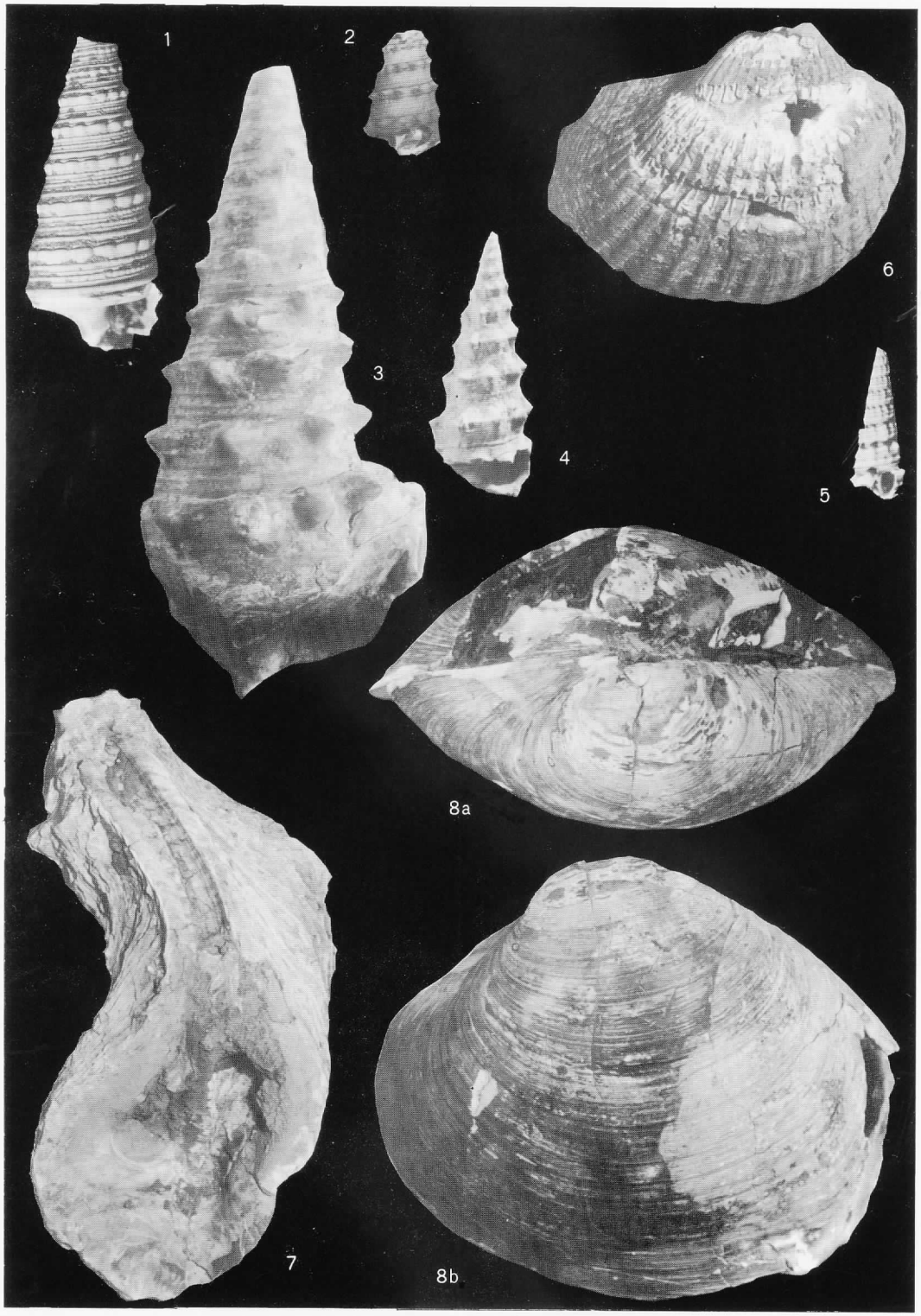
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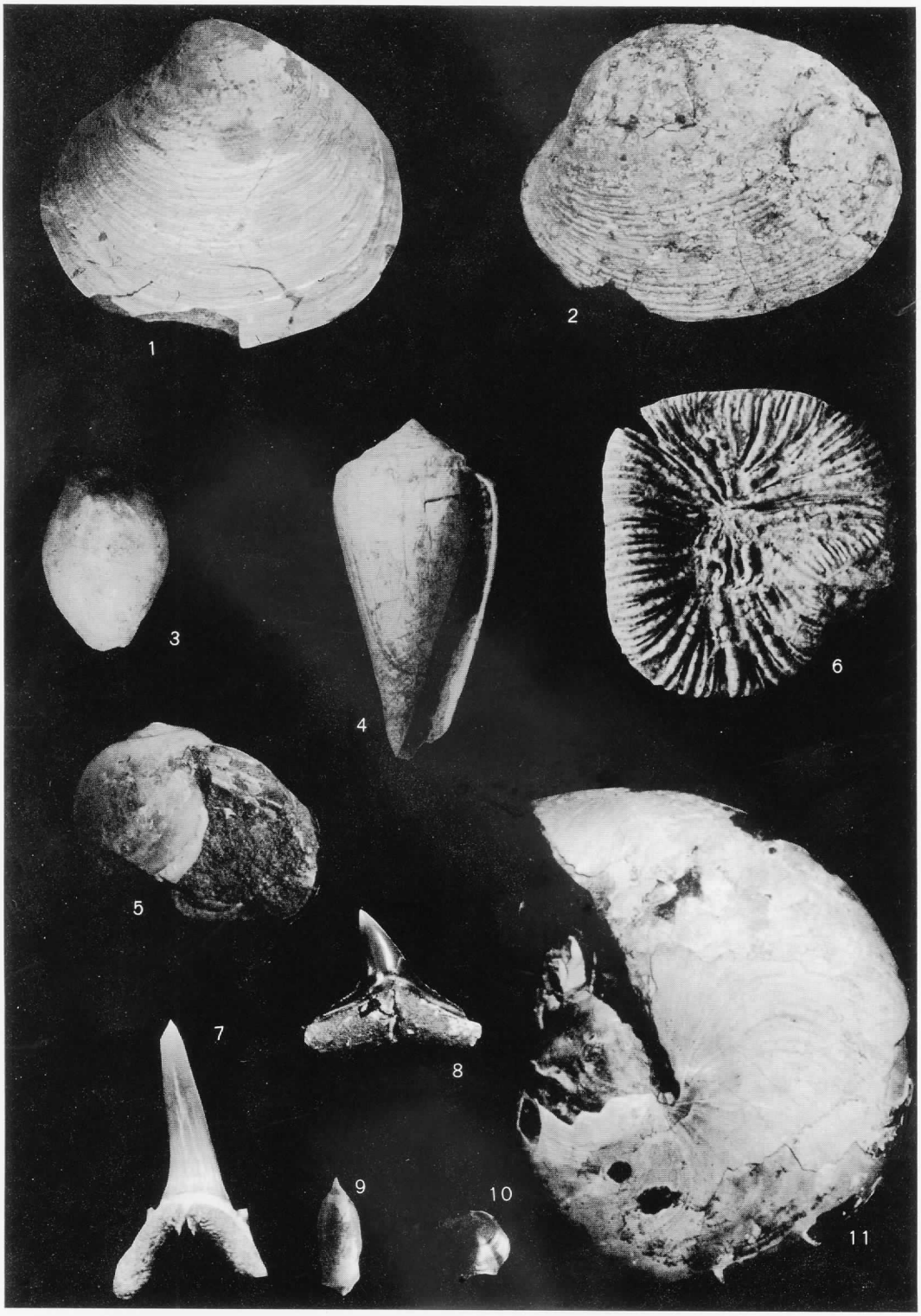
Plate 3

Fig. 1. *Geloina yamanei* OYAMA ×1.4 (lower member of the Bihoku group)
Fig. 2. *Periglypta* sp. *ibid.*)
Fig. 3. "*Erosaria*" sp. × 1 (Shukunohora facies of the Mizunami group)
Fig. 4. *Chelyconus* sp. × 1 (*ibid.*)
Fig. 5. *Globularia nakamurai* OTUKA × 1 (lower member of the Bihoku group)
Fig. 6. *Lobophyllia* sp. × 1 (Shukunohora facies)
Fig. 7 *Odontaspis acutissima* AGASSIZ × 1 (Nataki conglomerate of the Mizunami group)
Fig. 8. *Carcharhinus priscus* (AGASSIZ) × 2 (*ibid.*)
Fig. 9. *Vaginella depressa* DAUDIN × 4 (Ichishi group, after H. SHIBATA)
Fig. 10. *Cavolinia ratitatis* (NOMURA and ZINBO) × 2 *ibid.*, after H. SHIBATA)
Fig. 11. *Aturia minoensis* KOBAYASHI × 1 (Yamanouchi member of the Mizunami group)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