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Mesozoic Formations and their Molluscan Faunas in the Haidateyama Area, Oita Prefecture, Southwest Japan

By

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with 13 Tables, 21 Text-figures and 5 Plates

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ABSTRACT

The Mesozoic strata of the Haidateyama area, Oita Prefecture, Kyushu, are distributed in several narrow subbelts within the Chichibu Belt. On the basis of stratigraphical and paleontological studies, they are classified into the following formations: the Kashimine (Carnian) and Shinkai (Tithonian) Formations in the Shinkai subbelt; the Motoyamabu (Upper Tithonian-Lower Berriasian ?) and Yamabu (Hauterivian-Barremian) Formations in the Yamabu subbelt; the Koshigoe (Hauterivian-Lower Barremian ?), Haidateyama (Lower Barremian), Tamarimizu (Upper Aptian) and Sukubo (Upper Albian) Formations in the Haidateyama subbelt; the Osaka (Barremian-Aptian), Tamarimizu (Upper Aptian) and Higashidani (Albian) Formations in the Osaka subbelt. Among them, the Koshigoe, Haidateyama, Osaka and Higashidani Formations are combined under the name of the Haidateyama Group, while the Yamabu, Tamarimizu and Sukubo Formations under the name of the Amabe Group. Six brackish to shallow-marine bivalve faunas, namely, the Yamabu, Koshigoe, Haidateyama, Tamarimizu, Osaka and Sukubo faunas, are discriminated in the Lower Cretaceous. In this paper, the stratigraphy is described in some detail, with remarks on correlation, and the features of the bivalve faunas are made clear. The faunal comparison with other areas of the Chichibu Belt, together with the faunal change in time and space, is also discussed.

In the Chichibu Belt, many characteristic bivalve faunas have been recognized from various localities of different depositional environment and geologic age. They are roughly grouped into the Monobegawa-Type Fauna, the Nankai-Type Fauna and the Intermediate-Type Fauna. The Koshigoe, Haidateyama and Osaka faunas belong to the Monobegawa-Type, while the Yamabu, Tamarimizu and Sukubo faunas to the Nankai-Type. Judging from the difference in litho- and bio-facies between the Haidateyama and Amabe Groups, it is presumable that there were two "deltas" where the Lower Cretaceous brackish-water to neritic sediments were thickly piled up. The older rocks of the Kurosegawa Tectonic Belt might have been upheaved early in the Cretaceous to form chains of islands near the boundary between the two "deltas".

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I. INTRODUCTION

The Cretaceous strata of Japan are most extensively distributed in the meridional zone of Hokkaido, where they are represented by an almost continuous marine sequence of whole Cretaceous age. The Albian

and later Cretaceous rocks are rich in molluscan fossils, especially ammonoids and inocerami, together with planktonic microfossils. Zonation and international correlation have recently been made successfully on the basis of these mega- and micro-fossils. In contrast to wide outcrops of the fossiliferous Upper

Cretaceous strata in Hokkaido, the Lower Cretaceous deposits are distributed narrowly in some isolated area of Honshu, Shikoku and Kyushu in addition to Hokkaido.

The Lower Cretaceous System in the Chichibu Belt, the Outer Zone of Southwest Japan, has been considered to have been formed on an unstable shelf with the basement of the Upper Paleozoic-Jurassic Chichibu Supergroup. It is represented by sediments of brackish-water to neritic (near-shore and offshore) environments; non-marine beds with plants and brackish-water shells are frequently interfingering with marine ones which contain index species of ammonites and other marine bivalves. Therefore, the geological age of the former can be determined by that of the latter in terms of the international scale. The results have recently been summarized by MATSUMOTO et al. (1982), which would be most useful for the correlation of continental deposits in Eastern Asia. Nevertheless, our knowledge on the Lower Cretaceous biostratigraphy and paleontology of the Chichibu Belt still remains very insufficient, owing to the complicated geologic structure and the scarcity of well-preserved index fossils. It is necessary to establish an appropriate scheme of biostratigraphic zonation available for wide areas.

Recently, the detailed stratigraphical and paleontological studies on the Lower Cretaceous of the Chichibu Belt have rapidly been advanced by a number of authors (HAYAMI, 1965-66; HAYAMI and OJI, 1980; MATSUKAWA, 1977, 1979, 1983; MATSUMOTO et al., 1968; MATSUMOTO and TASHIRO, 1975; MATSUMOTO et al., 1980; NAKAI, 1968; NAKAI and MATSUMOTO, 1968; OHTA, 1982; TAMURA, 1980; TANAKA and KOZAI, 1982; TANAKA et al., 1984; TASHIRO et al., 1980; TASHIRO and KOZAI, 1984; TASHIRO and MATSUDA, 1982, 1983; etc.). In addition to them, I have examined critically the Mesozoic stratigraphy and fossil faunas of the Haidateyama area in Oita Prefecture under the guidance of Prof. A. HASE of Hiroshima University and Emeritus Prof. Y. OHTA of Fukuoka University of Education.

The Haidateyama area in Oita Prefecture is situated near the eastern end of the Chichibu Belt in Kyushu. Fairly fossiliferous Lower Cretaceous marine and non-marine deposits crop out there, and prolific bivalve faunas, the exact ages of which are checked by ammonites, occur from various localities. Therefore, the area in question seems to be one of the favourable fields to make up for a deficiency of the Lower Cretaceous stratigraphical and paleontological data in Japan. The main purpose of this study is to establish the stratigraphy of Mesozoic (especially Lower Cretaceous) strata in the Haidateyama area, and to make clear the stratigraphic positions and geological ages of the molluscan faunas. The faunal comparison with other areas of the Chichibu Belt is also discussed. Furthermore, brief notes on paleogeography and geologic history in relation to the Kurosegawa Tectonic Belt are added.

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II. OUTLINE OF GEOLOGY.

The Haidateyama area is located in eastern Kyushu, and belongs geotectonically to the middle subbelt of the Chichibu Belt (Fig. 1). The investigated area extends about 6-10km from east to west and approximately 15km from south to north, and is underlain mainly by rocks ranging in age from Middle Carboniferous to Upper Cretaceous, with a partial covering of the Quaternary volcanic ejecta.

The bulk of the basement rocks is represented by the Middle Carboniferous to Jurassic strata. They are composed of slate (partly phyllite), feldspathic greywacke-type sandstone, chert and subordinate limestone, with a small amount of greenstone and conglomerate, showing in some places a facies of olistostrome. They form a considerably complicated structure with steep to vertical dip, original bedding planes being often changed to shear planes. Fossils such as fusulinids, calcareous algae, smaller foraminifers, corals and radiolarians are obtained locally.

The Chichibu Belt of the Haidateyama area is divided into several parallel to subparallel subbelts by tectonic lines of ENE-WSW trend. They are named the Shinkai, Yamabu, Haidateyama and Osaka subbelts from south to north (Fig. 2). The tectonic lines are represented by steep faults or thrusts as well as by strongly contorted and sheared rocks. Along the tectonic lines, occur gneiss, amphibolite, quartz porphyry, porphyrite, diabase, serpentinite, granite and schist which are referable to the constituent rocks of the Kurosegawa Tectonic Belt in Shikoku. The eastern margin of the investigated area is cut by the Kabunoki fault trending NNE-SSW or NE-SW.

The Mesozoic strata in the southernmost Shinkai subbelt consist of the Kashimine (Carnian) and Shinkai (Tithonian) Formations. The Shinkai Formation forms a synclinal structure with an axis approximately trending ENE-WSW, and is in fault contact with the Kashimine Formation which is interposed in the axial part. The Upper Mesozoic strata in the Yamabu subbelt are composed of the Motoyamabu (Upper Tithonian-Lower Berriasian?) and Yamabu (Hauterivian-Barremian) Formations. The Yamabu Formation forms an asymmetric syncline with an axis

of E-W trend, and unconformably covers the Motoyamabu Formation. The Lower Cretaceous System in the Haidateyama subbelt, lying on the basement rocks with a clino-unconformity, is divided into the Koshigoe (Hauterivian-Lower Barremian ?), Haidateyama (Lower Barremian), Tamarimizu (Upper Aptian) and Sukubo (Upper Albian) Formations. They form a gentle semibasin structure cut by a fault on the southern side. The Lower Cretaceous System in the northernmost Osaka subbelt is classified into the Osaka (Barremian-Aptian), Tamarimizu (Upper Aptian) and Higashidani (Albian) Formations. As a whole, they form an anticlinal structure with an axis trending ENE-WSW (Fig. 3). The Koshigoe, Haidateyama, Osaka and Higashidani Formations are combined under the name of the Haidateyama Group, while the Yamabu, Tamarimizu and Sukubo Formations under the new name of the Amabe Group. The two groups are possibly interfingering with each other.

The Mesozoic strata of the Haidateyama area have certain characteristics concerning their distribution and sedimentary facies as follows.

1). Roughly speaking, there is a tendency that the geological age of the formations becomes younger towards the north.

2). Each of the Mesozoic formations usually shows a hemicycle of sedimentation, beginning with conglomerate or sandstone, passing upwards to alternation of sandstone and siltstone, and ending with siltstone or shale.

3). It is worthy to note that certain formations contain small lenses of oolitic limestone or biohermal limestone.

The Mesozoic strata are mostly intensely folded and faulted, but they are not so highly contorted and

cloven as the Paleozoic rocks. The stratification is well preserved except along faults or tectonic lines. Neither appreciable metamorphism nor intrusive effect of granite and serpentinite has been observed.

III. STRATIGRAPHY

A. MESOZOIC STRATA IN THE SHINKAI SUBBELT

The Shinkai subbelt is located in the southernmost part of the investigated area, and is bordered on the north by the Kashimine Tectonic Line and on the south by the Shinkai Tectonic Line. The Mesozoic strata developed in this subbelt are classified into the Kashimine and Shinkai Formations.

Historical review : In 1954, FUJII described the Upper Jurassic beds which consist of conglomerate, sandstone and shale under the name of the Shinkai Formation. He correlated it to the Torinosu Group of South Shikoku. Subsequently, TAMURA (1960) briefly reported the stratigraphy and geologic structure of this formation, and the occurrence of *Nerinea* sp. and *Cidaris* sp. from a lenticular limestone. The nomenclature was taken over by TERAOKA (1970), and by OHTA and TANAKA (1980). Recently, the bivalve fauna referable to the Early Triassic (Carnian) in age was discovered by myself from the sandy shale which has so far been included in the upper member of the Shinkai Formation (TANAKA et al., 1985). This Upper Triassic beds are newly named the Kashimine Formation.

1. Kashimine Formation

Name: New name derived from a place-name, Kashimine, 3.5km southwest of Shinkai, Honjo-son,

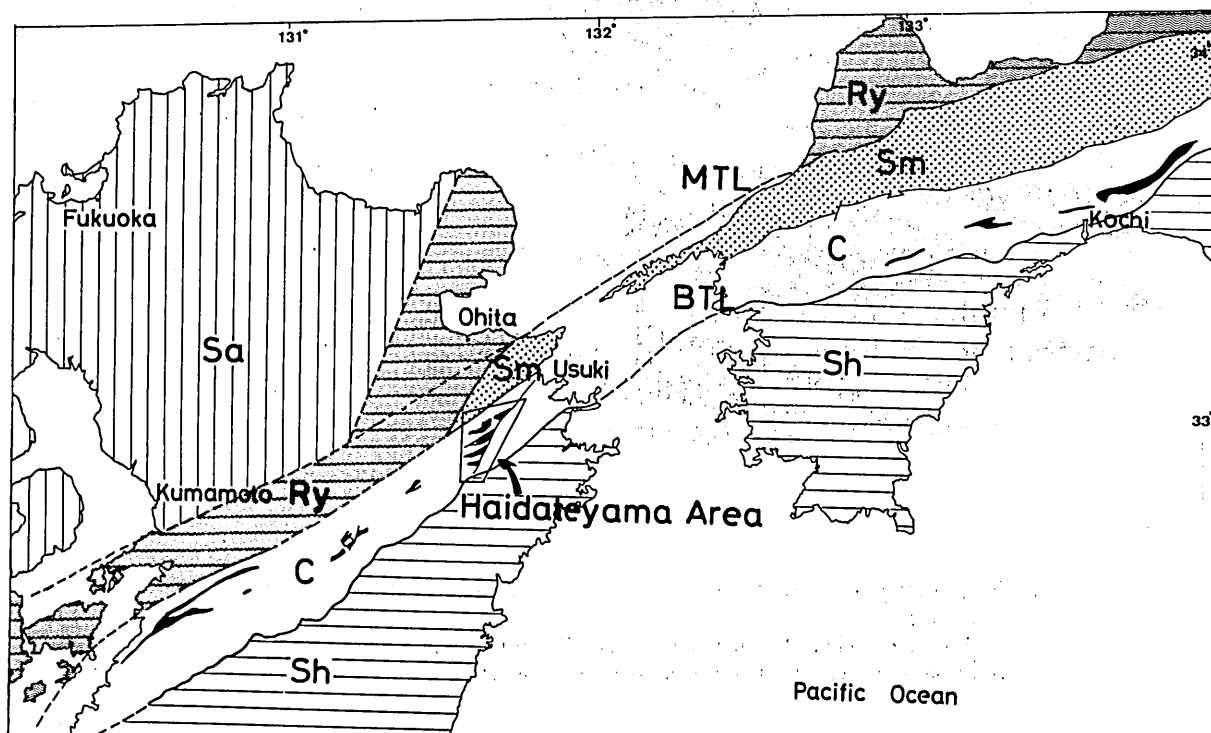


FIG. 1. Map showing the geotectonic division of eastern Kyushu and western Shikoku (After YAMADA et al. 1982).

Sa: Sangun Belt, Ry: Ryoike Belt, Sm: Sambagawa Belt, C: Chichibu Belt, Sh: Shimanto Belt, MTL: Median Tectonic Line, BTL: Butsuzo Tectonic Line.

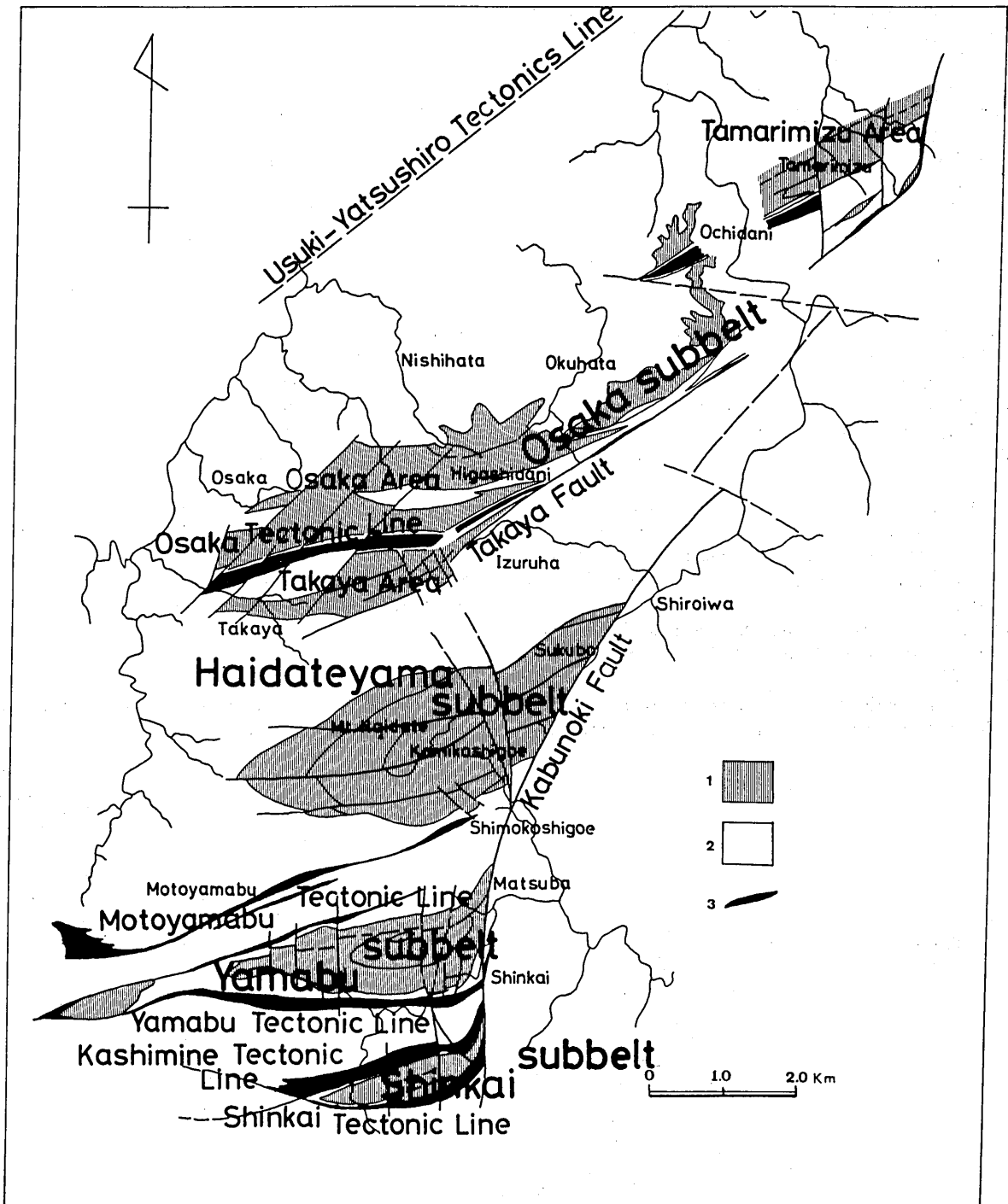


FIG. 2. Simplified geological sketch-map showing the structural division of the Haidateyama area.

1: Mesozoic rocks, 2: Basement rocks (Chichibu Supergroup), 3: Metamorphic and plutonic rocks of the Kurosegawa Tectonic Belt.

TABLE 1. CORRELATION OF THE STRATIGRAPHIC DIVISION OF THE MESOZOIC STRATA IN THE HAIDATEYAMA AREA AMONG AUTHORS.

STANDARD AGE	This paper	Tashiro et al. (1983)	Ohta & Tanaka, (1980)	Nada, (1972, 1977)	Teraoka (1970)	Fujii (1954)
CRETACEOUS	Albian	Sukubo F. Higashidani F.	IV	Sukubo F.	Higashidani F. Sukubo F. Koshigoe F.	U. M. L.
	Aptian	Tamarimizu F. Osaka F.	III	Koshigoe F.	Tamarimizu F. Ochidani ?	
	Barremian	Yamabu F.	II	Haidateyama F.		
	Hauterivian		I			
	Valanginian		(NOT SURVEYED)	Yamabu F.	Yb4 Yb3 Yb2 Yb1	Yamabu F.
JURASSIC	Tithonian	Motoyamabu F. Shinkai F.	Shinkai F.	(NOT SURVEYED)	Shinkai F.	Shinkai F.
TRIASSIC	Carnian	Kashimine F.				

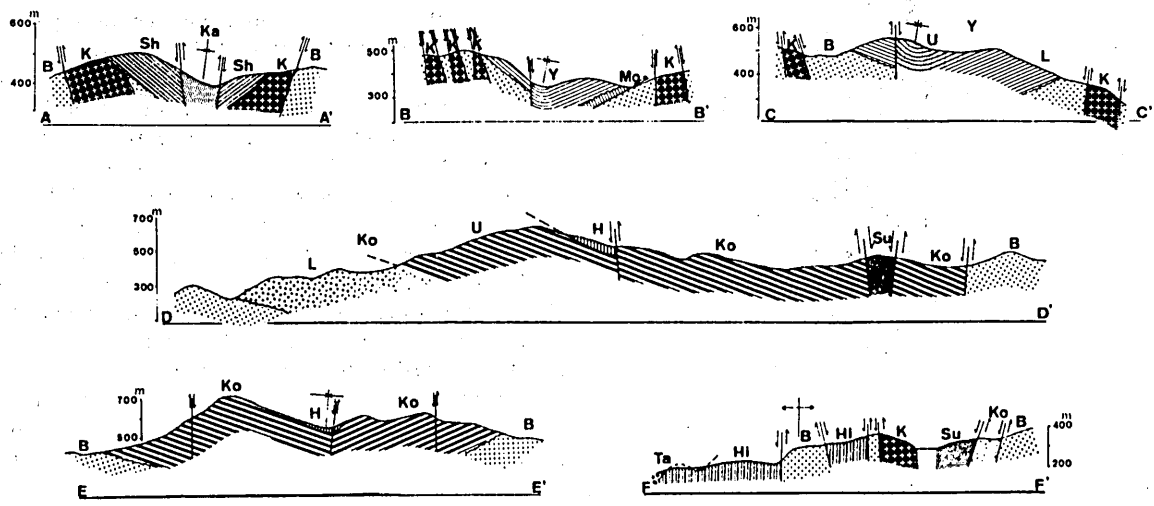


FIG. 3. Geological profiles of the Haidateyama area. Lines of sections are shown in FIG. 21.

Ta: Tano Formation, Su: Sukubo Formation, Hi: Higashidani Formation, H: Haidateyama Formation, Ko: Koshigoe Formation (L: Lower member, U: Upper member), Y: Yamabu Formation (L: Lower member, U: Upper member), Mo: Motoyamabu Formation, Sh: Shinkai Formation, Ka: Kashimine Formation, B: Basement complex, K: Metamorphic and plutonic rocks of the Kurosegawa Tectonic Belt.

Minamiyamabe-gun, Oita Prefecture.

General conception: The Kashimine Formation is characterized by gray-greenish sandstone, and contains the Kochigatani-type bivalve fauna of early Late Triassic.

Stratotype: The holostatotype (B in Fig. 5) is along the Ooyabu valley, about 2km east of Kashimine.

Thickness: 70m (columnar section D in Fig. 6).

Distribution: The formation crops out very limitedly in the central part of the Shinkai subbelt, being in fault contact with the Shinkai Formation to be described below.

Lithology and fossils: The Kashimine Formation is generally composed of greenish-gray medium- to coarse-grained sandstone with intercalation of thinly bedded conglomerate, followed by alternating beds of sandy shale and shale and further by muddy sandstone. The alternating beds contain marine fossils such as *Halobia* sp., *Tosapekten* sp., *Otapiria* sp. and *Unionites* sp.

2. Shinkai Formation

Name: The formation name was introduced by FUJII (1954). It is derived from a place-name, Shinkai.

General conception: The Shinkai Formation is composed of conglomerate, sandstone and shale, showing a hemicycle of sedimentation. Small lenses of the Torinosu-type limestone are included in its upper part.

Stratotype: The holostatotype (A in Fig. 5) is

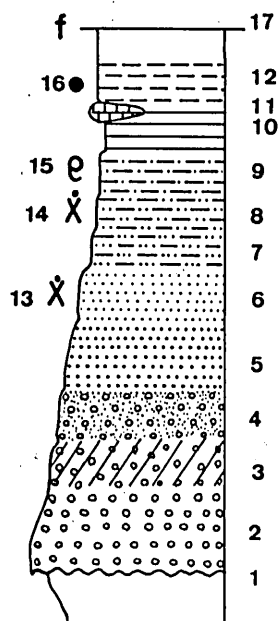


FIG. 4. Legends for the stratigraphic columnar sections. 1: Unconformity, 2: Conglomerate, 3: Red sediments, 4: Conglomeratic sandstone, 5: Coarse to medium-grained sandstone, 6: Fine-grained sandstone, 7: Sandstone and shale in alternating (sandstone being predominant), 8: Sandstone and shale in alternation (both being approximately inequal amount), 9: Sandstone and shale in alternation (shale being predominant), 10: Mudstone or sandy shale, 11: Limestone, 12: Siltstone or sandy shale, 13: Brackish-water shells, 14: Marine organisms, 15: Plants; 16: Ammonites, 17: Fault.

along the Ooyabu valley, east of Kashimine.

Thickness: 150m in maximum (columnar section A in Fig. 7).

Distribution: The formation occupies the main part of the Shinkai subbelt, forming a gentle semi-basin structure with an axis of ENE-WSW trend.

Lithology and fossils: The Shinkai Formation rests unconformably upon the granitic rocks, which belong to the older metamorphic and plutonic complex of Kurosegawa Tectonic Belt. It begins with basal conglomerate and passes upwards through sandstone to alternation of sandstone and shale. The basal conglomerate comprises mainly pebbles and cobbles of various kinds of igneous rocks (granite, granodiorite, quartz-porphry etc.), with minor amount of sedimentaries (sandstone, chert, limestone etc.). The alternation of sandstone and shale of the upper part laterally changes to dark-gray shale, which includes lenses of limestone of less than 5m thick. The limestone is composed mainly of bioclasts, oolites, intraclasts and other carbonate fragments, and contains abundant fossils such as hexacorals, stromatoporoids, calcareous algae and cidarid spine. Well-preserved radiolarian fossils listed in Table 2 are collected from the shale.

B. MESOZOIC STRATA IN THE YAMABU SUBBELT

The Yamabu subbelt is located to the north of the Shinkai subbelt, and is delimited on the north by the Motoyamabu Tectonic Line and on the south by the Yamabu Tectonic Line. The Mesozoic strata developed there are classified into two formations, the Motoyamabu and the Yamabu. The Yamabu Formation is included in the newly introduced Amabe Group.

Historical review: The Lower Cretaceous System in the Yamabu subbelt, which is characterized by the predominance of white feldspathic quartz-sandstone, was primarily named the Yamabu Formation by FUJII (1954). He considered that the main part of the formation might be correlated to the Ryoseki Group, especially the Ryoseki Formation of southern Shikoku and the Kawaguchi Formation of Yatsushiro area, western Kyushu. A similar correlation was accepted by MATSUMOTO (1954, 1967) and TERAOKA (1970). NODA (1972) reported the occurrence of Berriasella and other ammonites from dark gray shale intercalated in the basal conglomerate, and concluded that the Yamabu Formation is partly of marine origin and probably ranges down to the Berriasian in age. Recently, OHTA and TANAKA (1980) subdivided the formation in question into three members: the lower member contains ammonites, while the middle and upper members yield many brackish-water shells ("Ryoseki fauna") and terrestrial plants ("Ryoseki flora"). In this paper, the ammonite-bearing lower member of Ohta and Tanaka (1980) is separated from the Yamabu Formation proper, and is called the Motoyamabu Formation. Thus, the Mesozoic strata developed in the Yamabu subbelt are represented by the marine Motoyamabu Formation and the mostly non-marine Yamabu Formation.

1. Motoyamabu Formation

Name: New name. Motoyamabu is the name of a place which is located about 1.5km north-northeast of Katauchi, Mie-cho.

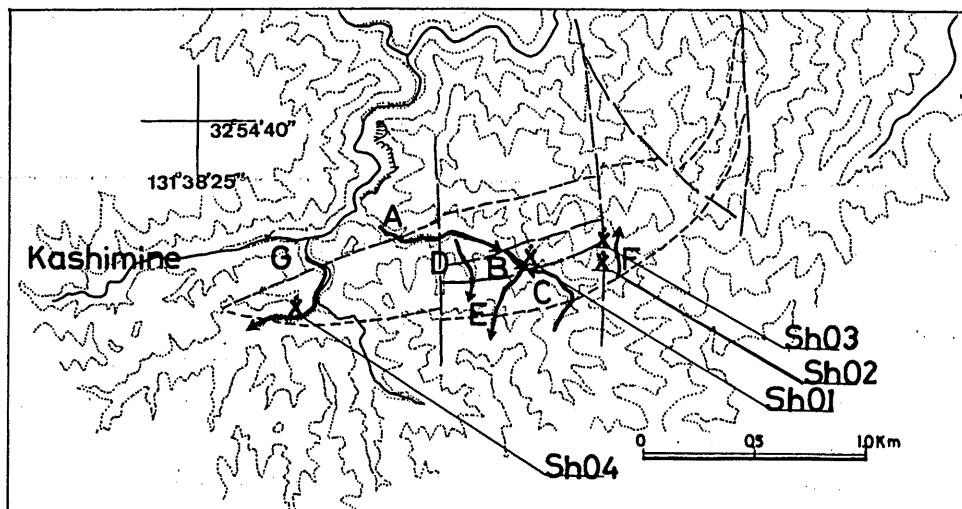


FIG. 5. Map showing the localities of stratotypes and localities of fossils in the Shinkai subbelt.

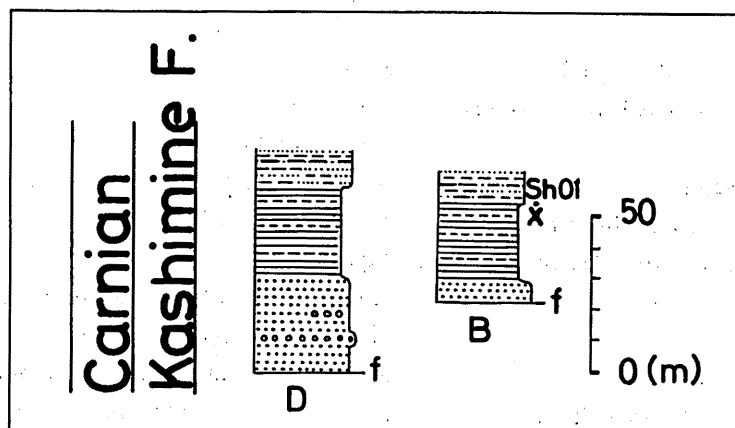


FIG. 6. Stratigraphic columnar sections of the Kashimine Formation.

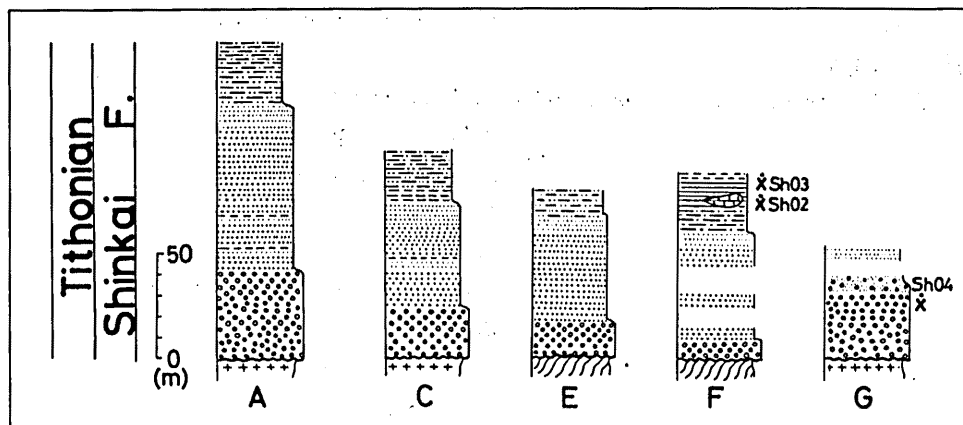


FIG. 7. Stratigraphic columnar sections of the Shinkai Formation.

TABLE 2. LIST OF THE RADIODARIAN FOSSILS FROM THE SHINKAI FORMATION (Loc. SH 03).

SPUMELLARIA	NASSELLARIA
<i>Acaeoniotyle</i> sp.	<i>Amphipyndax</i> (?) sp.
<i>Alievium</i> (?) sp.	<i>Archaeodictyomitra apiara</i> (Rüst)
<i>Angulobracchia</i> (?) sp.	A. sp. aff. <i>A. browneri</i> (T.S.Hok)
<i>Archaeospongoprimum imlayi</i> Pessagno	A. spp.
A. spp.	<i>Cinguloturris carpatica</i> Dumitrica
<i>Cromyodruppa</i> sp. aff. <i>C. concentrica</i> Lipman	C. sp. cf. <i>C. carpatica</i> Dumitrica
<i>Crucella</i> sp. cf. <i>C. theokastensis</i> Baumgartner	C. sp.
c. sp.	<i>Drolyus</i> (?) sp.
<i>Flustrella</i> (?) sp.	<i>Eucyrtidium</i> (?) <i>ptyctum</i> Riedel and Sanfilippo
<i>Haliodictya</i> sp.	E. (?) sp.
<i>Homoeoparonaella elegans</i> (Pessagno)	<i>Hsuum</i> spp.
<i>Orbiculiforma</i> sp. cf. <i>O. quadrata</i> Pessagno	H. (?) sp.
O. spp.	<i>Lupherium</i> (?) sp.
<i>Paronaella bandyi</i> Pessagno	<i>Mirifusus mediodilatatus</i> (Rust)
P. sp. cf. <i>P. kotura</i> Baumgartner	M. spp.
P. sp. cf. <i>P. mulleri</i> Pessagno	<i>Napora</i> spp.
P. sp.	<i>Parvicingula</i> sp. cf. <i>P. cosmoconica</i> (Foreman)
P. (?) sp.	P. <i>hsui</i> Pessagno
<i>Praeconocaryomma</i> (?) sp.	P. sp. cf. <i>P. hsui</i> Pessagno
<i>Sphaerostylus lanceola</i> (Parona) Group	P. sp. aff. <i>P. hsui</i> Pessagno
<i>Spongodiscus</i> sp.	P. (?) spp.
<i>Spongopyle</i> sp. aff. <i>S. insolita</i> Kozlova	<i>Podobursa</i> sp. cf. <i>P. triacantha</i> (Fischli)
S. spp.	P. spp.
<i>Triactoma</i> sp.	<i>Protunuma</i> sp. D
<i>Tripodietya</i> (?) sp.	<i>Pseudodictyomyra</i> sp. A
<i>Tritrabs hayi</i> (Pessagno)	p. sp. B
T. sp. aff. <i>T. casmaliensis</i> (Pessagno)	<i>Sethocapsa</i> spp.
T. sp.	S. (?) spp.
	<i>Solenotryma</i> sp. A
	S. sp. B
	S. sp.
	<i>Stylocapsa</i> (?) <i>spralis</i> Matsuoka
	S. (?) sp.
	<i>Tricolocapsa</i> sp. A
	<i>Xitus</i> spp.

General conception: The Motoyamabu Formation is characterized by the development of dark gray shale including Tithonian-Berriasian ammonites.

Stratotype: The holostratotype (C in Fig. 8) is along the valley of ENE-WSW trend, about 1.5km east of Katauchi.

Thickness : 50m (columnar section C in Fig. 9).

Distribution: The formation is very narrowly distributed near the southern margin of the Yamabu subbelt, overlain unconformably by the Yamabu Formation to be described below.

Lithology and fossils: The present formation is composed of alternating beds of sandy shale and mudstone in the lower part and dark gray shale in the upper. The basal part is not exposed owing to the presumable fault. In addition to *Berriasella* sp. and *Pseudo-osterella* sp. which had been reported by NODA (1972), *Tithoniceras* sp. and *Thurmanniceras* (?) sp. were collected by myself from the upper shale.

2. Yamabu Formation

Name: The formation name was first introduced by FUJII (1954). It is derived from a place-name, Yamabu, 1.5km westnorthwest of Katauchi.

General conception: The Yamabu Formation is characterized by white arkose or feldspathic quartz-sandstone. It yields brackish-water pelecypods and gastropods ("Ryoseki fauna"), together with plant remains. This formation is subdivided lithostratigraphically into two members, the lower and the upper.

Stratotype: The holostratotype (D in Fig. 8) is along the road-cutting on the southern slope of Mt. Ohyama, east of Katauchi. The parastratotype (E in Fig. 8) is along the valley of NW-SE trend adjacent to the holostratotype.

Thickness: 500m - in maximum (columnar section E in Fig. 9).

Distribution: The formation occupies the main part of the Yamabu subbelt, forming an asymmetric

syncline with an axis of E-W trend. It overlies unconformably the Motoyamabu Formation locally, and oversteps directly the pre-Cretaceous rocks in most places. Along the eastern margin, however, a fault (Kabunoki Fault) is traceable between the Yamabu Formation and the basement complex.

Lithology and fossils:

a. Lower member

The lower member shows an upward-finishing hemicycle of sedimentation, consisting generally of conglomerate, sandstone, alternating beds of sandstone and mudstone, and mudstone in ascending order. The thickness is about 250 m. The basal conglomerate is made up of well-rounded boulders, cobbles and pebbles of various kinds of igneous and sedimentary rocks (granite, aplite, diorite, quartz-porphry, porphyry, sandstone, shale, chert etc.). The matrix is usually sandy, and rarely muddy. The succeeding sandstone is represented by white to white-gray, fine- to medium-grained arkose or feldspathic quartz-sandstone. Thin layers of shale are intercalated in it. The remaining part is mainly composed of sandstone and mudstone in alternation, with rather thick mudstone at the top. A graded bedding is observable in the alternation.

b. Upper member

The upper member, about 250m thick, overlies conformably the lower member, and is overlain with a distinct unconformity by the Sukubo Formation to be described below. It also shows an upward-finishing hemicycle, beginning with conglomerate. The conglomerate is similar in lithology to that of the lower member, with more muddy matrix. The main part of this member is chiefly composed of thick sandstone and alternating beds of sandstone and mudstone, while the uppermost part of dark-gray sandy shale. Ripple marks are observable at the top and bottom of interbedded sandstone.

The Yamabu Formation contains abundant brackish-water shells, together with plant remains. They

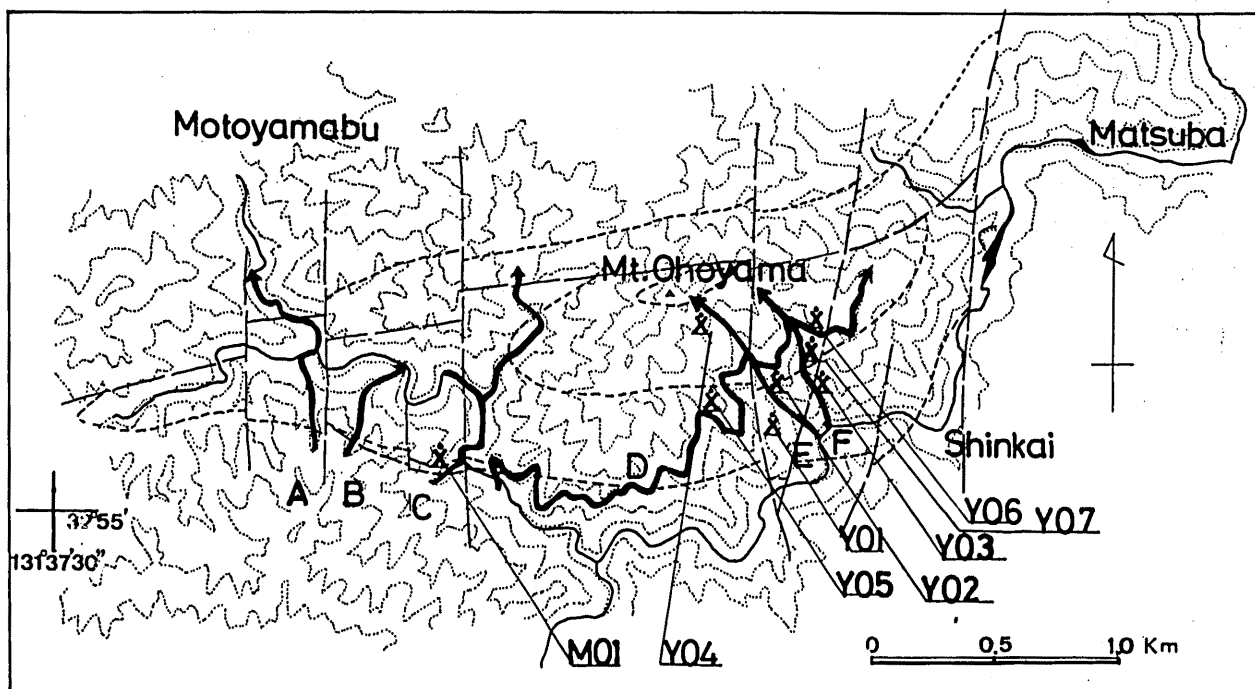


FIG. 8. Map showing the localities of stratotypes and localities of fossils in the Yamabu subbelt.

TABLE 3. LIST OF THE MOLLUSCAN FOSSILS FROM THE YAMABU FORMATION.

<i>Isodomella matsumotoi</i> Ohta.....	Y01, Y02, Y04, Y05, Y06
<i>Bakevelloides (Yoshimopsis) nagatoensis</i> Ohta.....	Y01, Y02, Y03
<i>Eomiodon nipponicus</i> Ohta.....	Y02, Y04, Y05
<i>E. matsumotoi</i> Ohta.....	Y01, Y03, Y04, Y05
<i>Hayamina</i> sp.	Y01, Y03, Y05, Y06
<i>Leptosolen</i> sp.	Y01, Y04
<i>Pulsides nagatoensis</i> Ohta.....	Y01, Y02, Y04
<i>Tetoria (Yoshimoa) yoshimoensis</i> Ohta.....	Y01, Y03
<i>Crassostrea</i> aff. <i>yoshimoensis</i> Kobayashi and Suzuki...	Y04, Y05, Y06
<i>Ostrea</i> cf. <i>ryosekiensis</i> Kobayashi and Suzuki.....	Y02, Y03, Y06
<i>Melanoides (Kumania) kawaguchiensis</i> Ohta.....	Y01, Y04, Y05
<i>Melanoides</i> sp.	Y04, Y05
<i>Pterotriconia</i> sp.	Y07
<i>Astarte (Yabea)</i> sp.	Y07

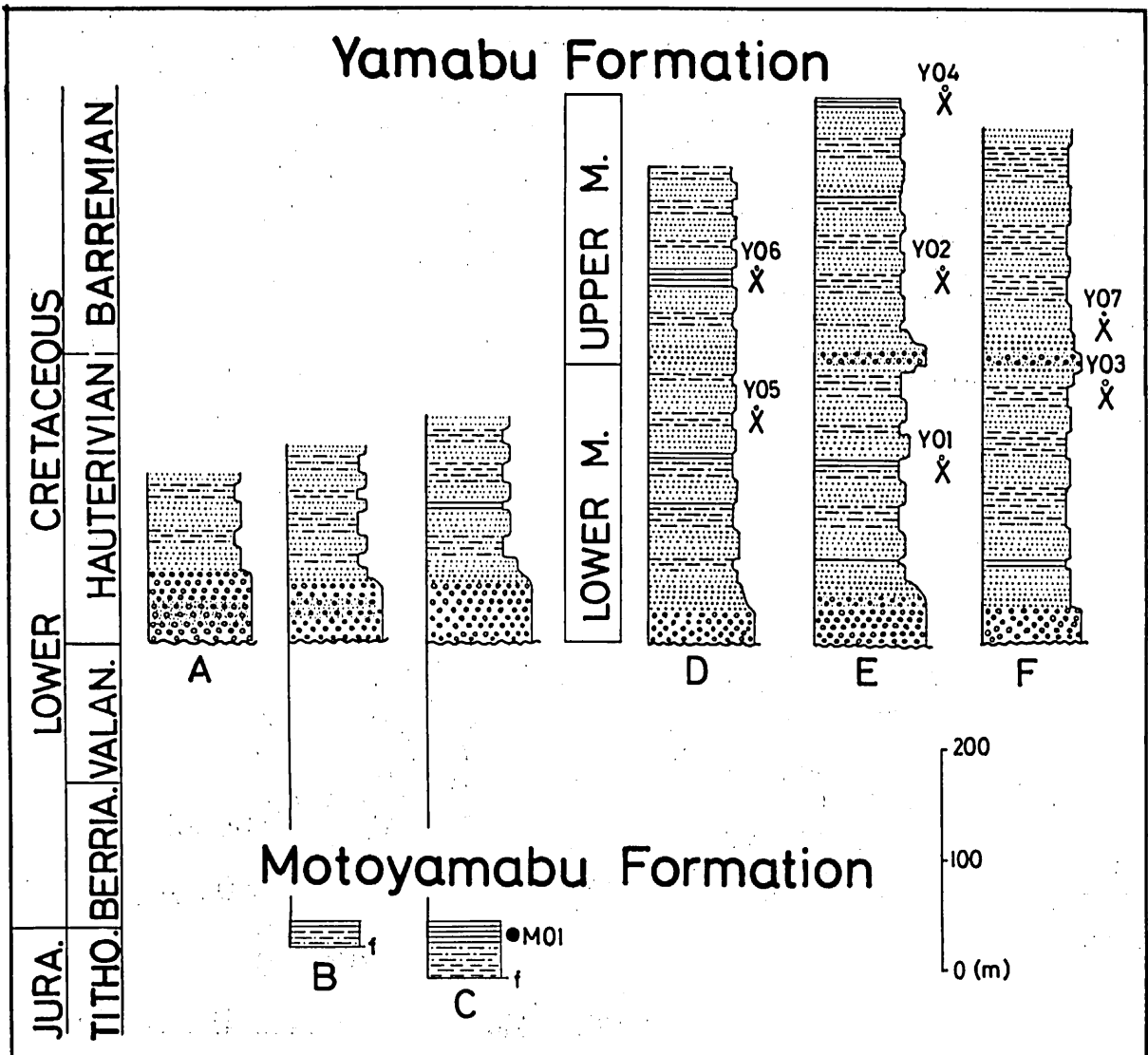


FIG. 9. Stratigraphic columnar sections of the Motoyamabu and Yamabu Formations.

are shown on Table 3. Among the listed species, *Hayamina* sp., *H. carinata*, *Isodomella matsumotoi*, *Bakevelloides nagatoensis* and *Eomiodon nipponicus* are diagnostic. Besides, poorly preserved marine bivalves such as *Pterotrigonia* sp. and *Astarte* (*Yabea*) sp. are rarely obtained from thin layers of medium- to fine-grained sandstone near locality Y07.

C. MESOZOIC STRATA IN THE HAIDATEYAMA SUBBELT

The Haidateyama subbelt occupies a central part of the surveyed area, and is delimited on the north by the Osaka Tectonic Line and on the south by the Motoyamabu Tectonic Line. The Lower Cretaceous strata are typically exposed around Mt. Haidate (754 m) situated on the boundary of Minami-amabe-gun and Ono-gun. Another exposure is found in the vicinity of Takaya, north of Mt. Haidate. The Lower Cretaceous System in the Haidateyama subbelt is divided into the Koshigoe, Haidateyama, Tamarimizu and Sukubo Formations, of which the former two are included in the redefined Haidateyama Group and the latter two in the Amabe Group. The Amabe Group is a new name derived from a district-name, Minami-amabe-gun.

Historical review: The stratigraphy and geologic structure of this area were previously reported by FUJII (1954). He described the Cretaceous strata characterized by the development of red-colored conglomerate and sandy shale under the name of the Haidateyama Formation, and correlated it to the Albian Yatsushiro Formation of western Kyushu. The name of the Haidateyama "Group" was later used by TERAOKA (1970) instead of "Formaiton". Teraoka suggested that this group may include somewhat younger sediments than the Yatsushiro Formation. NODA (1977) obtained a specimen of ammonite from the lower member of his Haidateyama Formation, and concluded that the age of the formation ranges down probably to the latest Barremian or earliest Aptian. TANAKA and OHTA (1980) reexamined the stratigraphy of the "Haidateyama Group" at its type locality, and divided it into the Haidateyama, Koshigoe and Sukubo Formations in ascending order, of which the Koshigoe Formation is all of brackish-water environment. TASHIRO, TANAKA and MATSUDA (1983) also attempted the stratigraphic division, and pointed out that the Aptian-Lower Albian strata are lacking in this area.

The following is the revised stratigraphy based on my recent research.

1. Koshigoe Formation

Name: The formation name was first used by TERAOKA (1970). It is derived from a place-name, Kamikoshigoe, 1.2 km east of Mt. Haidate. This formation is nearly correlated with the Haidate I and II formations of TASHIRO et al. (1983).

General conception: The Koshigoe Formation, an equivalent of the Yamabu Formation and of the Ryoseki Formation in Shikoku, is characterized by the frequent occurrence of red-colored rocks, with intercalation of brackish-water shell beds and plant beds. It is lithostratigraphically subdivided into the lower and upper members.

Stratotype: The holostatotype (B in Fig. 10) is on the north-western slope of Mt. Haidate. The

parastratotype (C in Fig. 10) is along the road from Kamikoshigoe to the summit of Mt. Haidate.

Thickness: 900 m in maximum (columnar section A in Fig. 11).

Distribution: The Koshigoe Formation is distributed widely around Mt. Haidate, from its western slope to Sukubo, forming a gentle semi-basin structure with an axis of ENE-WSW direction. The lower member is also exposed in the Takaya area. The formation covers the pre-Cretaceous basement rocks with a clino-unconformity both in the Mt. Haidate and Takaya areas, although a fault contact is observable in some places.

Lithology and fossils :

a. Lower member

The lower member, about 400 m thick, is composed mainly of thick-bedded reddish conglomerate with occasional intercalation of thin layers of coarse- to medium-grained sandstone and sandy shale. The conglomerate is moderately sorted, comprising sub-rounded to rounded boulders and cobbles of chert, sandstone and granitic rocks. The maximum diameter of boulders reaches 50 cm. The interbedded sandstone ranges in thickness from a few centimeters to 50 cm, and changes laterally to sandy shale. In the Takaya area, the reddish conglomerate of 150 m thick referable to the lower member is exposed.

b. Upper member

The upper member, about 500 m thick, overlies conformably the lower member in some places and oversteps directly the basement complex in others. Its top is covered by the Haidateyama Formation to be described below. It is composed mainly of conglomerate with intercalation of layers of sandstone and shale, showing the repetition of upward-fining minor sedimentary cycles, each of which is 30-70 m thick. The conglomerate comprises somewhat rounded pebbles and cobbles of chert and sandstone. Both the sandstone and shale in the middle and upper parts of this member yield abundant non-marine shells belonging to the so-called Ryoseki fauna. They are shown on Table 4. Among the listed species, *Hayamina bungoensis* and *Costocyrena otsukai* are most diagnostic.

2. Haidateyama Formation

Name: The formation name was introduced by FUJII (1954). It is derived from a mountain-name, Haidateyama (Mt. Haidate). This formation is nearly identical with the Haidate III formation of TASHIRO et al. (1983).

General conception: The Haidateyama Formation is characterized by sandy facies in the lower part and muddy facies in the upper. Abundant shallow marine bivalves, belonging to the Ishido type fauna, and a few important ammonites are found.

Stratotype: The holostatotype (a part of A in Fig. 10) is on the road-cutting and cliff located 0.5 km south-southeast of Mt. Haidate. The parastratotype (a part of E in Fig. 10) is on the road-cutting, 1.0-1.5 km southwest of Sukubo, Notsu-cho.

Thickness: 250 m in rough estimation (columnar section A and E in Fig. 11).

Distribution: The formation is distributed near the summit of Mt. Haidate and near Sukubo, overlying conformably the upper member of the Koshigoe Formation. Another limited exposure occurs in the

vicinity of Ishiba dam, east of Takaya, where a fault relation with the Koshigoe Formation is presumable.

Lithology and fossils: The Haidateyama Formation begins with conglomeratic sandstone, and is followed by fine-grained sandstone with intercalation of alternating beds of sandstone and shale, and further by thick-bedded dark gray sandy shale and shale. The basal conglomeratic sandstone is about 5 m thick, and is composed mainly of rounded granules of chert and sandstone, changing laterally to pebble-conglomerate. The upper thick-bedded sandy shale and shale are 150 m thick and lithologically unchangeable laterally, containing marine fossils such as cephalopods, pelecypods, gastropods and echinoids at several horizons. The identified species are listed on Table 5. The alternating beds of sandstone and shale in the lower part also yield some molluscan fossils.

3. Tamarimizu Formation

Name: The formation name was introduced by TERAOKA (1970). Tamarimizu is the name of a place which is located about 3km southeast of Notsu-ichi, Notsu-cho.

General conception: The Tamarimizu Formation is distributed both in the Haidateyama subbelt (Takaya area) and in the Osaka subbelt (Tamarimizu area) to be described below. It is characterized by the predominance of fine-grained arenite sandstone. Abundant bivalves are found in addition to ammonites. There is a difference in fossil contents between the Takaya and Tamarimizu areas, and it is considered that the somewhat higher horizon is exposed in the latter area.

Stratotype: One of the stratotypes (J in Fig. 14) is at the quarry located about 0.8km southwest of Tamarimizu, Tamarimizu area. The other stratotype (a part of I in Fig. 10) is on the road-cutting near Ishiba dam, Takaya area.

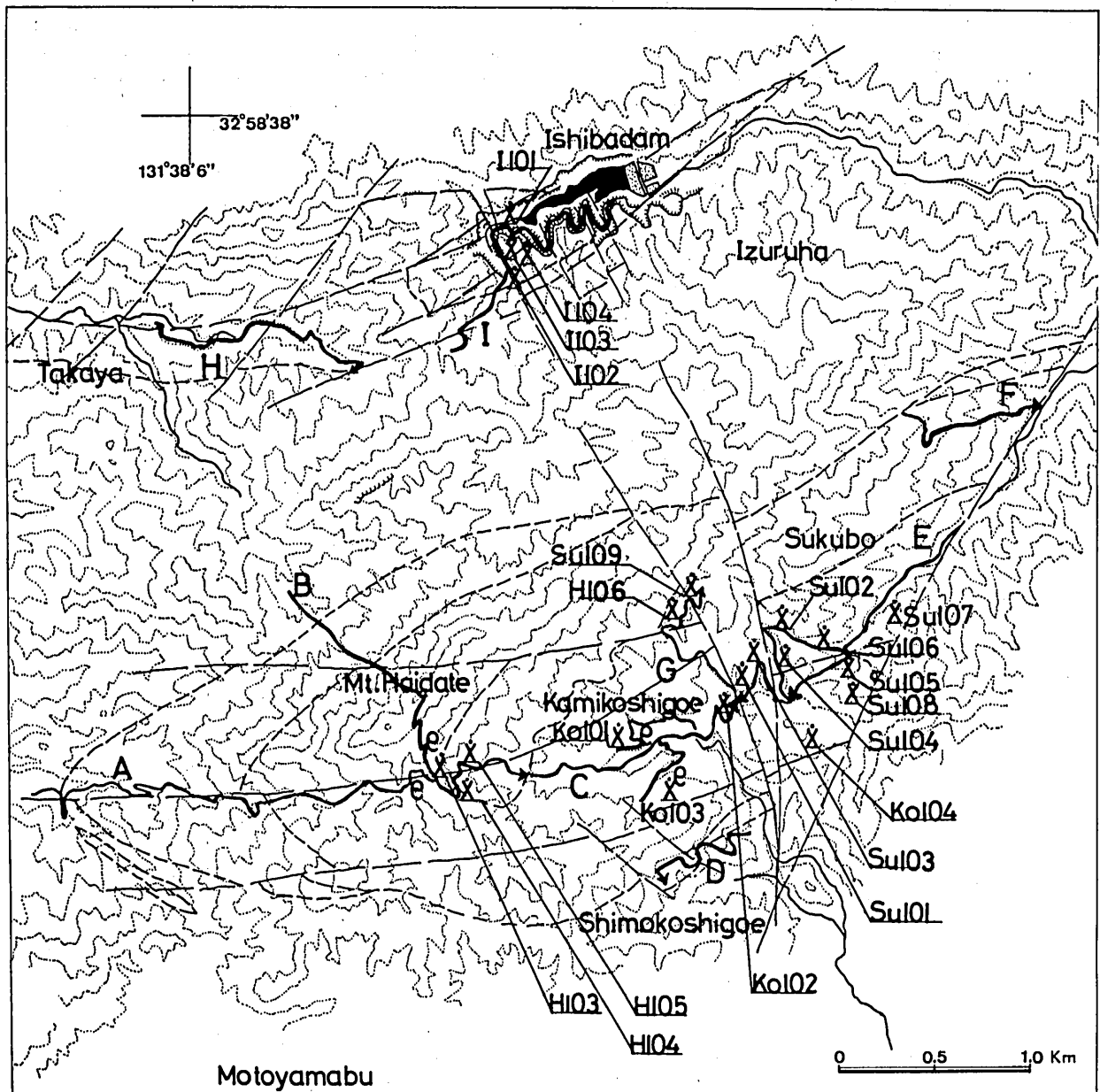


FIG. 10. Map showing the localities of stratotypes and localities of fossils in the Haidateyama subbelt.

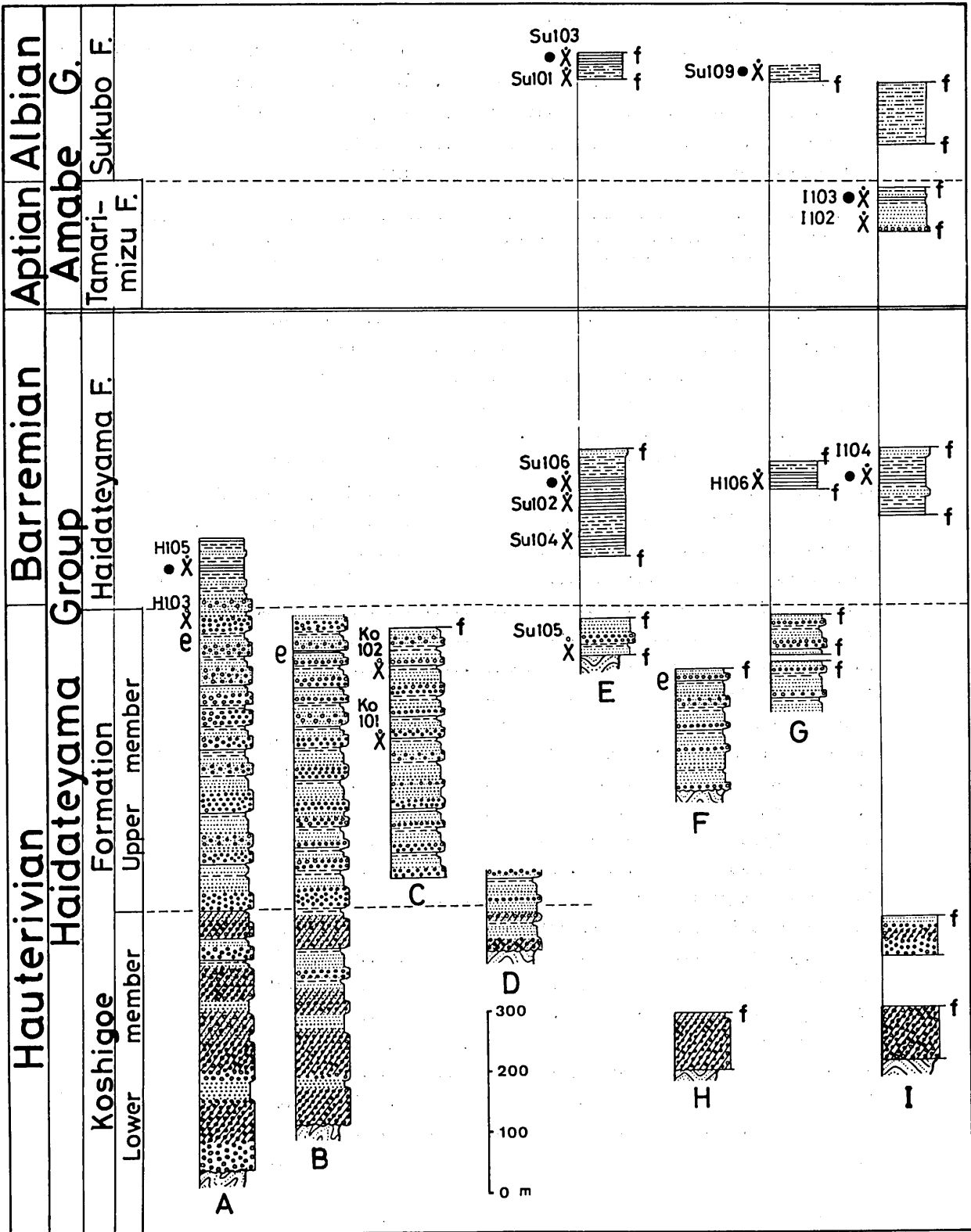


FIG. 11. Stratigraphic columnar sections of the Haidateyama and Amabe Groups in the Haidateyama subbelt.

TABLE 4. LIST OF THE MOLLUSCAN FOSSILS FROM THE KOSHIGOE FORMATION.

<i>Ostrea</i> sp.	Kol01, Kol02, Kol03, Su105
<i>Protocardia</i> sp.	Kol02
<i>Eomitodon</i> aff. <i>matsumotoi</i> Ohta.....	Kol01, Kol02
<i>Hayamina bungoensis</i> Ohta.....	H103, Kol01, Kol02, Kol03, Su105
<i>Costocyrena otsukai</i> (Yabe and Nagao)....	Kol01, Kol02, Kol03
<i>Tetoria (Haidatina) koshigoensis</i> Ohta...	Kol01, Kol02, Kol03
<i>Pulsidis</i> sp.	Kol01, Kol02
" <i>Corbicula</i> " sp.	Kol02

TABLE 5. LIST OF THE MOLLUSCAN FOSSILS FROM THE HAIDATEYAMA FORMATION.

<i>Portlandia</i> cf. <i>sanchuensis</i> Yabe and Nagao.....	H105
<i>Cosmetodon nipponicus</i> (Nagao).....	H105, Su106
<i>Nanonavis yokoyamai</i> (Yabe and Nagao).....	H105, H106, Su106, I104
<i>Modiolus</i> aff. <i>subsimpler</i> d'Orbigny.....	H105
<i>Amygdalum ishidoensis</i> (Yabe and Nagao).....	I104
<i>Pinna</i> sp.	H105, Su106, I104
<i>Pterinella shinoharai</i> Hayami.....	H105, Su104
<i>Gervillaria haradae</i> (Yokoyama).....	H105, H106, Su106, I104
<i>Gervillia</i> (s.s) <i>forbesiana</i> d'Orbigny.....	H105, Su104, I104
<i>Entolium</i> sp.	H105
<i>Neithea</i> (s.s) <i>atava</i> (Romer).....	H105, H106, Su102, I104
<i>Plicatula kiiensis</i> Hayami.....	H105, Su106, I101, I104
<i>P.</i> sp.	I104
<i>Rastellum (Arctostrea) carinatum</i> (Lamarck).....	Su102, Su104, I102
<i>Nipponitrigonia</i> aff. <i>sakamotoensis</i> (Yehara).....	Su107
<i>Pterotrigonia</i> (s.s) <i>pocilliformis</i> (Yokoyama) A form...	H104, H105, H106, Su104
<i>Astarte</i> (s.s) <i>subsenecta</i> (Yabe and Nagao).....	Su102, I104 H105, H106
<i>A.</i> sp. nov. A.	Su106, I104 H105
<i>A.</i> sp. nov. B.	I104
<i>A.</i> (<i>Yabea</i>) <i>shinanoensis</i> Yabe and Nagao.....	H105, I104
<i>Globocardium</i> sp.	I104
<i>Pachythaerus kagaharaensis</i> (Yokoyama).....	H105, I104
<i>Panoepa (Myopsis) plicata</i> (Sowerby).....	H105, Su102, Su106, Su107
<i>Pholadomya</i> sp.	H105, I104
<i>Goniomya</i> sp.	H105, Su102, Su107
<i>Ptychomya densicostata</i> (Yokoyama).....	H105, H106
<i>Plectomya</i> sp. cf. <i>P. aritagawana</i> Hayami.....	Su102
<i>Heteraster macroholcus</i> (Nishimura).....	H105, H106, Su102
<i>H.</i> <i>bungoensis</i> Tanaka and Noda.....	H105, H106, Su104
<i>H.</i> sp.	Su104
<i>Pseudowashitaster mysticus</i> Tanaka.....	H105, H106
<i>Crioceratites</i> cf. <i>koechlini</i> (Astier).....	H105
<i>Uhligia</i> sp.	H105
<i>Heminautilus lallierianus</i> (d'Orbigny).....	H105
<i>Cymatoceras</i> spp.	I104
<i>Pedioceras</i> sp.	I104

TABLE 6. LIST OF THE MOLLUSCAN FOSSILS FROM THE TAMARIMIZU FORMATION.

<i>Cucullaea fujii</i> Hayami.....	Ta501
<i>Glycymeris</i> sp.	Ta501
<i>Pinna</i> cf. <i>robinaldina</i> d'Orbigny.....	Ta501
<i>Gervillia</i> cf. <i>forbesiana</i> d'Orbigny.....	I103
<i>Nippononectes tamarimizuensis</i> m.s.	Ta501
<i>Neithea</i> (<i>Neithea</i>) <i>syriaca amanoi</i> (Hayami).....	Ta501
<i>Pterotrignia</i> cf. <i>hokkaidoana</i> (Yehara).....	Ta501, I103
<i>Nipponitrigonia</i> aff. <i>kikuchiana</i> (Yokoyama).....	Ta501
<i>Astarte</i> (s.s) <i>subsenecta</i> Yabe and Nagao.....	Ta501, I103
<i>Protocardia amanoi</i> Tashiro and Matsuda	I103
<i>Xenocardita amanoi</i> (Hayami).....	Ta501
<i>Chelonicerias</i> sp.	I103
<i>Dufrenoyia</i> aff. <i>justinae</i> (Hill).....	I103

TABLE 7. LIST OF THE MOLLUSCAN FOSSILS FROM THE SUKUBO FORMATION.

<i>Nucula</i> (<i>Leionucula</i>) <i>haidatensis</i> Tashiro and Matsuda.....	Sul01, Sul03
<i>Mesosacella insignis</i> (Nagao).....	Sul01, Sul03
<i>Nanonavis pseudocarinata</i> Tashiro and Matsuda.....	Sul01, Sul03
<i>Modiolus sukuboensis</i> Tashiro and Matsuda.....	Sul01, Sul03
<i>Pinna</i> (<i>Pinna</i>) aff. <i>robinaldina</i> d'Orbigny.....	Sul01, Sul03
<i>Inoceramus anglicus</i> Wood.....	Sul03
<i>Neithea</i> (<i>Neithea</i>) <i>matsumotoi</i> Hayami.....	Sul01, Sul03
<i>Parvamussium</i> sp.	Sul01
<i>Plicatula</i> sp.	Sul01, Sul03
<i>Pterotrignia</i> (<i>Pterotrignia</i>) cf. <i>yokoyamai</i> (Yehara).....	Sul01, Sul03, Sul09
P. (<i>Ptilotrignia</i>) <i>tanakai</i> Tashiro and Matsuda..	Sul03
<i>Astarte</i> (<i>Astarte</i>) <i>subsenecta</i> Yabe and Nagao.....	Sul01, Sul03, Sul09
A. (<i>Yabea</i>) <i>akatsui</i> Hayami.....	Sul01, Sul03
A. (<i>Nicaniella</i>) <i>sukuboensis</i> Tashiro and Matsuda.....	Sul03
<i>Bungoella yabeaformis</i> Tashiro and Matsuda.....	Sul03
<i>Pachythaerus nagaoi</i> (Matsumoto).....	Sul01, Sul03
? <i>Granocardium</i> (<i>Ethmocardium</i>) sp.	Sul03
<i>Leptosolen</i> sp.	Sul03
<i>Pholadomya</i> (<i>Phladomya</i>) sp.	Sul01, Sul03
P. (<i>Bucardiomya</i>) sp.	Sul03
<i>Goniomya</i> (<i>Goniomya</i>) cf. <i>subarchiaci</i> Nagao.....	Sul01, Sul03
<i>Plectomya amabeana</i> Tashiro and Matsuda.....	Sul01, Sul03
<i>Platymyoidea nipponica</i> Tashiro and Matsuda.....	Sul03
? <i>Laternula</i> sp.	Sul03
<i>Idiohamites</i> cf. <i>subspiniger</i> Spath.....	Sul03
I. cf. <i>favrinus</i> Pictet.....	Sul03
<i>Hamites</i> cf. <i>tenuicostatus</i> Spath.....	Sul03
? <i>Protanisoceras</i> cf. <i>iternotuberculatus</i> (Leymry).....	Sul03

Thickness: 80m- (columnar section I in Fig. 11).

Distribution: In the Haidateyama subbelt the formation is distributed only in a very limited area near Ishiba dam, being interspaced between two parallel faults of NE-SW trend.

Lithology and fossils: The Tamarimizu Formation of the Takaya area is composed mainly of massive, fine-grained, greenish-gray arenite sandstone, with a conglomerate at the base (the very base not exposed) and with alternating beds of sandstone and shale at the top. The conglomerate comprises pebbles and cobbles of various kinds of igneous and sedimentary rocks (granite, diorite, porphyrite, sandstone, shale, chert etc.). The matrix is bluish and sandy. The greenish-gray arenite sandstone of the main part is about 70m thick, changes laterally to sandy shale, and contains marine fossils such as cephalopods, pelecypods and gastropods at several horizons. Table 6 shows the list of identified species from the Tamarimizu Formation in the Tamarimizu area (Loc. Ta501) and Takaya area (Loc. 1103).

4. Sukubo Formation

Name: The formation name was first used by TERAOKA (1970). It is derived from a place-name, Sukubo, 3km east-northeast of Mt. Haidate. This formation is nearly correlated with the Haidate IV formation of TASHIRO et al. (1983).

General conception: The Sukubo Formation is characterized by dark gray mudstone in the main part. It yields abundant marine fossils (bivalves and ammonites) of late Albian age.

Stratotype: The holostatotype (a part of E in Fig. 10) is on the road-cutting located about 1.7km east of Mt. Haidate. It includes fossil localities, Su 101 and Su103.

Thickness: 40m (columnar section E in Fig. 11).

Distribution: The formation shows a cuneiform distribution between two faults of NNW-SSE and NW-SE trends on the eastern slope of Mt. Haidate. It is also exposed narrowly near Ishiba dam (Takaya area).

Lithology and fossils: The Sukubo Formation is mainly composed of dark gray mudstone with thin interbeds of finegrained sandstone in the lower part. In the Takaya area occurs a rhythmic alternation of sandstone and shale. The mudstone contains abundant well-preserved marine bivalves, together with ammonites. The identified species are listed on Table 7.

D. MESOZOIC STRATA IN THE OSAKA SUBBELT

The Osaka subbelt occupies the northernmost part of the surveyed area. It is delimited on the south by the Osaka Tectonic Line and is covered on the north by the Upper Cretaceous Tano Group and the Quaternary volcanic ejecta. Two narrow zones are separated by the interposition of basement complex extending in ENE-WSW trend. The Lower Cretaceous strata are distributed in two areas, that is, the Osaka area (central and western parts of the subbelt) and the Tamarimizu area (eastern part of the subbelt). Owing to the covering of the Quaternary volcanics, it is fairly difficult to make clear the stratigraphy and geologic structure of the Cretaceous rocks in detail.

The Lower Cretaceous System developed in the Osaka subbelt is divided into the Osaka, Tamarimizu and Higashidani Formations, of which the first and the third are included in the Haidateyama Group and the second in the Amabe Group.

Historical review: The stratigraphy and geologic structure of this subbelt were first reported by FUJII (1954) and then by TERAOKA (1970). TERAOKA separated the Tamarimizu Formation from the Haidateyama Formation of Fujii, and reported the occurrence of *Chelonicerias* (?) sp. (preliminary identification by MATSUMOTO) from the former. This fact suggests a possibility of the presence of the Upper Aptian in the so-called Haidateyama Group (s.l.). On the basis of my recent research, the Lower Cretaceous stratigraphy of the Osaka subbelt is summarized as follows.

1. Osaka Formation

Name: New name, derived from a place-name, Osaka, about 3km east-northeast of Ichiba, Mie-cho.

General conception: The Osaka Formation is characterized by sandstone, often calcareous and sometimes conglomeratic, accompanied with alternating beds of sandstone and shale and sandy shale. Lenses and nodules of limestone are included. Shallow marine bivalves and other fossils are found at horizons.

Stratotype: The holostatotype (C in Fig. 12) is along the narrow path, about 1km southeast of Osaka.

Thickness: 250m in rough estimation (columnar section C in Fig. 13).

Distribution: This formation is discontinuously distributed from Osaka to Tamarimizu in two zones separated by the exposure of basement rocks. As a whole, it forms an anticlinal structure with an axis trending ENE-WSW, modified by parallel faults. The base of the formation is in fault contact with the pre-Cretaceous rocks, while the top is unconformably overlain by the Upper Cretaceous Tano Group.

Lithology and fossils: In the Osaka area, the lower half of this formation is composed of conglomeratic or pebbly sandstone, medium- to coarse-grained calcareous sandstone, alternating beds of sandstone and shale, and dark gray sandy shale in ascending order. Patches of limestone are frequently included in the massive sandstone. The upper half is mainly composed of fine-grained sandstone accompanied with conglomeratic sandstone and dark gray siltstone. Lenses of limestone are also included. The conglomeratic sandstone often contains subrounded granules and pebbles of chert, sandstone, shale and granitic rocks, yielding hippuritids (bivalve). In the Tamarimizu area, the formation consists of conglomerate and thick-bedded sandstone with intercalation of thin-bedded sandy shale. A lenticular limestone occurs locally.

The Osaka Formation contains abundant shallow marine fossils such as pelecypods (including hippuritids and rudistids), gastropods, corals, bryozoans and echinoids. Ammonites are also obtained from the Tamarimizu area (Loc. Ta502). Locally, the lower part yields brackish-water shells (Loc. Hg05). Table 8 shows the list of identified species.

2. Tamarimizu Formation

Thickness: 40m-(columnar section J in Fig. 15).

Distribution: In the Osaka subbelt this forma-

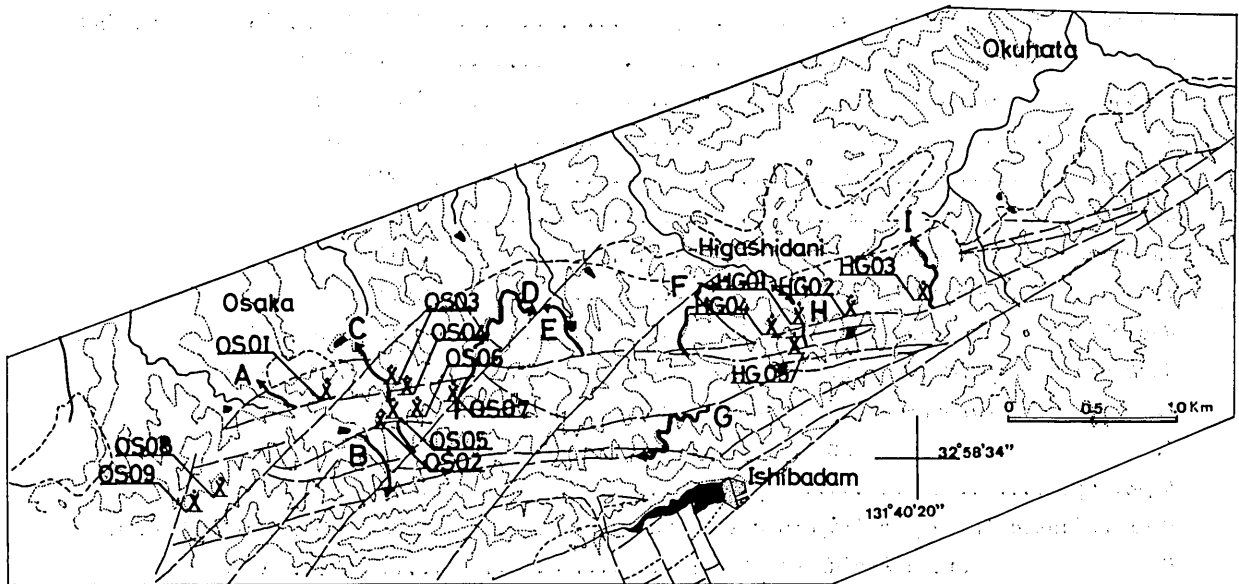


FIG. 12. Map showing the localities of stratotypes and localities of fossils in the Osaka subbelt (Osaka area).

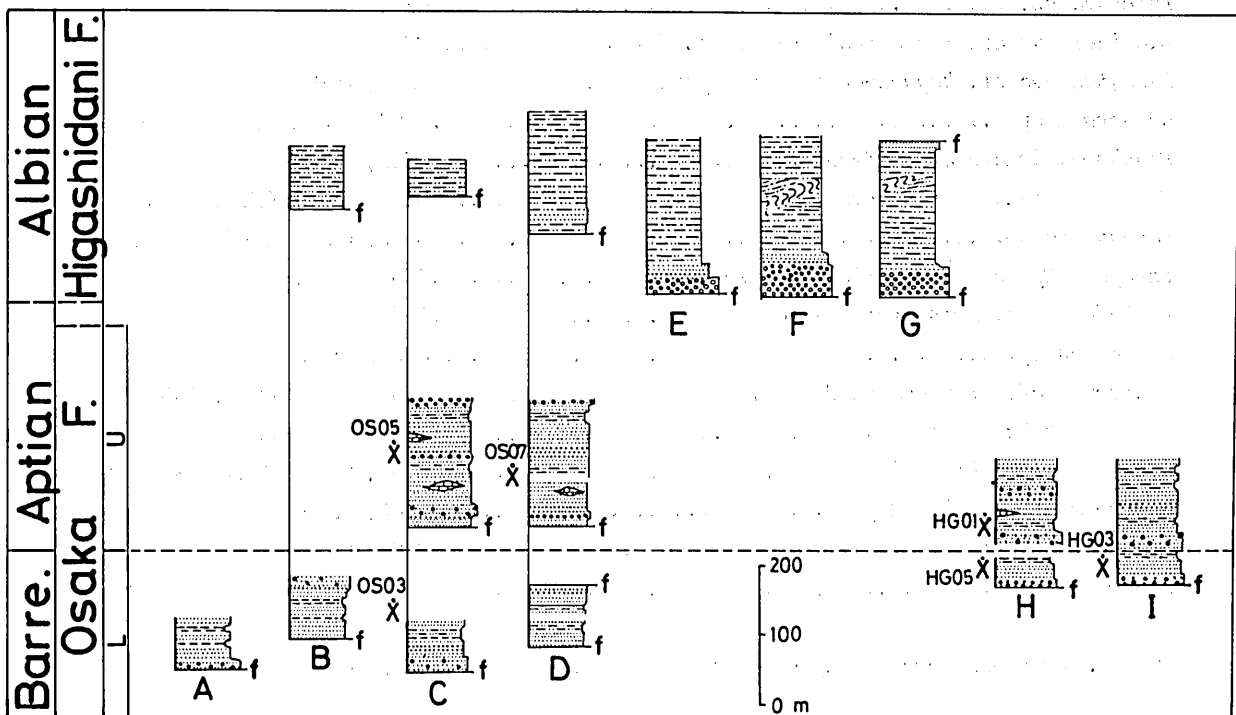


FIG. 13. Stratigraphic columnar sections of the Haidateyama Group in the Osaka subbelt (Osaka area).

TABLE 8. LIST OF THE MOLLUSCAN FOSSILS FROM THE OSAKA FORMATION.

<i>Nuculopsis (Palaeonucula) ishidoensis</i> (Yabe and Nagao)....	OS04, OS06
<i>Nanonavis yokoyamai</i> (Yabe and Nagao).....	Ta502
<i>Pinna</i> cf. <i>robinaldina</i> d'Orbigny	OS07
<i>Gervillia</i> aff. <i>forbesiana</i> d'Orbigny.....	OS04
<i>Gervillaria osakaensis</i> m.s.	OS02, OS03, OS05, OS06, OS07
<i>G.</i> sp.	OS04, Ta502
<i>Neithea atava miensis</i> m.s.	OS02, Ta502
<i>N.</i> sp.	OS06, OS07
<i>Chlamys</i> sp.	Ta502
<i>Entolium sanchuensis</i> Hayami.....	Ta502
<i>Isognomon</i> cf. <i>sanchuense</i> (Yabe and Nagao).....	Ta502
<i>I.</i> cf. <i>choshiensis</i> Hayami.....	OS02
<i>Rastellum (Arctostrea) carinatum</i> (Lamark).....	OS02, OS03, OS04, OS08, HG02
<i>Amphidonte (Amphidonte)</i> cf. <i>subhaliotoidea</i> (Nagao).....	Ta502 OS03, HG02
<i>A.</i> (<i>Ceratostrea</i>) cf. <i>yabei</i> (Nagao).....	Ta502
<i>A.</i> sp.	OS02, OS03, OS04
<i>Lopha</i> sp.	Ta502
<i>Pterotrigonia (s.s) pocilliformis</i> (Yokoyama) B form.....	OS02, OS04, OS07, OS08, OS09
<i>P.</i> cf. <i>hokkaidoana</i> (Yehara).....	Ta502 OS05, OS06
<i>Nipponitrigonia</i> cf. <i>kikuchiana</i> (Yokoyama).....	OS02, OS03, OS04
<i>N.</i> sp.	Ta502
" <i>Cardita</i> " sp.	OS06
<i>Astarte (s.s) subsenecta</i> Yabe and Nagao.....	OS02, OS03, OS04, OS06, OS07
<i>A.</i> (<i>s.s</i>) <i>semicostata</i> Nagao.....	OS09, Ta502 OS06
<i>A.</i> (<i>Trautsholdia</i>) <i>minor</i> (Nagao).....	OS06, OS07
<i>A.</i> (<i>Yabea</i>) cf. <i>shinanoensis</i> Yabe and Nagao.....	Ta502
<i>Anthonya</i> sp.....	OS06
<i>Laevicardium</i> cf. <i>ishidoensis</i> (Yabe and Nagao).....	OS06
<i>Pachythaerus</i> cf. <i>kagaharaensis</i> (Yokoyama).....	OS02, OS04
<i>Goshoraia</i> sp.	OS02, OS07, Ta502
<i>Ptychomya densicostata</i> Nagao.....	OS03, OS04
<i>P.</i> <i>densicostata hasei</i> m.s.	OS02, OS06, OS07, Ta502
<i>Pachytraga</i> sp.	OS02, OS06, OS07, Ta502
<i>Panopea (Myopsis)</i> cf. <i>plicata</i> (Sowerby).....	OS06, Ta502
<i>Pholadomya</i> cf. <i>brevitesta</i> Nagao.....	Ta502
<i>Myopholas</i> sp.	OS02, OS03
<i>Plectomya</i> cf. <i>aritagawana</i> Hayami.....	OS02, OS04, OS06, Ta502
<i>Caestocorbula minima</i> Hayami.....	OS04, OS06, OS07
<i>C.</i> <i>shikamai</i> Hayami.....	OS02, OS03, OS04, OS06, OS07
<i>Rasatrix</i> cf. <i>suzukii</i> Hayami.....	OS04, OS06
<i>Mesocallista</i> sp.	OS02, OS03
<i>Hayamina</i> sp.	HG05
<i>Pygurus (Pygurus) posterexpansus</i> Tanaka	OS02, OS06
<i>Hypophylloceras</i> cf. <i>onoensis</i> (Stanton).....	Ta502
<i>Shasticrioceras</i> sp.	Ta502

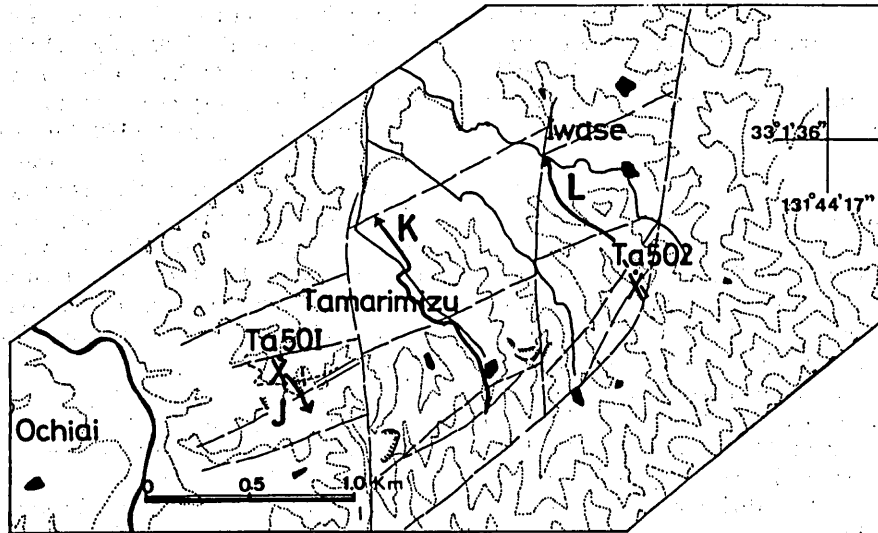


FIG. 14. Map showing the localities of stratotypes and localities of fossils in the Osaka subbelt (Tamarimizu area).

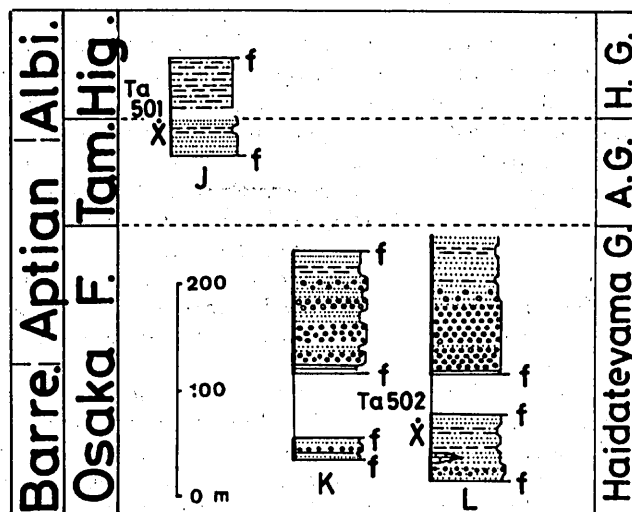


FIG. 15. Stratigraphic columnar sections of the Haidateyama and Amabe Groups in the Osaka subbelt (Tamarimizu area).

tion is exposed only in a narrow area near Tamarimizu. The base (northern border) is cut by a presumable fault from the Osaka Formation, while the top (southern border) is apparently conformably overlain by the Higashidani Formation to be described below.

Lithology and fossils: The Tamarimizu Formation of the Tamarimizu area is composed mainly of weathered, fine-grained, brownish arenite sandstone, with interbeds of thin-bedded, dark grayish sandy shale. Fossils obtained are shown on Table 6.

3. Higashidani Formation

Name: The formation name was first used by TERAOKA (1970). It is derived from a place-name, Higashidani, about 7km southsouthwest of Notsuichi, Notsu-cho.

General conception: The Higashidani Formation is characterized by thick-bedded regular alternation of sandstone and shale. It may partly be correlated with the Sukubo Formation from its stratigraphic position, although there is no fossil evidence.

Stratotype: The holostatotype (F and G in

Fig. 12) is along the path from Ishiba dam to Tanaka, east of Osaka.

Thickness: 250m (columnar section F or G in Fig. 13).

Distribution: This formation is discontinuously distributed from Osaka to Tamarimizu in two zones separated by the exposure of basement complex. It forms apparently an anticlinal structure with an axis of ENE-WSW trend, modified by faults. The base of the formation is cut by fault from the pre-Cretaceous rocks, while the top is unconformably overlain by a thick basal conglomerate of the Tano Group. In the Tamarimizu area, the present formation seems to overly conformably the Tamarimizu Formation, though there is a rapid change in lithology.

Lithology: The Higashidani Formation is composed of rhythmic alternation of sandstone and shale, with a conglomerate at the base and a white arkose sandstone at the top. The conglomerate is about 50m thick, consisting mainly of rounded cobbles and pebbles of chert, sandstone and shale and rarely of those of granitic rocks. It laterally changes to granule-

conglomerate. Each of the sandstone layers in alternating beds ranges in thickness from a few centimeters to 40cm, showing a graded bedding and parallel lamination. Small-scale slump structures are observable in a certain horizon.

IV. GEOLOGICAL AGE AND CORRELATION

The paleontological studies on marine faunas in the Haidateyama area have been pursued by many workers; for instance, TASHIOR et al. (1985) on marine bivalves, HATAMI and NODA (1977) on pectinids, NODA (1972, 1977) on ammonoids, YEHARA (1923), TAMURA (1978), KOBAYASHI and NAKANO (1958) on trigoniids, TANAKA et al. (1984), TANAKA (1984) on echinoids. I have also collected many molluscan fossils from more than 50 localities distributed at least in 20 stratigraphic horizons. Among them, ammonoids are especially important for international correlation. In this chapter, the geological age of the Mesozoic formations in the Haidateyama area is discussed on the basis of ammonoids and bivalves, and the correlation among various areas within the Outer Zone of Southwest Japan is attempted. For the correlation, not only the fossil evidence but also the stratigraphic records including sequence of strata, characters of sediments, cycle of sedimentation and disconformities are taken into consideration. The results are summarized in Table 9.

1. Kashimine Formation

The identified species from the Kashimine Formation are too small in number to conclude an affinity with the already-known faunas in Japan. Nevertheless, genera significant for age consideration are contained. They are *Halobia*, *Tosapecten*, *Otapiria* and *Unionites*. The bivalve fauna similar to that of the Kashimine Formation is known to occur from the Lower Kochigatani Subgroup of Shikoku (KATTO, 1982), which contains *Halobia* and *Tosapecten* as common genera and is characterized by the occurrence of *Paratrachyceras* aff. *hofmanni* and other ammonites of Carnian age. In Central Kyushu, the Takagochi and Tanoura Formations, corresponding to the Lower Kochigatani Subgroup, are characterized by the occurrence of Carno-Norian ammonites together with abundant bivalves. Especially, the middle Takagochi Formation (TAMURA et al., 1985) is well correlated to the Kashimine Formation by the presence of *Halobia*, *Tosapecten*, *Otapiria* and *Unionites*. The bivalve fauna of the Tanoura Formation (MATSUMOTO and KANMERA, 1964) also closely resembles that of the Kashimine Formation, though *Mytilus*, *Palaeopharus* and *Frenquelliella* are unknown in the latter.

From the faunal aspects and lithological characters, as well as from the geological situation, the Kashimine Formation is best comparable to the Lower Kochigatani Subgroup, and is assigned to the Sakawan stage (Carnian).

2. Shinkai Formation

The radiolarian fossils from the Shinkai Formation, which have already been reported by TANAKA et al. (1985), are listed in Table 2. This radiolarian fauna contains some elements of the so-called *Pseudo-*

dictyomitra primitiva - P. sp. A assemblage-zone proposed by YAO et al. (1982), YAO (1984) and Yao et al. (1985) from the Kii-Yura area. It also resembles in generic and even in specific level the *Mirifusus bayleyi* assemblage of MIZUTANI (1981) in the Mino Belt and the *Mirifusus mediodilatatus-Pseudodictyomitra* cf. *carpatica* assemblage of NISHIZONO et al. (1982) in the Chichibu Belt of Kyushu. Thus, the Shinkai Formation is assignable to the Tithonian, and is safely correlated to a part of the Torinosu Group. The correlation based on radiolarians is compatible with that on corals (after YAMAGIWA'S personal information).

3. Motoyamabu Formation

The Motoyamabu Formation is characterized by the occurrence of ammonites such as *Berriasella* aff. *patula*, *Pseudoosterella* sp. and *Thurmanniceras* (?) sp., together with a nautiloid, *Tithonoceras* sp. NODA (1972) considered that at least the basal part of the Yamabu Formation (author's Motoyamabu Formation) indicates Berriasian in age on the basis of *Berriasella* aff. *patula* and *Pseudoosterella* sp. However, there are some questions about the range of the Berriasian and Valanginian ammonites in Japan (NODA, 1972; SATO, 1958). The occurrence of *Tithonoceras* sp. is, though very rare, also noteworthy, because the genus is one of the index fossils of Tithonian. According to KUMMEL (1956), this genus occurs in the Tithonian strata of Crimea, Russia. Thus, the Motoyamabu Formation is probably correlated with the Tithonian to Lower Berriasian (?). The discovery of *Tithonoceras* sp. not only enables us to attempt the world-wide correlation, but also may contribute to the problem of the Jurassic-Cretaceous boundary.

4. Yamabu Formation

The Yamabu Formation is characterized by the predominance of white feldspathic quartz-sandstone, and yields brackish molluscs listed in Table 3. Among the identified species, *Isodomella matsumotoi*, *Bakevelloides* (*Yoshimopsis*) *nagatoensis*, *Eomiodon matsumotoi*, *E. nipponicus*, *Hayamina* sp. and *Plusides nagatoensis* are common or diagnostic. This formation has hitherto been compared with the so-called Ryoseki Formation in the Outer Zone of Southwest Japan. From the faunal aspects and lithological characters, the lower member especially resembles the Uminoura Formation of the Yatsushiro area (OHTA and MOJI, 1976) and the Yoshimo Formation of the Shimonoseki area (HASE, 1960; OHTA 1981) rather than the type Ryoseki Formation of the Monobegawa area. Besides, the upper member contains *Hayamina carinata*, which has been reported from the Upper Barremian Shobu Formation of the Katsuragawa area (TASHIRO and OHNISHI, 1985). Therefore, the formation in question can be correlated approximately with the Hauterivian to Upper Barremian. Thin layers of sandstone containing marine bivalves characteristic of the Haidateyama Formation are intercalated in the upper member. This fact may suggest the presence of the Barremian marine deposits in the Yamabu Formation.

5. Koshigoe Formation

The Koshigoe Formation is characterized by the frequent occurrence of red-colored rocks, and contains

TABLE 9. CORRELATION OF THE LOWER CRETACEOUS STRATA IN THE OUTER ZONE OF SOUTHWEST JAPAN.

AGE	AREA	Yatsushiro	Haidateyama	Monobe	Katsuragawa	Kishu	Sanchu	Choshi
CRETACEOUS	Albian	Miyaji F. Yatsushiro F.	Sukubo F. Higashi-dani F.	Hibihara F.	Katsuragawa F. Fujikawa F.	Nishihiro F.	Sanyama F.	Nagasakihana F. Toriakeura F.
	Aptian	Tonochi F. Hinagu F.	Tamarinizu F. Osaka F.	F. (Hibihara) Yunoki F.	Ikuna F. Hoji F.	F. (Nishihiro)	Sebayashi F.	Imubouzaki F.
	Barremian	Hachiryuzan F.	Haidateyama F. Koshigoe F.	F. (Yunoki) Monobe F. Ryoseki F.	Nakaizu F. Mamidani F. Stobu F.	Arida F. Yuasa Kita-hani F.	Ishido F.	Kimigahama F. Ashikajima F.
LOWER	Valanginian	Kawaguchi F.	Yamabu F.		Hanoura F. Tatsukawa F.	Yura F.	Ishido F.	
JURA	Berriasian	Uminoura F.	Shinkai F.	Torinosu Group	Torinosu Group	Obata & Oga (1976)	Matsukawa (1983)	
	Tithonian	Sakamoto F.	Motoyamabu F.	Torinosu Group	Torinosu Group	Obata & Oga (1976)	Matsukawa (1983)	Obata et al. (1982)
		Matsumoto et al. (1982)	This paper	Tashiro & Kozai, (1984)	Tashiro & Matsuda, (1985)	Obata & Oga (1976)	Matsukawa (1983)	Obata et al. (1982)

non-marine molluscs listed in Table 4. The age of the formation is not determined precisely, because no leading fossil has been obtained. It is, however, probably referable to the Hauterivian to Lower Barremian (?), judging from the following lines (TASHIRO et al., 1983).

1). The bivalve fauna of the Koshigoe Formation is closely similar to the Ryoseki fauna distributed widely in the Lower Cretaceous of the Outer Zone of Southwest Japan.

2). The Haidateyama Formation, which is characterized by the occurrence of Lower Barremian ammonites, covers conformably the top of the Koshigoe Formation.

From the fossil-contents and the stratigraphic position, the formation in question is comparable to the Shiroy Formation of the Sanchu area (MATSUKAWA, 1977, 1979, 1983), the Yuasa Formation of the Aridagawa area (HIRAYAMA and TANAKA, 1965), the Izumikawa Formation (SAKA et al., 1979) and the Matsuo Formation (OBATA et al., 1979) of the Shima area, the Tatsukawa Formation of the Katsuuragawa area (NAKAI, 1968) and the Ryoseki Formation of the Monobegawa area (TASHIRO et al., 1980).

6. Haidateyama Formation

The Haidateyama Formation is characterized by the occurrence of ammonites, nautiloids, marine bivalves and echinoids. They are listed in Table 5. The identified cephalopods are *Crioceratites cf. hochlini* (ASTIER), *Uhligia* sp., *Pedioceras* sp., *Heminautilus lallierians* (d'ORBIGNY) and *Cymatoceras* spp. (preliminary identification by MATSUMOTO). According to THOMEL (1964), *Crioceratites aff. hochlini* has been recorded from the Lower Barremian of Europe. In Japan, *C. cf. hochlini* occurs from an equivalent of the Monobe Formation in the vicinity of Kochi City (MATSUMOTO et al., 1982). *Heminautilus lallierianus* has been reported from the Lower Barremian of France and Bulgaria (d'ORBIGNY, 1840-42; DIMITROVA, 1967), and is obtained from the Aridagawa Formation of the Aridagawa area (OBATA and OGAWA, 1976). The other cephalopods are also characteristic of the Lower Barremian of the Tethys province. Thus, the Haidateyama Formation can safely be assigned to the Lower Barremian. This is supported by the occurrence of the Ishido-type molluscan fauna (TASHIRO et al., 1983; TASHIRO, 1985), and also by the discovery of early Barremian-type echinoids such as *Heteraster macroholcus*, *H. bungoensis*, *H. sp.* and *Pseudowashita ster mysticus* (TANAKA et al., 1984). From the fossil-contents and the stratigraphic position, the Haidateyama Formation is correlative with the Hachiryusan Formation of the Yatsushiro area (MATSUMOTO and KANMERA, 1964), the Monobe Formation of the Monobegawa area (TASHIRO, 1980), the Hanoura Formation of the Katsuuragawa area (TASHIRO and MATSUDA, 1983), the Arida Formation of the Aridagawa area (OBATA and OGAWA, 1976) and the Ishido Formation of the Sanchu area (MATSUKAWA, 1983; OBATA et al., 1976).

7. Tamarimizu Formation

The Tamarimizu Formation is characterized by the predominance of arenite sandstone, showing a shallow marine facies. It contains ammonites and bi-

valves listed in Table 6. The identified ammonites are *Chelonicerias* sp. and *Dufrenoyia aff. justinae* (HILL) (preliminary identification by MATSUMOTO). *Chelonicerias* has been known from the Upper Aptian strata of the Tethys province including the stratotype area. In Japan, it occurs from the Kimigahama and Nagasaki Formations of the Choshi area (OBATA et al., 1975), the Hoji Formation of the Katsuuragawa area (NAKAI, 1968), the lower part of the Hibihara Formation and the Hagino Formation of the Monobegawa area (TASHIRO et al., 1980; MATSUMOTO et al., 1982) and the Hinagu Formation of the Yatsushiro area (OBATA and MATSUMOTO, 1977). *Dufrenoyia aff. justinae* has been recorded from the Upper Aptian of Texas (ADKINS, 1928) and Taiwan (MATSUMOTO et al., 1965). Thus, the Tamarimizu Formation is undoubtedly assigned to the Upper Aptian.

The present formation is distributed both in the Takaya area of the Haidateyama subbelt and in the Tamarimizu area of the Osaka subbelt. There is a clear difference in faunal aspect between the two areas. The bivalve faunule of the Takaya area closely resembles that of the Upper Aptian Hagino Formation of the Monobegawa area, while the bivalve faunule of the Tamarimizu area is very similar to that of the Lower Albian (?) Ikuna Formation of the Katsuuragawa area (TASHIRO and KAWAJI, 1985). Therefore, the latter may represent somewhat higher horizon than the former.

8. Sukubo Formation

The Sukubo Formation contains abundant bivalve shells, together with ammonites. They are listed in Table 7. The bivalves have already been described by TASHIRO et al. (1985). The identified ammonites are *Idiohamites cf. subspiniger*, *I. cf. farrenus* and *Hamites cf. tenuicostatus* (preliminary identification by MATSUMOTO). These ammonites have been recorded from the Upper Albian of England (SPATH, 1939). Therefore, the Sukubo Formation is correlative with the Upper Albian. This is supported by the occurrence of *Inoceramus anglicus*, which also indicates late Albian age (WOOD, 1911).

9. Osaka Formation

This formation is characterized by the predominance of sandstone (often calcareous and sometimes conglomeratic), and yields abundant shallow marine fossils such as pelecypods (including hippuritids and rudistids), gastropods, hexacorals, bryozoans and echinoids. In addition, ammonites, e.g., *Shasticroceras* sp. and *Hypophylloceras cf. onoensis* (STANTON) (preliminary identification by MATSUMOTO) are obtained from the lower part (Loc. Ta502). *Shasticroceras*, which indicates Barremian in age, has been recorded from the Lower Horsetown Group in California (ANDERSON, 1938). In Japan, it occurs from the Ishido Formation of the Sanchu area (MATSUKAWA, 1983), the Idaira Formation near Lake Hamana (HAYASHI et al., 1981), the Arida Formation of the Aridagawa area (OBATA and OGAWA, 1976) and the Monobe Formation of the Monobegawa area (TASHIRO et al., 1980). *Hypophylloceras* is a long-lived genus ranging from Hauterivian to Maastrichtian. *H. onoensis* has been reported from the Aptian of California.

The bivalve fauna from the lower part of the

Osaka Formation is closely similar to that of the Haidateyama Formation, and is comparable with the faunas of the Monobe and Ishido Formations. On the other hand, the bivalve fauna from the upper part resembles the faunas of the Kimigahama Formation of the Choshi area (HAYAMI and OJI, 1980) and the lower part of the Hibihara Formation of the Monobegawa area (TASHIRO et al., 1980), containing Aptian-type genera and species such as *Anthonya*, *Goshoraia*, *Caestocorbula* and *Astarte* (*Trautsholdia*) *minor*. From the evidence of fossils mentioned above, the Osaka Formation is roughly correlative with the Barremian to Aptian. The correlation based on hippuritids (*Pachytraga* etc.) in West Europe by PAGUIER (1905) and KUTASSY (1934) may also suggest the age of the formation in question. In Japan, the occurrence of hippuritids is rather limited, though pachyodont pelecypods, e.g., *Praecaprotina yaegashii* (YEHARA), *Toucasia carinata* var. *Orientalis* NAGAO and *Pachytraga japonica* OKUBO were reported by YEHARA (1920), YABE and NAGAO (1926) and NAGAO (1933) from the Miyako area of Kitakami and the Sorachi area of Hokkaido, and also by OKUBO and MATSUSHIMA (1959) from the Akaishi area of Central Japan. I believe that they are of great value for interpretation of paleogeography and correlation.

10. Higashidani Formation

Although there is no reliable fossil, the Higashidani Formation may roughly be correlated to the Albian or thereabout, judging from the following lines.

1). The Higashidani Formation conformably overlies the Tamarimizu Formation, the latter of which is characterized by the occurrence of late Aptian ammonites.

2). The formation is comparable with the Fujikawa Formation of the Katsuuragawa area (Nakai, 1968) and the upper part of the Hibihara Formation of the Monobegawa area (Tanaka et al., 1984) from its lithofacies represented by rhythmically alternating beds of sandstone and shale.

The formation may be almost contemporaneous with the Sukubo Formation, but is a little older than the latter based on the lithostratigraphic comparison with the Hibihara Formation.

V. CHARACTERISTIC BIVALVE FAUNAS

Six bivalve faunas are discriminated in the Lower Cretaceous of the Haidateyama area. They are the Yamabu, Koshigoe, Haidateyama, Tamarimizu, Osaka and Sukubo faunas. In this chapter, the features of these faunas are described in comparison with the related ones in the Chichibu Belt, especially in Shikoku. The Lower Cretaceous System of the Chichibu Belt in Shikoku has been divided into the Monobegawa and Nankai Groups by the difference in lithology and faunal aspect, as reported by TASHIRO (1985b). In the Monobegawa Group, the Ryoseki-type brackish fauna, the Ishido-type fauna, the Yunoki-type brackish fauna, the Hibihara-type brackish fauna, the Lower Hibihara-type fauna and the Upper Hibihara-type fauna are developed in ascending order (TASHIRO, 1985a). These faunas are combined into the Monobegawa-Type Fauna. On the other hand, the Nankai Group is character-

ized by the Shobu-type brackish fauna, the Igenoki-type fauna, the Funadani-type brackish fauna, the Hagino-type fauna and the Hiura-type fauna (TASHIRO, 1985a; TASHIRO and MATSUDA, 1985). The Nankai-Type Fauna is composed of these faunas of the Nankai Group (Fig. 16).

1. Yamabu brackish fauna

The Yamabu brackish fauna is distributed in the Yamabu Formation of the Amabe Group, and is subdivided into two faunules, the lower and the upper.

(a). The lower faunule contains abundant brackish-water shells such as *Isodomella matsumotoi*, *Bakevelloides* (*Yoshimopsis*) *nagatoensis*, *Eomiodon matsumotoi*, *E. nipponicus*, *Plusides nagatoensis*, *Tetoria* (*Yoshimoa*) *yoshimoensis* and *Hayamina* sp. This faunule belongs to the Yoshimo-type brackish fauna, which is represented by the Yoshimo fauna (KOBAYASHI and SUZUKI, 1939; HASE, 1960) distributed in the Yoshimo Formation of the Shimonoseki area. A similar fauna has also been reported from the Uminoura Formation of the Yatsushiro area (OHTA and MOJI, 1976) (Table 10).

(b). The upper faunule consists mainly of *Hayamina carinata*, *Isodomella matsumotoi*, *Eomiodon matsumotoi* and *Ostrea* sp. It belongs to the Shobu-type brackish fauna typically distributed in the Shobu Formation of the Nankai Group. The Shobu-type fauna also comprises *Hayamina carinata*, *Eomiodon* sp and "*Ostrea*" sp.

The Yamabu brackish fauna, as a whole, belongs to the Nankai-Type Fauna.

2. Koshigoe brackish fauna

The Koshigoe brackish fauna is distributed in the Koshigoe Formation of the Haidateyama Group. The representative species are *Hayamina bungoensis*, *Costocyrena otsukai* and *Tetoria* (*Haidatina*) *koshigoensis*. The identical or similar species are known from the faunas of the Ryoseki Formation in the Monobegawa area, the Tatsukawa Formation in the Katsuuragawa area, the Yuasa Formation in the Aridagawa area and the Shiroy Formation in the Sanchu area, as shown in Table 10. These faunas belong to the Ryoseki-type brackish fauna of the Monobegawa-Type Fauna. One of the striking phenomena is that the Kawaguchi Formation in the Yatsushiro area (OHTA, 1977) contains the elements both of the Ryoseki-type brackish fauna and of the Yoshimo-type brackish fauna, the latter of which belongs to the Nankai-Type Fauna. Therefore, the Kawaguchi brackish fauna is referable to the intermediate-type between them.

3. Haidateyama fauna

The Haidateyama fauna is developed in the Haidateyama Formation of the Haidateyama Group. The representative species are *Nanonavis yokoyamai*, *Amygdalum ishidoensis*, *Plicatula kiiensis*, *Pterinella shinoharai*, *Gervillaria haradae*, *Neithea atava*, *Rastellium* (*Arctostrea*) *carinatum*, *Pterotrignia pocilliformis* A form, *Astarte* (*Yabea*) *shinanoensis*, *Pachythaerus kagaharensis* and *Ptychomya densicostata*. They are elements of the Ishido-type fauna of the Monobegawa-Type Fauna (TASHIRO, 1985a). The Ishido-type fauna has been known from the Hachiryuzan Formation in the Yatsushiro area, the Monobe

Formation in the Monobegawa area, the Hanoura Formation in the Katsuuragawa area, the Arida Formation in the Aridagawa area and the Ishido Formation in the Sanchu area, as shown in Table 11. Among the representative species, *Neithea atava* and *Pterotrignonia pocilliformis* A form are limited to occur in Upper Hauterivian to Barremian, showing a wide geographical distribution. From the faunal contents and the lithological characters, the Haidateyama, Hachiryuzan, Monobe, Hanoura, Arida and Ishido Formations are considered to be sediments of shallow marine or subtidal condition.

4. Tamarimizu fauna

The Tamarimizu fauna is distributed in the Tamarimizu Formation of the Amabe Group. It comprises *Cucullaea fujii*, *Nippononectes tamarimizuensis* (M.S.), *Neithea amanoi*, *Pterotrignonia* cf. *hokkaidoana*, *Nipponitrigonia* aff. *kikuchiana*, *Protocardia amanoi* and *Xenocardita amanoi*. The Upper Aptian Hagino-type fauna, which is typically developed in the Hagino Formation of the Monobegawa area, consists mainly of *Neithea amanoi*, *Pterotrignonia* (*Scabrotrignonia* ?) *moriana*, *Xenocardita amanoi* and *Protocardia amanoi*, as reported by TASHIRO (1985a). *Neithea amanoi* and *Protocardia amanoi* are common between the Tamarimizu fauna and the Hagino-type fauna. The Lower Albian? Hiura-type fauna, which is distributed in the Ikuna Formation of the Katsuuragawa area, is composed mainly of *Modiolus* cf. *forcatus*, *Cucullaea fujii*, *Pterotrignonia yokoyamai* and *P. hokkaidoana*

(TASHIRO, 1985a). *Cucullaea fujii* and *Pterotrignonia hokkaidoana* are common between the Tamarimizu and Ikuna Formations (Table 12).

Thus, the Tamarimizu fauna contains the elements both of the Hagino-type and Hiura-type faunas of the Nankai-Type Fauna. From the lithological and faunal aspects, the Tamarimizu Formation shows very shallow marine or intertidal environment.

5. Osaka fauna

The Osaka fauna is developed in the Osaka Formation of the Haidateyama Group, and is divided into two faunules, the lower and the upper.

(a) The lower faunule contains the following elements of the Barremian Ishido-type fauna: *Nanonavis yokoyamai*, *Entolium sanchuensis*, *Isognomon* cf. *sanchuensis*, *Rastellium* (*Arctostrea*) *carinatum*, *Astarte subsenecta*, *A. (Yabea) shinanorensis*, *Pachythaеous hagahaensis*, *Ptychomya densicostata*, *Panopea (Myopsis) plicata*, *Pholadomya brevitesta* and *Plectomya aritagawana*. In addition to them, several morphologically important species such as *Ptychomya densicostata hasei* (M.S.), *Gervillaria osakaensis* (M.S.) and *Pachytraga* sp. are obtained.

(b) The upper faunule contains *Pterotrignonia pocilliformis* B form, *P. cf. hokkaidoana*, *Astarte (Trautsholdia) minor*, *Anthonya* sp., *Caestocorbula minima*, *C. shikamai*, *Rasatrix suzukii*, *Goshoraia* sp., *Neithea atava miensis* (M.S.) and *Pachytraga* sp. This faunule closely resembles the Lower Hibihara-type fauna of Aptian age (TASHIRO, 1985a) typically distributed in

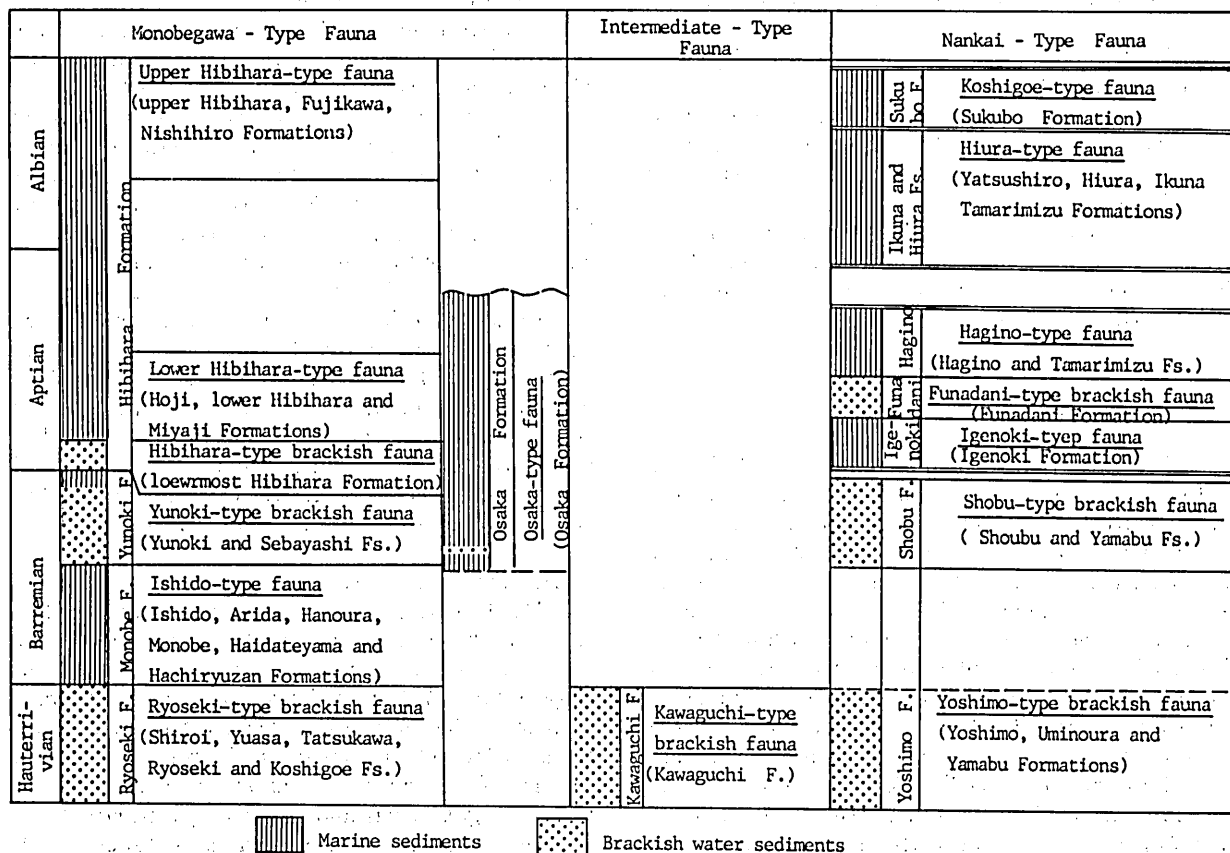


FIG. 16. Classification of the bivalve fauna succession in the Chichibu Belt.

TABLE 10. LIST OF BIVALVES FROM THE RYOSEKI FORMATION AND ITS EQUIVALENTS . .

SPECIFIC NAME	AREA		KYUSHU		SHIKOKU	SOUTH KINKI		SAN-CHU	YAMA-GU-CHI				
	FORMATION	AREA	KUMA	OHITA		KII	SHIMA						
			Kawaguchi Formation (Ohta, 1977)	Uminoura Formation (Ohta and Moji, 1976)	Koshigoe Formation (This paper)	Yamabu Formation (This paper)	Ryoseki Formation (Matsumoto et al. 1982)	Tatsukawa Formation (Nakai, 1968)	Yuasa Formation (Tanaka, 1965)	Izumikawa Formation (Saka et al. 1979)	Matsuo Formation (Obata et al. 1979)	Shiroi Formation (Matsukawa, 1979)	Yoshimo Formation (Ohta, 1981; Hase, 1960)
<i>Modiolus</i> sp.													
<i>Bakevella (Neobakevella) shinanoensis</i>										0			
* <i>Bakevelloides (Yoshimopsis) nagatoensis</i>	0			0									0
<i>Crassostrea</i> cf. <i>yoshimoensis</i>	0			0			0						0
<i>C.</i> <i>ryosekiensis</i>	0	0		0			0						0
<i>Ostrea</i> sp.	0			0		0						0	
<i>Leptosolen</i> sp.												0	
<i>Eomiodon sakawanus</i>	0							0					
<i>E.</i> <i>nipponicus</i>													0
* <i>E.</i> <i>matsumotoi</i>	0	0		0		0							
<i>E.</i> <i>hayami</i>													0
° <i>Hayamina naumanni</i>	0						0	0	0		0		
<i>H.</i> <i>bungoensis</i>				0									
<i>H.</i> sp.						0							
° <i>Costocyrena otsukai</i>	0			0		0	0	0	0		0		
<i>C.</i> cf. <i>radiatostrata</i>	0								0		0		
<i>C.</i> sp.	0					0							
<i>Isodomella shiroiensis</i>									0		0		
<i>I.</i> <i>matsumotoi</i>	0							0	0		0		0
<i>I.</i> sp.													
<i>Tetoria (Tetoria) yokoyamai</i>												0	
<i>T.</i> (<i>Yoshimoa</i>) <i>yoshimoensis</i>	0											0	
<i>T.</i> (<i>Haidatina</i>) <i>koshigoensis</i>				0									
<i>T.</i> (<i>H.</i>) <i>tatsukawaensis</i>							0						
* <i>Plusidis nagatoensis</i>	0	0		0									0
<i>P.</i> sp.				0									
<i>Corbicula imamurae</i>													0
<i>C.</i> sp.				0									
<i>Eoursivivas matsumotoi</i>	0												
<i>Myopholas carinatus</i>	0												0
<i>Placunopsis pseudotruncata</i>													0
<i>Pharella</i> (?) sp.	0												
° <i>Protocardia ibukii</i>						0					0		

TABLE 11. LIST OF THE BIVALVES FROM THE ISHIDO FORMATION AND ITS EQUIVALENTS (AFTER TASHIRO, 1985b, SUPPLEMENTED BY THE AUTHOR).

SPECIFIC NAME	AREA		KYUSHU		SHIKOKU		SOUTH KINKI		SAN-CHU	CHI-BA
	KUMA	OITA					KII	SHIMA		
FORMATION	Hachiryuzan Formation (Hayami, 1965-66)	Haideyama Formation (This paper)	Osaka Formation (This paper)	Monobe Formation (Tashiro, 1980)	Hanoura Formation (Nakai, 1968)	Arida Formation (Hayami, 1965-66)	Gokashoura Formation (Saka et al. 1979)	Ishido Formation (Matsukawa, 1983)	Kimigahama Formation (Hayami et al. 1980)	
<i>Nuculopsis (Palaeonucula) ishidoensis</i>			0	0	0	0	0	0	0	0
<i>Portlandia sanchuensis</i>	0			0	0	0	0	0	0	0
<i>Cosmetodon monobensis</i>				0	0	0				
<i>C. nipponicus</i>		0			0	0				
◦ <i>Nanonavis yokoyamai</i>		0	0	0	0	0		0	0	
<i>Arca (Eonavicula) shinanoensis</i>				0						
<i>Barbatia (Barbatia) hayami</i>				0						
<i>Brachidontes hanourensis</i>					0					
◦ <i>Amygdalum ishidoensis</i>		0		0				0		
<i>Pinna aff. robinaldina</i>		0	0	0	0			0	0	
<i>Trigoarca (?) obsoleta</i>								0	0	
<i>Pterinella shinoharai</i>		0		0	0	0		0		
<i>Gervillia aff. forbesiana</i>		0	0	0	0	0		0	0	0
◦ <i>Gervillaria haradae</i>		0		0	0			0		
* <i>G. osakaensis</i> m.s.			0							
◦ <i>Neithea atava</i>	0	0		0	0	0		0		
* <i>N. atava miensis</i> m.s.			0							
◦ <i>N. notabilis</i>					0			0	0	
<i>Chlamys hanourensis</i>					0					
<i>C. sp.</i>			0							
◦ <i>Entolium sanchuensis</i>		0	0	0				0		
◦ <i>Parvamussium kimurai</i>	0			0	0	0		0		
<i>Plicatula kiensis</i>		0		0	0	0				
<i>P. subovalis</i>				0						
<i>Isognomon sanchuensis</i>		0	0	0				0		
<i>I. ichikawai</i>				0				0		
<i>Limatula ishidoensis</i>								0		
◦ <i>Rastallium (Arctostrea) carinatum</i>		0	0	0	0			0	0	0
◦ <i>Pterotrigonia (Pterotrigonia) pocilliformis</i> A form	0	0		0	0	0	0	0	0	
<i>Nipponitrigonia plicata</i>								0		
<i>N. cf. sakamotoensis</i>	0	0		0	0	0				
<i>Rutitrigonia sanchuensis</i>								0		
<i>Astarte (Astarte) subsenecta</i>		0	0	0	0	0		0	0	
<i>A. (A.) costata</i>			0					0		
◦ <i>A. (Yabea) shinanoensis</i>		0	0	0				0		
<i>Eriphyla (Miyakoella) sp.</i>										
<i>Globocardium sp.</i>		0								
◦ <i>Pachythaerus kagaharaensis</i>		0	0	0				0		
<i>Laevicardium ishidoensis</i>		0	0	0				0	0	
◦ <i>Ptychomya densicostata</i>		0	0	0	0	0		0		
* <i>P. densicostata hasei</i> m.s.			0							
<i>Panopea (Myopsis) plicata</i>		0	0	0	0	0		0		
<i>P. (M.) nagaol</i>						0				
<i>Pholadomya brevitesta</i>			0					0		
<i>Pachytraga sp.</i>			0							
◦ <i>Goniomya sp.</i>		0		0	0	0		0		
◦ <i>Plectomya aritagawana</i>		0	0	0	0	0		0		

TABLE 12. LIST OF THE BIVALVES FROM THE LOWER HIBIHARA FORMATION AND ITS EQUIVALENTS (AFTER TASHIRO, 1985b, SUPPLEMENTED BY THE AUTHOR).

SPECIFIC NAME	AREA		KYUSHU		SHIKOKU		CHI-BA
	KUMA	OITA	MONOBE	KATSUURA	FORMATION	FORMATION	
<i>Nuculopsis (Paleonucula) ishidoensis</i>		0					0
<i>Nucula (Pectinucula) tosaensis</i>							0
<i>Portlandia sanchuensis</i>	0						0
<i>Mesosacella choshiensis</i>							0
<i>Nemodon tosaensis</i>							0
<i>N. sp.</i>					0		
<i>Cosmetodon nipponicus</i>	0						
<i>Nanonavis yokoyamai</i>		0				0	0
<i>Arca (Eonavicula) prolata</i>					0		
<i>A. (E.) shinanoensis</i>					0		
<i>A. (E.) minima</i>					0		
* <i>Cucullaea fujii</i>			0				0
<i>C. obliqueta</i>					0		
<i>C. transversa</i>							0
<i>Barbatia (Barbatia) kochiensis</i>					0		
<i>B. (B.) hibiharaensis</i>					0		
<i>Brachidontes igenokiensis</i>						0	
<i>B. pyliformis</i>					0		
° <i>Glycymeris (Hanaia) matsumotoi</i>					0		0
<i>G. (H.) sp.</i>			0				
<i>Monobearca cuculoides</i>					0		0
<i>Lycettia kochiensis</i>					0		
<i>Modiolus aff. falcatus</i>					0		0
<i>Pinna aff. robinaldina</i>	0	0	0	0	0	0	0
<i>Pterinella sp.</i>					0		
<i>Gervillia aff. forbesiana</i>	0	0	0	0	0	0	0
<i>Gervillaria cf. haradae</i>					0		
<i>G. osakaensis m.s.</i>		0					
<i>G. sp.</i>		0					
<i>Bakevella igenokiensis</i>						0	
<i>Nippononectes eleganus</i>					0		
<i>N. tamarimizuensis m.s.</i>			0				
<i>Neithea notabilis</i>							0
<i>N. atava miensis m.s.</i>		0					
* <i>N. amanoi</i>			0		0		
° <i>N. ficalhoi</i>					0		
<i>Chlamys shikokuensis</i>					0		
<i>C. sp.</i>		0					

<i>Parvamussium hinagense</i>	0							
<i>Plicatula tosaensis</i>			0			0		
<i>Isognomon cf. choshiensis</i>		0						0
I. sp.			0					
<i>Amphidonte (Ceratostrongyle) yabei</i>		0						0
A. (C.) <i>subhaliotoidea</i>		0						0
<i>Pterotrignonia (Pterotrignonia) pocilliformis</i> B form	0	0	0	0	0	0	0	0
P. (P.) <i>yokoyamai</i>							0	
P. (P.) <i>hokkaidoana</i>			0					
* P. (? <i>Scabrotrignonia</i>) <i>moriana</i>				0				
° <i>Nipponitrignonia convexa</i>	0		0			0		
N. <i>sakamotoensis</i>	0		0			0		
N. <i>kikuchiana</i>		0					0	
N. sp.			0					
<i>Xenocardita amanoi</i>				0				
<i>Astarte (Astarte) subsenecta</i>	0	0	0				0	0
A. (A.) <i>semicostata</i>		0						
A. (<i>Traustscholdia</i>) <i>minor</i>		0	0					
A. (<i>Yabea</i>) <i>densecrenulata</i>			0					
<i>Opis haginoensis</i>				0				
<i>Monobeopis costatus</i>			0					
° <i>Eriphila minima</i>			0			0		0
<i>Lucinoma (?) kotoi</i>			0					
° <i>Anthonia kochiensis</i>			0					
* A. <i>igenokiensis</i>					0			
A. sp.		0						
<i>Laevicardium (?) ishidoensis</i>		0						0
L. (?) <i>corpulentum</i>				0				
L. (?) <i>kochiensis</i>			0					
L. <i>brevis</i>			0					
* <i>Protocardia amanoi</i>			0	0				
* <i>Pseudocardia amanoi</i>			0					0
<i>Globocardium minor</i>					0			
<i>Leptosolen</i> sp.			0					
<i>Scittella japonica</i>			0			0		
<i>Eocallista (?) hibiharensis</i>			0					
° <i>Goshoraia minima</i>			0			0		
* <i>Pachytraga</i> sp.		0						
<i>Isocyprina aliquantula</i>				0				
<i>Ptychomya densicostata</i>		0						
P. <i>densicostata</i> <i>hasei</i> m.s.		0						
<i>Panopea (Myopsis) plicata</i>		0	0					
° <i>Caestocorbula minima</i>		0	0			0		0
° C. <i>shikamai</i>		0	0					0
° <i>Rasatrix suzukii</i>		0						0
<i>Corbulomima cf. nuciformis</i>								0
<i>Mesocallista</i> sp.		0						

TABLE 13. LIST OF THE BIVALVES FROM THE SUKUBO FORMATION AND ITS EQUIVALENTS (AFTER TASHIRO ET AL., 1985).

SPECIFIC NAME	AREA		SHIKOKU				KITA KAMI	
	FORMATION	KYUSHU	Yatsushiro Formation (Hayami, 1965-66)	Goshonoura Group (L) (Tashiro, 1985b)	Hibihara Formation (L) (Tashiro et al. 1980)	Hibihara Formation (U) (Tashiro et al. 1980)	Fukigoshi Formation (Tashiro et al. 1982)	Ikuna Formation (Tashiro & Kawaji, 1985)
<i>Nucula (Leionucula) haidatensis</i>							0	
<i>Mesosacella insignis</i>			0			0		0
<i>Nanonavis pseudocarinata</i>			0				0	
<i>Modiolus sukuboensis</i>							0	
<i>Pinna (Pinna) aff. robinaldina</i>			0		0			0
<i>Inoceramus anglicus</i>						0		
<i>Neithea (Neithea) matsumotoi</i>			0					
<i>Parvamussium</i> sp.						0		
<i>Plicatula</i> sp.								
<i>Pterotrigonia (Pterotrigonia) cf. yokoyamai</i>						0	0	0
P. (<i>Ptilotrigonia</i>) <i>tanakai</i>								
<i>Astarte (Astarte) subsenecta</i>			0		0			0
A. (<i>Yabea</i>) <i>akatsui</i>			0				0	
A. (<i>Nicaniella</i>) <i>sukuboensis</i>								
<i>Bungoella yabeaformis</i>								
<i>Pachythaerus nagaoui</i>				0				
? <i>Granocardium (Ethmocardium) sp.</i>								
<i>Leptosolen</i> sp.				0		0		
<i>Pholadomya (Pholadomya) sp.</i>								
P. (<i>Bucardiomya</i>) sp.								0
<i>Goniomya (Goniomya) cf. subarchiaci</i>								
<i>Plectomya amabeana</i>								
<i>Platymyoidea nipponica</i>								
? <i>Laternula</i> sp.								

the lower part of the Hibihara Formation in the Monobegawa area. The Lower Hibihara-type fauna consists mainly of *Nucula (Pectinucula) tosaensis*, *Arca (Eonavicula) minima*, *Glycymeris (Hanaia) matsumotoi*, *Nippononectes elegans*, *Neithea aff. ficalhoi*, *Pterotrigonia pocilliformis* B form, *Anthonya kochiensis*, *Goshoraia minima*, *Caestocorbula minima* and *C. shikamai*. A similar fauna is known also from the Hoji Formation in the Katsuuragawa area (TASHIRO, 1985a) (Table 12). It is worthy to note that some of the representative species of the Osaka fauna such as *Gervillaria osakaensis* (M.S.), *Neithea atava miensis* (M.S.) and *Ptychomya densicostata hasei* (M.S.) are

unknown from both the Ishido-type and Lower Hibihara-type faunas.

Gervillaria osakaensis (M.S.) is similar to *G. haradae*, one of the elements of the Ishido-type fauna, but the former is clearly distinguishable from the latter by its more vertically elongated outline, broader hinge-plate and more conspicuous radial ribs.

Neithea atava miensis (M.S.) has some similarities to *N. atava*, one of the diagnostic species of the Ishido-type fauna, but the former is distinguishable from the latter in its much longer size, larger apical angle and more numerous secondary riblets. This subspecies also somewhat resembles *N. kochiensis* from

the Doganaro Formation of the Shimantogawa Group.

Ptychomya densicostata hasei (M.S.) shows two noticeable zigzag arrangement of anterior riblets. This is somewhat larger in size and more elliptical in outline than *P. densicostata*, one of the diagnostic species of the Ishido-type fauna.

Furthermore, the Osaka fauna contains *Pachytraga* sp. (hippritids), *Archimedeia* cf. *rigida* (gastropods) and *Pygurus* (*P.*) *posteroexpansus* (echinoids) together with hexacorals and bryozoans. These fossils, as well as the lithologic characters, may suggest that the Osaka Formation has some resemblance to the Urgonian facies of warm subtropical shallow-sea condition. Thus, the Osaka Formation clearly differs from the Haidateyama Formation in sedimentary environment. The Osaka fauna contains some elements of both the Ishido-type and the Lower Hibiharatype faunas of the Monobegawa-Type Fauna, but shows the characters of Urgonian facies. The author names such faunas collectively the Osaka-type fauna.

6. Sukubo fauna (Koshigoe-type fauna by TASHIRO, 1985a)

The Sukubo fauna is distributed in the Sukubo Formation of the Amabe Group. It has already been described by TASHIRO, MATSUDA and TANAKA (1985). This is probably the first record of the Late Albian prolific shallow but purely marine bivalve fauna in the Outer Zone of Southwest Japan. Several species important for morphology or biostratigraphy, e.g., *Inoceramus anglicus*, *Neithea matsumotoi*, *Nanonavis pseudocarinata* and *Pterotrigonia* (*Ptilotrigonia*) *tanakai* etc., are contained in this fauna. *Neithea matsumotoi*, *Astarte subsenecta*, *A. (Yabea) akatsui* and *Pinna* sp. are common with the Ikuna fauna of the Katsuragawa area and the Yatsushiro fauna of the Yatsushiro area. The Ikuna and Yatsushiro faunas are referable to the Nankai-Type Fauna, as pointed out by TASHIRO (1985a). Therefore, the Sukubo fauna may also belong to the Nankai-Type Fauna. Further, the Sukubo fauna contains *Inoceramus anglicus*, *Mesosacella insignis*, and *Idiohamites* spp., which are common with the Upper Hibihara-type fauna of the Monobegawa Group (Table 13). These species are of offshore environment.

VI. DISCUSSION

A. FAUNAL CHANGE IN THE LOWER CRETACEOUS OF THE CHICHIBU BELT

As reported by TASHIRO (1985a, b), the Lower Cretaceous System in the Chichibu Belt in Shikoku is divided into the Monobegawa and Nankai Groups, whose bivalve faunas are named the Monobegawa-Type and Nankai-Type Faunas, respectively. In addition, the Intermediate-Type Fauna containing the elements of both types is recognized. It is represented by the fauna of the Kawaguchi Formation in the Yatsushiro area. Therefore, the Lower Cretaceous bivalve assemblages in the Chichibu Belt are classified into the three faunas of Monobegawa-Type, Nankai-Type and Intermediate-Type (Fig. 16). The faunal change in time and space is summarized below.

1. Vertical faunal change

The biostratigraphic ranges of the Lower Cretaceous bivalve species are shown in HAYAMI (1965-66) and TASHIRO (1985a), based on the occurrence from various strata in Japan.

As to the Monobegawa-Type Fauna, an important vertical change is recognized between the faunas of Barremian and Aptian age, as pointed out by TASHIRO (1985a). The Aptian Lower Hibiharatype fauna is characterized by the first appearance of *Anthonya*, *Nemodon*, *Glycymeris*, *Goshoraia*, *Nippononectes*, *Caestocorbula* etc., and by the degeneration of such genera as *Cosmetodon*, *Amygdalium* and *Ptychomya* which flourished in the Barremian Ishido-type fauna. There are, of course, several species common between the two faunas. They are *Nuculopsis* (*Palaeonucula*) *ishidoensis*, *Portlandia sanchuensis*, *Pinna* aff. *robinaldina*, *Gervillaria haradae*, *Gervillia forbesiana*, *Nipponitrigonia sakamotoensis* and *Astarte subsenecta*. In the Haidateyama area, the upper Osaka fauna of Aptian age contains such genera as *Anthonya*, *Goshoraia* and *Caestocorbula*, but the genera of *Cosmetodon* and *Amygdalium* which flourished in the Barremian Haidateyama fauna are lacking. The species belonging to the series of *Pterotrigonia* occur in successive formations from Barremian to Aptian, showing some modification in surface ornamentation. *Pterotrigonia pocilliformis* A form is obtained from the Haidateyama Formation and its equivalents, while *Pterotrigonia pocilliformis* B form from the upper part of the Osaka Formation and its correlatives. The most representative species of the Ishido-type fauna, *Neithea atava*, is limited to occur in the Barremian, while *Neithea atava miensis* (M. S.) is found from the Aptian (upper part of the Osaka Formation). Besides, *Neithea* cf. *ficahoi* has been reported by TASHIRO et al. (1980) from the lower member of the Hibihara Formation of the same age. Thus, the Barremian-Aptian faunal change bears a chronological meaning rather than environmental one.

The vertical change is also recognized in the brackish faunas of the Monobegawa Type Fauna. Particularly, the species belonging to the series of *Costocyrena* show some morphological change in accordance with their stratigraphic position, as pointed out by TASHIRO (1985a, b). *Costocyrena otsukai* is obtained from the Hauterivian Koshigoe and Ryoseki Formations, *C. radiatostriata* from the Upper Barremian Yunoki Formation, and *C. minima* from the basal part of the Hibihara Formation of Aptian age. Moreover, the species belonging to the lineage of *Hayamina* show a progressive modification in the shape of pallial sinus (TASHIRO and ONISHI, 1985). *Hayamina naumanni* and *H. bungoensis* are found from the Ryoseki and Koshigoe Formations respectively, while *H. solida* from the basal part of Hibihara Formation and the Hoji Formation. Such a change is useful for correlation, though supplementary.

The vertical faunal change in the Nankai-Type Fauna is not clear. It is, however, considered that the change from the Hagino-type to the Hiura-type fauna gradually progressed as the age passes, as pointed out by TASHIRO (1985a). The species belonging to the series of *Pterotrigonia* show some modification in surface ornamentation in accordance with the stratigraphic level. *Pterotrigonia* (*Scabrotigonia* ?) *moriana*,

which flourished in the Upper Aptian Hagino-type fauna, became extinct, and *Pterotrignia hokkaidoana* and *P. yokoyamai* appeared in the Lower Albian Hiura-type fauna and the Upper Albian Sukubo fauna.

As for the brackish faunas of the Nankai-Type Fauna, the lower member of the Hauterivian-Barremian Yamabu Formation yields abundantly *Isodomella matsumotoi*, *Bakevelloides (Yoshimopsis) nagatoensis* and *Hayamina* sp, while the upper member contains *Hayamina carinata*, *Eomiodon matsumotoi* and "*Ostrea*" sp.

2. Horizontal faunal change

There is a marked difference in generic and specific composition between the Monobegawa-Type and Nankai-Type Faunas. Remarks on the horizontal faunal change in each age are given below.

a. Hauterivian fauna

The Koshigoe fauna (Ryoseki-type brackish fauna) differs from the lower Yamabu fauna (Yoshimoto-type brackish fauna), in that the former yields abundantly *Hayamina bungoensis* and *Costocyrena otsukai* and the latter contains *Eomiodon matsumotoi*, *E. nipponicus* and *Bakevelloides (Yoshimopsis) nagatoensis*. This noticeable difference occurs between the northern side (Koshigoe fauna) and the southern side (Yamabu fauna) of the Motoyamabu Tectonic Line, which corresponds to a branch of the Kurosegawa Tectonic Belt in Shikoku.

b. Barremian fauna

The Haidateyama fauna and the lower Osaka fauna contain some elements of the Ishido-type fauna, but the latter shows features of the Urganian biofacies, yielding hippuritids, rudistids, peculiar gastropods, hexacorals, bryozoans and echinoids. It may be inferred that the sedimentary environment is substantially different between the Haidateyama and lower Osaka Formations. Furthermore, the Haidateyama fauna and the contemporaneous upper Yamabu fauna clearly differ from each other in that the former is of purely marine origin and the latter of mainly brackish origin. It seems that brackish beds are interfingered with marine ones. (*Pterotrignia* sp. and *Astarte (Yabea)* sp. are rarely found in the upper Yamabu Formation.)

c. Aptian fauna

The most marked difference is observable between the Lower Hibihara fauna and the Hagino-Igenoki fauna in Shikoku. According to TASHIRO (1985b), about 50 species of pelecypods are identified in the Lower Hibihara fauna and about 30 species in the Hagino-Igenoki fauna. Among them, 13 genera including 3 species (*Gervillaria haradae*, *Gervillia forbesiana* and *Pinna robinaldia*) are common between both faunas. In general, the Lower Hibihara fauna, which belongs to the Monobegawa-Type Fauna, contains abundantly *Glycymeris*, *Caestocorbula*, *Pterotrignia*, *Nipponitrigonia* and "*Ostrea*", while the Hagino-Igenoki fauna of the Nankai-Type Fauna yields *Neithea*, *Pinna*, *Protocardia*, *Scabrotrignia* (?) and *Cucullaea*. From the faunal contents, the latter may indicate more warm environment than the former. In

the Haidateyama area, the difference is observable between the Tamarimizu fauna and the upper Osaka faunule. About 26 species of pelecypods are discernible in the upper Osaka faunule and 11 species in the Tamarimizu fauna. Among them, only 2 species, i.e., *Gervillia* cf. *forbesiana* and *Pinna* cf. *robinaldina* are common between both faunas. Furthermore, the upper Osaka fauna contains some elements of the Urganian biofacies.

The faunal difference stated above is possibly primarily due to paleogeographical and environmental factors rather than chronological ones. In Shikoku, the Lower Hibihara fauna and the Hagino-Igenoki fauna are developed on the northern and southern sides of the Kurosegawa Tectonic Belt, respectively.

d. Osaka-type fauna

The Osaka fauna contains some elements of both the Ishidotype and Lower Hibihara-type faunas. It contains also elements of the Urganian biofacies. Further, *Ptychomya densicostata hasei* (M. S.), *Neithea atava miensis* (M. S.) and *Gervillaria osakaensis* (M. S.), which are characteristic of the Osaka fauna, have not yet been known from other areas. *Neithea atava miensis* (M. S.) is closely similar to *N. Kochiensis* from the Doganaro Formation of the Shimantogawa Group (HAYAMI and KAWASAWA, 1967). In addition, hippuritids and hexacorals are obtained also from the Shimantogawa Group in Akaishi Mountain (OKUBO and MATSISHIMA, 1959). These facts may suggest that the depositional site of the Osaka Formation was close to that of the Shimantogawa Group.

e. Albian fauna

As already reported by TASHIRO et al. (1985), a shallow marine bivalve fauna of Middle to Late Albian age occurs very rarely in Japan. The Sukubu fauna (Koshigoe-type fauna by TASHIRO, 1985a) is almost the only example. The Sukubo fauna yields some species common with the Yatsushiro and Ikuna faunas of the Nankai-Type Fauna (TASHIRO and KAWAJI, 1985). It also contains elements of the off-shore upper Hibihara-type fauna of the Monobegawa-Type Fauna.

B. COMPARISON BETWEEN THE HAIDATEYAMA AND AMABE GROUPS

The Lower Cretaceous System in the Haidateyama area is divided into the contemporaneous but heteropic Haidateyama and Amabe Groups, which correspond to the Monobegawa and Nankai Groups in Shikoku, respectively. The Haidateyama Group is further subdivided into the Koshigoe, Haidateyama, Osaka and Higashidani Formations, while the Amabe Group into the Yamabu, Tamarimizu and Sukubo Formations. The comparison between the two groups are discussed below.

1. Geographical distribution

According to TASHIRO (1985b), the Monobegawa Group is exposed in general on the northern side of the Kurosegawa Tectonic Belt, and lies unconformably over the constituent rocks of the "Northern Chichibu Belt". On the other hand, the Nankai Group crops out sporadically on the southern side of the belt, and

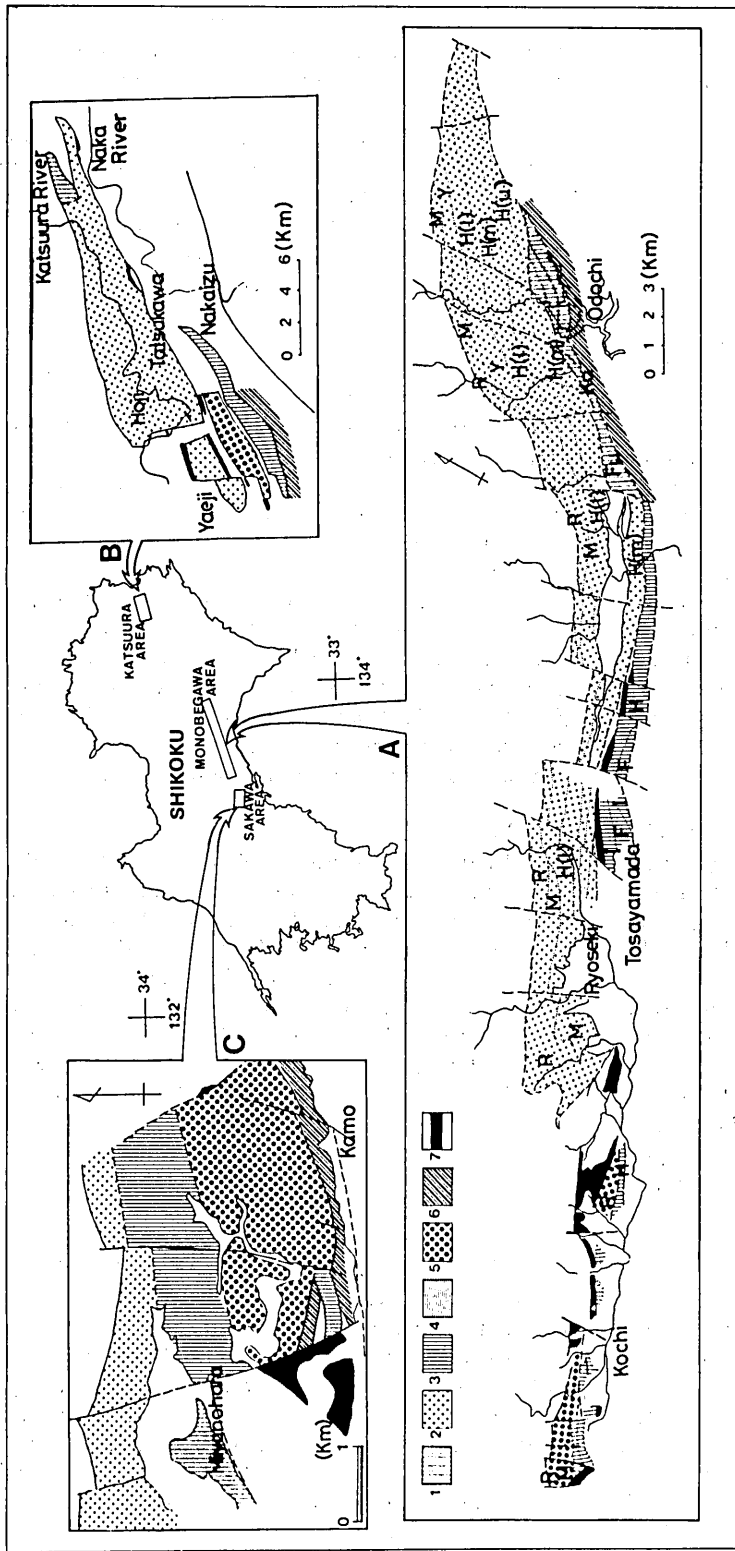


FIG. 17. Distribution map of the Lower Cretaceous in Shikoku (A: After TASHIRO and KOZAI, 1984; B: After TASHIRO and MATSUDA, 1985; C: After TASHIRO, 1985b). A: Monobegawa area, B: Katsuragawa area, C: Sakawa area. 1: Upper Cretaceous, 2: Lower Cretaceous (Monobegawa Group), 3: Lower Cretaceous (Nankai Group), 4: Lower Cretaceous (Kawaguchi Formation), 5: Lower Cretaceous (Monobegawa Group?), 6: Upper Jurassic (Torinosu Group), 7: Metamorphic and plutonic rocks of the Kurosegawa Tectonic Belt. R: Ryoseki Formation, M: Monobe Formation, H(l): Lower member of the Hibi-hara Formation, H(m): Middle member of the Hibi-hara Formation, H(u): Upper member of the Hibi-hara Formation, I: Igenoki Formation, F: Funadani Formation, H: Hagino Formation, Fu: Fukigoshi Formation, Ka: Kajisako Formation.

is in fault contact with the rocks of the "Middle Chichibu Belt", often accompanied with the Upper Jurassic Torinosu Group. Thus, the geographical distribution of the two groups in Shikoku is separated distinctly by the Kurosegawa Tectonic Belt (Fig. 17). In the Haidateyama area of Kyushu, the Haidateyama Group is developed in the Haidateyama and Osaka subbelts, and the Amabe Group in the Yamabu, Haidateyama and Osaka subbelts. The distribution of them is not so differentiated, but is overlapping. Nevertheless, branches of the Kurosegawa Tectonic Belt run in parallel, dividing the Chichibu terrain into the above-mentioned several tectonic subbelts. Particularly, the Motoyamabu Tectonic Line separates the Hauterivian-Barremian strata into the northern Koshigoe-Haidateyama Formation (Haidateyama Group) and the southern Yamabu Formation (Amabe Group).

Such being the case, the distributional pattern of the Lower Cretaceous System in the Haidateyama area differs to a certain degree from that in Monobegawa and Katsuragawa areas of Shikoku (Fig. 18).

2: Lithology

The Hauterivian Koshigoe Formation of the Haidateyama Group covers unconformably the pre-Creta-

ceous rocks with a thickbedded reddish conglomerate of possibly non-marine origin. The succeeding upper half of the formation is composed of conglomerate with intercalation of layers of sandstone and shale, showing the repetition of minor sedimentary cycles. The lithofacies is similar to that of the Ryoseki Formation of the Monobegawa Group in Shikoku. On the other hand, the lower Yamabu Formation of the Amabe Group of the same age overlies unconformably also the basement rocks in most places, and consists generally of conglomerate, sandstone and mudstone in ascending order, showing an upward-fining hemicycle. The sandstone is represented by white to white-gray, fine- to medium-grained arkose or feldspathic quartz-sandstone. The lithofacies resembles that of the Yoshimo Formation in Yamaguchi Prefecture and the Kawaguchi Formation in Yatsushiro area.

The Barremian Haidateyama Formation of the Haidateyama Group is composed mainly of sandy facies in the lower part and muddy facies in the upper. The sandstone is represented by graywacke-type one. The lithofacies is closely similar to that of the Monobe Formation of the Monobegawa Group. The Upper Aptian Tamarimizu Formation of the Amabe Group is characterized by the predominance of fine-

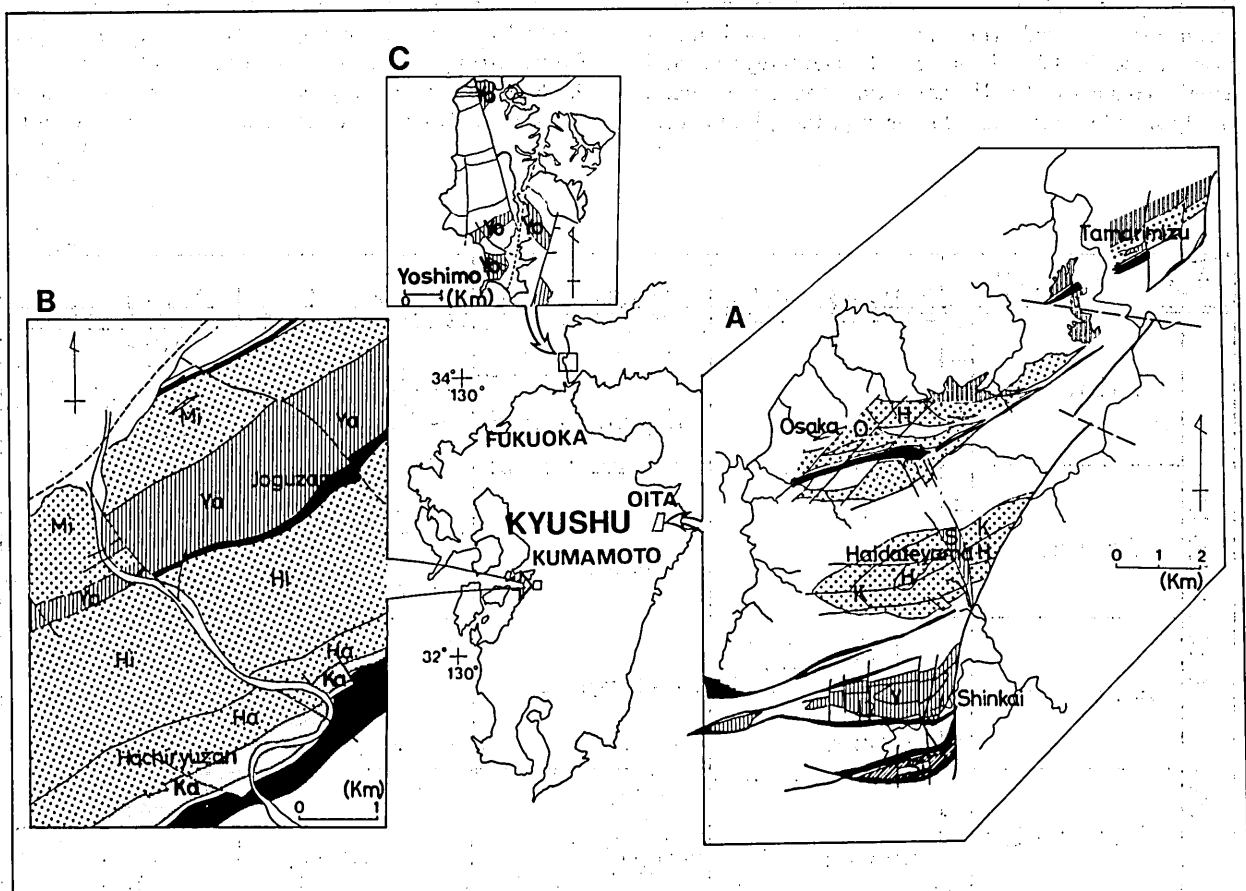


FIG. 18. Distribution map of the Lower Cretaceous in Kyushu and Yamaguchi Prefecture (B: After MATSUMOTO and KANMERA, 1964; C: After HASE, 1960). A: Haidateyama area, B: Yatsushiro area, C: Shimonoseki area. (Figure A) Si: Shinkai Formation, Y: Yamabu Formation, K: Koshigoe Formation, H: Haidateyama Formation, O: Osaka Formation. (Figure B) Ka: Kawaguchi Formation, Ha: Hachiryuzan Formation, Hi: Hinagu Formation, Ya: Yatsuhiro Formation, Mi: Miyaji Formation, (Figure C) Yo: Yoshimo Formation.

grained arenite sandstone, and resembles closely the Hagino Formation of the Nankai Group in Shikoku. The Barremian-Aptian Osaka Formation of the Haidateyama Group is characterized by the association of lenses and nodules of limestone and calcareous sandstone containing reef-building corals. It clearly differs in lithology from the Haidateyama and Tamarimizu Formations, but is somewhat similar to the Ishido Formation of the Sanchu graben.

The Albian Higashidani Formation of the Haidateyama Group consists of thick-bedded regular alternation of sandstone and shale, and is closely similar to the middle Hibihara Formation of the Monobegawa Group. The Upper Albian Sukubo Formation of the Amabe Group is mainly composed of dark gray mudstone with thin interbeds of fine-grained arenite sandstone in the lower part. The lithology resembles that of the Ikuna Formation of the Nankai Group.

Generally speaking, the Haidateyama Group has some similarities to the Monobegawa Group, while the Amabe Group to the Nankai Group. As for the sandstone, a graywacke-type is predominant in the former, and an arenite-type in the latter.

3. Relationship between the Haidateyama and Amabe Groups

In Shikoku, the original relationship between the Monobegawa and Nankai Groups is not ascertained, because their distribution is separated by the Kurosegawa Tectonic Belt. However, the Haidateyama and Amabe Groups in the Haidateyama area are at least partly in interfingering relationship, though in gener-

al they are in fault contact with each other. For example, the Tamarimizu Formation of the Amabe Group is apparently conformably overlain by the Higashidani Formation of the Haidateyama Group in the Osaka subbelt. The brackish Yamabu Formation of the Amabe Group is interbedded in its upper part with thin marine layers comparable with the Haidateyama Formation of the Haidateyama Group. Besides, the Sukubo Formation contains elements of the off-shore Upper Hibihara-type fauna of the Monobegawa-Type Fauna, together with abundant shallow marine bivalves of the Nankai-Type Fauna, suggesting the intermixing of two different facies. The relationship between the Haidateyama and Amabe Groups is diagrammatically shown in Fig. 19.

In general, the Lower Cretaceous System in the Chichibu Belt is represented by sediments of brackish-water to neritic environments; non-marine beds with plants and brackish-water shells are frequently interfingering with marine ones which contain index species of ammonites and other marine bivalves. Recently, the Cretaceous "delta" (used in a very wide meaning of MOORE and ASQUISH, 1971) has been supposed by TASHIRO and myself on the basements of the Chichibu terrain. This is verified by the sedimentological studies in the Sanchu and Aridagawa areas (MATSUKAWA, 1983; MAEJIMA, 1985). Judging from the difference in litho- and bio-facies, it is inferred that there were two "deltas", corresponding to the Monobegawa and Nankai Groups. The Lower Cretaceous System in the Haidateyama area may be regarded as the deposits of the transitional zone between two "deltas", because

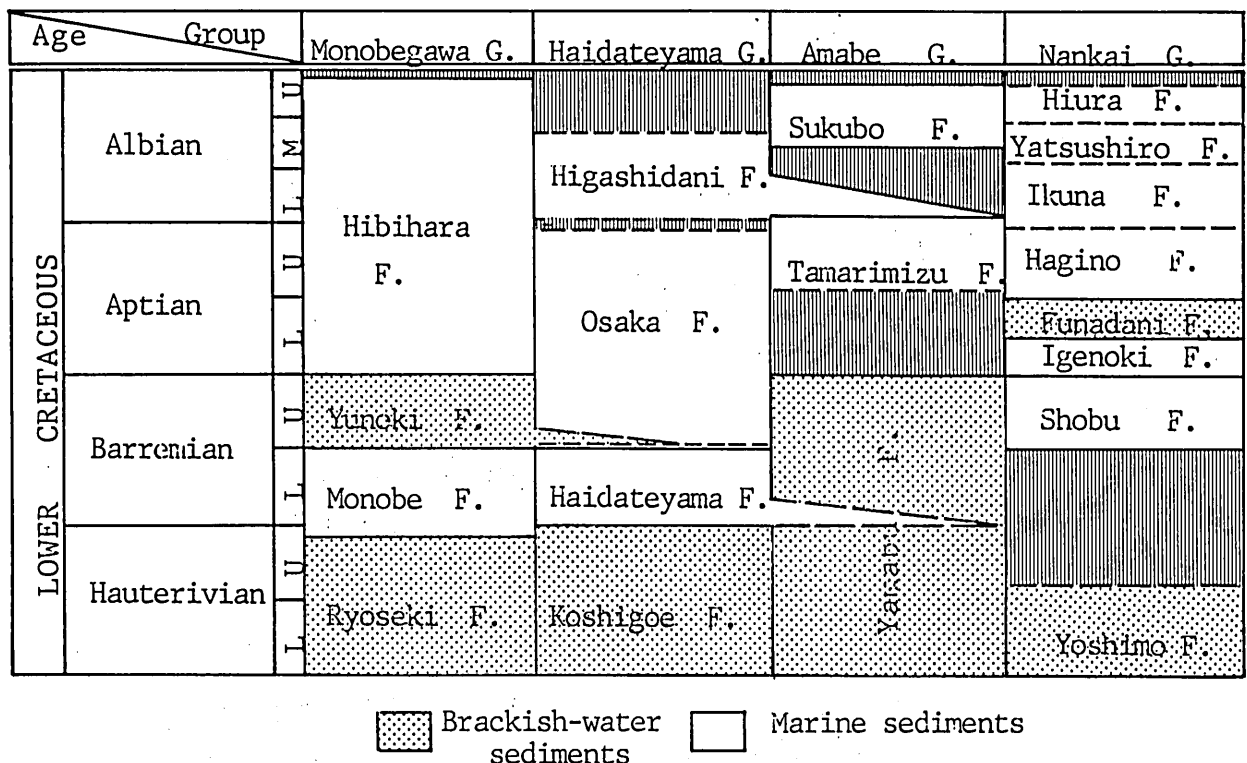


FIG. 19. Figure showing the interfingering relationship between the Haidateyama and Amabe Groups.

the Haidateyama and Amabe Groups show the inter-fingering relationship as stated above. Moreover, it is satisfactory to consider that there were barriers between the two "deltas", and that the barriers were composed of constituent rocks of the Kurosegawa Tectonic Belt, because the conglomerate of the Lower Cretaceous formations contains, though rarely, cobbles and pebbles of the granitic rocks referable to the older plutonic rocks of the belt. In other words, the rocks of the Kurosegawa Tectonic Belt might have been upheaved early in the Cretaceous to form the small-scale "Kurosegawa paleo-islands" (Fig. 20). The Osaka Formation, which is characterized by the development of lenticular and nodular limestones of Urgonian biofacies containing reef-building corals, might be sediments near such islands.

VII SUMMARY AND CONCLUSION

In this paper, the stratigraphy of the Mesozoic formations in the Haidateyama area is described, and the Lower Cretaceous bivalve faunas are analysed in comparison with the related ones in the Chichibu Belt. The results are summarized as follows.

1. The Chichibu Belt of the Haidateyama area is divided into several parallel to subparallel subbelts by tectonic lines of ENE-WSW trend. They are named the Shinkai, Yamabu, Haidateyama and Osaka subbelts from south to north. The bulk of the basement complex is represented by the Middle Carboniferous to Jurassic strata, consisting of slate (partly phyllite), sandstone, chert and subordinate limestone, with a small amount of greenstone. Besides, the older metamorphic and plutonic rocks referable to those of the Kurosegawa Tectonic Belt occur along the tectonic lines.

2. The Mesozoic strata are classified into 10 formations of Kashimine (Carnian), Shinkai (Tithonian),

Motoyamabu (Upper Tithonian-Lower Berriasian ?), Yamabu (Hauterivian-Barremian), Koshigoe (Hauterivian-Lower Barremian ?), Haidateyama (Lower Barremian), Tamarimizu (Upper Aptian), Sukubo (Upper Albian), Osaka (Barremian-Aptian) and Higashidani (Albian). The Koshigoe, Haidateyama, Osaka and Higashidani Formations are combined into the Haidateyama Group, while the Yamabu, Tamarimizu and Sukubo Formations into the Amabe Group. Each of the formations shows generally a hemicycle of sedimentation, beginning with the basal conglomerate and or sandstone. It seems that the sedimentary basin migrated towards the north with a change of times. The movement of the Kurosegawa Tectonic Belt might have an effect on this stepwise migration.

3. Six characteristic bivalve faunas are recognized in the Lower Cretaceous. They are the Koshigoe, Haidateyama and Osaka faunas distributed in the Haidateyama Group and the Yamabu, Tamarimizu and Sukubo faunas in the Amabe Group. The first three belong to the Monobegawa-Type Fauna, while the rest to the Nankai-Type Fauna.

4. Judging from the difference in distribution, lithofacies and faunal contents between the Haidateyama and Amabe Groups, which correspond to the Monobegawa and Nankai Groups in Shikoku respectively, it is inferred that there were two "deltas" where brackish-water to neritic sediments were accumulated. The older metamorphic and plutonic rocks of the Kurosegawa Tectonic Belt might have been upheaved early in the Cretaceous to form the small-scale "Kurosegawa paleo-islands" near the boundary of the two "deltas".

5. It is presumed that along the Large-scale lateral faults the Lower Cretaceous strata of the Chichibu Belt might have been transferred from low latitudes to the present site over several hundred kilometers or more. According to the paleomagnetic study of SA-

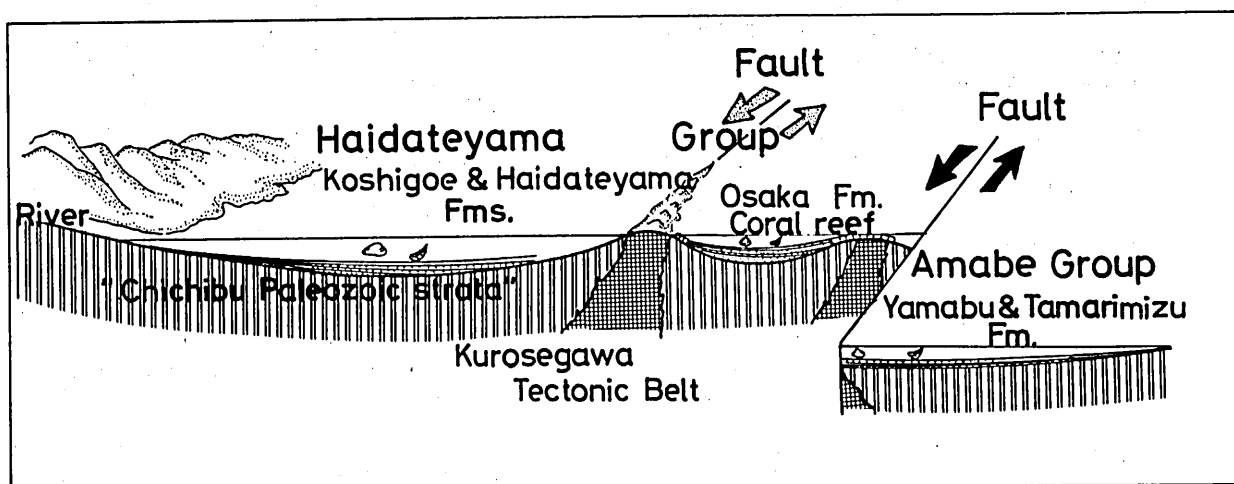


FIG. 20. Paleogeographical reconstruction showing the relationship between the Haidateyama and Amabe Groups.

KAI et al. (1985), the Kurosegawa paleoisland arc is considered to have been transferred from low latitudes (about 5° S) to the north during Late Jurassic to Early Cretaceous. This conclusion is in accordance with the results of paleomagnetic study of the Ryoseki Series by SASAJIMA et al. (1985). A similar conclusion has also been drawn from the analysis of bivalve faunas, by TASHIRO (1985b), whom I agree in general view, if not at every point.

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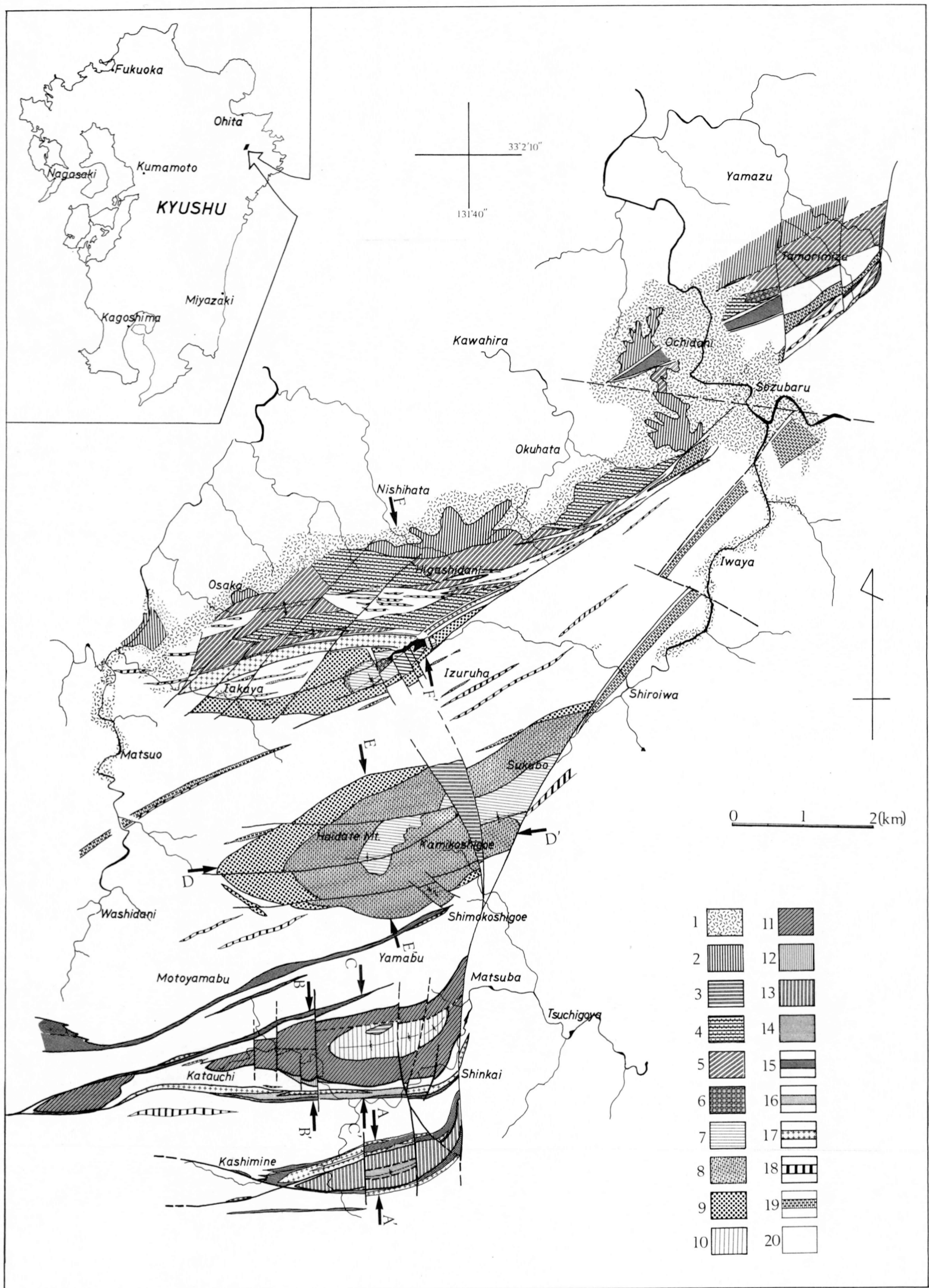


FIG. 21. Geological map of the Haidateyama area. 1: Aso pyroclastic flow deposits, 2: Tano Group (Upper Cretaceous), 3: Sukubo Formation (Upper Albian), 4: Higashidani Formation (Albian), 5: Osaka Formation (Barremian Aptian), 6: Tamarizake Formation (upper Aptian), 7: Haidateyama Formation (Lower Barremian), 8: Upper member of the Koshigoe Formation (Hauterivian-Lower Barremian ?), 9: Lower member of the Koshigoe Formation (Hauterivian) 10: Upper member of the Yamabu Formation (Barremian), 11: Lower member of the Yamabu Formation (Hauterivian), 12: Motoyamabu Formation (Upper Tithonian-Lower Berriasian ?), 13: Shinkai Formation (Tithonian), 14: Kashimine Formation (Carnian), 15: Serpentinite, 16: Metamorphic rocks, 17: Granitic rocks, 18: Chert, 19: Limestone, 20: Basement complex (Chichibu Super group).

EXPLANATION OF PLATE 1

- Fig. 1. *Crioceratites (Crioceratites)* sp. aff. *C. (C.) Koechlini* (ASTIER)
IGSH-TH 6001 from loc. H105. Lateral view, x 1.2
- Figs. 2, 3. *Idiohamites* sp. cf. *I. subspiniger* SPATH
IGSH-TH 50301 from loc. Su103. Lateral views (2, 3), x 1.1
- Fig. 4. *Hamites* sp. aff. *H. tenuicostatus* SPATH
IGSH-TH 50302 from loc. Su103. Lateral view, x 1.3
- Fig. 5. *Idiohamites* sp. cf. *I. favrinus* (PICTET)
IGSH-TH 50303 from loc. Su103. Lateral view, x 1.8
- Fig. 6. *Chelonicerias* sp.
IGSH-TH 7004 from loc. I103. Lateral view, x 1.0
- Fig. 7. *Heminautilus lallierianus* (d'ORBIGNY)
IGSH-TH 6003 from loc. H105. Vertical view, x 1.1
- Figs. 8, 9. *Tithonoceras* sp.
IGSH-TH 4002 from loc. M01. Lateral (8) and frontal (9) views, x 0.8
- Fig. 10. *Hypophylloceras* sp. cf. *H. onoense* (STANTON)
IGSH-TH 8002 from loc. Ta502. Lateral view, x 1.0
- Fig. 11. *Cymatoceras* sp.
IGSH-TH 7002 from loc. I103. Lateral view, x 1.0

EXPLANATION OF PLATE 2

- Figs. 1-3. *Eomiodon matsumotoi* OHTA
1. Rubber cast from a left external mould, x 1.3, Loc. Y02.
 2. Left internal mould, x 1.2, Loc. Y03.
 3. Rubber cast from a left external mould, x 1.3, Loc. ditto.
- Figs. 4-9. *Isodomella matsumotoi* OHTA
4. Rubber cast from a right external mould, x 1.7, Loc. Y05.
 5. Rubber cast from a right external mould, x 1.2, Loc. ditto.
 6. Right internal mould, x 1.1, Loc. Y01.
 7. Rubber cast from a right external mould, x 1.2, Loc. Y05.
 8. Right internal mould, x 1.4, Loc. ditto.
 9. Rubber cast from a left external mould, x 2.0, Loc. Y02.
- Figs. 10-12. *Bakevelloides (Yoshimopsis) nagatoensis* OHTA
10. Rubber cast from a left external mould, x 1.3, Loc. Y03.
 11. Rubber cast from a left external mould, x 1.4, Loc. ditto.
 12. Left internal mould, x 0.8, Loc. Y01.
- Figs. 13, 15. *Hayamina* sp.
13. Left internal mould, x 1.1, Loc. Y01.
 15. Right internal mould, x 1.0, Loc. Y03.
- Figs. 14, 16-17. *Hayamina carinata* TASHIRO and ONISHI
14. Right internal mould, x 1.6, Loc. Y04.
 16. Rubber cast from a left internal mould, x 1.0, Loc. ditto.
 17. Left internal mould, x 1.0, Loc. Y06.
- Figs. 1-17. Yamabu fauna
- Figs. 18-20. *Costocyrena otsukai* (YABE and NAGAO)
18. Rubber cast from a right external mould, x 3.0, Loc. Ko102.
 19. Rubber cast from a right external mould,

x 3.0, Loc. ditto.

20. Rubber cast from a left external mould, x 3.0, Loc. ditto.

Figs. 21-22. *Hayamina bungoensis* OHTA

21. Right internal mould, x 0.7, Loc. Su105.22.
 - Left internal mould, x 0.7, Loc. Ko102.
- Figs. 18-22. Koshigoe fauna

EXPLANATION OF PLATE 3

- Fig. 1. *Goniomya* sp.
Left valve, x 1.2, Loc. H105.
- Fig. 2. *Cosmetodon nipponicus* (NAGAO)
Right internal mould, x 1.3, Loc. ditto.
- Fig. 3. *Astarte subsenecta* (YABE and NAGAO)
Rubber cast from a right external mould, x 1.2, Loc. ditto.
- Fig. 4. *Nanonavis yokoyamai* (YABE and NAGAO)
Right internal mould, x 1.0, Loc. ditto.
- Fig. 5. *Plectomya* sp. cf. *P. aritagawana* HAYAMI
Right valve, x 1.1, Loc. Su102.
- Fig. 6. *Panopea (Myopsis) plicata* (SOWERBY)
Right valve, x 1.1, Loc. H105.
- Figs. 7, 8. *Pterotrignia pocilliformis* (YOKOYAMA) A form
7. Right valve, x 1.2, Loc. H105.
 8. Right valve, x 1.1, Loc. ditto.
- Fig. 9. *Ptychomya densicostata* (YOKOYAMA)
Right valve, x 1.0, Loc. ditto.
- Fig. 10. *Amydalum ishidoensis* (YABE and NAGAO)
Left valve, x 1.0, Loc. I104.
- Fig. 11. *Gervillia forbesiana* d'ORBIGNY
Right valve, x 1.3, Loc. Su104.
- Fig. 12. *Rastellum (Arctostrea) carinatum* (LAMARCK)
Ventral view of conjoint valves, x 1.0, Loc. ditto.
- Fig. 13. *Pinna* sp.
Right valve, x 1.0, Loc. ditto.
- Fig. 14. *Neithea atava* (ROMER)
Right internal mould, x 0.8, Loc. H105.
- Fig. 15. *Pterinera shinoharai* HAYAMI
Rubber cast from a left external mould, x 0.8, Loc. Su104.
- Figs. 1-15. Haidateyama fauna

EXPLANATION OF PLATE 4

- Fig. 1. *Caestocorbula minima* HAYAMI
Rubber cast from a right external mould, x 2.8, Loc. OS06.
- Figs. 2, 3. *Caestocorbula shikamai* HAYAMI
2. Left valve, x 1.2, Loc. ditto.
 3. Rubber cast from a left external mould, x 1.2, Loc. ditto.
- Fig. 4. *Nuculopsis (Palaeonucula) ishidoensis* (YABE and NAGAO)
Right internal mould, x 2.0, Loc. ditto.
- Fig. 5. *Astarte (s.s.) subsenecta* YABE and NAGAO
Rubber cast from a right external mould, x 1.0, Loc. OS04.
- Fig. 6. *Astarte (s.s.) semicostata* NAGAO
Rubber cast from a right external mould, x 3.0, Loc. OS06.
- Fig. 7. "*Cardita*" sp.
Rubber cast from a right external mould, x 3.0, Loc. ditto.
- Fig. 8. *Plectomya* sp. cf. *P. aritagawana* HAYAMI
Rubber cast from a left external mould, x 1.0, Loc. OS02.
- Fig. 9-10, *Coral* gen. et sp. indet.

9. External view, x 1.4, Loc. ditto.
 10. External view, x 1.4, Loc. ditto.
 Fig. 11. *Nipponitrigonia* sp. cf. *N. kikuchiana* (YOKOYAMA)
 Rubber cast from a left external mould,
 x 1.2, Loc. OS04.
 Fig. 12. *Panopea (Myopsis)* sp. cf. *P. (M.) plicata*
 (SOWERBY)
 Right valve, x 1.2, Loc. OS06.
 Fig. 13. *Anthonya* sp.
 Right internal mould, x 1.3, Loc. ditto.
 Fig. 14. *Pterotrigonia pocilliformis* (YOKOYAMA) B
 form
 Rubber cast from a right external mould,
 x 1.0, Loc. OS02.
 Fig. 15. *Pachytraga* sp.
 Right internal mould, x 0.7, Loc. OS07.
 Fig. 16. *Ptychomya densicostata hasei* m.s.
 Rubber cast from a right external mould,
 x 0.9, Loc. OS02.
 Fig. 17. *Rastellum (Arctostrea) carinatum* (LA-
 MARK)
 Lateral view of a left valve, x 1.3, Loc. OS03.
 Fig. 18. *Neithea atava miensis* m.s.
 Rubber cast from a right external mould,
 x 0.9, Loc. OS02.
 Fig. 19. *Gervillaria osakaensis* m.s.
 Rubber cast from a left external mould, x 0.9,
 Loc. OS06.

Figs. 1-19. Osaka fauna.

EXPLANATION OF PLATE 5.

- Figs. 1-6. *Cucullaea fujii* HAYAMI
 1. Left internal mould, x 1.4, Loc. Ta501.
 2. Left internal mould, x 1.2, Loc. ditto.
 3. Left internal mould, x 1.4, Loc. ditto.
 4. Left internal mould, x 1.4, Loc. ditto.
 5. Left internal mould, x 1.4, Loc. ditto.
 6. Right internal mould, x 1.5, Loc. ditto.
 Fig. 7. *Glycymeris (Hanaia)* sp.
 Right internal mould, x 1.8, Loc. ditto.
 Fig. 8. *Xenocardita amanoi* HAYAMI
 Right internal mould, x 2.0, Loc. ditto.
 Figs. 9-10. *Protocardia amanoi* TASHIRO and MATSU-
 DA
 9. Rubber cast from a right external mould,
 x 1.4, Loc. I103.
 10. Rubber cast from a right external mould,
 x 2.0, Loc. ditto.
 Figs. 11-12. *Pinna* sp. cf. *P. robinaldina* d'ORBIGNY
 11. Rubber cast from a right external mould,
 x 1.3, Loc. Ta501.
 12. Rubber cast from a right external mould,
 x 1.3, Loc. ditto.
 Fig. 13. *Nipponitrigonia* sp. aff. *N. kikuchiana*
 (YOKOYAMA)
 Left internal mould, x 1.5, Loc. ditto.
 Figs. 14-16. *Nipponnectes tamarimizuensis* m.s.
 14. Rubber cast from a left external mould, x 1.5,
 Loc. ditto.
 15. Rubber cast from a left external mould, x 1.3,
 Loc. ditto.
 16. Left internal mould, x 1.0, Loc. ditto.
 Figs. 17-18. *Neithea (Neithea) syriaca amanoi* (HAYA-
 MI)
 17. Right internal mould, x 1.5, Loc. ditto.
 18. Left internal mould, x 1.8, Loc. ditto.
 Figs. 19-20. *Pterotrigonia hokkaidoana* (YEHARA)
 19. Left internal mould, x 1.1, Loc. ditto.
 20. Left internal mould, x 1.3, Loc. ditto.

Figs. 1-20. Tamarimizu fauna

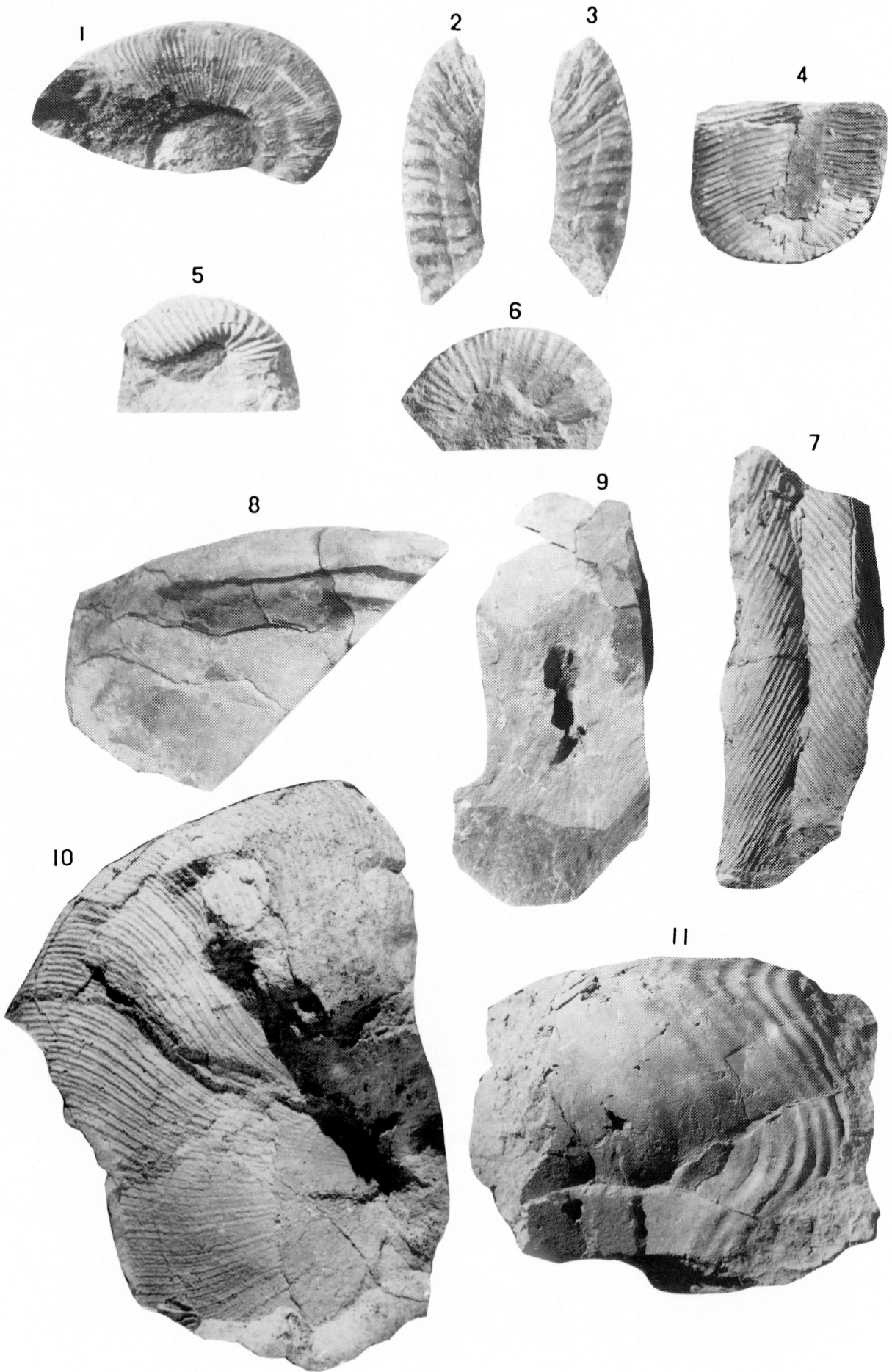


PLATE 1

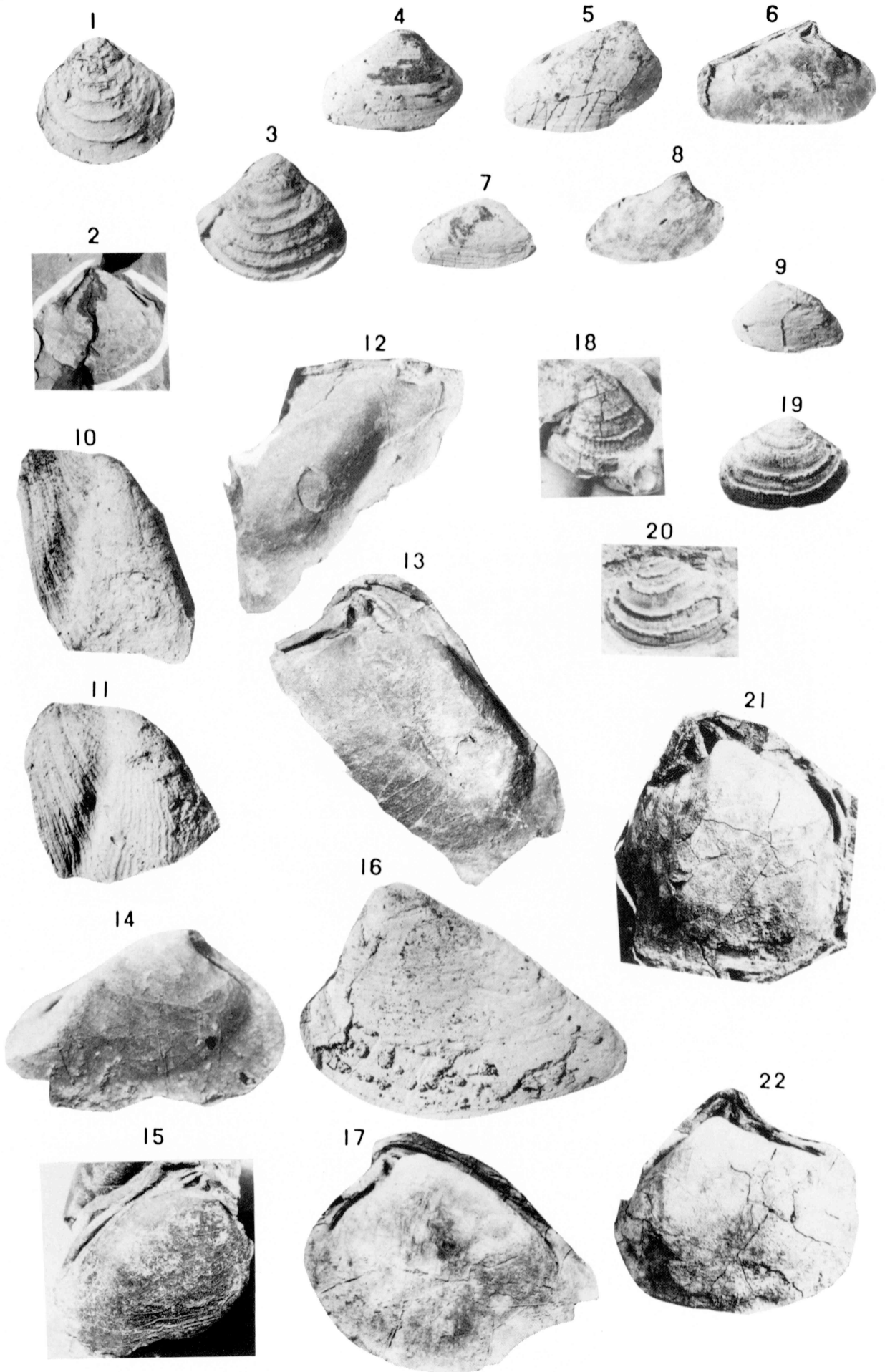


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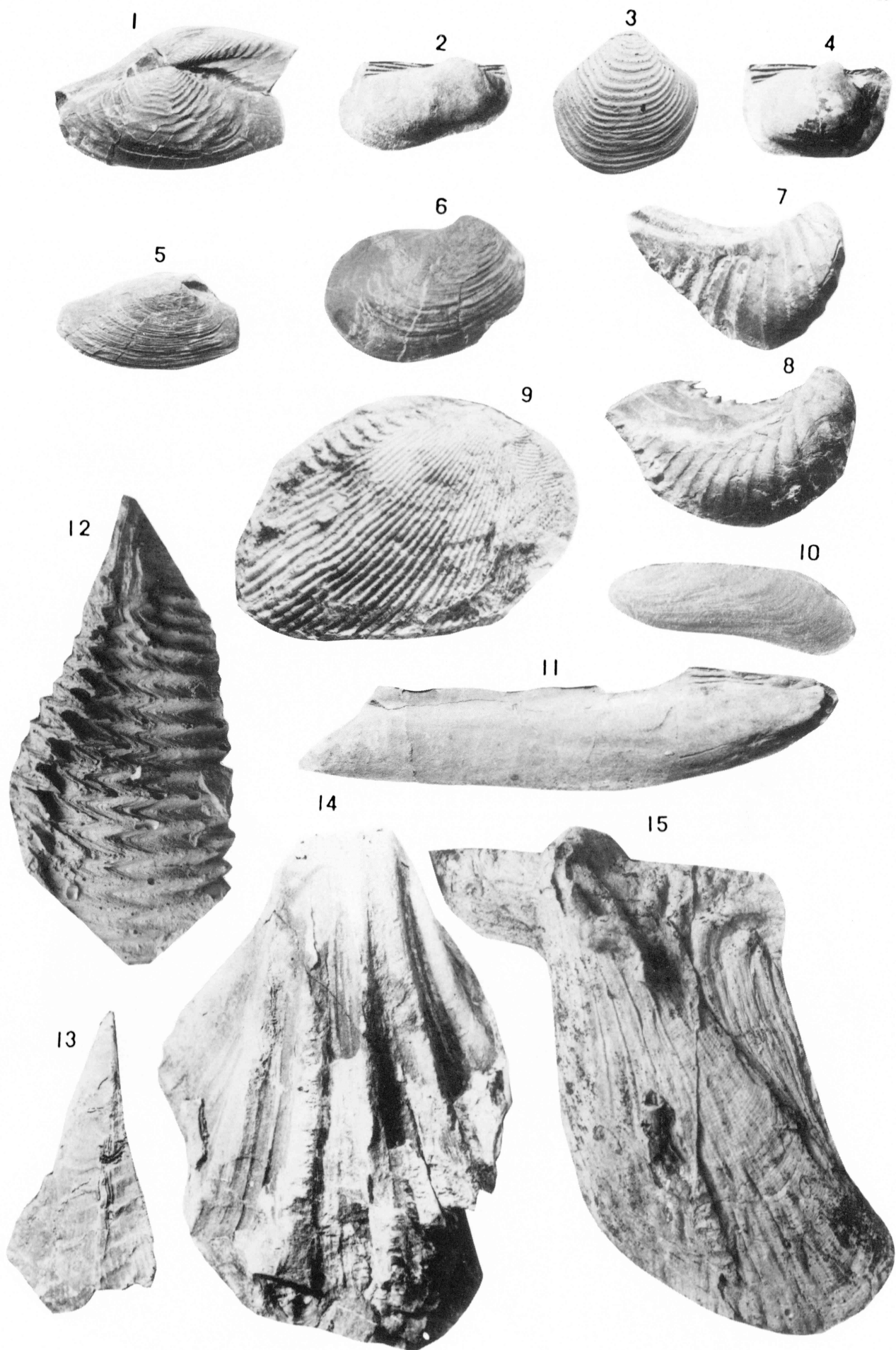


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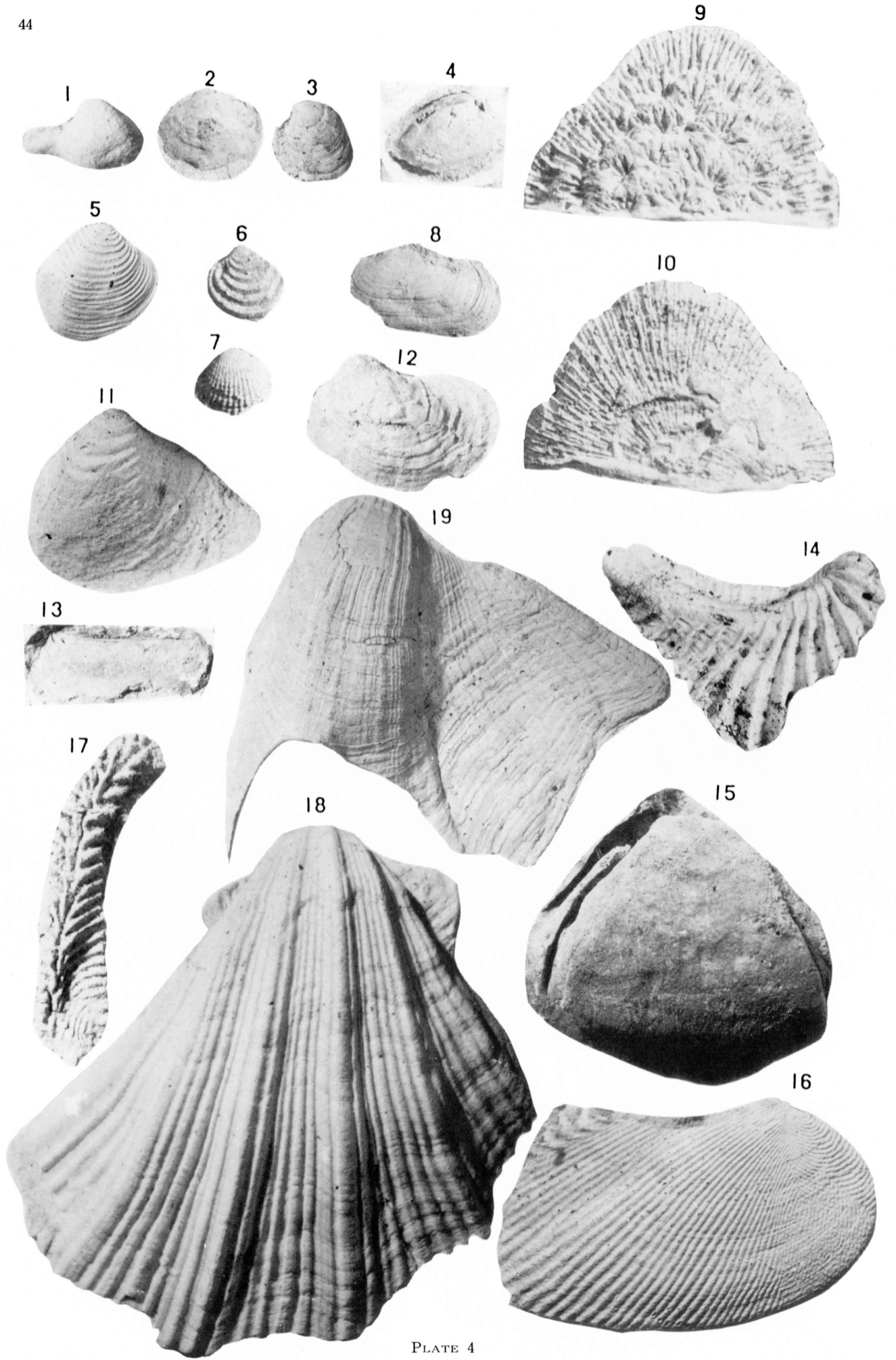


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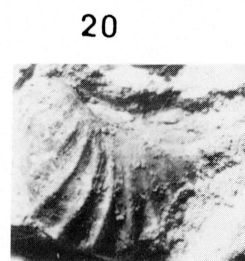
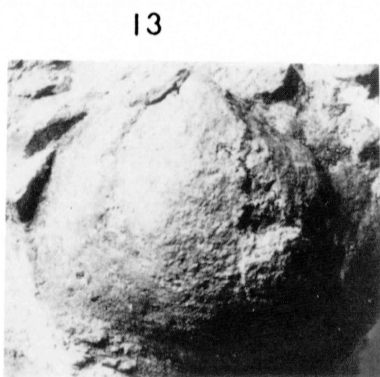
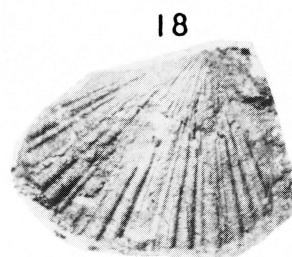
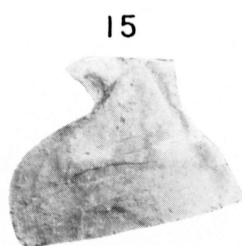
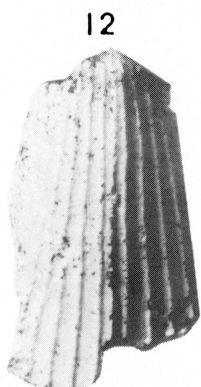
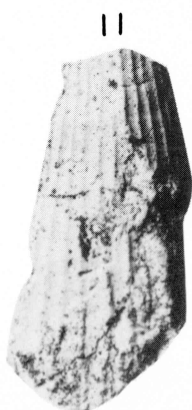
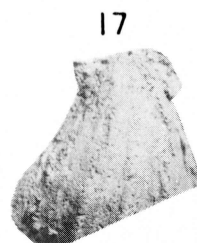
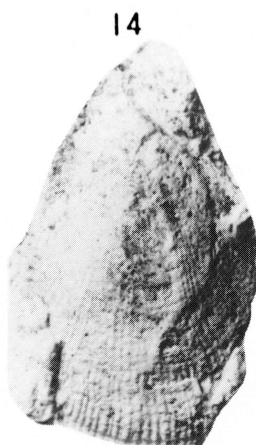
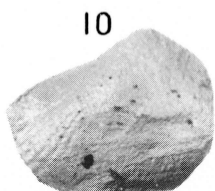
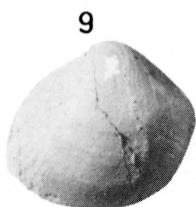
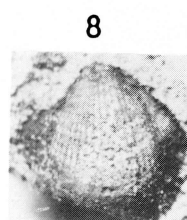
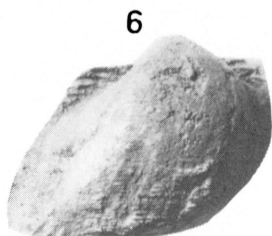
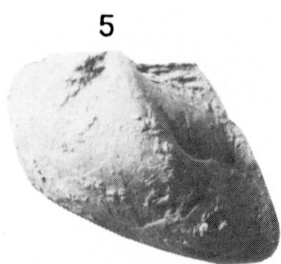
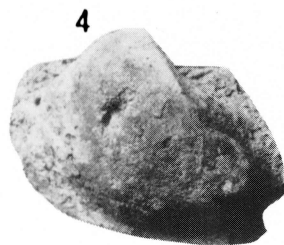
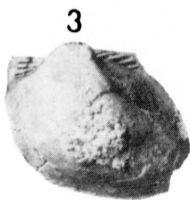
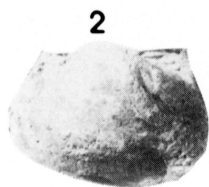
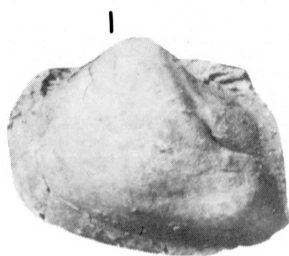


PLATE 5

