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Miocene Smaller Foraminifera from the Tsuyama Basin, Okayama Prefecture, Japan.*

By

Yoshirô TAI

I Introduction

In a previous report, the writer (1953) reported the Miocene Foraminifera derived from the sediments distributed in the Shôbara basin in the northern part of Hiroshima Prefecture. On that occasion he reported on the ecological conditions inferred from the Foraminifera and mentioned the relation existing between the Foraminifera to the entombing sediments. Also the results obtained from the Foraminifera were compared with those from the molluscan fossils as previously reported by Y. OTUKA (1938).

In the present report the writer deals with the smaller Foraminifera derived from several horizons of the Miocene sediments exposed in Yoshino-mura, Katsuta-gun in the Tsuyama basin, Okayama Prefecture.

The stratigraphy of the Tsuyama basin was first undertaken by T. TAKEYAMA (1930), who recognized two series, namely, the Uetsuki and Tsuyama, the former underlying the latter with parallel unconformity. He stated that the lower or Uetsuki series is an inland sea deposit of Lower Miocene age, while the upper or Tsuyama is a shallow water deposit of Middle Miocene age. His age determinations were based upon the occurrence of *Operculina* with other molluscan remains in the Tsuyama, and on *Vicarya callosa* Jenkins, *Pyrazus proavitum* (Yokoyama), *Tympanotonus kamiensis* n. sp., *Barbatia mimasakensis* n. sp., and undetermined species of the genera *Tellina*, *Ostrea*, *Anadara*, and *Diplodonta*, in the Uetsuki.

Subsequently K. SUYARI (1948) studied the geology of the same basin and classified the strata into the Mimasaka coal-bearing formation below and the Katsuta formation above. The latter is subdivided into two parts, the lower consisting of coarse sediments with *Operculina-Vicarya* and the upper of very fine-grained sediments with some molluscan remains. From his stratigraphical and paleontological work, he concluded that his Katsuta formation is a correlative of TAKEYAMA's Uetsuki and Tsuyama combined.

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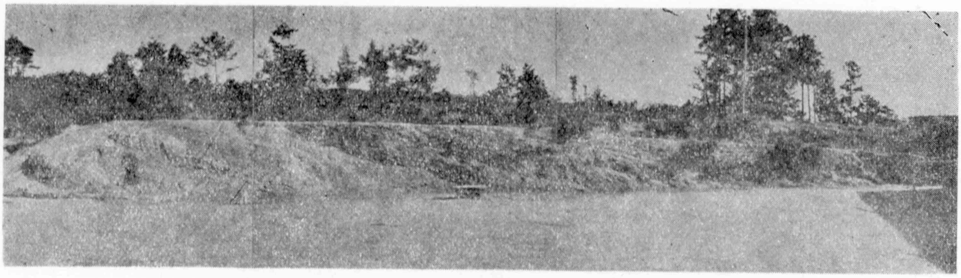


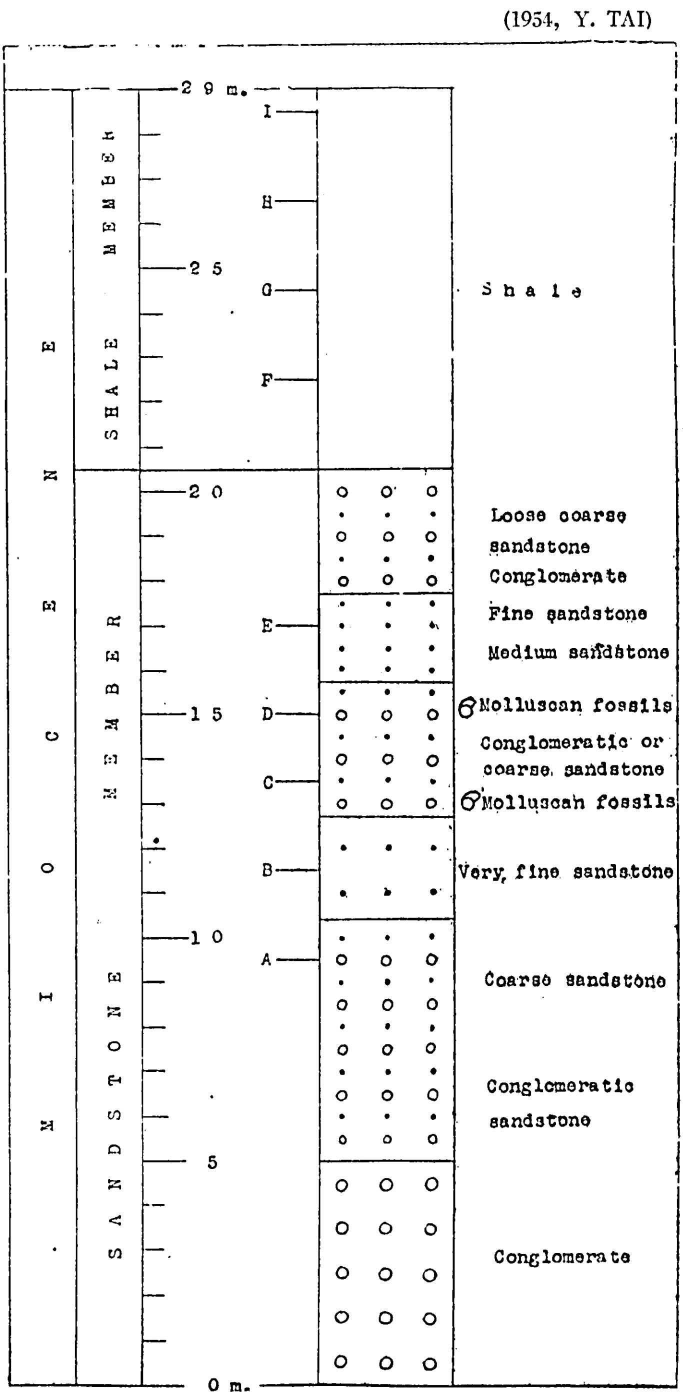
Fig. 1. Photograph of the Northern Cliff of the Yoshino Primary School, about 14 km. E of the Tsuyama City, Okayama Prefecture.
(by M. Tamura)

The megafossils reported by K. SUYARI from the lower part of his Katsuta formation are as follows:

Anadara kakehataensis Hatai and Nisiyama
Anadara kurosedaniensis Hatai and Nisiyama
Anadara cfr. *daitokudoensis* (Makiyama)
Anadara n. sp.
Anodonta n. sp.
Batillaria tateiwai Makiyama
Batillaria yamanarii Makiyama
Cardium sp.
Cerithidea cfr. *tokunagai* Otuka
Cerithidea cfr. *kanpokudoensis* Makiyama
Cerithidea sp.
Cerithium meisense Makiyama
Chlamys cfr. *denselineata* Nagao
Clementia vatheleti Mabille
Clementia nakamurai kuretiensis Otuka
Clinocardium arugai Otuka
Conus cfr. *tokunagai* Otuka
Corbula tsukaharai Yokoyama
Crassatellites n. sp.
Cultellus izumoensis Yokoyama
Dosinia akaisiana Nomura
Dosinia suketoensis Otuka
Glycymeris cfr. *rhynchonelloides* Nomura and Hatai
Joannisiella takeyamai Otuka var.
Lima cfr. *konnoi* Otuka
Mytilus sp.
Meretrix cfr. *arugai* Otuka
Nassarius cfr. *simizui* Otuka
Nassarius n. sp.
Natica sp.
Ostrea gravitesta Yokoyama
Panope japonica (A. Adams)
Pecten planicostulatus Nomura and Niino
Pitar cfr. *itoi* (Makiyama)
Polinices sp.
Protorotella depressa Makiyama
Sanguinolaria n. sp.
Searlesia cfr. *kurodai* Makiyama
Soletellina minoensis Yokoyama
Taras ustus (Gould)
Tellina cfr. *jedoensis* Lischke
Tellina sp.
Turbo n. sp.
Venus cfr. *toreuma* Gould
Vicarya callosa japonica Yabe and Hatai
Vicarya callosa semperi Martin
Vicarya yatsuoensis Yabe and Hatai
Vicaryelia tyosenica Yabe and Hatai
Turritella kiiensis Yokoyama
Melongena ? sp.
Operculina complanata japonica Hanzawa

From the upper part of the same formation, he reported on the occurrence of the following fossils:

Batillaria sp.
Cerithideopsilla n. sp.
Corbis ? sp.
Delectopecten n. sp. (aff. *intuscostatum* Yokoyama)
Limatula aff. *subauriculata* (Mont.)
Limatula sp.
Limatula ? sp.
Lucinoma ? sp.



Dentalium yokoyamai. Makiyama
Dentalium sp.
Glycymeris sp.
Propeamussium transnippcnica Mochizuki
Surculites (Megasurcula) sp.
Sagarites sp.
Echinoid gen. et sp. indet.

As to the geological age of the Katsuta formation, he merely mentioned that the age may range from Lower to Middle Miocene.

In the present paper, the writer deals with the smaller Foraminifera collected from the northern cliff (Fig. 1) (Lat. 35° 03′ 48″ N., long. 134° 09′ 46.4″ E.) of the Yoshino Primary School, which is situated about 14km east of Tsuyama City in the Tsuyama basin, Okayama Prefecture. The sediments exposed are referred

Fig. 2. Geologic Columnar Section of the Miocene Formation, distributed along the Northern Cliff of the Yoshino Primary School, about 14 km. E of the Tsuyama City.

to the Katsuta formation in modified sense, and the Foraminifera collected therefrom were studied both quantitatively and microbiostratigraphically. As shown in the columnar section (Fig.2), the writer subdivided SUYARI's Katsuta formation into two members, the Sandstone member below and the Shale member above, the former comprising coarse sediments and the latter only shale.

In this work, nine samples, each weighing 200 grams were collected from the sampling points numbered A–I in the columnar section shown in Figure 2. The intervals between each sampling was about 1.5 – 5.5 meters. The samples were first washed, sieved and then dried in an incubator. The dried materials were respectively divided into eight equal parts, and one-eighth part of each sample was studied under the binocular microscope for individual counting of the Foraminifera. The method is the same as used in the study of the Shôbara Miocene Foraminifera. Unfortunately horizons A–C yielded no Foraminifera. As a result of quantitative analyses of the foraminiferal fauna from each sampling horizon, the species and their individual numbers are indicated in Table 1.

Table 1

Species \ Horizons	D	E	F	G	H	I
Rhizamminidae :						
1. *Bathysiphon* sp.	0	0	16	2	0	3
Lituolidae :						
2. *Haplophragmoides trullissatum* (Brady)	0	0	20	16	0	2
3. *Haplophragmoides* sp.	0	0	2	23	6	0
4. *Haplophragmoides* ? sp.	0	0	1	5	2	8
5. *Cribrostomoides kyushuense* Asano	0	0	0	1	0	0
6. *Cribrostomoides* ? sp.	0	0	1	0	0	0
7. *Cyclammina* incisa (Stache)	0	0	3	42	6	4
8. *Cyclammina* cf. *incisa* (Stache)	0	0	0	2	0	0
9. *Cyclammina incisa* ? (Stache)	0	0	0	1	0	0
10. *Cyclammina* sp.	0	0	3	20	2	0
11. *Cyclammina* ? sp.	0	0	0	0	2	0
Verneuilinidae :						
12. *Gaudryina* (*Pseudogaudryina*) *ishikiensis* Asano	0	0	97	84	2	96
13. *Gaudryina* sp.	0	0	201	21	0	12
14. *Gaudryina* ? sp.	0	0	36	6	0	5
Valvulinidae :						

Species \ Horizons	D	E	F	G	H	I
15. *Martinottiella communis* (d'Orbigny)	0	0	92	114	25	63
Miliolidae :						
16. *Sigmoilina imamurai* Tai, n. sp.	0	0	48	0	0	32
17. *Sigmoilina* sp.	0	0	11	4	0	0
18. *Sigmoilina*? sp.	0	1	0	0	0	0
Lagenidae :						
19. *Robulus calcar* (Linnaeus)	0	0	1	0	0	0
20. *Robulus lucidus* (Cushman)	0	0	86	2	0	14
21. *Robulus nikobarensis* (Schwager)	0	0	69	0	0	1
22. *Robulus nikobarensis*? (Schwager)	0	0	4	0	0	0
23. *Robulus notoensis* Asano	0	0	13	2	0	0
24. *Robulus pseudorotulatus* Asano	0	0	35	14	23	8
25. *Robulus* cf. *pseudorotulatus* Asano	0	0	0	0	0	2
25. *Robulus* sp.	0	0	173	53	72	82
27. *Robulus*? sp.	0	0	33	0	5	11
28. *Lenticulina asanoi* Tai, n. sp.	0	0	1	0	0	0
29. *Lenticulina* sp.	0	0	1	2	0	2
30. *Lenticulina*? sp.	0	0	0	2	0	2
31. *Vaginulina bradyi* Cushman	0	0	179	38	12	18
32. *Vaginulina* sp.	0	0	6	0	0	0
33. *Marginulina aculeata* Neugeboren	0	0	2	0	5	2
34. *Marginulina* cf. *glabra* d'Orbigny	0	0	26	0	0	2
35. *Marginulina masudai* Asano	0	0	4	12	8	2
36. *Marginulina* cf. *masudai* Asano	0	0	21	0	0	0
37. *Marginulina* sp.	0	0	4	0	0	2
38. *Lagenonodosaria scalaris* (Batsch)	0	0	22	0	11	2
39. *Lagenonodosaria* cf. *scalaris sagamiensis* Asano	0	0	34	22	5	9
40. *Lagenonodosaria* sp.	0	0	33	24	8	24
41. *Lagenonodosaria*? sp.	0	0	5	0	0	1
42. *Nodosaria* cf. *longiscata* d'Orbigny	0	0	18	8	0	12
43. *Nodosaria notoensis* Asano	0	0	45	24	0	0
44. *Nodosaria pyrula* d'Orbigny var.	0	0	13	2	1	0
45. *Nodosaria pyrula*? d'Orbigny	0	0	0	0	0	1
46. *Nodosaria* cf. *vertebralis* (Batsch)	0	0	6	0	0	1
47. *Nodosaria* sp.	0	0	2	0	0	0
48. *Dentalina emaciata* Reuss	0	0	60	34	0	5

Species \ Horizons	D	E	F	G	H	I
49. *Dentalina* cf. *soluta* Asano	0	0	9	2	16	9
50. *Dentalina spinosa* d'Orbigny	0	0	2	0	0	0
51. *Dentalina* sp.	0	0	4	0	2	2
52. *Dentalina*? sp.	0	0	0	0	0	2
53. *Ellipsonodosaria japonica* Ishizaki	0	0	10	10	0	2
54. *Ellipsonodosaria lepidula* (Schwager)	0	0	29	108	2	78
55. *Ellipsonodosaria* sp.	0	0	0	2	0	1
56. *Ellipsonodosaria*? sp.	0	0	2	0	0	0
57. *Plectofrondicularia japonica* Asano	0	0	21	0	0	0
58. *Lagena laevis* (Montagu)	0	0	6	11	0	2
59. *Lagena* sp.	0	0	0	0	2	0
60. *Lagena*? sp.	0	0	0	0	0	2
Polymorphinidae :						
61. *Guttulina irregularis* (d'Orbigny)	0	0	21	4	0	0
62. *Guttulina sadoensis*? (Cushman and Ozawa)	0	0	1	0	0	0
63. *Guttulina* sp.	0	0	0	8	8	4
64. *Guttulina*? sp.	0	0	0	4	5	0
65. *Globulina*? sp.	0	0	0	0	0	1
Nonionidae :						
66. *Nonion japonicum* Asano	0	2	41	161	88	43
67. *Nonion nicobarense* Cushman	0	0	1	0	3	0
68. *Nonion* sp.	0	7	8	0	0	0
69. *Nonionella miocenica* Cushman	0	2	20	2	0	0
Buliminidae :						
70. *Bulimina inflata* Seguenza	0	0	4	0	0	0
71. *Bulimina striata* d'Orbigny	0	0	8	5	0	0
72. *Bulimina striata notoensis* Asano	0	0	13	26	0	56
73. *Bulimina* sp.	0	0	4	0	0	5
74. *Bulimina*? sp.	0	0	3	0	0	0
75. *Bolivina marginata* Cushman	0	0	4	0	0	24
76. *Bolivina marginata masudai* Asano	0	0	0	0	0	10
77. *Bolivina* sp.	0	0	2	0	0	0
78. *Uvigerina crassicostata* Schwager	0	0	53	26	0	23
79. *Uvigerina crassicostata*? Schwager	0	0	2	0	0	0
80. *Uvigerina hootsi* Rankin	0	0	0	106	0	0
81. *Uvigerina* cf. *hootsi* Rankin	0	0	72	35	0	2

Species \ Horizons	D	E	F	G	H	I
82. *Uvigerina nitidula* Schwager	0	0	0	15	0	0
83. *Uvigerina* cf. *subperegrina* Cushman and Kleinpell	0	0	2	5	0	0
84. *Uvigerina* sp.	0	0	8	23	0	11
85. *Uvigerina ?* sp.	0	0	0	0	4	4
86. *Siphogenerina ?* sp.	0	1	0	0	0	0
Rotaliidae :						
87. *Gyroidina soldanii* d'Orbigny	0	0	53	8	0	0
88. *Gyroidina* cf. *soldanii* d'Orbigny	0	0	2	0	0	0
89. *Gyroidina soldanii ?* d'Orbigny	0	2	0	0	0	0
90. *Gyroidina* sp.	0	0	2	1	0	0
91. *Gyroidina ?* sp.	0	2	0	0	0	0
92. *Eponides haidingerii* d'Orbigny	0	0	36	2	0	2
93. *Eponides* cf. *haidingerii* d'Orbigny	0	0	0	2	0	0
94. *Eponides praecinctus* (Karrer)	0	0	33	5	0	0
95. *Eponides subpraecinctus* (Karrer)	0	0	2	4	0	0
96. *Eponides umbonatus* (Reuss)	0	0	32	0	0	5
97. *Eponides* sp.	0	0	23	2	9	0
98. *Eponides ?* sp.	0	0	14	0	0	0
99. *Rotalia inflata* (Seguenza)	0	0	86	22	18	5
100. *Rotalia tochigiensis* Uchio	757	206	0	0	0	0
101. *Rotalia* sp.	0	6	35	0	6	4
102. *Rotalia ?* sp.	0	0	12	0	0	0
103. *Baggina notoensis* Asano	0	0	8	22	0	14
104. *Baggina* sp.	0	0	3	0	0	0
105. *Baggina ?* sp.	0	0	0	3	0	1
Cassidulinidae :						
106. *Cassidulina laevigata carinata* Cushman	0	0	8	71	6	0
107. *Cassidulina* sp.	0	0	8	12	0	4
108. *Cassidulina ?* sp.	0	0	9	0	0	0
Anomalinidae :						
109. *Planulina nipponica* Asano	0	0	6	2	0	0
110. *Planulina* cf. *nipponica* Asano	0	0	82	16	0	0
111. *Planulina* sp.	0	0	13	0	1	0
112. *Hanzawaia tagaensis* Asano	0	11	108	24	2	1
113. *Hanzawaia* sp.	0	0	2	23	6	0
114. *Hanzawaia ?* sp.	0	0	1	5	2	8

Species \ Horizons	D	E	F	G	H	I
115. *Cibicides pseudoungerianus* (Cushman)	0	2	63	4	0	35
116. *Cibicides* sp.	0	1	22	16	1	19
117. *Cibicides?* sp.	0	4	1	0	0	2
The total amount of specimens (benthonic Foram.)	757	247	2441	1377	376	814
Globigerinidae:	0	0	2549	469	113	574

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II Composition of the Smaller Foraminiferal Fauna

Of the total 117 species of smaller Foraminifera discriminated, excluding the pelagic forms, 65 are identified with species previously described, 2 are believed to be new to science, and 50 are not well enough preserved to permit identification. These are distributed among 12 families and 33 genera. The frequency-distribution of the dominant species, genera, and families are shown in Figs. 3, 4, 5. The letters (C–I) in Figs. 3–5, and Table 1, correspond to the fossil horizons given in the columnar section shown in Fig. 2. Namely, the horizons C–E belong to the Sandstone member, and F–I to the Shale member.

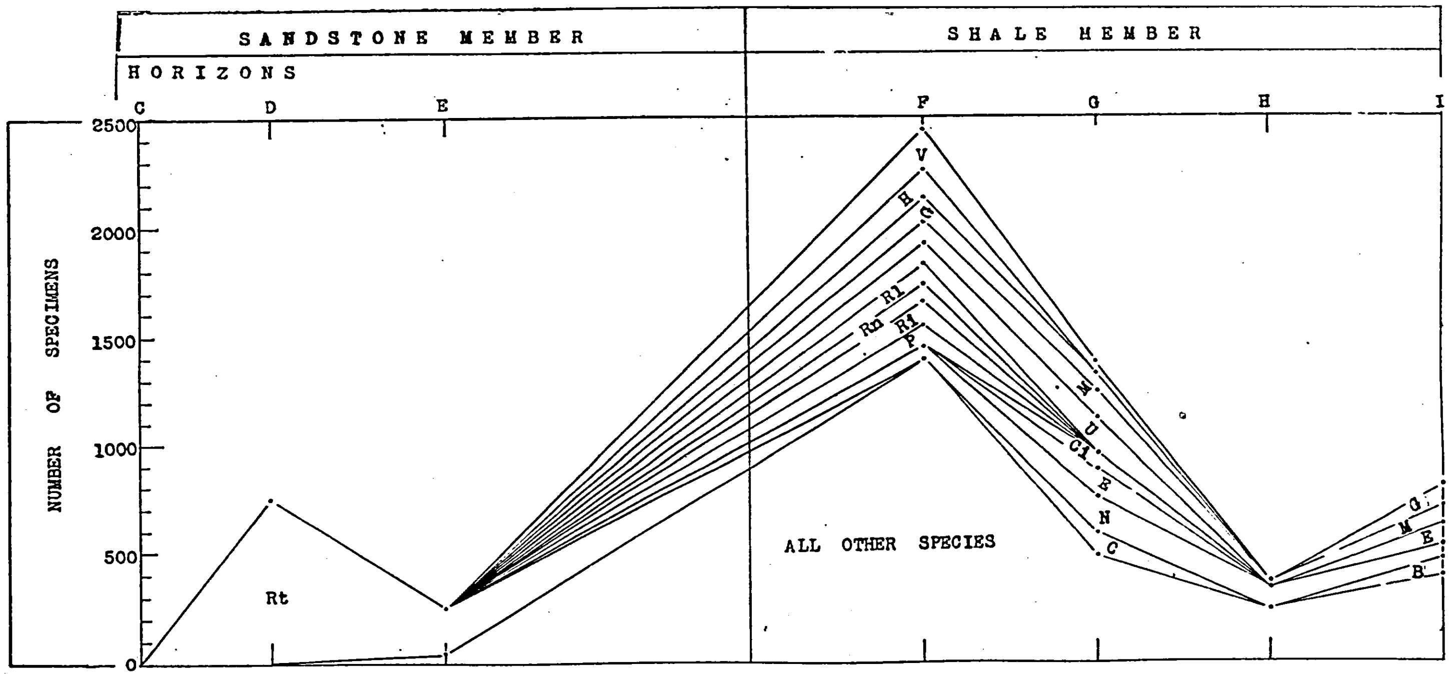

Fig. 3. Frequency Distribution of the Dominant Species from the Horizons C-I. (Tsuyama Basin)

Rt=*Rotalia tochigiensis*; V=*Vaginulina bradyi*; H=*Hanzawaia tagaensis*; G=*Gaudryina ishikiensis*; M=*Martinottiella communis*; U=*Uvigerina hootsi*; Rl=*Robulus lucidus*; Rn=*Robulus nikobarensis*; Ri=*Rotalia inflata*; P=*Planulina nipponica*; N=*Nonion japonicum*; Ci=*Cyclammina incisa*; E=*Ellipsonodosaria lepidula*; C=*Cassidulina laevigata carinata*; B=*Bulimina striata notoensis*.

(1954, Y. TAI)

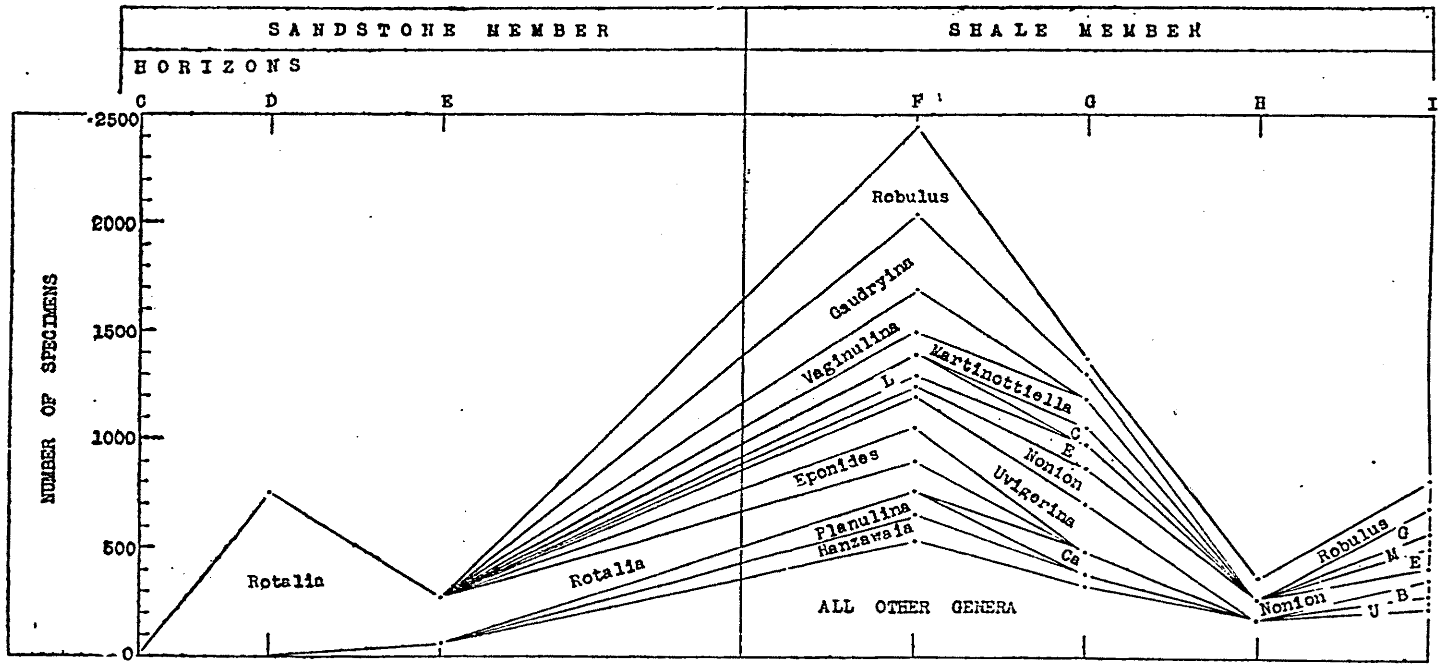

Fig. 4. Frequency Distribution of the Dominant Genera from the Horizons C-I. (Tsuyama Basin)
L=*Lagenonodosaria*; E=*Ellipsonodosaria*; C=*Cyclammina*; Ca=*Cassidulina*; G=*Gaudryina*; M=*Martinottiella*; B=*Bulimina*; U=*Uvigerina*.

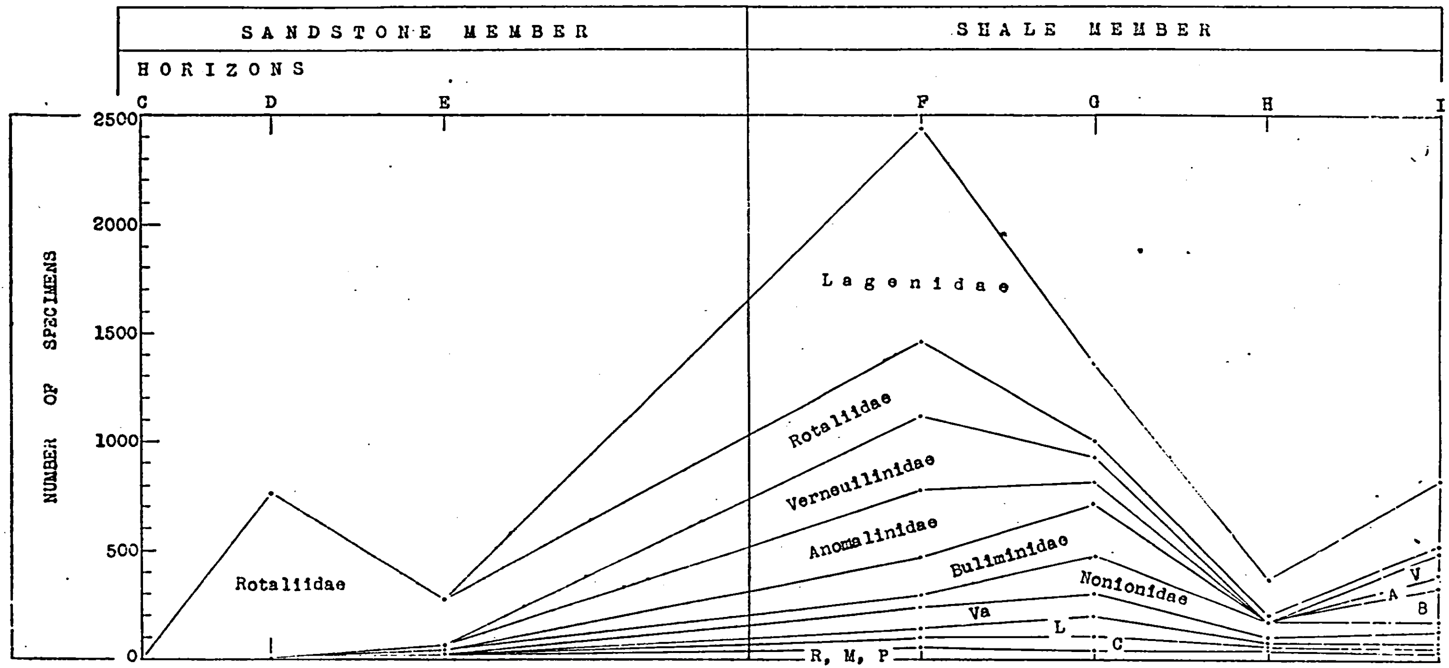

Fig. 5. Frequency Distribution of Families from the Horizons C-I. (Tsuyama Basin)
Va=Valvulinidae; L=Lituolidae; C=Cassidulinidae; R=Rhizamminidae; M=Miliolidae; P=Polymorphinidae; V=Verneuilinidae; A=Anomalinidae; B=Buliminidae.

From Table 1, it is noticed that there is a remarkable difference in the occurrence of species and individual numbers between the two members. From Figs. 3–5, which were constructed from Table 1, it is noteworthy that the peak of a pyramid-like shape occurs at horizon F, which indicates the maxima in individual number. In the following remarks are given to each of the horizons.

The horizons A–C are lacking in Foraminifera as already mentioned. This is considered to be due largely to the unsuitable environment as may be inferred from the fact that other kinds of marine megafossils do not occur in horizons A–B, although several appear in horizon C. The mollusc *Batillaria* occurs in horizon C, but this gastropod is known to flourish in water of low salinity, a condition unsuitable to the Foraminifera.

Horizon D is very characteristic in that only *Rotalia tochigiensis* occurs, no other species being found.

Horizon E reveals a somewhat decrease in the individual number of *Rotalia tochigiensis*, although proportionally it is the most abundant. This species was found only in and seems to be restricted to the coarse sandstone facies and as it dominates the horizons D and E, it is considered to characterize the Sandstone member. In this horizon there first appear several other species, but their individual number is exceedingly small.

At horizon F, as already mentioned, is found the richest occurrence of Foraminifera, and the population decreases in horizons both below and above. Particularly the specific numbers of the Lagenidae, Rotaliidae, Verneuilinidae, Anomalinidae, and Buliminidae are dominant. Among the genera, *Robulus*, *Gaudryina*, *Vaginulina*, *Eponides*, *Uvigerina*, *Rotalia*, *Hanzawaia*, *Planulina*, *Lagenonodosaria*, and *Martinottiella* have the largest number of species. Among the species, *Vaginulina bradyi*, *Hanzawaia tagaensis*, *Gaudryina* (*Pseudogaudryina*) *ishikiensis*, and *Martinottiella communis* are relatively dominant in proportion. The abrupt occurrence of abundant pelagic forms in this horizon is considered to indicate free connection with the open sea.

At horizon G, the specific and individual numbers show a decrease compared with those of horizon F. The decrease of the Lagenidae, Rotaliidae, Verneuilinidae, and Anomalinidae, which occupy a large proportion of horizon F, is a notable feature. Only the Lagenidae, however, remains still dominant. The increase of the Buliminidae, Nonionidae, Valvulinidae, Lituolidae, and Cassidulinidae is characteristic. Although there is a decrease in the specific number of the genera *Gaudryina*, *Robulus*, *Vaginulina*, *Lagenonodosaria*, *Eponides*, *Rotalia*, *Planulina*, and *Hanzawaia*, there is an increase in neritic or bathyal forms as *Cyclammina*, *Martinottiella*, *Ellipsonodosaria*, *Uvigerina*, *Cassidulina*, and *Haplophragmoides*. This increase in neritic or bathyal forms seems to reflect the environmental conditions under which deposition was taken place. The dominant species are *Nonion japonicum*, *Uvigerina hootsi*, *Martinottiella communis*, *Ellipsonodosaria laevigata carinata*, and *Cyclammina incisa*. The fact that the Globigerinidae remains as dominant as in horizon F, suggests that the connection with the open sea still existed.

At horizon H, there is a conspicuous decrease in the species and individual numbers.

The decrease of the Lituolidae, Verneuilinidae, Valvulinidae, Lagenidae, Nonionidae, Buliminidae, Rotaliidae, Cassidulinidae, and Anomalinidae is recognized, but the Lagenidae still remains dominant and is followed by the Nonionidae. Specific numbers of the genera *Robulus* and *Nonion* are dominant. Among the species, *Nonion japonicum* is outstanding.

At horizon I, the specific and individual numbers increase again. The individual numbers of the Lagenidae, Buliminidae, and Verneuilinidae occupy a considerably large proportion. The dominant genera are *Robulus*, *Gaudryina*, *Ellipsonodosaria*, *Martinottiella*, and *Bulimina*. Among the species, *Gaudryina* (*Pseudogaudryina*) *ishikiensis*, *Ellipsonodosaria lepidula*, *Martinottiella communis*, *Bulimina striata notoensis*, and *Nonion japonicum*, are remarkable at this horizon.

III Correlation and Geological Age

From the results of recent field surveys on the Tertiary sediments distributed in the Tsuyama basin, it has become evident that the stratigraphical sequence of the sediments and their lithological characters, general thickness, geological structure, and the fossils contained, are very similar to those of the Shôbara basin. Further, recent studies on the Foraminifera of the Shôbara Miocene reveal that they are correlative with the foraminiferal fauna of the Tsuyama basin.

As described in a previous paper (Y. TAI, 1953), the Shôbara Miocene marine sediments comprise two formations, the Upper and Middle. The Middle one is characterized with coarse sediments in which are contained the *Vicarya-Miogypsina-Operculina* fauna. The Upper formation conformably overlies the Middle and consists of very fine-grained sediments from

(1954, Y. TAI)

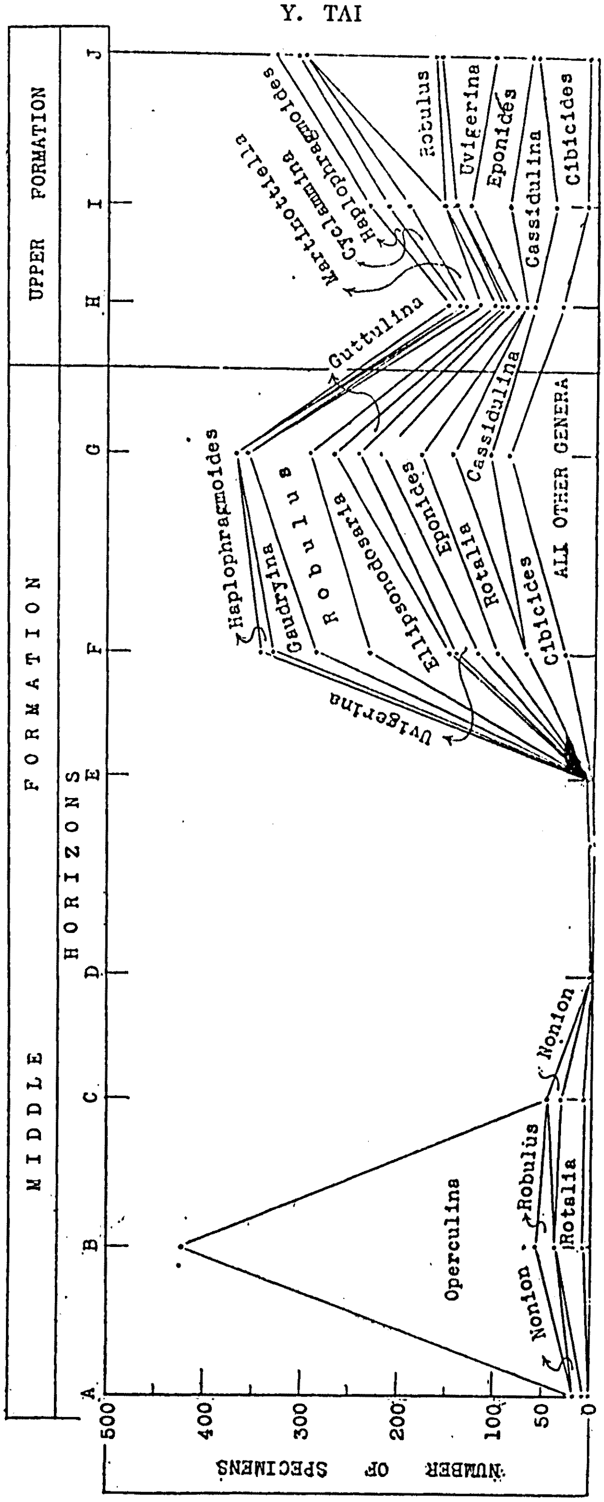

Fig. 6. Frequency Distribution of the Dominant Genera from the Horizons A-J. (Shōbara Basin)

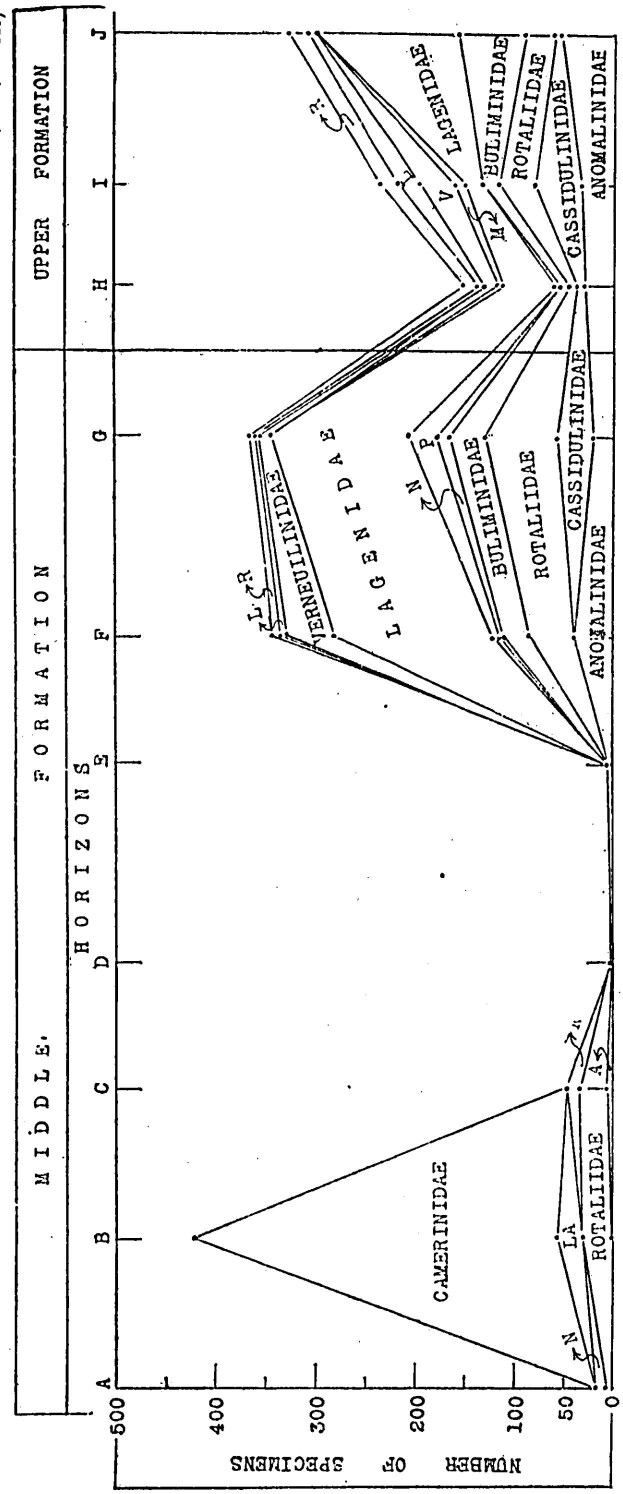

Fig. 7. Frequency Distribution of Families from the Horizons A-J. (Shōbara Basin)
N=NONIONIDAE; LA=LAGENIDAE; A=ANOMALINIDAE; L=LITUOLIDAE;
R=RHIZAMMINIDAE; P=POLYMORPHINIDAE; V=VALVULINIDAE; M=MILIOLIDAE.

which neritic or bathyal smaller Foraminifera were collected. The lower and middle parts of the Middle formation are characterized by having shallow water forms as *Operculina*, *Ostrea*. The Upper formation has yielded such neritic or bathyal forms as *Robulus*, *Bolivina*, *Uvigerina*, *Cassidulina*, *Haplophragmoides*, *Cyclammina*, and *Martinottiella*, etc. The uppermost part of the Middle formation is characterized by containing a mixed foraminiferal fauna and by having yielded the greatest numbers of neritic and littoral forms (Figs. 6–7). In this respect, it closely correlates with horizon F in the Tsuyama basin.

The characteristics presented by the Shôbara Miocene foraminiferal fauna, particularly the vertical distribution and frequency according to horizons, closely resemble to those of the Tsuyama fauna, notwithstanding the conspicuous differences of the individual numbers in each respective horizon.

Although the resemblance between the Shôbara and Tsuyama faunas is noteworthy as already mentioned, it must also be stated that from a microbiostratigraphical view, remarkable differences exist as to be stated. As shown in Figs. 3-5, the position of the mixed faunal association which is represented by the largest numbers of individuals, species, genera, and families, falls within horizon F, which consists only of shale; this is the Shale member. However, in the Shôbara basin, the corresponding association occurs in the Middle formation (Figs. 6–7) which consists of coarse sediments, contrary to the case of the Tsuyama basin. Therefore, from a lithological point of view one would expect the maxima of each faunal association to occur in a similar facies. However, the results are quite contrary to such an expectation.

Of the 67 specifically discriminated Foraminifera, 33 are known to occur in the Shôbara fauna, thus the percentage of common species is about 50. Should the 50 specifically indetermined ones be identified upon subsequent material, the percentage of common species between the Shôbara and Tsuyama faunas would probably be increased, thereby bringing the two isolated faunas into more intimate relationship.

From the percentage of common species, stratigraphic position of the maxima of the mixed associations, and general tendencies shown in the preceding and proceeding foraminiferal faunules, it is inferred that the Sandstone member in the Tsuyama basin is correlative to the Middle formation in the Shôbara basin, and the Shale member of the former locality to the Upper formation of the latter. Since the Sandstone member and the Shale member in the Tsuyama basin comprise one continuous series of a foraminiferal fauna, whose changes as observed are governed by local differentiation in environmental conditions and there is expressed a gradual deepening of the sea in its components. The geological age of both members combined is considered to be Middle Miocene from the evidence shown both by the smaller Foraminifera and the megafossils, which are mostly molluscs. Further support for the Middle Miocene age of the Tsuyama fauna is found in the lines to follow.

According to the stratigraphical works by K. MASUDA (1954) and the micropaleontological studies of K. ASANO (1953), the middle part of the Higashi-innai formation developed in the western part of Noto Peninsula, Ishikawa Prefecture, which contains the *Miogypsina-Operculina* fauna, is conformably overlain with both the upper part of the same formation and the Najimi formation which yield abundant smaller Foraminifera, although both formations are separated with tuff and plagioliparite in the western part of its field. K. ASANO (1953), as a result of his studies on the smaller Foraminifera, arrived to the conclusion that the fauna is similar to that of Kar Nicobar or Fiji Islands. The so-called late Tertiary deposits of Kar Nicobar and Fiji Islands were correlated with the Rembangian (Burdigalian) and Preangerian (Vindobonian) by M. F. GLAESSNER (1943), thus it is evident that two distinct stages are represented on the faunas of Kar Nicobar and Fiji Islands. ASANO further stated that the middle part of the Higashi-innai formation can be correlated with the lower part of the Nishikurosawa formation in Akita Prefecture, which contains the *Miogypsina-Operculina* fauna, afore-mentioned. Both the upper part of the Higashi-innai and the Najimi formation are correlated by him with the upper part of the Nishikurosawa formation, the Onnagawa and the Funakawa formation, which appear in succession along the southern coast of Oga Peninsula in Akita Prefecture.

Of the 67 species discriminated among the Tsuyama fauna, 53 occur in the foraminiferal fauna reported by K. ASANO from the upper part of the Higashi-innai and Najimi formations. The percentage of common species between the Tsuyama and Noto faunas is about 80. This large percentage is considered to indicate a surprising similarity in the conditions of deposition and environments of the foraminiferal faunas of the two geographically separated Miocene areas.

From the foregoing remarks, it seems possible that the Sandstone member of the Tsuyama basin may correspond to a part of the middle part of the Higashi-innai formation, and the Shale member of the former basin to both the upper part of the Higashi-innai and the Najimi formation of the Noto Peninsula. Permitting such a correlation, it then becomes evident that similar environmental conditions persisted in separated areas during the same age of Middle Miocene in western Japan.

Of the determined species, the following have been reported from the Miocene of Kar Nicobar Island (C. SCHWAGER, 1866) ;

Bulimina inflata Seguenza
Ellipsonodosaria lepidula (Schwager)
Nonion nicobarense Cushman
Robulus nikobarensis (Schwager)
Uvigerina crassicostata Schwager
Uvigerina nitidula Schwager

The species in common with the Miocene of Java and Sumatra (L. W. LEROY, 1944) are;

Bulimina inflata Seguenza
Bulimina striata d'Orbigny
Bolivina marginata Cushman
Eponides praecinctus (Karrer)
Eponides umbonatus (Reuss)
Lagenonodosaria scalaris (Batsch)
Nodosaria longiscata d'Orbigny
Nodosaria aff. *vertebralis* (Batsch)
Robulus calcar (Linnaeus)
Uvigerina crassicostata Schwager
Vaginulina bradyi Cushman

Of the present determined species, the following 5 occur from the Suva formation (Miocene) of Fiji Island (J. A. CUSHMAN, 1934) ;

Robulus calcar (Linnaeus)
Robulus nikobarensis (Schwager)
Bulimina inflata Seguenza
Uvigerina crassicostata Schwager
Uvigerina nitidula Schwager

Of the determined species from both the Shôbara and Tsuyama Miocene formations, the following are in common with those known only from the Miocene of Japan (K. ASANO, 1953) ;

Baggina notoensis Asano
Bolivina marginata masudai Asano
Bulimina striata notoensis Asano
Cyclammina japonica Asano
Elphidiella momiyamaensis Uchio

Gaudryina ishikiensis Asano
Marginulina masudai Asano
Nodosaria notoensis Asano
Planulina nipponica Asano
Plectofrondicularia japonica Asano
Robulus notoensis Asano
Rotalia tochigiensis Uchio

The following species occur from the Miocene of California of America. (R. M. KLEINPELL, 1938) ;

Bolivina marginata Cushman
Bulimina inflata Seguenza
Cassidulina laevigata carinata Cushman
Cyclammina incisa (Stache)
Gyroidina soldanii d'Orbigny
Nonionella miocenica Cushman
Uvigerina hootsi Rankin
Uvigerina subperegrina Cushman and Kleinpell

Of the determined 67 species, the following 15 occur in the living fauna of the Philippine and adjacent seas (J. A. CUSHMAN, 1921) ;

Bulimina inflata Seguenza
Dentalina emaciata Reuss
Ellipsonodosaria lepidula (Schwager)
Eponides haidingerii d'Orbigny
Eponides praecinctus (Karrer)
Eponides umbonatus (Reuss)
Gyroidina soldanii d'Orbigny
Lagenonodosaria scalaris (Batsch)
Lagena laevis (Montagu)
Martinottiella communis (d'Orbigny)
Marginulina glabra d'Orbigny
Nodosaria aff. *vertebralis* (Batsch)
Nodosaria pyrula d'Orbigny
Robulus calcar (Linnaeus)
Vaginulina bradyi Cushman

The percentage of Recent species found in the Middle Miocene of the Tsuyama basin is about 22.

IV Systematic Descriptions

Family Miliolidae

Genus *Sigmoilina* Schlumberger, 1887

Sigmoilina imamurai Tai, n. sp.

Plate 1, Figs. 13 a, b.

Test about 2 times longer than broad, strongly biconvex in end view; periphery rounded, base somewhat rounded, later 3–4 chambers distinct; sutures fairly distinct; wall finely arenaceous, surface rather smooth; aperture small, terminal, no distinct neck. Length up to 0.6 mm., breadth 0.3 mm.

Holotype: Northern cliff, Yoshino Primary School, Yoshino-mura, Katsuta-gun, Okayama Prefecture. Lat. 35° 03′ 48″ N., long. 134° 09′ 46.4″ E. Katsuta formation, Miocene. IGSH* coll. cat. no. T. Y. 1.

Occurrence: Common, found from the upper shale facies of this formation. This species occurs also in the Upper formation (shale facies) of the Shôbara basin, Hiroshima Prefecture.

Remarks: This species is similar to *Sigmoilina schlumbergeri* Silvestri, but differs from it in having a smooth surface, and without a distinct neck.

Family Lagenidae

Subfamily Nodosariinae

Genus *Lenticulina* Lamarck, 1804

Lenticulina asanoi Tai, n. sp.

Plate 1, Figs. 1 a, b.

Test comparatively large, somewhat ovoid in outline, lenticular in side view, about 1.5 times longer than broad, involute; 8–9 chambers in last whorl, periphery somewhat angled, but not keeled; sutures distinct, slightly curved; wall smooth, thick; apertures radiate in most chambers. Length up to 2.2 mm., breadth 1.4 mm.

Holotype: Northern cliff, Yoshino Primary School, Yoshino-mura, Katsuta-gun, Okayama Prefecture. Lat. 35° 03′ 48″ N., long. 134° 09′ 46.4″ E. Katsuta formation, Miocene. IGSH coll. cat. no. T. Y. 2.

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* IGSH-Abbreviation for Institute of Geology, Faculty of Science, Hiroshima University.

Occurrence: Very rare, found from the upper shale facies of this formation. K. ASANO (1953) reported this species as *Lenticulina* sp. from the Middle Miocene Higashi-innai formation in the Noto Peninsula, Ishikawa Prefecture. (Lat. 37° 20′ 55″ N., long. 137° 06′ 31″ E.).

Remarks: This species is similar to *Lenticulina rotulata* Lamarck, but differs from it in lacking an umbo, and in that the test is not closely coiled and not circular in outline.

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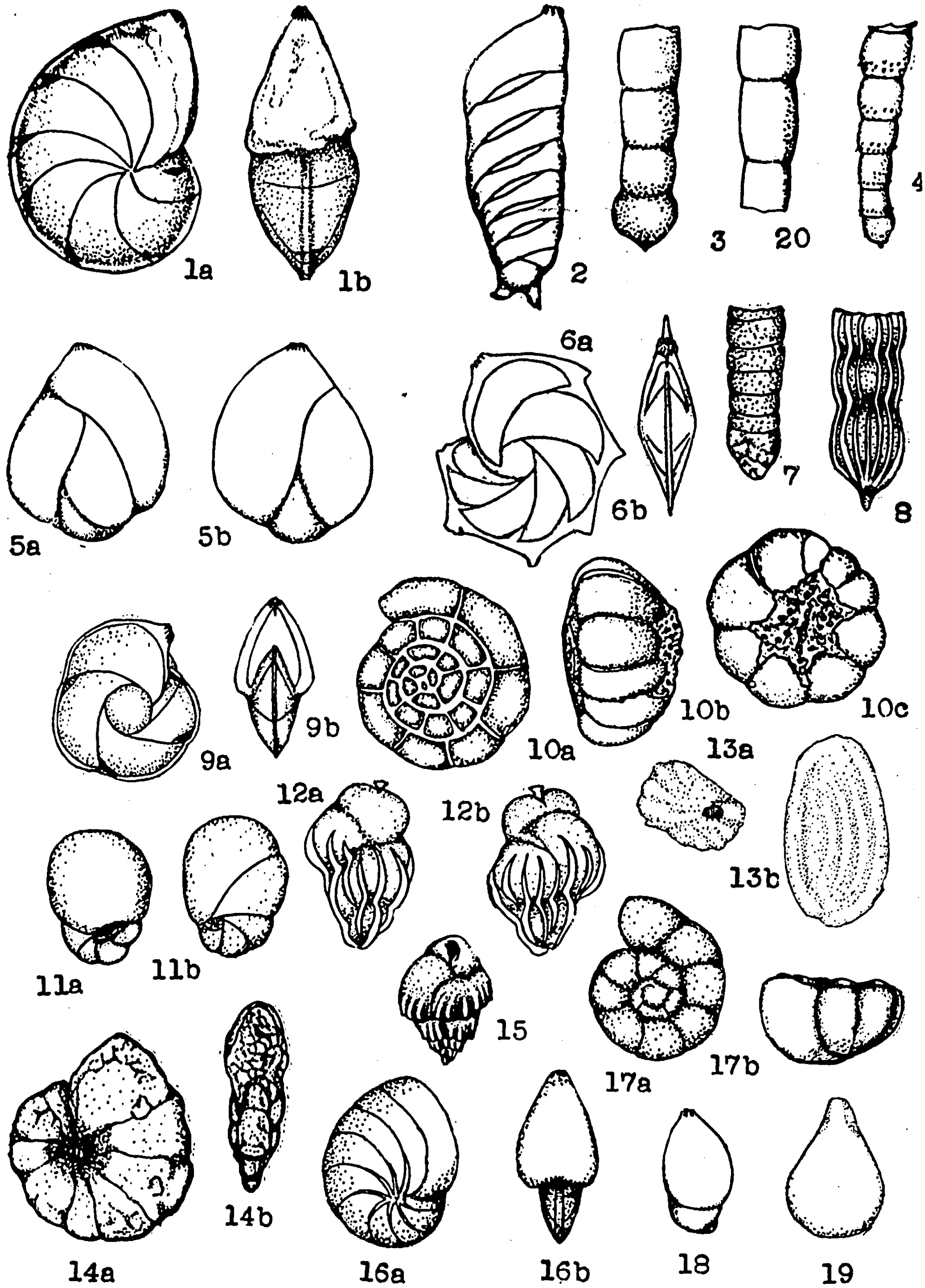
EXPLANATION OF PLATE I

Figs. 1 a, b — *Lenticulina asanoi* Tai, n. sp. × 17
Fig. 2 — *Vaginulina bradyi* Cushman × 22
Fig. 3 — *Dentalina emaciata* Reuss × 20
Fig. 4 — *Ellipsonodosaria lepidula* (Schwager) × 20
Figs. 5 a, b — *Guttulina irregularis* (d'Orbigny) × 30
Figs. 6 a, b — *Robulus calcar* (Linnaeus) ×30
Fig. 7 — *Martinottiella communis* (d'Orbigny) × 25
Fig. 8 — *Nodosaria notoensis* Asano × 10
Figs. 9 a, b — *Robulus lucidus* (Cushman) × 50
Figs. 10 a, b, c — *Rotalia inflata* (Seguenza) × 50
Figs. 11 a, b — *Baggina notoensis* Asano × 30
Figs. 12 a, b — *Uvigerina crassicostata* Schwager × 25
Figs. 13 a, b — *Sigmoilina imamurai* Tai, n. sp. × 50
Figs. 14 a, b — *Cyclammina incisa* (Stache) × 20
Fig. 15 — *Bulimina striata notoensis* Asano × 40
Figs. 16 a, b — *Nonion japonicum* Asano × 25
Figs. 17 a, b — *Gyroidina soldanii* d'Orbigny × 55
Fig. 18 — *Marginulina* cf. *glabra* d'Orbigny × 25
Fig. 19 — *Lagena laevis* (Montagu) × 50
Fig. 20 — *Dentalina emaciata* Reuss × 20



Y. TAI, Tsuyama Foraminifera