Geological Age and Structure of the Hina Limestone, Okayama Prefecture, Southwest Japan

By

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with 1 Table, 7 Text-figures and 4 Plates

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ABSTRACT: The geologic structure of the Carboniferous Hina Limestone exposed at Hina, near Nariwa, Okayama Prefecture, is described with the aid of subsurface data obtained from boring cores, and the geological age is discussed from the standpoint of brachiopod fauna.

The Hina limestone forms a complicated folding structure for the most part overturned towards the south, and is marked off by thrust-faults from the northern non-calcareous Permian rocks and the southern Upper Triassic strata. The axial planes of folding, as well as the thrust-planes, seem to incline steeply in a deeper part and then become nearly horizontal upwards. The writers are inclined to consider that the limestone is not a "Klippe" but a mass squeezed out or injected from the deep-seated autochthonous complex.

Brachiopods from the Hina limestone and the neighbouring Shodera limestone are classified into two faunal types: the one is characterized by *Spirifer* sp. aff. *S. besnossovae* ABRAMOV, *Schizophoria* sp. aff. *S. resupinata* (MARTIN), *Syringothyris* sp., etc., of which the first is most predominant, and the other by the abundance of *Striatifera striata* (FISCHER), with *Schizophoria* sp. aff. *S. resupinata* (MARTIN), *Phricodothyris insolita* GEORGE, etc. The former is distributed in the *Endothyra* zone, the lowest foraminiferal zone of the limestone, and the latter in the overlying *Eostaffella-Millerella* zone. It may be concluded that the *Spirifer* sp. aff. *S. besnossovae* fauna is assigned to the early Visean in age and the *Striatifera striata* fauna to the late Visean.

CONTENTS

I. INTRODUCTION

Along the southern margin of the non-metamorphic Upper Paleozoic terrain in the Oga district, a part of the Kibi plateau, central Chugoku, there are ten or more small masses of limestone mostly of Carboniferous age which are thrust upon the Permian non-calcareous rocks on the north and the Upper Triassic strata on the south. Since OZAWA (1925b) reported the late Mesozoic orogeny and related overthrust structure in the Inner Zone of Southwest Japan, these limestone masses have in general been regarded as "Klippen" arranged along the frontal margin of the "Oga Decke" (e.g. KAWAI, 1951; NAKANO, 1952; YOSHIMURA, 1961). The Hina limestone is a good example. It lies about 18 km. to the southwest of Nariwa (a well-known Triassic locality), Okayama Prefecture. The exposed area of the limestone and associated schalstein is about 2000 m. from east to west and 800 m. from north to south.

Numerous well-preserved specimens of brachiopods were newly collected from 3 localities distributed in 2 horizons of the Hina limestone. A large collection came also from the Shodera limestone, another small "Klippe" situated about 5 km. to the east-northeast of Hina. At the same time, by the courtesy of the Kokan Mining Co., Ltd. a number of boring data were available for investigating the subsurface geology.

As for the geological age of the lower part of the limestone group developed in Akiyoshi, Atetsu, Taishaku and Oga (all in the Chugoku district), to which the Hina limestone can safely be correlated, there is a divergence of opinions among authors. Based on corals the limestone group was at first considered to range down to the Visean (upper Lower Carboniferous) (e.g. OZAWA, 1925a; FUJIMOTO, 1944), but later the Bashkirian or Namurian age (lower Upper Carboniferous) was emphasized for the lowest part (e.g. MINATO, 1955, 75). Recently, OKIMURA (1966) correlated it again to the Visean on the basis of endothyroid and other smaller foraminifers, and YANAGIDA (1962, 65, 68, 73a) offered a similar view from his studies on the brachiopod fauna of Akiyoshi. Such being the case, it is necessary to examine the precise age of the lowest limit of the limestone group in each outcropping area through various kinds of fossils.

In this paper a possible interpretation somewhat different from the previous one is proposed concerning the geologic structure of the Hina limestone, and a discussion on the brachiopod fauna and its age is presented. The paleontological description will be published by the junior author in future.

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II. STRATIGRAPHY

As in the Akiyoshi and other limestone groups in the Chugoku district, the Hina limestone is underlain by the so-called schalstein. The zonation based on foraminifers is also concordant with that of the lower part of these limestone groups. The stratigraphic succession is summarized as follows in ascending order.

1) Basal schalstein: Composed of basic lavas and tuffs of dark greenish, dark reddish or variegated colour. An agglomerate or a tuff-breccia occurs locally. Layers, lenses and nodules of limestone, sometimes tuffaceous, are included in the upper part. The limestone contains a foraminiferal assemblage quite similar to that of the *Endothyra* zone.

The thickness is roughly estimated at 100 m. or so, though the lowest limit is not exposed.

2) Main limestone: Composed exclusively of massive, milky white to dark gray limestone. It is mostly bioclastic, with fragments of crinoids, bryozoans, calcareous algae, etc. (crinoid fragments predominant). The matrix is in some cases micritic and in others sparry (micrite predominating over sparite). An oolitic limestone is rather rare. Patches of algal biolithite occur at places. The following foraminiferal zones, though at the generic level, are recognized.

a) *Endothyra* zone: *Endothyra* is abundant and ubiquitous and *Endostaffella, Endothyranopsis, Mediocris, Palaeotextularia, Climacammina, Tuberitina, Tetrataxis* and *Archaediscus* are also not uncommon, though most of them range up to the overlying zones. The thickness is less than 150 m. This zone is usually divisible into two subzones, the lower and the upper. The lower subzone is characterized by *Endostaffella* and a species of

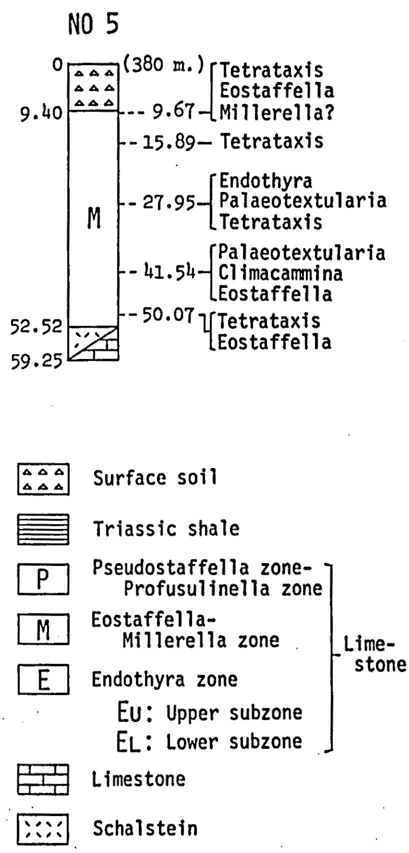


FIG. 1. Columnar section of the boring NO 5. Numerical values show the depth in meter under the ground. The height above sea-level is shown in parentheses.

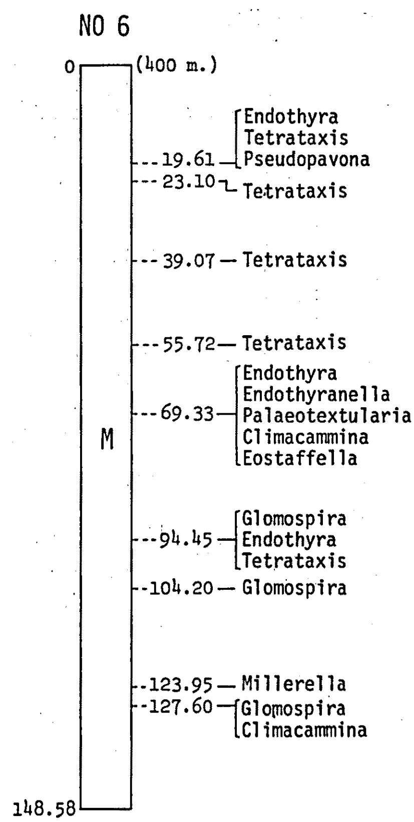


FIG. 2. Columnar section of the boring NO 6.

Mediocris (*M. breviscula*), while the upper by *Endothyranopsis* and another species of *Mediocris* (*M. mediocris*). Compared with OKIMURA's zonation (1966) in Akiyoshi, Atetsu and Taishaku, the former may possibly be equivalent to the *Endostaffella delicata* zone and the latter to the *Mediocris mediocris–M.* sp. A zone.

b) *Eostaffella–Millerella* zone: Characterized by the appearence of *Eostaffella* and *Millerella,* of which the latter is not so common as the former. *Glomospira* and *Globivalvulina* are also characteristic. The thickness is estimated approximately at 100–150 m. At Takahara, the eastern part of the surveyed area, the *Endothyra* zone is in some places lacking and the limestone of the *Eostaffella–Millerella* zone overlies directly the schalstein [see the geological map (PL. XV) and the columnar sections of borings NO 5 and TA 4 (Figs. 1, 3)]. Therefore, a disconformity is presumable at the base of the *Eostaffella–Millerella* zone.

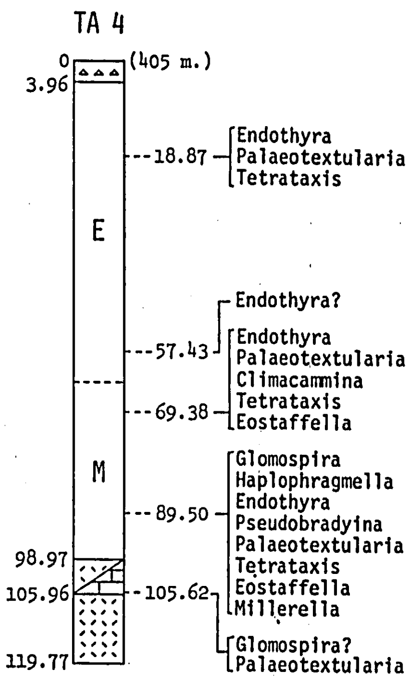


FIG. 3. Columnar section of the boring TA 4.

c) *Pseudostaffella* zone: Containing characteristically *Pseudostaffella,* in addition to *Eostaffella* and *Millerella.* The thickness of the outcropping part is 50 m. or less.

d) *Profusulinella* zone: Only from one of the cores of boring IW 2 (Fig. 7) at Ishigusa, the western part of the surveyed area, *Profusulinella* is found associated with *Pseudostaffella, Staffella, Eostaffella,* etc.

III. Geologic Structure

As both the limestone and the schalstein are for the most part massive, the strike and dip being hardly measurable, the geologic structure can only be concluded from tracing foraminiferal zones as well as rock-units. For this purpose, about 200 thin sections were prepared from exposures on the ground and about 100 from samples in underground borings and levels. The selected boring data are shown on Figs. 1–7.

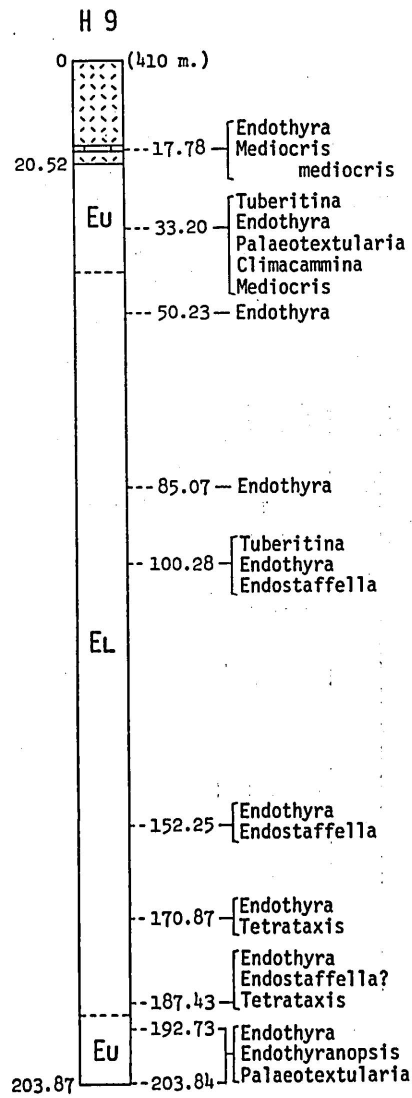


Fig. 4. Columnar section of the boring H 9.

1. *Structure within the Hina limestone*

As shown on the geological map and profiles (PL. XV), the schalstein is exposed narrowly along the northern margin of the limestone mass with a general trend of WNW–ESE. Interspaced by the limestone mostly of the *Endothyra* zone, the schalstein crops out again at Takahara (eastern area) and Ishigusa (western area) in the median part of the mass. From this distribution a syncline is inferable there. This is ascertained by borings at Takahara, where the schalstein lies beneath the limestone at a depth of 116.28 m., 91.23 m., 59.93 m., 98.97 m., 137.85 m. and 130.56 m. under the ground in TA 1, TA 2, TA 3, TA 4 (Fig. 3), TA 5 and TA 7, respectively. In NO 10 at Ishigusa the whole of 140.08 m. is composed of limestone. Judging from the depth where the schalstein appears, the strata seem to incline rather steeply. Moreover, the intervening occurrence of the *Eostaffella–Millerella* zone at Takahara may suggest the existence of the folding of the second order.

The belt of schalstein in the median area corresponds to an axial part of anticline, and on its southern side crop out the limestones of the *Endothyra*, *Eostaffella–Millerella* and *Pseudostaffella* zones successively, though there is a disorder in distribution according to the folding of minor scale. The boring data show that this anticline is overturned towards the south. In H 9 (Fig. 4) at Takahara, the limestone of the *Endothyra* zone lies beneath the schalstein at a depth of 20.52 m. under the ground and ranges down to a depth of

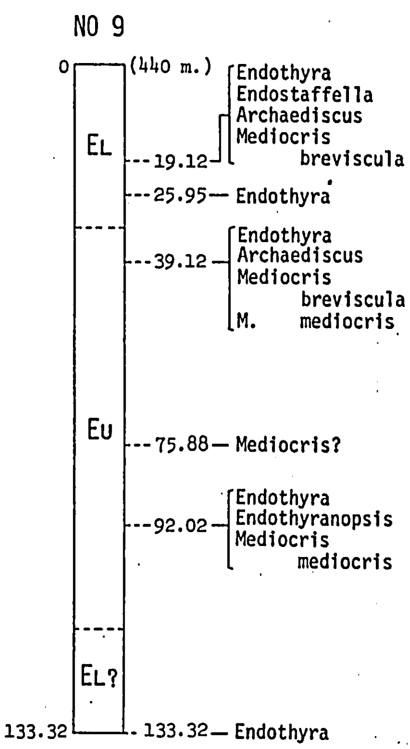


FIG. 5. Columnar section of the boring NO 9.

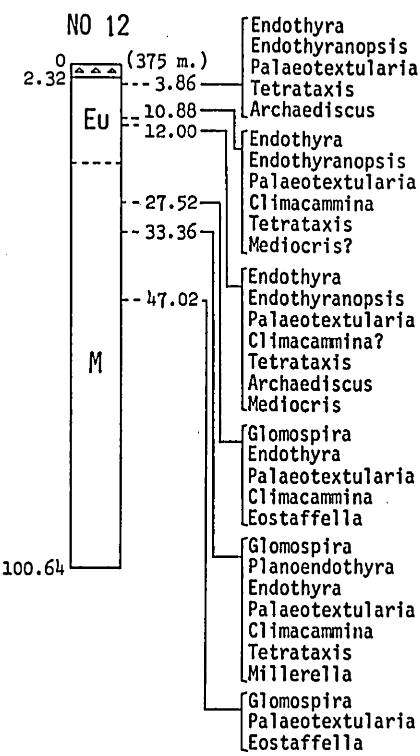


FIG. 6. Columnar section of the boring NO 12.

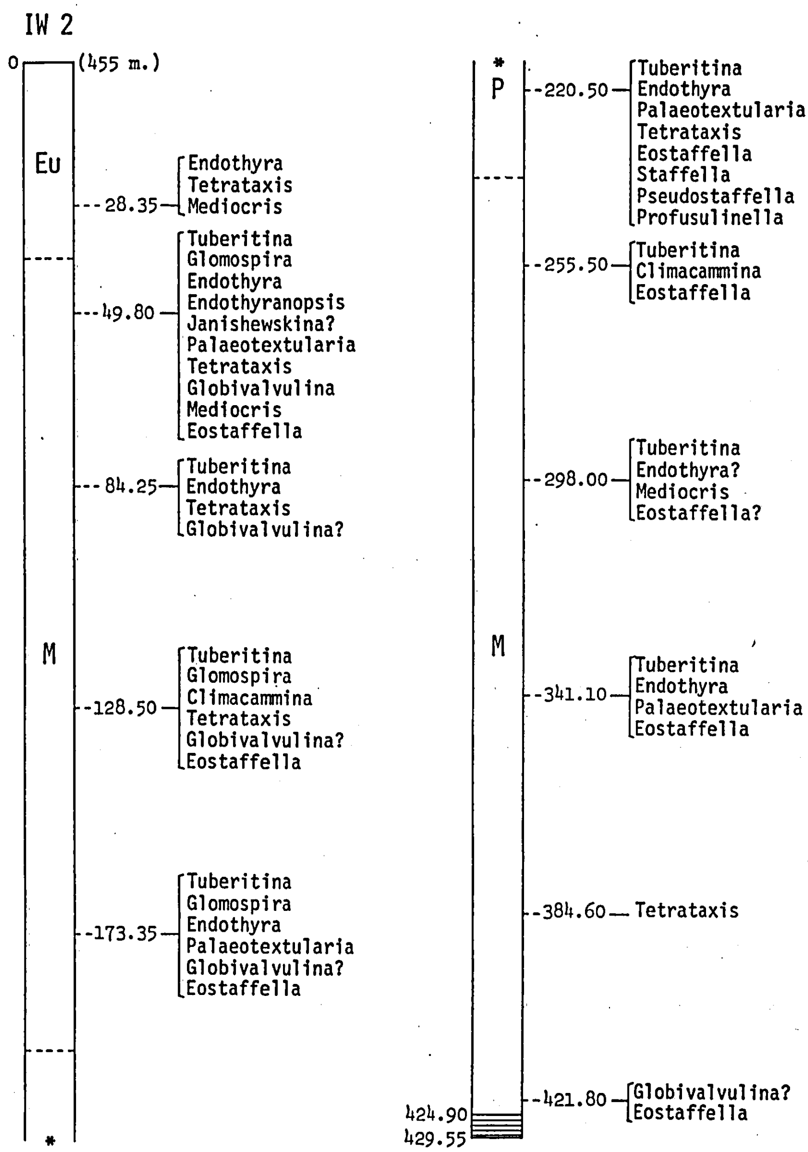


FIG. 7. Columnar section of the boring IW 2.

203.87 m. In NO 9 (Fig. 5) at Ishigusa the upper *Endothyra* subzone underlies the lower subzone, and in NO 12 (Fig. 6) the *Eostaffella–Millerella* zone does the *Endothyra* zone. Furthermore, in IW 2 (Fig. 7) the *Endothyra,* the *Eostaffella–Millerella,* the *Profusulinella* and again the *Eostaffella–Millerella* zone are recognized downwards; thus the strata are in reverse order and then return to normal. It seems that the dip of the strata, though steep near the schalstein, becomes gentler in the upper zones, judging from the wide distribution of the *Eostaffella–Millerella* zone, under which *Pseudostaffella* occurs in the 275 m. level at Takahara.

To sum up, the Hina limestone forms a complicated folding structure which is overturned towards the south in the median and southern areas. The axes of folding run in a direction of WNW–ESE or E–W, and the axial planes dip steeply in the deeper part and then become nearly horizontal upwards (southwards).

2. *Relationships of the Hina limestone to the adjacent Permian and Triassic rocks*

While KOBAYASHI (1941, 50) was of opinion that the Hina limestone is covered on its northern side by the non-calcareous Upper Paleozoic rocks (chert and alternation of sandstone and shale of YOSHIMURA's Yoshii group, 1961), NAKANO (1952) regarded this relationship as a fault. In the borings TA 2 and TA 5, the chert and sandstone occur beneath the limestone-schalstein sequence at a depth of 98.08 m. and 140.00 m. under the ground, respectively. The plane connecting the boundaries on and under the surface dips to the south with an angle of about 55 degrees. As the Yoshii group is of Permian age, this is a thrust-fault.

As has well been known, the limestone is thrust upon the Upper Triassic Nariwa group on its southern side (in some places also upon the Lower Cretaceous Inkstone group; NAKANO, 1952). In the boring IW 2 the Triassic shale appears at a depth of 424.90 m. under the ground, underlying a series of limestone. The plane connecting this point with the boundary on the surface dips to the north with an angle of about 60 degrees, even if it might become gentler as the thrust-sheet is advanced forwards. The high-angled thrusts on both sides of the limestone mass are also suggested by nearly straight boundary lines relative to a topographic relief.

A question arises whether the limestone (including the associated schalstein) is a "Klippe" horizontally shifted from more or less remote place or a mass vertically squeezed out (or injected) from a deeper part. Although the former interpretation has generally been accepted by previous authors, the present writers are inclined to prefer the latter from the following points.

1) The Hina limestone lies between the non-metamorphic Upper Paleozoic terrain and the Upper Triassic one. To the east of Takahara, there are wedge-like pieces of schalstein inserted at and near the boundary of the two terrains.

2) The high-angled thrusts on both the northern and southern margins.

3) The structural style of the limestone itself, with the axial planes of folding steep in the deeper part.

In these respects, further discussion will be given in another paper, with available data obtained from various localities.

IV. BRACHIOPOD FAUNAS AND THEIR AGES

1. *Brachiopod fossils*

A large number of brachiopod fossils were collected from the Hina limestone at three localities, THB 1, THB 2 (both at Takahara) and IGB 1 (at Ishigusa), of which the first is in the *Eostaffella–Millerella* zone and the others are in the *Endothyra* zone. Another collection was made from the Shodera limestone, a small limestone mass with underlying schalstein situated about 5 km. to the east-northeast of Hina. Here, fossiliferous blocks derived from nearby exposures of the limestone belonging to the *Endothyra* zone are piled up at the northern end of the mass. This locality is symbolized as SDB.

The brachiopod species hitherto identified at each locality are listed below (A: abundant, C: common, R: rare, VR: very rare).

1) Locality THB 1

Schizophoria sp. aff. *S. resupinata* (MARTIN)	.... R
Rugosochonetes sp.	........................VR
Avonia sp.	.... R
Eomarginifera sp.	........................VR
Dictyoclostus sp.	.... R
Striatifera striata (FISCHER)	.... A
Neospirifer? sp.	........................VR
Phricodothyris insolita GEORGE	.... R

The foraminifers coexisting with brachiopods are as follows: *Tuberitina* sp., *Glomospira* sp., *Endothyra* sp., *Mediocris* sp., *Eostaffella etoi* OTA, *E.* sp., *Millerella toriyamai* OTA, *M.* sp., *Climacammina* sp. and *Globivalvulina* sp. This foraminiferal assemblage is characteristic of the *Eostaffella–Millerella* zone.

2) Locality THB 2

Schizophoria sp. aff. *S. resupinata* (MARTIN)	.... R
Syringothyris sp.	........................VR
Spirifer sp. aff. *S. besnossovae* ABRAMOV	 C
Phricodothyris sp.	........................VR

The associated foraminifers are *Endothyra* sp., *Endostaffella* sp., *Palaeotextularia* sp. and *Spiroplectammina* sp.

3) Locality IGB 1

Schizophoria sp. aff. *S. resupinata* (MARTIN)	........................VR
Tylothyris sp.	........................VR
Spirifer sp. aff. *S. besnossovae* ABRAMOV	 C

The associated foraminifers are *Endothyra* sp. and *Mediocris breviscula* (GAMELINA).

4) Locality SDB

Schizophoria sp. aff. *S. resupinata* (MARTIN)	 C
Leptagonia sp.	........................VR
Megachonetes? sp.	........................VR
Gigantoproductus? sp.	........................VR
Goniophoria sp.	........................VR
Tylothyris sp.	........................VR
Syringothyris sp.	........................VR
Spirifer sp. aff. *S. besnossovae* ABRAMOV	.... A
Phricodothyris sp.	 C

The following foraminifers are also found in brachiopod-bearing blocks: *Tuberitina minima* SULEIMANOV, *T.* sp., *Endothyra* sp. cf. *E. prisca* RAUSER and REITLINGER, *E.* sp. cf. *E. rotayi* LEVEDEVA, *E.* sp. of *E. bradyi* MIKHAILOV group, *E.* sp. of *E. omphalota* RAUSER group, *E.* sp., *Mikhailovella* sp., *Endothyranopsis compressa* (RAUSER and REITLINGER), *E.* sp., *Rhenothyra?* sp., *Endostaffella* sp., *Bradyina* sp., *Mediocris mediocris* (VISSARIONOVA), *M.* sp., *Palaeotextularia vulgaris* (REITLINGER), *P. consobrina* LIPINA, *P.* sp., *Climacammina* sp., *Deckerellina?* sp., *Tetrataxis* sp. and *Archaediscus* sp. The foraminiferal assemblages of THB 2, IGB 1 and SDB are characteristic of the *Endothyra* zone.

2. *Consideration on geological age*

There is a remarkable difference in faunal assemblage of brachiopods between the *Endothyra* zone and the *Eostaffella–Millerella* zone. In the *Endothyra* zone, *Spirifer* sp. aff. *S. besnossovae* is predominant at every locality of THB 2, IGB 1 and SDB. Other spiriferaceans, *Tylothyris* sp. and *Syringothyris* sp., are, though very rare, also characteristic. On the other hand, the assemblage of THB 1 in the *Eostaffella–Millerella* zone is characterized by the abundance of *Striatifera striata,* with other productaceans such as *Avonia* sp., *Eomarginifera* sp. and *Dictyoclostus* sp. The occurrence of *Phricodothyris insolita* is also worthy to note. *Schizophoria* sp. aff. *S. resupinata* is the only species common to all localities.

The known stratigraphic ranges of the Hina and Shodera species or their close affinities, together with the ranges of the genera, are shown on Table 1 (after WILLIAMS et al., 1965, Treatise on Invertebrate Paleontology, Part H, Brachiopoda; and HATAI & YANAGIDA, 1974, Brachiopoda, in Paleontology, New Edition, Part II; with a slight emendation). At the generic level, the brachiopods from the Hina and Shodera limestones consist mainly of the Lower Carboniferous elements, of which some range down to the Devonian and some up to the Namurian, though there are several other longer ranging genera. The identified species are too small in number to conclude an affinity with the known faunas within and outside Japan; nevertheless the species significant for age-consideration are contained.

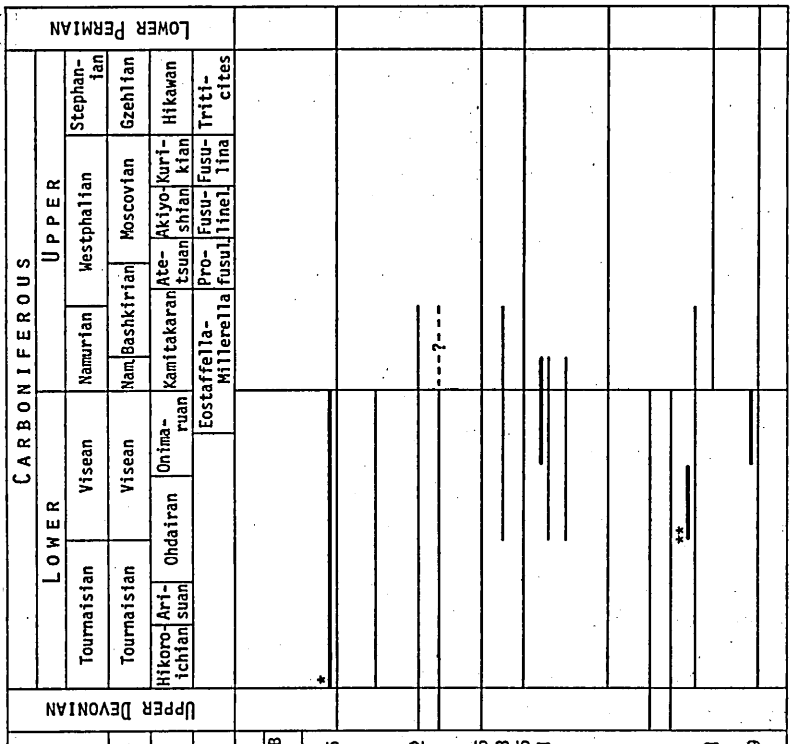
a. *Age of the brachiopod fauna in the Endothyra zone*

The representative species of this fauna, *Spirifer* sp. aff. *S. besnossovae* ABRAMOV, is closely allied to *S. besnossovae* from the Kuranakhsan series (lower Visean) of Sette-Dabana, southern Verkhoyansk, Siberia (ABRAMOV, 1970). It may belong to the group of *Spirifer striatus* (MARTIN) from the Lower Carboniferous of West Europe, and has some similarities to *S. humerosus* PHILLIPS from the Omi limestone, central Japan (HAYASAKA, 1925), *S.* sp. aff. *S. liangchowensis* CHAO from the *Millerella* zone of the Akiyoshi limestone (YANAGIDA, 1962), *S. liangchowensis* from the Visean Choniukou formation of Kansu, northwest China (CHAO, 1929) and *S.* sp. cf. *S. liangchowensis* from the Visean of Mt. Morgan district, Queensland, northeast Australia (MAXWELL, 1954).

Another important species of the fauna in question is *Schizophoria* sp. aff. *S. resupinata* (MARTIN), which is closely related to *S. resupinata,* the type-species of the genus. Although the genus *Schizophoria* has a long range from Silurian to Permian, *S. resupinata* is limited to occur in the Tournaisian and Visean, showing a wide geographical distribution. In western Europe, *S. resupinata* has been recorded from the K–D zones in the English Avonian and their equivalents in Belgium, with the most abundant occurrence in the upper Visean D zone (DELÉPINE, 1928; BOND, 1941; POCOCK, 1968). The identical or affinitive species reported from other localities are, for example, *S. resupinata* from the

TABLE 1. LIST OF BRACHIOPOD FOSSILS FROM THE HINA AND SHODERA LIMESTONES AND THE KNOWN STRATIGRAPHIC RANGES OF GENERA AND SPECIES.

SPECIES	SDB	IGB 1	THB 2	THB 1
ENTELETACEA				
Schizophoria sp. aff. S. resupinata	17	2	7	5
STROPHOMENACEA				
Leptagonia sp.	1			
CHONETACEA				
Rugosochonetes sp.				2
Megachonetes? sp.	1			
PRODUCTACEA				
Avonia sp.				6
Eomarginifera sp.				3
Dictyoclostus sp.				5
Striatifera striata				51
Gigantoproductus? sp.	1			
RHYNCHONELLACEA				
Goniophoria sp.	3			
SPIRIFERACEA				
Tylothyris sp.	1	1		
Syringothyris sp.	2		1	
Spirifer sp. aff. S. besnossovae	62	22	16	
Neospirifer? sp.				1
RETICULARIACEA				
Phricodothyris insolita				9
Phricodothyris sp.	11		1	



Arabic figures show the number of specimens. Thin line: range of genus, thick line: range of species, * range of *Schizophoria resupinata*, ** range of *Spirifer besnossovae*.

Chuguchanian series (upper Visean) of Sette-Dabana, southern Verkhoyansk (ABRAMOV, 1970), *S.* sp. cf. *S. resupinata* from the upper Tournaisian of Babbinboon, New South Wales (CAMPBELL, 1957) and the Tournaisian and Visean of the Bonaparte Gulf basin, northwestern Australia (ROBERT, 1971) and *S.* sp. aff. *S. resupinata* from the upper Tournaisian (and possibly lower Visean) of Mt. Morgan district, Queensland (MAXWELL, 1954). In Japan, *S. resupinata* is known from the upper Tournaisian Arisu series of the Kitakami massif (MINATO, 1952) and the Visean of Mitsuzawa, Kwanto massif (YANAGIDA, 1973b), and *S.* sp. aff. *S. resupinata* from the *Millerella* zone of Akiyoshi (YANAGIDA, 1962).

The occurrence of *Syringothyris* sp. is, though very rare, also noteworthy, because the genus is one of the index fossils of the Lower Carboniferous. In the Kitakami massif, it ranges from the uppermost Hikoroichi series to the lowest Ohdaira series, being most abundant in the upper Arisu (MINATO, 1951, 52; MINATO et al., 1953).

To sum up, it may be concluded that the *Spirifer* sp. aff. *S. besnossovae* fauna of the Hina and Shodera limestones is assigned to the Visean in age, and considering the age of the *Striatifera striata* fauna to be discussed below, the early Visean is preferable to the late Visean.

b. *Age of the brachiopod fauna in the Eostaffella–Millerella zone*

This is represented by *Striatifera striata* (FISCHER), an aberrant productid with a wide distribution and a restricted stratigraphic range. This species has been recorded from the upper Visean in western Europe and its equivalent (Okan and Serpukhovan series) in the Moscow basin (SARYTCHEVA, 1937). Other localities of *S. striata* are, for example, as follows: the Namurian ($C_1^n c$) of the Donetz basin (lowest Namurian in West European standard, AISENVERG et al., 1960), the upper Visean of Sette-Dabana, southern Verkhoyansk (ABRAMOV, 1970) and the Visean of Kweichow and Yunnan, southwest China (CHAO, 1927, 28). It must be noted that in southern Verkhoyansk the horizon of *Striatifera striata* is higher than that of *Spirifer besnossovae*. *Striatifera striata* described from the Omi limestone (HAYASAKA, 1925) is also conspecific with the Hina form.

Another important species is *Phricodothyris insolita* GEORGE. *Phricodothyris* is a cosmopolitan genus ranging from the Lower Carboniferous up to the Permian, showing its acme during the Visean. In Britain, *P. insolita* has been reported from the upper Visean D_2–D_3 zones (GEORGE, 1931). The same species occurs also in the *Millerella* zone of Akiyoshi (YANAGIDA, 1962). *Phricodothyris lineata* (MARTIN) from the upper Tournaisian and lower Visean of Queensland (MAXWELL, 1954) is similar to *P. insolita*.

As for *Schizophoria* sp. aff. *S. resupinata* (MARTIN), remarks are given in the preceding paragraph.

Summarizing the above, the *Striatifera striata* fauna of the Hina limestone may suggest the Visean age, with a high possibility of the late Visean. In this respect, the fauna in question is correlative with the *Cleiothyridina* fauna described by YANAGIDA (1962, 65) from Akiyoshi, with some genera and species common to each other, though *Striatifera striata* has not yet been known in the latter.

c. *Further consideration*

While MINATO and his collaborators (MINATO, 1975; MINATO & KATO, 1963) considered that the lowest part of the Akiyoshi and other limestones in the Chugoku district is correlated to the Namurian or Bashkirian from the evidence of corals, OKIMURA (1966) assigned it to the Visean on the basis of endothyroid and other smaller foraminifers. YANAGIDA (1968, 73a) offered a similar view through his study on brachiopods, suggesting the late Tournaisian or early Visean age of the lowest part of the Akiyoshi limestone. The age of the *Spirifer* sp. aff. *S. besnossovae* fauna from the Hina and Shodera limestones discussed above seems to support the opinions of OKIMURA and YANAGIDA.

If the limestone group in the Chugoku district ranges down to the Lower Carboniferous, then a question arises as to the boundary between Visean and Namurian (the boundary between Onimaruan and Kamitakaran in the Japanese standard). OKIMURA (1966) has drawn this boundary in the middle of his *Mediocris mediocris–M.* sp. A zone in Akiyoshi, Taishaku and Atetsu, and correlated the overlying *Millerella* sp. A–*Eostaffella* sp. A zone to the lower Bashkirian (middle Namurian in West European standard). This is adopted in TORIYAMA's comprehensive paper on the fusulinacean zones (TORIYAMA, 1967). As the *Striatifera striata* fauna in the Hina limestone, as well as the *Cleiothyridina* fauna in Akiyoshi (YANAGIDA, 1962, 65), is considered to be of late Visean age, the Visean-Namurian boundary must be, from the standpoint of brachiopod fossils, placed in the upper part of the so-called *Millerella* zone or just above it.

REFERENCES

ABRAMOV, B. S. (1970): *Biostratigraphy of the Carboniferous System, Sette-Dabana (southern Verkhoyank)* (in Russian). Izdatelistwo "Nauka", Moscow.

AISENVERG, D. E., BRAZHNIKOVA, N. E., NOVIK, K. O., ROTAY, A. P. & SHULGA, P. L. (1960): Carboniferous stratigraphy of the Donetz basin. *Compte rendu 4me Congr. Strat. Géol. Carbon., Heerlen, 1958,* 1–12.

BOND, G. (1941): Species and variation in British and Belgian Carboniferous Schizophoriidae. *Proc. Geol. Assoc., London,* **52**, (4), 285–303, 2 pls.

CAMPBELL, K. S. W. (1957): A Lower Carboniferous brachiopod-coral fauna from New South Wales. *Jour. Paleont.,* **31**, (1), 34–98, 7 pls.

CHAO, Y. T. (1927): Productidae of China, Part I. *Palaeont. Sinica, Ser. B,* **5**, (2), 1–192, 16 pls.

——— (1928): Productidae of China, Part II. *Ibid.,* **5**, (3), 1–79, 6 pls.

——— (1929): Carboniferous and Permian spiriferids of China. *Ibid.,* **11**, (1), 1–101, 11 pls.

DAVIDSON, T. (1857–63): A monograph of British Carboniferous brachiopoda. *Palaeontograph. Soc.,* **2**, (5), 1–280, 55 pls.

DELÉPINE, G. (1928): Les brachiopodes du Marbre noir de Dinant (Viséen inférieur). *Mém. Mus. roy. Hist. nat. Belgique,* (37), 1–38, 6 pls.

FUJIMOTO, H. (1944): Palaeontological study on Titibu-System of the Taisyaku-kyo region, Hirosima-Prefecture (in Japanese). *Studies Geol. Mineral. Inst., Tokyo Bunrika Daigaku,* (1), 1–19.

GEORGE, T. N. (1931): The British Carboniferous reticulate Spiriferidae. *Quart. Jour. Geol. Soc. London,* **88**, (4), 516–575, 5 pls.

HATAI, K. & YANAGIDA, J. (1974): Brachiopoda; in *Paleontology, New Edition, Part II* (Editor T. MATSUMOTO) (in Japanese). Asakura Shoten, Tokyo.

HAYASAKA, I. (1925): On the fauna of the anthracolithic limestone of Omi-mura in the western part of Echigo. *Sci. Rep. Tohoku Imp. Univ., 2nd Ser.,* **8**, 1–83, 7 pls.

KAWAI, M. (1951): Upper Triassic System in the environs of Nariwa, Okayama Prefecture; in "Triassic stratigraphy of Japan" (in Japanese). *Rep. Spec. No., Geol. Surv. Japan,* 57–72.

KOBAYASHI, T. (1941): The Sakawa orogenic cycle and its bearing on the origin of the Japanese Islands. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2,* **5**, (7), 219–578.

——— (1950): *Regional geology of Japan, Chugoku region* (in Japanese). Asakura Shoten, Tokyo.

KONINCK, L. G. de (1887): Faune du calcaire carbonifère de la Belgique. *Ann. Mus. roy. Hist. nat. Belgique,* **14**, (6), 1–154, 31 pls.

MAXWELL, W. G. H. (1954): Upper Palaeozoic formations in the Mount Morgan district, Faunas. *Publ. Univ. Queensland, Dept. Geol.,* **4**, (5), 1–58, 6 pls.

MINATO, M. (1951): On the Lower Carboniferous fossils of the Kitakami massif, northeast Honshu, Japan.

Jour. Fac. Sci., Hokkaido Univ., Ser. 4, **7**, (4), 355–382, 5 pls.

——— (1952): A further note on the Lower Carboniferous fossils of the Kitakami mountainland, northeast Japan. *Ibid.*, **8**, (2), 136–174, 10 pls.

——— (1955): Japanese Carboniferous and Permian corals. *Ibid.*, **9**, (2), 1–202, 43 pls.

——— (1975): Japanese Palaeozoic corals. *Jour. Geol. Soc. Japan*, **81**, (2), 103–126.

———, HASHIMOTO, S., SUYAMA, K., TAKEDA, H., SUZUKI, Y., KIMURA, S., YAMADA, K., KAKIMI, Y., ICHIKAWA, T. & SUETOMI, H. (1953): Biostratigraphie des Karbons im Kitakami-Gebirge, nordöstliches Honshu, Japan (in Japanese with German abstract). *Jour. Geol. Soc. Japan*, **59**, (695), 385–399.

——— & KATO, M. (1963): Fossils with the lowest Namurian aspect newly found by Dr. Y. HASEGAWA in the Akiyoshi province. *Earth Science*, (66), 32–42, 2 pls.

NAKANO, M. (1952): Geology of Kyowa-mura district, Shitsuki-gun, Okayama Prefecture, with special reference to the recent informations on the Palaeozoic and Mesozoic (in Japanese with English abstract). *Geol. Rep. Hiroshima Univ.*, (2), 15–30.

OKIMURA, Y. (1958): Biostratigraphical and paleontological studies on the endothyroid foraminifera from the Atetsu limestone plateau, Okayama Prefecture, Japan. *Jour. Sci. Hiroshima Univ., Ser. C*, **2**, (3), 235–264, 5 pls.

——— (1966): Microbiostratigraphical studies on the foraminiferal faunas of the Lower Carboniferous formations of the Chugoku region, Southwest Japan (in Japanese with English abstract). *Geol. Rep. Hiroshima Univ.*, (15), 1–46, 1 pl.

OZAWA, Y. (1925a): Paleontological and stratigraphical studies on the Permo-Carboniferous limestone of Nagato, Part II, Paleontology. *Jour. Coll. Sci., Imp. Univ. Tokyo*, **45**, (6), 1–90, 14 pls.

——— (1925b): The post-Paleozoic and late-Mesozoic earth-movements in the Inner Zone of Japan. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2*, **1**, (2), 91–104.

POCOCK, Y. P. (1968): Carboniferous schizophoriid brachiopods from western Europe. *Palaeont.*, **11**, (1), 64–93, 1 pl.

ROBERT, J. (1971): Devonian and Carboniferous brachiopods from the Bonaparte Gulf basin, northwestern Australia. *Bureau Min. Res. Geol. Geophy., Bull.*, (122), 1–319, 59 pls.

SARYTCHEVA, T. G. (1937): Productidés du Carbonifère inférieur du bassin de Moscou (genres *Striatifera*, *Linoproductus* et *Cancrinella*). *Trav. Inst. paléozool.*, **4**, (1), 7–116, 7 pls.

TORIYAMA, R. (1967): The fusulinacean zones of Japan. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **18**, (1), 35–260.

WILLIAMS, A., ROWELL, A. J., MUIR-WOOD, H. M., PITRAT, C. W., SCHMIDT, H., STEHLI, F. G., AGER, D. V., WRIGHT, A. D., ELLIOTT, G. F., AMSDEN, T. W., RUDWICK, M. J. S., HATAI, K., BIERNAT, G., McLAREN, D. J., BOUCOT, A. J., JOHNSON, J. G., STATON, R. D., GRANT, R. E. & JOPE, H. M. (1965): *Treatise on invertebrate paleontology* (Editor R. C. MOORE), *Part H, Brachiopoda*. Geol. Soc. America & Univ. Kansas Press.

YANAGIDA, J. (1962): Carboniferous brachiopods from Akiyoshi, Southwest Japan, Part I. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **12**, (1), 87–127, 8 pls.

——— (1965): Carboniferous brachiopods from Akiyoshi, Southwest Japan, Part II. *Ibid.*, **14**, (2), 113–142, 4 pls.

——— (1968): Carboniferous brachiopods from Akiyoshi, Southwest Japan, Part III, *Delepinea* from a pyroclastic rock near the lowest part of the Akiyoshi limestone group. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, (72), 327–339, 2 pls.

——— (1973a): Carboniferous brachiopods from Akiyoshi, Southwest Japan, Part IV, *Marginatia* from the lowest part of the Akiyoshi limestone group. *Bull. Akiyoshi-dai Sci. Museum*, (9), 39–51, 2 pls.

——— (1973b): Early Carboniferous Viséan faunas discovered from Mitsuzawa, southeastern part of the Kwanto massif, Part II, Brachiopods. *Trans. Proc. Palaeont. Sci. Japan, N. S.*, (90), 99–112, 2 pls.

YOSHIMURA, N. (1961): Geological studies of the Paleozoic groups in the Oga plateau, central Chugoku, Japan (in Japanese with English abstract). *Geol. Rep. Hiroshima Univ.*, (10), 1–36, 2 pls.

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EXPLANATION OF PLATES

PLATE XV. Geological map and profiles of the Hina area.

PLATE XVI.

Figs. 1–5. *Spirifer* sp. aff. *S. besnossovae* ABRAMOV

1. Ventral (a) and posterior (b) views of a pedicle valve, ×1. IGSH-THB-2042, Loc. THB 2.
2. Dorsal view of a brachial valve, ×1. IGSH-SDB-27, Loc. SDB.
3. Ventral (a), posterior (b) and lateral (c) views of a pedicle valve, ×1. IGSH-THB-2003, Loc. THB 2.
4. Ventral view of an incomplete pedicle valve, ×1. IGSH-THB-2008, Loc. THB 2.
5. Ventral view of a pedicle valve, ×1. IGSH-IGB-1001, Loc. IGB 1.

Figs. 6, 7. *Schizophoria* sp. aff. *S. resupinata* (MARTIN)

6. Dorsal view of a brachial valve, ×1.5. IGSH-SDB-123, Loc. SDB.
7. Ventral (a) and posterior (b) views of a pedicle valve, ×1.5. IGSH-THB-1015, Loc. THB 1.

Figs. 8, 9. *Phricodothyris insolita* GEORGE

8. Ventral (a) and lateral (b) views of an incomplete pedicle valve, ×2. IGSH-THB-1033, Loc. THB 1.
9. Ventral (a), lateral (b) and posterior (c) views of a pedicle valve, ×2. IGSH-THB-1029, Loc. THB 1.

Fig. 10. *Phricodothyris* sp.

Dorsal view of an incomplete brachial valve, ×2. IGSH-SDB-100, Loc. SDB.

PLATE XVII.

Fig. 1. *Syringothyris* sp.

Dorsal (a) and ventral (b) views of an incomplete pedicle valve, ×1. IGSH-SDB-117, Loc. SDB.

Figs. 2–5. *Striatifera striata* (FISCHER)

2. Ventral view of a pedicle valve, ×1. IGSH-THB-1016, Loc. THB 1.
3. Ventral view of an incomplete pedicle valve, ×1. IGSH-THB-1071, Loc. THB 1.
4. Ventral view of a pedicle valve, ×1. IGSH-THB-1066, Loc. THB 1.
5. Ventral view of an incomplete pedicle valve, ×1. IGSH-THB-1013, Loc. THB 1.

PLATE XVIII.

Fig. 1. *Dictyoclostus* sp.
Ventral (a) and posterior (b) views of an incomplete pedicle valve, ×1.5. IGSH-THB-1039, Loc. THB 1.

Figs. 2, 3. *Tylothyris* sp.
2. Ventral view of an incomplete pedicle valve, ×2. IGSH-IGB-1023, Loc. IGB 1.
3. Ventral view of an incomplete pedicle valve, ×2. IGSH-SDB-018, Loc. SDB.

Figs. 4, 5. *Goniophoria* sp.
4. Lateral view of an incomplete brachial valve, ×1.5. IGSH-SDB-010-1, Loc. SDB.
5. Lateral view of an incomplete brachial valve, ×1.5. IGSH-SDB-024, Loc. SDB.

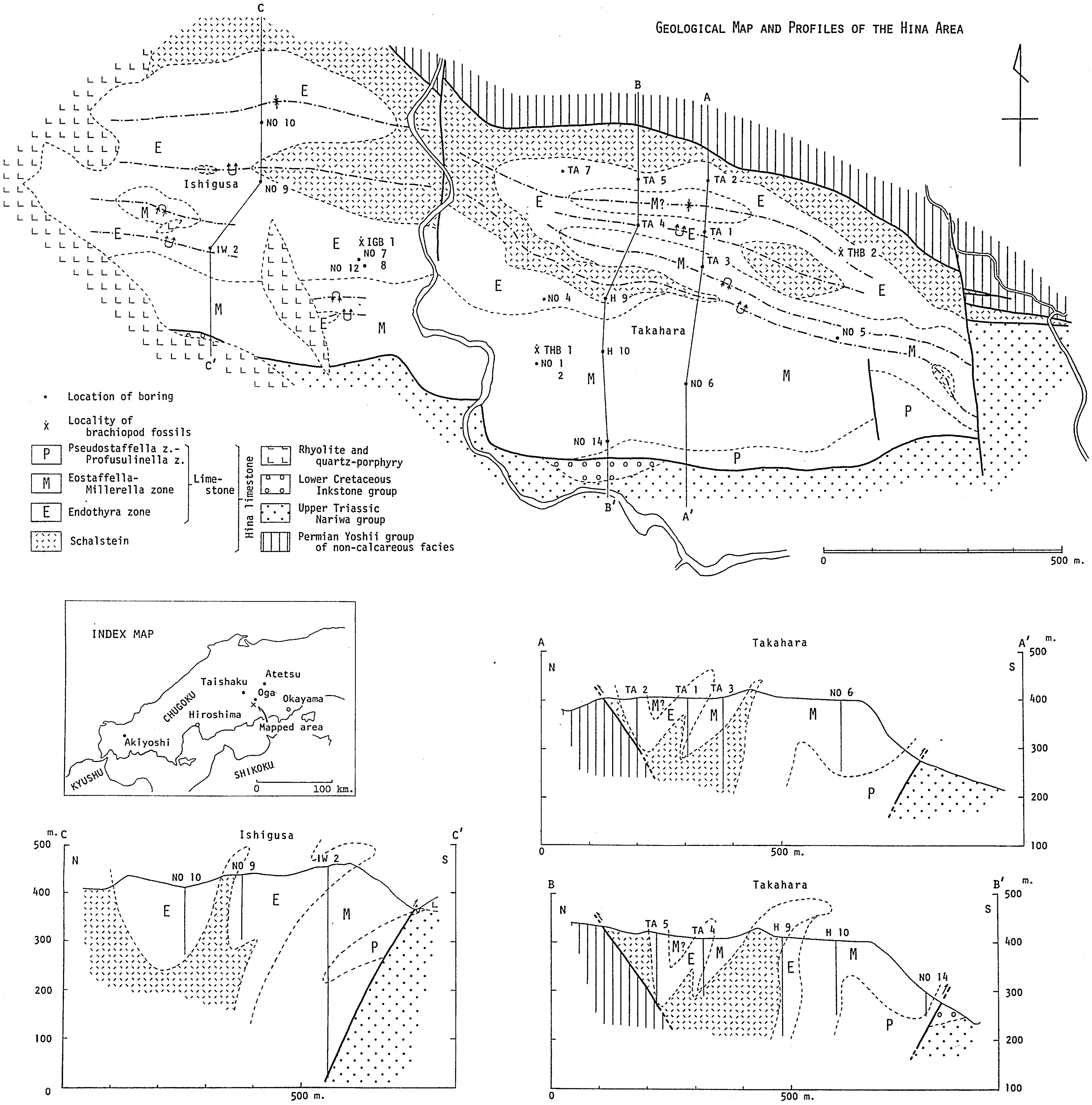
Fig. 6. *Leptagonia* sp.
Ventral view of a pedicle valve, ×2. IGSH-SDB-067, Loc. SDB.

Fig. 7. *Rugosochonetes* sp.
Ventral view of a pedicle valve, ×2. IGSH-THB-1010, Loc. THB 1.

Figs. 8, 9. *Avonia* sp.
8. Lateral (a) and ventral (b) views of a pedicle valve, ×2. IGSH-THB-1034, Loc. THB 1.
9. Ventral view of a pedicle valve, ×2. IGSH-THB-1028, Loc. THB 1.

Fig. 10. *Eomarginifera* sp.
Lateral (a), ventral (b) and posterior (c) views of an incomplete pedicle valve, ×2. IGSH-THB-1041, Loc. THB 1.

Photos by Yuji OKIMURA.


GEOLOGICAL MAP AND PROFILES OF THE HINA AREA
Ishigusa
Takahara
NO 10
NO 9
IW 2
IGB 1
NO 7
8
NO 12
TA 7
TA 5
TA 2
TA 4
TA 1
TA 3
THB 2
NO 4
H 9
NO 5
THB 1
NO 1
2
H 10
NO 6
NO 14
A
A'
B
B'
C
C'
0
500 m.
Location of boring
Locality of brachiopod fossils
P Pseudostaffella z.- Profusulinella z.
M Eostaffella- Millerella zone
E Endothyra zone
Lime-stone
Schalstein
Hina limestone
Rhyolite and quartz-porphyry
Lower Cretaceous Inkstone group
Upper Triassic Nariwa group
Permian Yoshii group of non-calcareous facies
INDEX MAP
Taishaku
Atetsu
Oga
Okayama
CHUGOKU
Hiroshima
Mapped area
Akiyoshi
KYUSHU
SHIKOKU
0
100 km.
N
S
m.
500
400
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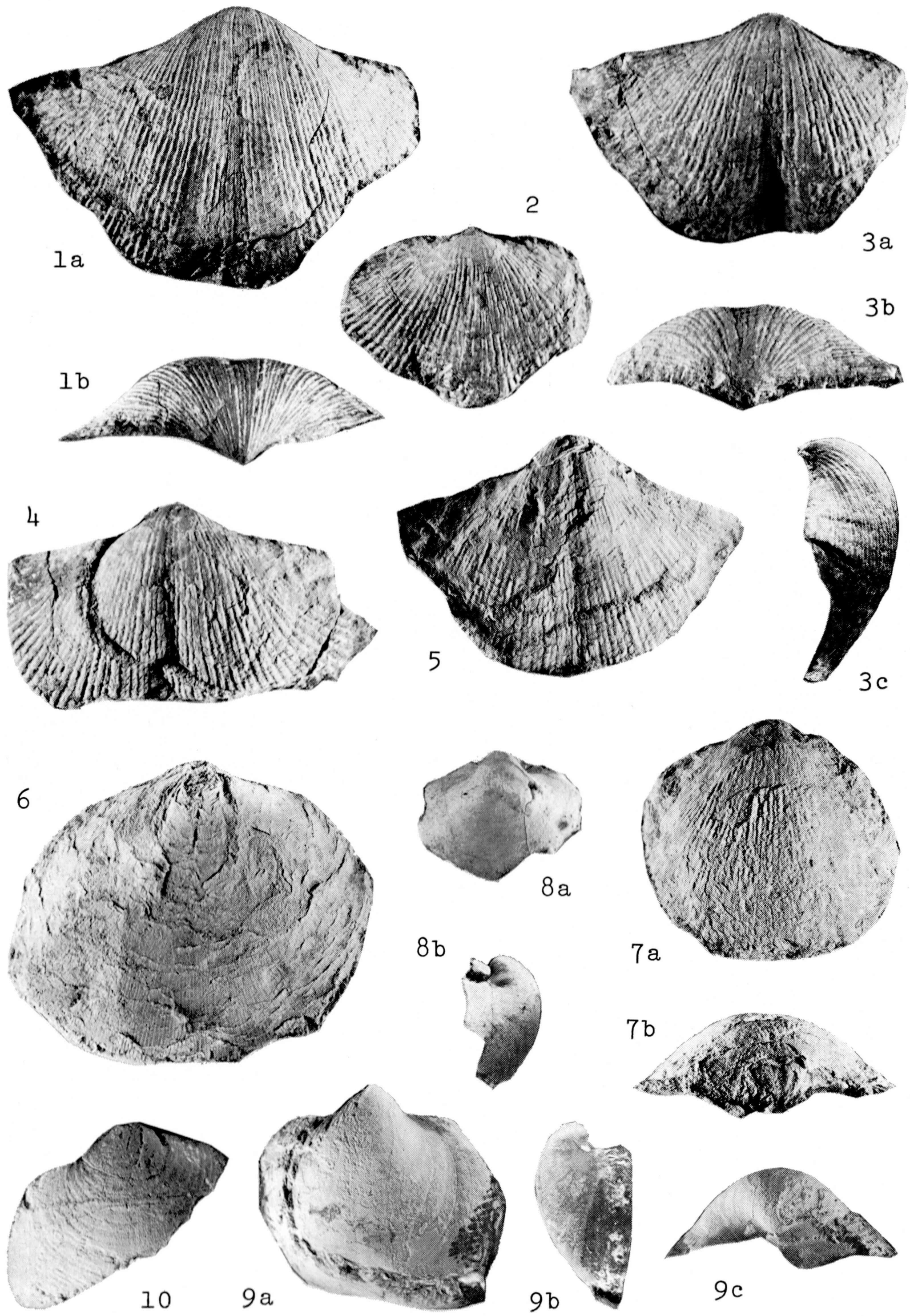
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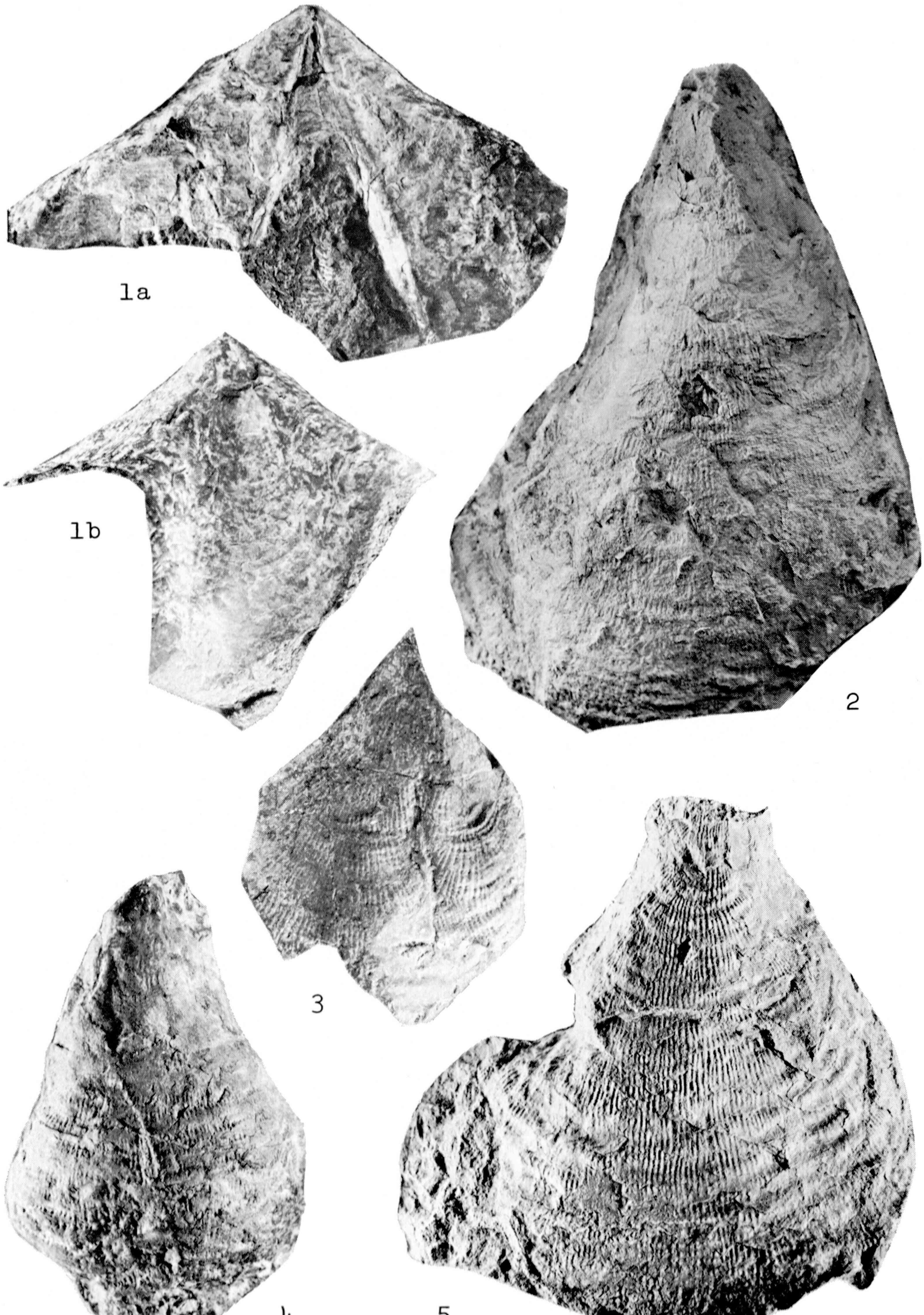
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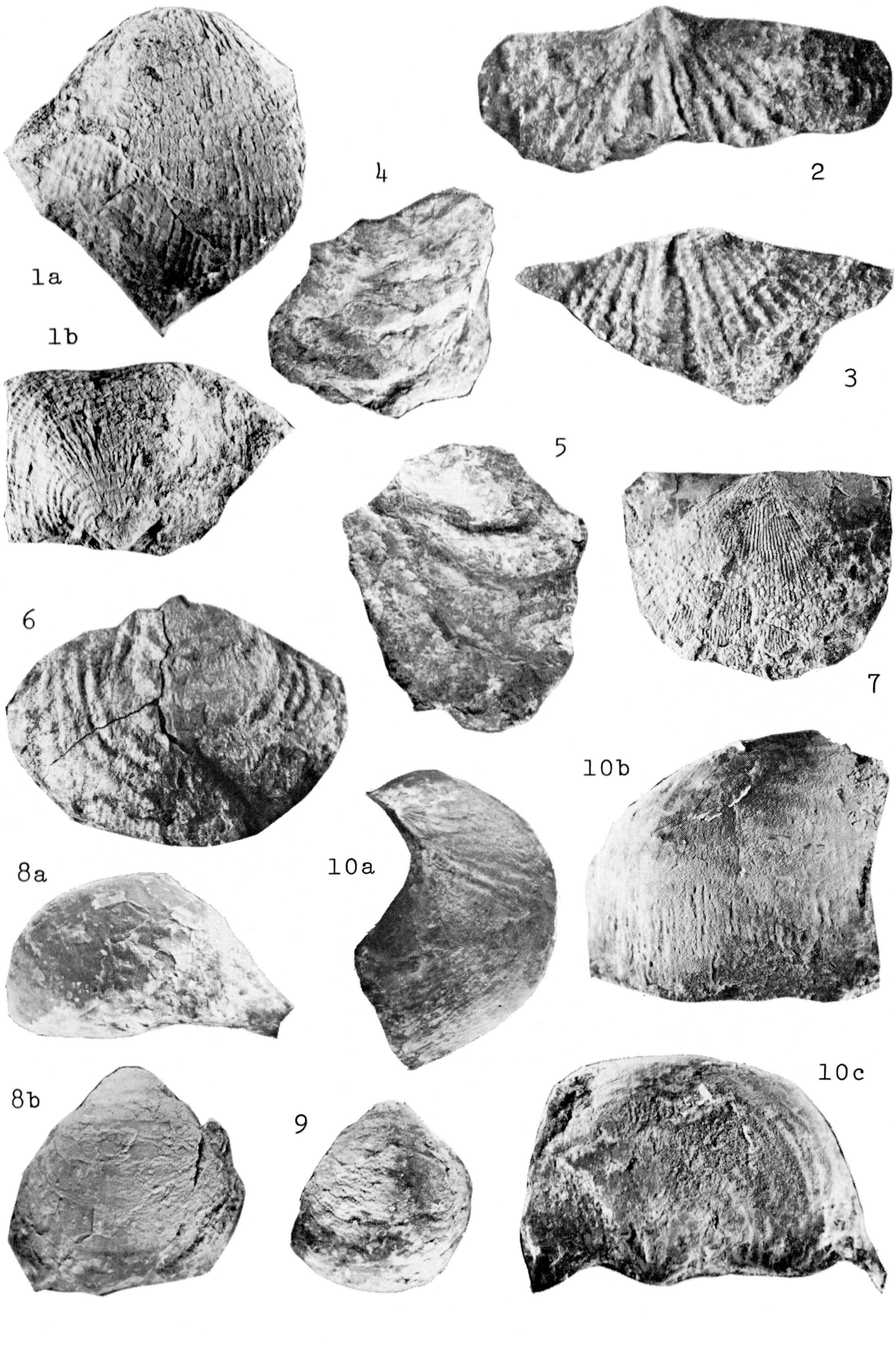
1a
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4
5
6
7
8a
8b
9
10a
10b
10c