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# ON THE JURASSIC PELECYPOD FAUNAS IN JAPAN

By

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By

**Itaru HAYAMI**

(With Plate XIV)

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# I. General Remarks

## 1) Introduction

Jurassic pelecypod in Japan seem important for the stratigraphy, palaeoecology and palaeobiogeography, because of their abundant occurrence in various facies of many localized sedimentary areas. Jurassic stratigraphy of this country was commenced already near the end of the last century and since then has been promoted by many authors, but few attempts had been done on the pelecypod palaeontology by the midst of this century except several works by YOKOYAMA (1904), YEHARA (1921, 1927), KOBAYASHI (1926), KOBAYASHI and SUZUKI (1937) and YABE and SATO (1942) on some trigoniids, inoceramids, cyrenoids and a few other pelecypod groups. After the war, however, KOBAYASHI, MORI and TAMURA surveyed carefully the rich Jurassic trigoniids not only in Japan but also in various areas of the Pacific region, discussing the classification and evolution. The study was lately accomplished with the publication of their work entitled "The bearing of the trigoniids on the Jurassic stratigraphy of Japan" in 1959. On the other hand the description of the rich pelecypod faunas of the Upper Jurassic Torinosu facies in the Soma area of northeast Japan and the Outer Zone of Southwest Japan was commenced by KIMURA (1951, 1956) and recently accomplished by TAMURA (1959a-e, 1960a-d).

Since 1954, I have engaged myself in the study on the Jurassic pelecypod faunas distributed in various areas of the Northeast Japan and the Inner Zone of Southwest Japan. Because of the unfavourable circumstances for publication, the taxonomic discussion and specific description were not compiled in one monograph but separated into 20 papers as listed below:

1957a. Liassic *Bakevellia* in Japan. *Japan. Jour. Geol. Geogr., Vol. 28*, pp. 47-59, 2 pls.

1957b. Liassic *Gervillia* and *Isognomon* in Japan. *Ibid., Vol. 28*, pp. 95-106, 2 pls.

1957c. On the Occurrence of *Cardinioides* from the Liassic Kuruma Group in Central Japan. *Trans. Proc. Pal. Soc. Japan, N. S., No. 26*, pp. 69-73, 1 pl.

1957d. *Radulonectites*, a new pectinid genus, from the Liassic Kuruma group in Central Japan. *Ibid., N. S., No. 27*, pp. 89-93, 1 pl.

1957e. Liassic *Chlamys*, "*Camptonectes*" and other pectinids from the Kuruma group in Central Japan. *Ibid., N. S., No. 28*, pp. 119-127, 1 pl.

1958a. Liassic *Volsella*, *Mytilus* and some other dysodont species in Japan. *Ibid., N. S., No. 29*, pp. 155-165, 2 pls.

1958b. A review of the so-called Liassic "cyrenoids" in Japan. *Japan. Jour. Geol. Geogr., Vol. 29*, pp. 11-27, 2 pls.

1958c. Some Hettangian Pelecypods from the "*Trigonia*-sandstone" of the Shizukawa group in Northeast Japan. *Ibid., Vol. 29*, pp. 99-110, 1 pl.

1958d. Supplementary descriptions of the Liassic pelecypod from the Kuruma and Shizukawa groups in Japan. *Trans. Proc. Pal. Soc. N. S., No. 30*, pp. 193-200, 1 pl.

1958e. Taxonomic notes on *Cardinia* with description of a new species from the Lias of western Japan. *Jour. Fac. Sci. Univ. Tokyo, Sec. 2, Vol. 11, Pt. 2*, pp. 115-130, 1 pl.

1959a. Pelecypods of the Mizunuma Jurassic in Miyagi Prefecture, with some stratigraphical remarks. *Trans. Proc. Pal. Soc. Japan, N. S., No. 34*, pp. 66-78, 1 pl.

1959c. Bajocian pelecypods of the Aratozaki formation in Northeast Japan. *Japan. Jour. Geol. Geogr., Vol. 30,* pp. 53 70, 1 pl.

1959d. Some pelecypods from the Tsukinoura formation in Miyagi Prefecture. *Trans. Proc. Pal. Soc. Japan, N.S., No. 35,* pp. 133-137.

1959e. Some pelecypods from the upper Aratozaki formation including a new genus *Kobayashites. Ibid., N.S., No. 35,* pp. 138-141, 1 pl.

1959f. Late Jurassic Lipodont, Taxodont and Dysodont pelecypods from Makito, Central Japan. *Japan. Jour. Geol. Geogr., Vol. 30,* pp. 135-150, 1 pl.

1959g. Late Jurassic Isodont and Myacid pelecypods from Makito, Central Japan. *Ibid., Vol. 30,* pp. 151-167, 1 pl.

1959i. Lower Liassic Lamellibranch fauna of the Higashinagano formation in west Japan. *Jour. Fac. Sci. Univ. Tokyo, Sec. 2, Vol. 12, Pt. 1,* pp. 31-84, 4 pls.

1960b. Pelecypods of the Jusanhama group (Purbeckian or Wealden) in Hashiura area, Northeast Japan. *Japan. Jour. Geol. Geogr., Vol. 31,* pp. 13-22, 1 pl.

1960c. Jurassic Inoceramids in Japan. *Jour. Fac. Sci. Univ. Tokyo, Sec. 2, Vol. 12, Pt. 2,* pp. 277-328, 4 pls.

1960. (with M. SUGITA and Y. NAGUMO). Pelecypods of the Upper Jurassic and Lowermost Cretaceous Shishiori group in Northeast Japan. *Japan. Jour. Geol. Geogr., Vol. 31,* pp. 85-98, 1 pl.

The taxonomic descriptions in above mentioned publications have dealt with the greater part of the important representatives of the Jurassic pelecypod faunas hithero known in Japan, although several local faunules remain undescribed because of the insufficient material. More than 90 genera and more than 350 species of pelecypods can be distinguished in the Japanese Jurassic. Therefore, I dare to say that we have completed the first stage of the work.

However, little has been done as to their application to geology. Since pelecypods are the most ubiquitous fossil group in the Japanese Jurassic, it seems an essential problem for the Jurassic stratigraphy to recognize their stratigraphical and geographical distribution on the basis of the facts in local sedimentary areas. Many species of these pelecypods apparently occur in certain limited stages and geographical provinces, and they are, of course, important for intraprovincial correlation and palaeogeographical consideration. Their occurrences are, however, much dependent on facies as many other fossil groups, and attention must be paid also to their palaeoecology, especially mode of occurrence, assemblage and relationship between the bio- and litho-facies.

Here I will summerize the stratigraphical and geographical distribution of these pelecypods, and further discuss the zonation, palaeoecology and palaeobiogeography in some detail on the basis of the field observations and laboratory works. My special attention has been paid to the pelecypod faunas in the Pacific region, since Japan belongs to the circum Pacific orogenic belt and many evidences about pelecypod evolution, which may or may not agree with those in Europe, can be expected. A comprehensive catalogue of Japanese Jurassic pelecypods is added to this paper.

## 2) Acknowledgements

I express my most sincere thanks to Prof. Teiichi KOBAYASHI of the

University of Tokyo, who kindly guided and encouraged me in completing the study. He gave me valuable advices and assistances from his comprehensive knowledge of geology and palaeontology since the year 1954 when I took this subject for study upon his suggestion. I am deeply indebted to Dr. Leslie R. COX of the British Museum, Prof. Tatsuro MATSUMOTO of the Kyushu University and Assist. Prof. Kôichirô ICHIKAWA of the Osaka City University for their kind advices and instructive informations about pelecypod palaeontology. I appreciate also the kindness of Prof. Fuyuji TAKAI, Assist. Prof. Toshio KIMURA, Assist. Prof. Tetsuro HANAI, Assist. Prof. Tadashi SATO and Dr. Akira TOKUYAMA of the University of Tokyo and Dr. Minoru TAMURA of the Kumamoto University who gave me various assistances and frequent opportunities for discussions in the laboratory.

### 3) Distribution and faunal ages

I divide tentatively the Jurassic pelecypod faunas of Japan into three suits, namely, Lower (Hettangian-Aalenian), Middle (Bajocian-Bathonian) and Upper (Callovian-Tithonian) ones. It is not only for convenience's sake but also due to their correspondence with major sedimentary cycles. These pelecypods may or may not associate with ammonites. Therefore, the faunas often cannot be dated on firm bases. The symbols*, J1a-g, J2a-c, J3a-e and J4 in Table 1, which are applied in this paper, show roughly estimated horizons on the basis of the stratigraphic sequences and associated index fossils in a few type areas.

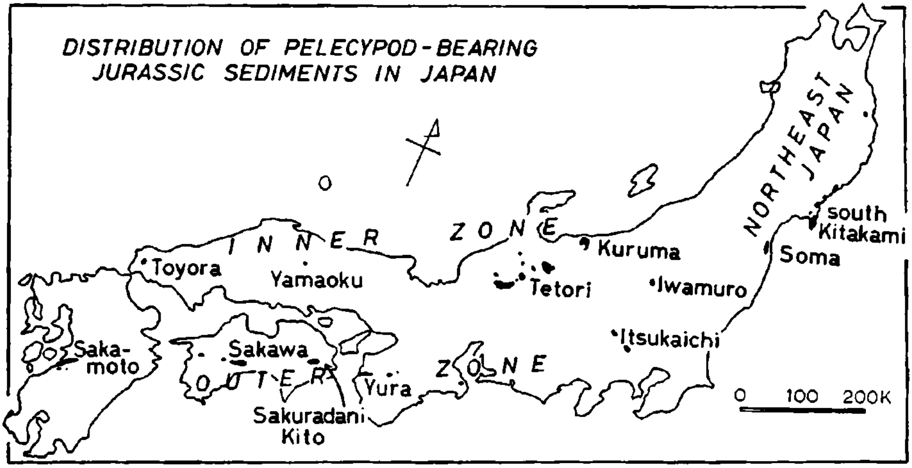

Fig. 1.

Lower Jurassic faunas are represented in the Shizukawa group in northeast Japan (Kitakami mountainland), the Kuruma group in central Japan (Hida plateau) and the Toyora group (exclusive of the main part of the Utano formation) in west Japan (Nagato region). Some pelecypods from the Yama-

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* The nomination is applied only for the indication of faunal ages instead of letter nomination for local chronological division.

oku formation of west Japan and the Iwamuro formation of the Kwanto mountainland are considered also Lower Jurassic owing to their similar aspect to the Kuruma fauna. The main localities of Lower Jurassic pelecypods which are dealt with in this study are listed below:

a. Niranohama formation of the Shizukawa, Hashiura and Mizunuma areas in Miyagi Prefecture.
   1. Coast of Niranohama, Utatsu town (Jla-b); 2. Hoinyashiki of Hosoura, Shizukawa town (Jlb); 3. East of Hosoura, Shizukawa town (Jla); 4. Ippaishimizu of Hosoura, Shizukawa town (Jla); 5. North of Ippaishimizu of Hosoura, Shizukawa town (Jla-b); 6. West of Yoriki, Utatsu town (Jla); 7. Small island off the coast of Gongen, Shizukawa town (Jlb); 8. Magenosu, Kahoku town (Jla) (Loc. 3, in MORI, 1949); 9. Oiwazawa, Kitakami village (Jla-b) (Loc. 4, in MORI, 1949); 10. Yokokurazawa, Kitakami village (Jla-b) (Loc. 5, in MORI, 1949); 11. A tributary of Aikawazawa, Kitakami village (Jlb) (Loc. 6, in MORI, 1949); 12. Mozasawa, Kitakami village (Jla) (Loc. 7, in MORI, 1949); 13. Tate of Onagawa, Kitakami village (Jla) (Loc. 8, in MORI, 1949); 14. A tributary of Aikawazawa, Kitakami village (Jlb or Jlc); 15. Middle stream of Futamataji, Mizunuma, Inai village* (Jla) (cf. HAYAMI, 1959h); 16. Southern slope of Mt. Kusakariyama, Inai village* (Jla); 17. Northern slope of Mt. Kusakariyama (Jla).

b. Hosoura formation of the Shizukawa area in Miyagi Prefecture.
   18. Small island off the coast of Gongen, Shizukawa town (Jlc); 19. Bentenzaki of Hosoura, Shizukawa town* (Jlf); 20. Jaou of Hosoura, Shizukawa town (Jlg); 21. Akaiwazaki of Hosoura, Shizukawa town (Jlg).

c. Mizunuma formation of the Mizunuma area in Miyagi Prefecture.
   22. Middle stream of Kanagezawa, Mizunuma, Inai village* (?Jlc).

d. Iwamuro formation of the Katashina area in Gumma Prefecture.
   23. East of the Iwamuro power plant along Katashina river, Akagine village (?Jle or Jlf) (cf. KIMURA, 1952).

e. Tsuchizawa formation of the Kuruma area in Nagano Prefecture.
   24. Kamikawara of Kuruma, Kitaotari village (Jl); 25. Upper stream of Tsuchizawa, Kuruma, Kitaotari village (Jl); 26. Middle stream of Tsuchizawa, Kuruma, Kitaotari village (Jl); 27. River cliff, south of Kuruma, Kitaotari village* (Jl).

f. Kitamatadani formation of the Kurobe National Forest and Kotaki area of Niigata and Toyama Prefectures.
   28. Upper stream of Kitamatadani, Kurobe National Forest* (?Jlc); 29. Fukisawadani, Kurobe National Forest (?Jlc); 30. Shibakurazawa of Kotaki, Itoigawa city, Niigata Prefecture (?Jlc); 31. Lower stream of Nishimatazawa of Kotaki, Itoigawa city (?Jlc); 32. Matsuozawa of Kotaki, Itoigawa city (?Jlc); 33. Sakuraozawa of Kotaki, Itoigawa city (?Jlc); 34. Ohishi of Kotaki, Itoigawa city (?Jlc); 35. Yogurazawa of Odokoro, Itoigawa city (?Jlc); 36. Middle stream of Odokoro river, Odokoro, Itoigawa city (?Jlc).

g. Negoya formation of the Kurobe National Forest and Hashidate area in Niigata and Toyama Prefectures.
   37. Negoya of Daira, Kurobe National Forest* (Jld); 38. Kitadani of Daira, Kurobe National Forest (Jld); 39. Mouth of Teradani, Daira, Kurobe National forest (Jld); 40. Kawagurodani of Daira, Kurobe National Forest (Jld); 41. Neiridani of Daira, Kurobe National Forest* (Jld); 42. Upper stream of Aisawadani, Hashidate, Omi town, Niigata Prefecture* (Jld); 43. A tributary of Aisawadani, Hashidate, Omi town (Jld).

h. Teradani formation of the Kurobe National Forest and Hashidate area in Niigata and Toyama Prefectures.

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* Many isolated outcrops.

44. Lower stream of Teradani, Daira, Kurobe National Forest (J1e); 45. Middle stream of Kanayamadani, Hashidate, Omi town, Niigata Prefecture (J1e).

i. Shinatani formation of the Kurobe National Forest and the Hashidate and Agero areas in Niigata Prefecture.

46. Upper stream of Kanayamadani, Hashidate, Omi town (J1e or J1f); 47. A tributary of Kanayamadani, Hashidate, Omi town (J1e or J1f); 48. Upper stream of Teradani, Daira, Kurobe National Forest (J1e or J1f); 49. Upper stream of Shinatani, Agero, Omi town (J1e or J1f).

j. Otakidani formation of the Agero area in Niigata Prefecture.

50. Middle stream of Otakidani, Agero, Omi twon (J1f). (see the geological map and fossil list in KOBAYASHI et al. (1957) about Locs. 24-50).

k. Yamaoku formation of the Osakabe area, Okayama Prefecture.

51. Primary school at Ochiai, Osakabe town (Y1 and Y2 members*) (?J1 or J1f) (cf. KONISHI, 1954).

l. Higashinagano formation of the Toyora area in Yamaguchi Prefecture.

52. West of Takayama, northeast of Higashinagano, Toyoda town* (J1b) (Locs. 1, 2, in HAYAMI, 1959i); 53-56. Four localities at Higashinagano, Toyoda town (J1b) (Locs. 3-6, in HAYAMI, 1959i); 57-59. Three localities at Higashinakayama, Kikukawa town (J1b, J1c) (Locs. 7-9, in HAYAMI, 1959i).

m. Nishinakayama formation of the Toyora area in Yamaguchi Prefecture.

60. Sakuraguchi, southwest of Ishimachi, Toyoda town (J1c) (Loc. 98, in MATSUMOTO and ONO, 1947); 61. Ishimachi, Toyoda town* (J1f) (Loc. 27, in MATSUMOTO and ONO, 1947).

n. Utano formation of the Toyora area in Yamaguchi Prefecture.

62. Todani, southwest of Nishinakayama, Kikukawa town* (J1g) (? Locs. 226, 230, in MATSUMOTO, and ONO, 1947).

Table 1.

*HORIZONS OF MAIN JURASSIC PELECYPOD FAUNAS IN JAPAN*

| stage | symbol | Kitakami west | Kitakami east | Soma | Tetori Kuruma | Torinosu Toyora |
|---|---|---|---|---|---|---|
| Berriasian | J4 | ? Jusanhama | Isokusa<br>Nagasaki | | ? Izuki | |
| Tithonian | J3e | | up. Kogoshio | Koyamada | | up. Sakamoto<br>Kambaradani |
| | J3d | | low. Kogoshio<br>Tashiro | | | |
| Kimmeridgian | J3c | | Mone | Nakanosawa | ? Yambara | Kurisaka |
| Oxfordian | J3b | | | | Kiritani, Mitarai<br>Yambarazaka | |
| Callovian | J3a | up. Arato | | ? Yamagami | Kaizara | Yatsuji |
| Bathonian | J2c | | | Awazu | | up. Utano<br>?Naradani |
| Bajocian | J2b | low. Arato | Tsunakizaka | ? Hatsuno | | |
| | J2a | Aratozaki | Tsukinoura<br>Kosubu | | | |
| Aalenian | J1g | up. Hosoura | ?Kodaijima | | | low. Utano |
| Toarcian | J1f | | | | Otakidani<br>? Shinatani<br>Teradani | Nishinakayama |
| Pliensbachian | J1e | | | | | |
| | J1d | | | | Negoya | |
| Sinemurian | J1c | low. Hosoura | | | ? Kitamatadani | Higashinagano |
| Hettangian | J1b | up. Niranohama | | | | |
| | J1a | low. Niranohama | | | | |

Middle Jurassic pelecypods seem comparatively poor in this country except for several small faunas distributed in the following areas of northeast

Japan.

o. Aratozaki formation of the Shizukawa, Hashiura and Mizunuma areas in Miyagi Prefecture.
63. Akaiwazaki of Hosoura, Shizukawa town (J2a); 64. Coast of Gongen, Shizukawa town* (J2a); 65. Hinokuchi, Utatsu town (J2a); 66. West of Akaiwazaki, Shizuhama, Shizukawa town (J2a); 67. Okami, Kitakami village (J2a) (Loc. 10, in MORI, 1949); 68. Nakahara of Onagawa, Kitakami village (J2a) (Loc. 11, in MORI, 1949); 69. North of Mizunuma, Inai village* (J2a).

p. Kodaijima formation of the Ojika area in Miyagi Prefecture.
70. Southern coast of Kodaijima, Ishinomaki city* (J1g or J2a); 71. Northern coast of Kodaijima, Ishinomaki city (J1g or J2a).

q. Tsukinoura formation of the Ojika area in Miyagi Prefecture.
72. Kodaijima strait near Tsukinoura, Ishinomaki city (J2a); 73. East of Tsukinoura along the Kinkazan highway, Ishinomaki city (J2a).

r. Kosaba formation of the Karakuwa area in Miyagi Prefecture.
74. Shibitachi, Karakuwa town (J2a); 75. West of Tadakoshi along the Higashihama highway, Karakuwa town (J2a); 76. Matsubatake, Karakuwa town* (J2a).

s. Tsunakizaka formation of the Karakuwa area in Miyagi Prefecture.
77. Southwest of Tsunakizaka-pass in Kesennuma city* (J2b); 78. A valley, south of Tsunakizaka in Kesennuma city (J2b).

t. Arato formation of the Shizukawa and Hashiura areas in Miyagi Prefecture.
79. West of Shizuhama along the Higashihama highway, Shizukawa town (J2b); 80. Kuromorisawa, Kitakami village* (? J2b, J2c or J3a) (Locs. 15, 16, in MORI, 1949).

Besides, some inoceramid fauna from the upper part of the Utano formation at Utano of Kikukawa village (Loc. 81) in Yamaguchi Prefecture may be upper Middle Jurassic or lower Upper Jurassic.

Upper Jurassic pelecypods are widely distributed in the Kitakami and Soma regions of northeast Japan, Tetori region of central Japan and Torinosu group in the Sakuradani-Kito, Monobegawa, Sakawa, Sakamoto and some other areas of the Outer Zone of Southwest Japan. In the Kitakami mountainland Upper Jurassic pelecypods occur at the following localities:

u. Mone formation of the Karakuwa area in Miyagi Prefecture.
81. Udoura, east coast of Oshima island, Kesennuma city* (J3c).

v. Kogoshio formation of the Karakuwa area in Miyagi Prefecture.
82. East of Shishiori along Higashihama highway, Kesennuma city (? J3e); 83. West of Ycbaiji-pass, Kesennuma city (? J3e); 84. Wakagihama (Niranowaki), east coast of Oshima island, Kesennuma city (J3e); 85. Isokusa, west coast of Oshima island, Kesennuma city (J4); 86. Nagasaki, east coast of Oshima island, Kesennuma city (J4).

w. Kozumi formation (Tashiro sandstone) of the Ojika area in Miyagi Prefecture.
87. West coast of Tashiro island, Ishinomaki city (? J3d); 88. West of Ayukawa, Ojika town (? J3d).

As to the numerous localities of Middle Jurassic pelecypods in the Soma group and Upper Jurassic ones in the Soma, Tetori and Torinosu groups, MASATANI (1950), MAEDA (1952a, b, 1957, etc.), KIMURA (1956) and TAMURA's (1959a-e, 1960a-f) reports including the locality maps and lists were already published. Since I could not add any other localities to their results, list of localities in these groups is omitted in this paper.

## List of Jurassic Pelecypods in Japan

In this list, the original specific name, author name of original description, altered specific name, author name of subsequent desc iption, formation name (as to the complicated Torinosu group of the Sakawa basin only the zone name is listed) and horizon are treated. Generic names are arranged systematically, and the specific names alphabetically. Several undescribed pelecypods, whose generic reference is more or less clear, are also listed with asterisks.

Family Solemyacidae GRAY
  Genus *Solemya* LAMARCK, 1818
    *Solemya kobayashii* TAMURA, 1960d, Torinosu belt, J3a.
    *Solemya suprajurensis* HAYAMI, 1959f, Mitarai, J3b.
Family Ctenodontidae WOHRMANN
  Genus *Palaeoneilo* HALL, 1869
    *Palaeoneilo* sp., HAYAMI, 1959f, Mitarai, J3b.
Family Nuculidae GRAY
  Genus *Nuculopsis* GIRTY, 1911
   Subgenus *Palaeonucula* QUENSTEDT, 1930
    *Nuculopsis* (*Palaeonucula*) *mitaraiensis* HAYAMI, 1959f, Mitarai, J3b.
    *Nuculopsis* (*Palaeonucula*) sp., HAYAMI. 1959f, Mitarai, J3b.
    *Nuculopsis* (*Palaeonucula*) sp., HAYAMI, 1959i, Higashinagano, J1b.
Family *Nuculanidae* ADAMS
  Genus *Nuculana* LINK, 1807
   Subgenus *Dacryomya* AGASSIZ, 1840
    *Nuculana* (*Dacryomya*) *minutula* KIMURA, 1956; TAMURA, 1960d; Torinosu belt, J3a-J3e.
    *Nuculana* (*Dacryomya*) *stenodolichos* KIMURA, 1956; TAMURA, 1959b, 1959d, 1960d; Torinosu belt, Nakanosawa, Sakamoto, J3a-J3e.
    *Nuculana* (*Dacryomya*) *toriyamae* HAYAMI, 1959i, Higashinagano, J1b.
   Subgenus *Praesaccella* COX, 1940
    *Nuculana* (*Praesaccella*) *yatsushiroensis* TAMURA, 1959b; TAMURA, 1960d; Sakamoto, Torinosu belt, J3d-J3e.
    *Nuculana* (*Praesaccella*) sp. ex gr. *yatsushiroensis* TAMURA, HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e.
    *Nuculana* (*Rollieria* ?) *erinoennsis* KIMURA, 1956; *Nuculana* (*Praesaccella*) *erinoensis*, TAMURA, 1959b, 1960d; Torinosu belt, Sakamoto, Miyakodani; J3a-J3e.
    *Nuculana* (*Praesaccella*) sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e.
    **Nuculana* (*Praesaccella*) sp., Kiritani, J3b.
Family Parallelodontidae DALL
  Genus *Parallelodon* MEEK and WORTHEN, 1866
    *Parallelodon inflatus* TAMURA, 1959b, Sakamoto, J3e.
    *Parallelodon* aff. *inflatus* TAMURA, TAMURA, 1959d, Koyamada, J3e.
    *Parallelodon infraliassicus* HAYAMI, 1959i, Higashinagano, J1b.
    *Parallelodon* cf. *infraliassicus* HAYAMI, HAYAMI, 1959i, Higashinagano, J1b.
    *Parallelodon kesennumensis* HAYAMI, in HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e.
    *Parallelodon koikensis* TAMURA, 1959d; TAMURA, 1960; Nakanosawa, Kurisaka, J3c-J3d.
    *Parallelodon niranohamensis* HAYAMI, 1958c; HAYAMI, 1959a; Niranohama, J1a-J1b.
    *Parallelodon* sp., HAYAMI, 1958d, Shinatani, J1e or J1f.
    **Parallelodon* sp., Tsukinoura, J2a.
   Subgenus *Torinosucatella* TAMURA, 1959
    *Catella* (*Torinosucatella*) *kobayashii* TAMURA, 1959b; TAMURA, 1959d, 1960d; *Parallelodon* (*Torinosucatella*) *kobayashii*, HAYAMI, SUGITA and NAGUMO, 1960; Saka-

moto, Nakanosawa, Kurisaka, Kogoshio, J3c-J3e.
Subgenus *Palaeocucullaea* TOKUYAMA, 1960
*Parallelodon* (?) *subnavicellus* HAYAMI, 1959i, Higashinagano, J1b.
Family Cucullaeidae FINLAY and MARWICK
Genus *Grammatodon* MEEK, 1860
*Grammatodon takiensis* KIMURA, 1956; TAMURA, 1959b, 1959d, 1960d. HAYAMI, SUGITA and NAGUMO, 1960; Torinosu belt, Kaisekiyama belt, Kurisaka, Miyakodani, Sakamoto, Nakanosawasa, Koyamada, Kogoshio, J3a-J3c, J4.
*Grammatodon toyorensis* HAYAMI, 1959i, Higashinagano, J1b.
*Grammatodon* sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e, J4.
*Grammatodon* (?) sp., HAYAMI, 1958d, Shinatani, J1e or J1f.
Subgenus *Indogrammatodon* COX, 1937
*Grammatodon* (*Indogrammatodon*) *densestriatus* TAMURA, 1959d, Nakanosawa, J3c.
*Grammatodon* (*Indogrammatodon* ?) *nakanoi* HAYAMI, 1958c, Niranohahama, J1b.
Genus *Cucullaea* LAMARCK, 1801
*Cucullaea* (s. l.) sp. ex gr. *aalensis* QUENSTEDT, HAYAMI, 1959c, Aratozaki, J2a.
*Cucullaea* (s. l.) *mabuchii* HAYAMI, 1958c, Niranohama, J1b.
*Cucullaea* (s. l.) sp., HAYAMI, 1959c, Aratozaki, J2a.
Family Mytilidae FLEMING
Genus *Modiolus* LAMARCK, 1799
*Volsella bakevelloides* HAYAMI, 1958a; *Modiolus bakevelloides*, HAYAMI, 1958d, 1959a; Niranohama, J1a.
*Modiolus* cf. *bipartitus* SOWERBY, TAMURA, 1960b, Nakanosawa, J3c.
*Modiolus maedae* HAYAMI, 1959f, Mitarai, J3b.
*Modiolus magatama* HAYAMI, 1959i, Higashinagano, J1b.
*Volsella* sp., HAYAMI, 1958a, Shinatani, J1e or J1f.
Subgenus *Inoperna* CONRAD, 1875
*Modiolus* (*Inoperna*) *plicatus* SOWERBY, TAMURA, 1960b, Nakanosawa, J3c.
*Modiolus* (*Inoperna*) sp., HAYAMI, 1959c, Aratozaki, J2a.
*Modiolus* (*Inoperna*) sp., TAMURA, 1960b, Nakanosawa, J3c.
Genus *Mytilus* LINNÉ, 1758
Subgenus *Falcimytilus* COX, 1937
*Mytilus* (*Falcimytilus*) *heranirus* HAYAMI, 1958a, Tsuchizawa, J1.
*Mytilus* (*Falcimytilus*) *heranirus* subsp., HAYAMI, 1958a, Kitamatadani, (?) J1c.
*Mytilus* (*Falcimytilus*) *stricapillatus* HAYAMI, 1958a, Shinatani, Tsuchizawa, J1e or J1f.
*Mytilus* (*Falcimytilus*) *stricapillatus* subsp., HAYAMI, 1958a, Negoya, J1d.
*Mytilus* (*Falcimytilus*) sp., HAYAMI, 1958a, Negoya, J1d.
**Mytilus* (*Falcimytilus*) sp., Kiritani, J3b.
Genus *Arcomytilus* AGASSIZ, 1842
*Arcomytilus dairensis* KOBAYASHI and HAYAMI, in HAYAMI, 1958a, (?) Shinatani, J1e or J1f.
*Brachidontes* (*Arcomytilus*) *laitmairensis* (DE LORIOL); TAMURA, 1960b, 1960d, Nakanosawa, Kaisekiyama belt, J3c, J3e.
*Arcomytilus* sp., HAYAMI, 1958a, Shinatani, J1e or J1f.
Genus *Brachidontes* SWAINSON, 1840
*Brachidontes* (?) sp., HAYAMI, 1959f, Mitarai, J3b.
Family Pteriidae MEEK
Genus *Pteria* SCOPOLI, 1777
*Pteria* (s. l.) *kitakamiensis* HAYAMI, 1958a, 1959a, Niranohama, J1a.
*Pteria masatanii* TAMURA, 1960a, Nakanosawa, J3c.
*Pteria* (s. l.) sp., HAYAMI, 1959f. Mitarai, J3b.
"*Pteria*" sp., TAMURA, 1960a, Nakanosawa, J3c.
Genus *Pteroperna* MORRIS and LYCETT, 1853

      - _Pteroperna lingulata_ Tamura, 1960a, Nakanosawa, J3c.
      - _Pteroperna pauciradiata_ Tamura, 1960a, Nakanosawa, J3c.
      - _Pteroperna_ sp., Tamura, 1959a, Sakamoto, J3e.
      - _Pteroperna_ sp., Tamura, 1960a, Nakanosawa, J3c.
      - _Pteroperna?_ sp., Tamura, 1960a, Nakanosawa, J3c.
    - Genus _Somapteria_ Tamura, 1960
      - _Somapteria koikensis_ Tamura, 1960a, Nakanosawa, J3c.
- Family Aviculopectinidae Etheridge, em. Newell
  - Subfamily Oxytominae Ichikawa
    - Genus _Oxytoma_ Meek, 1864
      - _Oxytoma_ cf. _cygnipes_ (Young and Bird); Hayami, 1959i; Higashinagano, J1b.
      - _Oxytoma inequivalvis_ (Sowerby); Hayami, 1959i, Higashinagano, J1b. J1c.
      - _Oxytoma kobayashii_ Hayami, 1959i, Higashinagano, J1c.
      - _Oxytoma_ cf. _münsteri_ (Goldfuss); Hayami, 1959c; Aratozaki, J2a.
      - _Oxytoma tetoriensis_ Hayami, 1959f, Mitarai, J3b.
      - *_Oxytoma_ sp., Otakidani, J1f.
      - *_Oxytoma_ sp., $Y_2$ member of Yamaoku, J1.
      - _Oxytoma_ (?) sp., Hayami, 1958a, Shinatani, J1c or J1f.
    - Genus _Meleagrinella_ Whitfield, 1885
      - _Meleagrinella japonica_ Hayami, 1959i, Higashinagano, J1e or J1f.
      - *_Meleagrinella_ sp., Niranohama, J1b.
      - *_Meleagrinella_ sp., $Y_2$ member of Yamaoku, J1.
- Family Posidoniidae
    - Genus _Posidonia_ Bronn, 1828
      - *_Posidonia_ sp. ex gr. _ornati_ Quenstedt, Utano, J1g.
      - *_Posidonia_ sp., Hosoura, J1g.
      - *_Posidonia_ sp., Tsunakizaka, J2b.
      - *_Posidonia_ sp., Kaizara, J3a.
    - Genus _Amonotis_ Kittl, 1904
      - *_Amonotis_ n. sp., Nishinakayama, J1e.
    - Genus _Aulacomyella_ Furlani, 1910
      - _Aulacomyella_ (?) sp., Tamura, 1960a, Nakanosawa, J3c.
- Family Bakevelliidae King
    - Genus _Bakevellia_ King, 1848
      - _Bakevellia_ (s. l.) _cassianelloides_ Kobayashi and Hayami, in Hayami, 1957a, Tsuchizawa, J1.
      - _Bakevellia magnissima_ Hayami, 1957a, Shinatani, Iwamuro, $Y_1$ member of Yamaoku, J1e or J1f.
      - _Bakevellia negoyensis_ Hayami, 1957a, Negoya, J1d.
      - _Bakevellia ohishiensis_ Hayami, 1957a, Kitamatadani, (?) J1c.
      - _Bakevellia otariensis_ Hayami, 1957a, Tsuchizawa, J1.
      - _Gervillia trigona_ Yokoyama, 1904; _Bakevellia trigona_, Hayami, 1957a, 1959a, Niranohama, J1a-J1b.
      - _Bakevellia_ cf. _trigona_ (Yokoyama); Hayami, 1959a, Mizunuma, (?) J1c.
      - *_Bakevellia_ sp., Tsukinoura, J2a.
    - Genus _Gervillia_ Defrance, 1820
      - _Gervillia takiensis_ Tamura, 1960d, Torinosu belt, Kurisaka, J3a-J3d.
      - _Gervillia tatenosawensis_ Tamura, 1960a; Tamura, 1960d, Nakanosawa, Kurisaka, J3c-J3d.
      - _Gervillia_ sp., Hayami, 1957b, Niranohama, J1a.
      - _Gervillia_ sp., Hayami, Sugita and Nagumo, 1960, Kogoshio, J3e.
      - Subgenus _Cultriopsis_ Cossmann, 1904
        - _Gervillia_ (_Cultriopsis_) _shizukawensis_ Hayami, 1957b, 1959a, Niranohama, J1a.
        - _Gervillia_ (_Cultriopsis_) sp., Hayami, 1957b, Tsuchizawa, J1.
    - Genus _Gervillella_ Waagen, 1907, em. Cox, 1940

*Gervillella* (?) sp., Tamura, 1959a, Sakamoto, J3e.

Genus *Kobayashites* Hayami, 1959

*Kobayashites hemicylindricus* Hayami, 1959a, Aratozaki, Tsukinoura, J2a.

Family Isognomonidae Dall

Genus *Isognomon* Solander, 1786

*Perna rikuzenica* Yokoyama, 1904; *Isognomon rikuzenicus*, Hayami, 1957b, 1959a, Niranohama, Hosoura, J1a-J1f.

*Isognomon* cf. *rikuzenicus* (Yokoyama), Hayami, 1957b, Negoya, J1d.

**Isognomon* cf. *rikuzenicus* (Yokoyama), Aratozaki, J2a.

*Isognomon* sp., Hayami, 1957b, Shinatani, J1e or J1f.

*Isognomon* sp., Hayami, 1957b, $Y_1$ member of Yamaoku, J1.

Subgenus *Mytiloperna* Ihring, 1903

*Isognomon* (*Mytiloperna*) *ageroensis* Hayami, 1957b, Shinatani, J1e or J1f.

Family Inoceramidae Zittel

Genus *Parainoceramus* Voronetz, 1936

*Parainoceramus lunaris* Hayami, 1960c, Nishinakayama, J1e.

*Parainoceramus matsumotoi* Hayami, 1960c, Nishinakayama, J1f.

*Parainoceramus* cf. *matsumotoi* Hayami, Hayami, 1960c, Nishinakayama, J1f.

*Parainoceramus* sp. ex gr. *matsumotoi* Hayami, Hayami, 1960c, Nishinakayama, J1f.

*Inoceramus* (s. l.) sp., Hayami, 1959c; *Parainoceramus* sp., Hayami, 1960c; Aratozaki, J2a.

Genus *Inoceramus* Sowerby, 1814

*Inoceramus* (s. l.) *fukadae* Hayami, 1960c, Kodaijima, J1g or J2a.

*Inoceramus furukawensis* Hayami, 1960c, Sugizaki, J3b.

*Inoceramus* sp. ex gr. *fuscus* Quenstedt, Hayami, 1960c, Utano, J1g.

*Inoceramus* sp. ex gr. *galoi* Boehm, Hayami, 1960c, Arato, somewhere from J2b to J3d.

*Inoceramus hamadae* Hayami, 1960c, Kaizara, J3a.

*Inoceramus hashiurensis* Hayami, 1960c, Arato, somewhere from J2b to J3d.

*Inoceramus* (s. l.) *kudoi* Hayami, 1960c, Hosoura, J1g.

*Inoceramus* cf. *lucifer* von Eichwald, Hayami, 1960c, Tsunakizaka, J2b.

*Inoceramus maedae* Hayami, 1960c, Mitarai, J3b.

*Inoceramus maedae* Hayami, var., Hayami, 1960c, Mitarai, J3b.

*Inoceramus maedae* Hayami, var., Hayami, 1960c, Mitarai, J3b.

*Inoceramus morii* Hayami, 1959c; Hayami, 1960c; Aratozaki, Kosaba, J2a.

*Inoceramus* (?) *naganoensis* Hayami, 1960c, Nagano, J3b.

*Inoceramus* cf. *nitescens* Arkell, Hayami, 1960c, Nagano, J3b.

*Inoceramus ogurai* Kobayashi, 1926; Hayami, 1960c; Utano, J2c or J3a.

*Inoceramus utanoensis* Kobayashi, 1926; Hayami, 1960c; Utano, J2c or J3a.

*Inoceramus* (s. l.) sp., Hayami, 1960c, Kodaijima, J1g or J2a.

*Inoceramus* (s. l.) sp., Hayami, 1960c, Tsunakizaka, J2b.

*Inoceramus* (s. l.) sp., Hayami, 1960c, Mitarai, J3b.

**Inoceramus* (s. l.) sp., Tsukinoura, J2a.

**Inoceramus* sp., Shimohambara, (?) J2b.

Subgenus *Mytiloceramus* Rollier, 1914

*Inoceramus* (*Mytiloceramus*) *karakuwensis* Hayami, 1960c, Tsunakizaka, J2b.

Family Pinnidae Gray

Genus *Pinna* Linné, 1758

*Pinna* cf. *mitis* Phillips, Tamura, 1960b, Nakanosawa, J3c.

*Pinna* sp. ex gr. *sandsfootensis* Arkell, Hayami, 1959f, Mitarai, J3b.

*Pinna* sp., Tamura, 1960d, Kaisekiyama belt, J3.

*Pinna* sp., Hayami, Sugita and Nagumo, 1960, Kegoshio, J3c.

**Pinna* sp., Kiritani, J3b.

Family Plicatulidae Iredale

- Genus *Plicatula* LAMARCK, 1801
  - *Plicatula dichotomocosta* TAMURA, 1959d, Nakanosawa, J3c.
  - *Plicatula* aff. *dichotomocosta* TAMURA, TAMURA, 1960d, Kaisekiyama belt, J3.
  - *Plicatula praenipponica* HAYAMI, 1959i, Higashinagano, J1b.
  - *Plicatula subcircularis* HAYAMI, 1959i, Higashinagano, J1b.
  - *Plicatula yatsujiensis* TAMURA, 1960d, Torinosu belt, Kaisekiyama belt, Miyakodani, J3a, J3.
  - **Plicatula* sp., Shinatani, J1e or J1f.
  - **Plicatula* sp., Niranohama, J1b.
- Family Pectinidae LAMARCK
  - Genus *Chlamys* RÖDING, 1798
    - *Chlamys camptonectoides* TAMURA, 1959d, Nakanosawa, J3c.
    - *Chlamys iboibo* KURATA and KIMURA, in KIMURA, 1951; TAMURA, 1959b, 1960d, Kaisekiyama belt, Mitoda belt, Sakamoto, J3a–J3e.
    - *Chlamys kobayashii* HAYAMI, 1959d, Tsukinoura, Kosaba, J2a.
    - *Chlamys kotakiensis* TAKAI and HAYAMI, in HAYAMI, 1957e, Kitamatadani, (?) J1c.
    - *Chlamys kurumensis* KOBAYASHI and HAYAMI, in HAYAMI, 1957e, Tsuchizawa, J1.
    - *Chlamys* cf. *kurumensis* KOBAYASHI and HAYAMI, HAYAMI, 1957e, Tsuchziawa, J1.
    - *Chlamys mitaraiensis* HAYAMI, 1959g, Mitarai, J3b.
    - *Chlamys textoria* (SCHLOTHEIM); HAYAMI, 1959i, Higashinagano, J1b.
    - *Chlamys* sp., HAYAMI, 1957e, Tsuchizawa, J1.
    - *Chlamys* sp., TAMURA, 1959d, Nakanosawa, J3c.
    - *Chlamys* (*Chlamys*) sp., TAMURA, 1959b, Sakamoto, J3e.
    - **Chlamys* sp., Yamagami, (?) J3a.
  - Genus "*Aequipecten*" FISCHER, 1887
    - *Neithea kotsubu* KIMURA, 1951; "*Aequipecten*" *kotsubu*, TAMURA, 1959b, 1959d, 1960d; Kaisekiyama belt Torinosu belt, Kurisaka, Sakamoto, Nakanosawa, J3a–J3e.
    - "*Aequipecten*" *toyorensis* HAYAMI, 1959i, Higashinagano, J1b.
    - *Aequipecten vulgaris* KIMURA, 1951; "*Aequipecten*" *vulgaris*, TAMURA, 1959b, 1959d, 1960d; Torinosu belt, Kaisekiyama belt, Kurisaka, Miyakodani, Nakanosawa, Sakamoto, J3a–J3e.
    - "*Aequipecten*" sp., HAYAMI, 1959i, Higashinagano, J1b.
  - Genus *Radulopecten* ROLLIER, 1911
    - *Chlamys nagatakensis* KURATA and KIMURA, in KIMURA, 1951; *Chlamys* (*Radulopecten*) *nagatakensis*, TAMURA, 1959b, 1960d; Mitoda belt, Sakamoto, J3, J3e.
    - *Aequipecten ogawensis* KIMURA, 1951; *Chlamys* (*Radulopecten*) *ogawensis*, TAMURA, 1959b, 1959d, 1960d; Torinosu belt, Shiraishigo, Sakamoto, Nakanosawa, J3a–J3e.
  - Genus *Camptonectes* MEEK, 1864
    - *Camptonectes* cf. *auritus* (SCHLOTHEIM), HAYAMI, 1959c, Aratozaki, J2a.
    - *Camptonectes* aff. *browni* COX, TAMURA, 1959b, Sakamoto, J3e.
    - *Camptonectes inexpectatus* HAYAMI, 1959a, Niranohama, J1a.
    - *Camptonectes* (?) *mimikirensis* KURATA and KIMURA, in KIMURA, 1951; TAMURA, 1960d, Kaisekiyama belt, J3.
    - "*Camptonectes*" *oishii* KOBAYASHI and HAYAMI, in HAYAMI, 1957e, Tsuchizawa, Kitamatadani, J1, (?) J1c.
    - "*Camptonectes*" *subflabèlliformis* HAYAMI, 1957e, Kitamatadani, (?) J1c.
    - *Camptonectes torinosuensis* KURATA and KIMURA, in KIMURA, 1951; TAMURA, 1960d; Kaisekiyama belt, Kurisaka, J3, J3c.
    - *Camptonectes* sp., TAMURA, 1960d, Torinosu belt, (?) J3d.
    - *Camptonectes* sp., TAMURA, 1959d, Nakanosawa, J3c.
    - *Camptonectes* sp., HAYAMI, 1959g, Mitarai, J3b.
    - **Camptonectes* sp., Niranohama, J1b.
    - "*Camptonectes*" sp., HAYAMI, 1957e, Kitamatadani, (?) J1c.

"*Camptonectes*" sp., Hayami, 1957e, Shinatani, J1e or J1f.

Genus *Radulonectites* Hayrmi, 1957

*Radulonectites japonicus* Hayami, 1957d, Tsuchizawa, J1.

*Radulonectites japonicus* Hayami, var. *convexus*, Hayami, 1957d, Tsuchizawa, J1.

Genus *Eopecten* Douvillé, 1897

*Eopecten kurisakensis* Tamura, 1960d, Kurisaka, J3c.

*Velata puncta* Kimura, 1951; *Eopecten punctus*, Tamura, 1959d, 1960d; Kaisekiyama belt, Nakanosawa, J3c, J3.

*Eopecten* n. sp., Tamura, 1959b, Sakamoto, J3e.

*Eopecten* (?) sp., Hayami, 1957e, Iwamuro, J1.

Family Amusiidae Ridewood

Genus *Entolium* Meek, 1865

*Entolium* cf. *calvum* (Goldfuss); Hayami, 1959i, Higashinagano, J1b, (?) J1c.

*Entolium* cf. *disciforme* (Schübler); Hayami, 1959c, Aratozaki, Kodaijima, (?) J1g, J2a.

*Entolium inequivalve* Hayami, 1959g, Mitarai, J3b.

*Entolium japonicum* Kurata and Kimura, in Kimura, 1951; Tamura, 1960d, Kaisekiyama belt, J3.

*Entolium kimurai* Tamura, 1959b; Tamura, 1959d, 1960d; Hayami, Sugita and Nagumo, 1960; Sakamoto, Koyamada, Kurisaka, Torinosu belt, Kaisekiyama belt, Kogoshio, J3a–J3e.

*Entolium* cf. *lunare* (Roemer); Hayami, 1959i, Higashinagano, J1b.

*Entolium yatsujiense* Kurata and Kimura, in Kimura, 1951; Tamura, 1959b, 1959d, 1960d, Torinosu belt, Go, Nagayasu, Miyakodani, Sakamoto, Nakanosawa, J3a–J3e.

*Entolium* sp., Hayami, 1957e, Tsuchizawa, J1 (=*Entolium* cf. *calvum* (Goldfuss) in Hayami, 1959i).

*Entolium* sp., Hayami, 1959i, Higashinagano, J1c.

*Entolium* (?) sp., Hayami, 1959i, Higashinagano, J1b.

Genus *Somapecten* Kimura, 1951

*Somapecten kamimanensis* Kimura, 1951; Tamura, 1959b, 1959d, 1960d, Nakanosawa, Torinosu belt, Kaisekiyama belt, Kurisaka, Miyakodani, Sakamoto, J3a–J3e.

Genus *Variamussium* Sacco, 1897

*Propeamussium habunokawensis* Kimura, 1951; *Variamussium habunokawense*, Tamura, 1959b, 1960d; Torinosu belt, Miyakodani, Sakamoto, J3a–J3e.

*Variamussium* cf. *habunokawense* (Kimura); Hayami, Sugita and Nagumo, 1960, Kogoshio, J4.

**Variamussium* sp., Hosoura, J1c.

*Variamussium* (?) sp., Hayami, 1957e, Teradani, J1e.

Family Limidae d'Orbigny

Genus *Lima* Bruguière, 1957

"*Lima*" sp., Hayami, 1959i, Higashinagano, J1c.

Genus *Plagiostoma* Sowerby, 1814

*Lima* (*Plagiostoma*) *enormicosta* Tamura, 1959d; Tamura, 1960d; Nakanosawa, Kaisekiyama belt, J3c.

*Plagiostoma kobayashii* Hayami, 1959i, Higashinagano, J1b.

*Plagiostoma matsumotoi* Hayami, 1959i, Higashinagano, J1b, (?) J1c.

**Plagiostoma* sp. ex gr. *subcardiiforme* (Greppin), Yamagami, (?) J3a.

*Plagiostoma* sp., Hayami, 1959i, Higashinagano, J1c.

*Lima* (*Plagiostoma*) sp., Tamura, 1959b, Sakamoto, J3e.

*Lima* (*Plagiostoma*) sp., Tamura, 1959d, Nakanosawa, J3c.

**Plagiostoma* sp., Tsukinoura, J2a.

Genus *Antiquilima* Cox, 1943

*Antiquilima nagatoensis* HAYAMI, 1959i, Higashinagano, J1b.
Genus *Ctenoides* MÖRCH, 1853
*Lima* (*Ctenoides*) *tosana* KURATA and KIMURA, in KIMURA, 1951; TAMURA, 1959b, 1960d; Kaisekiyama belt, Mitoda belt, Torinosu belt, Kurisaka, Miyakodani, Sakamoto, (?) J3a, J3c-J3e.
Genus *Limatula* WOOD, 1839
*Limatula akiyamae* HAYAMI, in HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J4.
*Limatula iwayae* HAYAMI, 1959g, Mitarai, J3b.
*Limatula reticulata* TAMURA, 1959b, Sakamoto, J3e.
Genus *Ctenostreon* VON EICHWALD, 1862
*Ctenostreon japonicum* HAYAMI, 1959i, Higashinagano, J1b.
*Ctenostreon ojikense* HAYAMI, 1959d, Tsukinoura, J2a.
*Ctenostreon proboscideum* (SOWERBY); TAMURA, 1959d, Nakanosawa, J3c.
*Ctenostreon* sp. ex gr. *proboscideum* (SOWERBY), HAYAMI, 1959c, Aratozaki, J2a.
*Ctenostreon* sp., HAYAMI, 1959i, Higashinagano, J1b.
Family Ostreidae LAMARCK
Genus *Liostrea* DOUVILLÉ, 1904
*Liostrea toyorensis* HAYAMI, 1959i, Higashinagano, J1b.
*Liostrea* sp., TAMURA, 1959b, Sakamoto, J3e.
Subgenus *Catinula* ROLLIER, 1911
*Liostrea* (*Catinula*) cf. *stoliczkai* COX, TAMURA, 1960d, Kaisekiyama belt, Kurisaka, J3, J3c.
Genus *Ostrea* LINNÉ, 1758
"*Ostrea*" sp., HAYAMI, 1958a, Shinatani, J1e or J1f.
"*Ostrea*" sp., HAYAMI, 1958a, Tsuchizawa, J1.
*"*Ostrea*" sp., Niranohama, J1a.
*"*Ostrea*" sp., Ushimaru, (?) J3a.
Genus *Exogyra* SAY, 1819
*Exogyra kumensis* TAMURA, 1959a; TAMURA, 1960c, 1960d; Sakamoto, Nakanosawa, Kurisaka, Miyakodani, Kaisekiyama belt, J3c-J3e.
Genus *Lopha* RÖDING, 1798
*Lopha* cf. *eruca* (DEFRANCE); TAMURA, 1960d, Kaisekiyama belt, Kurisaka, J3, J3c.
*Lopha gregarea* (SOWERBY); TAMURA, 1960d, Kaisekiyama belt, J3.
*Lopha* cf. *marshii* (SOWERBY), TAMURA, 1960d, Kaisekiyama belt, Torinosu belt, Kurisaka
*Lopha sazanami* HAYAMI, 1959i, Higashinagano, J1b.
**Lopha* sp., Niranohama, J1a.
*Lopha* sp., HAYAMI, 1959d, Tsukinoura, J2a.
*Lopha* sp., HAYAMI, 1959d, Tsukinoura, J2a.
**Lopha* sp., Kogoshio, J3e.
Family Trigoniidae LAMARCK
Subfamily Trigoniinae KOBAYASHI
Genus *Trigonia* BRUGUIÈRE, 1789
*Trigonia senex* KOBAYASHI and MORI, 1954, Niranohama, J1b.
*Trigonia sumiyagura* KOBAYASHI and KASENO, 1947; KOBAYASHI and MORI, 1954; HAYAMI, 1959c; Aratozaki, Kosaba, J2a.
*Trigonia sumiyagura* KOBAYASHI and KASENO, var., KOBAYASHI and MORI, 1954, Kodaijima, J1g or J2a.
Genus *Geratrigonia* KOBAYASHI, 1954
*Trigonia hosourensis* YOKOYAMA, 1904; *Geratrigonia hosourensis*, KOBAYASHI and MORI, 1954; HAYAMI, 1959a; Niranohama, J1a, (?) J1b.
*Geratrigonia hosourensis* (YOKOYAMA) var. *convexa* KOBAYASHI, in KOBAYASHI and MORI, 1954, Niranohama, J1a.

*Geratrigonia lata* KOBAYASHI, in KOBAYASHI and MORI, 1954, Niranohama, J1a–J1b.

*Geratrigonia kurumensis* KOBAYASHI, 1957a, Otakidani, J1f.

Genus *Latitrigonia* KOBAYASHI, 1957

*Latitrigonia orbicularis* KOBAYASHI, 1957a, Yambarazaka, J3b.

*Latitrigonia pyramidalis* KOBAYASHI and TAMURA, 1957, Awazu, J2c.

*Latitrigonia tetoriensis* KOBAYASHI, 1957a, Yambarazaka, J3b.

*Latitrigonia unicarinata* KOBAYASHI and TAMURA, 1957, Yamagami, (?) J3a.

*Latitrigonia unituberculata* KOBAYASHI and TAMURA, 1957, Yamagami, (?) J3a.

Genus *Ibotrigonia* KOBAYASHI, 1957

*Ibotrigonia masatanii* KOBAYASHI and TAMURA, 1957, Awazu, Yamagami, J2c, (?) J3a.

*Ibotrigonia masatanii* KOBAYASHI and TAMURA, var., KOBAYASHI and TAMURA, 1957, Yamagami, (?) J3a.

Genus *Nipponitrigonia* COX, 1952

*Trigonia sagawai* YEHARA, 1926; *Nipponitrigonia sagawai*, KOBAYASHI, 1957c; TAMURA, 1960d; Kaisekiyama, belt, Torinosu belt, Awazu, Yamagami, Nakanosawa, Kiritani, (?) Sugizaki, J2c–J3e.

Subfamily Prosogyrotrigoniinae KOBAYASHI

Genus *Prosogyrotrigonia* KRUMBECK, 1924

*Trigonia inouyei* YEHARA, 1921; YEHARA, 1931; *Prosogyrotrigonia inouyei*, KOBAYASHI and MORI, 1954; Higashinagano, J1b.

Subfamily Vaugoniinae KOBAYASHI

Genus *Vaugonia* CRICKMAY, 1930

*Vaugonia awazuensis* KOBAYASHI in KOBAYASHI and TAMURA, 1957, Awazu, J2c.

*Vaugonia kodaijimensis* KOBAYASHI and MORI, 1955, Kodaijima, Tsukinoura, (?) Aratozaki, J1g–J2a.

*Vaugonia namigashira* KOBAYASHI and MORI, 1955, Niranohama, J1b.

*Vaugonia niranohamensis* KOBAYASHI and MORI, 1955, Niranohama, Hosoura, Aratozaki, J1b–J2a.

*Vaugonia yambarensis* KOBAYASHI, 1956, Yambara, J3.

*Vaugonia yokoyamai* KOBAYASHI and MORI, 1955, Niranohama, Aratozaki, Tsukinoura, J1b–J2a. (=*Trigonia v-costata* YOKOYAMA, 1904, non LYCETT, 1872)

*Vaugonia yokoyamai* forma *gracilis* KOBAYASHI and MORI, 1955, Niranohama, J1b.

Subgenus *Hijitrigonia* KOBAYASHI, 1955

*Vaugonia* (*Hijitrigonia*) *geniculata* KOBAYASHI and MORI, 1955; HAYAMI, 1959c, Aratozaki, Kosaba, J2a.

*Vaugonia* (*Hijitrigonia*) *kojiwa* KOBAYASHI and MORI, 1955, Niranohama, J1b.

Genus *Orthotrigonia* COX, 1952

*Orthotrigonia corrugata* KOBAYASHI and MORI, 1955, Niranohama, J1b.

*Orthotrigonia midareta* KOBAYASHI and MORI, 1955, Niranohama, J1b.

Genus *Scaphotrigonia* COX, 1952

*Scaphotrigonia somensis* KOBAYASHI and TAMURA, 1957, Yamagami, (?) J3a.

Subfamily Myophorellinae KOBAYASHI

Genus *Myophorella* BAYLE, 1878

*Myophorella* (*Myophorella*) *dekaiboda* KOBAYASHI and TAMURA, 1955, Nakanosawa, J3c.

Subgenus *Promyophorella* KOBAYASHI and TAMURA, 1955

*Myophorella* (*Promyophorella* ?) *hashimotoi* KOBAYASHI, 1956; TAMURA, 1960d, Kurisaka, J3c.

*Myophorella* (*Promyophorella*) *imamurai* KOBAYASHI, 1956, Kiritani, J3b.

*Myophorella* (*Promyophorella*) *obsoleta* KOBAYASHI and TAMURA, 1955; KOBAYASHI, 1956; HAYAMI, SUGITA and NAGUMO, 1960; Kogoshio, Hommura, (?) Arimine, J3e–J4.

*Myophorella* (*Promyophorella*) *orientalis* KOBAYASHI and TAMURA, 1955; KOBAYASHI, 1957a, 1957b; Koyamada, Tashiro, Kogoshio, Yambarazaka, J3b-J3e.

*Myophorella* (*Promyophorella*) *sigmoidalis* KOBAYASHI and TAMURA, 1955; HAYAMI, 1959c; Aratozaki, J2a.

*Myophorella* (*Promyophorella*) *sugayensis* KOBAYASHI and TAMURA, 1955, Yamagami, (?) J3a.

*Myophorella* (*Promyophorella*) *sugayensis* var. *geniculata* KOBAYASHI and TAMURA, 1955, Yamagami, (?) J3a.

*Myophorella* (*Promyophorella*) sp., TAMURA, 1959a, Sakamoto, J3e.

*Myophorella* (*Promyophorella*) sp., TAMURA, 1959a, Sakamoto, J3e.

Subgenus *Haidaia* CRICKMAY, 1930, em. KOBAYASHI and TAMURA, 1955

*Myophorella* (*Haidaia*) *crenulata* KOBAYASHI and TAMURA, 1955; KOBAYASHI, 1957b; Nakanosawa, Mone, J3c.

*Myophorella* (*Haidaia*) *crenulata* var. *lunulata* KOBAYASHI and TAMURA, 1955, Nakanosawa, J3c.

*Myophorella* (*Haidaia*) *gracilenta* KOBAYASHI, 1956; TAMURA, 1959a, 1960d; Kaisekiyama belt, Mitoda belt, Sakamoto, J3a-J3e.

*Myophorella* (*Haidaia*) *ohmachii* TAMURA, 1959a, Sakamoto, J3e.

*Myophorella* (*Haidaia*) *pulex* TAMURA, 1959a; TAMURA, 1960d; Sakamoto, Torinosu belt, Mitoda belt, Kaisekiyama belt, Kurisaka, J3a-J3e.

*Myophorella* (*Haidaia*) *subcircularis* KOBAYASHI and TAMURA, 1955, Nakanosawa, J3c.

*Myophorella* (*Haidaia*) sp., KOBAYASHI, 1956, Kappazaka, (?) J3c.

Genus *Linotrigonia* VAN HOEPEN, 1929

*Trigonia toyamai* YEHARA, 1923; YEHARA, 1927, 1931; *Linotrigonia toyamai*, KOBAYASHI, 1956d; TAMURA, 1960d; Torinosu belt, Kaisekiyama, belt, Kurisaka, Miyakodani, J3a-J3c.

Genus *Oistotrigonia* COX, 1952

*Oistotrigonia prima* KOBAYASHI and TAMURA, 1955, Nakanosawa, J3c.

Family Unionidae FLEMING

"Genus *Unio* RETZIUS, 1788"

*Unio ogamigoensis* KOBAYASHI and SUZUKI, 1937, Ogamigo, J3 or later.

Family Pachicardiidae

Genus *Cardinioides* KOBAYASHI aud ICHIKAWA, 1952

*Cardinioides ovatus* HAYAMI, 1957c, Kitamatadani, (?) J1c.

*Cardinioides varidus* HAYAMI, 1957c, Tsuchizawa, J1.

*Cardinioides* (?) sp., HAYAMI, 1957c, Iwamuro, J1.

Family Cardiniidae ZITTEL

Genus *Cardinia* AGASSIZ, 1841

*Cardinia orientalis* HAYAMI, 1959i, Higashinagano, J1b.

*Cardinia toriyamai* HAYAMI, 1958e; HAYAMI, 1959i; Higashinagano, J1b.

Family Myoconchidae

Genus *Myoconcha* SOWERBY, 1824

*Myoconcha* (?) sp., TAMURA, 1960b, Nakanosawa, J3c.

Family Astartidae GRAY

Genus *Astarte* SOWERBY, 1817

*Astarte defecta* TAMURA, 1959a; TAMURA, 1960c, 1960d; Sakamoto, Nakanosawa, Mitoda belt, Kaisekiyama belt, (?) Kurisaka, J3c-J3e.

*Astarte* (?) sp. aff. *hermanni* OPPEL, TAMURA, 1959a, Sakamoto, J3e.

*Astarte higoensis* TAMURA, 1959a; TAMURA, 1960d; Sakamoto, (?) Torinosu belt, J3e, (?) J3a.

*Astarte kambarensis* KIMURA, 1956; TAMURA, 1960c, 1960d; Torinosu Nakanosawa, Koyamada, J3c-J3e.

*Astarte kambarensis* var. *elongata* KIMURA, 1956, Torinosu belt, J3e.

*Astarte ogawensis* KIMURA, 1956; TAMURA, 1959a, 1960c, 1960d; Torinosu belt, Sakamoto, Nakanosawa, J3a-J3e.
*Astarte* cf. *spitiensis* STOLICZKA, HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e-J4.
*Astarte subdepressa* BLAKE and HUDLESTON, TAMURA, 1960c, Nakanosawa, Koyamada, J3c-J3e.
*Astarte* sp., HAYAMI, 1959i, Higashinagano, J1b.
*Astarte* sp., HAYAMI, 1959i, Higashinagano, J1b.
*Astarte* n. sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J4.
*Astarte* (?) sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e.
Genus *Coelastarte* BOEHM, 1893
*Coelastarte cardiniiformis* HAYAMI, 1958c, Niranohama, J1b.
*Coelastarte* sp. ex gr. *cardiniiformis* HAYAMI, HAYAMI, 1959c, Aratozaki, J2a.
*Astarte* (*Coelastarte*) *somensis* TAMURA, 1960c, Nakanosawa, J3c.
*Coelastarte* sp., HAYAMI, 1959i, Aratozaki, J2a.
*Coelastarte* sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e.
**Coelastarte* sp., Kiritani, J3b.
Genus *Praeconia* STOLICZKA, 1871
*Praeconia* cf. *tetragona* (TERQUEM), HAYAMI, 1959i, Higashinagano, J1b.
Genus *Opis* DEFRANCE, 1825
Subgenus *Trigonopis* MUNIER-CHALMAS, 1887
*Opis* (*Trigonopis*) n. sp. aff. *corallina* DAMON, ICHIKAWA, 1954, Osako, J3.
*Opis* (*Trigonopis*) *torinosuensis* KIMURA, 1956; TAMURA, 1959c, 1960c, 1960d; Torinosu belt, Kaisekiyama belt, Nagayasu, Sakamoto, Nakanosawa, J3a-J3e.
*Opis* (*Trigonopis*) *trigonalis* TAMURA, 1959c, Sakamoto, J3c.
Subgenus *Coelopis* MUNIER-CHALMAS, 1887
*Opis* (*Coelopis*) *tanourensis* TAMURA, 1959c, Sakamoto, J3e.
*Opis* (*Coelopis*?) sp., TAMURA, 1960c, Nakanosawa, J3c.
Family Neomiodontidae CASEY
Genus *Eomiodon* COX, 1935
*Eomiodon* (?) *giganteus* HAYAMI, 1958b, Niranohama, J1a, (?) J1b.
*Eomiodon kumamotoensis* TAMURA, 1959c; TAMURA, 1960d; Sakamoto, Miyakodani, J3, J3e.
*Cyrena lunulata* YOKOYAMA, 1904; *Polymesoda lunulata*, SUZUKI and OYAMA, 1943; *Eomiodon lunulatus*, HAYAMI, 1958b, 1959b, Niranohama, J1a, (?) J1b.
*Eomiodon vulgaris* HAYAMI, 1958b, Kitamatadani, Negoya, Shinatani, (?) Otakidani, Tsuchizawa, Niranohama, Tsukinoura, Iwamuro, $Y_1$ member of Yamaoku, J1a J2a.
*Eomiodon* sp., HAYAMI, 1958b, Kitamatadani, (?) J1c.
*Eomiodon* (?) sp., HAYAMI, 1958b, Tsuchizawa, J1.
**Eomiodon* sp., Aratozaki, J2a.
Genus *Crenotrapezium* HAYAMI, 1958
*Crenotrapezium kitakamiense* HAYAMI, 1960b, Jusanhama, (?) J4.
*Crenotrapezium kurigata* HAYAMI, 1958b, Kitamatadani, Tsuchizawa, (?) J1c, J1.
*Crenotrapezium kurumense* HAYAMI, 1958b, Kitamatadani, Negoya, Shinatani, Tsuchizawa, $Y_1$ member of Yamaoku, (?) Iwamuro, J1c-J1f.
?Genus *Neomiodon* FISCHER, 1887
*Corbicula amagashiraensis* KOBAYASHI and SUZUKI, 1937, Amagashiradani, (?) J3.
*Corbicula tetoriensis* KOBAYASHI and SUZUKI, 1937; *Corbicula* (*Mesocorbicula*) *tetoriensis*, SUZUKI and OYAMA, 1943; Izuki, Numamachi, Ushimaru, Ogamigo, J3.
Family Corbiculidae GRAY
Genus *Batissa* GRAY, 1852
*Batissa antiqua* KOBAYASHI and SUZUKI, 1937, Izuki, Numamachi, J3.
*Batissa yokoyamai* KOBAYASHI and SUZUKI, 1937, Izuki, Ushimaru, Numamachi, J3.

Genus *Filosina* CASEY, 1955
*Filosina jusanhamensis* HAYAMI, 1960b, Jusanhama, J4 (?).
Family Arcticidae NICOL
Genus *Anisocardia* MUNIER-CHALMAS, 1863
*Anisocardia* sp., TAMURA, 1959c, Sakamoto, J3e.
Genus *Isocyprina* ROEDER, 1882
*Isocyprina shizuhamensis* HAYAMI, 1959c. Aratozaki, J2a.
Genus *Arctica* SCHUMACHER, 1817
Subgenus *Somarctica* TAMURA, 1960
*Arctica* (*Somarctica*) *abukumensis* TAMURA, 1960c, Nakanosawa, J3c.
Genus *Eocallista* DOUVILLÉ, 1912
"*Eocallista*" *regularis* TAMURA, 1959c, Sakamoto, J3e.
Genus *Yokoyamaina* HAYAMI, 1958
*Cyrena elliptica* YOKOYAMA, 1904; *Polymesoda elliptica*, SUZUKI and OYAMA, 1943; *Yokoyamaina elliptica*, HAYAMI, 1958b, 1959a; Niranohama, J1a.
*Yokoyamaina* cf. *elliptica* (YOKOYAMA), HAYAMI, 1958b, Negoya, J1d.
*Yokoyamaina* (?) sp., HAYAMI, 1958b, Tsuchizawa, J1.
Family Lucinidae
Genus *Lucina* LAMARCK, 1799
*Lucina* (s. l.) *hasei* HAYAMI, 1959i, Higashinagano, J1b.
"*Lucina*" *toishiyamensis* TAMURA, 1960d, Torinosu belt, (?) J3d.
*Lucina tsunoensis* KIMURA, 1956b; TAMURA, 1959c, 1960d; Torinosu belt, Kaisekiyama belt, Sakamoto, J3a–J3e.
Family Fimbriidae NICOL
Genus *Fimbria* MEGERLE, 1811
*Fimbria* (?) *tenuiconcha* HAYAMI, 1959c, Aratozaki, J2a.
*Fimbria* sp., HAYAMI, 1959i, Higashinagano, J1b.
Genus *Sphaeriola* STOLICZKA, 1871
*Sphaeriola nipponica* HAYAMI, 1959i, Higashinagano, J1b.
Family Tancrediidae FISCHER
Genus *Tancredia* LYCETT, 1850
*Tancredia rostrata* TAMURA, 1959c, Sakamoto, J3e.
**Tancredia* sp., Kiritani, J3b.
Family Cardiidae LAMARCK
Genus *Cardium* LINNÉ, 1758
*Cardium* (s. l.) *naganoense* HAYAMI, 1959i, Higashinagano, J1b.
Genus *Protocardia* BEYRICH, 1845
*Protocardia inaii* HAYAMI, 1959e, Aratozaki, J2a.
*Protocardia kurumensis* HAYAMI, 1958d, Shinatani, Tsuchizawa, J1e or J1f.
*Protocardia morii* HAYAMI, 1960b, Jusanhama, J4 (?).
*Protocardia onoi* HAYAMI, 1959i, Higashinagano, J1b.
*Protocardia tosensis* KIMURA, 1956b; TAMURA, 1959a, 1960c, 1960d; Torinosu belt, Kurisaka, Sakamoto, Nakanosawa, Koyamada, J3a–J3e.
*Protocardia* sp., HAYAMI, 1959g, Mitarai, J3b.
**Protocardia* sp., Kiritani, J3b.
**Protocardia* sp., Kogoshio, J3e.
Family Corbulidae FLEMING
Genus *Corbula* BRUGUIÈRE, 1797
*Corbula globosa* TAMURA, 1959c; TAMURA, 1960c, 1960d; Sakamoto, Nakanosawa, Koyamada, Mitoda belt, Torinosu belt, Kurisaka, J3c–J3e.
*Corbula* (?) sp., HAYAMI, 1960b, Jusanhama, J4 (?).
Family Pholadidae LEACH
Genus *Myopholas* DOUVILLÉ, 1907
*Myopholas* cf. *acuticostata* (SOWERBY), TAMURA, 1960b, Nakanosawa, J3c.
Family Pleuromyacidae ZITTEL

Genus *Pleuromya* AGASSIZ, 1843
  *Pleuromya hashidatensis* HAYAMI, 1958d, Teradani, J1e.
  *Pleuromya hidensis* HAYAMI, 1959g, Mitarai, J3b.
  *Pleuromya* (?) *punctostriae* TAMURA, 1959c; TAMURA, 1960b; *Pleuromya punctostriae*, TAMURA, 1960d; Sakamoto, Nakanosawa, Torinosu belt, J3a–J3c.
  *Pleuromya* sp., HAYAMI, SUGITA and NAGUMO, 1960, Kogoshio, J3e–J4.
  *Pleuromya* sp., HAYAMI, 1959i, Higashinagano, J1b.
Family Pholadomyacidae GRAY
 Genus *Pholadomya* SOWERBY, 1823
  *Pholadomya* (?) *ashikitensis* TAMURA, 1959c, Sakamoto, J3e.
  *Pholadomya somensis* TAMURA, 1960b, Nakanosawa, J3c.
  *Pholadomya* cf. *somensis* TAMURA, TAMURA, 1960d, Kurisaka, J3c.
  *Pholadomya* sp., HAYAMI, 1959c, Aratozaki, J2a.
 Genus *Tetorimya* HAYAMI, 1959
  *Tetorimya carinata* HAYAMI, 1959g, Mitarai, J3b.
 Genus *Neoburmesia* YABE and SATO, 1942
  *Neoburmesia iwakiensis* YABE and SATO, 1942; TAMURA, 1960b, Nakanosawa, J3c.
 Genus *Goniomya* AGASSIZ, 1843
  *Goniomya nonvscripta* TAMURA, 1960b, Nakanosawa, J3c.
  *Goniomya* cf. *nonvscripta* TAMURA, TAMURA, 1960d, Kurisaka, J3c.
  *Goniomya* sp., TAMURA, 1959c, Sakamoto, J3e (=*Goniomya nonvscripta* TAMURA).
 Genus *Homomya* AGASSIZ, 1843
  *Homomya gibbosa* (SOWERBY); TAMURA, 1960b, Nakanosawa, J3c.
  *Homomya satoi* HAYAMI, 1958d, Shinatani, J1e or J1f.
  *Homomya* sp., HAYAMI, 1958d, Kuruma group (exact horizon unknown).
 Genus *Arcomya* AGASSIZ, 1843
  *Arcomya* (?) sp., TAMURA, 1959c, Sakamoto, J3e.
Family Burmesiidae HEALEY
 Genus *Burmesia* HEALEY, 1908
  *Burmesia japonica* HAYAMI, 1959a, Niranohama, J1a.
Family Thraciidae DALL
 Genus *Thracia* BLAINVILLE, 1824
  *Thracia fukushimensis* TAMURA, 1960c, Nakanosawa, J3c.
  *Thracia shokawensis* HAYAMI, 1959g, Mitarai, J3b.
  **Thracia* cf. *shokawensis* HAYAMI, Kiritani, J3b.
  *Thracia subrhombica* HAYAMI, 1958d; HAYAMI, 1959a; Niranohama, J1a.
  *Thracia* (?) sp., HAYAMI, 1958d, Shinatani, J1e or J1f.
Family Cuspidariidae FISHER
 Genus *Cuspidaria* NARDO, 1840
  *Cuspidaria* (?) *praenipponica* HAYAMI, 1959a, Niranohama, J1a.
  *Cuspidaria* (?) sp., HAYAMI, 1958d, Niranohama, J1a. (=*Cuspidaria* (?) *praenipponica* HAYAMI).
  *Cuspidaria* (?) sp., HAYAMI, 1958d, Shinatani, J1e or J1f.
  *Cuspidaria* (?) sp., HAYAMI, 1960b, Jusanhama, J4 (?).

Besides, there are some Jurassic pelecypods, which were listed but remain undescribed, from the Sodenohama, Mone, Kogoshio and Kozumi formations of south Kitakami (SHIIDA, 1940; MATSUMOTO, 1953; ONUKI, 1956, etc.), the Sugizaki and Arimine formations of Hida (MAEDA, 1957; MAEDA and TAKENAMI, 1957, etc.) and the Torinosu group and its correlatives in Kyushu, Shikoku and Kii peninsula (ICHIKAWA, 1954; TAMURA, 1960e). As I have not yet examined those collections, they are mostly omitted in this list.

Table 2. Number of pelecypods in the Jurassic of Japan

| Family | Kitakami | Hida | Nagato | Soma | Torinosu | Total |
|---|---|---|---|---|---|---|
| Solemyacidae | 0 | 1 | 0 | 0 | 1 | 2 |
| Ctenodontidae | 0 | 1 | 0 | 0 | 0 | 1 |
| Nuculidae | 0 | 2 | 1 | 0 | 0 | 3 |
| Nuculanidae | 2 | 1 | 1 | 1 | 4 | 8 |
| Parallelodontidae | 4 | 1 | 3 | 3 | 3 | 11 |
| Cucullaeidae | 6 | 1 | 1 | 2 | 1 | 9 |
| Mytilidae | 2 | 11 | 1 | 4 | 1 | 18 |
| Pteriidae | 1 | 1 | 0 | 7 | 1 | 10 |
| Aviculopectinidae | 2 | 5 | 4 | 0 | 0 | 11 |
| Posidoniidae | 2 | 1 | 2 | 1 | 0 | 6 |
| Bakevelliidae | 7 | 6 | 0 | 1 | 2 | 16 |
| Isognomonidae | 2 | 4 | 0 | 0 | 0 | 6 |
| Inoceramidae | 11 | 9 | 7 | 0 | 0 | 27 |
| Pinnidae | 1 | 2 | 0 | 1 | 1 | 5 |
| Plicatulidae | 1 | 1 | 2 | 1 | 2 | 7 |
| Pectinidae | 4 | 13 | 3 | 7 | 13 | 37 |
| Amusiidae | 3 | 3 | 4 | 3 | 5 | 15 |
| Limidae | 4 | 1 | 7 | 4 | 4 | 18 |
| Ostreidae | 5 | 3 | 2 | 1 | 6 | 16 |
| Trigoniidae | 19 | 8 | 1 | 17 | 11 | 47 |
| Unionidae | 0 | 1 | 0 | 0 | 0 | 1 |
| Pachicardiidae | 0 | 3 | 0 | 0 | 0 | 3 |
| Cardiniidae | 0 | 0 | 2 | 0 | 0 | 2 |
| Myoconchidae | 0 | 0 | 0 | 1 | 0 | 1 |
| Astartidae | 7 | 1 | 3 | 7 | 11 | 25 |
| Neomiodontidae | 5 | 7 | 0 | 0 | 1 | 12 |
| Corbiculidae | 1 | 2 | 0 | 0 | 0 | 3 |
| Arcticidae | 2 | 2 | 0 | 1 | 2 | 7 |
| Lucinidae | 0 | 0 | 1 | 0 | 2 | 3 |
| Fimbriidae | 1 | 0 | 2 | 0 | 0 | 3 |
| Tancrediidae | 0 | 1 | 0 | 0 | 1 | 2 |
| Cardiidae | 3 | 3 | 2 | 1 | 1 | 9 |
| Corbulidae | 1 | 0 | 0 | 1 | 1 | 2 |
| Pholadiidae | 0 | 0 | 0 | 1 | 0 | 1 |
| Pleuromyacidae | 1 | 2 | 1 | 1 | 1 | 5 |
| Pholadomyacidae | 1 | 3 | 0 | 4 | 5 | 13 |
| Burmesiidae | 1 | 0 | 0 | 0 | 0 | 1 |
| Thraciidae | 1 | 3 | 0 | 1 | 0 | 5 |
| Cuspidariidae | 2 | 1 | 0 | 0 | 0 | 3 |
| Total | 102 | 104 | 50 | 71 | 80 | 374 |

## II. Faunules and Zonation

Among various groups of Jurassic fossils ammonites are, of course, of primary importance for the age determination and international correlation. The specific range of pelecypods is generally much longer than ammonites': life range of a single pelecypod species is often as long as a third or even a half of Jurassic period in which many ammonite zones are involved. Their value as keen time-indicator for interprovincial correlation and palaeogeographical consideration is therefore much inferior to ammonites. However, pelecypods have some advantages for intraprovincial correlation among isopic or even heteropic strata, because of their explosive development and common occurrence in various rock types. They seem generally to have been able to adapt to wider environment than ammonites. Incidentally, the occurrence of Jurassic ammonites of this country is almost restricted to arenaceous shales and sandstones of more or less off-shore facies. On the other hand, pelecypods are common in sandstones of various grain-size, sandy shales, black shales, marls, limestones and even in conglomerate.

Since 1955 I have visited most of the Jurassic pelecypod localities so far known in the North Japan and the Inner Zone of Southwest Japan, which were listed in the preceding chapter and attempted to recognize the specific assemblage in each fossil bed. Especially in the Kitakami and Hida mountainlands where similar facies appear repeatedly at many horizons of the stratigraphic columns, the determination of life range of each pelecypod species is indispensable for the biostratigraphical consideration in ammonite-lacking strata.

If one intends to carry out a biostratigraphical subdivision of Jurassic strata by means of pelecypods which is comparable in accuracy with that by ammonite genera, it must be dependent on the specific or infra-specific assemblages. Moreover, the subdivision must be based chiefly on the experince in each local sedimentary area instead of the introduction of faunal successions in foreign type areas. The faunal successions in the Jurassic of Japan are more or less discontinuous, and many fossil groups may be disqualified for chronology, because of their colonial habits and considerable dependence on facies. Taking care for these points, I tried to determine provisionally the range of each pelecypod species and to distinguish many characteristic faunules which seem useful intraprovincial correlation. Among Kitakami, Hida and Toyora regions there are only a few common species. This fact indicates the distribution of faunules to be confined to each palaeobiogeographical province, where the following zonations are independently established (Table 3).

### 1) Kitakami region

In the Kitakami mountainland, Hettangian, Sinemurian, Aalenian, Bajocian, Tithonian and Berriasian pelecypod faunules are well represented, but Pliensbachian deposit is unknown and Bathonian to Kimmeridgian species

Table 3.

CHARACTERISTIC PELECYPOD FAUNULES IN NORTHEAST JAPAN AND INNER ZONE OF SOUTHWEST JAPAN

| stage \ region | | NORTHEAST JAPAN | | | | | | CENTRAL JAPAN | WEST JAPAN |
|---|---|---|---|---|---|---|---|---|---|
| | | Kitakami | Shizukawa | Hashiura | Mizunuma | Karakuwa | Ojika | Hida | Nagato |
| LOW. NEOCOMIAN | J4 | ("Polymesoda" naumanni f.) | | | | | X | | |
| | | (Filosina jusanhamensis f.) | | X | | | | | |
| | | *Myophorella obsoleta* f. | | | | X | | ("Corbicula" tetoriensis f.) | |
| TITHONIAN | J3e | *Parallelodon kesennumensis* f. | | | | X | | | |
| | | *Myophorella orientalis* f | | | | X | X | | |
| | J3d | | | | | | | | |
| KIMMERIDGIAN | J3c | *Myophorella crenulata* f | | | | X | | | |
| OXFORDIAN | J3b | | | | | | | (*Entolium inequivalve* f)<br>(*Tetorimya carinata* f.)<br>(*Inoceramus maedae* f)<br>(*Nipponitrigonia sagawai* f)<br>*Latitrigonia tetoriensis* f<br>*Inoceramus* cf. *nitescens* f | |
| CALLOVIAN | J3a | (*Inoceramus hashiurensis* f) | ? | X | | | | *Inoceramus hamadae* f | (*Inoceramus utanoensis* f) |
| BATHONIAN | J2c | | | | | | | | |
| BAJOCIAN | J2b | *Inoceramus karakuwensis* f. | | | | X | | | |
| | J2a | *Chlamys kobayashii* f. | | | | X | X | | |
| | | *Kobayashites hemicylindricus* f. | X | | | | X | | |
| | | *Trigonia sumiyagura* f | X | X | X | X | X | | |
| | | (*Vaugonia kodaijimensis* f.) | ? | | | | X | | |
| AALENIAN | J1g | *Inoceramus kudoi* f | X | | | | | | *Inoceramus* sp ex gr. *fuscus* f |
| TOARCIAN | J1f | | | | | | | *Geratrigonia kurumensis* f.<br>*Bakevellia magnissima* f.<br>*Camptonectes* sp. f. | *Posidonia* sp. ex gr. *ornati* f<br>*Parainoceramus matsumotoi* f |
| PLIENSBACHIAN | J1e | | | | | | | *Pleuromya hashidatensis* f. | *Parainoceramus lunaris* f |
| | J1d | | | | | | | *Bakevellia negoyensis* f | |
| SINEMURIAN | J1c | *Variamussium* sp f. | X | | | | | *Bakevellia ohishiensis* f. | *Oxytoma kobayashii* f. |
| HETTANGIAN | | *Meleagrinella* sp. f. | X | X | | | | (*Chlamys kurumensis* f.) | *Prosogyrotrigonia inouyei* f |
| | J1b | *Trigonia senex* f | X | X | | | | (*Radulonectites japonicus* f.) | *Cardinia toriyamai* f. |
| | J1a | *Geratrigonia hosourensis* f. | X | X | X | | | | |
| | | *Burmesia japonica* f | X | | X | | | | |

seem quite rare. Pelecypods occur most commonly in coastal and embayment deposits, and the scarceness of pelecypods except for inoceramids and posidoniids in the monotonous Arato formation and similar strata is possibly due to the too off-shore environment.

(1) *Burmesia japonica* faunule (J1a, Locs. 1, 15)

This faunule is found in the black bituminous shales of the lowermost part of the Niranohama formation (lower Hettangian or ? Rhaetic) at Shizukawa and Mizunuma areas, and composed of the following species: *Burmesia japonica* HAYAMI*, *Modiolus bakevelloides* (HAYAMI), *Bakevellia trigona* (YOKOYAMA), *Eomiodon vulgaris* HAYAMI, *Thracia subrhombica* HAYAMI and *Cuspidaria* (?) *praenipponica* HAYAMI. The genus *Burmesia*, established by HEALEY (1908) from the Napeng beds of Upper Burma, has been reported from the Noric-Rhaetic of Southeastern Asia. But the associated pelecypods in the Kitakami region are commonly found also in the superjacent *Geratrigonia hosourensis* beds, and the age must not be much older than the latter faunule.

(2) *Geratrigonia hosourensis* (J1a, Locs. 1, 3, 4, 5, 6, 8, 9, 10, 12, 13, 15, 16, 17)

The characteristic assemblage of this faunule is commonly found in the black bituminous shales and sandstones of the lower Niranohama formation (lower-middle Hettangian) in Shizukawa, Hashiura and Mizunuma areas, where *Geratrigonia hosourensis* (YOKOYAMA)* forms striking fossil banks altogether

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* Characteristic species of the faunule.

with the following species: *Parallelodon niranohamensis* HAYAMI, *Modiolus bakevelloides* (HAYAMI), *Pteria* (s. l.) *kitakamiensis* HAYAMI*, *Bakevellia trigona* (YOKOYAMA), *Gervillia* (*Cultriopsis*) *shizukawensis* HAYAMI*, *Isognomon rikuzenicus* (YOKOYAMA), *Camptonectes inexpectatus* HAYAMI*, *Eomiodon lunulatus* (YOKOYAMA)*, *E. vulgaris* HAYAMI, *Eomiodon* (?) *giganteus* HAYAMI*, *Yokoyamaina elliptica* (YOKOYAMA)*, *Thracia subrhombica* HAYAMI and *Cuspidaria* (?) *praenipponica* HAYAMI. *Modiolus, Thracia* and *Cuspidaria* (?) are especially common in the shaly part.

(3) *Trigonia senex* faunule (J1b, Locs. 1, 2, 5, 9, 10, 11)

This faunule is seen in the strikingly crowded trigoniid banks of the upper Niranohama formation (middle-upper Hettangian) in the Shizukawa area. *Trigonia senex* KOBAYASHI* occurs in common with *Parallelodon niranohamensis* HAYAMI, *Grammatodon* (*Indogrammatodon* ?) *nakanoi* HAYAMI*, *Cucullaea* (s. l.) *mabuchii* HAYAMI*, *Bakevellia trigona* (YOKOYAMA), *Isognomon rikuzenicus* (YOKOYAMA), *Vaugonia niranohamensis* KOBAYASHI and MORI, *V. yokoyamai* KOBAYASHI and MORI, *V. namigashira* KOBAYASHI and MORI*, *V.* (*Hijitrigonia*) *kojiuca* KOBAYASHI and MORI*, *Geratrigonia lata* KOBAYASHI, *Orthotrigonia midareta* KOBAYASHI and MORI*, *O. corrugata* KOBAYASHI and MORI*, *Coelastarte cardiniiformis* HAYAMI*, *Yebisites onoderai* MATSUMOTO* and *Latomeandra yabei* EGUCHI*. Some species of this faunule are also common in the similar trigoniid banks of the upper Niranohama formation of the Hashiura area.

(4) *Meleagrinella* sp. faunule (J1b, Locs. 7, 14)

This is an undescribed faunule but very characteristic of the uppermost part of the Niranohama formation in Shizukawa and Hashiura areas. *Meleagrinella* sp.*, *Camptonectes* sp. and some other minute pelecypods forms a thin crowded fossil bed. (upper Hettangian or lower Sinemurian).

(5) *Variamussium* sp. faunule (J1c, Loc. 18)

This is also undescribed but seem to characterize the poor faunule of the lowermost Hosoura formation (Hi in SATO, 1957, lower Sinemurian in the Shizukawa area. *Vaugonia ninanohamensis* is found in association.

(6) *Inoceramus* (s. l.) *kudoi* faunule (J1g, Locs. 20, 21)

This faunule including *Inoceramus* (s. l.) *kudoi* HAYAMI*, *Pinna* sp.* and *Posidonia* sp. occurs in the Aalenian *Hammatoceras* beds (SATO, 1954) of the Hosoura formation in the Shizukawa area. Associate ammonites are *Hammatoceras chibai, H. hosourense, H. subtile, H. tuberculatum, H. kitakamiense, Tmetoceras recticostatum, Hyperlioceras* sp. and *Graphoceras* spp.

(7) *Vaugonia kodaijimensis* faunule (J1g or J2a, Loc. 70)

This faunule comprising *Vaugonia kodaijimensis* KOBAYASHI and MORI*, *Entolium* cf. *disciforme* (SCHÜBLER) and some other undescribed pelecypods is found in several fossil banks of the Kodaijima formation in the Ojika area. The age is not determinable in detail but presumably Aalenian or lower Bajocian. *Inoceramus fukakae* HAYAMI* was found nearby. A few specimens of *V. kodaijimensis* are known from the lower part of the Aratozaki formation in the Shizukawa area.

(8) *Trigonia sumiyagura* faunule (J2a, Locs. 63, 64, 65, 67, 68, 69, 71, 74, 75)

This is one of the most widely distributed and characteristic faunule in the Kitakami Jurassic. It is found in the lower part of the Aratozaki formation (lower Bajocian) in Shizukawa and the lower part the Kosaba formation (probably same age) in the Karakuwa. In the Shizukawa area *Trigonia sumiyagura* KOBAYASHI and KASENO* occurs in common with *Cucullaea* sp. ex gr. *aalensis* QUENSTEDT*, *Modiolus* (*Inoperna*) sp.*, *Oxytoma* cf. *münsteri* BRONN*, *Inoceramus morii* HAYAMI*, *Parainoceramus* (?) sp., *Camptonectes* cf. *auritus* (SCHLOTHEIM)*, *Entolium* cf. *disciforme* (SCHÜBLER), *Ctenostreon* sp. ex gr. *proboscideum* (SOWERBY)*, *Vaugonia niranohamensis* KOBAYASHI and MORI, *V.* (*Hijitrigonia*) *geniculata* KOBAYASHI and MORI*, *Myophorella* (*Promyophorella*) *sigmoidalis* KOBAYASHI and TAMURA*, *Coelastarte* sp. ex gr. *cardiniiformis* HAYAMI*, *Coelastarte* sp., *Isocyprina shizuhamensis* HAYAMI*, *Fimbria* (?) *tenuiconcha* HAYAMI*, a soninid (?) ammonite, "*Rhynchonella*" sp. and *Isastraea* sp. It is of special interest that this faunule comprises several forms which are, if not identical with, very similar to foreign famous Middle Jurassic pelecypods. In the Kosaba formation this faunule is represented by *Trigonia sumiyagura*, *Vaugonia* (*Hijitrigonia*) *geniculata*, *Inoceramus morii*, *Lopha* sp. and *Fimbria* (?) *tenuiconcha*. In Hashiura area *Trigonia sumiyagura* has not been found, but the "Nakahara sandstone", which is certainly an equivalent of the Aratozaki, yields *Vaugonia niranohamensis* and *V. yokoyamai*. *Vaugonia* (*Hijitrigonia*) cf. *geniculata* and *Myophorella* (*Promyophorella*) cf. *sigmoidalis* are collected also from the comparable formation in Mizunuma area. A varietal form of *Trigonia sumiyagura* was described from the upper part of the Kodaijima formation in the Ojika area. This faunule appears at the beginning of the Middle Jurassic sedimentary cycle in the Kitakami region and stratigraphically important.

(9) *Kobayashites hemicylindricus* faunule (J2a, Locs. 66, 72, 73)

This is found characteristically in the black bituminous slales of the upper Aratozaki formation (lower Bajocian) of the Shizukawa area and the Tsukinoura formation (probably Bajocian) of the Ojika area. *Kobayashites hemicylindricus* HAYAMI*, is accompanied by *Isognomon* sp. ex gr. *rikuzenicus* (YOKOYAMA), *Protocardia inaii* HAYAMI*, and *Eomiodon* (?) sp. in the upper Aratozaki and by *Parallelodon* sp., *Bakevellia* sp. and *Eomiodon vulgaris* HAYAMI in the Tsukinoura.

(10) *Chlamys kobayashii* faunule (J2a, Locs. 72, 74)

This is characteristic in the trigoniid-sandstone of the Tsukinoura formation (probably Bajocian) in Ojika. It is almost coeval with the preceding faunule but appears in different facies. The constituent species are *Chlamys kobayashii* HAYAMI*, *Ctenostreon ojikense* HAYAMI*, *Lopha* spp. and *Vaugonia yokoyamai* KOBAYASHI and MORI. *Chlamys kobayashii* is found also in the upper part of the Kosaba formation of the Karakuwa area and the middle part of the Tsukinoura formation of the Takenoura area, and seems important in the Jurassic stratigraphy of the eastern belt.

(11) *Inoceramus karakuwensis* faunule (J2b, Locs. 75, 76)

*Inoceramus* (*Mytiloceramus*) *karakuwensis* HAYAMI*, *I.* cf. *lucifer* VON EICHWALD* and *Posidonia* sp. are known in the ammonite beds of the Tsunakizaka formation (middle Bajocian) of the Karakuwa area. *Stephanoceras* sp. ex gr. *plicatissimum* and some other ammonite occur near this horizon. *Inoceramus lucifer* has been treated as a Bajocian index in Alaska, and distributed also in Prince Patrick and Sichota Alin (?) regions. Its coexistence with *Stephanoceras* is highly probable.

(12) *Inoceramus hashiurensis* faunule (J2b-J3c, Loc. 80, etc.)

*Inoceramus hashiurensis* HAYAMI* and *I.* sp. ex gr. *galoi* BOEHM* are known in the middle (?) part of the Arato formation of Hashiura. *Inoceramus galoi* is an index of Oxfordian age in Moluccas and New Zealand, but the exact age of this faunule is indeterminable.

(13) *Myophorella crenulata* faunule (J3c, Loc. 81)

This undescribed faunule is characteristic in the upper part of the Mone alternation formation of the Karakuwa area. *Myophorella* (*Haidaia*) *crenulata* KOBAYASHI and TAMURA* associates with *Myophorella* (*Promyophorella*) sp. and *Nuculana* sp. (Pl. XIV, Fig. 8). The age is not strictly determinable but the occurrence of *crenulata* suggest that this faunule is roughly correlative to that of the "*Lima*-sandstone" of the lower Nakanosawa formation (Kimmeridgian) in the Soma area. Incidentally, *Haidaia* is unknown from other horizons in the south Kitakami region.

(14) *Myophorella orientalis* faunule (? J3d-J3e, Loc. 87)

*Myophorella* (*Promyophorella*) *orientalis* KOBAYASHI and TAMURA* occurs in the Tashiro sandstone (upper Kozumi formation) of the Ojika area and (?) the Kogoshio formation of the Karakuwa area. The species is distributed widely in Soma, Kitakami and Tetori regions and also in Mindoro island, and ranges from Oxfordian to Tithonian (or Berriasian).

(15) *Parallelodon kesennumensis* faunule (J3e, Loc. 84)

*Parallelodon kesennumensis* HAYAMI*, *Gervillia* sp.*, *Entolium kimurai* TAMURA, *Coelastarte* sp., *Pleuromya* sp., *Parallelodon* (*Torinosucatella*) *kobayashii* TAMURA, *Substeueroceras* sp.* and *Trochocyathus* (*Platycyathus*) sp.* are found in the upper part of the Kogoshio formation of Karakuwa.

(16) *Myophorella obsoleta* faunule (J3e-J4, Locs. 82, 83, 85, 86)

This faunule is found in the upper part of the Kogoshio formation and Isokusa and Nagasaki blocks in the Karakuwa area, and Tithonian-Berriasian in age. The ranges of the present and preceding faunules seem to overlap each other, but the two are fairly different in specific assemblage. *Myophorella* (*Promyophorella*) *obsoleta* KOBAYASHI and TAMURA* associates with *Nuculana* (*Praeasccella*) sp. ex gr. *yatsushiroensis* TAMURA, *Grammatodon takiensis* KIMURA, *Variamussium* cf. *habunokawense* (KIMURA), *Pinna* sp., *Limatula akiyamae* HAYAMI*, *Astarte* cf. *spitiensis* STOLICZKA*, *Protocardia* sp. and *Pleuromya* sp. Some of these pelecypods are accompanied by *Thurmanniceras isokusense*, *Kilianella* sp. and an echinoid at Isokusa and by *Olcostephanus* sp., *Berriasella* sp. and *Spiticeras* sp. at Nagasaki. This faunule thus comprises some elements of the Torinosu and upper Soma groups. Many forms are identical or comparable with the species from the Nakanosawa and Koyamada formations of Soma and the Kurisaka, Yatsuji, Kambaradani and Sakamoto formations of the Outer Zone of Southwest Japan.

(17) *Filosina jusanhamensis* faunule (? J4, Loc. 89

*Filosina jusanhamensis* HAYAMI* forms a striking fossil bank altogether with *Crenotrapezium kitakamiense* HAYAMI*, *Protocardia morii* HAYAMI*, *Corbula* (?) sp. and *Cuspidaria* (?) sp. in the middle part of the Jusanhama group (Purbeckian or Wealden) of the Hashiura area. This is a unique faunule, and its exact age and distribution outside this bed is as yet unknown.

(18) "*Polymesoda*" *naumanni* faunule

"*Polymesoda*" *naumanni* NEUMAYR*, *Bakavellia* cf. *shinanoensis* (YABE and NAGAO) and some other cyrenoid pelecypods occur in the Ayukawa formation of the Ojika area (ONUKI, 1956). The first species is well known in the Wealden Ryoseki group of the Katsuragawa, Ryoseki and Sanchu Graben regions, and indicates the Lower Cretaceous age of the Ayukawa formation.

## 2 Hida region

In the Hida mountainland Lower Jurassic pelecypods are well represented in the Kuruma group and Upper Jurassic ones in the Tetori group. But Middle Jurassic faunas seem poor. In this region ammonites and pelecypods occur usually in different facies. Generally, this region constituted a more or less restricted province at that time, and cosmopolitan pelecypod elements are very rare. The following faunules are composed of several characteristic species, though their exact ages are not always confirmed.

(1) *Radulonectites japonicus* faunule (J1, Locs. 25, 26, 27

This faunule is found in the black shales and sandstones of the Tsuchizawa formation of the Kuruma area. The age is indeterminable but must be somewhere in Lias. The constituent pelecypods are *Radulonectites japonicus* HAYAMI*, *R. japonicus* var. *convexus* HAYAMI*, *Mytilus* (*Falcimytilus*) *heranirus* HAYAMI*, *M.* (*F.*) *stricapillatus* HAYAMI, *Bakevellia otariensis* HAYAMI*, *Bakevellia* s. l. *cassianelloides* KOBAYASHI and HAYAMI*, *Isognomon* sp., "*Camptonectes*" *oishii* KOBAYASHI and HAYAMI, *Cardinioides varidus* HAYAMI*, *Crenotrapezium kurumense* HAYAMI, *C. kurigata* HAYAMI, *Eomiodon vulgaris* HAYAMI and *E.* (?) sp.

(2) *Chlamys kurumensis* faunule J1, Loc. 24

*Chlamys kurumensis* KOBAYASHI and HAYAMI* coexists with *Chlamys* sp., *Entolium* cf. *calvum* (GOLDFUSS) and *Gervillia Cultriopsis*? sp. in the medium sandstone of the Tsuchizawa formation at Kamikawara of the Kuruma area. The pectinids are somewhat similar to those in the lower Liassic Higashinagano formation of the Nagato region.

(3) *Bakevellia ohishiensis* faunule (? J1c, Locs. 28, 29, 30, 33, 34, 36

This faunule is characteristic of the Kitamatadani formation (probably lower Lias) in the Inugatake area, comprising the following species: *Bakevellia ohishiensis* HAYAMI*, *Mytilus* (*Falcimytilus*) *heranirus* HAYAMI subsp.*, *Chlamys kotakiensis* TAKAI and HAYAMI*, "*Camptonectes*" *oishii* KOBAYASHI and HAYAMI, "*C.*" *subflabelliformis* HAYAMI*, "*C.*" sp., *Cardinoides ovatus* HAYAMI*, *Crenotrapezium kurumense* HAYAMI, *C. kurigata* HAYAMI, *Eomiodon vulgaris*

Hayami and *E.* sp.*

(4) *Bakevellia negoyensis* faunule (J1d, Locs. 37, 38, 40, 41, 42, 43)

*Bakevellia negoyensis* Hayami* is characteristic in the Negoya formation (lower? Pliensbachian) of the Inugatake area and associates with *Mytilus stricapillatus* Hayami subsp.*, *Isognomon* sp., *Crenotrapezium kurumense* Hayami, *Eomiodon vulgaris* and *Yokoyamaina* sp.

(5) *Pleuromya hashidatensis* faunule (J1e, Locs. 44, 45)

*Pleuromya hashidatensis* Hayami* and *Variamussium* (?) sp.* occur in the marine sandy shales of the Teradani formation (upper Pliensbachian) of the Inugatake area. *Amaltheus* sp. and *Canavaria* sp. ex gr. *geyeriana* associated with them. But the most part of the Kuruma group is represented by much different facies and the exact range of this pelecypod faunule cannot be determined.

(6) "*Camptonectes*" sp. faunule (J1e or J1f, Loc. 46)

"*Camptonectes*" sp.* and *Oxytoma* sp. occur in the lower part of the Shinatani formation of the Inugatake area (upper Pliensbachian or Toarcian). It is also a unique facies in the Kuruma group.

(7) *Bakevellia magnissima* faunule (J1e or J1f, Locs. 47, 48, 49, 51, 23)

This is an important faunule in the embayment facies of the Inner Zone, distributed not only in the Kuruma group but also in the Iwamuro and Yamaoku formations respectively in Gumma and Okayama Prefectures. In the Inugatake area *Bakevellia magnissima* Hayami* occurs in the black sandstones and shales of the middle-upper part of the Shinatani formation (upper Pliensbachian-Toarcian) in common with *Parallelodon* sp., *Grammatodon* (?) sp., *Modiolus* sp., *Arcomytilus* sp., *Mytilus* (*Falcimytilus*) *stricapillatus* Hayami, *Isognomon* (*Mytiloperna*) *ageroensis* Hayami*, *Isognomon* sp., *Ostrea* sp., *Crenotrapezium kurumense* Hayami, *Eomiodon vulgaris* Hayami, *Protocardia kurumensis* Hayami*, *Homomya satoi* Hayami*, *Thracia* sp., *Cuspidaria* (? sp. and *Pseudotrapezium* sp. *Bakevellia magnissima* is accompanied by *Eopecten* ? sp., *Cardinioides* ? sp., *Crenotrapezium kurumense* and *Eomiodon vulgaris* in the lower-middle part of the Iwamuro formation and by *Isognomon* sp., *Crenotrapezium kurumense* n. subsp., *Eomiodon vulgaris*, etc. in the $Y_1$ member of the Yamaoku formation. There is no good evidence of the upper Liassic age for these two fossil beds, but they are provisionally correlated to the Shinatani formation in view of the similar aspect of pelecypod assemblage.

(8) *Meleagrinella* sp. faunle (J1, probably J1e or J1f, Loc. 51)

*Meleagrinella* sp., *Oxytoma* sp. and *Nuculana* (*Dacryomya*) sp. constitute a small faunule in the $Y_2$ member of the Yamaoku formation.

(9) *Geratrigonia kurumensis* faunule (J1f, Loc. 50)

*Geratrigonia kurumensis* Kobayashi* and *Oxytoma* sp., though rarely, occur in the marine sandy shales of the Otakidani formation of the Inugatake area. Upper Toarcian age is indicated by the occurrence of *Grammoceras* and *Hammatoceras*.

(10) *Inoceramus hamadae* faunule (J3a)

*Inoceramus hamadae* Hayami* occurs in the Kaizara formation (Callovian) in Kuzuryu area. The formation is mostly composed of ammonite bearing shales, and pelecypods are uncommon except some inoceramids, posidoniids and pectinids. "*Katroliceras*" *yokoyamai*, *Kepplerites* (*Seymourites*) *japonicus*, *K.* (*S.*) *acuticostum*, *K.* (*S.*) *kuzuryuensis*, "*Grossouvria*" *hikii* and some oppeliids are known, but the biostratigraphy of this formation should be further examined in future.

(11) *Inoceramus* cf. *nitescens* faunule (J3b)

*Inoceramus* cf. *nitescens* ARKELL* and *I.* (?) *naganoensis* HAYAMI* occur in the "Nagano formation" of the Kuzuryu area. *Inoceramus nitescens* was established from the Corallian of England, and the occurrence of its comparable form agree well with the chronology suggested by *Kranaosphinctes matsushimai*. An inoceramid from the similar black shale of Shimohambara area seems close to cf. *nitescens*.

(12) *Latitrigonia tetoriensis* faunule (J2b)

This faunule is represented by *Latitrigonia tetoriensis* KOBAYASHI* *L. orbicularis* KOBAYASHI* and *Myophorella* (*Promyophorella*) *orientalis* KOBAYASHI and TAMURA from the Oxfordian Yambarazaka formation of the Kuzuryu area. This faunule must be nearly coeval with the preceding, though the lithology is somewhat different from the "Nagano formation".

(13) *Nipponitrigonia sagawai* faunule (J3b)

*Nipponitrigonia sagawai* (YEHARA), *Myophorella* (*Promyophorella*) *imamurai* KOBAYASHI*, *Nuculana* sp., *Coelastarte* sp., *Tancredia* sp. and *Protocardia* sp. are common in the Kiritani formation of the Jinzu area (Oxfordian). *Nipponitrigonia sagawai* has a wide life range in the Soma area and Outer Zone of Southwest Japan, but the acmaeic development of the species in the Inner Zone is very unique. *Sagawai*-like trigoniid occurs in the *Inoceramus furukawensis* bearing Sugizaki sandy formation of the Furukawa area, which can be correlated to the Kiritani formation.

14) *Inoceramus maedae* faunule (J3b)

*Inoceramus maedae* HAYAMI* including several varietal forms is characteristic in the lower part ($M_1$ member) of the Mitarai formation of Makito area. This marine formation is generally assigned to the Oxfordian invasion phase, but the exact age is indeterminable.

(15) *Tetorimya carinata* faunule (J3b)

This faunule occurs in the tuffaceous siltstone of the middle part ($M_2$ member) of the Mitarai formation of the Makito area, and is composed of the following species: *Tetorimya carinata* HAYAMI*, *Nuculopsis* (*Palaeonucula*) *makitoensis* HAYAMI, *Modiolus maedae* HAYAMI, *Pinna* sp. ex gr. *sandsfootensis* ARKELL*, *Pteria* (s. l.) sp., *Chlamys mitaraiensis* HAYAMI, *Protocardia* sp., *Oxytoma tetoriensis* and *Thracia shokawensis* HAYAMI. Most of these species occur also in the $M_3$ member but the frequency of each species is much different. *Tetorimya* seems characteristic in the Upper Jurassic (mainly Oxfordian) of the boreal region. *Pinna sandsfootensis* was originally described from the Corallian of England.

(16) *Entolium inequivalue* faunule (J3b)

This is also a characteristic faunule occurring in the black shales of the upper part ($M_3$ member) of the Mitarai formation of the Makito area, and consists of the following species: *Entolium inequivalve* HAYAMI*, *Solemya suprajurensis* HAYAMI*, *Paraeoneilo* sp.*, *Nuculopsis* (*Palaeonucula*) *makitoensis* HAYAMI, *Modiolus maedae* HAYAMI, *Brachidontes* (?) sp., *Oxytoma tetoriensis* HAYAMI*, *Chlamys mitaraiensis* HAYAMI, *Camptonectes* sp.*, *Limatula iwayae* HAYAMI*, *Pleuromya hidensis* HAYAMI*, *Tetorimya carinata* HAYAMI (rare) and *Thracia shokawensis* HAYAMI. This is one of the richest marine pelecypod faunule in the Hida region, but the distribution of these species outside the Makito area is unknown except for a comparable form to *Thracia shokawensis* from the shaly part of the Kiritani formation. As I noted elsewhere, *Entolium inequivalve* resembles closely *E. orbiculare* from the European Cenomanian and *E. nummularis* from the Volgian and (?) Valanginian of Siberia and Spitzbergen. Generally, this faunule seems to be related to boreal faunas instead of the Torinosu and Tethyan faunas.

(17) *Vaugonia yambarensis* faunule (? J3c or later

*Vaugonia yambarensis* KOBAYASHI occurs in the conglomeratic Yambara formation of Kuzuryu area. But other marine pelecypods are unknown in the Itoshiro subgroup.

(18) "*Corbicula*" *tetoriensis* faunule

This is the most ubiquitous faunule in the brackish and non-marine beds of the Tetori group. "*Corbicula*" (*Mesocorbicula*) *tetoriensis* KOBAYASHI and SUZUKI* is accompanied by *Batissa antiqua* KOBAYASHI and SUZUKI*, *Pila nipponica*, *Malanoides vulgaris minima* in the Yanogidani formation of Furukawa, by *Batissa yokoyamai* KOBAYASHI and SUZUKI and *Melanoides vulgaris minima* in the Ushimaru formation of Makito, by "*Unio*" *ogamigoensis* KOBAYASHI and SUZUKI in Ogamigo, and by *Viviparus onogoensis*, *Pila nipponica*, *Melanoides vulgaris* and *M. vulgaris minima* in the Izuki formation of Kuzuryu. This faunule is thus found both in the Kuzuryu and Itoshiro subgroups, and the range may cover the greater part of the Upper Jurassic.

### 3) Nagato region

In the Nagato region the Jurassic System was represented by the Toyora and (?) Toyonishi groups, but the occurrence of pelecypods is restricted to a few horizons in the former group. In the lower part of the Toyora group considerable number of lower Liassic pelecypods occur fairly commonly, while in the middle-upper part ammonite-bearing shaly facies is predominant and pelecypods are quite rare except for several inoceramids and posidoniids.

(1) *Cardinia toriyamai* faunule (J1b, Locs. 53, 55, 57

This is one of the richest faunules in the Japanese Jurassic, and found in the lower part (Nbc, Nbs by MATSUMOTO and ONO, 1947) of the Higashinagano formation in the Toyora area. It comprises the following species: *Cardinia toriyamai* HAYAMI*, *Nuculopsis* (*Palaeonucula*) sp., *Nuculana* (*Dacryomya*) *toriyamae* HAYAMI, *Parallelodon infraliassicus* HAYAMI*, *P.* cf. *infraliassicus* HAYAMI*, *P.* (?) *subnavicellus* HAYAMI*, *Grammatodon toyorensis* HAYAMI*, *Oxytoma* cf. *cygnipes* (YOUNG and BIRD)*, *Chlamys textoria* (SCHLOTHEIM), "*Aequipecten*" *toyorensis* HAYAMI, "*A.*" sp., *Entolium* cf. *calvum* (GOLDFUSS), *Entolium* (?) sp., *Plicatula subcircularis* HAYAMI*, *Plicatula praenipponica* HAYAMI*, *Plagiostoma kobayashii* HAYAMI*, *P. matsumotoi* HAYAMI*, *Antiquilima nagatoensis* HAYAMI*, *Ctenostreon japonicus* HAYAMI*, *C.* sp., *Liostrea toyorensis* HAYAMI*, *Lopha sazanami* HAYAMI*, *Prosogyrotrigonia inouyei* (YEHARA) (varietal form), *Praeconia* cf. *tetragona* (TERQUEM)*, *Astarte* spp., *Fimbria* sp.*, *Sphaeriola nipponica* HAYAMI*, *Lucina hasei* HAYAMI*, *Cardium* (s. l.) *naganoense* HAYAMI*, *Neritopsis mutabilis* HAYAMI*, *N. elegans* HAYAMI*, *Promathildia* sp. ex gr. *turritella* (DUNKER)*, *Pictavia toyorana* HAYAMI*, *Pseudomelania* (?) sp., "*Dentalium*" sp., *Juraphillites* sp.*, *Rimirhynchia* sp.*, *Chomatoseris cyclitoides* (YABE and EGUCHI)* and *Isastrea* sp. The age must be somewhere in lower Lias. As I noted before (1959, p. 39), many species of the faunule are allied to the lower Liassic faunas of the Western Europe, north Africa, Amur, Sichota Alins and western Canada.

(2) *Prosogyrotrigonia inouyei* faunule (J1b, Locs. 52, 54, 56, 58)

*Prosogyrotrigonia inouyei* (YEHARA) is contained in the preceding faunule, but more abundant in the middle part of the Higashinagano formation. The associated species are *Nuculana* (*Dacryomya*) *toriyamae* HAYAMI, *Modiolus magatama* HAYAMI*, *Meleagrinella japonica* HAYAMI, "*Aequipecten*" *toyorensis* HAYAMI, *Entolium* cf. *calvum* (GOLDFUUSS) and *Plagiostoma matsumotoi* HAYAMI. *Chomatoseris cyclolitoides* is especially common in this part.

(3) *Oxytoma kobayashii* faunule (J1c, Loc. 59)

This faunule is found sporadically in the upper part of the Higashinagano formation, and consists of *Oxytoma kobayashii* HAYAMI*, *O. inequivalvis* (SOWERBY), *Meleagrinella japonica* HAYAMI, *Entolium* sp., *Plagiostoma* sp. and "*Lima*" sp.

(4) *Parainoceramus lunaris* faunule (J1e, Loc. 60, etc.)

*Parainoceramus lunaris* HAYAMI*, *Amonotis* n. sp.* (Pl. 1, Fig. 7) and many aptychi are characteristic in the lower part of the Nishinakayama formation (Ne zone). Associate ammonites, *Fontanelliceras* cf. *fontanellense**, *Fuciniceras primordium** and *Paltarpites toyoranus** indicate upper Pliensbachian age.

(5) *Parainoceramus matsumotoi* faunule (J1f, Loc. 61, etc.)

*Parainoceramus matsumotoi* HAYAMI* and its comparable forms are characteristic in the middle-upper part (Nd zone and partly Ng zone) of the Nishinakayama formation. They associated with *Hildoceras chrysantemum*, *H. inouyei*, *H. densicostatum*, *Harpoceras okadai*, *Peronoceras subfibulatum*, *Dactylioceras helianthoides* and some aptychi. This member was correlated to *Commune* and *Falcifer* Zones by ARKELL (1956).

(6) *Posidonia* sp. ex gr. *ornati* faunule (J1f, Loc. 62, etc.)

*Posidonia* sp. ex gr. *ornati* QUENSTEDT* forms a striking bed in the lower part of the Utano formation (Up beds) of the Toyora area (Pl. 1, Fig. 6). *Phymatoceras toyoranum* was found nearby, and the age is assignable to Aalenian.

(7) *Inoceramus* sp. ex gr. *fuscus* faunule (J1g, Loc. 62, etc.)

*Inoceramus* sp. ex gr. *fuscus* QUENSTEDT* occurs in the lower part of the Utano formation (Uh beds). *Hammatoceras* cf. *kitakamiense* and *Dumortieria?* sp. from this horizon suggest Aalenian age. *Inoceramus fuscus* is known in the Aalenian and lower Bajocian of Western Europe.

(8) *Inoceramus utanoensis* faunule (J2c or J3a, Loc. 81)

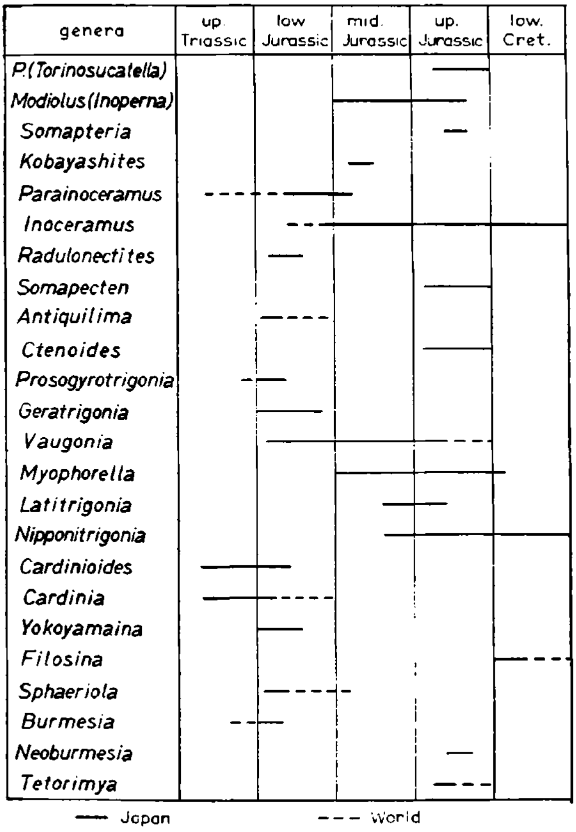
This faunule consists of *Inoceramus utanoensis* KOBAYASHI* and *I. ogurai* KOBAYASHI* from the upper part of the Utano formation. The age is unknown in detail, but the upper Middle Jurassic or lower Upper Jurassic in view of the resemblance of *utanoensis* with *Inoceramus kystatymensis* and *I. retrorsus* which are characteristic in the Bathonio-Callovian of boreal region.

These faunules include the main Jurassic pelecypod species hitherto known in the Kitakami, Hida and Nagato regions. Their life ranges should be further checked by more careful fossil-huntings, but such specific assemblages may serve to a certain extent for age determination of pelecypod-bearing strata which will be found in Japan and her surroundings in future.

Jurassic pelecypod genera have generally wide ranges and there are only a few useful genera for detailed chronology. But if compared with Upper

Table 4.

RANGE OF SOME CHARACTERISTIC PELECYPOD GENERA



Triassic faunas, the generic assemblage of Liassic faunas are clearly different. On the other hand no striking faunal gap exists between Upper Jurassic and Lower Cretaceous; it is very hard to distinguish the two by means of generic assemblage. The range of pelecypod genera frequently varies between Europe ane Pacific regions. *Oxytoma, Cadinia, Vaugonia, Coelastarte, Arcomytilus, Eomiodon* and some other genera seem to have appeared in Japan much earlier than in Europe. Several genera, which are treated in Table 4 seem to have appeared or disappeared at certain stages of Jurassic, and may be useful for rough estimaation of faunal age.

## III. Biofacies and Palaeoecology

As the result of my observations on the various fossil-coeneses in the Japanese Jurassic, it is concluded that the specific assemblage of pelecypods is closely connected with the mode of occurrence, lithofacies and therefore sedimentary environment. Since pelecypods are the most common fossil group in Jurassic of this country, they seem to constitute important facies-indicators for the palaeoecological work.

The Jurassic rocks of Kitakami, Hida and Toyora regions are mostly composed of terrigenous material, i. e. sandstones, shales and conglomerates. Pure limestone, dolomite, chert, phosphatic rocks, red beds and evaporites are unknown. In the Hida region detrital sediments unusually attain enormous thickness, and bituminous or carbonoceous sandstones and shales were rapidly accumulated in localized intermontane basins. The Kitakami region have been more flattened at that time: the topography is reflected in the comparatively thin sediments, scarceness of basal conglomerate and predominancy of ammonite-bearing shales showing calm deposition. Therefore, the sedimentary environment was probably somewhat apart from that of Hida.

In view of the rock- and bio-facies and their combination, however, there are many similar tendencies between the two regions. The Teradani formation of the Kuruma group and the Kaizara formation of the Tetori group are ammonite-bearing sandy-shales, and very similar to the Hosoura and Arato formations of Kitakami in the litho-facies and generic assemblage of pelecypods. The pelecypod faunules in the bituminous or carbonaceous rocks of the Hida region are fairly akin to those of the Shizukawa, Hashiura and Jusanhama groups in the generic assemblage and mode of occurrence. Such a facies is not predominant in the Toyora region but for some coaly layers near the base. But the change of litho- and bio-facies from the sandy Higashinagano to the shaly Nishinakayama formation is just comparable to the sequence from the Niranohama to the Hosoura formation in Kitakami. Taking rock-facies, mode of fossil-occurrence and faunal assemblage into consideration, the Jurassic fossiliferous sediments of these three regions can be roughly divided into three categories, namely, 1) Ammonite-facies, 2) Trigoniid-facies and 3) Cyrenoid-facies. These three facies are often seen in a stratigraphic column of one area. The trigoniid-facies (mainly littoral coarse sandstone facies is usually found at the passage from cyrenoid to ammonite-facies and *vice versa*, and indicates the initial or last stage of marine invasion into the basin, though trigoniid does not always occur. The ammonite-facies shows neritic and somewhat off-shore deposition, and the cyrenoid-facies lagoonal and sometimes brackish environment. The ratio of ammonite/pelecypod seem to support this interpretation. In the ammonite-facies ammonite species are generally not much smaller in number than pelecypod species, but in the trigoniid-facies ammonites are quite rare and fossils are mostly trigoniids, other thick-shelled pelecypods, belemnites and hexacorals. In the cyrenoid facies no ammonite has ever been found.

This division probably cannot be applied to the Upper Jurassic Torinosu group of the Outer Zone of Southwest Japan, because cyrenoid-facies is not represented and calcareous open-sea facies is very predominant. The distribution of the Torinosu pelecypods has been recently studied by TAMURA (1959-1960) in detail, and the Jurassic palaeoecology and facies division will become more complete by taking his data into consideration.

### 1 Mode of occurrence of organisms other than pelecypods

Before entering into the palaeoecological interpretation by pelecypods, I shall give a brief note on the distribution and mode of occurrence of ammonites, aptychi, belemnites, gastropods, brachiopods, hexacorals, echinoids and some other organisms found in the Jurassic of Japan.

#### 1 Ammonites and aptychi

Ammonites are fairly common in the neritic sandy shales or muddy shales which are more or less characteristic of the inundation phases in the Northeast and Inner Zone of Southwest Japan. In such shaly strata as the Nishinakayama, Hosoura, Teradani, Tsunakizaka, Kaizara and upper Kogoshio formations the individuals are assembled in some narrow and mainly massive part. *Parainoceramus, Inoceramus, Posidonia, Amonotis, Oxytoma* and *Variamussium* sometimes associate with ammonites in the Lower and Middle Jurassic, and *Inoceramus, Astarte, Limatula* and some other relatively thin-shelled pelecypods in the Upper Jurassic. The relation of shell-form of ammonites to sedimentary environment was observed by some authors. Sharp-edged discoidal ammonites with comparatively smooth surface are said to be common generally in fine-grained rocks such as marls and clays, while highly ornamented benthonic forms seem predominant in calcareous or detrital shelly facies. In the Japanese Jurassic discoidal or planulate species are fairly common in muddy or fine sandy facies, but thick and highly ornamented forms appear comparatively rare.

Aptychi (mainly "*Cornaptychus*"), ammonites' opercula, are fairly common in two horizons of the Nishinakayama shaly formation altogether with some thin-shelled and fragile pelecypods and small ammonites (Pl. 1, Figs. 2-4). There aptychi form more or less characteristic "Aptychien schiefer" in the highly fissile shales of Ne and Nd members which are composed of frequent alternation of whity silty and greyish muddy layers and show relatively calm environment. It is supposed that aptychi and small ammonites have been transported to different places by weak current. The present isolated specimens of aptychi, especially the larger ones (figs. 2-3), are fairly similar to *Cornaptychus nagatoensis* NAGAO, 1932, from the same horizon in the external feature and outline. But it is difficult at present to determine their specific reference because there are more than two species of hildoceratids in the fossil bed. Aptychi *in situ* are quite rare, but a harpoceratoid ammonite, probably "*Hildoceras*" *chrysanthemum* YOKOYAMA, from the Nd beds has an operculum near its aperture (Pl. I, Fig. 1). Though the whorls are flatly compressed, there is no doubt that the ammonite has not been drifted far from its habitat. In the Pliensbachian Teradani formation of the Kuruma group and the Upper Jurassic Sakamoto formation of the Torinosu group aptychi are known very sporadically. According to ARKELL (1956), "Aptychi are especially common in bituminous shales of the Toarcian and lower Kimmeridgian and in Tithonian limestones in many parts of the world." It is an interesting fact that these occurrences agree well with his statement.

### (2) Belemnites

Belemnites often associate with ammonites in the neritic shales but are also common in more coarse-grained sandstones and coquina-like littoral deposits. The difference of the occurrence of belemnites from ammonites may be partly due to the brittle test which can be preserved in much more agitated condition.

### (3) Gastropods

In the lower Higashinagano formation *Neritopsis*, *Promathildia* and *Pictavia* form striking fossil beds with *Grammatodon*, *Chlamys*, *Plagiostoma*, *Cardinia*, *Sphaeriola* and many other pelecypods (HAYAMI, 1960e). In the bituminous beds of the Shizukawa, Kuruma and Tetori groups brackish gastropods often associate with cyrenoid pelecypods (KOBAYASHI and SUZUKI, 1937, etc.). Jurassic gastropods are thus fairly common at certain horizons, but generally much rarer than pelecypods both in number of species and individuals. Gastropods at rocky shores are apt to be damaged and may be hard to be preserved in comparison with pelecypods. But the scarceness seems a general tendency both in the Triassic and Jurassic of Japan. More than 150 species of pelecypods were described from the Triassic of Japan, while only a few gastropods are known. I cannot adduce the reason with certain confidence, but maintain that the rarity may be partly due to the scarceness of calcareous deposits in the Triassic and Jurassic of the Kitakami, Hida and Nagato regions. In the Outer Zone the Upper Jurassic Torinosu group and upper Soma group contain nerineids and many other gastropods in the limestones and marls, while the coeval deposits are represented by clastic rocks in the North Japan and Inner Zone of Southwest Japan.

### (4) Brachiopods

Generally, brachiopods except for lingulae seem common in more off-shore facies than normal pelecypods. In the Outer Zone rhynchonellids and terebratulids are commonly found in the limestones and somewhat siliceous shales of the Torinosu group at Miyakodani, Sakawa and Nomazaki and the Naradani formation at Sakawa and Sakamoto (TOKUYAMA, 1957, 1958, 1959; TAMURA, 1960). But brachiopods are comparatively rare in the Kitakami, Hida and Nagato regions. It may be also due to the scarceness of calcareous open-sea deposits. Only a few rhynchonellids are found in the fine sandstones of the Higashinagano and Aratozaki formations and black shales of the Kogoshio formation. In the Aratozaki numerous valves of a small rhynchonellid are contained in certain layers together with fragile right valves of *Oxytoma* and some other thin pelecypods.

(5) Hexacorals

Many species of reef-building hexacorals were described by EGUCHI (1942, 1951) from the Torinosu limestone of the Outer Zone. *Isastraea* and some other colonial corals are found also in the trigoniid-sandstones of the Kitakami and Nagato regions. They are hermatypic but probably not reef-builders, since neither reef limestone nor bioherm is known in the regions. The distribution of reef corals is restricted to the shallow clear waters of tropics, but one must pay attention to the fact chat hermatypic corals survive also in temperate areas without forming striking reefs. Some dendritic corals are found in reworked pebbles of black impure limestone of the lower Kogoshio formation of Kitakami and remind one of their similarity to the Torinosu limestone, but there is no other limy facies in the Kitakami, Hida and Nagato Jurassics. The scarceness of corals in ammonite-bearing shales is probably due to the inadequate factors for coral life. Although there is no indication for the temperature of the sea-waters at present, it is highly probable that the stagnant muddy bottom condition and rapid sedimentation arrested the development of reef corals. Solitary corals are abundant in the lower Higashinagano and upper Kogoshio formations. *Chomatoseris cyclolitoides* from the Higashinagano is hermatypic and probably a sandy inhabitant of more or less agitated neritic or littoral condition. *Trochocyathus* (*Platycyathus*) sp. from the Kogoshio is ahermatypic, and probably lived on muddy bottom of fairly deep and cool condition. (HAYAMI, SUGITA and NAGUMO, 1960). The small basal plate of the corallum suggest a calm environment. According to WELLS (1956, 1957), *Trochocyathus* (*Platycyathus*) is known from the depth of 366-549 meters in recent seas, and there is a maximum development of ahermatypic coral species between 180 and 360 meters, near the margins of continental shelves in the "mud line" of MURRAY, though the distribution is less restricted ecologically than hermatypics'.

(6) Stromatoporoids

Stromatoporoids often associate with hermatypic corals in the Torinosu limestone (YABE and SUGIYAMA, 1940, 1935, etc.), but no definite specimen is found in the Kitakami, Hida and Nagato Jurassics.

(7) Crinoids

Columnar stellates of a pentacrinid occur in the lower Higashinagano formation (Pl. 2, Fig. 1). But no planktonic form is known in the Kitakami, Hida and Nagato regions.

(8) Echinoids

Numerous spines and a few bodies of "*Cidaris*" are contained in the calcareous rocks of the Naradani, Torinosu and Soma groups, but echinoids seem uncommon in the Kitakami, Hida and Nagato regions. Only a few specimens were found in the Kogoshio, Teradani and Kaizara formations. Echinoids are generally said to dislike mud, which presumably clogs their water system and to be found of sandy or limy bottom under clear water. The rarity of echinoids in these regions is probably due to the inpredominancy of calcareous and clear water condition.

(9) Plants

The predominancy of fossil plants is a striking feature in the bituminous beds of the Inner Zone of Southwest Japan. Many species of plants were described or listed by YOKOYAMA, OISHI, KIMURA and others from the Kuruma and Tetori groups. Gregarious plant beds are generally considered as brackish or non-marine sediments, because no marine fossils are found therein. In the Kuruma group especially the Kitamatadani, Negoya and Shinatani formations plant beds with *Cladophlebis*, *Nilssonia*, *Equisetites*, *Dictyophyllum* and other leaves alternate with cyrenoid shell-banks characterized by *Bakevellia*, *Eomiodon* and *Crenotrapezium*. Such a relation between plants and cyrenoids is seen also in the Tetori group, Iwamuro and Yamaoku formations. In the Kitakami and Nagato regions the Jurassic is represented properly by marine deposits, and plant beds are restricted to several horizons of the lower Niranohama, Oginohama, Mone and Kogoshio formations of Kitakami and Utano formation of Nagato. Drift woods are, however, fairly common in marine beds especially in the ammonite-bearing shales of Kitakami and Nagato. The oldest fossil forest in this country is known in the upper Liassic Shinatani formation. Many giant stems of *Equisetites* stand subvertically to the bedding plane, and *Eomiodon* beds and striking ripple marks are found near its base. The fact reminds enough one of the *Equisetites* forest, which grew near the shore of an embayment.

## 2) Pelecypod facies in the Kitakami Jurassic

The change of bio-facies and sedimentary environment of the Kitakami region is well typified by the sequence of the Shizukawa area. I intend to describe and discuss the biofacies of the Lower Jurassic on the basis of the field observation in the environs of Shizukawa in some detail, and then to deal with generalities.

(1) Lower Jurassic biofacies in the environs of Shizukawa

As stated in the article for stratigraphy, the Jurassic sedimentation of Shizukawa area began with the lower Niranohama formation under profound embayment condition. The bituminous rock-facies, abundance of cyrenoid pelecypods and absence of ammonites, belemnites and other purely marine organisms tell that it was accumulated in a kind of lagoonal condition, where waters may have been stagnant. There are abundant bituminous material and pyrite deposits which were probably originated in hydrogen sulphide.

The embayment must have been restricted from open sea in its front by a spit or a certain barrier, which prevented waves and coastal currents from entering. Little is known of the salinity of the embayment, but it was presumably not much lower than open sea, so far as can be judged from the assemblage of pelecypod genera. The fauna of the lower Niranohama formation has been called "cyrenids", because of the misidentification of two species with *Cyrena* (=*Corbicula*), a brackish or fresh-water genus in Tertiary and Recent times. But as the result of my palaeontological study they are most certainly nearly marine. Besides, *Palallelodon, Modiolus, Bakevellia, Isognomon, Pteria* (s. l.), "*Ostrea*", *Geratrigonia, Thracia, Cuspidaria,* (?) and *Burmesia* are found in association with them (HAYAMI, 1958c, 1959a etc.). The occurrence of *Camptonectes* in the same horizon of the Mizunuma area may support this interpretation, since pectinids probably cannot survive under much decreased salinity. Most trigoniids are characteristic in the neritic or littoral deposits such as the overlying upper Niranohama formation. But *Geratrigonia* alone is very predominant in these cyrenoid beds not only in Shizukawa but also Hashiura and Mizunuma areas.

Fossils, chiefly *Eomiodon* (?) *giganteus* in the less bituminous sandy layers of the Niranohama ($Nh_3$ member), seem sometimes autochthonous in view of the scattered occurrence and subvertical orientation of the comissure plane. However, most fossils of the lower Niranohama are very crowded in several banks and, if pelecypod valves are intact with ligaments, must be allochthonous. Generally speaking, in a stagnant embayment, oxygen is gradually decreasing and hydrogen sulphide increasing towards the bottom, where black muds are accumulated and no organisms but for anaerobic bacteria can inhabit. These crowded fossils were presumably derived from the communities which flourished in less reducing and probably shallower environments. Generic and specific assemblages of pelecypods is much different among fossil beds, but two types of community can be distinguished. In some beds *Geratrigonia, Isognomon, Pteria* (s. l.) and some other genera indicating high salinity occur commonly with *Bakevellia, Modiolus, Eomiodon* and *Yokoyamaina* (*Geratrigonia*-subfacies), while in some other banks the former three genera cannot be found and the fauna is composed of the latter four genera (*Bakevellia*-subfacies). *Bakevellia* and *Eomiodon* are probably euryhaline genera, and could adapt to wide environment of unstable salinity. Incidentally it has been known that the number of constituent species decreases in brackish faunas and that the number of individuals, however, often become larger than marine ones. THIENEMANN's law seems to hold true in this case.

In some shaly layers *Thracia, Cuspidaria* (?) and juvenile *Bakevellia* and *Eomiodon* are gregariously assembled. These thin pelecypods may be inhabitants on muddy bottom, but the differential occurrence may be partly due to the sorting by weak currents. "*Ostrea*" has a marked tendency to make extremely crowded banks which look at a glance limestone layers and to exclude other pelecypods. It is probably due to temporal explosive propagation of oysters in the embayment.

The cyrenoid-bearing bituminous rocks merges upwards with the very coarse sandstones of the upper Niranohama formation with striking *Vaugonia* banks. Numerous valves of *Vaugonia, Cucullcea* and *Coelastarte* form many banks, but no intact specimen is found. The shells are often fragmental and surface-ornaments frequently effaced mechanically by waves. Sometimes gastropods, belemnites and hexacorals associate with them, but organisms with thin shells are scarcely met with. At the basal part a thin layer of shell sands is found and cross-laminations are often developed. The overlying sandy shales ($Ns_2$ member) show striking intraformational foldings, and their reworked pebbles are abundantly contained in trigoniid-banks. These facts indicate that the sedimentation was carried out under fairly agitated waters of littoral zone. I cannot presume that the vaugoniid fauna was living in such a condition, because in modern sandy beaches the strongly agitated waters may forbid the life of pelecypods except for a few subplanktonic forms such as *Donax* which show unique method of rhythmic migration near the shore-line.

Generally a thanatocoenesis of recent benthonic mollusks at sandy beach is mostly composed of littoral and inner neritic elements which are the inhabitants of about 30 meters at the deepest. The constituents of the upper Niranohama fauna seem to have derived from such a range of depth. There are a few individuals of *Bakevellia, Isognomon, Geratrigonia* and *Eomiodon* which are quite predominant in the embayment facies of the lower Niranohama. They were probably derived accidentally from the lagoons behind a certain barrier.

The uppermost part of the Niranohama formation is composed of finer well-sorted sandstones. *Vaugonia* occurs sporadically, and *Meleagrinella* and *Camptonectes* are characteristic in certain layers. This suggests less agitated and slightly more off-shore environment, and I distinguish it as *Meleagrinella*-subfacies from typical trigoniid sandstones.

The fine sandstones of the uppermost Niranohama alternate with and passing gradually into the dark grey sandy shales of the Hosoura formation. Its lower part (Hi member by SATO, 1957) is composed of well stratified sandy shales with considerable amount of sandy intercalations and yields *Vaugonia* and *Variamussium* at some localities. Free circulation of waters can be expected for the lithology. Its main part (Ha, Hl, Hh members by SATO, 1957) is dark and massive muddy shales and bears many calcareous nodules at the top. These members are believed to have been deposited in more off-shore and calm environments than the trigoniid-sandstones and *Variamussium*-sandy shales. Fossils are never autochthonous in the Hosoura formation but do not form so crowded beds as in the Niranohama. Sometimes thin intercalations of black sandstone are observed in Hl and Hh members, and *Trigonia, Vaugonia* and some other coastal pelecypods are crowded. In several cases it is very difficult to determine from field observation whether they are lenticular fossil beds or reworked pebbles of the underlying trigoniid-sandstone.

Ignoring these pelecypods, the organisms of the Hosoura sea are confined to ammonites, belemnites, several thin-shelled pelecypods such as *Inoceramus* (s. l.), *Pinna, Posidonia* and ill-preserved drift woods. Many individuals of *Posidonia* form colonies in the upper part. The Hosoura formation was deposited probably on neritic calm bottom, but the abundance of bituminous matter suggest that the environment was still limited from open sea by a certain barrier. In the Mizunuma area contemporaneous black shales yield some pelecypods of embayment facies, and trigoniid-sandstone is not developed. It may imply the presence of a meridional bay which was closed to the south.

The Aratozaki sandy formation covers disconformably the noduliferous muddy shales of the Hosoura formation. Its basal part ($As_1$ member) yields *Cucullaea, Modiolus (Inoperna), Oxytoma, Camptonectes, Entolium, Ctenostreon, Trigonia, Vaugonia, Myophorella, Coelastarte, Isocyprina, Fimbria* (?), *Pholadomya,* minute ammonites, rhynchonellid and massive hexacorals in some small lenticular fossil banks along the basal plane. *Oxytoma* and brachiopod are especially common in thin layers of fine sandstone. The generic assemblage of pelecypods is at a glance similar to that of the upper Niranohama fauna, but the constituent species are much larger in number, in spite of the smaller number of individuals. Pectinids and some other pelecypods with relatively thin shells are common in this fauna and indicate neritic character rather than littoral. Considering the wide distribution of this fauna in the Kitakami region, the bio-facies may imply wider and less restricted environment than the trigoniid-sandstones of the Niranohama.

The main part of the Aratozaki formation is composed of conglomeratic coarse sandstones of littoral or deltaic origin, but its palaeoecology is not clear, since no fossils are contained except for some cyrenoids in bituminous intercalations. The small fauna comprises *Kobayashites, Isognomon, Protocardia* and *Eomiodon* (? and suggests that a certain local lagoonal condition may have been produced temporally at the time of the sedimentation of the coarse-grained material.

The second transgression and inundation in this area are indicated by the monotonous deposition of the Arato shaly formation. But the scarceness of fossils except for a few ammonites and inoceramids makes it difficult to analyze the palaeoecology by the change of bio-facies. In the lower part there are many sandy intercalations on which curious Lebensspuren are sometimes impressed (Pl. 1, Fig. 9). They are probably the crawling prints of a certain gastropod in shallow sea bottom or tidal flant. The overlying noduliferous muddy shales are lithologically similar to the uppermost part of the Hosoura formation, though the size of nodules is much smaller. The main part of the Arato formation is monotonous sandy or muddy shales and was deposited in off-shore and calm environment. The litho- and bio-facies are similar to the Hosoura formation in many aspects, and the two typify the ammonite-facies in the Kitakami and the Inner Zone of Southwest Japan.

(2) Cyrenoid-facies

Cyrenoid-facies, well typified by the lower Niranohama formation of Shizukawa, Hashiura and Mizunuma, are found at some other horizons in the south

Kitakami region, showing similarly enclosed environments.

In the Tsukinoura formation of Ojika, *Kobayashites, Parallelodon, Bakevellia* and *Eomiodon* form striking fossil banks in bituminous black shales. They seem to interfinger with *Chlamys*- and *Ctenostreon*-bearing coarse ferruginous sandstones towards the southwest, and it is highly probable that the *Kobayashites* beds were deposited in a stagnant lagoon which was isolated from an agitated sea of the south or west side.

The upper half of the Kitakami Jurassic is represented mainly by purely marine deposits except for some plant beds in the Mone, Kogoshio and Oginohama formations, and cyrenoid fauna has not been found. The Jusanhama group of the Hashiura area, which may be Lowermost Cretaceous, bears strikingly crowded fossil beds with *Filosina, Crenotrapezium, Protocardia, Corbula* (?) and *Cuspidaria* (?). The mother rock is not very bituminous, but the bio-facies is distinctly of this category.

(3) Trigoniid-facies

The gregarious occurrence of trigoniids (mainly *Vaugonia* and *Myophorella*) is intimately connected with coarse non-bituminous sandy lithology which shows littoral and much agitated environment. Such trigoniid sandstones, typified by the upper Niranohama formation of Shizukawa, are found at many horizons especially in the Kitakami and Soma Jurassics. The faunas of the lower Kosaba formation of Karakuwa and the Kodaijima formation of Ojika are nearly coeval with the Aratozaki fauna of Shizukawa, Hashiura and Mizunuma, and bear similar specific assemblages and mode of occurrence. The trigoniid sandstone of the Kosaba formation seems to pass gradually into *Isognomon*- and *Lopha*-bearing slightly bituminous sandstone towards the north, and the embayment at that time may have been open to the south. The trigoniid beds of the Tsukinoura formation is lithologically comparable with the upper Niranohama, but *Chlamys, Ctenostreon* and other neritic genera associate with *Vaugonia*.

In the Upper Jurassic of Kitakami, trigoniid sandstones are found in the Tashiro sandstone (upper Kozumi formation) of Ojika and the upper Mone formation of Karakuwa. *Myophorella* (*Promyophorella*) is the main constituent of the faunas, and *Myophorella* (*Haidaia*), *Nuculana* and some other neritic pelecypods occur in association in the latter beds. *Myophorella* (*Promyophorella*) is fairly common in the Kogoshio formation and Nagasaki-Isokusa blocks of Karakuwa, but it does not form striking trigoniid sandstones and occur in shales of much finer grain-size together with *Grammatodon, Astarte, Pinna* and other neritic (or even pelagic) pelecypods and ammonites.

The sand-grains of this facies are variable in size and mineral assemblage. The sandstones of the Niranohama and Aratozaki formations are fairly quartzose, while the Tashiro sandstone is very arkosic. The difference may be, however, due to the different states of backland instead of maturity or sedimentary environment, since Upper Jurassic sandstones of Kitakami and Soma regions are always much more arkosic than Middle and Lower Jurassic ones.

(4) Ammonite facies

Most individuals of Jurassic ammonites in the Kitakami region have been found in dark grey or black sandy or muddy shales such as the Hosoura and Arato formations of the Shizukawa area. A few specimens are found in sandy formations such as the Niranohama, Aratozaki and Kodaijima, but they seem rather accidental. The Samuraihama formation of Ojika and the Tsunakizaka formation of Karakuwa show similar litho- and bio-facies to the Arato formation of Shizukawa, Hashiura and Mizunuma. In the Tsunakizaka formation pelecypods are rare in comparison with ammonites, but *Inoceramus* and *Posidonia* are fairly common at some localities.

The upper part of the Kogoshio formation of Karakuwa and the main part of the Kozumi formation of Ojika are composed of black muddy shales and assigned to this category. But the generic assemblage of pelecypods are much different from the above mentioned ammonite beds of the Lower and Middle Jurassic. *Inoceramus* and *Posidonia* are unknown, while ammonites are usually accompanied by rich pelecypods such as *Nuculana* (*Praesaccella*), *Parallelodon*, *Grammatodon*, *Entolium*, *Limatula*, *Myophorella*, *Astarte* and *Pleuromya*. Such a generic assemblage is commonly seen in the shaly formations of the upper Soma and Torinosu groups, and indicates probably less restricted environments than *Inoceramus*-shales. The Kogoshio pelecypods are mostly small in size, and the tendency is seen also in the shaly formations of the Torinosu group. But it is not due to dwarfing by geographical isolation, since corresponding species are equally small in more sandy formations. The common occurrence of *Variamussium* cf. *habunokawense* and its exclusive tendency as seen in the Isokusa block suggest deep and more or less pelagic condition. OYAMA (1952) studied the ecological distribution of pectinids and noted *Propeamussium* and *Palliorum* can survive on deep muddy bottom where *Chlamys* and other pectinids cannot inhabit. Similar mode of life can be expected for *Propeamussium* and *Variamussium*, judging from the similar shell morphology. Such an ecology of *Variamussium* was studied also in the Torinosu group by TAMURA (1960d), and its coexistence with some species of *Entolium* and *Limatula* was announced. *Trochocyathus* (*Platycyathus*) is probably another facies-indicator of outer neritic or bathyal environment for the upper part of the Kogoshio formation.

### 3) Pelecypod Facies in the Hida and Nagato Jurassic

In the Jurassic of the Hida region cyrenoid-facies is very predominant, and bituminous or carbonaceous sandstones and shales occupy the greater part of all stratigraphical columns. Trigoniid sandstones are comparatively undeveloped in the lower half, though ammonite shales are found in some invasion stages. On the contrary in the Nagato region ammonite-facies is the most predominant, and trigoniid sandstones are restricted to the basal part, and cyrenoid-facies is absent at all. Thus the Jurassic fossiliferous rocks of the Inner Zone of Southwest Japan can be roughly divided also into three facies, though the proportion among the three is much different among areas. Since there are only a few common pelecypod species among Kitakami, Hida and Nagato, it is difficult to compare the bio-facies with that of Kitakami. However, as to the relation between the bio- and litho-facies there are many similar tendencies.

(1) Cyrenoid-facies

Bituminous (or carbonaceous) cyrenoid- and plant-bearing sandstones and black shales are widely distributed in the Kuruma group (inclusive of the Iwamuro and Yamaoku formations) and Tetori group which were sedimented in intermontane basins. The Kitamatadani, Negoya, Shinatani and Tsuchizawa formations of the Kuruma group bear gregarious *Eomiodon* beds at many horizons. Other ubiquitous genera are *Mytilus* (*Falcimytilus*), *Bakevellia*, *Isognomon* and *Crenotrapezium*, and they are frequently accompanied by *Chlamys*, "*Camptonectes*", *Radulonectites*, ostreids, *Cardinioides*, *Protocardia* and *Homomya*. These pelecypod beds are often adjacent to plant beds and probably accumulated under stagnant condition of profound embayment. Since pectinids cannot inhabit in much decreased salinity, the cyrenoid-fauna may be properly marine just as the lower Niranohama fauna of Kitakami. But in some cases, only *Bakevellia*, *Eomiodon* and *Crenotrapezium* form fossil banks. The absence of pure marine elements in such banks may indicate somewhat unstable salinity. The abundance of pyrite and chalcopyrite of sedimentary origin in the fossil beds is noticeable. It cannot be concluded always that the pelecypods are actually inhabitants in such a reduced condition, for none is exactly autochthonous except for a few doubtful cases. But pelecypods are often bivalved and free from secondary destruction and water-wear, and their transportation may be negligible in comparison with other facies.

The cyrenoid beds in the Iwamuro and Yamaoku formations contain similar pelecypod species to the Kuruma fauna, and the sedimentary condition is generally considered to be nearly the same.

"*Corbicula*" beds are commonly found in the Jurasso-Cretaceous Tetori group. The generic assemblage of the beds is, however, fairly different among localities, as pointed out by KOBAYASHI and SUZUKI (1937). At Ushimaru of the Makito area "*Corbicula*" (*Mesocorbicula*) and *Batissa* associate with *Ostrea* and some other brackish elements, while at Izuki of the Kuzuryu area main associated mollusks are *Pila*, *Melanoides* and *Viviparus*, and no definite marine or brackish genus is found. Anyhow, the smaller number of constituent pelecypod species and absence of any definite marine element may suggest restricted environment and much decreased salinity.

(2) Trigoniid-facies

Trigoniid sandstone is generally undeveloped in the Kuruma group, but the non-bituminous sandstones at the passages from ammonite-facies to cyrenoid-facies show similar lithological aspect to the trigoniid-facies of Kitakami. The lower part of the Shinatani formation is composed of well-sorted fine-medium massive sandstones, yielding *Chlamys*, "*Camptonectes*" and *Oxytoma*. Pectinid-bearing medium sandstone at Kamikawara of the Kuruma area is also comparable with this facies.

In the Tetori group (Kuzuryu subgroup) trigoniid-facies show local development in Jinzu, Furukawa, Arimine and Kuzuryu areas, of which the Kiritani conglomeratic sandstone of Jinzu with numerous valves of *Nipponitrigonia* and a few *Myophorella, Coelastarte, Nuculana* and *Tancredia* is the most striking. Similar assemblage is known also in the Sugizaki formation of Furukawa. *Myophorella* and *Latitrigonia* are known in the Yambara conglomerate and Yambarazaka sandy formations of Kuzuryu, but they do not form fossil banks.

In the Toyora region, similar sandstones are distributed in the basal part of the Higashinagano formation, and represent the initial stage of early Liassic transgression. As noted elsewhere (HAYAMI, 1959i), this formation does not yield trigoniids but for *Prosogyrotrigonia*, but the mode of occurrence, generic assemblage and lithology bear alliances to the trigoniid sandstones of Kitakami, especially to the lower Aratozaki formation. Hermatypic hexacorals, brachiopods, columnar stellates of a pentacrinid and highly ornamented gastropods are associate with the pelecypods in the fossil banks. The predominant pelecypod genera of the sandstone are *Parallelodon, Grammatodon, Chlamys,* "*Aequipecten*", *Entolium, Plicatula, Plagiostoma, Liostrea, Cardinia, Lucina* and *Sphaeriola*. No intact specimen of pelecypod is found, and thin pelecypod shells and apertures of gastropods are often broken. The fact suggests that the sedimentary condition is attributable to fairly agitated littoral and/or neritic bottom. The fossiliferous sandstone merges upwards with finer bluish sandstone of more off-shore origin which contains sporadically *Meleagrinella, Oxytoma, Entolium* and *Plagiostoma*. This subfacies may be ecologically corresponding to that of the *Meleagrinella* sandstone of the uppermost Niranohama formation of Kitakami.

(3) Ammonite-facies

Ammonites and inoceramids are fairly common in the Hida and Nagato regions, and their occurrence is properly confined to this facies characterized by dark grey or black sandy of muddy shales. The lithology is almost equal to the ammonite-facies of Kitakami, but in these two regions there are somewhat deviated subfacies characterized by the common occurrence of posidoniids, pectinids, myacids and aptychi.

In the Kuruma group of the Hida region the Teradani and Otakidani ammonite-bearing silty shales wedge themselves into the sequence of bituminous rocks (KOBAYASHI et al., 1957). They constitute two inundation phases. Inoceramids and posidonids are unknown at present in the formations, but the pelecypod faunules consisting of *Variamussium*? and *Pleuromya* in the Teradani and of *Geratrigonia* and *Oxytoma* in the Otakidani are quite different from other faunules of the Kuruma group. The $Y_2$ beds of the Yamaoku formation (KONISHI, 1954) bear *Nuculana, Meleagrinella* and some marine pelecypods, and lithologically belong to this facies.

The ammonite-facies developed in the Toyora group where the Lower to Middle Jurassic sequence is mostly occupied by ammonite- and inoceramid bearing muddy shales. The Nishinakayama formation is generally rich in ammonites and inoceramids (mainly *Parainoceramus*), and comprises also some characteristic aptychi- and *Amonotis*-shales at definite horizons. A considerable amount of thin valves of *Amonotis* are concentrated in a thin layer of the lower Nishinakayama formation (Ne beds) (Pl. 1, Fig. 7). The aptychi-shales in Ne and Ng beds show similar appearance (Pl. 1, Figs. 2, 3, 4). Thin valves of *Parainoceramus* and small ammonites occur in the shales, but no larger organism with heavy test is found in association. The lithology of the *Amonotis*- and aptychi-shales is well characterized by the numerous thin whity silty layers which alternate frequently with greyish muddy part and cause the high fissility of the rocks. The *Posidonia*-shales in the Up beds of the lower Utano formation (Pl. 1, Fig. 6) is not so fissile, but the fossil occurrence is very similar to the above cases. It may be rather inadequate to compare their sedimentary conditions to the "Aptychienschiefer" and "Posidonienschiefer" in Swabia and some other areas of Western Europe, whose petrography and bituminous matter have been precisely studied by many authors. But it is certain that these subfacies indicate very calm and stagnant bottom condition of an inland sea, where only thin shells such as aptychi could be differentially derived from their habitat.

The main part of the Utano formation yields some plant fossils, but is mostly occupied by marine sandy shales which contains inoceramids and a posidoniid in the upper part.

The Kaizara and Yambarazaka formations and their comparable marine strata are extensively distributed in the lower Tetori group (Kuzuryu subgroup) of the Hida plateau region. Perisphinctoids occur fairly commonly in the silty or muddy shales. *Inoceramus* seems to have adapted to the environment, and many individuals are found at many localities. But the specific assemblage is quite different among Kaizara, Nagano, lower Mitarai and Sugizaki formations. As noted before (HAYAMI, 1960c), small forms are predominant in the Kaizara and Nagano formations of Kuzuryu, while the Mitarai forms are quite large and inequivalve and remind at a glance one of certain Cretaceous species. The pelecypod fauna of the Mitarai formation (HAYAMI, 1959f, g) is the richest one in the ammonite facies of this country. It consists of *Solemya*, *Nuculopsis* (*Palaeonucula*), *Palaeoneilo*, *Modiolus*, *Pinna*, *Oxytoma*, *Chlamys*, *Camptonectes*, *Entolium*, *Limatula*, *Protocardia*, *Pleuromya*, *Tetorimya* and *Thracia* besides *Inoceramus*. The absence of trigoniid and scarceness of heterodont pelecypods with thick tests are noticeable. A whity tuffaceous siltstone is inserted in the middle part of the formation, where *Modiolus*, *Pinna* and *Tetorimya* occur sporadically showing autochthonous occurrence, as illuminated by MAEDA (1952b). Pectinids and myacids are more predominant in the dark muddy shales of the upper part. These pelecypods were probably fond of calm, muddy and somewhat deep bottom of inland sea.

### 4) Ecological distribution of pelecypod genera*

The occurrence of the following pelecypod genera is confined to some

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* The mode of occurrence of many Upper Jurassic pelecypods in the Soma and Torinosu groups studied by TAMURA (1959, etc.) is also taken into consideration.

definite sedimentary environment, if a few exceptional cases are ignored.

*Parallelodon* (s. s.) and *Cucullaea* (s. l.) are most common in gregarious trigoniid sandstones, but *Grammatodon* is found also in more off-shore facies. *Parallelodon* (*Torinosucatella*) is restricted to open-sea environment. All genera are quite rare in cyrenoid-facies.

*Modiolus* occurs in various facies, but *Modiolus* (*Inoperna*) could live in coastal environment of purely marine waters and *Mytilus* (*Falcimytilus*) is most predominant in embayment condition of somewhat unstable salinity.

*Bakevellia* shows a marked development and attain large size in the bituminous shales and sandstones of deep embayment facies in Kitakami and Hida regions, and almost always associate with *Eomiodon* and mytilids. Triassic and Cretaceous bakevelliids in Japan often occur in purely marine deposits and even in limestones, but in the Jurassic such an occurrence is not found.

*Isognomon* lives at present in littoral or neritic clear water of tropical and subtropical seas. Jurassic species except for subgenus *Mytiloperna*, are probably sessil benthos as Recent ones in view of the wide byssal gape, but their occurrence is restricted properly to bituminous cyrenoid-facies and only a few specimens were found in trigoniid- and ammonite-facies. *Inoceramus* and *Parainoceramus* are, on the contrary, most common in neritic silty shales and often associate with ammonites and *Posidonia*. Only a few specimens are found in trigoniid sandstones such as the lower Aratozaki and Kodaijima formations. It is a marked tendency that these three genera are absent at all in the calcareous facies of the Outer Zone of Southwest Japan.

*Oxytoma* and *Meleagrinella* form characteristic communities in neritic fine sandstones which seem to be slightly more off-shore than normal trigoniid sandstones. A few specimens are known in neritic silty shales.

*Entolium* and *Variamussium* are probably free-swinming scallops. The former is common in various neritic sandstones and shales, but the latter is restricted to more or less pelagic off-shore deposits. *Chlamys* and *Camptonectes* are neritic inhabitants but sometimes occur in trigoniid sandstones and even cyrenoid shales. *Plicatula* seems a stenopic group since it is very common in certain trigoniid sandstones but quite rare in other facies.

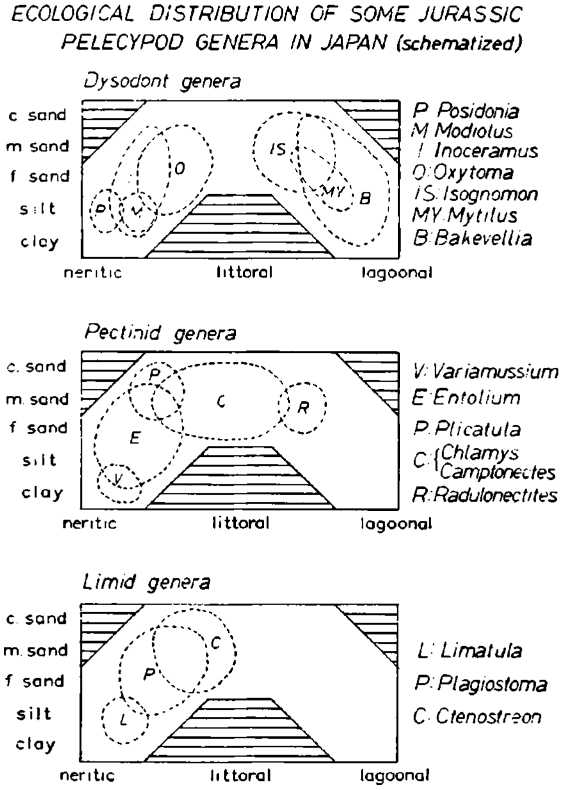
The occurrence of *Plagiostoma* and *Ctenostreon*, which are believed to have adhered to certain objects by means of byssi, is restricted to littoral and neritic sandstones, and trigoniids and pectinids are often found in association. But limids may be generally more stenohaline than pectinids in view of the absence of the former in the cyrenoid facies. Free swimming *Limatula* may have lived generally in more off-shore environment than other groups of the Limidae, and often is accompanied by *Entolium* and *Variamussium*.

*Geratrigonia* could live exceptionally in profound embayment condition altogether with *Bakevellia*, *Isognomon* and *Eomiodon*, but other trigoniids are restricted to purely marine conditions and form striking banks in agitated littoral coarse sandstones. They are also found in neritic shaly sediments, but it seems a general tendency that trigoniids in shales are smaller in size than those in sandstones.

*Cardinia* and *Coelastarte* occur in littoral and neritic sandstones with trigoniids, prionodonts and other pelecypods with heavy tests. *Astarte* seems more euripic but their occurrence is restricted to pure marine deposits and unknown in cyrenoid-facies. Most species hitherto listed as *Astarte* from such embayment facies, if they have concentric sculptures, may be referable to *Eomiodon* and some other genera of the Neomiodontidae.

*Eomiodon* is characteristic in bituminous shales and sandstones of deep embayment origin, and quite ubiquitous in the Lower and Middle Jurassic cyrenoid-faunas of Japan. The genus must have been able to adapt to unstable salinity. *Crenotrapezium*, *Filosina* and *Yokoyamaina* may have lived in similar environments. "*Corbicula*" (*Mesocorbicula*) and *Batissa* in the Tetori group are probably brackish or non-marine inhabitants, since it never associate with definite marine organisms.

Myacids with thin tests probably cannot adapt to much agitated condition. In view of their deep pallial sinus and mode of occurrence, they seem to have adapted to soft bottom of calm environment. *Pleuromya*, *Pholadomya* and *Tetorimya* occur in neritic silty or muddy shales, and *Burmesia* and *Cuspidaria* (?) in bituminous shales of embayment facies. *Thracia* seems quite euripic but occurs always in shales.



ECOLOGICAL DISTRIBUTION OF SOME JURASSIC PELECYPOD GENERA IN JAPAN (schematized)

Fig. 2-1.

According to TAMURA's and my observations on the Soma and Torinosu pelecypod faunas, *Entolium, Variamussium, Limatula* and *Ctenoides* are common in shaly part, *Plagiostoma, Camptonectes, Plicatula* and large species of trigoniids in sandstones, and pteriids and *Neoburmesia* in marly or limy rocks. *Grammatodon, Astarte* and *Protocardia* occur in various rock-types. Though the generic assemblage of the Soma-Torinosu fauna is much different from those of Kitakami and the Inner Zone, there are many similar tendencies about the ecological distribution of pelecypods. The tendencies also agree to a certain extent with GIGNOUX's observation (1926) on the European Jurassic pelecypods.

The ecological distribution of above mentioned pelecypod genera in the Kitakami, Hida and Nagato Jurassics is summerized in Fig. 2. The grain-size of mother rocks, which may reflect the nature of bottom, is an easily determinable factor (vertical axis). The degree of environment restriction (horizontal axis) is presumed from the maturity of grains, the ratio of ammonite/pelecypod, bituminous matter and mode of fossil occurrence, and the determination may be inevitably more or less subjective. But the distinctness of lithology and bio-facies among ammonite- (neritic), trigoniid- (littoral) and cyrenoid- (embayment) facies are fairly clear in the Jurassic areas dealt with in this paper, and it can be well ascertained from many stratigraphical columns that the trigoniid-facies appear at the passages from cyrenoid-facies to ammonite-facies and *vice versa*.

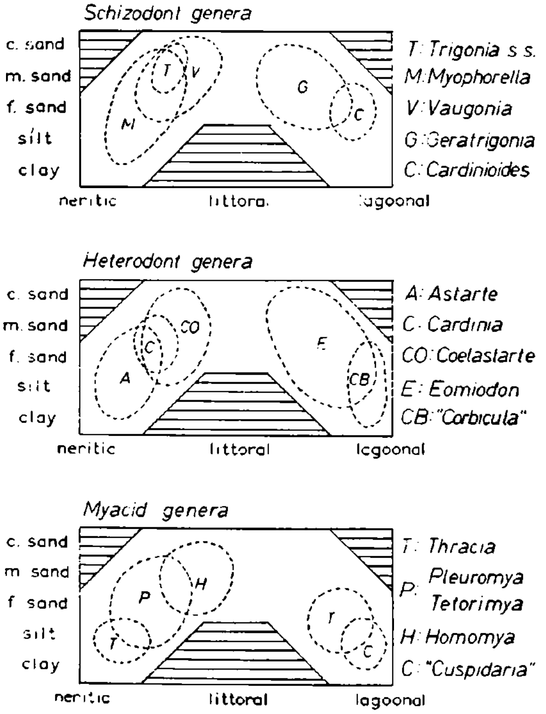


Fig. 2-2.

## IV. Palaeobiogeography

In Japan Jurassic sedimentary basins are highly localized. The fauna of each sedimentary region bears many characteristic elements and is clearly different from those other regions. It may be partly due to the heavy dependence of pelecypod distribution on sedimentary facies, but must be dependent also upon certain biogeographic isolation. Since the distribution is much related to litho-facies, the assemblages of pelecypod genera, which are summerized before, seem to represent to a certain extent some physico-chemical states of sedimentary environments (depth, bottom nature, salinity and state of water agitation). On the other hand, similar specific assemblages between two isolated regions must imply an intimate sea connection. If one finds two contemporaneous faunas of isolated basins are composed of similar genera and subgenera but quite different in specific assemblage, one can generally consider that their biogeographical connection is not intimate. In this article I estimate the faunal connections among various Jurassic sedimentary basins based on SIMPSON's indices for faunal resemblance, and discuss the palaeobiogeography in relation to the Jurassic surface feature of Japanese islands which can be deduced from many stratigraphical points. I intend also to make a brief review on the distribution and characters of the Jurassic pelecypods in the Indo-Pacific regions on the basis of many previous works.

### 1) Palaeobiogeography of Early Jurassic Sea in Japan and its Surroundings

It seems reasonable to consider the Jurassic biogeography of Japan separately in the early (Hettangian-Aalenian), middle (Bajocian-Bathonian) and later (Callovian-Berriasian) periods.

SATO (1956) noted that the Liassic ammonite faunas of the Toyora, Kuruma and Shizukawa are composed of fairly different elements, and that the localization must be explained by the discrepancy of sedimentary period or the sea connection with different trends. The Pliensbachian and Toarcian ammonites of the Toyora group (MATSUMOTO and ONO, 1947) bear a considerable amount of Tethyan (especially Italian) elements such as *Fontanelliceras* and *Fuciniceras* (ARKELL, 1956). The Pliensbachian ammonites of the Kuruma group are the mixture of a Tethyan element, *Canavaria*, and a boreal one, *Amaltheus* (SATO, 1955). The Sinemurian and Aalenian ammonites of the Shizukawa group is generally represented respectively by *Arnioceras* and *Hammatoceras* which are common in the southeastern Asia and some other areas of Pacific region. Bajocian and Aalenian ammonites of Alaska are said not to be boreal, and SATO (1956) noted the *Tmetoceras* fauna of the Hosoura formation shows marked affinities with those of south Alaska.

Similar localization is seen also in the Liassic pelecypod faunas. The pelecypod faunas of the Shizukawa, Kuruma and Toyora groups are respectively composed of 40, 52 and 48 forms (including species, subspecies, and varieties). However, there are only a few comparable species among the three groups (see Table 5). *Eomiodon vulgaris* occurs commonly in the cyrenoid shales of the Shizukawa and Kuruma groups, and *Entolium* cf. *calvum* does in the neritic sandy facies of the Kuruma and Toyora groups. But most other pelecypods are endemic in each sedimentary region. These three palaeobiogeographical provinces seem distinct in Early Jurassic times. The Kitakami province is well characterized by the prolific occurrence of *Geratrigonia*, *Vaugonia* and other trigoniids. The appearance of *Vaugonia* already in the Lower Lias is a striking feature in the Kitakami province. To the bituminous embayment conditions may have adapted *Bakevellia*, *Isognomon*, *Modiolus* and *Eomiodon* and some aberrant genera such as *Geratrigonia* and *Yokoyamaina*. It is of special interest that *Burmesia*, which is characteristic of the Noric-Rhaetic of Upper Burma, Indochina and Moluccas, occur in the basal part of the Kitakami Jurassic. If the resemblance of Sinemurian and Aalenian ammonites between Kitakami and Moluccas is also considered, the sea of Kitakami may have been intimately connected with the southwestern Pacific region.

In the Kuruma faunal province the cyrenoid faunas show a splendid development, adapting to the bituminous environment of profound embayment. *Bakevellia*, *Isognomon*, *Mytilus* (*Falcimytilus*), *Eomidon* and *Crenotrapezium* are represented by many forms and quite abundant, forming gregarious fossil banks. The generic assemblage is similar to the cyrenoid fauna in the similar facies of the Kitakami province, but the greater part is specifically distinct. The scarceness of cosmopolitan elements and predominance of specialized genera and species suggest a restricted province for the Kuruma fauna. *Cardinioides* and *Radulonectites* are two endemic genera of this province. The former genus is restricted to the Inner Zone also in Upper Triassic times.

The lower Liassic Higashinagano fauna of the Toyora province bear some cosmopolitan elements such as *Oxytoma inequivalvis*, *O.* cf. *cygnipes*, *Chlamys textoria*, *Entolium* cf. *calvum*, *E*, cf. *lunare* and *Praeconia* cf. *tetragona*. These species were originally described in Europe, and some of them later reported from the Lias of Madagascar, Moluccas, Amur, Sichota Alins, Alaska, Alberta, Nevada, Neuquén and some other regions of the world. Other Higashinagano species are mostly new, but their allied species are frequently found in the Lias of Europe, North Africa and Pacific regions. The resemblance of the pelecypods to the Amur fauna described by KIPARISOVA (1952) is noteworthy, since the connection of the Toyora sea to the north has not been reported. The Tethyan similarity of the Pliensbachian and Toarcian inoceramids and posidoniids agrees well with that of the ammonite fauna. The flourish of *Posidonia* and *Parainoceramus* in the upper Lias is known also in the western Tethys region especially in Alps and Caucasus. In the eastern Tethys region, however, Liassic fauna is not represented enough to discuss further the sea connection between eastern Asia and Europe.

If the occurrence of *Haugia japonica* (NEUMAYR) from "Mitoda of Sakawa basin" is erroneous, there is no indication for the presence of Lias in the Outer Zone of Southwest Japan. But in view of the similar assemblage of Torinosu pelecypod genera to Higashinagano, Liassic pelecypods, if discovered in the Outer Zone in future, may be composed of similar elements to the

Higashinagano fauna.

SIMPSON (1959) mentioned several indices to express the degree of faunal resemblance between two isolated areas and discussed their adequacy in various cases. One of his indices, $\frac{100C}{N_1}$, is introduced here and calculated about the faunal resemblance among Lower Jurassic pelecypod species and genera (independently) of Shizukawa, Iwamuro, Kuruma, Yamaoku and Toyora areas. Here $N_1$ is the number of constituent species (or genera) of smaller fauna, and C is common species (or genera) between two faunas. Comparable species, subspecies and doubtful occurrence are counted as 0.5. In Table 5, the numerator is the index of specific resemblance and the denominator of generic resemblance. In this case, it is safely concluded that the Toyora fauna is quite different from other faunas both in specific and generic assemblages. The Shizukawa fauna is fairly similar to the Kuruma in generic assemblage but specifically quite different. The Iwamuro and Yamaoku faunas, though their constituents may be too small to discuss the palaeobiogeography, seem to be quite intimate to the Kuruma fauna.

Table 5.

FAUNAL RESEMBLANCE IN THE LOWER JURASSIC

| fauna | $\frac{\text{species}}{\text{genera}}$ | Shizukawa | Iwamuro | Kuruma | Yamaoku | Toyora | |
|---|---|---|---|---|---|---|---|
| SHIZUKAWA | $\frac{40}{27}$ | | $\frac{1}{2}$ | $\frac{2}{15.5}$ | $\frac{1}{4}$ | $\frac{0}{7.5}$ | $\frac{\text{number of common species}}{\text{number of common genera}}$ |
| IWAMURO | $\frac{5}{5}$ | $\frac{20.0}{40.0}$ | | $\frac{3}{4}$ | $\frac{3}{3}$ | $\frac{0}{0}$ | |
| KURUMA | $\frac{52}{26}$ | $\frac{5.0}{59.6}$ | $\frac{60.0}{80.0}$ | | $\frac{3}{4}$ | $\frac{1}{8}$ | |
| YAMAOKU | $\frac{6}{6}$ | $\frac{16.7}{66.7}$ | $\frac{60.0}{60.0}$ | $\frac{50.0}{66.7}$ | | $\frac{0}{1}$ | |
| TOYORA | $\frac{48}{31}$ | $\frac{0}{27.8}$ | $\frac{0}{0}$ | $\frac{2.1}{30.8}$ | $\frac{0}{16.7}$ | | |
| | | Simpson's formula $\frac{100C}{N_1}$ | | | | | |

## 2. Palaeobiogeography of Middle Jurassic Sea in Japan and its Srroundings

The Bajocian Aratozaki fauna of Kitakami bears some allied forms to cosmopolitan species, such as *Oxytoma münsteri*, *Camptonectes auritus*, *Entolium disciforme* and *Ctenostreon proboscideum*. But the occurrence of *Vaugonia* (s. s. and *Hijitrigonia*), *Cucullaea* and *Coelastarte*, some of which are hardly distinguishable from the species of the lower Liassic Niranohama formation, reminds one of the peculiarity of the Kitakami province in the Lias. *Inoceramus morii* from the Aratozaki and *I.* cf. *lucifer* from the Tsunakizaka formation are intimate respectively to *I. subambiguus* from the Aalenian of Okhotsk and *I.*

*lucifer* from the Bajocian of Alaska and Prince Patrick. In this period stephanoceratids seem to have travelled far to the northern area, and there may have been certain temporal faunal connection with those regions. Middle Jurassic pelecypod faunas seem rather rare in other regions than Kitakami mountainland. A trigoniid fauna of the Bajocio-Bathonian Awazu formation of Soma comprises *Vaugonia, Latitrigonia, Ibotrigonia* and *Nipponitrigonia,* and is more akin to Upper Jurassic faunas than Lower Jurassic ones in general aspect. TOKUYAMA (1958) noted that the brachiopod fauna of the Narakani formation of the Sakawa basin is of Bajocio-Bathonian, but associated pelecypods are too poor to be regarded as the representatives of the fauna on the Pacific coast. It is of special interest that *Inoceramus utanoensis* from the upper Utano formation of the Toyora area is probably conspecific with *I. kystatymensis* from the Bathonian of Lena. It may be an element of boreal sea, since its allied species such as *I. retrorsus* seem very characteristic in the Bathonian-Callovian of Siberia and Greenland. But no associated species with the *Inoceramus* are known in the upper Utano formation, and the palaeobiogeographical relationship with other regions cannot be further discussed.

### 3) Palaeobiogeography of Late Jurassic Sea in Japan and its Surroundings

The late Jurassic sedimentary areas are much different from early Jurassic ones. Four palaeobiogeographic provinces are distinguished in the Upper Jurassic of Japan: they are Kitakami, Hida (Tetori), Soma and Torinosu provinces.

In many areas of the Kitakami region the Middle and Upper Jurassic overlaps the Lower, and marine realm was much more extensive. But the number of pelecypods is rather inferior to the Lower both in species and individuals. It is probably because of the scarceness of embayment and littoral deposits where normal pelecypods are most common. The Upper Jurassic pelecypods of Kitakami are quite different from those of the Hida region (Tetori group) except for *Myophorella (Promyophorella) orientalis,* but bear many similar elements to the Soma and Torinosu faunas. *Myophorella (Haidaia) crenulata* from the Mone formation of Karakuwa suggests the similarity of the Mone fauna to that of the "*Lima*-sandstone" of the Nakanosawa formation in Soma. The Tithonian and Berriasian pelecypods of the Kogoshio formation bear many common or comparable species to the faunas of the Nakanosawa and Koyamada formations of Soma, Kurisaka formation of Sakuradani-Kito, Yatsuji formation of Sakawa and Sakamoto formation of Kuma, such as *Parallelodon (Torinosucatella) kobayashii, Grammatodon takiensis, Nuculana (Praesaccella)* sp. ex gr. *yatsushiroensis, Entolium kimurai* and *Variamussium* cf. *habunokawense,*

ARKELL (1956, p. 429, 599) noted that lower Kimmeridgian Mexican ammonite, *Idoceras,* occurs in the Arato formation of Shizukawa, and emphasized the uninterupted sea-connection across the Pacific. SATO (1958) suggested the generic assemblage of the Tithonian-Berriasian ammonites from the Kogoshio formation is similar to that of Mexico. And similar assemblages were subsequently reported from Colombia (HAAS, 1960) and Peru (RIVERA, 1951, DIAZ, 1959). Therefore, the Upper Jurassic sea of Kitakami must have been intimately connected with the Torinosu sea and Pacific ocean at that time.

The pelecypod fauna of the Tetori group is, however, quite different from those of Kitakami, Soma and Torinosu except for a few trigoniids. The neritic species from the Mitarai formation of Makito, as I (1959f, g) described in detail, bear some comparable forms to the Upper Jurassic (and Lower Cretaceous) of Western Europe, Ural, Lower Yenisei and Alaska. Considering also the occurrence of *Kepplerites* (*Seymourites*) from the Callovian Kaizara formation, the Tetori fauna is composed in part of boreal species. *Inoceramus* cf. *nitescens* from the Nagano formation and *Pinna* sp. ex gr. *sandsfootensis* from the Mitarai resemble Corallian species of England, but most other species, especially the cyrenoids* in the embayment facies, seem indigenous to the Tetori basin. As to ammonites, two forms from the Arato and Oginohama formations of Kitakami have been compared respectively with *Kepplerites* (*Seymourites*) *acuticostum* and *Kranaosphinctes matsushimai* from the Callovio-Oxfordian of the Kuzuryu area.

As discussed precisely by TAMURA (1959d, 1960a-c), the Upper Jurassic pelecypod faunas of the Nakanosawa and Koyamada formations of the Soma group are intimate with the Torinosu fauna of Shikoku and Kyushu. 61 Soma species and 76 Torinosu species were described by YABE and SATO (1942), KIMURA (1951, 1956) and TAMURA (1959a-d, 1960a-d), of which 25 species occur in common between the two provinces. Moreover, *Modiolus bipartitus*, *M.* (*Inoperna*) *plicatus*, *Arcomytilus laitmairensis*, *Pinna mitis*, *Camptonectes browni*, *Myopholas acuticostata*, *Pholadomya somensis* and *Homomya gibbosa* are known widely in the Upper Jurassic of Europe, Somaliland, Kenya and Cutch, and the occurrence of identical or comparable specimens with them in the Soma and Torinosu groups is quite important for palaeobiogeographical consideration. KRUMBECK (1905) pointed out that the several species of *Cidaris*, *Terebratula*, *Alectryonia* (=*Lopha*) and *Nerinea* in the Torinosu limestone are identical or allied to those of the "Glandarienkalk" in Lebanon. Although none of the Glandarienkalk pelecypods is as yet found in Japan, the generic assemblage seems similar to the Soma-Torinosu fauna. It is, however, a marked difference between the Torinosu and Etyopian provinces that *Eligmus-Gryphaea* fauna is unknown in the former. The generic assemblage of trigoniids is also somewhat different. *Trigonia* (s. s.), *Indotrigonia*, *Laevitrigonia*, *Iotrigonia* and *Pterotrigonia* flourished in the Upper Jurassic (especially Argovian and Tithonian) of Cutch (KITCHIN, 1903; COX, 1952), but those genera are unknown in the Upper Jurassic of Japan. On the other hand, *Latitrigonia*, *Myophorella* (*Promyophorella* and *Haidaia*), *Linotrigonia* and *Nipponitrigonia* which often form trigoniid banks in the Soma-Torinosu province and sometimes in Tetori

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* "*Corbicula*" *tetoriensis* KOBAYASHI and SUZUKI was announced from the Sichota Alins region, but the species was said to coexist with some elements of the Lower Cretaceous Ryoseki fauna.

basin, but scarcely known in Cutch and Etyopian province. It may be rightly concluded that the Soma-Torinosu fauna includes many characteristic genera and species of the Pacific region besides a considerable amount of Tethyan elements.

Table 6.

FAUNAL RESEMBLANCE IN THE UPPER JURASSIC

| fauna | $\frac{\text{species}}{\text{genera}}$ | Shishiori +Ojika | Soma | Tetori | Torinosu | |
|---|---|---|---|---|---|---|
| SHISHIORI + OJIKA | $\frac{26}{19}$ | | $\frac{4.5}{12}$ | $\frac{1}{9}$ | $\frac{4}{14}$ | $\frac{\text{number of common species}}{\text{number of common genera}}$ |
| SOMA | $\frac{69}{42}$ | $\frac{17.3}{63.2}$ | | $\frac{2}{14}$ | $\frac{25}{26}$ | |
| TETORI | $\frac{43}{29}$ | $\frac{3.8}{52.6}$ | $\frac{4.7}{48.3}$ | | $\frac{1}{10}$ | |
| TORINOSU | $\frac{77}{40}$ | $\frac{15.4}{73.7}$ | $\frac{36.2}{65.0}$ | $\frac{2.3}{34.5}$ | | |
| | | Simpson's formula $\frac{100\,C}{N_i}$ | | | | |

SIMPSON's indices (Table 6) calculated among the four Upper Jurassic faunal provinces of Japan seem to reflect well the sea connection among the Kitakami, Soma and Torinosu provinces and also the isolation of the Tetori fauna from those of Pacific side.

Examining widely distributed species in detail, it is noticed through the Jurassic that most of them occur in neritic sandy or calcareous facies except for a few comparable forms to foreign species in muddy facies. The lower parts of the Higashinagano, Aratozaki and Nakanosawa formations, which bear the greater part ef cosmopolitan species in Japanese Jurassic, are composed similarly of fine to medium-grained sandstones (sometimes calcareous), which were deposited on shallow bottom under free circulation of waters. On the other hand, in restricted basins such as Kuruma and Tetori, conditions were apt to become peculiar and unstable, and cosmopolitan elements could not settle, notwithstanding the fact that several specialized genera and species show striking local development.

### 4) "Eo-nippon Cordillera" and its bearing on the Jurassic palaeobiogeography

KOBAYASHI (1941, 1947) opined that "Eo-nippon Cordillera" appeared by the Rhaetic Toyogatake and the Middle Jurassic Hida emergences in relation to the Sambagawa metamorphism and pre-Ryoseki intrusion of the Sakawa orogenic cycle. He noted further that the Jurassic litho- and bio-facies in the Inner Zone of Southwest Japan are much different from those of the Outer Zone, and that the "Eo-nippon Cordillera" formed a land barrier between the two sedimentary suits, just as the "Vindelizische Gebirge" between the Alpine and German facies in Triassic period.

In fact, the Upper Jurassic faunas of the Tetori group are different in many respects from those of the Soma-Torinosu groups. Reef-building hexacorals, stromatoporoids, calcareous algae, *Cidaris*, *Nerinea* and brachiopods are common in the calcareous facies of the Soma-Torinosu groups, but scarcely met with in the Inner Zone. The faunal discordance is well reflected also in the generic assemblage of pelecypods. In the Soma-Torinosu faunas *Parallelodon* (*Torinosucatella*), *Grammatodon*, *Modiolus* (*Inoperna*), *Pteroperna*, "*Aequipecten*", *Somapecten*, *Variamussium*, *Ctenostreon*, *Ctenoides*, *Exogyra*, *Myophorella* (*Haidaia*), *Opis*, *Pholadomya*, *Neoburmesia* and *Goniomya* are important constituents, but those genera are scarcely found in the marine beds of the Inner Zone. On the other hand, the important genera of the Tetori marine fauna such as *Nuculopsis* (*Palaeonucula*), *Oxytoma*, *Inoceramus*, *Posidonia* and *Tetorimya*, are unknown in the Outer Zone. *Modiolus*, *Pinna*, *Chlamys*, *Entolium*, *Limatula*, *Protocardia*, *Thracia*, *Pleuromya* and *Solemya* were described commonly in the two suits, but are represented by quite different and unrelated species. A similar tendency is found in the ammonite faunas: none of the Tetori ammonites was ever found in the Torinosu and Soma groups, though the main ammonite beds of the Tetori group may be slightly older than those of the Outer Zone.

The Oxfordian Kiritani and (?) Sugizaki formations of the Hida region show somewhat unique bio-facies in the Inner Zone. As noted by IMAMURA (1933, 1959) and KOBAYASHI (1956) the former formation bears *Nipponitrigonia sagawai* which is common in the Soma-Torinosu groups. The fossil occurrence seems to me fairly similar to the shell banks of the Kambaradani sandstone of the Torinosu group in the Sakawa basin, though the age of the Kiritani beds is probably older than the Kambaradani. For the similarity KOBAYASHI (1947) presumed the presence of "Kurisaka channel" which crossed diagonally the Eo-nippon Cordillera and stretched from eastern Shikoku to the Tetori basin. But the presence of the channel cannot be endorsed by other ammonite and pelecypod species.

The Upper Jurassic fauna of the Kitakami province is intermediate between the Tetori and the Soma-Torinosu provinces in many respects. The Callovian and Oxfordian faunas from the Arato and Oginohama formations bear *Seymourites*, *Kranaosphinctes*, *Inoceramus* and *Posidonia*, and is quite different from the Soma-Torinosu faunas, while the Kimmeridgian (?), Tithonian and Berriassian faunas from the Mone, Kogoshio and Kozumi formations show marked similarity to the non-calcareous formations of the Outer Zone. It can be readily imagined that the Tetori and Torinosu seas were connected in North Japan where the "Eo-nippon Cordillera" decreased its height.

The significance of the "Eo-nippon Cordillera" on the Jurassic biogeography is thus very important. The Recent molluscan communities of the Japan Sea coast is fairly different from the Pacific coast, but the Jurassic biogeographical isolation is no less striking than the Recent case.

The development of the land barrier can be traced back into Early Jurassic times. Since no Liassic fossil is known in the Outer Zone, it is now difficult to make clear the faunal isolation in Early Jurassic times. But if one presumes that the Liassic fauna in the Outer Zone is composed of similar genera to the Soma-Torinosu faunas, the more or less specialized pelecypods of the Kuruma and Shizukawa groups must be extraneous from the Outer Zone. The similarity of the Iwamuro and Yamaoku faunas to the Kuruma fauna suggests that the land barrier at that time was situated somewhat more southwards than the present watershed. The generic assemblage of the Higashinagano pelecypods is fairly similar to the Torinosu fauna, though none of them is actually conspecific. Among 27 genera of the Higashinagano fauna, 5 are extinct already by the Upper Jurassic and 15 are represented also in the Soma-Torinosu fauna sometimes by intimate (probably descendant) species. Taking the Tethyan similarity of the Upper Liassic ammonites and inoceramids into consideration, the Toyora sea was situated near the western end of the land barrier and opened mainly to the south. The sea may have connected also to the Kuruma basin and further to the Amur geosynclinal region, passing through the rear side of the land barrier.

The Upper Triassic faunas of the Inner and Outer Zones of Southwest Japan have been analized enough to consider the biogeography. The Carnic faunas of the Mine, Nariwa, Nabae and Kochigatani groups have several characteristic elements in respective areas but at the same time intimately connected with one another. The Mine group in the Inner Zone is more than 10 times thicker than the contemporaneous Kochigatani group of the Outer Zone, but there are many common pelecypods between the two regions. The Noric fauna is not yet completely analyzed, but the *Entomonotis* fauna seems to have spread very widely both in the Outer and Inner Zones. Therefore,

Table 7.

*DISTRIBUTION OF MESOZOIC CYRENOID (PLANT) BEDS*

| tectonic province / age | *Inner Zone of S.W. Japan* | *Kitakami (west belt)* | *Kitakami (east belt) and Soma* | *Outer Zone of S.W. Japan & Northern Kitakami* |
|---|---|---|---|---|
| *Lower Cretaceous* | Yoshimo<br>Tochio | Jusanhama | Ofunato<br>Oshima<br>Ayukawa | Monobegawa<br>Ryoseki<br>Omoto |
| *Upper Jurassic* | Izuki<br>Numamachi<br>Ushimaru | | (Kogoshio)<br>(Mone)<br>(Oginohama) | |
| *Middle Jurassic* | | Aratozaki | (Tochikubo)<br>Hatsuno<br>Tsukinoura | |
| *Lower Jurassic* | Iwamuro<br>Yamaoku<br>Shinatani<br>Negoya<br>Kitamatadani | Mizunuma<br>Niranohama | | |
| *Upper Triassic* | (Nariwa)<br>Mine | | | |

Table 8.

DISTRIBUTION OF MESOZOIC TRIGONIID SANDSTONES (TRIGONIID-BEARING BEDS)

| tectonic province / age | Inner Zone of S.W. Japan | Kitakami (west belt) | Kitakami (east belt) | Soma | Outer Zone of S.W. Japan |
|---|---|---|---|---|---|
| Lower Cretaceous | | | (Oshima)<br>(Isokusa)<br>(Nagasaki) | | Yamanokami |
| Upper Jurassic | Yambara<br>Sugizaki<br>Arimine<br>Kiritani<br>Yambarazaka | | Kogoshio<br>Toshiro<br>Mone | Koyamada<br>Nakanosawa<br>Yamagami | Kambaradani<br>(Sakamoto)<br>(Kurisaka)<br>Yatsuji |
| Middle Jurassic | | Aratozaki | Tsukinoura<br>Kosaba | (Awazu) | |
| Lower Jurassic | (Otakidani)<br>Higashinagano | (Hosoura)<br>Niranohama | Kodaijima | | |
| Upper Triassic | Heki<br>(Nabae)<br>(Mine) | | | | (Usugatani) |

Kobayashi's opinion that the Eo-nippon Cordillera was developed by the Rhaetic Toyogatake and succeeding emergencies can be well endorsed from the palaeobiogeographical point of view.

It is interesting to see the zonal migration of cyrenoid-bearing embayment facies from the Inner to the Outer Zone (Table 7). Gregarious fossil banks with *Eomiodon* and some other cyrenoids appeared already in the lower Lias in the Hida region and the western belt of Kitakami, and *Anodontophora* banks in the Carnic of the Nagato region show similar bio-facies. In the eastern belt of Kitakami and Soma the first appearance of eomiodontids can be dated as Bajocian. In the Outer Zone of Southwest Japan and northern Kitakami region the development of such cyrenoid-facies is unknown until the Lower Cretaceous Ryoseki epoch. A similar tendency is found as to the distribution of plant beds. Upon Kobayashi's suggestion Oishi divided the Mesozoic floras into the "Rhaeto-Liassic *Dictyophyllum* suit" and the "Wealden *Onychiopsis* suit". Many floras belonging to the former suit occur in the Triassic Mine, Nariwa and Shidaka groups and the Liassic Kuruma, Iwamuro and Yamaoku formations of the Inner Zone, while the suit is unknown in the Outer Zone. The first striking flora in the Outer Zone is found in the Lower Cretaceous Ryoseki group. The discrepancy is, I think, attributable to the different topographical state of the two zones in the Jurassic times; that is to say, intermontane and deep embayment conditions did not predominate in the Outer Zone where the foregone Akiyoshi orogeny gave less effect than in the Inner Zone.

## 5) Distribution of Jurassic Pelecypods in the Indo-Pacific Regions

I intend to make a brief review on the distribution, assemblage and main previous works of the Jurassic pelecypods in the Indo-Pacific regions, which I could refer to for this study. For convenience I divide the regions into several provinces in accordance with ARKELL's division (1956).

1) Indian Peninsula and Himalayas (Cutch, Baluchistan, Attock, Ferghana, Karakorum, Spiti and Upper Burma)

Since OPPEL (1863) and STOLICZKA (1866) described some Jurassic pelecypods from Himalayas, many important works were published by European authors.

*Nuculopsis* (*Palaeonucula*), *Inoceramus*, *Aucella*, *Lima* (mainly *Plagiostoma* and *Limatula*), *Trigonia*, *Astarte* and some other thin-shelled pelecypods from the Spiti shales were monographed by HOLDHAUS (1913). The fauna is somewhat similar to those of Moluccas and 3N-arc, and very important for the correlation and palaeogeographical consideration in cooperation with the rich ammonites. The bio-facies of the Spiti shales, I presume, is somewhat allied to that of the ammonite shales in the Northeast and Inner Zone of Southwest Japan. KITCHIN (1903) described many trigoniids from the marine coastal facies of Cutch on the shallow shelf of Gondwana. COX (1937, 1940, 1941, 1952) greatly contributed to the description of the Middle and Upper Jurassic neritic fauna of Cutch and general classification of Mesozoic pelecypods. About 120 species of palaeotaxodont, prionodont, dysodont, isodont and schizodont pelecypods were monographed by the authority. *Nuculopsis* (*Palaeonucula*), *Nuculana* (*Praesaccella*), *Nuculana* (*Dacryomya*), *Grammatodon* s. s. and *Indogrammatodon*), *Modiolus* (s. s. and *Inoperna*), *Oxytoma*, *Bakevellia*, *Gervillella*, *Isognomon* (*Mytiloperna*), *Eligmus*. *Chlamys*, *Eopecten*, *Camptonectes*, *Entolium*, *Plicatula*, *Plagiostoma*, *Liostrea* (s. s. and *Catinula*), *Gryphaea*, *Lopha* and *Trigonia* seem predominant. The Cutch fauna is different from those of the Himalayan geosynclinal region in the scarceness of *Inoceramus* and *Aucella*, but it may be chiefly due to the contrary sedimentary environment. According to COX, a considerable amount of the Cutch pelecypods occur also in western Europe. The abundance of *Indogrammatodon*, *Eopecten*, *Eligmus* and *Gryphaea* shows the Cutch sea was intimately connected with East Africa. The generic assemblage of trigoniids such as *Indotrigonia*, *Laevitrigonia*, *Iotrigonia* and *Pterotrigonia* seems characteristic of the Indo-African region.

According to REED (1931, 1936), the *Eligmus-Gryphaea* fauna is found also in the Bathonian Namyau beds of Upper Burma. The development of *Eomiodon* in the Bathonian seems a striking feature of the Tethyan region. Bathonian species of the genus were hitherto reported from the Great Oolite and Great Estuarine series of England (MORRIS and LYCETT, 1853; LYCETT, 1863; COX and ARKELL, 1948; ANDERSON and COX, 1949), the Larzac beds of south France (COX and MAUBEUGE, 1950), Madagascar, Kuar Bet beds of Cutch and Attock district (COX, 1935) besides the Namyau beds. In many places of those areas, *Eomiodon* is accompanied by *Protocardia*, *Corbula* and *Bakevellia*, and the assemblage and lithology indicate a certain embayment condition just as the cyrenoid faunas of Japanese Lias. In fact, the Bathonian *Eomiodon* beds appear prior to the *Macrocephalites*-bearing pure marine deposits belonging to the Upper Jurassic transgression.

In contrast with the abundance of Bathonian and later pelecypods, earlier species seem much rarer in the Indian region. Only several trigoniids, limids and pectinids are known in the Lias of Baluchistan (HOLLAND, 1909), Spiti (STOLICZKA, 1866) and Attock (COX, 1935). Some Bajocian species were announced from Karakorum (STAESCHE, 1932). Most of those species have been said to be identical with European or Madagascar faunas, but the analysis may not be satisfactory to make a biogeographical interpretation.

(2) Indochina and Indonesia (Tonkin, Laos, Annam, Cochin China, Thailand, Malay (?), Sumatra, Borneo, Timor, Moluccas)

In this region Jurassic pelecypods are known in Phu-nhoquan, Sontay and Na Cham of Tonkin, Tchepone and Sam Nena of northeast Laos, Hun-Nien of Annam, Trian of Cochin China, Mae Sot and Chumphon of Thailand, (?) Singapore, Jambi of middle Sumatra, Sambas and Sarawak river of Borneo, southwest Mindoro of Philippine, Taliabu, Buru, Misol and Ceram of Moluccas and Timor.

Liassic species seem fairly common in Indochina (COUNILLON, 1909; MANSUY, 1914, 1919a, b). Many species were compared with European famous pelecypods, and the elongate forms of *Cardinia* are also of European type. Middle and Upper Jurassic species are rare except for a few pectinids and limids described by MANSUY (1920). Taking the occurrence of *Gryphaea arcuata* in some *Uptonia* beds (FROMAGET, 1952) also into consideration, the Jurassic pelecypod fauna of Indochina is more intimate with Europe and Indian regions than north Pacific region. *Astarte*, *Goniomya*, etc. were described by NEWTON (1906) from Singapore, but SCRIVENOR (1931) is of opinion that the age is pre-Rhaetic. The *Eomiodon* beds at the mouth of Chumphon river of south Thailand (HAYAMI, 1960a) may be related to the Bathonian fauna of the Indian region.

In Sumatra and Borneo the occurrence of Jurassic pelecypods is rather sporadical. *Astarte*, *Opis*, *Protocardia*, *Corbula*, etc. described by KRAUSE (1896), VOGEL (1896, 1899-1902), NEWTON (1903), and FRECH and MEYER (1922) from the (? Middle Jurassic of Jambi and Sarawak are endemic species, and only a few are comparable with the faunas of Indian region. As pointed by KOBAYASHI (1957b), *Trigonia molengraffi* NEWTON from Borneo is referable to *Myophorella* (*Haidaia*) which is fairly characteristic in the Upper Jurassic of north Pacific region. KOBAYASHI (1957) described *Solemya*, *Latitrigonia*, *Rutitrigonia*, *Myophorella* (*Promyophorella*), *Nipponitrigonia* and *Chlamys* from the Upper Jurassic or Lower Cretaceous along the Amaga river of Mindoro, and it is quite interesting that some of them are identical or comparable with certain Tithonian and Neocomian trigoniids in the Outer Zone of Japan. HAYASAKA (1943) described a trigoniid near Mansaley of this island, which was refered to *Vaugonia* by KOBAYASHI and MORI (1955). *Vaugonia* shows special development in the Lower-Middle Jurassic of Japan, and the faunal connection between Mindoro and Japan is generally thought to be very close. Unfortunately, most of these fossil beds in western Indonesia and Philippine are not yet firmly dated, and the range of each species cannot be estimated in accuracy. But it is evident that the faunas comprise many different elements from Indian region.

Eastern Indonesia region including Taliabu, Buru, Misol, Ceram, Jamdena, Timor and Rotti is important for the consideration of pelecypod evolution in the western Pacific. The rich Liassic, Callovian and Oxfordian species were described chiefly by German and Dutch authors. Liassic *Palaeonucula, Grammatodon* and *Trigonia* from Misol (WANDEL, 1936) show European affinity, but the middle Liassic fauna of Timor and Rotti includes many aberrant forms such as *Gervilleioperna, Lithotis, Mytilus,* (?) *Nucula,* "*Myophoria*", *Opisoma,* (?) *Pachymegalodus,* "*Schafhäutlia* and *Paradoxia* (KRUMBECK, 1923). *Gervilleioperna* is known also in the middle Lias of North Africa (DUBAR, 1948), but all species are unknown outside Timor and Rotti, suggesting a distinct small province from other areas of this region. Middle Jurassic pelecypods are known in Misol, and most forms are said to be identical with or allied to European species (SOERGEL, 1913; JAWORSKI, 1920; WANDEL, 1936), such as *Camptonectes lens, Entolium demissum, Ctenostreon pectiniforme, Plagiostoma semicirculare* and *Oxytoma münsteri.* But it seems more reasonable to regard that those forms are cosmopolitan elements, since they are mostly found also in the Bajocian of Japan and South America. The Upper Jurassic faunas of Moluccas are different from the Lower-Middle ones in generic assemblage and are well characterized by the prolific occurrence of coarse-ribbed *Inoceramus* (the group of *I. galoi* in my classification, 1960c), *Aucella* and *Posidonia* (BOEHM, 1907, 1912; HUMMEL, 1923; KRUMBECK, 1923, 1924; WANDEL, 1936). The *Inoceramus*-bearing shaly facies is extensively distributed in the Oxfordian, and the fauna shows an intimate sea connection with Spiti of Himalaya and 3N-arc region. However, because of the scarceness of other faunas in the Upper Jurassic of Moluccas, the faunal connection with the northern Pacific region cannot be further ascertained.

(3) Australia and 3N-arc

In this region Jurassic pelecypod faunas are known in Upper Sepik of New Guinea, west and central New Caledonia, Kawhia of north New Zealand, Hokonui of south New Zealand and Western Australia.

In New Zealand the Jurassic pelecypod faunas are of primary importance for stratigraphy, for ammonites seem comparatively rare except a few definite horizons. The fauna, which was monographed by MARWICK (1953), is characterized by *Otapiria, Kalentera, Haastina* and some highly specialized groups besides a considerable amount of Tethyan affinities. *Otapiria, Kalentera, Oxytoma, Entolium, Pseudoaucella* and *Chlamys* occur in the Lias (TRECHMANN, 1923; FLEMING, 1953; MARWICK, 1953), but the distribution of these species is now confined to New Zealand and New Caledonia. The occurrence of *Sphaeriola* already in lower Lias is probably a striking feature of the Pacific region, since the genus is found also in the similar stages in western Japan and Amur. Middle Jurassic faunas bear some Tethyan elements such as *Meleagrinella echinata* and *Camptonectes* cf. *laminatus*, but most other species belonging to *Variamussium, Astarte, Kalentera, Tancredia, Homomya* and *Pleuromya* are endemic. MARWICK referred some Bathonio-Callovian fossils to the Spiti species described by STOLICZKA (1866) and HOLDHAUS (1913). The Upper Jurassic fauna of New Zealand is composed of *Nuculopsis* (*Palaeonucula*), *Nuculana, Grammatodon* (*Indogrammatodon*), *Inoceramus, Otapiria, Aucella, Pinna, Plagiostoma, Astarte* and *Haastina*. The resemblance of specific assemblage between the Upper Jurassic of Himalayas and this region is a striking feature. Especially Oxfordian and later inoceramid faunas of New Zealand and New Caledonia bear some common species with the Spiti shales such as *Inoceramus* aff. *everesti* and *Aucella extensa*. Coarsely ribbed inoceramids such as *Inoceramus galoi* and *I. haasti* flourished in the Oxfordian-Tithonian of New Zealand and New Caledonia (ZITTEL, 1864; TRECHMANN, 1923; MARWICK, 1953; BARTRUM, 1937; ROUTHIER, 1953; AVIAS, 1953; MILLIGAN, 1959; FLEMING, 1959). Most of the inoceramids and associate *Aucella* occur also in the Upper Jurassic of Moluccas. The Jurassic of Moluccas and 3N-arc is generally represented by geosynclinal facies, and trigoniid- and cyrenoid-facies seem undeveloped.

The Jurassic fauna of Australia seem to be composed of quite different species from the 3N-arc region. MOORE (1870) described many species of "*Avicula*", "*Pecten*", "*Lima*", "*Arca*", *Astarte* and *Cucullaea* from the "Oolite" of Queensland and Western Australia, but their generic references should be revised in future. According to TEICHERT (1939), two species of *Aucella* from the Kimmeridgian of Western Australia are identical with Misol fauna. *Frenguelliella moorei* is another common species between the Bajocian of Australia and Moluccas (WANDEL, 1936).

(4) Eastern Siberia (Lower Amur, Sichote Alins, Lower Lena and Olenek)

In eastern Siberia marine Jurassic pelecypods occur in lower Amur, Bureya basin, Okhotsk, Sichote Alins, lower Lena and Olenek. In the Amur geosyncline area the lower Lias is represented by neritic pelecypod facies with *Cardinia, Plagiostoma, Ctenostreon, Chlamys, Myoconcha* and *Sphaeriola*. The generic and even specific assemblages seem to me to be fairly similar to the coeval Higashinagano fauna of western Japan (KIPARISOVA, 1952; HAYAMI, 1959i). Middle Liassic species seem comparatively rare except for some cosmopolitan species of *Plicatula* and *Oxytoma*. In Sichote Alins and Bureya area of lower Amur, some species of *Inoceramus* occur in the Toarcian-Aalenian (KIPARISOVA et al., 1958, 1960; KCHUDOLEY, 1959). The occurrence of *Inoceramus eximius, I.* cf. *lucifer* and *I. ambiguus* suggests the faunal connection with Alaska. *I. subambiguus* from the Aalenian of Okhotsk is quite similar to *I. morii* of Northeast Japan. Bajocio-Bathonian pelecypods seem quite rare in this region because of an extensive regression. LAHUSEN (1886) and VORONETZ (1936) described *Inoceramus retrorsus, Solemya, Modiolus, Tancredia* and some other thin-shelled pelecypods from the Lena and Olenek regions.

The inoceramid was reported also from the Bathonio-Callovian of Greenland (SPATH, 1932), and can be regarded as an element of boreal sea. *Inoceramus utanoensis* from the upper Toyora group of western Japan, which is a member of the group of *I. retrorsus*, seems to indicate the sea-connection with boreal province together with the *Seymourites*-fauna in the Callovian of central Japan (KOBAYASHI, 1947; HAYAMI, 1960c). According to KRIMHOLZ (1939) and others, *Modiolus* shales with *Modiolus*, *Meleagrinella* and some Callovian boreal ammonites occur in Bureya basin. Several species of "*Eumorphotis*" from the Middle-Upper Jurassic were lately denominated as *Arctotis*. Besides, *Bureiamya* was reported from the Callovio-Oxfordian of this region and *Aucellae* seem quite common in the Kimmeridgian and Volgian, though I could not refer to their original descriptions.

From the biogeographical point of view, it is recognized that the faunal connection between eastern Siberia and the Inner Zone of Southwest Japan was fairly intimate not only in the Triassic but also in many stages of the Jurassic period. In fact, many related species appear almost coevally both in the two regions as listed below:

| | Eastern Siberia, Ural | Inner Zone of Southwest Japan and North Japan |
|---|---|---|
| Lower Jurassic | *Cardinia amurensis* KIPARISOVA | *Cardinia toriyamai* HAY. |
| | *Sphaeriola sibirica* KIP. | *Sphaeriola nipponica* HAY. |
| | *Lima (Pl.) parapuncta* KIP. | *Plagiostoma matsumotoi* HAY. |
| | *Chlamys textoria* (SCHLOTH.) | *Chlamys textoria* (SCHLOTH.) |
| | *Oxytoma cygnipes* var. | *Oxytoma* cf. *cygnipes* |
| Middle Jurassic | *Inoceramus subambiguus* PČELINCEVA | *Inoceramus morii* HAYAMI |
| | *Inoceramus* cf. *lucifer* | *Inoceramus* cf. *lucifer* |
| Upper Jurassic | *Inoceramus kystatymensis* KOSCHELKINA | *Inoceramus utanoensis* KOB. |
| | *Solemya strigata* LAHUSEN | *Solemya suprajurensis* HAY. |
| | *Entolium nummulare* (D'ORBIGNY) | *Entolium inequivalve* HAY. |
| | *Lima consobrina* D'ORBIGNY | *Limatula iwayae* HAYAMI |
| | *Modiolus sibiricus* BODYLEVSKY | *Modiolus maedae* HAYAMI |
| | *Thracia* cf. *lata* AGASSIZ | *Thracia shokawensis* HAY. |
| | *Pholadomya uralensis* D'ORBIGNY | *Tetorimya carinata* HAYAMI |

The presence of a brackish fauna in the Upper Jurassic of Sichote Alins is very interesting for the consideration of palaeobiogeography and evolution of cyrenoid pelecypods, since cyrecoids is quite abundant also in the Upper Jurassic of the Inner Zone of Japan. But the discussion should be founded on firmer palaeontological basis. In the boreal province no striking faunal gap exists between the Upper Jurassic and Lower Cretaceous. One pelecypod species often occur both in the two epochs.

(5) North America (Alaska, Prince Patrick, British Columbia, Yukon, Alberta, Pacific coast and Western Interior of U. S. A.)

In Alaska VON EICHWALD (1871) described *Inoceramus* and many other pelecypods as "Neocomian or Gault species", but MARTIN (1926) and many others regarded them as Jurassic species. MARTIN listed numerous pelecypods from the Lower, Middle and Upper Jurassic of Cook Inlet, Kenai peninsula, Malanuska, Talkeetna, Alaska range, Susitina valley, Chitina valley and Alaska peninsula, but the greater part of them is as yet undescribed. IMLAY (1955) regarded *Inoceramus lucifer* and *Aucella mosquensis* respectively as Bajocian and Kimmeridgian indices of north and south Alaska. *Aucella spitiensis*, an element of Spiti shales of Himalaya, occurs also in this region. Although the detailed comparison with Japanese fauna belongs to a future problem, it is now presumed that several pelecypods accompanied by *Tmetoceras* and *Stephanoceras* in the Aalenian and Bajocian Texedni formation may be allied to the faunas of the upper Shizukawa and lower Hashiura groups in Northeast Japan. Besides, ULRICH (1910) proposed *Inoceramya* for a transitional form between *Posidonia* and *Inoceramus* from the undated Mesozoic terrain of Yakutat area.

In Canada, Jurassic pelecypods are distributed widely in Prince Patrick, west Yukon, and various localities of British Columbia and Alberta (FREBOLD, 1953). FREBOLD (1957) described *Cucullaea, Protocardia* and *Pleuromya* from the Toarcian, and *Oxytoma* and *Goniomya* from the Bajocian of Prince Patrick. The lower Bajocian with *Oxytoma jacksoni* fauna is widespread in Melville, Mackenzie King and Axel Heiberg islands besides Prince Patrick (TOZER, 1960), and the species shows the presence of faunal connection with Cape Flora and Franz Joseph Land. *Inoceramus lucifer* is found also in Prince Patrick. LEES (1934) reported a Liassic fauna including *Gervillia, Trigonia, Modiolus, Pleuromya* and *Goniomya* from the Laberge area of Yukon, but the fauna is unknown in other places.

The pelecypod faunas in the Pacific coast of British Columbia were investigated by CRICKMAY (1928, 1930a, b). He described *Parallelodon* (including *Gilbertwhitea*), *Grammatodon, Modiolus, Gervillia, Entolium, Pinna, Gryphaea, Vaugonia, Myophorella* (*Haidaia*), *Astarte, Pleuromya* and many other pelecypods from the Middle Jurassic of the Harrison Lake and Ashcroft areas. Some of his newly established genera such as *Ashcroftia, Parapecten, Vaugonia* and *Haidaia* are important groups not only in British Columbia but also in various areas of the Pacific region. FREBOLD (1959) reported the occurrence of *Chlamys, Plagiostoma, Trigonia, Cardinia* and *Goniomya* from the Sinemurian and Bajocian of the Nelson-Salmo area. The fauna bears some European affinities, but *Cardinia* aff. *regularis* Terquem seems not much different from *C. toriyamai* from the lower Lias of west Japan. In Vancouver Island and Tyaughton Lake area *Aucella* occurs together with Oxfordian or later arctic ammonites.

In the Canadian Rocky mountains and the foothills the Jurassic is well represented by the characteristic Fernie shales. WARREN (1931), COLLET (1931) and FRDBOLD (1957) reported some Sinemurian and Toarcian pelecypods comprising some cosmopolitan elements such as *Oxytoma cygnipes*, "*Lima*" *terquemi*, *Inoceramus* cf. *dubius*, *Lima* cf. *gigantea* and *Meleagrinella substriata*. MC-

LEARN (1924), WARREN (1932) FREBOLD (1957) described many pelecypods from the Bajocian and Callovian of the Fernie shales in Alberta. The faunas are composed of *Cucullaea, Oxytoma, Inoceramus, Camptonectes, Entolium, Plagiostoma, Gryphaea, Trigonia, Protocardia, Arctica, Pleuromya* and *Corbula*. These genera can be commonly found in the Jurassic of many other areas, but the specific assemblage is quite different from either of Europe-Tethys and western and southern Pacific regions. The characteristic occurrence of *Gryphaea impressimarginata* and *Corbula munda* at the Bathonian-Callovian passage remind at a glance one of *Eligmus-Gryphaea* fauna of the Ethiopian province, but the constituent species seems quite different from each other. Oxfordian *Aucella* is found also in Fernie shales together with cardioceratids.

In the Pacific coast of the United States Jurassic pelecypods are known in east-central Oregon, north and central California and west Nevada. GABB (1870), HYATT (1894) and CRICKMAY (1933) described *Pinna, Entolium, Parapecten,* etc. from the Lower and lower Middle Jurassic of Mt Jura area. MULLER and FERGUSON (1939) listed some Liassic pelecypods from Hawthorne-Tonopar area of western Nevada, and pointed out that CRICKMAY's *Parapecten* appear to be nothing but the famous South American Liassic species, *Weyla alata* (BUCH). Besides, *Myophorella, Vaugonia, Entolium, Pholadomya, Chlamys* and *Goniomya* occur in the lower-middle Lias, and some of them were lately described by SANBORN (1960).

PACKARD (1921) monograghed the trigoniids of California and some other areas of Pacific coast, and many generic names were given them by CRICKMAY (1932). In accordance with recent trigonian studies accomplished by COX (1951) and KOBAYASHI, MORI and TAMURA (1954–1959), *Trigonia, Vaugonia, Myophorella, M. (Haidaia), M. (Promyophorella)* seem to occur in this region. The generic assemblage is more similar to the normal Jurassic trigoniid faunas of Japan than Europe and India.

The Tithonian fauna of the Knoxville beds, which STANTON (1896) regarded as Lower Cretaceous, includes *Nucula, Oxytoma, Aucella, Inoceramus,* "*Pecten*", *Astarte, Opis, Lucina* and *Corbula*. *Cardiniopsis* is characteristic of the Knoxville. GILLET (1924) regarded the fauna as a member of boreal province (north-andine subprovince), and the abundant *Aucella* may constitute an element of northern sea. The ammonites of the Callovian-Kimmeridgian of Sierra Nevada are also of boreal type, but the Knoxville ammonites appear in part to show the connection with Mexican province. The Franciscan group of the Coastal Range is at least in part Lower Cretaceous (SCHLOCKER et. al., 1954), but some Tithonian (?) pelecypods including *Aucella piochii* occur in the group in south California (EASTON and IMLAY, 1955).

In the Western Interior Jurassic pelecypods are known from the Bajocian, Callovian and Oxfordian of the Sundance inland sea facies and Kimmeridgian-Tithonian non-marine Morrison formation in Utah, Wyoming and some other states (IMLAY, 1952, etc.). MEEK (1877, etc.) STANTON (1899), WHITFIELD and HOVEY (1906) and CRICKMAY (1936) descibed some marine pelecypods such as *Cucullaea, Modiolus, Gervillia, Meleagrinella, Camptonectes, Ostrea, Gryphaea,* *Trigonia, Astarte, Pholadomya, Pleuromya, Thracia* and *Ceromya* chiefly from the Bajocian and Callovian of Wyoming. It is noticeable that few pelecypod species range from Callovian into Oxfordian, and that a certain faunal change took place at the regressive period. The generic assemblage is not much different from normal Middle-Upper Jurassic faunas of other regions, but most constituent species are endemic in the inland sea. IMLAY 1957 discussed the palaeoecology of the Sundance sea, making clear the relation between the fossil assemblage and lithology. "*Astarte, Trigonia, Pleuromya, Grammatodon* and *Pinna* were adapted to a considerable range of environment, as they lived on sandy, shaly and limy bottoms. *Mytilus* is commonly associate with *Ostrea* in shallow sandy deposits but not with *Gryphaea*. On less sandy limy bottoms lived such forms as *Cucullaea, Nucula, Ctenostreon, Oxytoma, Plagiostoma, Gryphaea, Ostrea, Lopha, Gervillia, Volsella, Pholadomya, Panope, Homomya, Goniomya, Cercomya, Pleuromya, Protocardia* and *Inoceramus*. On softer muddy bottoms lived *Isocyprina, Thracia, Pleuromya, Pholadomya, Panope, Astarte, Trigonia* and *Pinna, Opis* and *Corbis* occur in the Middle Jurassic dolomites and limestones with gypsum and red beds." Such tendencies may or may not agree with the bio-facies in the Jurassic of Japan which I described already. A comprehensive study on the genus *Aucella*, which ranges from upper Oxfordian to Valanginian in North America, was accomplished by IMLAY (1959).

The non-marine Morrison formation of Wyoming, Utah and Colorado yields many species of unionids (MEEK and HAYDEN, 1858; WHITE, 1886; LOGAN, 1900; HENDERSON, 1935; BRANSON, 1935; YEN and REESIDE, 1946, 1950).

(6) Mexico and Gulf Coast

FELIX (1894) reported some *Exogyra* and *Gryphaea* from the Upper Jurassic of the Oaxaca area of south Mexico. CASTILLO and AGUILERA (1895) described many pelecypods from the Sierra de Catorce in San Luis Potosi of Mexico. The work was carefully revised by IMLAY (1940), and is known that the Mexican Upper Jurassic fauna is well characterized by the prolific occurrence of *Grammatodon* (probably *Indogrammatodon*), some characteristic trigoniids, *Aulacomyella, Meleagrinella, Astarte, Arctica* and (?) *Solenomorpha*. The distribution of the fauna is now confined to the coastal deposits of the Mexican geosyncline in Mexico and Gulf Coast, and the generic assemblage and associate ammonite seem more intimate to Tethyan faunas than those of the Pacific coast and the Western Interior. *Aulacomyella* is said to have been recorded only from middle Kimmeridgian.

In the Malone area of western Texas is displayed a splendid neritic calcareous formations with rich Upper Jurassic pelecypods. CRAGIN (1905) described many species of *Gryphaea, Exogyra, Lima, Plicatula, Ctenostreon, Camptonectes, Gervillia, Mytilus, Modiolus, Pinna, Cucullaea, Astarte, Ptychomya, Lucina, Arctica, Pholadomya, Pleuromya, Anatina* and *Martesia*. Many species are common with the Mexican Upper Jurassic faunas, and a few are allied to South American ones. There are a few intimate forms with the Knoxville beds of California, but no species is common with the Western Interior. The appearance of *Steinmannella* and *Apiotrigonia* seem somewhat earlier than western Pacific. Many elements of the Mexican and Malone faunas are known in the Cotton Valley formation and Smackover limestone which belong to the deeply buried Jurassic of Arkansas, Alabama, Louisiana and eastern Texas (IMLAY, 1941, 1945). The Smackover fauna is said to bear several European affinities.

Lower and Middle Jurassic pelecypods are undescribed in this region except a few species of *Chlamys, Plagiostoma, Lopha, Trigonia, Astarte* and *Myoconcha* from the Lias of Sonora. Some species were compared with European species, and there are several South American elements (JAWORSKI, 1929).

(7) South America (Peru, Chile, Mendoza, Neuquen, Patagonia)

The distribution of Jurassic pelecypods in South America is almost confined to the middle and southern part of the Andine geosynclinal area, namely Peru, Bolivia, north Chile, Mendoza, Neuquén and Patagonia. The assemblage of pelecypods of these areas are very similar to one another, and this region constitutes a distinct faunal province from other regions of Pacific. However, I am rather astonished to find that so many names of famous European species have been given to South American pelecypods, though some of them certainly should be separated from typical forms.

The Liassic faunas of this region are well characterized by the prolific occurrence of *Weyla alata* (BUCH) or its allied pectinids, *Gryphaea* (mainly *G. darwini*), *Freguelliella, Vaugonia* and *Cardinia* (mainly *densistriata*-subgroup in my classification, 1958e) (BAYLE and COQUAND, 1850; MORICKE, 1894; TILMANN, 1917; JAWORSKI, 1913, 1916, 1926a, b; WEAVER, 1931; FERUGLIO, 1934; LEANZA, 1942). Other constituent genera are *Nucula,* "*Cucullaea*" (mostly *Grammatodon*), *Modiolus, Isognomon, Inoceramus* (probably *Parainoceramus*), *Gervillia, Oxytoma, Lopha, Gryphaea, Chlamys, Entolium, Variamussium, Plagiostoma, Ctenosteon, Myoconcha, Astarte, Lucina, Arcomya, Homomya, Pleuromya* and *Pholadomya.* The assemblage reminds at a glance one of normal European Liassic faunas. In fact, "*Arca*" *rhomboidalis, Oxytoma inequivalvis, Chlamys textoria, Entolium disciforme, Eopecten valatus, Arcomya elongata, Pholadomya hemicardia, Pleuromya striatula* and many other species from Neuquén indicate intimate faunal connection with Europe. But some of them, especially the pectinids, are known also in Japan and southeastern Asia and regarded as cosmopolitan elements. As I noted before (1957d), *Camptonectes lens* by LEANZA (1942) resembles *Radulonectites* which is found in the Lias of Central Japan.

Middle Jurassic pelecypods seem also very common in this region especially in the Bajocian at Espinazito pass of Argentina (GOTTSCHE, 1878; TORNQUIST, 1898; BURCKHARDT, 1903; JAWORSKI, 1926; WEAVER, 1931). *Nuculana, Cucullaea, Modiolus, Oxytoma, Meleagrinella, Posidonia, Camptonectes, Entolium, Trigonia, Jaworskiella, Frenguelliella, Vaugonia* (s. s. and *Hijitrigonia*) *Myophorella, Cardiniopsis, Astarte, Protocardia, Sowerbya, Gresslya, Pleuromya* and *Pholadomya* are well represented in this part. Many species range from Upper Lias into Bajocian. *Modiolus imbricata, Oxytoma münsteri, O. costata, Meleagrinella substriata, M. echinata, Camptonectes laminatus, Entolium disciforme, Gryphaea calceola, G. subobata, Pleuromya jurassi, Pholadomya fidicula* and many other forms are said to be identical with the Middle Jurassic faunas of Europe. According to JAWORSKI (1926) an allied species to *Inoceramus galoi*, an element of Moluccas and 3N-arc, occurs in the same stage. All the trigoniids of Neuquén monographed by LAMBERT (1944) are endemic species in South America. *Trigonia, Frenguelliella* and *Vaugonia* are well represented by many species at various horizons until Upper Jurassic. PHILLIPI (1899) described trigoniids and many other fossils from the Jurassic of Chile, and the fauna is said to be mostly composed of endemic species.

Upper Jurassic pelecypods are known also in Neuquén and some other areas (HAUPT, 1907; WEAVER, 1931; DIAZ, 1959), but the constituent species are much smaller in number. *Gervillia, Gryphaea, Trigonia, Ctenostreon, Modiolus, Pleuromya, Pholadomya, Astarte* and *Lucina* occur in the Callovian, and *Aucella, "Ostrea", Entolium, Apiotrigonia, Myophorella, Astarte, Lucina* and *Pholadomya* in the Tithonian.

The Jurassic faunas of Caracoles area of in the frontier between Chile and Bolivia described by STEINMANN (1881) have similar specific assemblages to those of Neuquén. *Posidonia* seems especially common in the Middle Jurassic.

## V. Evolution of Jurassic Pelecypods

To my regret, the Jurassic pelecypod specimens in Japan and its adjacent territories are often worse than European ones in the state of preservation. Nevertheless, I perceive that the evolution of Mesozoic pelecypods seems fairly different in many respects between Pacific and European regions. Therefore, it leaves much room for improvement upon the concept about the evolution of Mesozoic pelecypods which is generally founded on the evidences in Europe. There are many common genera and subgenera between the two regions, but some appeared much earlier in one region than the other. My special attention has been paid on the faunas of the Pacific region, since Japan belongs to the circum-Pacific orogenic belt and the region seems lagging behind the European and Tethyan regions in the palaeontology. It can be readily imagined that some peculiar physico-chemical conditions, which were absent in Europe, were produced in the Pacific region by the strong Mesozoic orogenic disturbances. It seems an interesting problem to recognize how the different conditions have influenced on the generic and specific assemblages and pelecypod evolution.

In this article are treated the stratigraphical and geographical distributions of some pelecypod groups which are more or less commonly found in the Indo-Pacific region. Presumable general trends of evolution, if ascertained from the morphological transformation and stratigraphical occurrence, are also noted in some detail. Jurassic pelecypod faunas are generally much different from Triassic ones in the generic assemblage. In fact, some genera appeared at first in lower Lias and some other stages of Jurassic. But some other genera, which have been said in many text-books to have appeared at first in Lias, are actually represented by a few species already in Upper Triassic. In northwestern Europe Rhaetic (or Infraliassic) transgression took place on the Upper Triassic non-marine terrains, and many pelecypod genera apparently evolved since the stage. In view of the stratigraphical distribution of Triassic and Jurassic species of the world, however, the faunal change must be said to be fairly gradual.

The stratigraphical and geographical distribution of Jurassic pelecypods belonging to more or less common genera in the Indo-Pacific regions are summerized in the following tables. In this occasion I emend the generic references of some species in the Pacific region in accordance to modern pelecypod classification. Each vertical column does not mean phylogenetical relationship, and each species has a certain vertical range. But the material seems not enough to establish reliable genealogical trees and detailed range charts. Comparable European species are also tabulated in the left columns.

(1) Solemyacidae appeared already in Silurian, and *Solemya* was seemingly persistent during whole Mesozoic times without any striking morphological transformation. It probably adapted to calm muddy bottom of neritic to considerable depth, and made a bare living until Recent. Some of Jurassic *Solemya* seem to have *Acharax*-like ligament position, but in most cases the ignorance of ligament prevents me from determining the subgeneric references.

(2) Ctenodontidae are a primitive palaeotaxodont family ranging from Devonian (or earlier) to Jurassic. Mesozoic *Palaeoneilo* is probably a terminal group of the family. In Cutch *Palaeoneilo belaensis* and *P. indicus* seem common respectively in the Bathonian and Oxfordian, but their trace to the Pacific region is as yet unknown.

(3) Nuculidae are fairly common in various Jurassic stages of Indo-Pacific

Table 9.

*NUCULOPSIS (PALAEONUCULA)*

| | Europe | India | Indonesia | SN-arc | Japan | Mexico | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | menkii<br>subhammeri | spitiensis<br>hyomorpha<br>cf. menkii<br>stoliczkai<br>blanfordi<br>kaoraensis | taliabutica | truncata | makitoensis | antiqua | |
| Middle Jurassic | waltoni<br>variabilis<br>hammeri | cuneiformis | hammeri<br>cf. eudorae | | | | leufuensis |
| Lower Jurassic | hausmanni | | ovum<br>cf. hausmanni<br>subserraiensis<br>subovalis | | sp. | | patagonidica |

Table 10.

NUCULANA (DACRYOMYA) & N. (PRAESACCELLA) * Nuculana (Praesaccella)

| | Europe | India | 3N-arc | Japan | S. America |
|---|---|---|---|---|---|
| Upper Jurassic | | juriana* | australis | yatsushiroensis*<br>stenodolichos<br>minutula<br>erinoensis* | |
| Middle Jurassic | lacryma | lacryma | | | striatissima |
| Lower Jurassic | doris<br>complanata<br>graphica<br>tenuistriata<br>texturata | | vexillata | toriyamae | acuta<br>acuminata |

Table 11.

PARALLELODON * Parallelodon (Torinosucatella)

| | Europe | India | 3N-arc | Japan | N. America |
|---|---|---|---|---|---|
| Upper Jurassic | keyserlingii | lerensis | "egertonianum" | kobayashii*<br>kesennumensis<br>inflatus<br>koikensis | taffii<br>cardioceratanus |
| Middle Jurassic | bynei<br>rudis<br>hirsonensis<br>rugosus | | | sp. | micromorpha |
| Lower Jurassic | daharensis<br>buckmanni | | | sp.<br>infraliassicus<br>niranohamensis | |

regions, and most species of the family with entire ventral margins, I think, belong to *Nuculopsis* (*Palaeonucula*) which is persistent from Triassic and probably ancestral to Cretaceous *Leionucula*. *N.* (*P.*) cf. *hausmanni* and allied forms are known in the Lias of Moluccas, Timor and (?) South America. Many cuneiform species of *Palaeonucula* allied to *N.* (*P.*) *hammeri* appeared in the Bathonian-Tithonian of Cutch and Spiti, and their trace into Pacific is known in the Middle Jurassic of Misol.

(4) Nuculanidae are also common in the Jurassic of Indo-Pacific regions and generally classified into *Nuculana* (*Dacryomya*), *N.* (*Praesaccella*) and *Rollieria*. *Dacryomya* occurs in Japan, New Zealand and Mendoza besides India. It seems a general tendency for Liassic species to have less prominent umbo and more elongated posterior rostrum than Upper Jurassic ones. It is highly probable that such Liassic species belong to the group called "*Ryderia*" by some authors and that true *Dacryomya* appeared at first in the Middle Jurassic or later in the Pacific region.

(5) Parallelodontidae are not very common except for certain horizons of limited area. Though *Parallelodon* is an important member of Jurassic faunas in Japan, only some sporadical occurrences were announced in the Upper Jurassic of India and Canada. No definite species was so far reported from boreal and south Pacific regions. *Parallelodon* itself ranges from Devonian to Jurassic, and the Uppermost Jurassic species appear terminal. In fact, some deviated forms from typical *Parallelodon* appear in the Upper Jurassic of Japan, for instances, *P. kesennumensis* and *P.* (*Torinosucatella*) *kobayashii*. A similar form to *Torinosucatella* is known in the Lias of Sweden (TROEDSSON, 1951), but it is a question whether there was a persistent stock of the subgenus during the Jurassic period or not.

Table 12.

*GRAMMATODON*

* Grammatodon (Indogrammatodon)

| | Europe | India | 3N-arc | Japan | N. America | Mexico | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | alsaticus<br>concinnus | egertonianus*<br>iddurghurensis*<br>kantkotensis*<br>jurianus<br>virgatus* | fyfei*<br>sparsilineatus*<br>taylori* | takiensis<br>densistriatus* | | cassilineatus*<br>delicatulus*<br>reticulatus* | |
| Middle Jurassic | bathonicus | sp.<br>andhouensis | | | ornatus<br>sonninianus<br>semiornatus<br>ferniensis | | |
| Lower Jurassic | inequivalvis* | | inequivalvis* | sp.<br>toyorensis<br>nakanoi* | | | |

(6) Cucullaeidae first appeared in Upper Triassic, and flourished world-widely in Jurassic and Cretaceous. The differentiation of *Grammatodon* (s. s.), *G.* (*Indogrammatodon*) and *Cucullaea* (s. l.) from *Parallelodon* occurred already by the beginning of Jurassic, because each group can be found in the lower Lias of Japan and some other areas. Liassic species such as *G. inequivalvis*

and *G. nakanoi* are relatively small in size and probably early representatives of *Indogrammatodon*. Upper Jurassic *Indogrammatodon* with large dimensions and characteristic ornamentation is common not only in Cutch and Spiti but also in Japan, 3N-arc, Mexico and Gulf Coast. *Grammatodon toyorensis* from the lower Lias of Japan, *G. andhouensis* from the Bathonian of Cutch and *G. takiensis* from the Upper Jurassic of Japan are very similar to one another, and a persistent trunk of *Grammatodon* (s. s.) is suggested to exist also in the Indo-Pacific regions. *Grammatodon* is found also in Neuquén, Canada and Western Interior, but its scarceness in the boreal region including Siberia and Alaska is a remarkable fact. Typical species of *Cucullaea* are probably did not yet appear in the Jurassic. Many Jurassic species described under the generic name of *Cucullaea* are at least subgenerically separable from *Cucullaea* (s. s.). Middle Jurassic species including *Ashcroftia* from Canada seem especially common in the northern Pacific and South America. *Megacucullaea* appeared in the Upper Jurassic of Indian region and survived into Lower Cretaceous.

Table 13.

*MODIOLUS*

* Modiolus (Inoperna)

| | Europe | India | Indonesia | Japan | E.Siberia | N.America<br>Mexico | S.America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | perplicatus*<br>plicatus*<br>bipartitus | plicatus*<br>glendayi<br>cf.bipartitus | | cf.bipartitus<br>plicatus*<br>maedae | solenoides | geniculata<br>malonianus<br>subimbricatus<br>rosii<br>frankensis | |
| Middle Jurassic | imbricatus<br>sowerbyanus*<br>plicatus*<br>solenoides<br>giganteus<br>imbricatus<br>cuneatus<br>plicatus* | imbricatus<br>patchamensis<br>cf.angustissimus<br>cuneatus<br>imbricatus | cf.scalatus | sp.* | | sphenoproratus<br>abbreviatus | cf.giganteus<br>cuneatus<br>imbricatus |
| Lower Jurassic | scalatus<br>scalprus<br>hillanus | | | sp.<br>bakevelloides | | scalprus<br>mandannaensis | gigantoides<br>hillanus<br>mollensis<br>scalprus |

(7) Mytilidae ranging from Devonian to Recent flourished in the Jurassic, and various groups were differentiated from persistent trunk of *Modiolus* in this period. *Modiolus imbricatus* and *M. cuneatus* flourished world-widely in the Middle Jurassic. *M. bipartitus* and its allied forms occur in the Upper Jurassic of Europe, India and Japan. *M. maedae* from the Oxfordian (?) of inner Japan is probably intimate with certain Russian species such as *M. sibiricus* and *M. turkestanicus*. Subgenus *Inoperna* is a well defined group in Middle-Upper Jurassic and Cretaceous, and it has been said to have been derived from certain Liassic ensiform species of *Modiolus*. *M.* (*Inoperna*) *plicatus* shows a wide distribution in the Upper Jurassic of Tethys and Japan. But

Jurassic species of *Inoperna* seem rare in other regions of Pacific, though Cretaceous species are well represented in North America. Most Jurassic mytilids without radial ribs, umbonal septum and anterior wing may belong to *Mytilus* (*Falcimytilus*). *Falcimytilus* was probably branched from *Modiolus* in the Upper Triassic and Lower Jurassic, and its derivation is suggested by many intermediate species in the Jurassic of various regions. *Lycettia* is known in the Middle and Upper Jurassic os Tethyan regions but unknown in the Pacific. *Arcomytilus* seems also rare, but some primitive (?) species occur in the Lias of Japan, and typical species such as *A. laitmairensis* in the Upper Jurassic of Tethys, Japan and Mexico.

(8) Pteriidae are said to have appeared already in Devonian, and many Jurassic species were described from the Pacific region as *Pteria* (or *Avicula*), though some of them are surely referable to the Aviculopectinidae. *Pteroperna* seems to have flourished in the Middle and Upper Jurassic of India, Borneo, Japan and Mexico, but probably is unknown in boreal province. Typical *Pteria* appeared probably at first in the Upper Jurassic, and is found in the calcareous deposits of Japan as well as European Corallian.

(9) Aviculopectinidae flourished chiefly in Upper Palaeozoic and Triassic, and represented by *Oxytoma* and *Meleagrinella* in Jurassic and Cretaceous. *Oxytoma* appeared at first in the Rhaetic in Europe, but in eastern Asia typical representatives with large dimensions flourished already in the Carnic. *O. cygnipes* or allied forms with small number of primary radials show cosmopolitan distribution in lower and middle Lias. *O. inequivalvis* mainly from the Lower Jurassic and *O. münsteri* from the Middle-Upper Jurassic are also cosmopolitan, and form a main trunk of *Oxytoma* during the Jurassic period. Such a species can be found in various areas of Pacific region except for North America where *O. jacksoni* shows extensive distribution in Middle Jurassic

Table 14.

*MELEAGRINELLA*

*Arctotis

| | Europe | India | 3N-arc | Japan | E. Siberia | Mexico | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | laevis<br>ovalis | | | | echinata<br>lenaensis* | durangensis<br>louisianensis<br>tamaulipana | |
| Middle Jurassic | echinata | echinata | echinata<br>sinuata | | intermedia* | | echinata<br>substriata |
| Lower Jurassic | substriata<br>papyria | | | sp.<br>sp.<br>japonica | | | cf. papyria |

Table 15.

*OXYTOMA*

| | Europe | India | Indonesia | 3N-arc | Japan | N. America | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | münsteri | münsteri | münsteri | | tetoriensis | wyomingensis<br>blairmorensis | |
| Middle Jurassic | expansa<br>costata<br>münsteri | | cf. münsteri | sp. | cf. münsteri | submcconnelli<br>mclearni<br>jacksoni | costata<br>münsteri |
| Lower Jurassic | inequivalvis<br>cygnipes<br>scanica | | inequivalvis | sp.<br>sp. | sp.<br>inequivalvis<br>cf. cygnipes | septentrionalis<br>cygnipes | inequivalvis |

Table 16.

*AUCELLA*

* Pseudaucella

| | Europe | India | Indonesia | 3N-arc | E. Siberia | N. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | lahuseni<br>pallasi<br>lindstroemi<br>mosquensis<br>bronni | spitiensis<br>leguminosa<br>blanfordiana | plicata<br>misolica<br>malayomaorica<br>motlolensis<br>subspitiensis | extensa<br>plicata<br>malayomaorica<br>subpallasi<br>subspitiensis<br>boehmi | mosquensis<br>pallasi<br>lindstroemi<br>ochotica<br>piochei<br>bronni | fischeriana<br>piochii<br>rugosa<br>mosquensis<br>concentrica<br>spitiensis |
| Middle Jurassic | | | | | subbronni<br>minima | |
| Lower Jurassic | | | | marshalli* | | |

times. *Meleagrinella* (=*Echinotis*) typified by *M. echinata* is also common in Indo-Pacific regions. Many species hitherto described as *Pseudomonotis* from the Lower-Middle Jurassic of South America and Upper Jurassic of Mexico belong to this genus. In the boreal region *Meleagrinella* appears comparatively rare, but several species with large dimensions and comparatively weak convexity of left valve such as "*Pseudomonotis*" *lenaensis*, for which BODYLEVSKI (1960) proposed *Arctotis*, seem to be related to *Meleagrinella*.

(10) Aucellidae flourished in Upper Jurassic and Lower Cretaceous. It had

been said that *Aucella* is characteristic of the boreal province, but typical species are common also in deep facies of Himalayas, Moluccas, New Zealand and ? South America besides eastern Siberia, North America and Europe. In North America, especially boreal province, *Aucella* flourished sinch upper Oxfordian until Lower Cretaceous, and several zones have been recognized in Alaska, Oregon and California by means of the assemblage of species. In Himalaya, Moluccas and New Zealand several species of *Aucella* are represented in the Upper Jurassic shaly formations, but in Japan and many other areas of Pacific I have not heard the occurrence of the genus. *Pseudoaucella* is characteristic in the Lias of 3N-arc region, but the phyletic relationship between the two genera is unknown. Many authors consider *Aucella* to have been derived from the Aviculopectinidae such as *Meleagrinella* (POMPECKJ, 1901; IMLAY, 1959).

(11) Posidoniidae ranges from Carboniferous to Jurassic. Jurassic *Posidonia* is generally smaller than earlier species. *P. ornati* or its allies show cosmopolitan distribution in Middle-Upper Jurassic. *P. bronni* from the Lias of Europe and South America is said to have multivincular ligament structure and some authors distinguish it as *Steinmannia* (or *Aulacomya*) from typical *Posidonia*. If it is phyletically related to *Inoceramya* from the Unknown Mesozoic group of South Alaska, they may be ancestral to some Middle Jurassic or later inoceramids.

(12) Halobiidae were derived from *Posidonia* in Triassic, and much declined after Rhaetic. However, *Amonotis*, *Posidonotis* and *Aulacomyella* occur respectively in the Lower, Middle and Upper Jurassic of Tethys, Japan and Mexico. These genera have usually narrow stratigraphical range and wide geographical distribution just as Upper Cretaceous descendant genus *Didymotis*.

Table 17.

*GERVILLIA*

* Gervillia (Cultriopsis) ** Gervillella
\+ Bakevellia ++ Gervillaria

| | Europe | India | Indonesia | Japan | N.America | S.America |
|---|---|---|---|---|---|---|
| Upper Jurassic | aviculoides**<br>siliqua** | anceps**<br>kantkotensis**<br>siliqua** | borneensis | sp.<br>takiensis<br>tatenosawensis | cinderella<br>corrugata+<br>montanaensis+<br>ferrieri<br>dolabrata | leufuensis++ |
| Middle Jurassic | waltoni+<br>acuta**<br>ovata**<br>northamptonensis*<br>dundriensis* | waltoni+ | cf.sulcata | | ashcroftensis | cf.oblonga |
| Lower Jurassic | | | cf.lanceolata | magnissima+<br>negoyensis+<br>otariensis+<br>cassianelloides+<br>ohishiensis+<br>shizukawensis*<br>trigona+ | | pallas<br>cf.lamellosa |

Though their phylogenetical relationship is not very clear, the intermittent occurrences of this family in the Jurassic and Cretaceous offer exceptional attractions to Mesozoic stratigraphers and conchologists.

(13) Bakevelliidae are a common group in many Jurassic faunas of Indo-Pacific regions, but their specific assemblage and evolution seem much localized. *Bakevellia* flourished especially in the embayment facies of Japanese Lias, and often attains large size in comparison with Permian and Triassic species. The distribution of *B. waltoni* is traceable in the Bathonian from Europe to Cutch, and some pteriform "*Gervillia*" from the Upper Jurassic of Mexican region may be referable to the genus. In South America "*Gervillia*" *leufuensis* appeared in the Callovian prior to *Gervillaria alaeformis* and its allies which flourished world-widely in Lower Cretaceous. It can be generally considered that Lower and Middle Jurassic *Gervillia* (*Cultriopsis*) is ancestral to Upper Jurassic and later *Gervillia* (s. s.). The stratigraphical occurrence of the two groups in the Pacific region agrees well with the fact in Europe. *Gervillella*, which may have been derived from *Bakevellia* in the Upper Triassic or Lower Jurassic, is common in the Middle-Upper Jurassic or Europe and India but scarcely found in the Pacific region. *Cuneigervillia* is more or less common in the Lias of Europe, but unknown in Indo-Pacific.

Table 18.

*ISOGNOMON*

* Isognomon (Mytiloperna)
** Gervilleioperna

| | Europe | India | Indonesia 3N-arc | Japan | N.America | S.America |
|---|---|---|---|---|---|---|
| Upper Jurassic | subplanus<br>mytiloides | | giganteus<br>cf.subplanus | | | bayani<br>americanus* |
| Middle Jurassic | mytiliformis*<br>isognomonoides<br>bathonicus*<br>rugosus | patchamensis* | | cf.rikuzenicus | weelaupensis | isognomonoides |
| Lower Jurassic | isognomonoides | | timorensis** | ageroensis*<br>sp.<br>rikuzenicus | | |

(14) Isognomonidae appeared at first in Middle Permian. Although Triassic species of this family are scarce but for a few species of *Waagenoperna* (=*Edentula*), a persistent trunk, which is independent from that of the Bakevelliidae, can be expected through Triassic. *Isognomon* flourished in the Lower and Middle Jurassic embayment condition of Japan, and appeared again in the Lower Cretaceous without striking morphological change. Jurassic *Isognomon* is usually equivalve and thick and frequently attains large size,

Table 19.

INOCERAMUS

* Parainoceramus

| | Europe | India | Indonesia | 3N-arc | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | nitescens<br>inoceramoides | stoliczkai<br>gracilis<br>everesti<br>sularum<br>sp. | haasti<br>subhaasti<br>sularum<br>taliabuticus<br>galoi | haasti<br>galoi | furukawensis<br>maedae<br>cf.nitescens<br>hamadae<br>ogurai | retrorsus | obliquiformis | ex gr.galoi |
| Middle Jurassic | fittoni<br>polyplocus<br>fuscus | | | inconditus<br>brownei | utanoensis<br>cf.galoi<br>hashiurensis<br>karakuwensis<br>cf.lucifer<br>morii | kystatymensis<br>menneri | ambiguus<br>platyperforatus<br>ferniensis<br>lucifer | |
| Lower Jurassic | dubius*<br>substriatus*<br>pernoides* | | | | cf.fuscus<br>kudoi<br>matsumotoi*<br>lunaris* | lucifer<br>subambiguus<br>ussuriensis | dubius* | dubius*<br>apollo* |

while Recent species often have inequivalve, irregular outlines and comparatively thin tests. Subgenus *Mytiloperna* is found in the upper Lias of Japan, Bathonian of Cutch and Upper Jurassic of South America. *Gervilleioperna*, which seems at a glance intermediate between *Bakevellia* and *Isognomon*, appeared coevally in the middle Lias of Timor and north Africa.

(15) Inoceramidae probably appeared at first in Upper Triassic, but their world-wide distribution is found after Hettangian. As I have discussed before (1960c), there are some general tendencies as to the morphological transformation of this family during Jurassic period. Small Liassic species often have *Bakevellia*-like dentition and are mostly referable to *Parainoceramus*. Middle and Upper Liassic species of *Parainoceramus* spread not only in Europe and western Tethys but also in Japan, Canada and South America. They may be the collateral ancestors to the group of *Inoceramus fuscus* with mytiliform or rhomboidal outline, which is commonly found in the Aalenian-Oxfordian of Europe, Caucasus and Japan. The group of *Inoceramus lucifer* with elongate outline and strong constrictions is found characteristically in the Bajocian of Alaska, Prince Patrick, eastern Siberia and north Japan. The group of *Inoceramus retrorsus* with more or less developed posterior wing, small apical angle and irregular concentrics may be also boreal, and flourished in the Bathonian-Callovian of Greenland, Siberia and western Japan. The group of *Inoceramus polyplocus* (i.e. subgenus *Mytiloceramus*) with orbicular outline appeared nearly coevally in the Bajocian of Europe and Japan. The group may have been derived from *Posidonia*-like shells, as noted above. On the other hand, the group of *Inoceramus galoi*, characterized by the regular coarse ribbing, developed in the Callovian-Tithonian of Himalayas, Moluccas and 3N-arc. In the Uppermost Jurassic *Anopaea* with non-terminal umbo and more or less

characteristic "lunule" associates with *Inoceramus* in European Russia, New Zealand and (?) Himalayas. *Inoceramus maedae* from the (?) Oxfordian of inner Japan has an unusually prominent umbo and highly inequivalve shells for Jurassic species, and seems to belong to the group of *Inoceramus neocomiensis* which flourished properly in Lower Cretaceous. The evolution of inoceramids seems thus fairly rapid in comparison with other pelecypod groups. Similar species appeared often coevally in far distant areas, though certain species groups show somewhat local development.

(16) Vulsellidae appeared in Jurassic, and it is known that Recent species (and probably fossil species) live commensally with sponges. *Eligmus* ranging from Bajocian to Callovian flourished especially in the Tethyan region. *E. rollandi* or its allied forms show wide distribution in the Bathonian of east Africa, Madagascar, Turkey, Cutch and Upper Burma. Bathonian deposits are comparatively rare in the Pacific region, but it may bear something on palaeobiogeography and pelecypod evolution that no specimen of the genus has ever been found therefrom.

(17) Pinnidae are said to be persistent from Palaeozoic and derived from certain group of the Pteriidae. The extensive development of *Pinna* is, however, found at first in the Middle Jurassic. Many of Jurassic species in the Indo-Pacific regions have a distinct median parting and fine radial striations on the surface. *Pinna mitis* or its allied forms are distributed in the Upper Jurassic of Europe, India and Japan. *Trichites* is found in the Upper Jurassic of Cutch but probably unknown in the Pacific.

(18) Pectinidae flourished world-widely in the Triassic and later periods. Undoubted *Chlamys* exists already in the Carnic of Japan and eastern Siberia. *Chlamys textoria* is a cosmopolitan Liassic species, and constitutes one of main

Table 20.

*CHLAMYS*

* "Aequipecten"

| | Europe | India | Indonesia | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | splendens | subtextoria<br>cf.episcopalis | | iboibo<br>vulgaris*<br>camptonectoides<br>mitaraiensis<br>sp. | | mcconnelli | |
| Middle Jurassic | ambigua<br>subtextoria<br>viminea<br>dewalquei | ambigua<br>curvivarians | | kobayashii | | pardeios | |
| Lower Jurassic | textoria | | textoria | kurumensis<br>kotakiensis<br>textoria<br>toyorensis* | textoria | textoria | textoria<br>priscus* |

stocks of the genus in each region. *Textoria* and most other Liassic *Chlamys* have comparatively flattenend right valves, but Middle Jurassic and later *Chlamys* is generally equivalve except for the byssal part. *Chlamys mitaraiensis* from the Upper Jurassic of Inner Japan, having *Camptochlamys*-like lattice ornamentation, is probably phyletically related to some boreal *Chlamys* instead of *Camptochlamys*. "*Aequipecten*" which I use for the group of "*Pecten*" *priscus*, is common in various Jurassic stages of Indo-Pacific regions as well as Europe. *Radulopecten* is probably a Tethyan element, and its distribution seems to be confined properly to western Europe, Africa, India, (?) Mindoro and outer Japan. *Pseudopecten, Spondylopecten, Plesiopecten* are unknown in Pacific. "*Pecten* „ *alata* its allied well inflated forms occur commonly in the Lias of South America. They seem most intimate to modern *Pecten* (s. s.) among various Jurassic scallops and may be ancestral to it. *Parapecten ntlakapamuxanus, P. praecursor* and *P. acutiplicatus* from the Pacific coast of North America are probably related to the South American species, but such a pectinid is unknown in the western Pacific region.

Table 21.

CAMPTONECTES

* Camptonectes (s. l.)

| | Europe | India | Indonesia | 3N-arc | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | auritus | indicus<br>auritus | | grandis* | aff. browni<br>mimikirensis*<br>torinosuensis*<br>sp. | | bellistriatus<br>pertenuistriatus<br>platessiformis | |
| Middle Jurassic | auritus<br>laminatus | luchiangensis<br>laminatus<br>cf.arcuatus<br>cf.browni | aalensis | cf.laminatus | cf.auritus | | subbellistriatus<br>albertensis | lens<br>laminatus |
| Lower Jurassic | aalensis | | | | sp.*<br>subflabelliformis*<br>oishii*<br>inexpectatus | sp. | | |

*Camptonectes* flourished explosively in the Jurassic period. But the presence of typical *Camptonectes*-striations in certain Permian, Triassic and lower Liassic species indicates that the origin of this genus can be traced back into earlier period than formerly supposed by some authors. It is probable that *Camptonectes* was derived from the Aviculopectinidae parallel to other pectinid groups. In the Lower and Middle Jurassic typical species such as *Camptonectes auritus* and *C. laminatus* are known in Japan, New Zealand and South America besides various areas of the world. In North America *C. bellistriatus* and its allies occur in the Upper Jurassic. *Radulonectites*, which is characterized by *Pleuronectites*-like out-line and ventral radial grooves, is found in the Lias of inner Japan. Several South American species such as *Camptonectes lens* Leanza non Sowerby and *Pecten soneadoensis* Weaver are morphologically similar to the Japanese species. *Eopecten*, a well defined pectinid group, was probably derived from the Aviculopectinidae in Triassic, and Liassic species are more or less common in Europe and India. It is found also in the Upper Jurassic of India and Japan, but seems comparatively rare in Pacific.

Table 22.

*ENTOLIUM*

* Variamussium

| | Europe | India | Indonesia | 3H-arc | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | | partitum | | | habunokawense*<br>kimurai<br>japonicum<br>yatsujiense<br>inequivalve | nummulare | leachi<br>vulcanicum<br>herleini | |
| Middle Jurassic | corneolum<br>demissum<br>disciforme | | demissum | | cf.disciforme | | parviaure<br>semlini | pumilis<br>disciforme |
| Lower Jurassic | hehli<br>lunare<br>calvum<br>cingulatum | | donaiensis* | fossatum | sp.*<br>cf.lunare<br>cf.calvum | | equatle<br>meeki | disciforme<br>hehli<br>coloradoense |

(19) Amusiidae especially *Entolium* and *Variamussium* occur commonly in many areas of Indo-Pacific. *Entolium* was probably originated in Upper Palaeozoic *Pernopecten* and flourished in Mesozoic especially Jurassic. Several Liassic species such as *E. calvum* often have shallow byssal notches. But the fact does not mean that they were derived from *Chlamys*-like pectinids, because such a notch can be observed also in *Pernopecten* and some Upper Jurassic *Entolium*. *E. disciforme* is probably a cosmopolitan element, and comparable forms to *E. disciforme* and *E. demissum* occur in the Upper Lias and Bajocian of Japan, Moluccas and South America. *E. japonicum* and *E. kimurai* from the Upper Jurassic of Japan may be descendants from the group of *E. calvum*, and *E. yatsujiense* from the group of *E. lunare*. In North America *Entolium* is also common at some Jurassic horizons. *Entolium nummulare* and its allies which constitute a well defined species group with distinct concentric sculptures, flourished in the period from Oxfordian to Valanginian chiefly in boreal province. *E, inequivalve* from the Upper Jurassic of inner Japan is intimate to *E. nummulare* and also to *E. orbiculare* from the Albio-Cenomanian of Europe and Greenland. *Somapecten* is a characteristic genus of this family. It occurs commonly in the Upper Jurassic of outer Japan, and may be a small branch from *Entolium*. *Variamussium*, which seems ancestral to Cretaceous

Table 23.

*PLICATULA*

* Plicatula (Harpax)

| | Europe | India | Indonesia | Japan | E.Siberia | N. America<br>Mexico | S.America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | weymouthiana | blanfordi<br>badiensis<br>peregrina | sp. | yatsujiensis<br>dichotomocosta | | sportella | vacaensis |
| Middle Jurassic | fistulosa<br>tuberculosa | | weberi<br>cf.spinosa* | | | | |
| Lower Jurassic | dabarensis*<br>spinosa* | | | subcircularis<br>praenipponica* | spinosa* | | rapa |

Table 24.

*PLAGIOSTOMA*

| | Europe | India | Indonesia | 3N-arc | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | laeviusculum<br>rigida<br>callovicum | strigillata<br>blanfordi<br>callovicum | | | enormicosta<br>cf.cardiiforme | | | laeviusculum |
| Middle Jurassic | cardiiforme<br>semicirculare | cf.complanata<br>cardiiforme<br>jumaraense | semicirculare | | | | hazeltonense<br>albertense<br>intermedium | truncatifrons<br>semicirculare |
| Lower Jurassic | punctatum<br>giganteum<br>compressum<br>nodulosum<br>succinctum<br>garlandica | giganteum | | aff.giganteum | matsumotoi<br>kobayashii | aff.ovalis<br>parapunctum<br>subcompressum<br>savrassovi | nodulosum<br>exaltatum | cardiiforme<br>succinctum<br>giganteum<br>nodulosum<br>punctatum |

and later *Propeamussium,* occurs at various horizons of Jurassic in Japan, Cochin China, New Zealand, Canada and Neuquén.

(20) Plicatulidae are found already in the Upper Triassic of Japan, but developed extensively in Lias and later stages. Early species such as *P. spinosa,* which probably can be grouped as subgenus *Harpax,* are comparatively large in size, and occur in the Lias of Japan, eastern Siberia and South America and the Middle Jurassic of Moluccas. But they often associate with more typical species of *Plicatula.*

(21) Limidae are represented by many genera in the Jurassic whose assemblage is somewhat different from that of Triassic. *Plagiostoma* is generally considered to have been derived from Triassic *Mysidioptera*. A few species of *Plagiostoma* exist in the Upper Triassic of some regions, but its world-wide development is found after Rhaetic. *Plagiostoma succinctum*, *P. giganteum*, *P. nodulosum*, *P. semicirculare* and *P. cardiiformis* show wide distribution also in the Pacific region. Their stratigraphical occurrence agree roughly with those in Europe. Some authors referred some Jurassic limids to *Acesta*, but *Acesta* was, I think, derived from *Plagiostoma* properly after Jurassic. *Pseudolimea* is common at various horizons in European Jurassic. In Japan the genus occurs already in the Upper Triassic, but Jurassic species are scarcely known in the Pacific region except for *P. duplicata* from the upper Lias of Neuquén. *Antiquilima* is known in the Lias and Aalenian of Europe, and *A. nagatoensis* occurs in the lower Lias of western Japan. The genus resembles at a glance Upper Jurassic and later *Ctenoides*, though their phylogenetic relationship cannot be warranted. *Limatula*, though Jurassic species are sometimes fairly deviated from Recent typical species in outline, is common in many areas of Pacific. *Ctenostreon* is an important member in many Jurassic faunas of Indo-Pacific. *C. proboscideum* are probably a Tethyan elements, and its distribution can be traced in the Middle-Upper Jurassic from Europe to India, Indonesia and Japan. Lower Liassic species are known in western Japan and Amur. In South America several species of *Ctenostreon* with much thickened ligament area such as *C. paucicostatum* appeared in the Lias and succeeded by some Callovian species such as *C. chilense*.

(22) Anomidae are represented by *Placunopsis* in Jurassic period. Some Upper Jurassic species occur in India and New Zealand.

Table 25.

CTENOSTREON

| | Europe | India | Indonesia | Japan | E. Siberia | N. America Mexico | S. America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | proboscideum | | | proboscideum | | riograndense | neuquense<br>chilense |
| Middle Jurassic | proboscideum<br>rugosum<br>wrighti<br>pectiniforme | proboscideum | pectiniforme | ojikense<br>sp. | | gikshanense | raricostatum<br>pectiniforme<br>wrighti |
| Lower Jurassic | chlamidiforme<br>terquemi | | cf. terquemi | sp.<br>japonicum | orientale | | paucicostatum |

Table 26.

GRYPHAEA

| | Europe | India | N. America | Mexico | S. America |
|---|---|---|---|---|---|
| Upper Jurassic | lobata<br>dilatata<br>bilobata | balli<br>moondanensis<br>sicula<br>hennigi<br>bilobata | planoconvexa<br>calceola var. | mexicana<br>impressimarginata | dilatata<br>leufuensis<br>carinata |
| Middle Jurassic | sandalina | balli<br>eminens<br>lashioensis<br>cf.virassai | patera<br>minutula<br>cadominensis | | neuquensis<br>cf.santiaguensis<br>tricarinata<br>sandalina<br>subovata<br>calceola |
| Lower Jurassic | cymbium | | cf.cymbium<br>rockymontana | | calceola<br>cf.cymbium<br>darwini |

Table 27.

LOPHA

| | Europe | India | Indonesia | Japan | N. America | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | solitaria<br>gregarea<br>marshii | eruca | amor | gregarea<br>cf.eruca<br>cf.marshii<br>sp. | mcevoyi<br>informis | |
| Middle Jurassic | marshii<br>gregarea<br>solitaria<br>pulligera | marshii<br>gregarea | sp. | spp. | | solitaria<br>pulligera |
| Lower Jurassic | | | | sazanami | ? gregarea | longistriata<br>keideli |

(23) Ostreidae become more common after Rhaetic, though *Gryphaea, Lopha* and *Liostrea* which are the main representative genera of the family appeared already in Triassic times. *Gryphaea* is said to have been derived from *Liostrea* through *Liostrea* (*Catinula*), and the morphic transformation among the three, in fact, seems gradual. *Gryphaea* seems very common in North and South America since Lias besides Europe and India, but the genus is scarcely found

in many areas of western Pacific region. *G. bilobata* and many other Tethyan species cannot be traced into Indonesia, 3N-arc and Japan. It is probably because the geosynclinal sedimentary condition in the western Pacific may have inhibited its development. However, the distribution of sedentary species of *Lopha* extends from Europe and India to Indonesia and Japan. *L. marshii* with broad outline and radiating plications and *Lopha eruca* with narrow outline and divaricate ribs constitute two stocks in the Middle-Upper Jurassic of these regions. *Heterostrea steinmanni* from the Bajocian of Peru is said to possess dimyarian adductors.

(24) Trigoniidae may have evolved polyphyletically from several groups of the Myophoriidae, as suggested by some authors. KOBAYASHI, MORI and TAMURA (1954-1959) studied this family and determined the generic positions of many Jurassic species not only in Japan but also in various areas of Pacific. It was clarified by them that the evolution of trigoniids in the Pacific region is somewhat different from European and Indian regions. The result of their studies can be summerized as follows. *Trigonia* (s. s.) shows worldwide distribution and occurs at various horizons of Jurassic in Indo-Pacific. *Frenguelliella* is common in the Lower and Middle Jurassic of South America, and it is probable that certain species of *Vaugonia* were derived from *Frenguelliella*. It is interesting to see in many species of *Vaugonia* that there are *Frenguelliella, Jaworskiella* and *Vaugonia*-stages in their ontogeny. Some authors suggested that *Vaugonia* was derived from *Myophorella*, but in Japan *Vaugonia* appeared already in lower Lias prior to the first appearance of *Myophorella*—a fact denying the evolutional trend from *Myophorella* to *Vaugonia*. *Vaugonia* flourished in the Middle Jurassic of South America but seems comparatively rare in North America. *Myophorella* is on the contrary more common in north

Table 28.

*TRIGONIA*

* Frenguelliella
** Jaworskiella

| | Europe | India | Indochina | Japan | N. America | Mexico | S.America |
|---|---|---|---|---|---|---|---|
| Upper Jurassic | reticulata | spitiensis<br>nitida | | | americana | minuta<br>rudicostata | mirandaensis<br>mollesensis<br>corderoi |
| Middle Jurassic | elongata<br>cassiope | elongata<br>prora<br>kheraensis<br>tealei | moorei* | sumiyagura | | | cassiope<br>sterzneri<br>denticulata |
| Lower Jurassic | costata | | | senex | cf.denticulata<br>aff. costata<br>litteri | | burckhardti**<br>inexpectata*<br>chubutensis<br>tapiai* |

Pacific. The distribution of *Myophorella* (*Promyophorella*) *orientalis* extends from north Japan to Mindoro. *Myophorella* (*Haidaia*) is also common in north Pacific and seems especially common in outer Japan and Mexico. *Geratrigonia*, *Prosogyrotrigonia* (Jurassic species), *Latitrigonia*, *Ibotrigonia* and *Nipponitrigonia* are quite interesting groups for the consideration of trigoniid evolution, but their distribution is now confined to Japan and its surroundings. In the Indian region *Indotrigonia* and *Pterotrigonia* are well represented in the Upper Jurassic,

Table 29.

*VAUGONIA*

* Hijitrigonia

| | Europe | Indonesia | SN-arc | Japan | N.America | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | | | | yambarensis | obliqua | pichimon<br>colensis |
| Middle Jurassic | flecta<br>moretoni<br>angulata | mindoroensis | kawhiana | awazuensis<br>yokoyamai<br>geniculata* | obliqua<br>doroschini | ovallei<br>rectangularis<br>praelonga<br>covuncoensis<br>exotica<br>chunumayensis<br>gottschei<br>literata*<br>lycetti* |
| Lower Jurassic | v-costata*<br>costatula | | | kodaijimensis<br>kojiwa*<br>yokoyamai<br>niranohamensis<br>namigashira | aff.costatula | |

Table 30.

*MYOPHORELLA*

* Haidaia

| | Europe | Indonesia | SN-arc | Japan | N. America<br>Mexico | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | perlata<br>hudlestoni<br>clavellata | orientalis<br>molengraffi* | | obsoleta<br>orientalis<br>purex*<br>gracilenta*<br>dekaiboda<br>imamurai<br>crenulata*<br>sugayensis | vyschelzkii<br>proscabra*<br>dawsoni*<br>montanaensis<br>ferrieri | |
| Middle Jurassic | imbricata<br>scarburgensis<br>witchelli<br>signata | | | sigmoidalis | trafalgarensis<br>devexa<br>undulata | signata |
| Lower Jurassic | formosa | | | | aff.formosa | |

and Jurassic trigoniids faunas are composed of much different genera from Pacific ones. It is concluded that the rise and fall of trigoniids are fairly different among regions, and that some groups show local development in certain limited biogeographical provinces.

(25) Pachicardiidae including *Pachicardia*, *Heminajas*, *Trigonodus* and *Cardinioides* developed in the Triassic of various regions, but most genera disappeared before the beginning of Jurassic. Only two endemic species of *Cardinioides* occur in the Lias of inner Japan.

Table 31.

*CARDINIA*

| | Europe | Indonesia | Japan | E. Siberia | N. America | S. America |
|---|---|---|---|---|---|---|
| Middle Jurassic | | | | | inexpectata | jurensis |
| Lower Jurassic | philea<br>hybrida<br>regularis<br>henocquii<br>concinna | aff. philea<br>nachamensis<br>latitruncata | orientalis<br>toriyamai | nostra<br>aff. collenoti<br>amurensis<br>aff. hennocquii | regularis | densestriata<br>andium |

(26) Cardiniidae are known already from the Carnic of Japan, but the extensive development of *Cardinia* is known in Rhaetic and lower-middle Lias. In the Pacific region Liassic species are found in Japan, eastern Siberia, Indochina, Canada and South America, but the constituent species are quite different from European faunas. Splendidly imbricated species, which I (1958) treated as a subgroup of *C. hybrida* are distributed in northern Pacific, while the subgroup of *C. densestriata*, characterized by the numerous concentric lines between the imbrications is restricted to South America. Typical *Cardinia* with large dimensions and more or less elongate-ovate outline occurs in Indochina and Japan besides Europe but seems comparatively rare in Pacific. In the Indian region *Cardinia* probably has not been found, but it is possibly due to the scarceness of lower Liassic deposits. Some species of Triassic *Palaeopharus* and *Pleurophorus* show similar internal characters to *Cardinia*, and it is highly probable that *Cardinia* was derived from certain preheterodont pelecypods.

(27) Myoconchidae are persistent from Triassic. Jurassic species in the Pacific region can be grouped into *Myoconcha* from South America and *Kalentera* from New Zealand. *Myoconcha* is known in the Lias of eastern Siberia and (?) Upper Jurassic of Japan, but this family seems rare in other areas of Pacific.

(28) Astartidae appeared at first in Upper Triassic and developed extensively in Jurassic. Cretaceous species are also very common in various areas

Table 32.

*ASTARTE*

* Coelastarte

| | Europe | India | Indonesia | 3N-arc | Japan | N. America | Mexico | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | ovata<br>subdepressa | spitiensis<br>hermanni<br>sowerbyana<br>scytalis | eastoni<br>borneensis | | cf.spitiensis<br>kambarensis<br>sakamotoensis<br>ogawensis<br>higoensis<br>defecta<br>subdepressa<br>somensis* | meeki<br>packardi<br>harrisonensis<br>morion | malonensis<br>cf.rathieri<br>microphyes<br>breviacola<br>grubbi<br>magnoliana<br>smackoverensis<br>hazzardi | "minima" |
| Middle Jurassic | wiltoni<br>pumila<br>excavata*<br>depressa<br>elegans | rustica | elegans | spitiensis | cf.cardiniiformis* | sonniniarum | | pulmae<br>mirabilis<br>gracilis<br>excavata*<br>ardium |
| Lower Jurassic | subtetragona<br>lurida<br>voltzi | | subcarinata<br>voltzi | | cardiniiformis*<br>spp. | | cf.antipodum | subtetragona<br>antipodum<br>aureliae<br>fontis |

but Recent ones are not numerous, their distribution being confined properly to cold seas. Liassic species are generally small in size, and typical species with large dimensions, prosogyrous umbo, ventral crenules and characteristic shell- convexity flourished chiefly in Aalenian and later. Typical *Astrate* is common in the Middle Jurassic of Cutch and South America and Upper Jurassic of Cutch, Himalayas, Japan and Mexico. *A. spitiensis* occur typically in the Uppermost Jurassic of Himalayas, and allied forms are found also in New Zealand and Japan. *Coelastarte* is known in Bajocian and later in Europe and South America, but in Japan *C. cardiniiformis* appeared already in Hettangian, though it has not distinct ventral crenulations. *Praeconia* appeared in the lower Lias of Japan just as in Europe.

(29) Neomiodontidae including several Mesozoic cyrenoid genera at first appeared already in Lias prior to the Corbiculidae. *Eomiodon* existed in the lower Lias of Japan and flourished until Bajocian, but in Tethys regions its development is found in Bathonian and later. *Crenotrapezium*, which was probably derived from *Eotrapezium*-like cyprinid pelecypods and is characterized by the carinated trigonal outline and elongated lateral teeth with numerous transverse crenulations, often associates with *Eomiodon* in the Lias of Japan. However, the two genera are scarcely known in other areas of the Pacific region.

(30) Corbiculidae at least in part may have derived from the Arcticidae and Neomiodontidae in late Jurassic and early Cretaceous times, and may be a polyphyletic family. Although some Jurassic cyrenoids were referred to *Corbicula* (=*Cyrena*), *Polymesoda* and *Batissa* in Japan and some other areas, none is typical of those genera. Only *Filosina*, which is typically known in the Wealden of Europe and said to have arisen from Upper Jurassic *Eocallista*,

Table 33.

*EOMIODON*

| | Europe | India | Indonesia | Japan |
|---|---|---|---|---|
| Upper Jurassic | cuneatus | | | kumamotoensis |
| Middle Jurassic | fimbriatus<br>angulatus<br>nortonensis | indicus<br>namtuensis<br>namyauensis | chumphonensis | vulgaris |
| Lower Jurassic | | | | vulgaris<br>lunulatus |

occurs in the Purbeckian or Wealden beds of north Japan. The elongation and crenulation of lateral teeth, which are commonly seen in many genera of the Corbiculidae and Neomiodontidae, are a marked tendency in brackish and non-marine heterodont pelecypods.

(31) Arcticidae (=Cyprinidae) flourished in Jurassic and Cretaceous times, and constitute an ancestral group to Cretaceous and later venerid pelecypods. Although many characteristic genera are known in the European Jurassic, Jurassic species seem less common in the Pacific region. Several species from the Bajocian of Canada and Upper Jurassic of Mexico and Western Interior were referred to *Arctica*. In Japan *Arctica* (*Somarctica*) which is characterized by the smaller anterior cardinal 3a and apparently intermediate between *Eocallista* and *Arctica* (s. s.), occurs in the Upper Jurassic. *Yokoyamaina*, having a distinct pallial sinus and cyprinid like dentition, is found abundantly in the lower-middle Lias of Japan, though the family reference is uncertain. Besides, *Isocyprina*, *Eocallista* and *Anisocardia* occur sporadically in the Middle and Upper Jurassic of Japan.

(32) Lucinidae are said to have developed since Triassic. *Lucina* (s. l.) *hasei* from the lower Lias of western Japan has subvertically elongated adductor scars of *Lucina*-type, A lot of Jurassic species were hitherto described as *Lucina* from South America, Mexico and Japan besides Europe, but their generic references should be revised in future, because typical Recent species of *Lucina* has almost edentulous hingement and may be fairly deviated from normal Jurassic species.

(33) Fimbriidae (=Corbidae) including *Fimbria*, *Sphaeriola* and *Sphaera*

flourished especially in Jurassic. *Sphaera* is known chiefly in the Middle Jurassic of Europe, but in Japan, eastern Siberia and New Zealand the genus occurs already in the lower Lias. It seems highly probable that *Sphaeriola* evolved from Triassic *Schafhäutlia* by the differentiation of chevron-like cardinal tooth 3 into distinct 3a and 3b. Jurassic *Fimbria* occurs commonly in Europe and north Africa, but in the Pacific only two forms are known in the lower Lias of Japan and Middle Jurassic of South America.

Table 34.

*TANCREDIA*

| | Europe | Indonesia | 3N-arc | Japan | N. America Mexico | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | curtansata | | plana | rostrata<br>sp. | louisianensis<br>texana<br>knowltoni | cf.donaciformis |
| Middle Jurassic | truncata<br>angulata<br>extensa | | allani | | canadensis | |
| Lower Jurassic | | marcignyana | | | | |

Table 35.

*PROTOCARDIA*

| | Europe | India | Indonesia | Japan | N. America | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | | | tenuicostata<br>multiformis<br>crassicosta | morii<br>tosensis<br>sp. | shumardi<br>schucherti | |
| Middle Jurassic | buckmani<br>stricklandi<br>striatula | grandidieri | | inaii | obliquata<br>erecta | substricklandi<br>striatula |
| Lower Jurassic | philippianum<br>rhaetica | | philippianum | kurumensis<br>onoi | | koeki<br>cf.hillana |

(34) Tancrediidae and Quenstedtiidae flourished world-widely in the Middle and Upper Jurassic. *Tancredia* and *Quenstedtia* occur commonly in the Upper Jurassic of Mexico and Western Interior, but seem rather rare in the western Pacific region.

(35) Cardiidae appeared in Triassic and flourished in Jurassic and later. The greater part of Jurassic species of the family belongs to *Protocardia* which survived until Cretaceous and is succeeded by *Nemocardium* in Cenozoic. *Protocardia* seems an euripic genus and occurs abundantly in various facies in the Jurassic of Japan, Burma, Borneo, North and South Americas. *Cardium asaphum* and *C.* (s. l.) *naganoense* respectively from the Lias of Neuquén and Japan show much different surface-ornamentation from *Protocardia*. The two species are, of course, not typical *Cardium*, but imply the presence of other stocks of the Cardiidae than *Protocardia*.

Table 36.

CORBULA

| | Europe | India | Indonesia | Japan | N. America |
|---|---|---|---|---|---|
| Upper Jurassic | oxoniensis | | borneensis<br>eastonii<br>vogeli | sp.<br>globosa | maloniana |
| Middle Jurassic | buckmani<br>lyrata | lyrata<br>cf. involuta | | | munda |
| Lower Jurassic | | | | | |

(36) Corbulidae appeared probably at first in Middle Jurassic. Bathonian and Callovian species of *Corbula*, though their generic reference should be further examined, are common in India, (?) Borneo and Western Interior of North America.

(37) Pholadidae mostly composed of boring shells occur at first in (?) Middle Jurassic with the appearance of *Myopholas*. A comparable species with Tethyan *M. acuticostata* occurs in the Upper Jurassic of Japan.

(38) Pleuromyacidae are common in every stage from Triassic to Lower Cretaceous, and numerous species of *Pleuromya* developed in Indo-Pacific as well as in Europe. In North America Bajocian and Callovian species are especially common, while only a few species are known in each area of western

Table 37.

*PLEUROMYA*

| | Europe | India | Indonesia | 3N-arc | Japan | E. Siberia | N. America Mexico | S. America |
|---|---|---|---|---|---|---|---|---|
| Upper Jurassic | alduini<br>uniformis | uniformis | alduini | | punctostriae<br>hidensis | impressa | inconstans<br>subcompressa<br>summissiornata<br>obtusiprorata<br>postculminata | cf.varians<br>cf.alduini |
| Middle Jurassic | uniformis<br>marginata<br>alduini<br>jurassi | | | milleformis | | | weberensis<br>rhynchophora<br>oblonga<br>nuda<br>hectica<br>burnsi<br>antolycus<br>chlutosensis<br>simplex | jurassi<br>gottschei |
| Lower Jurassic | rotundata<br>unioides<br>striatula<br>liasina | | | urnula | hashidatensis<br>sp. | | cf.gregarius<br>yukonensis | striatula<br>rotundata<br>liasina<br>cf.unioides |

Table 38.

*PHOLADOMYA*

* Tetorimya

| | Europe | India | Indonesia | Japan | N. America Mexico | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | donacinna<br>hemicardia<br>protei<br>multicostata<br>uralensis* | somensis | cf.multicostata | somensis<br>carinata* | marcoui<br>paucicostata<br>praeposita<br>inequiplicata<br>kingi<br>tosta<br>panderi* | plagemanni |
| Middle Jurassic | | | cf.angustata | sp. | | acostae<br>abbreviata<br>fidicula |
| Lower Jurassic | fidicula<br>voltzi<br>ambigua | | | | donacina | andina<br>corrugata<br>cf.fortunata<br>ambigua<br>hemicardia<br>voltzi |

Pacific. South American species from the Lias and Bajocian are mostly identical or closely allied to European famous species.

(39) Pholadomyacidae also appeared in Triassic but their explosive development is found in Jurassic. *Pholadomya* is quite common in the upper Lias and Bajocian of South America and Upper Jurassic of North America and Mexico. In the western Pacific region, however, the genus seems uncommon, and it is probably due to the predominance of coarse clastic and geosynclinal sediments and impredominance of marly facies of calm sedimentary con-

Table 39.

*GONIOMYA*

| | Europe | 3N-arc | Japan | N. America | S. America |
|---|---|---|---|---|---|
| Upper Jurassic | literata | depressa | nonvscripta | | |
| Middle Jurassic | hemicostata<br>literata<br>v-scripta<br>duboisi<br>proboscidea | | | sp. | cf.duboisi |
| Lower Jurassic | heteropleura | | | aff.heteropleura | proboscidea<br>sp. |

Table 40.

*HOMOMYA*

| | Europe | India | 3N-arc | Japan | N. America | S. America |
|---|---|---|---|---|---|---|
| Upper Jurassic | gibbosa | | | gibbosa | gallatinensis | gracilis |
| Middle Jurassic | gibbosa | | signicollina | | jurozephyriensis | gibbosa |
| Lower Jurassic | | | | satoi | | neuquena<br>bodenbenderi<br>obliquata |

dition where *Pholadomya* and other thin-shelled myacids developed. It may be the same as to the distribution of Jurassic *Gryphaea*. *Tetorimya carinata*, an aberrant myacid, occurs in the (?) Oxfordian of inner Japan. Similar species are known in the Oxfordian of Ural and Upper Jurassic of Alaska, and the genus flourished chiefly in boreal province. *Homomya* occurs in the Upper Lias, Bajocian, and Upper Jurassic of Japan, New Zealand, North America and South America. *H. gibbosa* seems a cosmopolitan species. *Goniomya* is comparatively rare except for several species from the Lias of Canada and Neuquén and Upper Jurassic of Himalayas, Queensland and Japan. *Neoburmesia* is a characteristic genus found in the Upper Jurassic of Japan. The absence of chondrophore suggests that the genus belongs to the Pholadomyacidae instead of the Burmesiidae.

(40) Burmesiidae, though the taxonomic position has not been firmly settled, seem a characteristic family found chiefly in the Noric-Rhaetic of southeastern Asia. A lower Liassic species of *Burmesia* is found in north Japan, and the range of the family extends into Jurassic.

Table 41.

*THRACIA*

| | Europe | Japan | E. Siberia | N. America |
|---|---|---|---|---|
| Upper Jurassic | lata<br>depressa | fukushimensis<br>shokawensis | cf.lata | maloniana<br>montanaensis<br>weedi<br>canadensis |
| Middle Jurassic | depressa<br>lens<br>elongata | | | dubia<br>convexa |
| Lower Jurassic | | sp.<br>subrhombica | | |

(41) Thraciidae appeared at first in Triassic, and flourished in Jurassic. *Thracia* is common in the shaly facies of Japan, Siberia and North America besides Europe, but the genus is scarcely known in southern Pacific.

(42) Cuspidariidae flourished probably after Jurassic, but several species from the Upper Triassic and Jurassic of southeastern Asia and Japan constitute a well defined taxonomic group showing *Cuspidaria*-like rostrate outline, and may belong to the family.

## Summary

For the last ten years the greater part of the Jurassic pelecypod faunas in many localized sedimentary areas of Japan was described by KOBAYASHI, MORI, TAMURA, KIMURA and myself. More than 90 genera and more than 350 forms have been distinguished in various Jurassic formations of Kitakami, Hida, Nagato, Soma and the Outer Zone of Southwest Japan. Pelecypods are the most ubiquitous fossil group in these regions, and the faunas seem important for the stratigraphical, palaeoecological and palaeobiographical considerations besides the palaeontology proper. In this paper I summerize and discuss their stratigraphical and geographical distribution, zonation, palaeoecology and palaeobiogeography, based on the hitherto published taxonomic descriptions and my field observations, and make some interpretations on the pelecypod evolution in the Pacific region.

In the Kitakami region 17 faunules, which are characterized respectively by *Burmesia japonica, Geretrigonia hosourensis, Trigonia senex, Meleagrinella* sp., *Variamussium* sp., *Inoceramus kudoi, Vaugonia kodaijimensis, Trigonia sumiyagura, Kobayashites hemicylindricus, Chlamys kobayashii, Inoceramus karakuwensis, Inoceramus hashiurensis, Myophorella orientalis, Parallelodon kesennumensis, Myophorella obsoleta* and *Filosina jusanhamensis*, are important for biostratigraphy and intraprovincial correlation. The Kuruma-Tetori fauna of the Hida region comprises 18 faunules characterized by *Radulonectites japonicus, Chlamys kurumensis, Bakevellia ohishiensis, Bakevellia negoyensis, Pleuromya hashidatensis*, "*Camptonectes*" sp., *Bakevellia magnissima, Meleagrinella* sp., *Geratrigonia kurumensis, Inoceramus hamadae, Inoceramus* cf. *nitescens, Latitrigonia tetoriensis, Nipponitrigonia sagawai, Inoceramus maedae, Tetorimya carinata, Entolium inequivalve, Vaugonia yambarensis* and "*Corbicula*" *tetoriensis*, though their ages are not always determinable strictly. In the Toyora region 8 faunules represented by *Cardinia toriyamai, Prosogyrotrigonia inouyei, Oxytoma kobayashii, Parainoceramus lunaris, Parainoceramus matsumotoi, Posidonia* sp. ex gr. *ornati, Inoceramus* sp. ex gr. *fuscus* and *Inoceramus utanoensis* occur in ascending order.

Because of the considerable dependence of pelecypod distribution on facies, the faunas are important facies-indicators in the Japanese Jurassic. In the Kitakami region and the Inner Zone of Southwest Japan, the fossiliferous sediments can be roughly divided into three categories, namely ammonite-facies (off-shore neritic shales), trigoniid-facies (near-shore or littoral sandstones) and cyrenoid-facies (embayment shales and sandstones). Trigoniid-facies shows generally somewhat agitated sedimentary condition, and ammonite- and cyrenoid-facies calm and somewhat stagnant environments. *Inoceramus, Posidonia, Pleuromya* and some other thin-shelled forms are predominant in the ammonite-facies, *Oxytoma*, normal trigoniids, prionodonts and heterodonts with heavy tests in the trigoniid-facies, and *Bakevellia Isognomon, Mytilus, Eomiodon* and some other cyrenoids fairly characteristic in the cyrenoid-facies. This division is, however, inapplicable to the bio-facies of the Outer Zone where calcareous and open-sea sediments are predominant.

The marked difference of generic and specific assemblage of pelecypods among Jurassic sedimentary regions of Japan may be partly due to various sedimentary environments but at the same time must be dependent also on certain biogeographical isolation. In the Lower Jurassic, Kitakami, Kuruma (inclusive of Iwamuro and Yamaoku) and Toyora regions constituted three distinct faunal provinces. In the Upper Jurassic the Tetori fauna suggests an almost distinct province from that of the Outer Zone, but it is found that the Kitakami, Soma and Torinosu faunas are intimately connected with one another, as shown with SIMPSON's indices of faunal resemblance. The greater part of the Kuruma, Tetori and Kitakami pelecypods is endemic, but Tethyan, Pacific and even cosmopolitan elements are not rare in the sandy or limy facies of the Toyora, Kitakami (in part), Soma and Torinosu faunal provinces. In certain stages of Middle-Upper Jurassic boreal elements are found in the Tetori and Toyora regions. The differentiation of Jurassic fauna into the outer and inner suits is attributable to the development of " Eo-nippon Cordillera ", a land barrier, which stretched longitudinally from west Japan to northeast Japan.

The evolution of Mesozoic pelecypods seems fairly different in many respects between the Pacific and European regions. There are, of course, many common genera and subgenera between the two regions, but some appeared much earlier in one region than the other. For instance, *Oxytoma*, *Vaugonia*, *Cardinia*, *Coelastarte*, *Sphaeriola* and some other genera appeared somewhat earlier in eastern Asia. South American and Indian faunas bear marked affinities with European ones, but many characteristic genera and species are found in the Pacific region especially in Japan, Indonesia and 3N-arc.

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I. HAYAMI

Jurassic Fossils from Nagato and Kitakami

# Plate XIV

## Explanation of Plate XIV

Figs. 1a-b. "*Hildoceras*" *chrysanthemum* YOKOYAMA. Compressed specimen with nearly complete body chamber and operculum near the aperture, ×1. 5. Loc. Aptychi-shale of the Nishinakayama formation (Ng beds) at Ishimachi, Toyoda town, Yamaguchi Prefecture (Toarcian).

Figs. 2–3. "*Cornaptychus*" a sp., ×2. Opercula of a harpoceratid like the preceding species. Loc. ditto.

Fig. 4. "*Cornaptychus*" b sp., ×2. Loc. Aptychi-shale of the Nishinakayama formation (Ne beds) at the southwest of Ishimachi (upper Pliensbachian).

Fig. 5. *Pentacrinus* sp., ×3. Loc. *Cardinia*-sandstone of the Higashinagano formation at the south of Higashinagano, Toyoda town. (lower Lias).

Fig. 6. *Posidonia* sp. ex gr. *ornati* QUENSTEDT. Slab with many specimens, ×2. Loc. *Posidonia*-shale of the Utano formation (Up beds) at Todani, southwest of Ishimachi (Aalenian).

Fig. 7. *Amonotis* n. sp. Slab with many specimens, ×3. Loc. *Amonotis*-shale of the Nishinakayama formation (Ne beds) at the south west of Ishimachi (upper Pliensbachian).

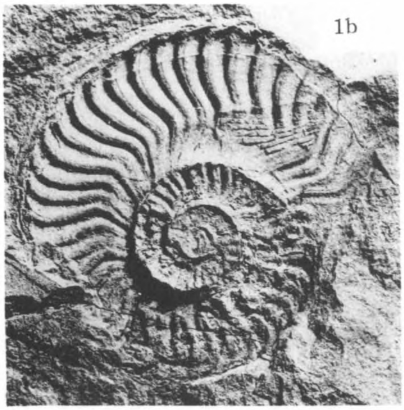
Fig. 8. *Myophorella* (*Haidaia*) *crenulata* KOBAYASHI and TAMURA. Rubber cast from left external mould, ×1. Loc. *Trigonia*-sandstone of the Mone formation ($Sm_2$ member) at Udohama of Oshima, Kesennuma city, Miyagi Prefecture (Oxfordian or Kimmeridgian).

Fig. 9. ? Trail of a gastropod. ×1. Loc. $Ah_1$ member of the Arato formation at the west of Hosoura, Shizukawa town, Miyagi Prefecture.

All specimens illustrated are kept in the Geological Institute, University of Tokyo. Photo by UEKI.

MM4833


1a


1b


2

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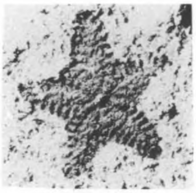
MM 4836

4a


4b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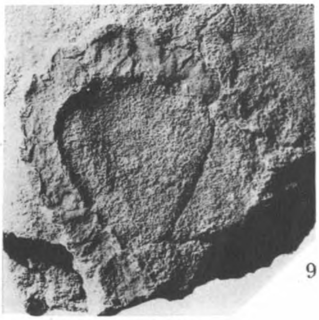
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