Geological Significance of Anadara (Hataiarca) kakehataensis Hatai and Nisiyama in the Arcid-Potamid Fauna in Japan

Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Special Volume, no. 6 (Hatai Memorial Volume), p. 205–215, 1 fig., 2 tables, pl. 18, February 25, 1973

Geological Significance of *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama in the Arcid-Potamid Fauna in Japan

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Abstract

The chronostratigraphic distribution of *Anadara* (*Hataiarca*) *kakehataensis* species group in relation with the Arcid-Potamid fauna is discussed, and correlation and classification of the species are undertaken.

FOREWARD

The writer takes great pleasure in submitting this article for publication in the memorial volume dedicated to Professor Kotora Hatai of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, who first introduced the writer to the study of molluscan paleontology, in recognition of his great contributions in the fields of paleontology, sedimentology, historical geology and paleoichnology.

INTRODUCTION

Among the abundant assemblages of marine molluscan fossils in the Japanese Neogene sediments, the Arcid-Potamid fauna proposed by Tsuda (1965) in his studies of the Middle Miocene molluscan fossils in the Japan Sea side (Tsuda, 1955, 1956, 1956a) is one of the remarkable ones. *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama, the subject of this article is an important species for the recognition, correlation and paleoecological analysis of the Arcid-Potamid fauna because of its limited geological and geographical distributions. Formerly, the writer (Noda, 1966) stated that the distribution of *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama is limited to the Zone of *Anadara kakehataensis-Anadara makiyamai* and is recognized mainly on the Japan Sea side. Subsequently, *Anadara* (*Hataiarca*) *shimonakaensis* which resembles *Anadara* (*Hataiarca*) *kakehataensis* was described from Tanegashima, Kagoshima Prefecture facing the Pacific Ocean by Hayasaka (1969). Recently, the present writer collected *Anadara* (*Hataiarca*) *kakehataensis* from the Miocene Asagawa Formation, Ibaraki Prefecture on the Pacific Ocean side of Japan in association with *Vicarya callosa japonica* Yabe and Hatai and also recognized the species in the collection by Suyari (1948) from the Tsuyama basin. These records are evidently important for the anadarid biostratigraphy and correlation of the Neogene sediments between the Japan Sea and Pacific Ocean sides of Japan. Therefore, the present article records the new discovery of *Anadara* (*Hataiarca*) *kakehataensis* along the Pacific Ocean side of Northeast Japan and discusses the geological significance of the species.

ACKNOWLEDGMENTS

The present writer takes this opportunity to express his deepest appreciation to Professor Kotora Hatai of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University for his contiguous encouragement and supervision during the present study. Deep appreciation is due to Professor Nobu Kitamura and Associate Professor

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Tamio Kotaka of the same Institute for their kind informations and suggestions on the biostratigraphy of the Arcid- Potamid fauna around the Kuji River basin. Acknowledgments are also due to Mr. Kenshiro Otsuki of the School of Science of the Tohoku University and Mr. Fumio Akiba of the Japan Petroleum Exploration Co., for their kind information on the fossil locality around the Kuji River basin. Thanks are due to Mr. Kimiji Kumagai for photographic work.

GEOLOGICAL DISTRIBUTION OF THF ARCID-POTAMID FAUNA

The Arcid-Potamid fauna was first recognized in the lower part of the Kurosedani Formation in Toyama Prefecture by Tsuda (1965). The fauna is defined by; *Anadara kakehataensis*, *Anadara kurosedaniensis*, *Striarca uetsukiensis*, *Cucullaea toyamensis*, *Vicarya yokoyamai*, *Vicaryella notoensis*, *Cerithidea kanpokuensis*, *Cerithidea yatsuoensis*, *Ostrea gravitesta*, *Geloina stachi*, *Geloina yamanei*, *Littorinopsis miodericatura*. Prior to Tsuda (1965), Kotaka (1958) recognized five faunal features in the Neogene of Northern Honshu according to the stratigraphic sequences and megafaunal peculiarity, *viz.*, pO, O, F, K and P. Among them, the unit pO was defined by Kotaka (1958) as "represented by characteristic genera of tropical shallow and brackish water conditions (*Vicarya*, *Tateiwaia*), and occurs only along the marginal parts or around the old land masses". This *Vicarya*, *Tateiwaia* fauna (both of the Potamidae, thus being called Potamid) seems to be analogous with the Arcid-Potamid fauna of Tsuda (1965) though the abundancy of the Arcid-Potamid species in Northeast Honshu is less compared with that of the Hokuriku area probably being influenced by latitude. Recently Chinzei and Iwasaki (1967) and Iwasaki (1970) recognized four or five assemblages in the Lower Kadonosawa Fauna in Iwate Prefecture; their *Batillaria* assemblage was characterized by the occurrence of *Vicarya callosa*, *Vicaryella ishiiana*, *Batillaria yamanarii*, *Nassarius* sp., *Ringicula ninohensis*, "*Anadara kakehataensis*", *Soletellina minoensis*, *Macoma* sp. However, the classification of their four or five assemblages is not always practical for the Kadonosawa type fauna in Japan. However, should emphasis be given to the great importance of the association of *Anadara kakehataensis* and its allied species (*Anadara kurosedaniensis*, *A. takayamai*, *A. yatsuoensis*, *A. oshimaensis*) with Vicaryan species, the faunal characteristics of the Early Middle Miocene of the Japanese Islands would become more distinct because the Hataiarcan and Vicaryan species (Arcid-Potamid fauna) have prime significance and are an important key for the interpretation of chronological, paleoecological and paleogeographical meanings (Hatai, 1960, 1967).

As shown in Fig. 1, the Vicaryan species are distributed relatively widely from Kyushu to Hokkaido and the Hataiarcan species have similar distribution, therefore it is inferred that both species groups in the Early Middle Miocene may have flourished in similar environmental conditions. Both species groups are limited to the Zone of *Anadara kakehataensis-Anadara makiyamai*, (Noda, 1966; Hatai, 1967; Kitamura and Takayanagi, 1971; Ikebe, Chiji, Takayanagi and Chinzei, 1972). The stratigraphic position of the Arcid-Potamid fauna is shown in Table 1. The selected stratigraphic sequences show the stratigraphic position of *Anadara kakehataensis* in association with Vicaryan species. Though the Vicaryan species were recorded from the various localities of the Japanese Islands as already stated by Takeyama (1933), Yabe and Hatai (1938), Matsuno (1951), Masuda (1957, 1966), Yamana (1966), Hayasaka (1969), Goto (1971) and others except for the stratigraphic sections mentioned in Table 1, they do not associate with *Anadara kekehataensis*.

The new localities of *Anadara kakehataensis* in association with Vicaryan species are the Katsuyama basin and the Kuji River basin. The Arcid-Potamid fauna has been

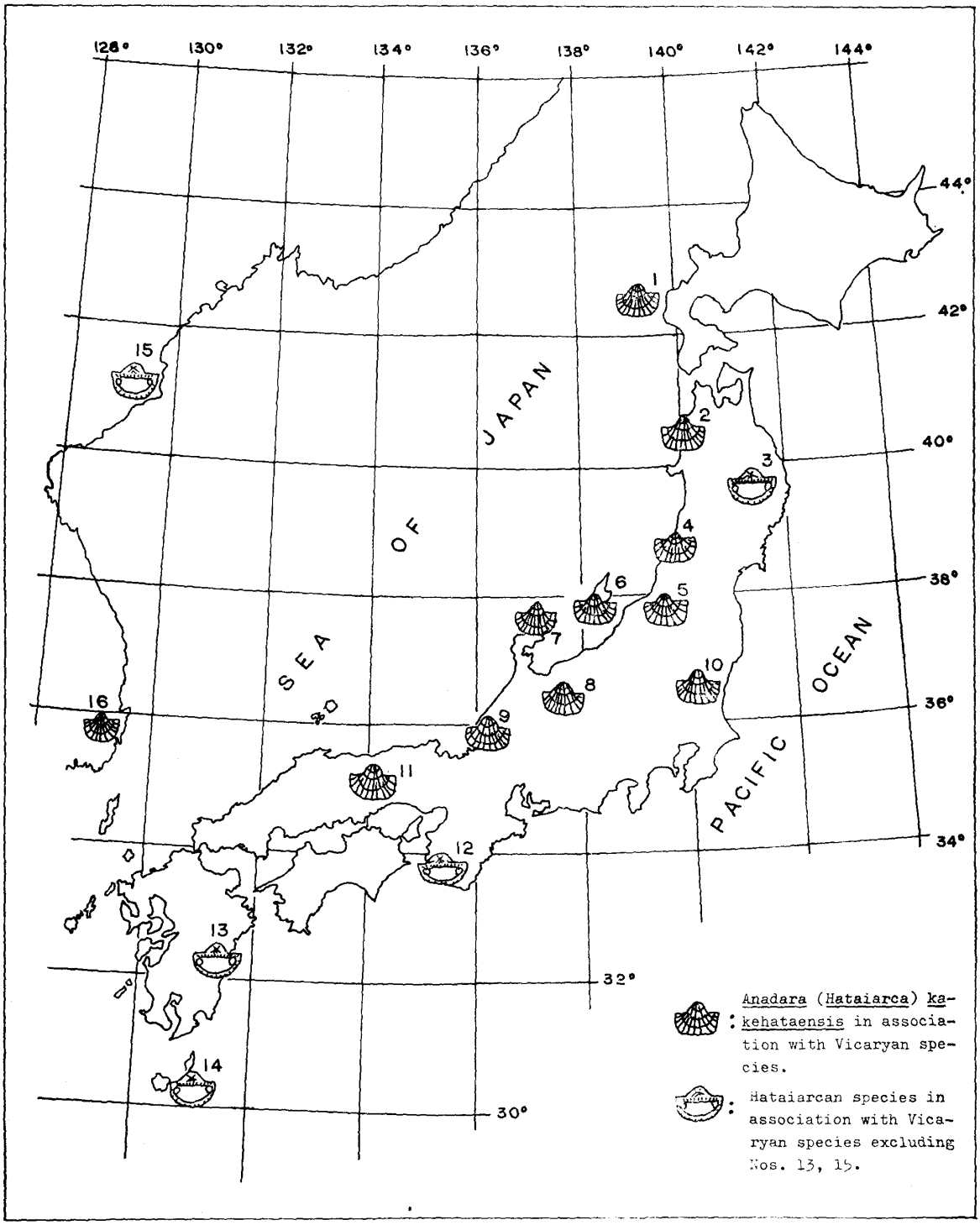


Fig. 1. Distribution of Hataiarcan species in association with Vicaryan species in Japan and the Korean Peninsula.

1: Tsurikake Formation (Uozumi and Fujie, 1966), 2: Tanosawa Formation (Iwai, 1960), 3: Kadonosawa Formation (Noda, 1966), 4: Oyama Formation (Noda, 1966), 5: Iwafune Formation (Tsuda, 1965), 6: Kasatoriyama Formation (Tsuda, 1953), 7: Higashi-Innai Formation (Masuda, 1956), 8: Kurosedani Formation (Hatai and Nisiyama, 1949), 9: Kunimi Formation (Kaseno, 1956), 10: Asagawa Formation (present paper), 11: Yoshino Formation (present paper), 12: Kanayama Group (Yokoyama, 1923), 13: Udo Formation (Shuto, 1961), 14: Kawachi and Osaki formations (Hayasaka, 1969), 15: Heiroku Formation (Makiyama, 1926), 16: Eoil Formation (Kim, Yun and Noda, 1973).

Table 1. Stratigraphic position of *Anadara* (*Hataiarca*) *kakehataensis* in

Tsuyama Basin (Kawai, 1957)	Ayukawa (Kaseno, 1956; Tsukano and Miura, 1954)	Yatsuo Basin (Tsuda, 1953)	Noto Peninsula (Masuda, 1970)
Takakura Formation	Ichinose Member	Joyama Formation	Awagura Formation
Yoshino Formation: Izumoto Sandstone Member; Mataki Conglomerate Member	Kunimi Formation: Tobu Member	Kurosedani Formation: Kashio alternation	Higashi-Innai Formation: Akagami Member
	Oniu Member	Kakehata alternation	Fujio Member
	Fukatani Member	Kamikurose alternation	Orito Member
Uetsuki Formation	Pre-Tertiary	Iwaine Formation	Tokunari Formation

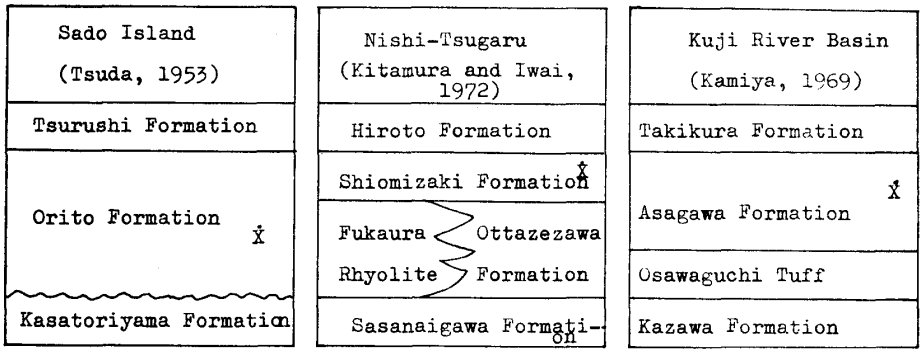
described from the Miocene Eoil Formation, Korea by Kim, Yun and Noda (1973). The new discovery of *Anadara kakehataensis* and its stratigraphic notes are as follow.

1). Tsuyama Basin: The stratigraphic sequence is shown in Table 1. *Arca* cf. *camuloensis* Osmont (1905) described from the Miocene deposits of the Tsuyama basin was re-identified as *Anadara daitokudoensis* by Makiyama (1959). *Arca camuloensis* was first described from Camlos, Ventura County in the Puenta Hills, Los Angeles by Osmont (1905) who stated the specific characters are "ribs about 32 in number, rounded and without grooves, considerably wider than interspaces, ... at about the ninth rib from the posterior end is very distinct shouldered from which there is a steep concave slope to the posterior margin". According to Osmont (1905), *Arca camuloensis* may be belong to *Hataiarca* but is different from *Anadara daitokudoensis* which has 28–30 narrowly elevated radial ribs. However, the opinion of Makiyama (1959) was accepted by Uozumi and Fujie (1966) who illustrated it on their distribution map of *Anadara daitokudoensis* in Japan. Though Uozumi and Fujie (1966) included Tsuyama in the distribution map as a locality of *Anadara daitokudoensis*, the present writer (1966, p. 115) compared *Arca* cf. *camuloensis* of Yokoyama (1929) with a more similar form known as *Anadara kiiensis* Mizuno (1953) according to the description and illustration of Yokoyama (1929). *Anadara kiiensis* was originally described from the Miocene Mitsuno Formation in Wakayama Prefecture and subsequently from the Miocene Yoshino Formation in Okayama Prefecture, Tsuyama basin (Noda, 1966) and is characterized by the well swollen shell, with 27–29 strongly elevated flat-topped radial ribs having granules on the anterior and umbonal area without a depressed area along the posterior margin. Whereas *Anadara daitokudoensis* has a posterior depressed area which serves to distinguish *Anadara kiiensis* from *Anadara daitokudoensis*.

Previously Suyari (1948) collected *Anadara kakehataensis* in association with *Vicarya callosa japonica* from the lower part of the Katsuta Formation (Suyari, 1948; Toyohisada sandstone and mudstone of Suyari, 1951; Izumoto Sandstone of Kawai, 1957; Yoshino Formation of Noda, 1966); both are now preserved in the collection of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University. *Anadara kakehataensis* from the Tsuyama basin mentioned here is the first record of the species from the Pacific side of Southwest Japan. The species is characterized by the well depressed area along the posterior side and the shell surface is sculptured with strongly elevated 24–25 radial ribs with granules on the anterior part of the ribs and a triangular ligamental area with chevron-shaped grooves (Pl. 18, figs. 9, 15).

It may be mentioned that the specimens from the Katsuta Formation are from a very coarse grained pebbly sandstone containing pebbles of granodiorite, chert, rhyolite, sandstone and others, though the shell materials are well preserved. From the viewpoint of habitat of the species and its Recent allied species and its associated species in other

association with Vicaryan species (marked by $\dot{X}$) in different areas.



localities of Japan, the Katsuta specimens are considered to have been derived from the original life area. According to Suyari (1948) and Kawai (1957), the lower part of the Katsuta Formation shows lateral change in its lithology; they recorded the following remarkable species; *Vicarya callosa japonica*, *Vicaryella tyosenica*, *Batillaria tateiwai*, *Batillaria yamanarii*, *Cerithium tokunagai*, *Barbatia uetsukiensis*, *Ostrea gravitesta* and etc., from the lower part of Katsuta Formation from where *Anadara kakehataensis* occurred. Therefore the above mentioned fossil assemblage can be referred to the Arcid-Potamid fauna. Concerning the *Anadara kakehataensis* from the coarse grained sandstone, it is inferred that it may be a derived fossil but it is also thought that there may have been an original life area of muddy facies near the fossil locality.

2). Kuji River Basin: When Kamiya (1969) studied the northern part of the Kuji River basin, Ibaraki Prefecture, he classified the Asagawa Group of Omori (1959) into three formations; Osawaguchi Tuff, Asagawa Formation and Takikura Formation in ascending order. Some species similar to the Asagawa and Takikura formations of Kamiya (1969) in assemblage and geological age around the Kuji River basin were already reported from the Seki Formation in Ibaraki Prefecture (Saito, Toshio, 1952), and Tamagawa Formation also in Ibaraki Prefecture (Akutsu, 1952). However, to date, *Anadara kakehataensis* has not been discovered from this area until Akiba and Otsuki found the species in association with *Vicarya callosa japonica* from the southern extension of the Asagawa Formation of Kamiya (1969) during their geological survey in 1970 and 1972. After a re-examination of the Arcid-Potamid fauna and stratigraphy of the basin area, the following molluscan species including *Anadara kakehataensis* and *Vicarya callosa japonica* were identified (Table 2), from three isolated localities of the Asagawa Formation. Among them, *Anadara kakehataensis* is associated with *Vicarya callosa japonica* at Loc. no. 2, but their geological distribution in the columnar sections of the three isolated areas belong to the upper part of the Asagawa Formation ranging through a thickness of about 100 meters. This thickness through which *Anadara kakehataensis* ranges may be the maximum as known in Japan. The molluscan assemblage (Table 2) of the Asagawa Formation should be referred to the Arcid-Potamid fauna of Tsuda (1960). Though Vicaryan species were already known from areas further north of the present locality (36° 49'N. lat.) such as at Kunugidaira and Nakayama formations in Fukushima Prefecture (Kamada, 1960), Upper shell-beds, *Cultellus izumoensis* zone in Miyagi Prefecture (Nomura, 1935) and Lower Kadonosawa Formation (Otuka, 1934; Otatume, 1943; Kamada, 1960) of the Pacific Ocean side*, but not in association with *Anadara kakehataensis*. Accordingly, the present record of *Anadara kakehataensis* from the Asagawa Formation is the first in

* =Once *Vicarya* cf. *callosa* was reported by Yabe (1921) from the Morai shell bed (Kawabata Series in Hokkaido) without illustration and description, this is the northernmost record of Vicaryan species but not in association with Hataiarcan species.

Table 2. Molluscan fossils from the upper part of the Asagawa Formation

Species \ Localities	Loc. no. 1	Loc. no. 2	Loc. no. 3	Loc. no. 3–1
Anadara (Hataiarca) kakehataensis Hatai and Nisiyama	○*	×*	○*	×
Crassostrea sp.		○		
Thracia hataii Kamada			+	
Diplodonta ferruginata Makiyama			×	
Lucinoma sp.	+			
Lucinisca sp.	×			
Pitar sp.		+		
Dosinia (Phacosoma) cf. *nomurai* Otuka		○	×	
Cyclina (Cyclina) japonica Kamada	×	○*	○*	×*
Chione sp.		+		
Siratoria siratoriensis (Otuka)		×		
Paphia sp.		+		
Clementia (Clementia) nakamurai Otuka		×		+
Clementia sp.	+*			
Spisula sp.				+
Soletellina sp.				×
Cultellus sp.		+		
Batillaria (Tateiwaia) yamanarii Makiyama		+		
Cerithium (Proclava) ancisum (Yokoyama)	+	+		
Vicarya (Shoshiroia) callosa japonica Yabe and Hatai		+		
Cerithidea ohiroi Masuda	○	○		
Cerithidea sp.		+		

○=more than 10 specimens, ×=5 to 10 specimens, +=less than 5 specimens, *=included conjoined valves

Fossil localities;

Loc. no. 1; Small river side cliff, about 200 meters southeast of Nakago bridge, Arayashiki, Daigo-cho.

Loc. no. 2; River side cliff, about 200 meters south of small bridge, Onodaira, Daigo-cho.

Loc. no. 3; Small river side cliff, about 700 meters west of Kami-Toshikatsu, Kanasago-mura.

Loc. no. 3–1; About 30 meters east of Loc. no. 3.

All localities are in Kuji-gun, Ibaraki Prefecture.

association with *Vicarya* species on the Pacific Ocean side of Japan. Hataiarcan species from the Pacific Ocean side such as *Anadara (Hataiarca) daitokudoensis* from the Lower Kadonosawa Formation in Iwate Prefecture (Noda, 1966) and the Boroishi Member of the Udo Formation in Miyazaki Prefecture (Shuto, 1961), and *Anadara (Hataiarca) valentula* from the Kanayama Group in Wakayama Prefecture (Yokoyama, 1923) and the Boroishi Member of Udo Formation in Miyazaki Prefecture (Shuto, 1961) have been recorded, among them the Kadonosawa and Kanayama formations yielded Vicaryan species.

Specific characteristic of the Asagawa Formation is as; Shells were collected from the three isolated localities; Rock facies at Loc. no. 1, is carbonaceous dark gray siltstone and *Anadara kakehataensis* is abundant in individuals sometimes with conjoined valves but the specimens are strongly deformed and occurred in association with such potamids as *Cerithidea ohiroi*, *Cerithium ancisum* and etc. (Table 2). The mentioned arcid is characterized by being medium in size, with prominent high umbonal area, rather high triangular ligamental area, and 22–24 narrowly elevated radial ribs with depressed area extending from near beak to the posterior ventral margin (Pl. 18, figs. 5, 8, 11). Loc. no. 2 is white to pale bluish gray pumiceous tuff to tuff breccia, and the arcid species retain their original shell material. They are not common but occur in association with *Vicarya callosa japonica*, *Batillaria yamanarii*, *Cerithidea ohiroi*, *Cyclina japonica*, *Siratoria siratoriensis* and others (Table 2). The arcid is characterized by well depressed area along the

posterior side, narrowly elevated radial ribs with granules on the anterior and umbonal area. At this locality, the fossil bearing tuff or tuff breccia is very hard but yielded well preserved shells. Loc. no. 3 exposes pale brownish gray to whitish gray pumiceous tuff to sandy tuff. The species at this locality are abundant and occur with conjoined valves but the original shell materials are almost lacking. At this place, *Anadara kakehataensis* is associated with *Thracia hataii*, *Dosinia* cf. *nomurai*, *Cyclina japonica* and others (Table 2). There is another shell dominant layer situated at about 5–6 meters higher than the horizon of Loc. no. 3 and from the locality (Loc. no. 3–1) *Anadara kakehataensis* occurred in association with *Cyclina japonica*, *Soletellina* sp., and others from the tuff or sandy tuff. The species at this locality are rather large in size, provided with 24–25 narrowly elevated radial ribs with granules on the anterior or umbonal area, a high triangular ligamental area with distinct chevron-shaped ligamental grooves and depressed area along the posterior side but the original materials are dissolved (Pl. 18, figs. 1, 6).

Beside the above mentioned, Akiba (1970) collected from near Loc. no. 3 of the Asagawa Formation the following remarkable species, *Anadara makiyamai*, *Mactra nagakoensis*, *Soletellina minoensis*, *Peronidea protovenulosa* and *Batillaria yamanarii*. From the fossils, the upper part of Asagawa Formation can be referred to the Arcid-Potamid Fauna or the Zone of *Anadara kakehataensis-Anadara makiyamai* of Noda (1966).

REMARKS ON THE HATAIARCAN SPECIES AND THE GEOLOGICAL SIGNIFICANCE OF *ANADARA KAKEHATAENSIS*

Anadara (*Hataiarca*) *kakehataensis* was originally described from the Susahara Formation (equivalent to the Kurosedani Formation of Tsuda, 1959) in Toyama Prefecture by Hatai and Nisiyama in 1949. Subsequently the species was recorded from the Higashi-Innai Formation (Masuda, 1955; Noda, 1966), Kunimi Formation (Kaseno, 1956), Kurosedani Formation (Tsuda, 1953, 1955, 1956, 1956a; Fujii, 1961), Orito Formation (Tsuda, 1956), Iwafune Formation (Tsuda, 1965), Oyama Formation (Noda, 1966; Tsuda in Nishida and Chihara, 1966), Tanosawa Formation (Iwai, 1960) and Shiomizaki Formation (Kitamura, Iwai, and Tada, 1972) in association with Vicaryan species.

Anadara kakehataensis is the type species of the subgenus *Hataiarca* Noda, 1966, and is characterized by having strongly elevated non-dichotomous radial ribs with granules on the anterior or umbonal area with a posterior depressed area from beak to posterior ventral margin. Surface sculptures on the right and left valves somewhat different, distinct on the left valve and slightly obscure on the right (Pl. 18, figs. 3, 4). Teeth continuous between anterior and posterior series. Ligamental area triangular to asymmetrical in profile on both sides of beak. No ventral gape. Muscle scars well impressed of A or C types of Noda (1966). Ligamental grooves rather distinct, chevron-shaped. Inner ventral margin crenulated according to external radial ribs. Up to date, the following Hataiarcan species have been recorded from Japan;

Anadara	(*Hataiarca*)	*kakehataensis* Hatai and Nisiyama, 1949
A.	(*H.*)	*kurosedaniensis* Hatai and Nisiyama, 1949
A.	(*H.*)	*takayamai* Noda, 1966
A.	(*H.*)	*yatsuoensis* Noda, 1966
A.	(*H.*)	*daitokudoensis* (Makiyama, 1928)
A.	(*H.*)	*shimonakaensis* Hayasaka, 1969
A.	(*H.*)	*valentula* (Yokoyama, 1923)
A.	(*H.*)	*castellata* (Yokoyama, 1923)
A.	(*H.*)	*kogachiensis* Noda, 1971
A.	(*H.*)	sp. of Noda, 1963
A.	(*H.*)	*masudai* Noda, 1966
A.	(*H.*)	*rhombea* (Born, 1778)

A. (*H.*) *subcrenata* (Lischke, 1869)
A. (*H.*) *troscheli* (Dunker, 1882)

Among them, *Anadara kakehataensis*, *A. kurosedaniensis*, *A. takayamai*, *A. yatsuoensis*, *A. daitokudoensis*, *A. shimonakaensis*, and *A. valentula* are restricted in geological occurrence to the Zone of *Anadara kakehataensis-Anadara makiyamai* of Noda (1966), and do not cross the upper anadarid zones except for *Anadara shimonakaensis* from the Kawachi and Osaki formations in Tanegashima, Kagoshima Prefecture. It seems to be interest to note that though there are only three species, *Anadara castellata*, *A. kogachiensis* and *A.* sp., of Miyagian age (Hatai, 1967) or Pliocene, they are all limited to the Zone of *Anadara suzukii-Anadara castellata* of Noda (1966). They also do not cross the upper horizon of the anadarid units (Noda, 1966). From the data mentioned above, it can be said that the Hataiarcan species in the Japanese Neogene sediments are restricted to the two anadarid zones, the lower one is *Anadara kakehataensis-Anadara makiyamai* and the upper is *Anadara suzukii-Anadara castellata*. The former is distributed widely from Hokkaido to Kyushu (Noda, 1966) but the latter is known only from area of Southwest Japan facing the Pacific Ocean. The above mentioned two zones nearly correspond to the major transgressions of the Japanese Neogene in age. Namely, the former may be the first transgression of the Mizuho Tō (revised definition of Yabe and Aoki, 1923 by Hatai, 1962) with regional volcanics and it brought into the Japanese Islands a new tropical to subtropical marine fauna in which was included the Arcid-Potamid fauna. The latter one was once mentioned by Hatai (1962) as "the transgressive phase is the opening phenomena of the Upper Mizuho Tō or Miyagian." This transgression brought into the borderland of the Pacific Ocean side of Southwest Japan a warm southern type fauna called the Kakegawa Fauna. At that time, the Japanese Islands was separated into North and South and both areas had a distinct fauna, the faunal boundary being at or near the present Kanto region. So the transgression at the opening of the Mizuho Tō (Hatai, 1962) was much more significant than that of the Upper Mizuho Tō or Early Miyagian.

From another point of view, the Hataiarcan species seem to be geographical and specific relict forms (Simpson, 1953) and the thermal gradient may have decreased from Early to Late Mizuho Tō as can be inferred from the geographical and geological distribution of the Hataiarcan species analogous to the evidence afforded by the molluscan fauna in Northeast Honshu by Kotaka (1958). Therefore from the evidence just given it is judged that the Arcid-Potamid fauna including *Anadara kakehataensis* flourished under the warm thermal condition during the Japanese Neogene. As *Anadara kekehataensis* preferred brackish water areas with sandy mud bottom in the inner embayment environment under the influence of the subtropical temperature, the species is always found from the marginal facies or inner parts of the sedimentary basin bordering the old-land areas. Accordingly, the distribution of the Arcid-Potamid fauna defines the ancient shore line. However, to date, paleogeographical maps have been drawn by many authors as, Watanabe 1938; Otuka, 1939; Hanzawa, 1950; Minato, 1952; Ikebe, 1957; Saito, Tsunemasa, 1963; Minato *et al.*, 1965, and others but each were based upon rather large scale geological units, and therefore the details remain covered and thus problems remain concerning the geological correlation between remote or different sedimentary basins. Therefore, inter-basin, regional and inter-regional geochronological correlation is necessary as already attempted by Asano and Hatai (1967) and Ikebe, Chiji, Takayanagi and Chinzei (1972) based upon detail paleontological data. The occurrence of *Anadara kakehataensis* in association with *Vicarya callosa japonica*, as pointed out, is one of the criteria that should be used as data for the problems mentioned above.

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Plate 18

(Natural size)

Figs. 1, 6, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; Small river side cliff about 700 m. west of Kami-Toshikatsu, Kanasago-mura, Kuji-gun, Ibaraki Prefecture, (Loc. no. 3–1), Asagawa Formation, (Plasto-type), IGPS coll. cat. no. 91762.

Fig. 2, *Anadara* (*Hataiarca*) *kurosedaniensis* Hatai and Nisiyama. Locality; Sea cliff of Ayukawa, Ayukawa-cho, Niu-gun, Fukui Prefecture, Kunimi Formation, for comparison, IGPS coll. cat. no. 78495.

Figs. 3, 4, 7, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; Tokunari, Machino-cho, Fugeshi-gun, Ishikawa Prefecture, Higashi-Innai Formation, IGPS coll. cat. no. 92597, showing the difference in granules on the radial ribs between right and left valves.

Figs. 5, 8, 11, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; Small river side cliff, about 200 m. southeast of Nakago bridge, Arayashiki, Daigo-cho, Kuji-gun, Ibaraki Prefecture, (Loc. no. 1), Asagawa Formation, IGPS coll. cat. no. 91763.

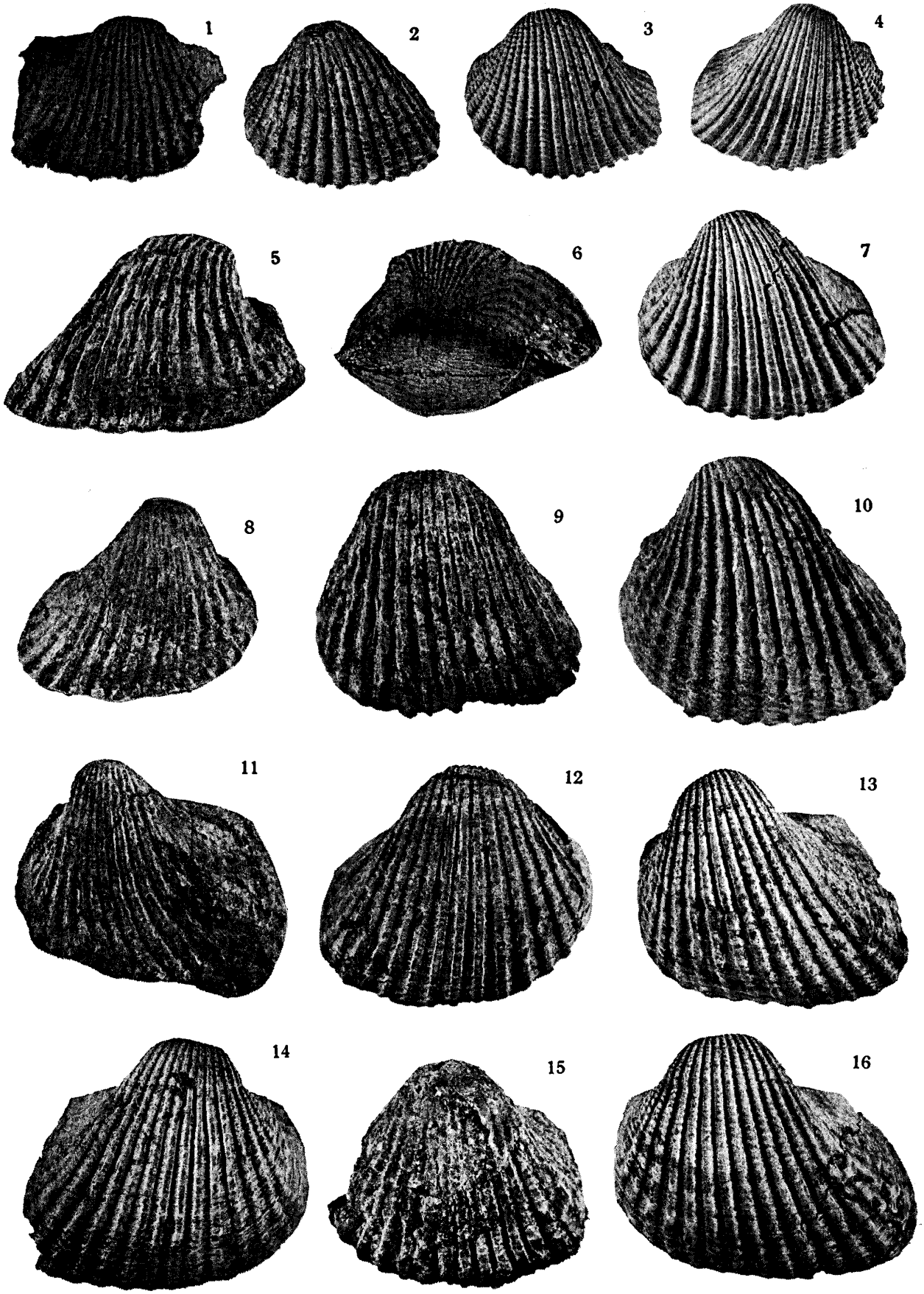
Figs. 9, 15, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; Small lake side, Innai, Nakajima-Higashi, Toyota-mura, Katsuta-gun, Okayama Prefecture, Katsuta Formation, IGPS coll. cat. no. 92598.

Fig. 10, *Anadara* (*Hatairaca*) *kakehataensis* Hatai and Nisiyama. Locality; Sea cliff of Ayukawa, Ayukawa-cho, Niu-gun, Fukui Prefecture, Kunimi Formation, IGPS coll. cat. no. 78494.

Fig. 12, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; Tokunari, Machino-cho, Fugeshi-gun, Ishikawa Prefecture, Higashi-Innai Formation, IGPS coll. cat. no. 92599.

Figs. 13, 14, 16, *Anadara* (*Hataiarca*) *kakehataensis* Hatai and Nisiyama. Locality; River side cliff about 50 m south of Kakehata bridge, Kakehata, Yatsuo-cho, Nei-gun, Toyama Prefecture, Kurosedani Formation (Topotype), IGPS coll. cat. no. 78487 (Figs. 13, 16), IGPS coll. cat. no. 78498 (Fig. 14).

IGPS coll. cat. no. is the abbreviation for the catalogued number of specimens preserved in the collection of the Institute of Geology and Paleontology, Faculty of Science, Tohoku University.



K. Kumagai photo.