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Geology of the Tomioka Area, Gunma Prefecture, with a note on "*Lepidocyclina*" from the Abuta Limestone Member

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ABSTRACT

The Tertiary System distributed in the area extending from Shimonita-machi to the west of Takasaki City, Gunma Prefecture was studied with the purpose to make a biostratigraphical classification of the different lithological units based upon the Foraminifera (planktonic and benthonic). Emphasis was given to the interpretation of the geostructure, sedimentary environment of the fossiliferous Tertiary strata, geological ages of the stratigraphic units, correlation with other areas and to make a paleontological study on *Nephrolepidina* from the present area. Descriptions are given to each of the formations recognized in the field, preserved specimens of *Nephrolepidina* from the Abuta Limestone Member of the Idozawa Formation and the planktonic Foraminifera from several localities of each formation are treated in detail.

CONTENTS

INTRODUCTION

In this paper, the biostratigraphy of the Tomioka area, especially of the lower part of the Tomioka Group is described in order to determine the stratigraphical position of Lepidocyclinids, and an attempt was made to determine the geological ages of the respective formations based upon the Foraminifera. Also, correlation was made with the Tertiary rocks developed in other areas of the Kwanto massif.

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PREVIOUS WORKS

The stratigraphical units of authors are compared with one another and shown in Table 1. The first work on the geology of the Tomioka area is by Yabe and Hanzawa (1922), who also made a paleontological study of the genus *Lepidocyclina* from the western part of the area. Murakoshi (1931, MS) described the stratigraphy and geological structure of the Tomioka area.

Table 1. Correlation of the Stratigraphic units of Authors

<table>
<tr><td colspan="3">Kanra-,Tano-,Usui-Gun and Tomioka A.</td><td>Usui-Gun Area</td><td colspan="6">Kanra-,Tano-,Usui-Gun and Tomioka Area</td></tr>
<tr><td>MURAKOSHI(1931)</td><td colspan="2">HUZIMOTO and KOBAYASHI(1938)</td><td>ISHIWADA (1948)</td><td colspan="2">WATANABE(1952,'54)</td><td>MIZUNO (1961)</td><td colspan="3">MATSUMARU (1967)</td></tr>
<tr><td rowspan="2">Onomura Formation</td><td colspan="2" rowspan="7">Tomioka Formation</td><td>Haraichi Siltstone</td><td rowspan="8">Tomioka Group</td><td rowspan="2">Yoshii Formation</td><td rowspan="2">Ono Formation</td><td rowspan="7">Tomioka Group</td><td colspan="2">Yoshii Formation</td></tr>
<tr><td>Shomyoji Sandst.</td><td colspan="2">Niwaya Formation</td></tr>
<tr><td>Tomioka Form.</td><td>Isobe Alternation</td><td rowspan="2">Fukushima Form.</td><td>Isobe Formation</td><td colspan="2">Haratajino Form.</td></tr>
<tr><td rowspan="4">Lepidocyclina Formation</td><td rowspan="5">Tsukahara Siltstone</td><td>Fukushima Form.</td><td colspan="2" rowspan="2">Idozawa Form.</td></tr>
<tr><td rowspan="2">Idozawa Form.</td><td rowspan="4">Nukabe Formation</td></tr>
<tr><td colspan="2">Obata Formation</td></tr>
<tr><td>Shimonita Form.</td><td>Shimonita Form.</td><td>Ushibuse Form.</td></tr>
<tr><td>Shimonita Form.</td><td>Kanohara Form.</td><td>Ushibuse Form.</td><td>Kanohara Conglo.</td><td colspan="3"></td></tr>
</table>

A. = Area

Huzimoto and Kobayashi (1938) published on the geology of the Tomioka-Takasaki area and recognised many units. In 1950, 1952, and 1954, Watanabe classified the Tomioka, Itahana and Akima formations previously proposed by Huzimoto and Kobayashi (1938) into the two Tomioka and Takasaki groups based upon the distribution of plagio-rhyolitic tuff.

Subsequently, Mizuno (1961, MS) described the Tertiary geology of this area and pointed out that the alternating beds in the Nukabe Formation may correspond to the Shimonita and Idozawa Formations of Watanabe (1950, 1952, 1954). He also considered the

Kanohara Conglomerate to be the basal part of the Tertiary deposits as already suggested by Watanabe, and that it gradually changes into the Ushibuse Formation. Arai *et al.* (1966) discovered that the Kanohara Conglomerate was overlain by the Tertiary Group with unconformity.

Concerning the paleontological studies of this area Yokoyama (1926) reported *Mya grewingki* Böhn and other molluscan fossils from near the Yachio bridge of Shimonita-machi, Kanra-Gun. Otuka (1939) described *Mya grewingki* from the Shimonita Formation and mentioned that it is Oligocene in age. Lately, Saito (1963) studied the planktonic Foraminifera from each of the formations of the Tomioka Group and reported five foraminiferal zones which range from *Globigerinita unicava* to *Globorotalia bykovae*. The writer also confirmed the five foraminiferal zones previously recorded by Saito (1963).

STRATIGRAPHY

A) Basement Rocks

The basement rocks of the Tertiary sediments exposed in this area are the Sanbagawa Green Schist, Nanjyai Formation, Hiraname Granite, Kanohara Conglomerate and Kottate-yama Tuff.

Sanbagawa Green Schist: – The type locality is the Sanbagawa valley in Minami-kanra-Gun, Gunma Prefecture. This lithologic unit is distributed in E-W direction mostly on the southern side of the Okitano-Iwayama line in the southern part of Tomioka City. The rocks consist almost of green schist showing good schistose texture. At Iwayama in Shimonita-machi, this schist alternates with white colored crystalline limestone; the strike is N 50°W with dip of 22°NE.

Nanjyai Formation: – The type locality is from Morizawa to Nakakosaka along the Saimoku River in Shimonita-machi. The rocks consist mainly of black mudstone intercalated with sandstone, quartzite, hornfels and rarely with thin beds of acidic tuff. Generally, the rocks are deformed and sheared. Those rocks come into contact with the Tertiary formations with fault, but in the Kanohara area of Tomioka City, the Tertiary rocks are superposed upon the Nanjyai with unconformity. Although the geological age of this formation is unknown, it is considered to be Cretaceous (pre-Atokura stage) from its similarity with rocks of that age in other areas.

Hiraname Granite: – The type locality is the vicinity of Hiraname, Nakakosaka in Shimonita-machi, Kanra-gun, Gunma Prefecture. This rock intrudes the Nanjyai Formation in the northwest and northeast of Shimonita-machi and had been considered to be Cretaceous in age. From the result of Potassium-Argon dating of the rock sample from Karasawa at the west of the type locality, the age is 44×10^6 years.

This granite is exposed also in the vicinities of Sendaira, Miyashiro of Nukabe, south of Kanohara and Jyagui in Tomioka City. This granite is medium to coarse grained, rarely with biotite, and is associated with quartz diorite at places. Mylonite is found in the west of Hiraname. It is in fault contact with the Tertiary Tomioka Group.

Kanohara Conglomerate: – The type locality is along the Kabura River south of the Kanohara station (Jyoshin railway). It is composed mainly of boulder conglomerate (up to 2 m in diameter) consisting of granite porphyry, diorite, welded tuff, rarely of granite and very rarely of green schist. The matrix of this conglomerate is generally of coarse grained sandstone, but at places of tuffaceous materials. This conglomerate frequently contains thin lenses of sandstone. The Tertiary formations overlie this conglomerate with unconformity in the area of Nakajima and are in fault contact in Shimonita-machi. Indeterminable molluscan fossils have been found from the sandstone lenses.

Kotsutateyama Tuff: The type locality is Mt. Kotsutateyama and its vicinity. It is distributed in the area of Kotsutateyama and southwest of Kanohara with a general trend of E-W. The formation is composed mainly of acidic rocks with light brown and reddish brown colored hard rock fragments. The formation is overlain with unconformity by the Miocene Obata Formation. The thickness of the formation is considered to be about 150 m on the basis of its structure.

B) Tertiary System (Tomioka Group)

The Tertiary sequence given in Table 1 is described below in ascending order.

The Tomioka Group is subdivided into the Shimonita Formation, Ushibuse Formation, Obata Formation, Abuta Limestone Member of the Idozawa Formation, Oketayama Andesite, Kawagoishi Andesite, Haratajino Formation, Niwaya Formation, and Yoshii Formation.

a) *Shimonita Formation*

Murakoshi (1931, MS) proposed the name of Shimonita Formation for the Kanohara Conglomerate distributed in the vicinity of Shimonita-machi and the *Lepidocyclina* Formation for the fossiliferous marine, hard muddy sandstone developed from the Yachio bridge of Shimonita-machi to the upper course of the Saimoku River.

In 1938, Huzimoto and Kobayashi used the name of Kanohara Formation for the Shimonita Formation of Murakoshi and placed Murakoshi's *Lepidocyclina* Formation in the lower part of the their Tomioka Formation. Watanabe (1950, 1952), however, proposed to use the name of Shimonita Formation for the marine fossiliferous hard muddy deposits and stated that the formation covers the Kanohara Formation of Huzimoto and Kobayashi with conformity. However, Arai *et al.* (1966) reported that the stratigraphic relation between those two formation was an unconformity.

The writer uses the Shimonita Formation redefined by Watanabe. It is composed of sandstone and siltstone layers which overlie the Kanohara Conglomerate with unconformity as already pointed out by Arai *et al.*

Type locality: Along the Saimoku River west of Shimonita-machi, Kanra-gun, Gunma Prefecture.

Distribution: The formation crops out in the lenticular shaped area north of the Okitano-Iwayama line, abuts against the Sanbagawa Green Schist, is delimited at the south by the Morizawa-Iwayama (Higashimura) fault, abuts against the Nanjyai Formation and the Kanohara Conglomerate, and is also exposed in the narrow area of the Seisenji Temple. The formation rests upon the Kanohara Conglomerate with unconformity.

Lithology: The formation is mainly composed of grayish white to yellowish white coarse grained sandstone or sometimes of granule conglomerate in the lower part and hard gray shale, blue gray sandy siltstone and massive gray siltstone in the middle part and of massive gray to brownish siltstone, sometimes intercalated with thin pumiceous sandstone in the upper part. In the lower part it very rarely yields plant fossils. Intercalated in the lower part are thin lenses of dark gray hard shale which gradually change to a gray siltstone. The stratified siltstone and sandy siltstone in the middle part sometimes intercalate thin hard fine to medium grained gray to brownish gray sandstone. In the upper part, there is a gray siltstone which forms an alternation with brownish gray fine to medium grained sandstone and this gradually changes to massive non-stratified siltstone brownish gray to gray on the fresh surface.

In the Okitano-zawa a tributary of the Nanmoku River, the formation covers the Kanohara Conglomerate with unconformity. At the basal part of the formation in this area is developed a nearly 8 m thick granule conglomerate composed of fragments of

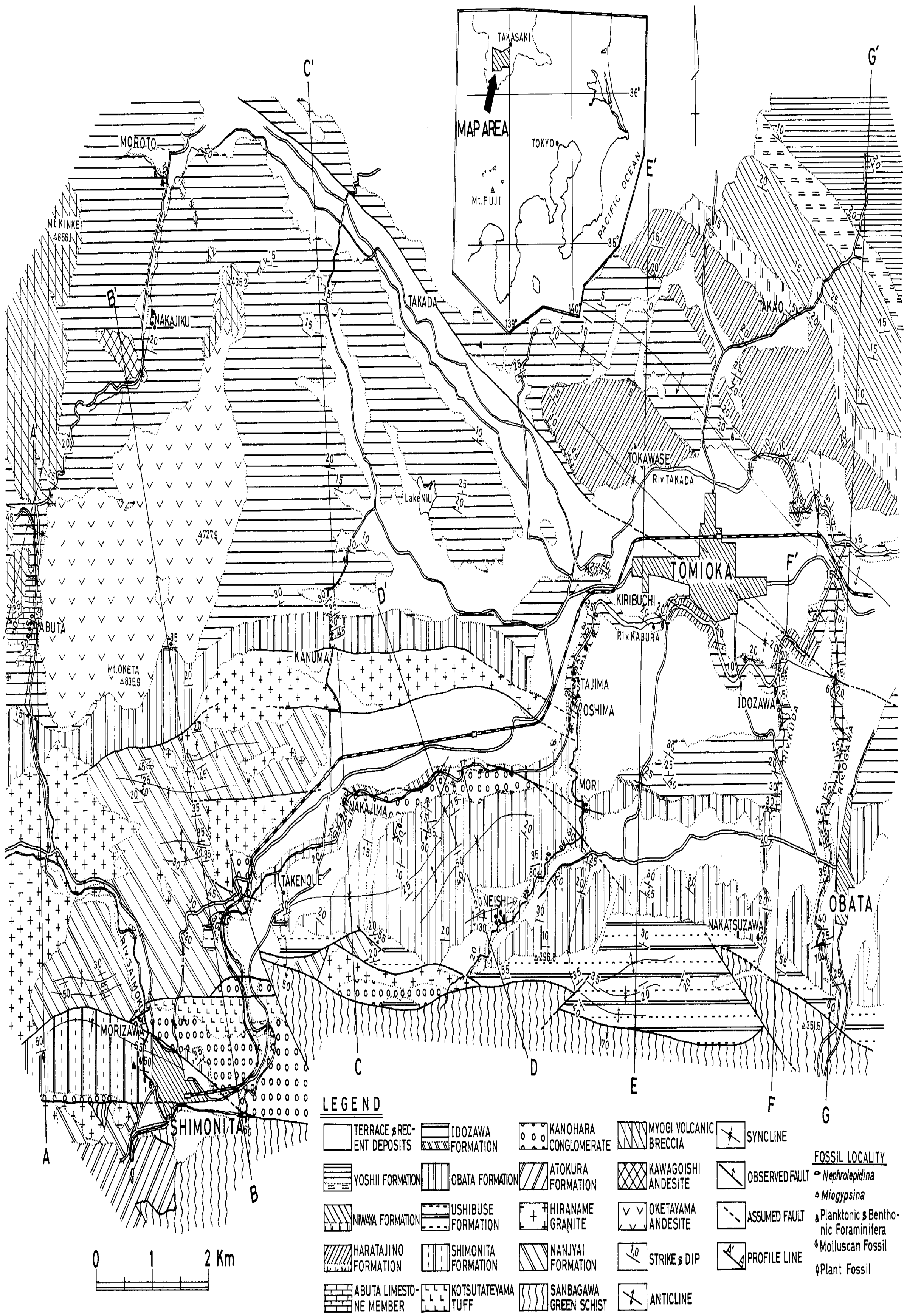

Fig. 1. Geological map of the Tomioka area, Gunma Prefecture.

pebbles of acidic lithic fragments bearing arkosic sandstone. The sequence of the rocks is shown in the figures.

The medium to coarse grained sandstone developed at Kogitano which covers the Kanohara Conglomerate gradually changes into an alternation with gray siltstone.

Between Shimonita-machi and Morizawa along the Osaka River, the formation which rests on the Kanohara Conglomerate with unconformity consists of thick (25 cm) granule conglomerate, siltstone and sandy siltstone.

In the Seisenji area, the formation is composed mainly of brownish gray massive and stratified siltstone which show onion structure; the strike and dip is N 30°E with dip of 35°SE.

As a whole, the formation makes a sedimentary cycle of granule conglomerate or coarse sandstone-medium sandstone, fine sandstone, shale and siltstone lignite streaks and plant fossils bearing siltstone, fine sandstone, alternation of sandstone and siltstone and siltstone with lignite streaks.

The formation forms a synclinal structure as shown in the annexed map.

This formation yielded abundant marine molluscan fossils from the sandy siltstone or fine grained sandstone below the Yachio bridge in Shimonita-machi, namely: *Lucinoma* sp., *Dosinia* sp., *Macoma optiva, M.* cf. *optiva,* and *M. sejugata.*

Mizuno (1961, MS) reported the following marine molluscan fossils from the same locality: *Callista yessoensis, Lucinoma* sp., *Macoma optiva, M.* cf. *aomoriensis, Yoldia* sp. Yokoyama (1926) and Otuka (1939, 1942) reported *Mya grewingki* from the same locality as mentioned above. Omori (from Arai *et al.*, 1966) reported from the same locality; *Volsella* sp., *Mytilus* cf. *tichanovitichi, Brachidontes matchgarensis, Conchocele bisecta, Lucinoma hannibali, Macoma hirma, M. asagaiensis, M. calcarea, M. izurensis, M. oinomikadoi, M. optiva, Serripes fujinensis, Callista hanzawai, Cyclina lunulata, Dosinia* sp., *Periploma besshoensis, Turritella* cf. *importuna* and *Mya grewingki.*

Globorotalia (*Turborotalia*) sp. was washed out of 100 grams of dark gray to black hard siltstone from the mouth of the Morizawa River. Saito (1963) recorded from this formation at Shimonita-machi, *Globigerina glutinata, G. dehiscens dehiscens, Globoquadrina venezuelana, Globigerinoides trilobus immaturus, G. ruber subquadratus* and benthonic Foraminifera as *Anomalina* sp., *Baggina sphaerina, Cassidulina* sp., *Guttulina yabei, G. irregularis, Hanzawaia nipponica, Lagena flatulenta, Nonion kidoharense, N. nicobarense, Pullenia bulloides, Robulus calcar, Rotalia* sp. and *Uvigerina subperegrina.*

b) *Ushibuse Formation*

The formation was proposed by Huzimoto and Kobayashi (1938) for the strata at the basal part of the Tertiary System. The Ushibuse Formation overlies the Kanohara conglomerate with unconformity.

Type locality: From the vicinity of Higashitani in Yoshii-machi to Mt. Ushibuse and Mt. Shiro both in Yoshii-machi all in Tano-gun, Gunma Prefecture.

Subtype locality: Cliffs along the Ogawa River at Machiya in Obata-machi, Kanra-gun.

Distribution: The formation is distributed in the four areas of Horinouchi and Yokose areas along the Yokose River, Kamikamata area and the area from Hirata through Iwazome and Kunimine to Machiya each being separated from one another by faults. In the Horinouchi area, the formation lies upon the Nanjyai Formation with unconformity and is subjacent to the Quaternary sediments. In the other areas the formation is superjacent to the Kanohara Conglomerate with unconformity and subjacent to the Obata Formation with conformity.

In the Horinouchi area it is mainly composed of light brownish white and orange colored white coarse grained sandstone. The sandstone sometimes changes laterally to orthoquartzite and more or less resembles that of the Ushibuse Formation of the type and subtype areas in being of the same color, same grain size, and in rarely intercalated with carbonaceous matter. Sometimes it contains granule to small pebble size lithic fragments of rather well rounded chert, slate and granite. No marine fossils have been found.

In the southern part of Kamikamata, the formation is composed of an alternation of sandstone and siltstone. In the area where the formation comes into contact with the Nanjyai Formation with the fault there are intercalated white fine tuff lenses between the gray tuffaceous siltstone and bluish white coarse sandstone. In the southern part of the area, the formation rests on the Kanohara Conglomerate with unconformity (?).

From Oshio at the north to Karasawa at the south of this area, the formation is overlain by the Obata with conformity and is in fault contact with Sanbagawa Green Schist.

At Kunimine, the formation is composed of gray siltstone, pumice bearing fine grained sandstone, gray siltstone and pumice bearing fine to medium grained massive sandstone sometimes intercalating thin gray siltstone. At Machiya it consists mainly of bluish white or brownish white coarse grained sandstone intercalated rarely with thin brownish gray siltstone and is covered with conformity by the Obata Formation. No marine fossils have been found from the formation.

c) *Obata Formation*

The formation occupies the lower part of the Idozawa Formation of Watanabe (1954).

Type locality: Cliffs along the Ogawa River in Obata-machi in Tomioka City, Gunma Prefecture.

Distribution: Widely distributed in the Nukabe syncline and in the belt area from Niiya of Shimonita-machi via Kanuma and Tajima to the vicinity of Obata-machi. The formation rests upon the Ushibuse Formation with conformity and is overlain by the Idozawa with conformity. It is composed of an alternation of yellowish white to bluish white coarse grained sandstone and dark gray to black siltstone in the lower part and intercalates two lenses of thick plagio-trachy tuff layers. The upper part is composed of an alternation of orange white to grayish white sandstone and gray siltstone showing a rhythmic alternation.

At Negishi *Nephrolepidina* and *Miogypsina* were collected from the calcareous coarse grained pumice bearing sandstone with marine molluscan fossils (*Lucinoma* sp., *Macoma* sp.) in the upper part of the alternation stated above. The gray siltstone in the upper part of the *Nephrolepidina* bearing sandstone, gradually changes to an alternation with the fine grained sandstone and shows slumping structures. The strata overlying this slumping structure consists of gray siltstone, pink white colored medium grained clean sandstone, an alternation of greenish white colored fine to medium grained sandstone with *Nephrolepidina* and *Miogypsina* and gray to dark gray siltstone, medium grained sandstone, bluish white coarse grained massive sandstone yielding *Nephrolepidina* and *Miogypsina*, thick fine to medium grained sandstone, an alternation of greenish white medium grained sandstone yielding of *Nephrolepidina* and *Miogypsina* and brownish gray siltstone, thick fine grained massive sandstone,thick gray siltstone intercalated with sandstone and thick bluish white coarse grained sandstone.

Along the route bordering the Nogami Rvier two horizons of *Nephroplepidina* were noticed, namely one in the vicinity of Negishi and the other near Nishidaira. The two apparent horizons of *Nephrolepidina* may be repeated by the many faults developed in the area.

In the area bordering the Ogawa River, the formation rests on the Ushibuse Formation with conformity and is overlain by the Idozawa Formation with conformity. The formation distributed from Machiya in Obata-machi to the vicinity of Kudai forms a homoclinal structure. It is composed of gray siltstone, thick pumice bearing sandstone intercalated with white plagio-trachy tuff, an alternation of medium to coarse grained sandstone yielding *Miogypsina* and gray siltstone, thick gray siltstone, thick sandstone with round pull-apart sandstones arranged parallel with the bedding plane, thick slumping structure of medium to coarse sandstone and gray siltstone, medium grained sandstone including pull-apart sandstones, and there are overlain by an alternation of sandstone and gray siltstone, thick siltstone intercalated with several layers of fine grained sandstone, granule bearing coarse grained sandstone, dark greay siltstone, granule bearing medium grained sandstone grading upwards into siltstone. The formation judged to be 880 m in thickness, although it is cut by faults with trends of N 75° to 80° E and dips of 65° to 70° SE.

In the area from Nakatsuzawa near Obata-machi to Takumi along the Kuda River, the formation is composed of siltstone layers which overlies the Ushibuse Formation with conformity and these gradually change to an alternation of dark gray to black siltstone yielding benthonic Foraminifera and ill-preserved molluscs besides fossils of *Makiyama* sp. (cf. *chitanii*) and a thick alternation with greenish white fine to medium grained sandstone. In the upper part, it is composed of thick grayish white fine grained sandstone, an alternation of fine grained sandstone and dark gray siltstone, granules of lithic fragment bearing grayish white medium grained sandstone and is covered with conformity by the white trachy tuff of the Idozawa Formation. The formation in this area has many penecontemporaneous faults.

In the area from Iwazome to Tajima along the Iwazome River, the Obata comprises the rock-facies shown in the columnar sections. The formation is about 950 m thick and makes a homoclinal structure and the general strikes and dips are N 20° to 80° W with dips of 10° to 35° NE. There are two remarkable faults along the Iwazome River, namely a normal fault of N 65° to 70° W with dip of 74° NE at Mori and another one which trends WNW to ESE about 500 m from Mori.

In the area along the Kabura River at about 750m southeast of Nanjyai in Tomioka City, the formation covers the Kanohara Conglomerate with unconformity, and consists of greenish white to white arkosic coarse grained hard sandstone rarely yielding bryozoa, brownish white fine grained sandstone brownish gray siltstone, greenish white arkosic medium to coarse grained sandstone, gray siltstone and dirty gray siltstone with molluscan fossils, *Cyclammina*, corals, shark's teeth and *Aphrocallistes*. This is succeeded upwards with an alternation of medium to coarse sandstone and gray siltstone. Along the Kabura River near Otuka and Nakajima in the south of this area, an alternation of brownish white arkose grained sandstone crops out. It shows good grading and yielded molluscan fossils as "*Nuculana*" sp., "*Yoldia*" sp., *Conchocele* sp., *Cyclina* sp., *Paphia* sp., *Macoma* sp., *Soletellina* sp., *Dentalium yokoyamai* and *Isurus hastalis* Agassiz.

Nephrolepidina was found from the bluish white arkosic grained sandstone of the Obata Formation below the bridge at Takenoue in Shimonita-machi and at the mouth of the Yokose River, a tributary of the Kabura.

At Kanuma, the southern part of the formation is cut by the Miyazaki-Kanuma fault and its basal part is, therefore, not known. The lower part of the formation exposed close to the fault, consists of thick brownish gray siltstone which is succeeded upwards with a slumping structure composed of an alternation of bluish gray fine grained sandstone and gray siltstone. This is overlain by a thick rhythmic alternation of calcareous medium to coarse grained sandstone which yielded *Nephrolepidina*, *Miogypsina*, *Amphistegina*, bryozoa and corals from the upper horizon. Sometimes the glauconite and pumice bearing medium grained sandstone and dark gray to black siltstone yield benthonic Foraminifera.

In the Mt. Oketa area along the Ogura valley in the northwest part of Ogura village, the formation is distributed in belt shape from east to west. It comprises in upward sequence, thick gray siltstone, an alternation of sandstone, and siltstone, an alternation of sandstone with *Nephrolepidina* and siltstone, massive siltstone, thick alternation of sandstone and siltstone, dark gray siltstone, sandstone or sandy siltstone and this is covered with white trachy tuff of the base of the Idozawa Formation. The strike of the formation is EW to N 55° to 80° W dips at 20° to 40° NE and is about 260 m in thickness.

Kobayashi was the first to find *Nephrolepidina* in this area and he considered that the *Nephrolepidina* bearing horizon in this area corresponds to the horizon of *Nephrolepidina* in the Abuta Limestone. However, detail stratigraphical works shows that the former horizon is lower than that of the latter.

In the Niiya area along the Osaka River, the formation rests upon the Hiraname Granite with unconformity and is composed mainly of dark gray siliceous siltstone intercalated with several graded sandstones. This siltstone is intruded by the Oketayama Andesite near the Miyataira bridge of Niiya. The strike and dip of the formation in this area are N 50° to 60° W with dips of 20° to 35° NE. The marine fossils from this formation are listed in Tables 2 and 4.

Table 2. Molluscan fossils from the Shimonita (S.F.), Obata, Idozawa, Haratajino (H.F.), Niwaya (N.F.) and Yoshii Formations (Yosh. F.).

FORMATION	S.F.	OBATA F.			IDOZAWA FORMAT.						H.F.	N.F.	YOSH. F.	
LOCALITY / SPECIES	MORIZAWA, SHIMONITA-MACHI	NAKAJIMA, SHIMONITA-MACHI	NEISHI, TOMIOKA CITY	NAKATSUZAWA, TOMIOKA CITY	IDOZAWA, TOMIOKA CITY	KUDAGAWA, TOMIOKA CITY	KIRIBUCHI, TOMIOKA CITY	TAHO, TOMIOKA CITY	ICHINOMIYA, TOMIOKA CITY	IDOZAWA BRIDGE TOMIOKA CITY	TAKAO, TOMIOKA CITY	ANAOKA, TANO-GUN	TAKO BRIDGE, YOSHII-MACHI	HONGOU, YOSHII-MACHI
Pelecypoda														
Nuculana sp.												+		
"*Nuculana*" sp.		+												
Portlandia sp.								+			+		+	
"*Yoldia*" sp.									+					
Crassatellites sp.		+												
Lucinoma sp.	+													
Venericardia sp.			+											
Diplodonta sp.					+									
Conchocele sp.		+												
Dosinia sp.	+													
Cyclina sp.		+												
Paphia sp.		+												
Macoma optiva YOKOYAMA	+													
M. cf. *optiva* YOKOYAMA	+													
M. sp. (cf. *optiva* YOKOYAMA)	+													
M. sejugata YOKOYAMA	+													
M. cf. *sejugata* YOKOYAMA	+													
M. sp.	+	+	+											
Soletellina sp.		+												
Scaphopoda														
Dentalium yokoyamai MAKIYAMA		+												
D. sp.													+	
Gastropoda														
Tugali sp.						+								
Brachiopoda														
Terebratulina tohokuensis NOMURA & HATAI														+
Sponge														
Makiyama sp. (cf. *chitanii* MAKIYAMA)				+										
Echinodermata														
Echinolampas cf. *yoshiwarai* P. DE LORIAL										+				
Echinoid gen. sp. indet.							+							
Pisces														
Corryphaenoides							+							
Myctophidae								+						
Isurus hastalis AGASSIZ		+												
Problematica														
Terebrellina cf. *kattoi* HATAI							+							

Table 3. Planktonic Foramnifera from the Shimonita (S.F.), Idozawa and Yoshii Formations (Y.F.).

FORMATION	S.F.	IDOZAWA FORM.						Y.F.
LOCALITY / SPECIES	MORIZAWA, SHIMONITA-MACHI	WAGOU, TOMIOKA CITY	KUDAGAWA, TOMIOKA CITY	NAKAJIKU, MYOGI-MACHI	MOROTO, MYOGI-MACHI	ICHINOMIYA, TOMIOKA CITY	TAJIMA, TOMIOKA CITY	TAKO BRIDGE, YOSHII-MACHI
Hastigerina sp.					+			
Globorotaiia (s.s.) cf. fohsi CUSHMAN & ELLISOR								+
G. (s.s.) tumida (BRADY)								+
G. (Turborotalia) peripheroronda BLOW & BANNER			+	+		+		
G. (T.) praescitula BLOW				+		+		
G. (T.) sp.	+							
Globigerina falconensis BLOW								+
G. cf. falconensis BLOW						+		
G. praebulloides BLOW			+		+	+	+	
G. woodi JENKINS					+			+
G. sp.		+	+	+			+	+
Globigerinoides bisphericus TODD			+	+				
G. immaturus LEROY			+		+	+		
G. ruber (D'ORBIGNY)				+	+	+		
G. trilobus (REUSS)					+	+		+
G. sp.						+	+	
Globoquadrina altispira globosa BOLLI				+	+			
G. cf. conglomerata (SCHWAGER)						+		
G. dehiscens (CHAPMAN, PARR & COLLINS)			+		+	+		
G.? sp.							+	
Sphaeroidinellopsis seminulina (SCHWAGER)			+	+		+		
Orbulina suturalis BRONNIMAN								+
Globigerina glutinata (EGGER)				+		+		

Table 4. Larger Foraminifera from the Obata and Idozawa Formations

FORMATION	OBATA FORMATION											IDOZAWA FORM. (A.L.M.)					
LOCALITY / SPECIES	OTSUKA, SHIMONITA-MACHI	KANUMA, TOMIOKA CITY	TAKENOUE, SHIMONITA-MACHI	SHIMOKAMATA, TOMIOKA CITY	NEISHI, TOMIOKA CITY	CHOFUKUJI, TOMIOKA CITY	SAYADO, TOMIOKA CITY	NISHIDAIRA, TOMIOKA CITY	MORI, TOMIOKA CITY	OSHIMA, TOMIOKA CITY	OBATA, KANRA-GUN	ABUTA, SHIMONITA-MACHI	NAKAJIKU, MYOGI-MACHI	OGURA, SHIMONITA-MACHI	ICHINOMIYA, TOMIOKA CITY	TAJIMA, TOMIOKA CITY	KUDAGAWA, TOMIOKA CITY
Nephrolepidina japonica (YABE)	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Miogypsina kotoi HANZAWA		+			+	+	+	+	+		+	+	+			+	+
Cycloclypeus postaeidae TAN												+					
Amphistegina radiata (FICHTEL & MOLL)		+										+	+	+	+	+	+

A.L.M. = ABUTA LIMESTONE MEMBER

d) *Idozawa Formation*

The formation is equivalent to the middle part of the Tomioka Formation of Huzimoto and Kobayashi (1938), and the upper part of the Idozawa Formation and the lower part of the Fukushima Formation of Watanabe (1950, 1942, 1954).

Type locality: Cliffs along the Kuda River at Takumi in Tomioka City to the junction of the Kabura River, also along the Ogawa River at Kudai, about 1 km northwest of Obata-machi, Gunma Prefecture.

Distribution: The formation is distributed in the southern and the northern parts of the area shown in the map. In the south the formation is distributed from Kudai through Idozawa and Ichinomiya to Myogi-machi with nearly a homoclinal structure and general trend of WNW-ESE, dipping at 10° to 40° NE. It is overlain with conformity by the

Haratajino. In the north it is distributed from Shimotajino in Fukushima-machi to Kitayama in Myogi-machi with a general trend of WNW-ESE. It shows one syncline and one anticline and is cut by three faults. In the north block the formation is overlain with conformity by the Haratajino in the Togawase and Shimokuroiwa areas.

Lithology and fossils in the southern block; In the area along the Ogawa River, the formation covers the Obata Formation with conformity. It is composed of the lithofacies shown in the columnar sections.

In the area along the Kuda River, it is composed mainly of an alternation of bluish white calcareous medium to coarse grained sandstone and brownish gray to dark gray siltstone showing a slumping structure. The rocks in this area from the lower part to upper part are thick white trachy tuff, alternation of bluish gray fine to medium sandstone and gray to dark gray siltstone, thick slumping structure consisting of an alternation of fine to medium grained graded sandstone and gray siltstone, thick alternation of bluish white medium grained sandstone, thick dark gray siltstone which yields *Diplodonta* sp. and intercalates several calcareous sandstone beds with *Nephrolepidina* and *Miogypsina* and another with planktonic Foraminifera was found. The latter comprise, *Globorotalia* (*Turborotalia*) *peripheroronda* Blow and Banner, *Globigerina praebulloides* Blow, *G.* sp., *Globigerinoides bisphericus* Todd, *G. immaturus* LeRoy, *Globoquadrina dehiscens* (Chapman, Parr and Collins), and *Spaeroidinellopsis* sp. and rarely molluscan fossils as *Tugali* sp.

In the area along the Kabura River from Tajino to Ichinomiya, the formation which rests on the bluish white calcareous fine to medium grained sandstone beds of the Obata Formation is composed of thick plagio-trachy tuff, dark gray siltstone yielding *Miogypsina* and benthonic Foraminifera, an alternation of fine to medium grained glauconite and pumice bearing sandstone which yielded *Miogypsina* and gray to dark gray siltstone which yielded *Globigerina* sp. These rocks are overlain by hard sandstone, gray to brownish gray siltstone, massive sandstone, pumice bearing sandstone, siltstone, a thick rhythmic alternation of sandstone and siltstone, an alternation of sandstone and siltstone, siltstone, beds of sandstone which yielded many *Nephrolepidina* and *Miogypsina*, hard shale with "*Yoldia*" sp., an alternation of sandstone and siltstone, alternation of dirty fine grained sandstone and siltstone with Echinoids, Coryphaenoides and *Terebrellina* cf. *kattoi*. These rocks are overlain with conformity by the Niwaya Formation.

In the area bordering the Osaka River from Miyataira bridge via Abuta to Hirokawara, the formation comprises in upward sequence white trachy tuff, orange white coarse grained sandstone, an alternation of sandstone and hard siliceous shale, an alternation of brecciated or pure limestone and gray hard siliceous shale (Abuta Limestone Member), gray to dark gray siltstone penetrated by the Oketayama Andesite and the Midouyama Andesite (=Myogi Andesite) and with intercalated dirty bluish gray tuffaceous fine grained sandstone. No marine fossils have been found except from the Abuta Limestone Member.

In the area bordering the Takada River from Kawagoishi to Ozaki, the formation consists mainly of dark gray siltstone sometimes intercalated with several beds of dirty bluish white fine to medium grained calcareous sandstone which yielded *Nephrolepidina*, *Miogypsina* and benthonic Foraminifera at Nakajiku of Myogi-machi. The planktonic Foraminifera from the siltstone at Nakajiku yielded. *Globorotalia* (*Turborotalia*) *peripheroronda* Blow and Banner, *G.* (*T.*) *praescitula* Blow, *Globigerina* sp., *Globigerinoides bisphericus* Todd, *G. ruber* (d'Orbigny), *Globoquadrina altispira globosa* Bolli, *Sphaeroidinellopsis seminulina* (Schwager) and *Globigerinita glutinata* (Egger).

From Moroto, the following were found *Hastigerina* sp., *Globigerina praebulloides* Blow, *G. woodi* Jenkins, *G. immaturus* LeRoy, *G. ruber* (d'Orbigny), *G. trilobus* (Reuss), *Globoquardrina altispira globosa* Bolli and *G. dehiscens* (Chapman, Parr and Collins)

The formation is penetrated by the Kawagoishi Andesite in Kawagoishi village and has several pyrite veins.

Lithology and fossils in the northern block; In the area from Tajino to the vicinity of Fukushima-machi, the formation forms one syncline at Tajino and one anticline near the junction of the two rivers. The formation consists mainly of dark gray siltstone sometimes intercalated with several thin beds of bluish white pumice bearing fine to medium grained sandstone and bluish white to brownish white medium grained sandstone. In the vinicity of the railway bridge, it forms an anticline with axis of WNW-ESE trend and is cut by a fault in the area between Kimikawa village and Sogi along the Takada River.

At Kamikuroiwa, the formation consists mainly of brownish gray to dark gray siltstone grading upwards into medium grained sandstone and is covered by the Haratajino Formation. Between Kamikuroiwa and Kuroiwa the formation makes a syncline. Marine fossils from the *Makiyama*-bearing siltstone are *Portlandia* sp. and Myctophidae gen. et sp. indet.

d-1) *Abuta Limestone Member*

Type locality: Along the Osaka River from Niiya to Abuta, Shimonita-machi, Gunma Prefecture.

Distribution: The Osaka River and its environs; around Mt. Midouyama, the Karasawa valley and the Matsuozawa valley in the west of Abuta village.

Lithology: Mainly composed of an alternation of gray to bluish gray limestone intercalated with breccia of granule to pebble size breccia of gray siltstone, hard bluish white sandstone, glouconite, pumice and rarely sporadic minute lignite and gray to dark gray siliceous shale. The limestone yielded *Nephrolepidina*, very rarely *Miogypsina*, rarely *Cycloclypeus*, abundant *Amphistegina*, *Globigerina* sp., *Textularia* sp., corals, algae, and bryozoa. Smaller Foraminifera were found in the shale intercalated in the limestone.

d-2) *Oketayama Andesite*

The Oketayama Andesite is distributed along the provincial boundary between Tomioka City and Kanra-gun, Mt. Oketa (835.9 m) and Mt. Kannon (727.9 m). The andesite is pyroxene andesite, dark greenish blue to pale blackish blue in color with porphyritic texture and phenocrysts of pyroxene.

d-3) *Kawagoishi Andesite*

The Kawagoishi andesite is distributed in the environs of Kawagoishi village. The andesite is greenish light gray to greenish blue and is hornblende pyroxende andesite.

e) *Haratajino Formation*

The formation is equivalent to the upper part of the Fukushima Formation of Watanabe (1950, 1952, 1954) and nearly the same as the Isobe Formation of Mizuno (1961, MS).

Type locality: The area from Haratajino to the junction of the Kabura River and the Kuda to 600 meters downstream along the Kabura.

Distribution: From the Haratajino to Ichinomiya, Tomioka City. The Haratajino rests on the Idozawa with conformity, is cut by the Takada-Tajino fault, reappears in the area from Togawase to Shinden northwest of Tomioka City, abuts against the fault and forms a synclinal structure. It extends in belt shape with a general trend of NW-SE from Kimikawa through Sunada and Dainichi to Isobe.

The formation is composed mainly of an alternation of blue black to dark gray fine to coarse grained sandstone and light gray to pale brownish light gray siltstone in the lower part, sometimes intercalated with massive siltstone showing onion structures.

At Haratajino, the formation which rests on the siltstone of the uppermost part of the Idozawa Formation with conformity consists of in upward order, thick white trachy tuff, a rhythmic alternation of pale gray fine sandstone and light gray sandy siltstone.

From Haratajino to Sogi along the Kabura River, the formation is cut by the Takada-Tajino fault.

At Kamita in the south of Tomioka City, the formation is characterized by dirty bluish fine grained thick sandstone directly covering the gray siltstone of the uppermost part of the Idozawa Formation.

At Ichinomiya, the formation which covers conformably the rhythmic alternation of dirty gray fine grained sandstone and pale bluish gray to gray siltstone of the Idozawa Formation consists of from the lower, thick white trachy tuff, rhythmic alternation of dirty light gray silty sandstone and light gray siltstone and is overlain by the Quaternary sediments with unconformity.

In the Shinden area, the formation which covers the orange yellow to yellowish brown silty sandstone of the Idozawa Formation consists of from the lower, white silty tuff or trachy tuff, an alternation of tuffaceous light gray silty sandstone and light gray *Makiyama* bearing siltstone, and thick light gray siltstone sometimes intercalated with several beds of silty sandstone.

In the area of Mukoudaira in the north of Tomioka City, it consists of from the lower, thick trachy tuff, thick alternation of pale bluish gray fine grained sandstone, light gray siltstone but sometimes intercalated with massive siltstone and fine grained sandstone and is overlain by the basal bed of plagio-trachy tuff of the Niwaya Formation.

Portlandia sp. was found from a brownish light gray siltstone of the formation.

f) *Niwaya Formation*

Type locality: Along the Kabura River from Shiohatado of Fukushima-machi through Niiya and Hongo of Yoshii-machi to the vicinity of Ike.

Subtype locality: The area from Kimikawa to Shiraiwa both in Tomioka City.

Distribution: The formation is distributed from Goka in the northeast of Tomioka City to Kamimanita in Annaka-machi with nearly NW-SE trend and dip of 10 to 26°NE.

In the area from Kimikawa to Shiraiwa, the formation is composed mainly of pale brownish light gray siltstone. The basal white trachy tuff which rests on the uppermost bed of light gray siltstone of the Haratajino Formation with conformity can be traced from the southeast part to the northwest corner of the area studied. The thickness of the tuff varies from 15 to 20 m thick at Kimikawa, 15m or more thick at Kamitakao and 30 m thick at Mukoudaira.

In the area of Mukoudaira in the north of Tomioka City, the formation consists of from the lower, white trachy tuff, thick light gray siltstone intercalated with white trachy tuff lens showing intraformational folding at Niwaya in Fukushima-machi, an alternation of pale grayish brown fine grained sandstone and light gray siltstone, light gray to brownish light gray siltstone and is overlain with conformity by the basal trachy tuff of the Yoshii Formation.

From the light gray siltstone of the middle horizon of this formation at Anaoka (type locality) at the southeast of the studied area, the writer discovered, *Nuculana* sp. Mizuno (1961, MS.) reported *Neverita* sp. from Kamitakao and *Acila* (*Acila*) *divaricata*, *Acila* sp., *Macoma* sp., *Portlandia* (*Portlandia*) cf. *hurukutiensis*, *Natica* sp. and *Neverita* sp. from Sakaguchi.

Saito (1963) reported such planktonic Foraminifera from stations TK 17, 19, 28 as *Globorotalia bykovae* (Aisenstat), *G. fohsi fohsi*, *G. fohsi barisanensis*, *G. menardii miocenica*, *G. opima continuosa*, *G. praemenardii*, *G. scitula scitula* (Brady), *G. tumida* (Brady), *Globigerina angustiumbilicata*, *G. bulloides*, *G. descoraperta*, *G. falconensis*, *G. folitata*, *G. glutinata*, *G. woodi*, *Globoquadrina altispira altispira* (Cushman and Javis), *G. conglomerata* (Schwager), *G. dehiscens* (Chapman, Parr and Collins), *Globigerinoides immaturus*, *G. obliquus*, *G. ruber ruber* (d'Orbigny), *G. sacculifera* (Brady), *G. trilobus* (Reuss), *Sphaeroidinellopsis* *seminulina* (Schwager), *Orbulina suturalis*, *O. universa* and *Candeina amicula*.

On the basis of the concurrent ranges of the diagnostic species, this formation represents the *Globorotalia fohsi fohsi* zone.

g) *Yoshii Formation*

The Yoshii Formation was proposed by Watanabe (1950) for the strata developed widely from Shiohatado of Fukushima-machi to the vicinity of Ichinomiya in Yoshii-machi or the vicinity of Futago along the Yoshii-Takasaki Road. The formation can be divided into two stratigraphical units upon the lithofacies and the paleontological evidence. The writer proposes the name of the Niwaya Formation for the former and retains the name of Yoshii Formation (redefined) for the latter. Therefore, the Yoshii Formation here used is equivalent to the upper part of the Yoshii of Watanabe.

Type locality: Along the Tako River in the vicinity of Yoshii-machi, Tano-gun, Gunma Prefecture (Watanabe, 1950).

Subtype locality: Along the Fujiki River from Ono village of Shimotakao to the area between Fujiki and Suyama.

Distribution: The formationis distributed from Ike in the north of Yoshii-machi to Haraichi in Annaka-machi with nearly NW-SE trend dipping towards the northeast. It rests with conformity upon the Niwaya Formation.

In the environs of Ono village, the formation is composed of from the lower, thick plagio-trachy tuff, thick pale yellowish brown bearing gray siltstone intercalating two beds of white trachy tuff lens, brownish light gray siltstone, an alternation of pale bluish gray fine to medium grained sandstone which grades upwards into coarser grained sandstone.

The planktonic Foraminifera from the gray to dark gray siltstone of this formation are: *Globorotalia tumida* (Brady), *G.* cf. *fohsi* Cushman and Ellison (*s. l.*), *Globigerinoides trilobus*, *Globigerina falconensis*, *G. woodi*, G. sp., and *Orbulina suturalis*.

At almost the same locality as above, *Portlandia* sp. was collected. At Hongo in Yoshii-machi, *Terebratulina tohokuensis* Nomura and Hatai was collected from the glauconitic sandstone. Huzimoto and Kobayashi (1938) reported *Cyclammina japonica* from the middle part of this formation. Mizuno (1961, MS) reported *Saccella confusa* (Hanley) from this formation.

CORRELATION

The geological ages of the different formations and their correlation with stratigraphic units in other districts were made as shown in Tables 1 and 5.

As no marine fossils have been found from the Ushibuse Formation, its geological age is dobutful, but from stratigraphic position it may be early Miocene from the view point of the planktonic Foraminifera because it can be correlated with the Shimonita.

The Obata Formation yielded *Nephrolepidina japonica*, *Miogypsina kotoi*, *Amphistegina radiata* and other fossils of corals, bryozoans, algae and etc., and planktonic Foraminifera as *Globigerina* sp., benthonic Foraminifera as *Eponides tanaii*, *Cibicides pseudoungerianus*, *Lenticulina* sp., *Sigmomorphina* sp., *Guttulina* sp., and molluscan fossils as "*Nuculana*" sp., *Crassatellites* sp., *Venericardia* sp., *Conchocele* sp., *Cyclina* sp., *Paphia* sp., *Macoma* sp., *Soletellina* sp. and *Dentalium yokoyamai*.

From paleontological evidence, the Obata Formation is correlated with the Chichibumachi Group in the Chichibu basin, Saitama Prefecture.

The planktonic Foraminifera from localities TK 25, 26, 12, 11, and 9 of this formation reported by Saito (1963) are: *Globorotalia fohsi barisanensis*, *G. mayeri*, *G. praemenardii*, *G. scitula praescitula*, *Globigerina angustiumbilicata*, *G. glutinata G. praebulloides*, *G. woodi*, *Globoquadrina altispira altispira*, *Globoquadrina altispira globosa*, *G. conglomerata*, *G. dehiscens*, *G. obesa*, *Globigerinoides bisphericus*, *G. glomerosus*, *G. immaturus*, *G. ruber subquadratus*, *G.*

Table 5. Correlation chart

AREA / AGE	Kitaaiki-Arafune Dist. KASAI (1934), WATANABE (1954)	Present Area MATSUMARU (1967)	Kodama District WATANABE (1950, 54)	Ogawa Basin WATANABE & KANNO (1950)	Yorii-Matsuyama District WATANABE et al. (1950)	Chichibu Basin WATANABE et al. (1951)	Itsukaichi Basin FUJIMOTO (1926, 32) KANNO & ARAI (1964)
Middle Miocene	Yaekubo Formation	Tomioka Group: Yoshii Formation Niwaya Formation Haratajino Formation	Kodama Formation Osawa Formation (Fault)	Ogawamachi Group	Matsuyama Group: Hiki Subgroup Obusuma Subgroup		Itukaichimachi Group
Early Miocene	Komagome Formation Uchiyama Formation ?	Tomioka Group: Idozawa Formation Obata Formation Shimonita Form. / Ushibuse Form.			Osato Group: Tachigase Formation	Chichibumachi Group: Kamiyokose Formation Chichibumachi Form. Haraya Formation Matsuida Formation Akahira Group: Sakurai F. Yoshida F. Akahira F.	
Late Oligocene	Kitaaiki Formation						
Foundation	Mesozoic and Paleozoic Rocks	Kanohara Conglo., Atokura Formation, Hiraname Granite and Nanjyai Form.	Mesozoic and Paleozoic Rocks	Sanbagawa and Mikabu Metamorphic, and Paleozoic Rocks	Sanbagawa and Mikabu Metamorphic Rocks, and Granodiorite	Mesozoic and Paleozoic Rocks	Mesozoic and Paleozoic Rocks

trilobus, *Spheroidinellopsis seminulina* and *Globigerinitia unicava*.

These are the members of the *Globigerinatella insueta* zone and a part of them are probably of the *Globigerinita unicava* zone. These zones are said to correspond to the European Aquitanian by Saito (1963) and Asano and Hatai (1967).

As regards the *Nephrolepidina* rocks of Japan, Hanzawa (1964) states that they belong to the *Globigeriniatella* (*Globigerinoides*) *bisphericus* zone of the Burdigalian stage, but on the other hand Asano (1962), Saito (1960, 1963) and Asano and Takayanagi (1965) refer them to the Aquitanian stage. If the *Nephrolepidina* rocks of Japan belong to the Aquitanian stage, the significant Foraminifera genera such as *Eulepidina* (Rupelian-Aquitanian range) and *Spiroclypeus* (Upper Eocene-Aquitanian range) in the Indo-Pacific region should be found in rocks of that age in Japan. However, neither *Eulepidina* nor *Spiroclypeus* are known from the rocks of that age in Japan and none have been found from the Obata Formation.

It may be probable that thermal conditions during the Aquitanian stage in Japan may explain the absence of *Eulepidina* and *Spiroclypeus* in Japan as already pointed out by Hanzawa (1964). However, this view is in need of reconsideration.

The stratigraphic relationship between Larger Foraminifera and Planktonic Foraminifera can not be explained merely by the differences in the ecological environment. Saito (1963) failed to find Planktonic Foraminifera from the *Nephrolepidina* and *Miogypsina* rocks from many other localities of Japan.

In either case of the Obata Formation it is clear that the horizon of *Nephrolepdina* is a part of the *Globigerinatella insueta* zone and a part of *Globigerinita unicava* zone. The writer provisionally places the Obata Formation in the Lower Miocene (Aquitanian).

The Idozawa Formation which rests with conformity on the Obata Formation yielded *Nephrolepidina japonica*, *Miogypsina kotoi*, *Amphistegina radiata* and can be traced to the Abuta Limestone Member of the lower-middle part of the present formation. The formation yielded *Hastigerina* sp., *Globorotalia* (*Turborotalia*) *peripheroronda, G.* (*T.*) *praescitula, Globigerina* cf. *falconensis, G. praebulloides, G. woodi, G.* sp., *Globigerinoides bisphericus, G. immaturus, G. ruber* (d'Orbigny), *G. trilobus* (Reuss), *G.* sp., *Globoquadrina altipsira globosa, G.* cf. *conglomerata* (*Schwager*), G. *dehisence* (Chapman, Parr and Collins), *G.* ? sp., *Sphaeroidinellopsis seminulina* (Schwager), and *Globigerinita glutinata* (Egger). These foraminiferal species range from the *Globigerinatella insueta*/*Globigerinoides bisphericus* subzone of the upper part of *Globigerinatella insueta* zone to the *Globorotalia fohsi barisanensis* zone. Other fossils from the present formation are *Portlandia* sp., "*Yoldia*" sp., *Diplodonta* sp., *Tugali* sp., *Linthia yokoyamai*, Echinoid gen. sp. indet., *Coryphaenoides*, Myctophidae and etc.

The Abuta Limestone member of this formation yielded *Nephrolepidina japonica, Miogypsina kotoi, Cycloclypeus postaeidae,* and *Amphistegina radiata.* This member is correlative with the European Burdigalian stage based upon the results of studies on the embryonic chambers of *Nephrolepidina* and *Cycloclypeus* mentioned later.

Based upon paleontological evidences, this formation is correlated with the Chichibumachi Group of the Chichibu basin in Saitama Prefecture, the upper part of the Osato Group in the Yorii-Matsuyama area in Saitama Prefecture and is nearly equivalent with the Tsukahara Siltstone of Ishiwada (1948).

The Haratajino Formation is considered to be a correlative of the Ogawa Formation in the Kodama area in Saitama Prefecture, the Obusuma Subgroup in the Yorii-Matsuyama area in Saitama Prefecture and the lower to middle horizons of the Ogawamachi Group in the Ogawa basin which yielded *Vicaryella nipponica, Sanguinolaria minoensis* and etc. The present formation yielded *Portlandia* sp. Saito (1963) reported from locality TK 15, *Globorotalia scitula praescitula, G. zealandica, G. angustiumbilicata, Globigerina falconensis, G. glutinata, G. praebulloides, Globoquadrina altispira altispira, G. altispira globosa, G. conglomerata, G. dehiscens, Globigerinoides trilobus,* and *Orbulina suturalis*; these species belong to the *Globorotalia fohsi barisanensis* zone.

The Niwaya Formation is equivalent with the Kodama Formation in Saitama Prefecture, and the lower horizon of the Hiki Subgroup in the Yorii-Matsuyama area in Saitama Prefecture. Paleontologically, the Niwaya Formation belongs to the *Globorotalia fohsi fohsi* zone.

The geological age of the Yoshii Formation is upper Burdigalian to lower Helvetian (*Globorotalia bykovae* zone) from the evidence of the concurrent range of *Globorotalia tumida* Brady, *G.* cf. *fohsi* Cushman and Ellison (s.l.), *Globigerinoides trilobus, Globigerina falconensis, G. woodi, G.* sp. and from such molluscan fossils as *Lemintina* sp., *Protothaca tateiwai, Chlamys kaneharai, Cardium shiobarense,* and *Dosinia kaneharai.*

It is concluded that the Tomioka Group ranges from the Early Miocene to the Middle Miocene in age.

GEOLOGIC STRUCTURES

The geological structures (Fig. 2) of the area studied are described below.

A) Unconformity

A-1) Unconformity between the basement rocks and the Tomioka Group.

This unconformity between the Kanohara Conglomerate and the Obata Formation is observed along the Kabura River at Nakajima in Shimonita-machi, where the latter abuts against the former, which has strong relief as already pointed out by Arai *et al.* (1966). The coarse grained sandstone of the Obata Formation fills the cracks in the eroded surface of the Kanohara Conglomerate. At Okitano and Kokitano, west of Shimonita-machi, the basal part of the Shimonita Formation lies upon the eroded uneven surface of the Kanohara Conglomerate. In the vicinity of Niwaya, Shimonita-machi, the Obata Formation lies upon the Hiraname Granite and the former abuts against the eroded surface of the latter.

B) Folding

Three broad synclinal structures, one synclinorium and one anticlinal structure as well as minor foldings were recognized:

B-1) Shimonita Syncline. This syncline is developed in the west of Shimonita-machi. The axis shows a broad southward curve, has a general trend of WNW-ESE, and its northern extension flares and is cut by the Morizawa-Iwayama tectonic line. The dip of the strata of the northern wing is 40–50° towards the south, whereas the southern wing is 30–50 degrees towards the north.

B-2) Haratajino Syncline. This syncline is developed in the south of Tomioka City. The axis has a general trend of NW-SE, plunging southeastwards. Its southwestern extension flares upwards on the Idozawa Formation and its wing dips northeastwards at 10–20°, whereas the northeastern one is cut by the Takada-Tajino fault and its wing dips southwestwards at 20°. The development of this structure may be related with the Takada-Tajino fault.

B-3) Tokawase Syncline. This syncline extends in more or less NW-SE direction showing a southeastward plunging axis and is cut by the Takada-Tajino fault. The northeastern wing dips southwest at 5–20°. Whereas the southestern wing at angles of 10–15° northwards.

B-4) Nukabe Synclinorium. This synclinorium is developed in the southwest of Tomioka City and can traced from Mayama to Nishidaira in WNW-ESE direction. It shows a northeastward plunging axis. In the northwest wing of the synclinorium, the strata flares upwards and abuts against the Kanohara Conglomerate with unconformity and a part is cut by faults, whereas in the southeast, the rocks dip northwards being undulated or homoclinal and lies with conformity on the Ushibuse Formation. As the structures are more or less complicated, they do not suggest a simple synclinorium, but one cut by minor faults of nearly N-S direction. It is more or less of basin structure.

B-5) Kamikuroiwa Anticline. This anticline is developed in the northeast of Tomioka City. The axis trends NW-SE showing southeastwards curved axis, and the southwestern wing dips southwestwards at about 5°, whereas the northeastern one at angles of 10–30° northwards.

C) Faults

Although many faults are recognized in the area, only a few of them have been named because of their importance. There are also many penecontemporaneous faults which are judged to have been formed during or immediately after deposition but before consolidation of the sediments.

C-1) Takada-Tajino Fault. This fault occurs in the central part of the area. The fault shows a general strike of EW and dips of 60°S, and cuts the Idozawa and Haratajino Formations.

C-2) Sogi Fault

This fault (NS, dip nearly vertical) is observed in Sogi village at the northeast part of the field. On the east side of the fault, the Idozawa Formation dips northeastward at angles of 5–10 degrees with strike of N 60°E, whereas on the west side, the strata of the Haratajino dip southwestwards at angles of 20–25 degrees with strike of N 40°W. A nearly 5 m wide crushed zone is developed parallel with it. This fault cuts the axis of Kamikuroiwa Anticline. There is another fault (N 10°W, 50°S) on the west side almost parallel with it.

C-3) Mori Fault

This fault (N 70° W, 70° NE) with a 5–10 m wide crushed zone of rocks occurs in the southwest of Tomioka City.

Other important faults and foldings have been described by Huzimoto and Kobayashi (1938), Arai *et al.* (1966) and others.

The geological ages of the faults and foldings described here are after the deposition of the Tomioka Group. The Haratajino and Tokawase Synclines and Kamikuroiwa Anticline are post-Niwaya and pre-River Terrace deposits; the Takada-Tajino fault and the Sogi fault are post-Haratajino; the Tokawase Synclines and Kamikuroiwa Anticline are pre-Terrace deposits; the Shimonita Syncline was formed after Shimonita time and before River Terrace deposits and the Nukabe Synclinorium after Obata time and before the formation of the River Terrace deposits. The Mori fault which cuts the Obata Formation was developed probably after construction of the Nukabe Synclinorium and before the formation of the River Terrace deposits.

NOTE ON "*LEPIDOCYCLINA*"

Introduction

The Tertiary larger Foraminifera of the Family Lepidocyclinidae hitherto recorded from Japan, comprise *Lepidocyclina** (*Nephrolepidina*) *japonica*, *L.* (*N.*) *nipponica*, *L.* (*N.*) *angulosa*, *L.* (*N.*) *ferreroi*, *L.* (*N.*) *perornata*, *L.* (*N.*) *laevigata*, *L.* (*N.*) *polygonalis*, *L.* (*N.*) *scabra* and *L.* (*N.*) *makiyamai*. These species were defined on the basis of a few morphological features, whereas their populations based on statistics of both internal and external features were merely touched upon.

Hanzawa (1964) as the result of his studies on the genus is in the opinion that *Lepidocyclina* (*Nephrolepidina*) *nipponica*, *L.* (*N.*) *makiyamai* and *L.*(*N.*) *angulosa* are synonyms of *L.* (*N.*) *japonica* and that, *L.* (*N.*) *perornata*, *L.* (*N.*) *scabra* *L.* (*N.*) *polygonalis* and *L.* (*N.*) *laeviagata* are microspheric forms of *L.* (*N.*) *japonica*.

Koike (1951) was the first to make statistical studies of *Lepidocyclina japonica* based upon the free samples he collected from the Nakaobara Formation in the Boso Peninsula, Chiba Prefecture and from the Yugashima Formation at Shimoshiraiwa, Izu Peninsula, Shizuoka Prefecture.

The writer was fortunate in collecting many specimens of Lepidocyclinids from the Abuta Limestone Member of the Idozawa Formation and based upon them, many detailed measurements were made. A part of the results of the measurements are compared with those of Koike.

One of the important problems concerning the Family Lepidocyclinidae, is whether the genus *Nephrolepidina*, not subgenus *Nephrolepidina*, should be retained in the family Lepidocyclinidae or be included into the synonymy of the genus *Eulepidina*. The writer, following Hanzawa (1964), contrary to the interpretation of Cole (1960, 1963), places *Nephrolepidina* in generic rank from his study of the morphology of the embryonic chambers of *Lepidocyclina japonica* from the Abuta Limestone Member.

An attempt was made, based on the result of investigation on the nepionic spirals and the "evolution gradus", to explain the morphogenetic lineage of *Lepidocyclina*, and a study of the specific variation of *Lepidocyclina* from the exposure method of Vlerk (1963).

* As stated later, Hanzawa and the writer raise and use *Nephrolepidina* as a genus.

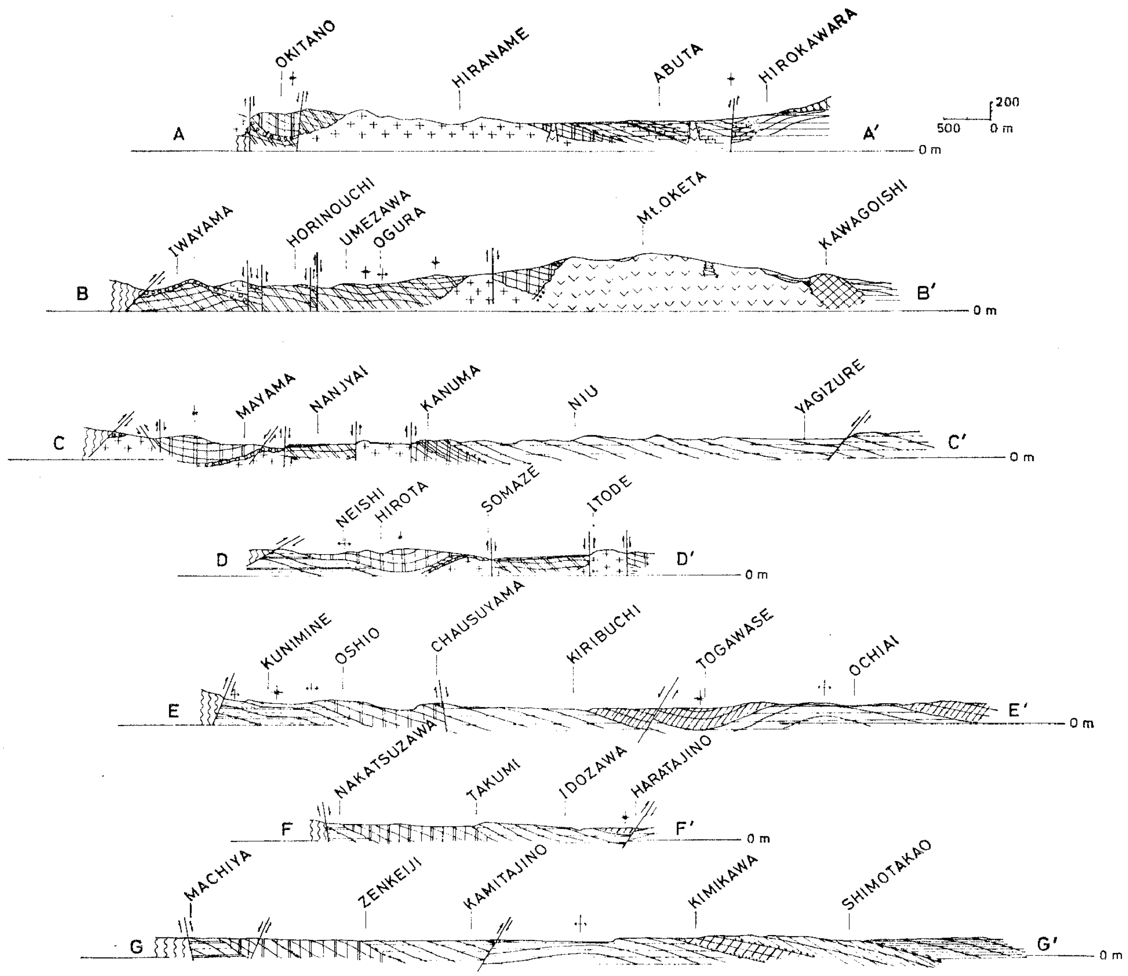

Fig 2. Geological profiles of the Tomioka Area.

Collection Localities

The materials for study were collected horizon by horizon from the Abuta Limestone Member, and their localities are shown in Fig. 4.

Frequency of "*Lepidocyclina*"

There are especially remarkable populations of *Nephrolepidina japonica* and *Amphistegina radiata* in the Abuta Limestone Member. The relationship of the occurrence of both populations is given in Fig. 5.

This figure shows the general relationship between the populations from localities no. 20 to no. 2 to be nearly stationary, whereas localities no. 38 to no. 58 indicates that the growth of the *Nephrolepidina* population becomes larger than that of the *Amphistegina radiata* population. The specimens of those two populations form localities no. 47 to 49 shows that the former becomes smaller than the latter.

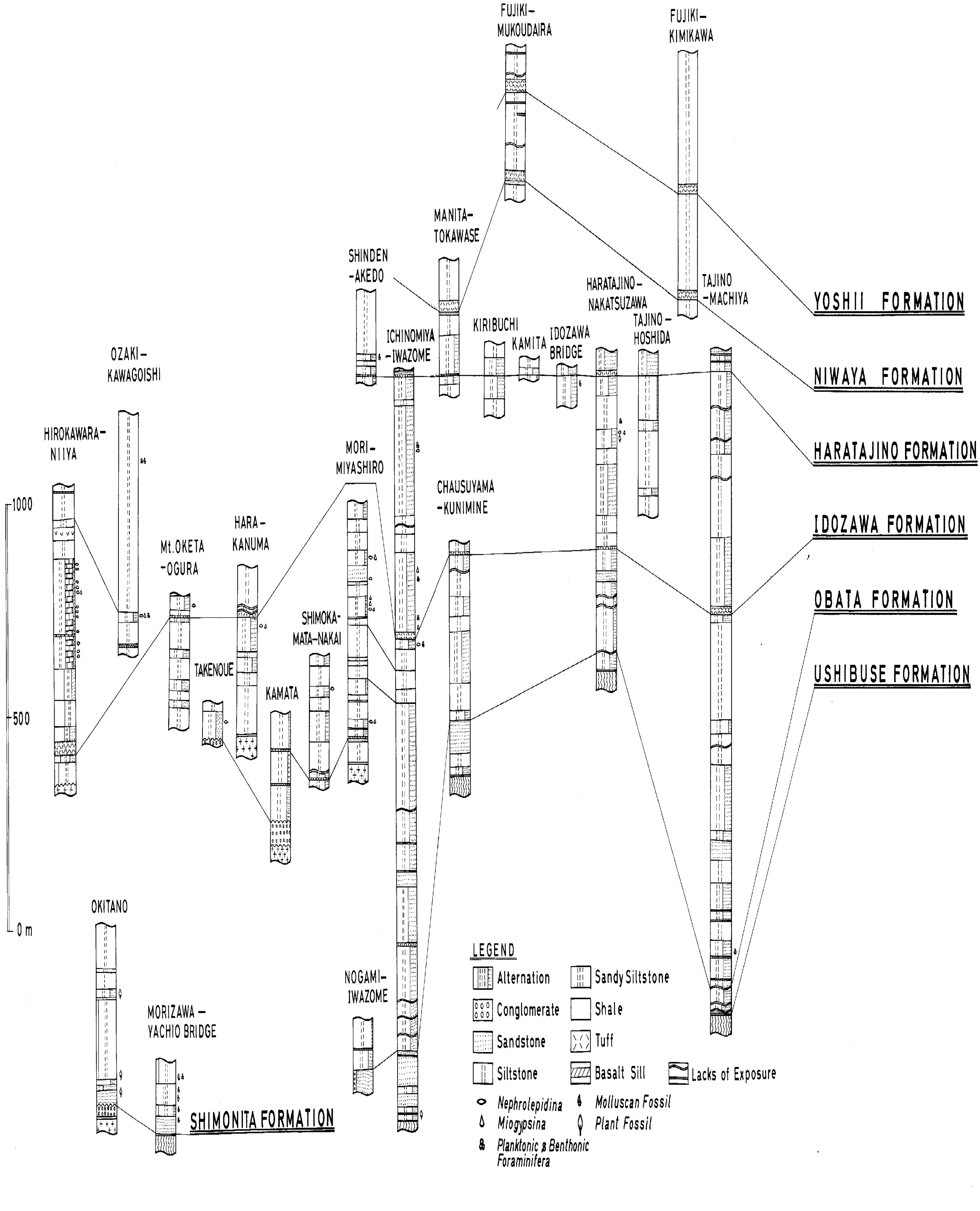

Fig. 3. Columnar sections of the Tomioka area.

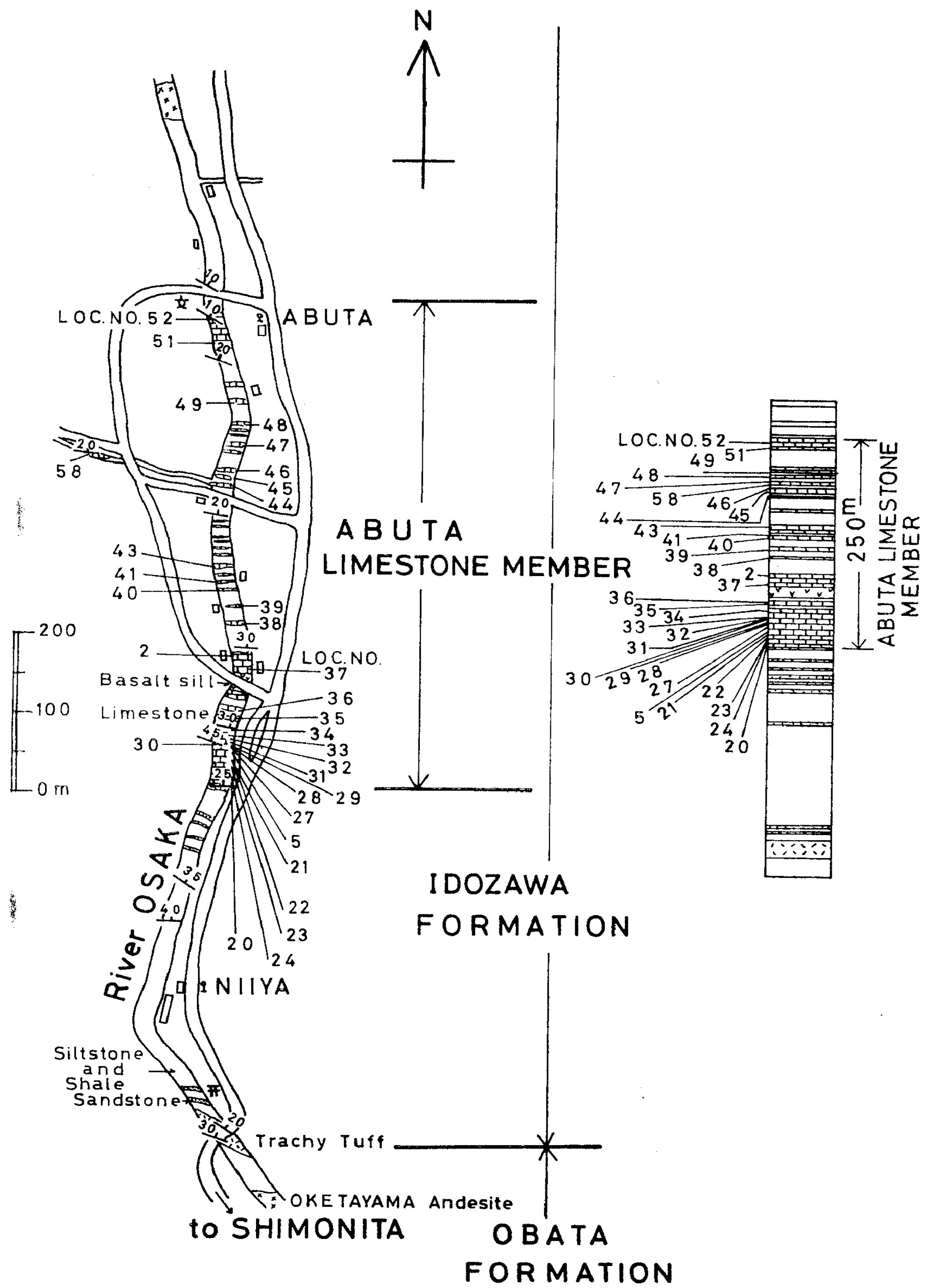

Fig 4. Route map, Abuta Limestone Member and localities of the larger Foraminifera, and columnar sections of the Abuta Limestone Member.

Description of Species
Family Lepidocyclinidae SCHEFFEN, 1932
Genus *Nephrolepidina* Douvillè, 1911

The morphological features of the nucleoconch of the megalospheric form of the Family Lepidocyclinidae can be classified into five types of lepidocycline embryonic chamber, nephrolepidine embryonic chamber, trybliolepidine embryonic chamber, eulepidine embryo-

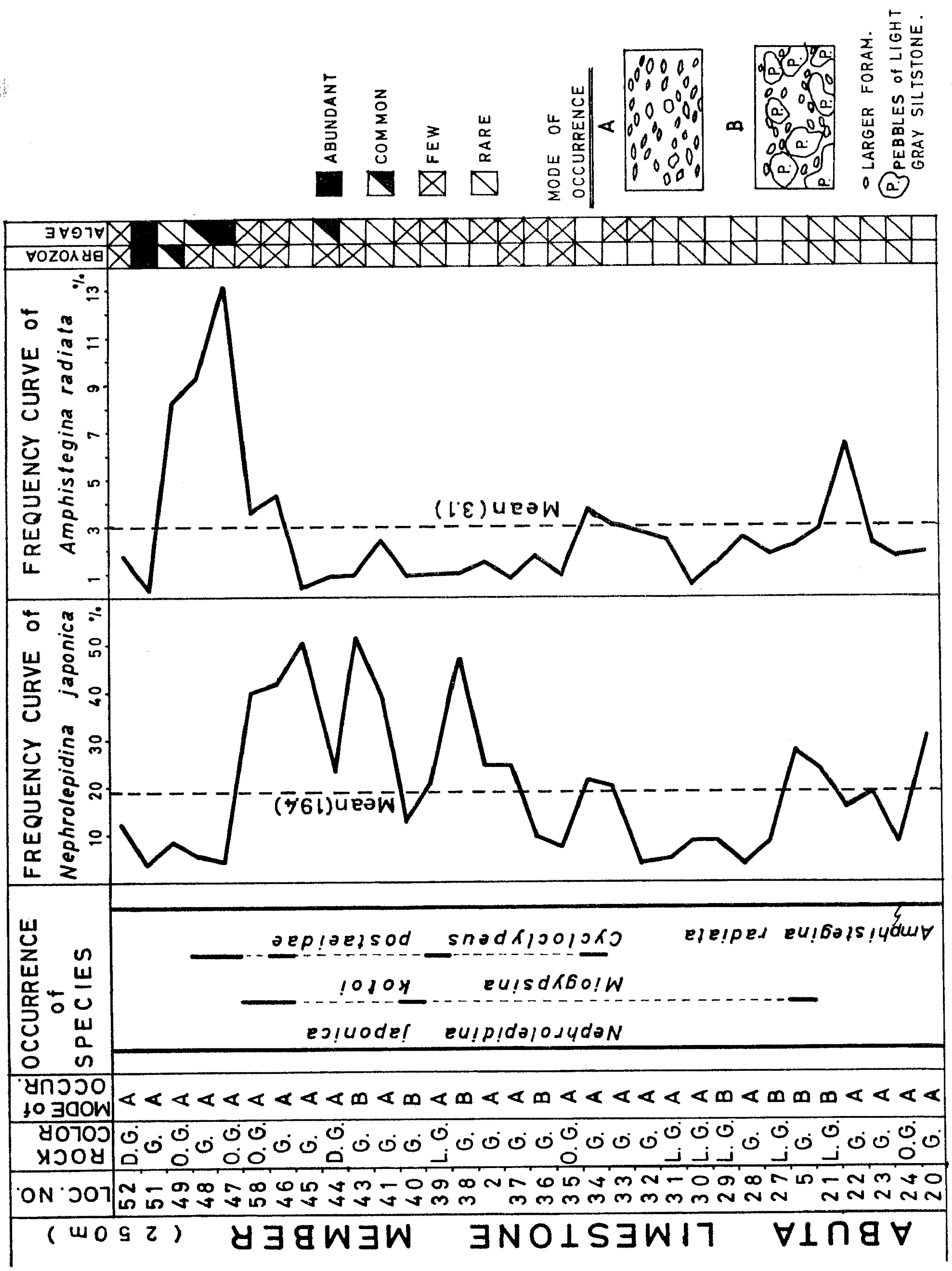

Fig 5. Frequency curve of the *Nephrolepidina japonica* population and the *Amphistegina radiata* population from the Abuta Limestone Member. (G.=gray, D.G.=dark gray, L.G.=light gray, O.G.=orange gray)

nic chamber and multilepidine embryonic chamber.

Mostly based on those nucleoconchal features in addition to the morphological characteristics of the median chambers, lateral chambers and pillars, the Family Lepidocyclinidae has been classified to include the genera *Lepidocyclina, Nephrolepidina, Trybliolepidina, Eulepidina, Pliolepidina* and *Multilepidina.*

According to Cole (1962), *Lepidocyclina radiata* (Martin) and *Lepidocyclina vaughani* Cushman show intergrading in the nucleoconchal feature from nephrolepidine through trybliolepidine and eulepidine to multilepidine.

Under the circumstances, the taxonomic value of the five types of nucleoconch must be restudied. For this purpose the morphological features of the nucleoconch of *Lepidocyclina japonica* were reexamined. From the equatorial sections of the megalospheric form of *Lepidocyclina japonica* from the Abuta Limestone Member, the embryonic chamber was bilocular in 104 specimens among the 105 studied and trilocular in only one as shown in Table 6. Among the specimens with bilocular nucleoconch, 92 were of the nephrolepidine type and 12 of the trybliolepidine as shown in Table 7.

Thus it is evident that *Lepidocyclina japonica* from the Abuta Limestone Member comprise forms of two different kinds of embryonic chambers.

Table 6. Percentage comparison of regular and irregular embryonic chambers of the *Nephrolepidina japonica* population and the *Lepidocyclina vaughani* and *L. radiata* populations according to Cole (1962)

KIND of EMBRYONIC CHAMBERS	MATSUMARU (1967)		COLE (1962)			
	Nephrolepidina japonica (YABE) from the ABUTA LIMESTONE MEMER		*Lepidocyclina vaughani* (CUSHMAN) from the PANAMA CANAL ZONE		*Lepidocyclina radiata* (MARTIN) from the LAU, FIJI	
	Number of Specimens	%	Number of Specimens	%	Number of Specimens	%
Bilocular	104	99.1	51	85.0	22	78.5
Trilocular	1	0.9	7	11.6	5	17.8
Multilocular	0	0.0	2	3.3	1	3.6
Total	105	100.0	60	99.9	28	99.9

Table 7. Percentage comparison of the specimens of three populations arranged according to the kind of embryonic chambers

KIND of EMBRYONIC CHAMBERS	MATSUMARU (1967)		COLE (1962)			
	Nephrolepidina japonica (YABE)		*Lepidocyclina vaughani* (CUSHMAN)		*Lepidocyclina radiata* (MARTIN)	
	Number of Specimens	%	Number of Specimens	%	Number of Specimens	%
Nephrolepidine	92	87.6	36	59.9	7	25.0
Trybliolepidine	12	11.4	4	6.6	8	28.5
Eulepidine	0	0.0	11	18.3	7	25.0
Trilocular	1	0.9	7	11.6	5	17.8
Multilocular	0	0.0	2	3.3	1	3.6
Total	105	99.9	60	99.7	28	99.9

As regards the trybliolepidine embryonic chambers, the morphological features of the embryonic chambers is similar to the embryonic chambers of the eulepidine type, but the protoconch wall is perpendicular to the wall of the deuteroconch and this is the basis upon which Vlerk (1928) established the new subgenus *Trybliolepidina* on the type species *Lepidocyclina rutteni* Vlerk, not *L. ephippioides* Jones and Chapman. Subsequently *Trybliolepidina* was once raised to the rank of genus.

Recently, Cole (1960, 1961, 1962, 1963) and Eames *et al.* (1926) placed *Trybliolepidina* in the synonymy of *Eulepidina*, whereas Douvillé and Hanzawa (1926) considered *Trybliole-*

pidina to be a synonym of *Nephrolepidina* Douvillé.

Judging from that the stratigraphic occurrence of *Trybliolepdina* which is in the upper part of the horizon of *Nephrolepidina* in Indonesia and the central Pacific area, and that the sizes of both test and embryonic chambers are smaller than those of *Eulepidina*, the writer follows Hanzawa's opinion in accepting *Trybliolepidina* as a synonym of *Nephrolepidina.*

Consequently, *Lepidocyclina japonica* with its two kinds of embryonic chambers called the nephrolepidine and trybliolepidine types respectively should now be named *Nephrolepidina japonica.*

Nephrolepidina japonica (Yabe), 1906

(Pl. 7, figs. 1-9; pl. 8, figs. 1-8)

1906, *Lepidocyclina japonica* Yabe, *Geol. Soc. Tokyo, Jour.* vol. 13, p. 317, figs. 1–2.

1922, *Lepidocyclina* (*Nephrolepidina*) *japonica*, Yabe and Hanzawa, *Jap. Jour. Geol. Geogr.*, vol. 1, no. 1, p. 47–48, pl. 6, figs. 3–4, pl. 7, figs. 2–5.

1928, *Lepidocyclina* (*Nephrolepidina*) *japonica*, Vlerk, I.M. van der, *Wetensh, Med.*, no. 8, p. 32, figs. 22 a-c.

1931, *Lepidocyclina* (*Amphilepidina*) *japonica*, Hanzawa, *Tohoku Imp. Univ. Sci. Rep., 2nd ser.* (*Geol*), vol. 12, no. 2a, p. 163–164, pl. 28, figs. 5–7.

1951, *Lepidocyclina* (*Nephrolepidina*) *japonica*, Koike, *Geol. Soc. Japan. Jour.*, vol. 57, no. 666, p. 87–92, pl. 2, figs. 1–11.

1957, *Lepidocyclina* (*Nephrolepidina*) *nipponica*, Hanzawa, *Geol. Soc. Amer., Mem.* 66, p. 80, pl. 19, figs. 1a-d, 4a-c.

Description: This species is composed of megalospheric forms [pl. 7, figs. 1–7, pl. 8, figs. 1–5] and microspheric forms [pl. 7, figs. 8, 9, pl. 8, figs. 6–8].

Megalospheric form: Test of moderate size, measuring 2.1–4.8 mm ($\bar{x}$=2.9 mm, $\sigma\bar{x}$=0.10 mm) in diameter and 0.6–1.3 mm ($\bar{y}$=1.0 mm, $\sigma\bar{y}$=0.03 mm) in thickness. Diameter-thickness ratio of test is given in Fig. 6. Test composed of swollen or comparatively flat-topped central boss, measuring 3.2–1.7 mm ($\bar{x}'$=2.4 mm $\sigma\bar{x}'$=0.05 mm) in diameter, and a thin peripheral portion composed only of median chamber layer or attended by one or two lateral chamber layers which are often lost. Ratio of diameter of central boss to thickness of test is given in Fig. 7. From ratio of diameter to thickness and of diameter of central boss to thickness given in Fig. 10.

Nucleoconch of nephrolepidine type, often trybliolepidine, of bilocular embryonic

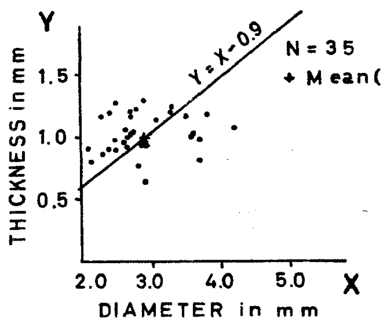

Fig. 6.

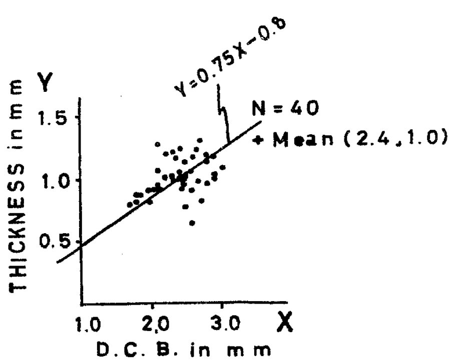

Fig. 7.

Fig. 6. Scatter diagram of the diameter to the thickness of the test of the megalospheric form.

Fig. 7. Scatter diagram of the diameter of the central boss (=D.C.B.) to the thickness of the test of the megalospheric form.

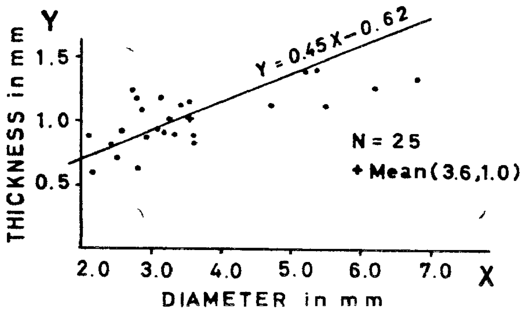

Fig. 8.

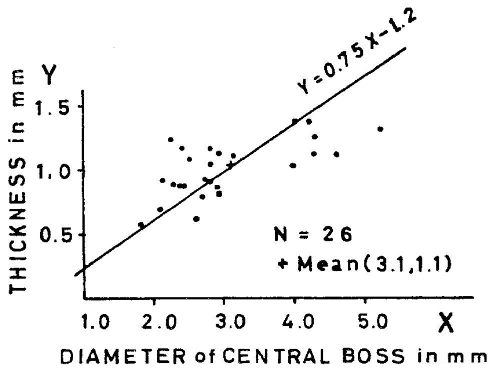

Fig. 9.

Fig. 8. Scatter diagram of the diameter to the thickness of the test of the microspheric form.

Fig. 9. Scatter diagram of the diameter of the central boss to the thickness of the test of the microspheric form.

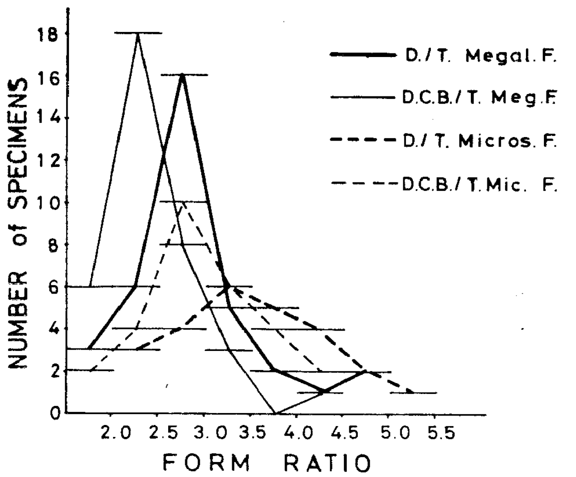

Fig. 10.

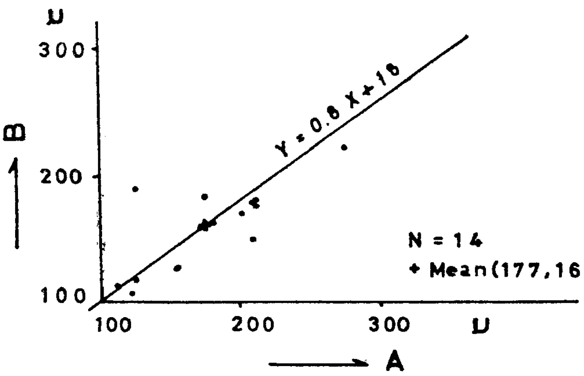

Fig. 11.

Fig. 10. Graph of Form Ratio of the diameter to the thickness (=D./T.) and the diameter of the central boss to the thickness (=D.C.B./T.) of the megalospheric form and microspheric form.

Fig. 11. Scatter diagram of the protoconch of the megalospheric form. A and B of the protoconch are the same factors as defined and used by Cosijin (1938).

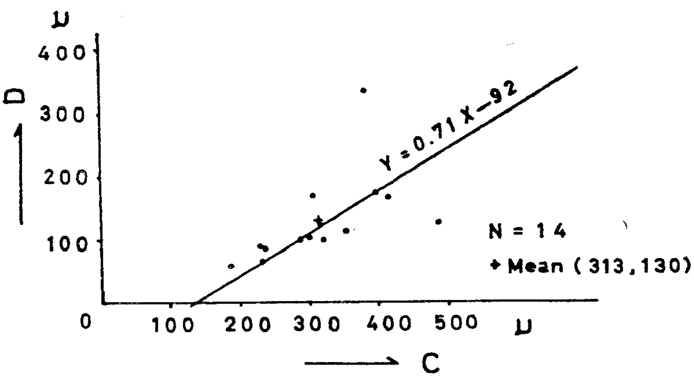

Fig. 12. Scatter diagram of the deuteroconch of the megalospheric form. C and D of the deuteroconch are parallel to the distance of A and B in Fig. 11.

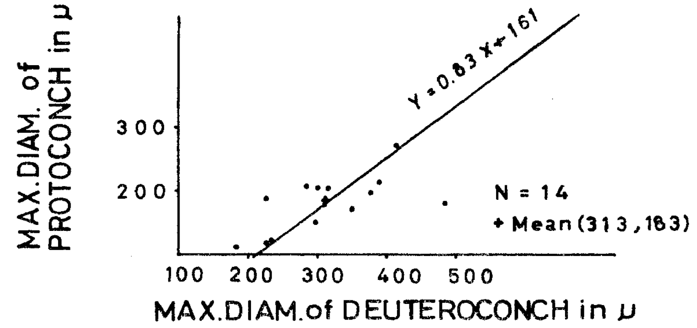

Fig. 13. Scatter diagram of the maximum diameter of the protoconch to the maximum diameter of the deuteroconch of the megalospheric form.

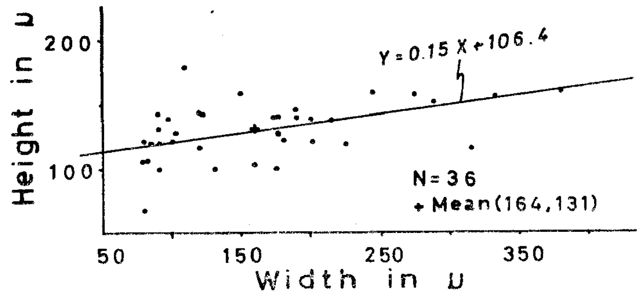

Fig. 14. Scatter diagram of the width to height of the nucleoconch in transverse section (Megalospheric form).

chambers, very rarely of trilocular embryonic chambers (Table 7), and characterized by reniform shape; proloculus smaller and subcircular in median section; deuteroconch large and kidney-shaped in median section and embraces the proloculus along half-length or more of its circumference in median section. Partition between two embryonic chambers solid and thin. Dimensions of protoconch, deuteroconch and maximum diameter of protoconch to deuteroconch given in Figs. 11, 12, and 13, respectively. The change of development of the size of nucleoconch of *Lepidocyclina* according to Cosijin (1938) does not, however, occur from the study of axial section of Lepidocyclinids occurrence of horizon by horizon as given in here (Figs. 11, 12).

Regression lines of respective dimensions given in figures above and coefficient of protoconch dimensions equal to nucleoconch diameter dimensions. Dimensions between width and height of nucleoconch in transverse sections given in Fig. 14, which indicates that nucleoconch is ellipsoidal and extends towards periphery. Thickness of outer wall of nucleoconch varies from 6μ to 50μ.

Median chambers of only a single layer almost spatuliform in median section, usually arcuate near nucleoconch, gradually elongated in radial direction of peripheral flange through ogival form to spatuliform in median section, dimensions of median chambers near nucleoconch and near periphery given in Figs. 16 and 17, respectively. Median chambers are disposed polygonal or often circular arrangment in median section. In transverse section, increasing in height very gradually from mean value of 46μ of 39 specimens near nucleoconch to mean value of 97μ of 39 specimens near periphery, dimensions between width and height of median chambers near nucleoconch and near periphery are given in Figs. 18 and 19. Dimensions between thickness of roofs and floors of median chamber near nucleoconch and near periphery are given in Fig. 22, which indicates a gradual increasing of thickness of roofs and floors of median chambers from nucleoconch to periphery.

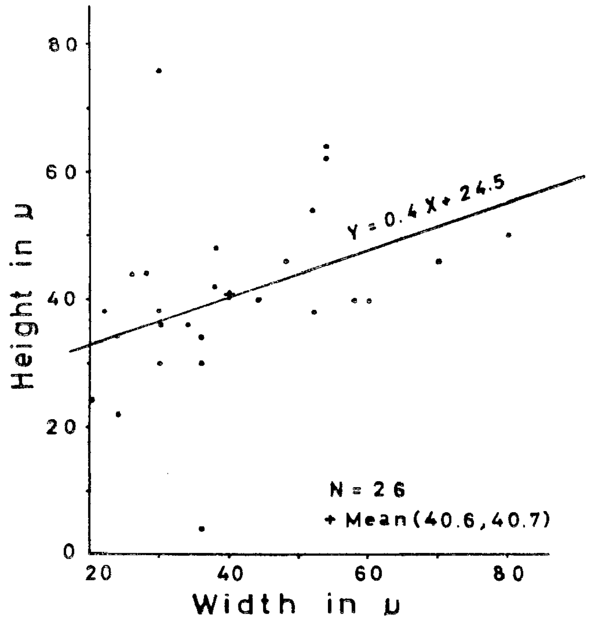

Fig. 15.

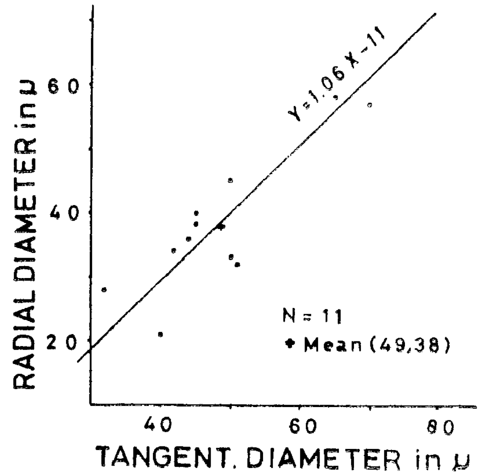

Fig. 16.

Fig. 15. Scatter diagram of the width to height of the proloculus in transverse section (Microspheric form).

Fig. 16. Scatter diagram of the tangential diameter to radial diameter of the median chambers near the nucleoconch (Megalospheric form).

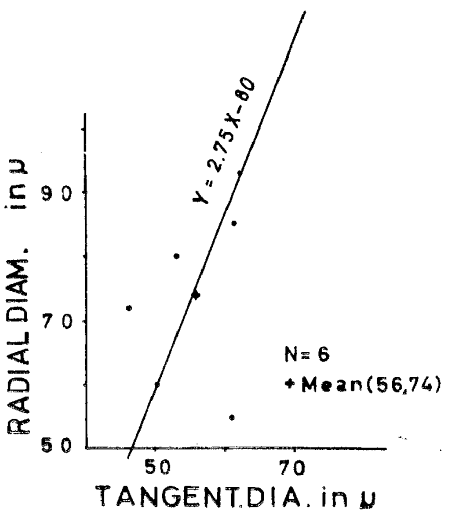

Fig. 17.

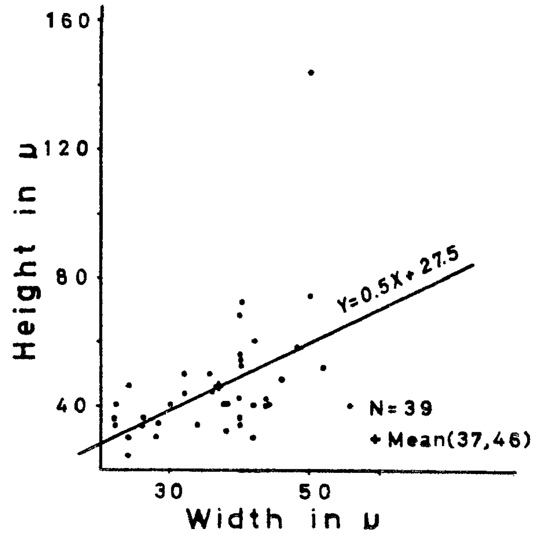

Fig. 18.

Fig. 17. Scatter diagram of the tangential diameter to radial diameter near the periphery (Megalospheric form).

Fig. 18. Scatter diagram of the width to height of the median chamber near the nucleoconch in transverse section (Megalosheric form).

Lateral chambers large, sub-circular, sub-cupul to sub-reniform in shape in tangential section, more or less spacious, being especially wide in tiers over nucleoconch, but narrow in tiers just above nucleoconch in transverse section, measuring 24–100μ in width and height of chambers ranging from 10–38μ. Ratio between width and height of lateral chambers over nucleoconch given in Fig. 23 and that near periphery in Fig. 24. In some specimens, two or

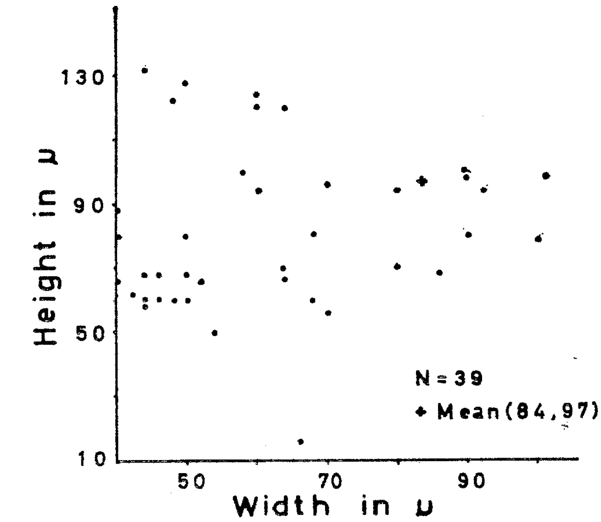

Fig. 19.

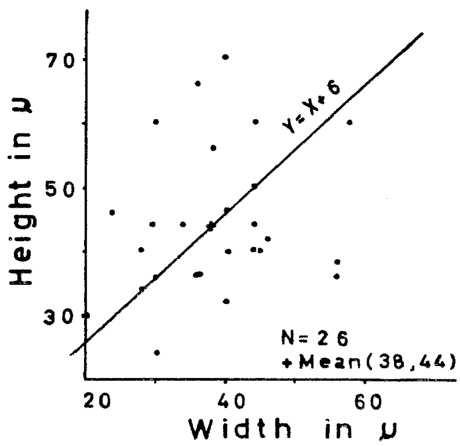

Fig. 20.

Fig. 19. Scatter diagram of the width to height of the median chamber near the periphery in transverse section (Megalospheric form).

Fig. 20. Scatter diagram of the width to height of the chamber near the nucleoconch in transverse section (Microspheric form).

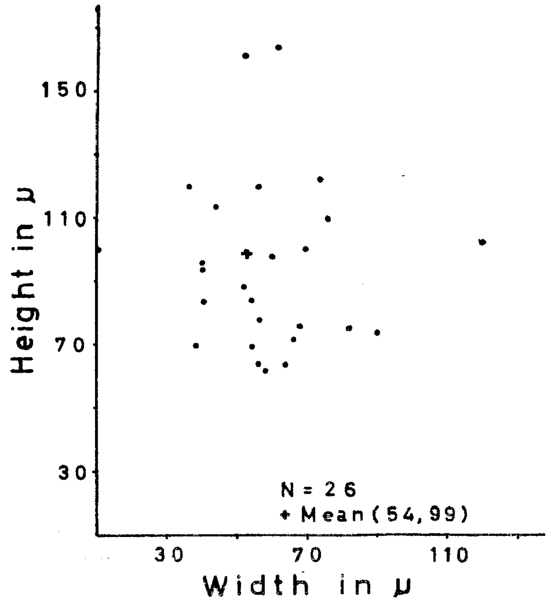

Fig. 21.

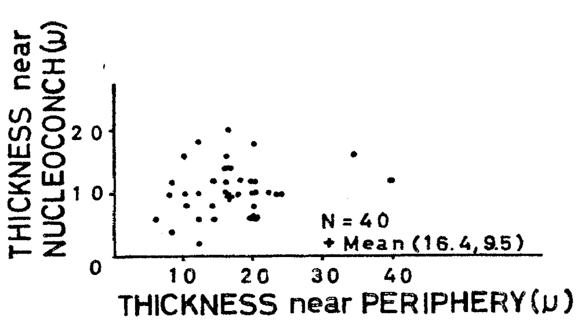

Fig. 22.

Fig. 21. Scatter diagram of the width to height of the median chamber near the periphery in transverse section (Microspheric form).

Fig. 22. Scatter diagram of the thickness of the roofs and floors of the median chamber near nucleoconch to that near the periphery (Megalospheric form).

three adjacent chambers often unite into a single chamber over nucleoconch. Number of chambers in a tier over nucleoconch is 7 to 12, 8 layers are common (38.5 percent of total) (Fig. 25). Pillars numerous, especially thick at end part of central boss of test, thin near skirts of central boss to peripheral part, thickness ranging from 20 to 260μ in width, mean being 160μ; prominent on external surface of test. Dimensions, width of pillars and

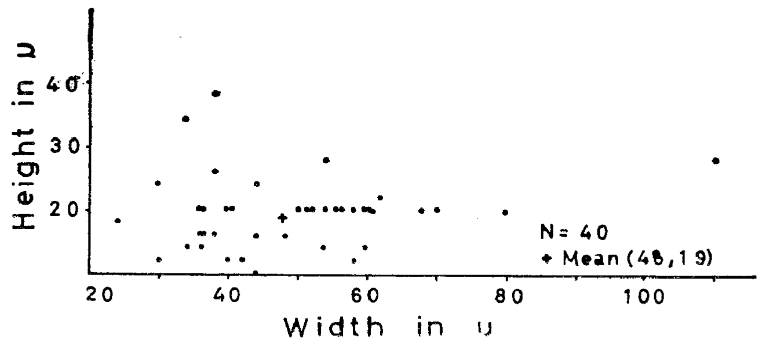

Fig. 23. Scatter diagram of the width to height of the lateral chambers over the nucleoconch (Megalospheric form).

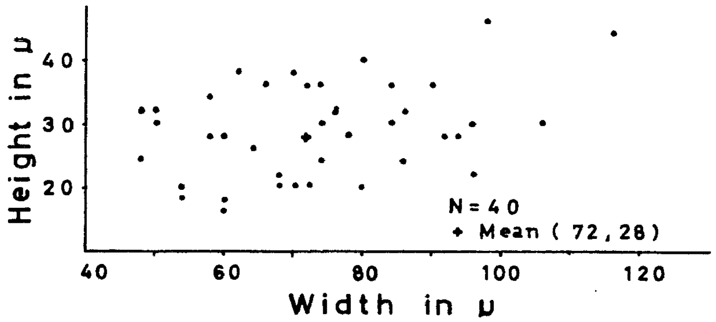

Fig. 24. Scatter diagram of the width to height of the lateral chambers near the periphery (Megalospheric form).

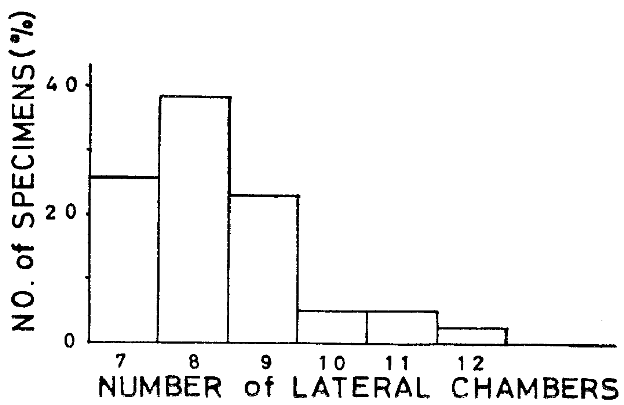

Fig. 25. Histogram showing the number of lateral chambers in a tier (Megalospheric form).

diameter of central boss given in Fig. 27.

Microspheric Form: Test of moderate size, somewhat larger than meglaospheric form, evenly thin lenticular with a diameter from 2.1 to 6.8 mm ($\bar{x}$=3.6 mm, $\sigma\bar{x}$=0.44 mm) and a thickness from 0.6 to 1.4 mm ($\bar{y}$=1.0 mm $\sigma\bar{y}$=0.04 mm) as shown in Fig. 8. Fig. 9 shows diameter of central boss and thickness of test; diameter of central boss ranges from 1.8 to 5.2 mm ($\bar{x}'$=3.1 mm, $\sigma\bar{x}'$=0.18 mm). From ratio is given in Fig. 10. Nucleoconch consists of only one minute proloculus, succeeding spirally to nepionic chambers. Dimensions between width and height of proloculus in transverse section given in Fig. 15.

Median chambers spatulate in adult stage, arcuate or lozengic in form near nucleoconch and usually given in middle portion and spatulate towards peripheral part of test.

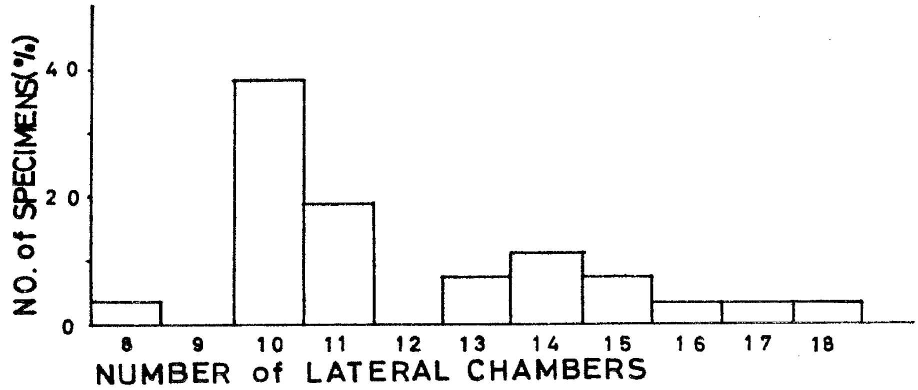

Fig. 26. Histogram showing the number of lateral chambers in a tier (Microspheric form).

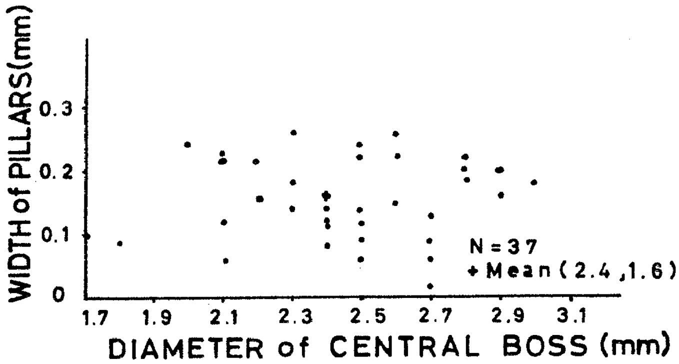

Fig. 27. Scatter diagram of the diameter of the central boss to width of the pillars (Megalospheric form).

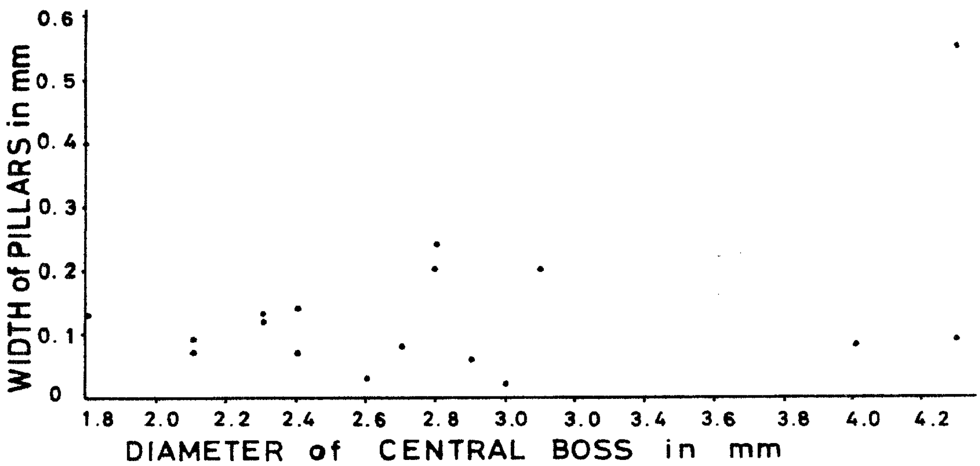

Fig. 28. Scatter diagram of the diameter of the central boss to width of the pillars (Microspheric form).

Radial and tangential diameters of median chambers in adult stage 32μ and 40μ, respectively. In transverse section, width and height of median chambers near nucleoconch vary from 20 to 58μ and from 22 to 70μ, respectively; dimentions between width and height of median chamber near nucleoconch given in Fig. 20. Median chambers near nucleoconch are gradually become quadrate in shape. In peripheral portion, the median chambers rectangular, height exceeding width, as shown in Fig. 21. Size of median chambers gradually increase from near nucleoconch to periphery, especially increasing in height.

Lateral chambers minute, measuring 28–78μ in width and 16–28μ in height over nucleoconch and 48–116μ in width and 16–46μ in height near periphery, respectively in transverse section. From 8 to 18 layers of lateral chambers in a tier over nucleoconch and 10 layers show higher frequency (Fig. 26). Pillars numerous, often indistinct or absent, 20 to 550μ in width. Dimensions between width of pillars and diameter of central boss given in Fig. 28.

Remarks: Considerable variation in the shape of the test appears at maturity. There is the lenticular shape of the megalospheric form (pl. 7, fig. 5) and of the microspheric form (pl. 7, figs. 8, 9; pl. 8, fig. 6). There is the shape of the flat-topped central boss of the megalospheric form (pl. 7, figs. 4, 6, 7) and the same shape of the microspheric form. There is, moreover, fair intergradational shape between both as stated above.

Therefore, considerable care should be taken to distinguish the megalospheric and microspheric forms from the surface observation of the free specimens. However, there is a difference between the forms in the size of test and the number of pillars.

The test of the flat-topped shape with the remarkably thick pillars was hitherto assigned to *Nephrolepidina angulosa* (Provale). Concerning *Nephrolepidina angulosa* Hanzawa (1964, p. 307) once stated, "Cole (1963, p. 21) also suppressed *Nephrolepdina angulosa* (Provale) as a synonym of *N. japonica* (Yabe) ignoring that the former is characterized by remarkably thick pillars traversing the lateral chambers, whereas the latter is equipped with thin pillars".

However, as lately pointed out by Hanzawa, *Nephrolepidina nipponica*, *N. angulosa*, *N. makiyamai*, *N. ferreoi*, *N. perornata*, *N. scabra*, *N. polygonalis* and *N. laevigata* are synonyms of the Megalospheric form and/or microspheric form of *Nephrolepdina japonica*.

Therefore, from the statistics of measurements, it is evident that *Nephrolepidina japonica* is a species with many varietal forms. Especially, the specimen shown in pl. 8, fig. 3 has a typical trybliolepidine embryonic chamber measuring 180μ in maximum diameter of protoconch and 480μ in maximum diameter of deuteroconch. In Fig. 13, is shown a specimen with weak relation line.

It is also interesting in notice that Fig. 29 shows some specimens with a variety value from 25 to 30 percent and from 75 to 80 percent as calculated by a formula of the "grade of exposure" method of Vlerk (1963).

Consideration of the Geological Age of the Abuta Limestone Member Based upon *Nephrolepidina*

Nephrolepidina japonica occurs in the lower to the upper part of the 250 m thick Abuta Limestone Member and is associated throughout that thickness with *Miogypsina kotoi*, *Cycloclypeus postaeidae* and *Amphistegina radiata*.

Lately, the number of nepionic spirals of the nepionic chambers are considered by Carter (1964) and others as essentially the most significant single feature of Lepidocyclinids for determination of the relative age. Therefore, the ranges of the nepionic spirals of *Nephrolepidina japonica* from the Abuta Limestone Member will be important for determination of the relative age from a method which has already been reported by Renz and Küpper (1946), Mohler (1946), Carter (1964), and others. This method was applied to determine the age of the Abuta Limestone Member.

Fig. 31 shows the ranges of nepionic variation in *Nephrolepidina japonica* from the Abuta Limestone Member. The Abuta *Nephrolepidina* population ranges from 10 to 14

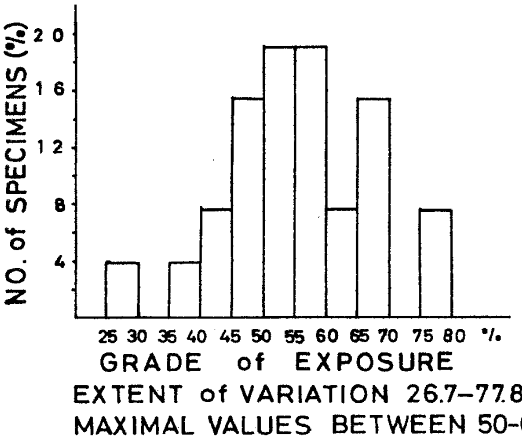

Fig. 29. Diagram showing the variation of the *Nephrolepidina japonica* populations from the Abuta Limestone Member, calculated by a formula of the "grade of exposure" method of Vlerk (1963).

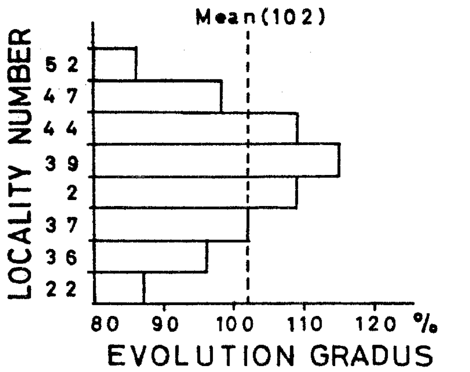

Fig. 30.

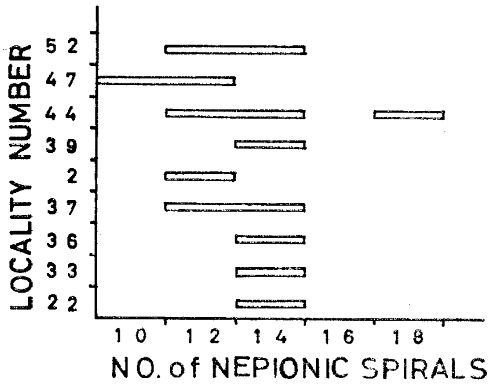

Fig. 31.

Fig. 30. Diagram showing the evolution gradus of *Nephrolepidina japonica* from the Abuta Limestone Member, calculated by the method of Vlerk (1959).

Fig. 31. Diagram showing the ranges of nepionic variation in *Nephrolepidina japonica.*

spirals in general.

According to Carter (1964, p. 139, fig. 34), the ranges of nepionic variation of *Lepidocyclina* for the specimens from the East Indies are 6 to 14 spirals and the relative time is reported to be correlative with the Burdigalian stage of Europe.

Therefore from the nepionic variation values it is considered that the age of the Abuta Limestone Member is approximately correlative with the Burdigalian (Early Miocene) stage.

With regard to locality no. 44 to the specimens with 18 spirals from the Abuta Limestone Member which is an exceptional case, the age of that part of the Abuta Limestone Member may be Vindobonian, because Renz and Küpper (1946, Table 18) recorded 10 to 20 spirals in the Vindobonian *Lepidocyclina* of Europe.

The range of the nepionic spirals of *Nephrolepidina japonica* from the horizon overlying the one that yielded locality no. 44 are 10 to 14 spirals and this range suggests that the age is Burdigalian, not Vindobonian.

Although it is difficult to decide the relative age of the Abuta Limestone Member, the writer was fortunate in obtaining important data from the evolution gradus of *Neph-*

rolepidina japonica which was calculated by the "evolution gradus" method according to Vlerk (1963), and also from the number of nepionic sprials of *Cycloclypeus*.

Vlerk (1963) found that by calculating the factor A, which means the degree the deuteroconch embraces the protoconch of Lepidocyclina, a percentage could be obtained that may be regarded as a grade of evolution of Lepidocyclinids and the value can be used for age determination.

The percentage of evolution gradus of X-lineage and Y-lineage of the stolon morphology of *Lepidocyclina* from deposits whose age is sufficiently known is given in Fig. 2 and Fig. 3 of Vlerk (1959).

His Fig. 2 shows 71 percent as the value of evolution gradus of *Lepidocyclina japonica* from the deposits of Upper of the East Indies stage of East Borneo.

The percentage of the evolution gradus of *Nephrolepidina japonica* from the Abuta Limestone Member ranges from 86 to 115 percentage and 102 percent is the mean value of 13 specimens (Fig. 30).

Therefore, the relative age judging from the evolution gradus of *Nephrolepidina japonica* from the Abuta Limestone Member is correlative with the Lower f of the East Indies stage or Burdigalian of the European stage, based upon the data shown in Vlerk's paper.

Although it may be inadvisable to draw hasty conclusions on the route of migration of *Lepidocyclina* as stated by Vlerk, it is interesting to know that *Lepidocyclina japonica* in East Borneo occurs from deposits of Upper f, whereas in the Abuta Limestone Member is occurs from deposits correlative with Lower f.

Formerly, Tan (1932, 1939) studied the phylogenetic history of *Cycloclypeus* based upon the results of statistical examination of the variations of the equatorial layer of chambers and simultaneously emphasized the importance of the so-called acceleration of the nepionic chambers.

A series of the studies of *Cycloclypeus* was done by Tan (1932), Cosijin (1938), Renz and Küpper (1946), Drooger (1955), Carter (1964) and others and it was, therefore, proved that the modal number of the nepionic chambers of *Cyclocypeus* show a gradual decreasing from the older age to the younger.

According to Tan, and Renz and Küpper, the Burdigalian *Cycloclypeus* has about 12 to 15 spirals.

Cycloclypeus postaeidae occurs from the locality nos. 34, 39, 46, and 48 of the Abuta Limestone Member and has 12 spirals. From the number of spirals the age of these *Cycloclypeus* from the Abuta is obviously equivalent to the Brudigalian stage of Europe.

Putting all data together, the relative age of the Abuta Limestone Member is equivalent to the Lower f of the East Indies, to the Burdigalian stage of Europe and the Vindobonian *Lepidocyclina* of the Abuta Limestone Member first appears from locality no. 44.

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Explanation of Plate 7

Nephrolepidina japonica (Yabe)

Geologic Horizon: Lower Miocene Abuta Limestone Member of the Idozawa Formation.

Figs. 1–3. Centered median section with nephrolepidine nucleoconch, nepionic chambers and median chambers of the megalospheric form.

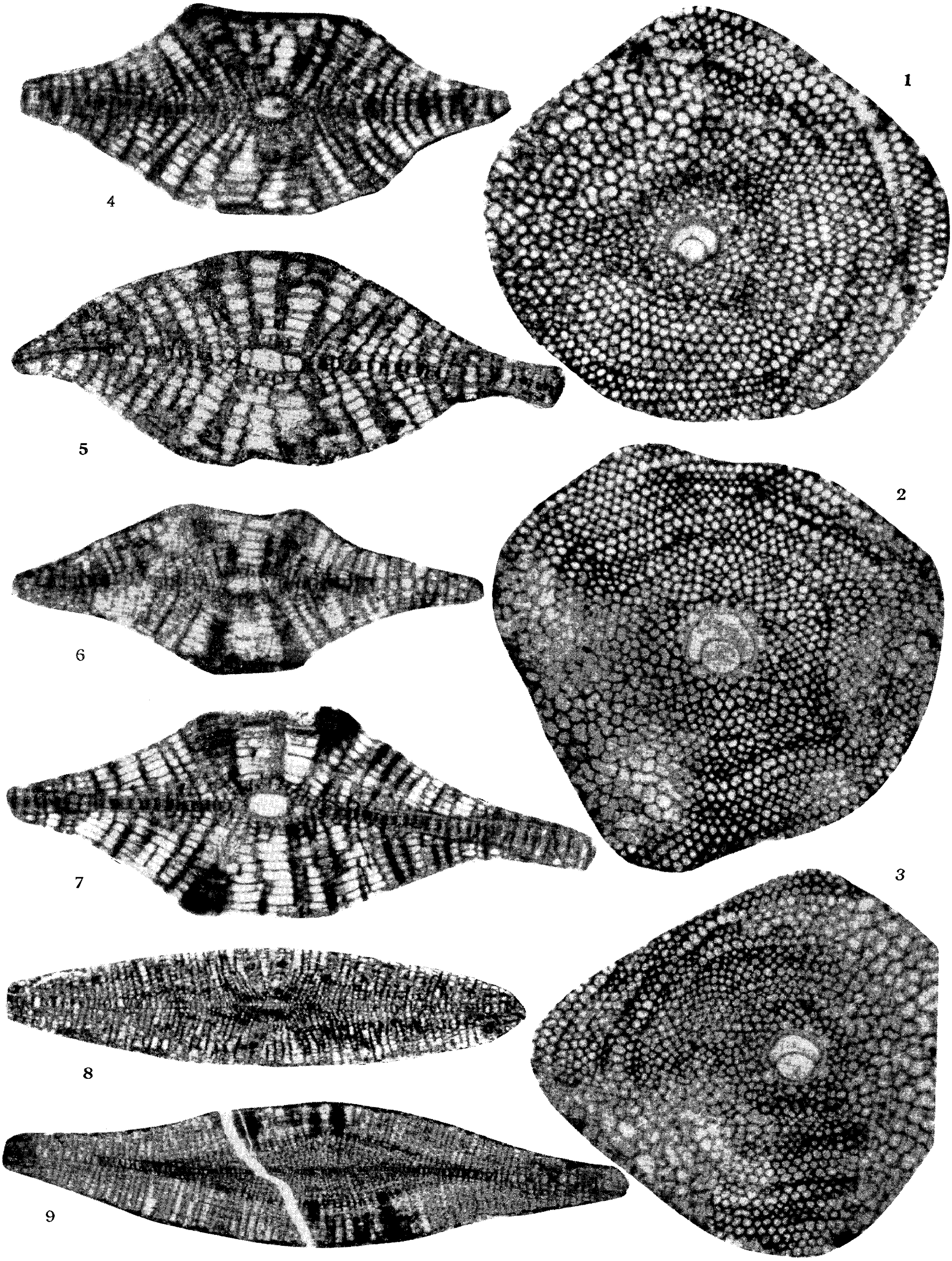
Fig. 1. ×35. Loc. no. 39. IGPS coll. cat. no. 88011.
Fig. 2. ×33. Loc. no. 2. IGPS coll. cat. no. 88012.
Fig. 3. ×29. Loc. no. 44. IGPS coll. cat. no. 88013.

Figs. 4–7. Centered transverse sections of the megalospheric form.

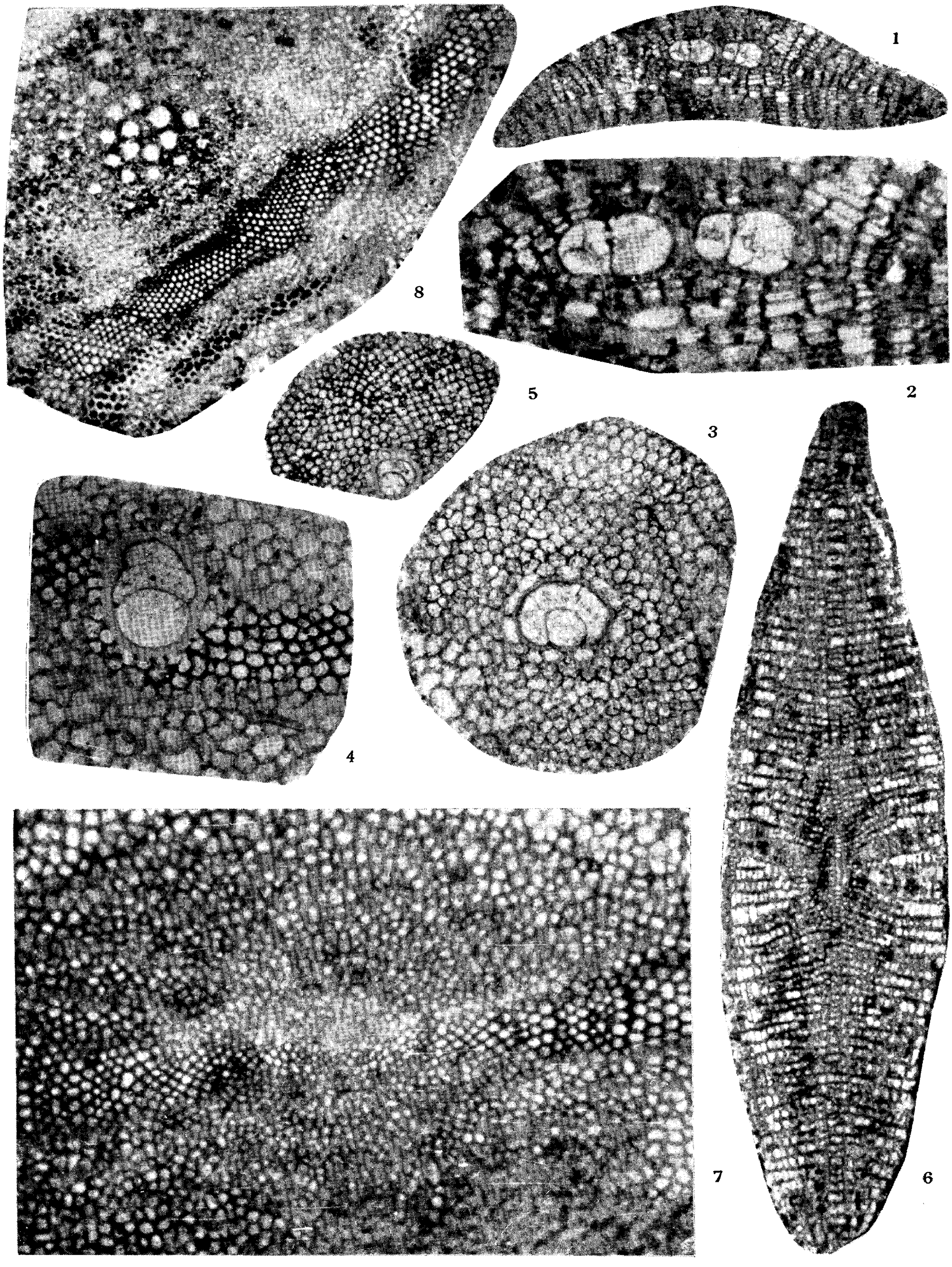
Fig. 4. ×29. Loc. no. 5. IGPS coll. cat. no. 88014.
Fig. 5. ×31. Loc. no. 29. IGPS coll. cat. no. 88015.
Fig. 6. ×22.5. Loc. no. 5. IGPS coll. cat. no. 88016.
Fig. 7. ×30. Loc. no. 5. IGPS coll. cat. no. 88017.

Figs. 8–9. Centered transverse sections of the microspheric Form.

Fig. 8. ×18. Loc. no. 29. IGPS coll. cat. no. 88018.
Fig. 9. ×17. Loc. no. 20. IGPS coll. cat. no. 88019.



Matsumaru and Kumagai photo.



Matsumaru and Kumagai photo.

Explanation of Plate 8

Nephrolepidina japonica (Yabe)

Geologic Horizon: Lower Miocene Abuta Limestone Member of the Idozawa Formation.

Fig. 1. Centered transverse section of the megalospheric form with two chambered nucleoconch, Rhumbler's Doppelschale. ×30. Loc. no. 29. IGPS coll. cat. no. 88020.

Fig. 2. Fig. 1 enlarged 80 times, to show the nucleoconch.

Fig. 3. Centered median section with trybliolepidine nucleoconch of the megalospheric form. × 35. Loc. no. 44. IGPS coll. cat. no. 88021.

Fig. 4. Centered median section with trilocular nucleoconch of the megalospheric form. ×52. Loc. no. 22. IGPS coll. cat. no. 88022.

Fig. 5. Centered median section of the megalospheric form. ×39. Loc. no. 47.

Fig. 6. Fig. 8 of plate enlarged 30 times to show the minute nucleoconch, median chambers and lateral chambers. Loc. no. 29. IGPS coll. cat. no. 88023.

Fig. 7. Centered median section of the microspheric form. ×68. Loc. no. 27. IGPS coll. cat. no. 88024.

Fig. 8. Tangential section cut near nucleoconch of the microspheric form. ×21. Loc. no. 58. IGPS coll. cat. no. 88025.