Taxonomic revision of Japanese Neogene *Aturia*

Susumu Tomida*

日本の新第三紀*Aturia*の分類学的再検討

冨田　進*

(要　旨)

瑞浪市化石博物館所蔵の新第三紀の *Aturia* 化石のうち，19標本と最近採集された他の3標本について検討を加えた．殻の形態と縫合線の特徴について，成殻だけでなく，幼殻についても比較を行った．その結果，新第三紀の *Aturia* に，*aturi* (Basterot)，*cubaensis* (Lea)，*complanata* Sturani，*formae* Parona，*coxi* Millerの5種を認めた．日本からはそのうち産地層準不明の *aturi* の他は4種とも産出している．*Aturia aturi* は成殻で *Aturia cubaensis* と違いが見られるが，幼殻でも明らかに相違がみられる．これまで日本で *minoensis* とされたものは *cubaensis* の synonym とする意見があるが，本報告でもこの意見に従い，その根拠を述べた．小型の *Aturia complanata* は，殻や縫合線の特徴が *Aturia cubaensis* の成殻に似ている．一方，小型の *Aturia formae* の縫合線は *Aturia cubaensis* の幼殻に類似する．*Aturia cubaensis* はこれら2種と系統的に近い関係にあり，それらの祖先型に当たるかもしれない．*Aturia coxi* の幼殻には成殻に特徴的な ventral lobe がない．したがって *aturi* や *cubaensis* のように ventral lobe を持たない種から派生したと思われる．*Aturia coxi* はこれまでの報告を参考に分布を考えると，Indo-Pacific 要素であるといえる．日本の新第三紀 *Aturia* 化石の産出層準は前期中新世末－中期中新世初頭，中期中新世末，末期中新世の3層準が顕著である．これらは新第三紀における古海中温暖気候 (Climatic Optimum 1-3) にそれぞれ相当する．

(Abstract)

Neogene *Aturia* specimens housed in the Mizunami Fossil Museum and lately collected other ones were examined. As the result of the study, it is confirmed that the Neogene *Aturia* are referred to five species, namely, *aturi* (Basterot), *cubaensis* (Lea) *complanata* Sturani, *formae* Parona and *coxi* Miller. *Aturia aturi* (Basterot) has the different suture lines from *Aturia cubaensis* (Lea) not only in the adult stage but in the juvenile stage. *Aturia minoensis* Kobayashi seems to be synonymous of *Aturia cubaensis* (Lea). The small *Aturia complanata* Sturani has a suture line similar to adult *Aturia cubaensis* (Lea). However, the small *Aturia formae* Parona has a suture line similar to juvenile *Aturia cubaensis* (Lea). *Aturia cubaensis* (Lea) may be an ancestral form of these species. *Aturia coxi* Miller is very characteristic having a ventral lobe in its adult stage, but not in its juvenile stage. Therefore this seems to have derived from *Aturia aturi* (Basterot) or *Aturia*

＊中京短期大学　Chukyo Junior College, Mizunami, 509-61, Japan
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cubaensis (Lea) which has no ventral lobe in both the juvenile and adult stages. Its occurrence records indicate *Aturia coxi* Miller is a past Indo-Pacific element. The occurrences of Japanese Neogene *Aturia* are largely from 3 horizons, which correspond to the remarkable warnings of marine climate (Climatic Optimum 1-3).

Introduction

Fossil *Aturia* occurs so rarely that it is generally known by one or a few specimens at each *Aturia* locality. It shows world-wide distribution, and ranges from the earliest Paleocene to the latest Miocene in age. Many Neogene spesies of *Aturia* have been previously described. Kummel (1956) taxonomically reviewed most of them, Jung (1966) described synonyms of *aturi* and *cubaensis*, and Beu (1973) described synonyms of *cubaensis* and *coxi*.

Nineteen Neogene *Aturia* specimens housed in the Mizunami Fossil Museum and three lately collected specimens were examined. Comparison of the septal sutures and shells was made not only on adult specimens but on juvenile specimens. This paper demonstrates they are referred to five species. The taxonomic relation of the Neogene *Aturia* species is discussed, and its geochrolological and geographical distribution in the world are presented.

Description of Neogene *Aturia* species

Neogene species of *Aturia* are referred to following five species. Characteristics of shell and septal suture of five species are described in the following lines. Their synonyms are listed in Appendix 1 at the end of this chapter.

Class Cephalopoda
Subclass Nautiloidea
Order Nautilida Agassiz, 1847
Family Aturiidae Chapman, 1857
Genus *Aturia* Bronn, 1838
Type species-*Nautilus aturi* Basterot, 1825

Remarks: The genus *Aturia* has a close phylogenetic relation with *Hercoglossa* and *Aturoidea*, and it derived from *Hercoglossa* through *Aturoidea*. *Hercoglossa* is characterized by a siphuncle being central or subcentral in position. *Aturoidea* has a siphuncle being nearer the dorsum than the venter. However, *Aturia* is distinguished from these two genera by a siphuncle being very close to or being in contact with the dorsum, and strongly curved sigmoid-sutures on the lateral side.

Aturia aturi (Basterot, 1825)

Remarks: The original description by Basterot (1825) is as follows, "Testâ subum-

bilicatâ; siphone continuo, buccinaeformi; septis sinuosis". Basterot did not show any figure but referred to the Montfort's illustration which shows an only section of the volute shell.

According to Benoist (1889), Parona (1898) and Sturani (1958), this species is characterized by having a whorl with a roundly trapezoidal section which is higher than wide (W/D ratio=0.40～0.46), a round and infundibular-formed septal foramen, a lateral lobe with an acutely pointed extremity and inflated sides, and a clear turn between the lateral lobe and the lateral saddle. (Fig. 1-3, 1-4)

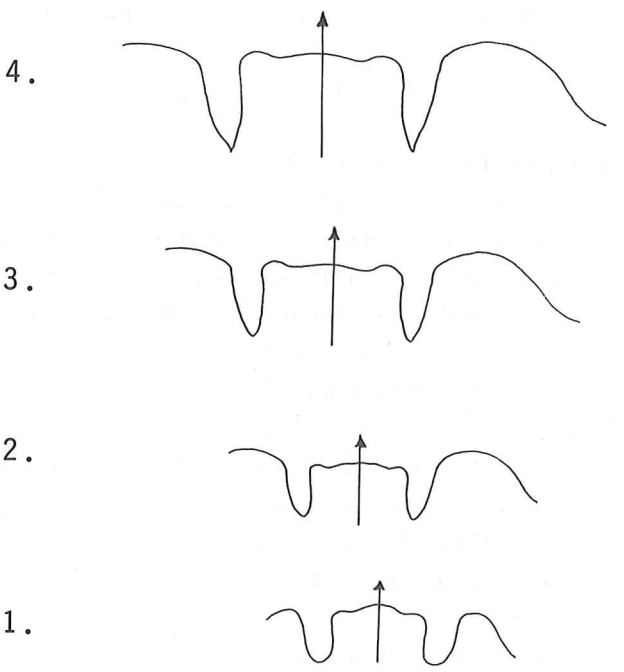


Fig. 1 Septal sutures of *Aturia aturi* (Basterot)

1. primitive (Hercoglossa type reconstructed after Sturani, 1958), 2. juvenile (15±mm in diameter), 3. adult (21-120mm in diameter), 4. adult (variety of 3., larger size)

Sturani (1958) described *Aturia* fossils obtained from Collina di Torino, Piemonte, North Italy, of which Langhian specimens measure 185 mm in the maximum diameter, Lower Helvetian specimens measure 100-150 mm in diameter, and Middle and Upper Helvetian specimens measure 25-40 (-70) mm in diameter.

Sturani (1958) proposed the name Hercoglossa type for the primitive suture lines (Fig. 1-1), examining *aturi* specimens obtained from Collina di Torino. The juvenile of this species which measures 20-35 mm in diameter, has suture lines similar to its adult, except only difference in number of suture lines a whorl and somewhat rounded extremity of the lateral lobe (Fig. 1-2).

The characteristics of suture lines of the adult *aturi* are very similar to those of *Aturia angustata* (Conrad, 1849), which is known from the Uppermost Oligocene to the Lowest Miocene in Alaska, the Lower Miocene in Washington and Oregon, and the Middle Miocene in California, in having the above mentioned feature. Synonyms are listed in the Appendix 1 at the end of this chapter.

Aturia aturi is closely related with *Aturia alabamaensis* (Morton), an Eocene species of southern U. S. A., in having an acutely pointed lateral lobe with inflated sides, and a clear turn between the lateral lobe and the lateral saddle. But it is distinguished from *alabamaen-*

sis by a slender whorl in section and more number of septa a whorl.

Aturia cubaensis (Lea, 1841)

Remarks: This species was first described by Lea (1841) from the Miocene in Cuba. It is characterized by having a rather small and half-closed umbilicus with an umbilical pocket, a roundly triangular whorl section which is higher than wide (W/D ratio=0.40~0.49), a rather largely opened and roundly infundibular-formed septal foramen, a lateral lobe with an acutely pointed extremity and inflated sides, and no turn between the lateral lobe and the lateral saddle (Fig. 2-2,2-3).

Several species which have the shell characteristics mentioned above, were hitherto described, namely, *australis* McCoy, 1867 ; *curvilineata* Miller & Thompson, 1937 ; *grangei* Fleming, 1945 ; *minoensis* Kobayashi, 1947 ; *aturi* var., Sturani, 1958. Jung (1966) and Beu (1973) compiled these species as synonyms of *Aturia cubaensis* (Lea, 1841). In this paper I followed their opinion. Because *Aturia minoensis* Kobayashi, 1947, which is well known from the Early and Middle Miocene in Japan, has a weakly inflated whorl with a roundly triangular section, a largely opened septal foramen, and no turn between the lateral lobe and the lateral saddle. Synonyms of *Aturia cubaensis* are shown later.

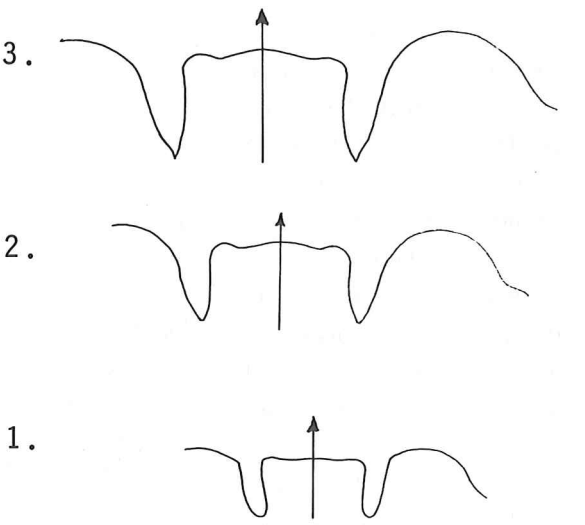


Fig. 2 Septal sutures of *Aturia cubaensis* (Lea)
1. juvenile (15-24.5mm in diameter), 2. adult (more than 24mm in diameter),
3.adult (variety of 2.)

Examination of septal sutures in juvenile specimens shown in the next chapter, reaches conclusions as follows.

The younger stage of this species is characterized by having a deep, parallel, quasi-straight-sided and roundly ending extremity of lateral lobe, where a clear turn is continuing from the lateral saddle (Fig. 2-1). Therefore this species is distinguished from *aturi* by no turn between the lateral lobe and the lateral saddle (in adults), and also by a parallel sided lateral lobe with a roundly ending extremity and a clear turn between the lateral lobe and the lateral saddle (in juveniles). This roundly ending extremity of lateral lobe resembles that of *Aturoidea mathewsonii* (Gabb) shown in Miller (1947), pl. 49, fig. 3. I propose the name Aturoidea type for this type of suture.

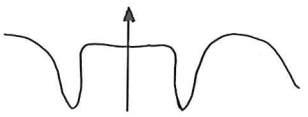


Fig. 3 Septal suture of *Aturia complanata* Sturani

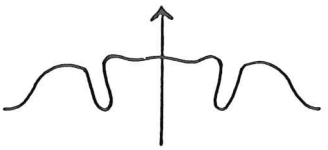


Fig. 4 Septal suture of *Aturia formae* Parona

Aturia complanata Sturani, 1958

Remarks: This species is characterized by having a small-sized shell with a subrectangular section which is higher than wide (W/D ratio=0.45±), flattened sides, a rounded venter, a largely opened and roundly infundibular-formed septal foramen, densely arranged septa (12-13 a whorl), a lateral lobe with a rather round extremity and inflated sides, and no turn between the lateral lobe and the lateral saddle (Fig. 3).

Sturani (1958) described that the specimen from Collina di Torino, Piemonte, North Italy, measures 24.9 mm in the maximum diameter, and measures 11.2 mm in the maximum width.

The characteristic of suture lines of *Aturia complanata* resembles of that of an adult of *Aturia cubaensis*. But *Aturia complanata* clearly differs from *Aturia cubaensis* in a juvenile stage, which measures 20-30 mm in diameter. It has densely arranged septa (*complanata*=12～13 ; juvenile *cubaensis*=10～12), the overlapping ultimate septum, more acutely pointed lateral lobe and no turn between the lateral lobe and the lateral saddle.

Aturia formae Parona, 1898

Remarks: This species is characterized by having a small-sized shell with a well inflated and roundly quadrangular whorl in section (W/D ratio=0.52～0.54), a thin siphuncle very close to the penultimate whorl, a little developed septal neck, a small and round septal foramen, a lateral lobe with a rounded extremity and parallel sides, and a clear turn between the lateral lobe and the lateral saddle (Fig. 4).

This species was first described by Parona (1898) from the Serravallian formation in Baldissero torinese, Piemonte, North Italy. Thereafter, Sacco (1904) reported this species, having a doubt of being a male juvenile of *Aturia aturi*. However, Sturani (1958) reexamined the Sciolze specimens and regarded them as the different species from *aturi*. He pointed out that major differences between *aturi* and *formae*, are present in a section of whorl and septal sutures, concerning the shell diameter of 20-30 mm. According to Sturani (1958), *Aturia formae* measures 26.6 mm in the maximum diameter and measures 14.2 mm in the maximum width, and Sciolze specimens measure less than 30 mm in the maximum diameter.

The shape of the suture line of *formae* is very similar to that of the juvenile of *cubaensis*, but the former differs from the latter in having a well inflated whorl (W/D ratio: *formae*=0.52～0.54 ; juvenile *cubaensis* =0.42～0.49), a siphuncle very close to the penul-

timate whorl, a small round septal foramen, less developed septal neck, thicker septa and the overlapping ultimate septum under the comparison on specimens of both species resembling in size.

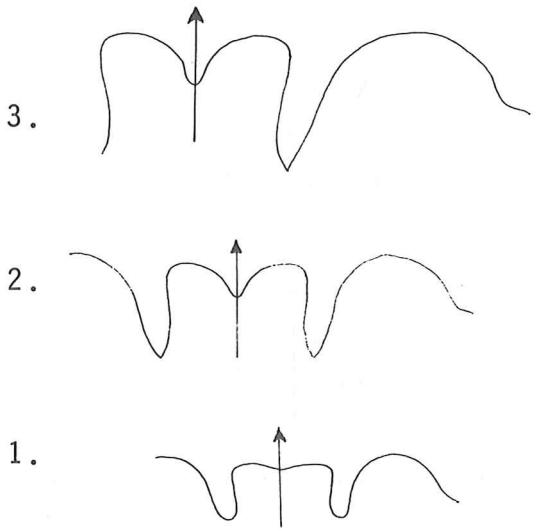


Fig. 5 Septal sutures of *Aturia coxi* Miller
1.juvenile (18±mm in diameter),
2. adult (28-110mm in diameter),
3. adult (variety of 2.)

Aturia coxi Miller, 1947

Remarks: This species is characterized by having a rather large-sized shell with a roundly trapezoidal section which is higher than wide (W/D ratio=0.38～0.45), septal neck well-developed, densely arranged septa (12 a whorl in juvenile and 15～16 a whorl in adult) very close to one another, a wide and rather deep ventral lobe at the center of ventral saddle, and no turn between the lateral lobe and the lateral saddle (Fig. 5-2, 5-3).

Cox (1927) described this species from the Lower Miocene formation in the Pemba Island, Zanzibar Protectrate, Tanzania, comparing with *Aturia narica* Vredenburg from the Oligocene in Sind, India. Thereafter, Miller (1947) newly named it *coxi*, but he did not make a detailed description but gave a figure showing the ventral lobe situated on the ventral saddle in his figure with a breaf explanation.

This species is very characteristic in the genus *Aturia* having a ventral lobe. However, in the younger stage of this species, the ventral lobe is not situated at the ventral saddle (Fig. 5-1). This fact suggests that *aturi* or *cubaensis* having no ventral saddle is an ancestral form of *coxi*.

From its occurrence records (shown in Appendix 1), *Aturia coxi* Miller seems to have been an Indo-Pacific element.

Appendix 1 - Synonymy of the Neogene *Aturia*

Jung (1966) described synonyms of *aturi* and *cubaensis* , and Beu (1973) described synonyms of *cubaensis* and *coxi*. In this paper, as above mentioned, the Neogene *Aturia* is referred to be synonymous as the following species. Occurrence of each species is also shown.

Aturia aturi (Basterot, 1825)

1825 *Nautilus aturi* Basterot, Mem. Soc. Hist. Nat. Paris, v.2, p.17.

1847 *Nautilus diluvii* Michelotti, Haarlem, p.346, pl.15, fig.4.
1847 *Clymenia morrisi* Michelotti, ibid., p.349, pl.15, figs.3,5.
1849 *Nautilus angustata* Conrad, Wilkes Explor. Exped., v.10, p.728. pl.20, figs .5,6.
1872 *Aturia radiata* Bellardi, Mem. R. Acc. Sci. Torino, ser.2, 27. pt.I, p.23, pl.3, fig.3.
1889 *Aturia aturi*, Benoist, Act. Soc. Linn. Bordeaux. v.42, p.13, pl.2, figs.1a,b.
1893 *Aturia aturi*, Simonelli, Atti Soc. Toscana Sci. Nat., 12, p.8.
1898 *Aturia aturi*, Parona, Paleo. Ital., v.4, p.161-164, pl.12(1), figs.2-6, pl.13(2), figs. 5-6.
1904 *Aturia aturi*, Sacco, Torino, C.Clausen, p.6-7, pl.1, figs.15-18, pl.2, figs.1-3.
1921 *Aturia aturi*, Chapman, Proc. Soc. Victoria, 34 (N.S.), pt.I, p.13.
1931 *Aturia aturi*, Schenck, Univ. Calif. Publ. Geol. Sci., v.19, n.19. p.448, pl.72, figs.3,4.
1931 *Aturia angustata*, Schenck, Univ. Calif. Publ. Geol. Sci., v.19, n.19, p.457-462, pl.69, figs.1-3, pl.70, figs.1-3,5, pl.71, figs.1-8.
1931 *Aturia alaskensis* Schenck, Univ. Calif. Publ. Bull. Dept. Geol. Sci., v.19, n.19, p. 463-464, pl.71, fig.2.
1939 *Aturia* cf. *ziczac* (Sowerby), Miller & Crespin, Jour. Paleo., v.13, n.1, p.80, pl.14, fig .1.
1947 *Aturia curvilineata*, Miller, Geol. Soc. Amer. Mem. 23, p.92, pl.85, figs.4-6.
1947 *Aturia angustata*, Miller, Geol. Soc. Amer. Mem. 23, p.85-88, pl.90, figs.1-3, pl.91, figs.1-3, pl.93, figs.3,4.
1957 *Aturia minoensis* var., Kobayashi, Trans. Proc. Paleo. Soc. Japan, N.S., n.28, p. 111-114, pl.19, figs.1-3.
1958 *Aturia aturi*, Sturani, Atti Soc. It. Sci. Nat. Mus. Civ. Stor. Nat. Milano, v. 97, n.4, p.366-377, pl.18, fig.1, pl.19, figs.1-2.
1966 *Aturia aturi*, Jung. Eclog. Geol. Helvet., v.59, n.1, p.487-489, pl.1, fig.1, pl.2, fig.1.
1971 *Aturia alaskensis*, Kanno, Jour. Paleo. Soc. Japan. Spec. Papers, n.16,p.131-135, pl. 16, figs.1-4, pl.18, fig.8.
1972 *Aturia aturi*, Robba, Riv. Ital. Paleont., v.77, p.104-105, pl.5, fig.13.

Occurrence:

France: Low. Miocene Mid. Burdigalian at Saint-Paul-lès-Dax, Mandillot, Bordeaux (Type locality).

Italia: Low. Miocene Up. Langhian to Mid. Miocene Helvetian (=Serravallian) in Collina di Torino, Piemonte; Mid. Miocene in Montolino; Mid. Miocene in Redella Monferrato.

Equador: Low. Miocene formation at St. Elena Peninsula, Guayaquil.

?Japan: Miocene in (?) Kusu-gun, Oita Prefecture.

U.S.A.: Uppermost Oligocene to lowest Miocene Upper Poul Creek Formation at Yakataga, Alaska; Low. Miocene Lincoln Creek Formation at Knappton, Washington; Low. Miocene Clallam Formation at Clallam Bay, Washington; Low. Miocene Astoria Formation at Astoria, Oregon; Mid. Miocene Temblor Formation in California.

Aturia cubaensis (Lea, 1841)

1841 *Nautilus cubaensis* Lea, Amer. Philos. Soc., Trans., N.S., v.7, p.259, pl.10, fig.15.
1867 *Aturia australis* McCoy, Ann. Mag. Nat. Hist., ser.3, v.20, p.192. (nomen nudum).
1910 *Aturia aturi*, Canavari, Paleo. Ital., v.16, p.107-108, pl.13(7), figs.6,7.
1914 *Aturia australis*, Chapman, Proc. Roy. Soc. Victoria, 27 (N.S.),pt.2, p.350-361.
1921 *Aturia australis*, Chapman, Proc. Roy. Soc. Victoria, 34 (N.S.), pt.1, p.13-14.
1937 *Aturia curvilineata* Miller & Thompson, Ecolog. Geol. Helvet., v.30, n.1, p.69-70, pl. 9, figs.1-4, pl.10, figs.1,2.
1941 *Aturia aturi*, Tricomi, Giorn. Sci. Nat. Econ. Palermo, v.42, p.4, pl.1, figs.2-7.
1941 *Aturia* cf. *aturi*, Miller, Jour. Paleo., 15, p.429-431, figs.1a,b.
1944 *Aturia australis*, Teichert, Jour. Paleo., v.18, n.1, p.73-79, pl.14, figs.1-4, pl.16, fig.3.
1945 *Aturia grangei* Fleming, Trans. Roy. Soc. N.Z., v.74, p.411, pl.60, figs.1-3, text-figs.1b,c,d.
1947 *Aturia cubaensis* , Miller, Geol. Soc. Amer. Mem. 23, p.92, pl.93, figs.4-6.
1947 *Aturia curvilineata*, Miller, Geol. Soc. Amer. Mem. 23, p.93, pl.73, figs.3,4 pl.84, figs.1,2,5-8.
1954 *Aturia minoensis* Kobayashi, Japan. Jour. Geol. Geogr., v.25, p.35-54, pl.5, figs.a-d.
1958 *Aturia aturi* var., Sturani, Atti Soc. Ital. Sci. Nat. Mus. Civ. Stor. Nat. Milano, v.97, n.4, p.370, pl.20, fig.2.
1966 *Aturia grangei* Fleming, Marwick's illus. N.Z. shells, Bull. N.Z. Dep. Sci. Indstr. Res., 173, p.87.
1966 *Aturia cubaensis*, Jung, Eclog. Geol. Helvet., v.59, n.1, p.489-491, pl.1, figs.2-4,7, pl.2, figs.2-6.
1968 *Aturia* cf. *grangei*, Beu, N.Z. Jour. Geol. Geophys., v.11, p.161-165, figs.1-2.
1973 *Aturia cubaensis*, Beu, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol., n.6, (Hatai Mem. Vol.), p.298-303, pl.32, figs.1-4,6,7.
1990 *Aturia cubaensis*, Beu & Maxwell, New Zealand Geol. Sur. Paleont. Bull. 58, p.239, pl.26, fig.q.

Occurrence:

Cuba: Miocene Matanzas Limestone in Matanzas (Type locality).
Trinidad: Mid. Miocene Brasso Formation in Trinidad Island.
Columbia: Mid. Miocene formation in Guajira.
Venezuela: Mid. Miocene formation at North Cantaure, Paraguana Peninsula.
Australia: Mid. Miocene Balcombian Balcombe Clay, Melbourn, Victoria; Mid. Miocene Balcombian Muddy Creek Marl, Hamilton, Victoria.
New Zealand: Mid. Miocene Mocau series; Low. Mid. Miocene Clifdenian Mohakatino Formation in North Taranaki; latest Miocene Kapitean stage at Bluecliff, Te Waewae Bay, Southland.

Japan; Low. to Mid. Miocene formations in Ibaragi, Chiba, Kanagawa, Saitama, Nagano, Gifu, Aichi, Mie, Wakayama, Toyama, Fukui, Okayama, Shimane and Yamaguchi.
Italia: Mid. Miocene Helvetian Baldissero Formation at Albugnano, Piemonte.
France: Low. Miocene Burdigalian formation at Dax, Saubrigues, Aquitaine.

Aturia complanata Sturani, 1958

1958 *Aturia complanata* Sturani, Atti Soc. Ital. Nat. Mus. Civ. Stor. Nat. Milano, v.97, n. 4, p.378-383, pl.18, figs.3a,b, pl.19, fig.3.
1972 *Aturia complanata*, Robba, Riv. Ital. Paleont., v.77, p.105-106, pl.5, fig.14.

Occurrence:
Italia: Low. Mid. Miocene Langhian Cessole Formation; Mid. Miocene, Mid. to Up. Helvetian formation in Collina di Torino, Piemonte (Type locality).
Japan: Upper Lower Miocene Yamanouchi Member, Akeyo Formation, Mizunami Group at Yamanouchi & Matsugase, Akeyo-chô, Mizunami City.

Aturia formae Parona, 1898

1898 *Aturia formae* Parona, Paleo. Ital., v.4, p.164, pl.13, figs.7-8.
1904 *Aturia formae*, Sacco, Torino, C.Clausen, p.7, pl.2, figs.4-5.
1926 *Aturia aturi*, var. *tokunagai* Shimizu, Sci. Rep. Tohoku Univ., ser.2, v.9, v.2, p. 25-27, pl.8(1), figs.7-10.
1958 *Aturia formae*, Sturani, Atti Soc. It. Sci. Nat. Mus. Civ. Stor. Nat. Milano, v.97,n.4, p.377-378, pl.18, fig.2, pl.19, fig.4.
1990 *Aturia formae*, Tomida, Bull. Mizunami Fossil Mus., n.17, p.97-103, pl.19, figs.1-5.

Occurrence:
Italia: Low. Mid. Miocene Langhian Cessole Formation; Mid. Miocene, Mid. to Up. Helvetian formations in Baldissero torinese & Sciolze, Torino, Piemonte (Type locality).
Japan: Upper Middle to lower Upper Miocene Kokozura Formation, Taga Group at Takai & Izura, Ohtsu-chô, Kitaibaragi City, Ibaragi Pref.

Aturia coxi Miller, 1947

1927 *Aturia narica*, Cox, Publ. Gover. Zanzibar, p.19, pl.19, figs.6,7.
1947 *Aturia coxi* Miller, Geol. Soc. Amer., Mem. 23, p.88, pl.74, fig.7.
1973 *Aturia coxi*, Beu, Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol., n.6 (Hatai Mem. Vol.), p.303-305, pl.33, figs.8-15.
1983 *Aturia coxi*, Tomida, Bull. Mizunami Fossil Mus., n.10, p.114-115, pl.36, figs.1a-f.
1989 *Aturia coxi*, Tomida, Bull. Mizunami Fossil Mus., n.16, p.100, pl.19, figs.1,2.

Occurrence:

Tanzania: Miocene Pemba Formation in Pemba Island, Zanzibar Protectorate (Type locality).

New Zealand: Low. Mid. Miocene Clifdenian basal Mohakatino Formation; Up. Mid. Miocene Waiauan in Westland; Up.Mid. to low. Up. Miocene Waiauan or Tongaporutuan in Scotshman's Creek; Up. Miocene Tongaportuan Hurupi Formation.

Australia: Uppermost Miocene Cheltenhamian Black Rock Sandstone in Beumaris, Melbourne.

Japan: Uppermost Miocene to Lowermost Pliocene Senhata Formation, Miura Group at Motona, Kyonan-chô, Awa-gun, Chiba Pref.

Appendix 2 - *Aturia minoensis* Kobayashi, a synonym of *A. cubaensis*

1954 *Aturia minoensis* Kobayashi, Japan. Jour. Geol. Geogr., v.25, p.35-54, pl.5, figs.a-d.

1955 *Aturia minoensis*, Kobayashi & Masatani, Trans. Proc. Paleo. Soc. Japan, N.S. n.17, p.1-4, pl.1, figs.1-5.

1958 *Aturia* cf. *minoensis*, Kobayashi & Horikoshi, Japan. Jour. Geol. Geogr., v.29, n.1-3, p.52-53, pl.5, figs.1a-c,2.

1960 *Aturia minoensis*, Kobayashi, Sci. Rep., Tohoku Univ., 2nd ser. (Geol.), Spec. Vol., n. 4, p.122-124, pl.12, figs.1a,b.

1960 *Aturi*a cf. *minoensis*, Kobayashi, Sci. Rep., Tohoku Univ., 2nd ser. (Geol.), Spec. Vol., n.4, pl.12, figs.2a,b.

1962 *Aturia* sp., Hatai & Masuda, Trans. Proc. Soc. Japan, N.S. n.46, pl.40, fig.29.

1967 *Aturia minoensis*, Shibata, Jour. Geol. Soc. Japan, 73, p.337-346.

1970 *Aturia minoensis*, Shibata, Jour. Earth Sci., Nagoya Univ., 18, p.27-84.

1973 *Aturia* cf. *minoensis*, Sugiura, Kaseki-no-tomo, p.4-5, 1 pl.

1974 *Aturia minoensis*, Itoigawa, Shibata & Nishimoto, Bull. Mizunami Fossil Mus., n.1, p.196, pl.62.

1975 *Aturia* cf. *minoensis*, Katto, Masuda & Sakou, Sci. Rep. Kochi Univ., v.24, Nat. Sci. n.15, p.7, pl.2 fig.4.

1975 *Aturia minoensis*, Okamoto & Suyama, in Geology of Yamaguchi Pref., p.191, fig.6 A-26.

1975 *Aturia minoensis*, Okubo, Mem. Fac. Lit. & Sci. Shimane Univ., Nat. Sci., 8, p.86-87, figs.1a,b.

1977 *Aturia* sp., Okamoto, Geol. Soc. Japan, v.83, n.6, p.359-362, fig.3.

1982 *Aturia* sp., Ozaki, Yokohama Nat. Univ., Bull. Spec. Study 2, p.43-45, pl.7, figs.A, B.

1982 *Aturia* sp., Kishimoto, Chigaku-kenkyu, v.33, nos.7-12, p.369.

1985 *Aturia minoensis*, Nakagawa & Takeyama, Bull. Mizunami Fossil Mus., n.12, p. 27-47, pl.24, figs.8-9.

1985 *Aturia* cf. *minoensis*, Tomida, Bull. Mizunami Fossil Mus., n.12, p.197-204, pl.48, figs.1,2.
1987 *Aturia* cf. *minoensis*, Tsuru, Geol. Rep. Shimane Univ., 6, p.95-100, fig.3.
1990 *Aturia* cf. *minoensis*, Hachiya, Kaseki-no-tomo, n.37, p.34-36.
1992 *Aturia* sp., Toyama Sci. Mus., Spec. Publ., n.5, p.30, pl.16, figs.1a,b.

Examination of *Aturia* specimens from Japan

Aturia cubaensis (Lea)

1) Izura specimen (Pl. 28, Figs. 1a,b); MFM 41002.
Locality: Shishigashira, Izura, Ohtsu-chô, Kitaibaragi City, Ibaragi Pref. (Loc. 1).
Horizon: Kokozura Formation, Taga Group.
Dimension: Diameter ca. 59 mm.
Remarks: This specimen was contained in a nodule and was obtained as a rolling stone at the seashore of Shishigashira, where sandstones of the Kokozura Formation outcrops. This spesimen is identical with *Aturia cubaensis* (Lea) in having an inflated-sided, subequilateral and acutely pointed lateral lobe, where no turn is continuing from the lateral saddle. This specimen shows the post-morten drifting because the serpulid fossils are adhering to its shell surface (Pl. 28, fig.1b).

2) Kawayatsu-1 specimens (Pl. 25, Figs. 1a,b, 2) ; MFM 41003 & MFM 41004.
Locality: Dam-site in Kawayatsu, Kamogawa City, Chiba Prefecture (Loc. 3).
Horizon: Kinone Formation, Sakuma Subgroup, Miura Group.
Dimensions: Length 40.5 × 38.8 mm (MFM 41004); length 28.5 × 24.0 mm, width 16.9 mm (MFM 41003).
Remarks: This (MFM 41004) is a fragmental specimen of a large-sized *Aturia*, on which only sectioned septal suture is observed. A small-sized specimen (MFM 41003) is deformed, so only a sigmoidal suture line is observed and it is one of important characteristics of *Aturia*. I doubtfully refer the specimen to *Aturia cubaensis* (Lea).

3) Kawayatsu-2 specimens (Pl. 25, Figs. 3, 4) ; MFM 41005& MFM 41006.
Locality: Road-cliff in Kawayatsu, Kamogawa City, Chiba Prefecture (Loc.3).
Horizon: Amatsu Formation, Sakuma Subgroup, Miura Group.
Dimensions: Max. diameter 59.6mm, min. diameter 53.7 mm (MFM 41006); max. diameter 37.6 mm, min. diameter 27.9 mm (MFM 41005).
Remarks: These two specimens are laterally compressed but have an inflated-sided, subequilateral and acutely pointed lateral lobe, where no turn is continuing from the large and rounded lateral saddle (13 septa a whorl). Therefore, these are identical with *Aturia cubaensis* (Lea).

4) Chichibu specimen (Pl. 24, Figs. 1a-f); Ogai's collection.
Locality: River bed of Arakawa, Ohnohara, Chichibu City, Saitama Pref. (Loc. 6).
Horizon: Nagura Formation, Chichibumachi Group.
Dimensions: Max. diameter 176.0 mm, min. diameter 154.5 mm, max. width 92.6

mm.

Remarks: This specimen has a very large-sized shell without a living chamber, 13 septa a whorl, the overlapped ultimate septum to the penultimate septum and a wide whorl, so it seems to be adult. This specimen is identical with *Aturia cubaensis* (Lea) in having a roundly triangular whorl in section, no turn between the lateral lobe and the lateral saddle, and a more broadly opened septal foramen. This is one of the largest *A. cubaensis* specimens in the world.

According to Takahashi (1992), Miocene strata in the Chichibu Basin, from the lower, Ushikubitoge Formation to the upper, Yokoze Formation, correspond to N 8 of Blow's zones in age.

5) Ichihara specimens (Pl. 27, Figs. 2a,b, 3); MFM 11029 & MFM 11030.

Locality: River-cliff in Ichihara, Toki-chô, Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Sakurado Facies, Akeyo Formation, Mizunami Group.

Dimensions: Max. diameter 42.0 mm, min. diameter 31.8 mm, max. width 17.8 mm (MFM 11029); diameter ca. 25 mm, max. width ca. 12 mm (MFM 11030).

Remarks: This (MFM 11029) has an almost complete and small-sized shell without the living chamber, so it is a juvenile. The whorl is slender and has flat sides in the younger stage, but has a roundly triangular section in the ultimate stage. This has a roundly ending extremity of lateral lobe with the parallel and quasi straight sides in the younger stage (Fig. 2-1), but the suture lines of the adult stage are seen near the ultimate part of this specimen (Fig. 2-2). The other specimen (MFM 11030) has an about half of the posterior disc, being largely destroyed. The whorl section is slender and has flattened sides, but the suture lines of the adult stage are seen near the ultimate part. These two specimens are referable to *Aturia cubaensis* (Lea) because of having no turn between the lateral lobe and the lateral saddle in their ultimate stage.

6) Matsubora specimen (Pl. 26, Figs, 1 a-d); MFM 11026.

Locality: Matsubora, Shimizu, Toki-chô, Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Tsukiyoshi Member, Akeyo Formation, Mizunami Group.

Dimensions: Length 70.6 mm, max. width 37.2 mm.

Remarks: This specimen is large in size with almost destroyed ventral side, but a roundly infundibular-formed and largely opened septal foramen, and no turn between the lateral lobe and the lateral saddle, are observed. Therefore this is identical with *Aturia cubaensis* (Lea).

This specimen was obtained as a rolling stone. Tuffaceous muddy sandstones of the Tsukiyoshi Member are exposed at the collection locality. This member is associated with the *Cyclina-Vicarya* assemblage (Itoigawa, 1980).

7) Yamanouchi-1 specimen (Pl. 26, Figs. 2 a-c); MFM 11027.

Locality: Yamanouchi, Akeyo-chô , Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Yamanouchi Member, Akeyo Formation, Mizunami Group.

Dimensions: Length 133.5 mm, width 60.5+mm, height of whorl 88.5 mm.

Remarks: This specimen was first described by Itoigawa *et al.* (1974 ; p. 196, pl. 62, figs. 1 a,b) as *minoensis*. The large part of the anterior shell is destroyed, but a roundly

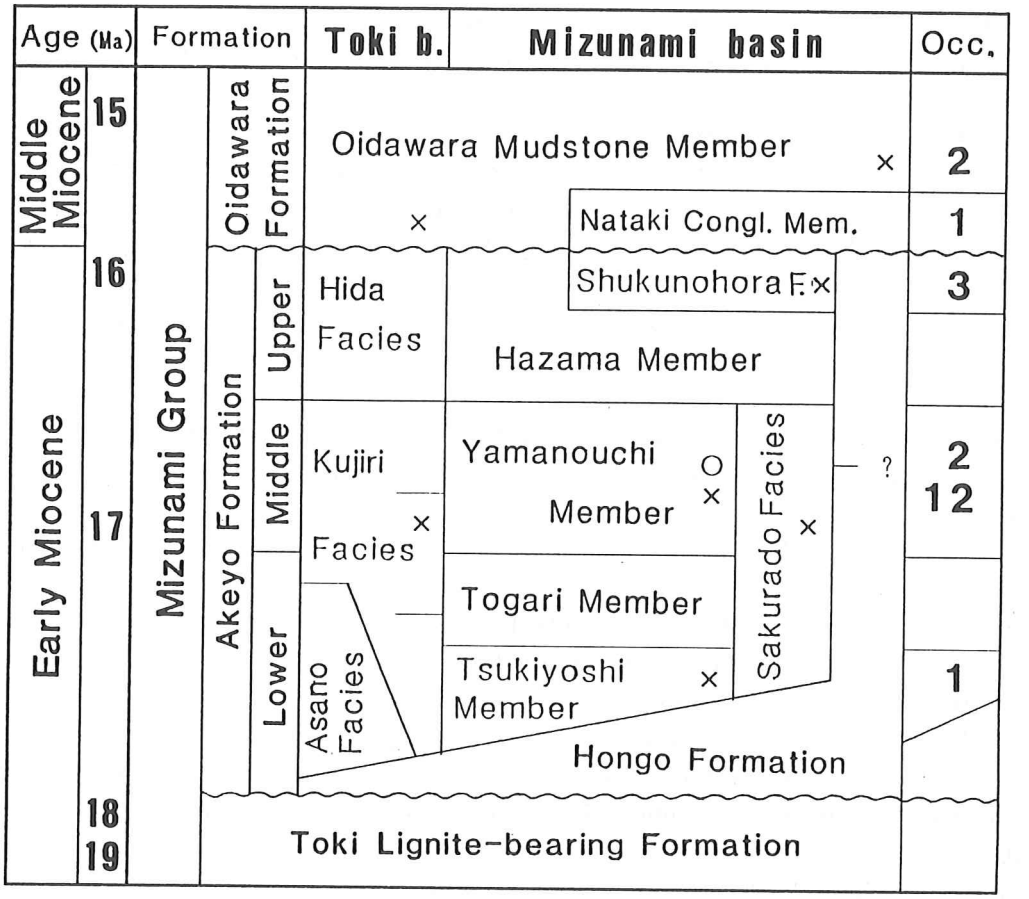


Fig.6 Stratigraphical correlation of the Mizunami Group (cited from Itoigawa, 1980)

{×···Occurrence of *Aturia cubaensis*, ○···Occurrence of *Aturia complanata*
Occ.···Numbers of *Aturia* fossils}

infundibular-formed and largely opened septal foramen is observed at the ultimate septum which is situated in a roundly triangular whorl in section. It has no turn between the lateral lobe and the lateral saddle. From these characteristics, it is identified with *Aturia cubaensis* (Lea).

The Akeyo Formation is assumed to be 16+ to 18 Ma in age (Itoigawa,1980). The Akeyo Formation so far has yielded more than 16 specimens of *Aturia* up to date (Fig. 6).

8) Matsugase specimen (Pl. 27, Figs, 1 a-c); MFM 11028.

Locality: Matsugase, Akeyo-chô, Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Yamanouchi Member, Akeyo Formation, Mizunami Group.

Dimensions: Max. diameter 24.5 mm, max. width 11.7 mm.

Remarks: This small specimen has a slender whorl section with flattened lateral sides in the younger stage, but has a roundly triangular whorl section in the ultimate part. This also has sparsely arranged septa (10 a whorl), a roundly ending extremity of lateral lobe

with the parallel and quasi-straight sides, and a clear turn between the lateral lobe and the lateral saddle (Fig. 2-1). These features indicate this is a juvenile of *A. cubaensis* , as above mentioned.

9) Oginoshima specimens (Pl. 25, Figs. 5 a-c, 6 a,b); MFM 11033 & MFM 11034.

Locality: Oginoshima, Kamado-chô, Mizunami City, Gifu Prefecture (Loc. 7).

Horizon: Shukunohora Facies, Mizunami Group.

Dimensions: Diameter 70.3 mm, max. width 39.0 mm (MFM 11033); max. diameter 38.5 mm, max. width 12.8 mm (compressed; MFM 11034).

Remarks: The living chamber of the larger specimen (MFM 11033) is damaged, and the large part of its disc was destroyed in course of collection. The smaller specimen (MFM 11034) has a laterally compressed shell with a living chamber, and roundly curved septal sutures. These specimens are identical with *Aturia cubaensis* (Lea), because they have no turn between the lateral lobe and the lateral saddle, and a roundly triangular whorl in section.

This locality yields abundant tropical water molluscs (Itoigawa, 1989 ; Itoigawa and Yamanoi, 1990).

10) Nakahida specimen; Tatematsu's collection.

Locality: Nakahida Hida-chô, Toki-City, Gifu Prefecture (Loc. 9).

Horizon: Nataki Conglomerate Member, Oidawara Formation, Mizunami Group.

Dimension: Diameter ca. 50mm.

Remarks: This specimen is so laterally defaced that septal sutures cannot be observed except only sectioned septal sutures. I doubtfully refer the specimen to *Aturia cubaensis* (Lea).

11) Oza specimen (Pl. 27, Fig. 4) ; Mizuno's collection.

Locality: Oza, Minamichita-chô, Chita-gun, Aichi Prefecture (Loc. 11).

Horizon: Toyohama Formation, Morozaki Group.

Dimensions: Max. diameter ca. 20 mm, min. diameter ca. 12 mm.

Remarks: This specimen was first reported by Hachiya (1990). This small specimen has a living chamber, so this is a very younger shell. From the nearly complete preservation of the living chamber, it seems to have been transported a short distance from its living site. This specimen has a deep, parallel, quasi-straight-sided and roundly ending extremity of lateral lobe, where a clear turn is continuing from the lateral saddle, in its younger stage (Fig. 2-1). However, this also has an inflated-cided, subequilateral and acutely pointed lateral lobe, where no turn is continuing from the lateral saddle (Fig. 2-2), at the ultimate and penultimate septa. This feature is important to know the ontogeny of this species. It is identified with *Aturia cubaensis* (Lea) on the basis of the absence of turn between the lateral lobe and the lateral saddle in the ultimate stage.

Aturia complanata Sturani

1) Matsugase specimen (Pl. 27, Fig. 6) ; MFM 11032.

Locality: Matsugase, Akeyo-chô, Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Yamanouchi Member, Akeyo Formation, Mizunami Group.

Dimension: Max. diameter 26.5 mm.

Remarks: This specimen has a small shell without a living chamber, but it seems to be adult on the basis of the ultimate septum overlapping on the penultimate septum. This has densely arranged septa (13 a whorl), a pointed but rather rounded extremity of lateral lobe with slightly inflated sides, largely rounded lateral saddle, and no turn between the lateral lobe and the lateral saddle. Therefore it is identified with *Aturia complanata* Sturani.

2) Yamanouchi-2 specimen (Pl. 27, Figs. 5 a,b); MFM 11031.

Locality: Yamanouchi 282 Y 6, Akeyo-chô, Mizunami City, Gifu Prefecture (Loc. 8).

Horizon: Yamanouchi, Member, Akeyo Formation, Mizunami Group.

Dimensions: Max. width 12.4 mm, height of whorl 17.5 mm.

Remarks: This specimen is largely destroyed but the overlapping ultimate septum indicates it is an adult specimen. This is referred to *Aturia complanata* Sturani on the basis of a rectangular whorl in section, flattened sides, a broadly rounded lateral saddle, and the absence of turn between the lateral lobe and the lateral saddle.

Aturia formae Parona

Izura specimen (Pl. 27, Fig. 7 a,b); MFM 41001.

Locality: Shishigashira, Izura, Ohtsu-chô, Kitaibaragi City, Ibaragi Pref. (Loc. 1).

Horizon: Kokozura Formation, Taga Group.

Dimensions: Max. diameter 31.5 mm, max. width 16.7 mm.

Remarks: This specimen was first reported as *Aturia formae* Parona by Tomida (1990). Its suture line is very similar to that of the juvenile specimen of *cubaensis* from Matsugase, Mizunami City, but the former differs from the latter in having a well-inflated whorl with a round section, a small round septal foramen, a siphuncle very close to the penultimate whorl, thicker septa and a roundly protruded shoulder of ventral saddle. Therefore this is identical with *Aturia formae* Parona. The European specimens by Parona (1898) and Sturani (1958), differ from the Izura specimen in having a somewhat smaller size, a more roundly quadrangular whorl in section and the overlapping septum, but W/D ratio of formers is very near to the latter in the numerical value (Tomida, 1990). This feature may show the sexual dimorphism of this species, like the living *Nautilus* (Stenzel, 1964).

Kato (1980) assigned the Kokozura Formation in Izura to Blow's zone N 15-16, the latest Middle to the earliest Late Miocene in age.

Aturia coxi Miller

Motona specimens (Pl. 28, Figs. 2-6) ; MFM 112110, Inoue's collection, MFM 112111, MFM 112112 & MFM 112113.

Locality: Okumotona Quarry, Kyonan-chô, Awa-gun, Chiba Prefecture (Loc. 2).

Horizon: Senhata Formation, Toyooka Subgroup, Miura Group.

Dimensions: Max. diameter 18 mm (MFM 112110); max. diameter 45 mm (Inoue's collection), max. length 23 mm (MFM 112111); max. diameter 26.5 mm (MFM 112112), max. diameter ca. 26.5 mm (MFM 112113).

Remarks: These specimens have septa very close to one another, a pointed extremity of the lateral lobe, the largely rounded lateral saddle, no turn between the lateral lobe and the lateral saddle, and a ventral lobe. Therefore these are identical with *Aturia coxi* Miller.

Tomida (1983) was the first that reported the occurrence of *Aturia coxi* from Japan. From this locality eight specimens of *Aturia coxi* including adult and juvenile specimens were obtained up to date. Moreover, the occurrence of the very young shell of 18 mm in diameter (Pl. 28, Fig. 2), suggests that *Aturia coxi* may have lived in the adjacent sea of Japan during deposition of their enclosing sediments. The Senhata Formation is characterized by a warm sea molluscan fauna, which is compared with a part of the Lower Miyazaki Group, and the New Zealand's and Australian faunas (Tomida, 1989).

Locality data on Japanese Neogene *Aturia*

Neogene *Aturia* localities in Japan are shown in Figure 7 and described in detail in following lines. The correlation of the *Aturia*-bearing formations is shown in Table 1.

1) Ohtsu-chô, Kitaibaragi City, Ibaragi Prefecture.
 * Takai; *Aturia formae* Parona; Kokozura Formation; (Shimizu, 1926).
 * Izura; *Aturia formae* Parona; Kokozura Formation; Tomida, 1990.
 Aturia cubaensis (Lea); Kokozura Formation; (this report).
2) Motona Quarry, Kyonan-chô, Awa-gun, Chiba Prefecture.
 Aturia coxi Miller; Senhata Formation; Tomida, 1983, 1989.
3) Kawayatsu, Kamogawa City, Chiba Prefecture.
 * Dam-site; *Aturia* cf. *cubaensis* (Lea); (this report).
 * Road-cliff; *Aturia cubaensis* (Lea); (this report).
4) Taira, Hayama-chô, Miura-gun, Kanagawa Prefecture.
 Aturia cubaensis (Lea); Morito Formation; (Ozaki, 1982).
5) Shôgunzawa, Ranzan-chô, Hiki-gun, Saitama Prefecture.
 Aturia cubaensis (Lea); Tokigawa Formation; (Hatai & Masuda, 1962).
6) Ohnohara, Chichibu City, Saitama Prefecture.
 Aturia cubaensis (Lea); (this report).
7) East side of Mizunami City, Gifu Prefecture.
 * Matsubora, Toki-chô; *Aturia cubaensis* (Lea); (this report).
 * Ichihara, Toki-chô; *Aturia cubaensis* (Lea); (this report).
 * Oginoshima, Kamado-chô; *Aturia cubaensis* (Lea); (this report).
8) West side of Mizunami City, Gifu Prefecture.
 * Togari, Akeyo-chô; *Aturia cubaensis* (Lea); Yamanouchi Member, Akeyo Formation; (Kobayashi, 1954) ; (Itoigawa *et al.*, 1974)

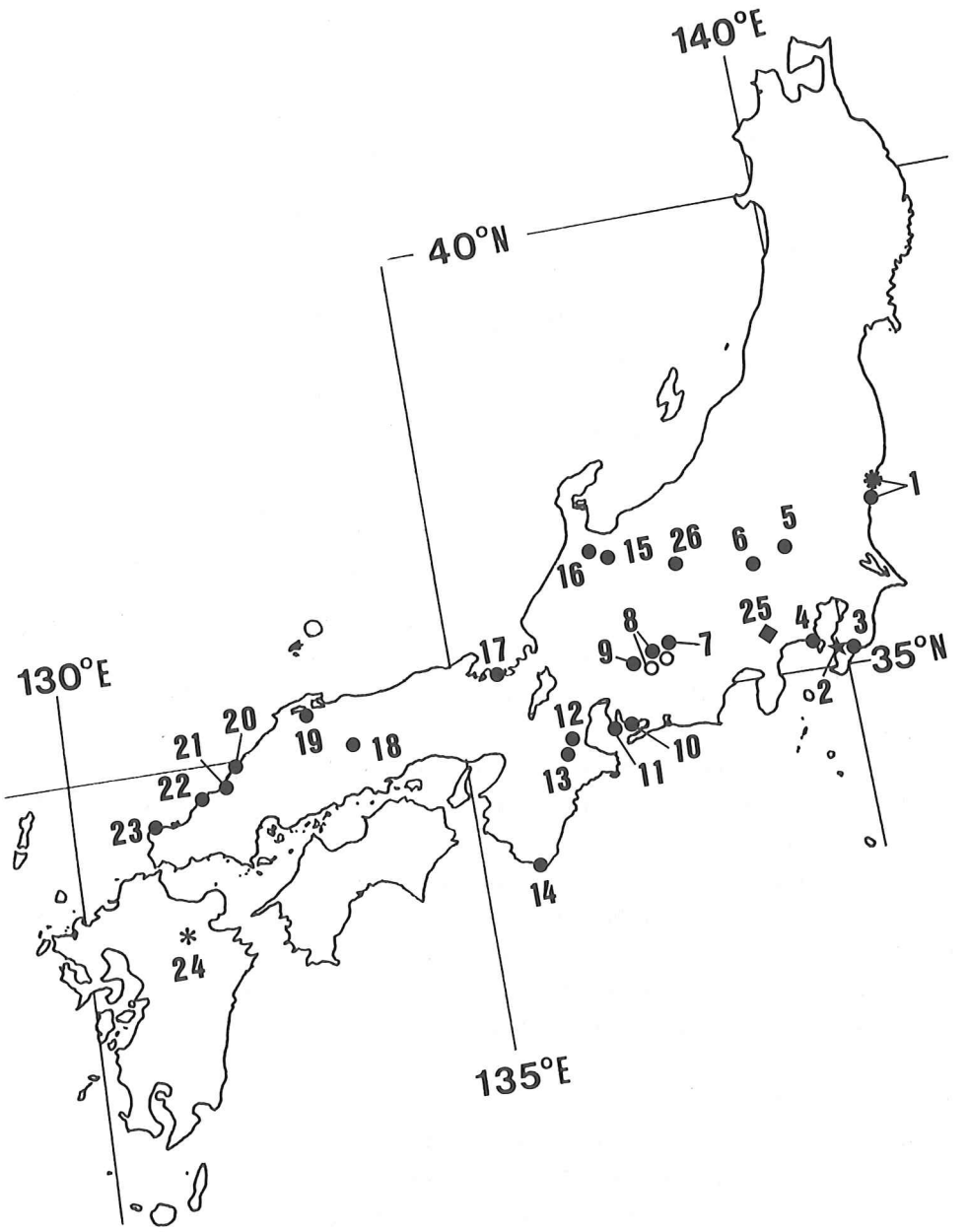


Fig. 7 Map showing the localities of the Japanese Neogene *Aturia*

*···*Aturia aturi*, ●···*Aturia cubaensis*, ○···*Aturia complanata*
✹···*Aturia formae*, ★···*Aturia coxi*, ◆···Nautilida, gen. et sp. indet.

＊Yamanouchi, Akeyo-chô; *Aturia cubaensis* (Lea); (Itoigawa *et al.*, 1974) ; (this report), *Aturia complanata* Sturani; (this report).

＊Matsugase, Akeyo-chô; *Aturia cubaensis* (Lea); (Itoigawa *et al.*, 1974) ; (this report), *Aturia complanata* Sturani; (this report).

9) Toki City, Gifu Prefecture.

＊Jorinji, Izumi-chô; *Aturia cubaensis* (Lea); Kujiri Facies, Mizunami Group; (Hachiya, 1990).

＊Nakahida, Hida-chô; *Aturia* cf. *cubaensis* (Lea); (this report).

10) Himaka-jima, Minamichita-chô, Chita-gun, Aichi Prefecture.
Aturia cubaensis (Lea); Himaka Formation; (Sugiura, 1973).

11) Chita Peninsula, Minamichita-chô, Chita-gun, Aichi Prefecture.

＊Hayashizaki; *Aturia cubaensis* (Lea); Toyohama Formation; (Tomida, 1986).

＊Oza; *Aturia cubaensis* (Lea); Toyohama Formation; (Hachiya, 1990) ; (this report).

12) Bungô, Misato-chô, Age-gun, Mie Prefecture.
Aturia cubaensis (Lea); Mitsugano Formation; (Hachiya, 1990).

13) Sada & Katada, Hakusan-chô, Ichishi-gun, Mie Prefecture.
Aturia cubaensis (Lea); Mitsugano Formation; (Shibata, 1967, 1970).

14) Tanosaki, Tanami, Kushimoto-chô, Nishimuro-gun, Wakayama Prefecture.
Aturia cubaensis (Lea); Tanami Formation; (Katto *et al.*, 1975).

15) Gohyakkoku, Tateyama-chô, Nakaniikawa-gun, Toyama Prefecture.
Aturia cubaensis (Lea); Tochizu Member, Yatsuo Formation; (Kobayashi, 1960)

16) Tsuzuwara, Osawano-chô, Kaminiikawa-gun, Toyama Prefecture.
Aturia cubaensis (Lea); Kurosedani Member, Yatsuo Formation; (Kobayashi & Masatani, 1955).

17) Ogurui, Takahama-chô, Ooi-gun, Fukui Prefecture.
Aturia cubaensis (Lea); Uchiura Group; (Kobayashi & Horikoshi, 1958) ; (Nakagawa & Takeyama, 1985).

18) Tajibe, Ohsa-chô, Atetsu-gun, Okayama Prefecture.
Aturia cubaensis (Lea); Bihoku Group; (Kishimoto, 1982).

19) Fujina, Tamayu-chô, Yatsuka-gun, Shimane Prefecture.
Aturia cubaensis (Lea); Fujina Formation; (Kobayashi, 1960).

20) Tatamigaura, Kokubu-chô, Hamada City, Shimane Prefecture.
Aturia cubaensis (Lea); Tôgane Formation; (Okubo, 1975).

21) Komataka, Honmataka-chô, Masuda City, Shimane Prefecture.
Aturia cubaensis (Lea); Masuda Group; (Tsuru, 1987).

22) Kouyama, Susa-chô, Abu-gun, Yamaguchi Prefecture.
Aturia cubaensis (Lea); Maeji Formation, Susa Group; (Okamoto & Suyama, 1975).

23) Kakebuchi, Yuya-chô, Ohtsu-gun, Yamaguchi Prefecture.
Aturia cubaensis (Lea); Kadoyama Formation, Yuyawan Group; (Okamoto, 1977).

24) ? Kusu-gun, Oita Prefecture.
Aturia aturi (Basterot); horizon unknown; (Kobayashi, 1957).

25) Hitodou, Yamakita-chô, Ashigarakami-gun, Kanagawa Prefecture.

Nautilida; Tanzawa Group; Kadota & Suekane, 1978.

26) Shittakou, Shiga-mura, Higashichikuma-gun, Nagano Prefecture.
Aturia cubaensis (Lea); Aoki Formation; (Hachiya, 1990).

Remarks: The geological range of the Neogene *Aturia* in Japan was hitherto reported by Okamoto and Suyama (1975), Tomida (1986) and Tsuru (1987), who pointed out the abundant occurrence of *Aturia* in the late Early to early Middle Miocene in age. However, from the features above mentioned and shown in Table 1, it can be stated that the occurrences of *Aturia* fossils in Japan are concentrated in 3 ages; the first is the late Early to early Middle Miocene (N 7-N 9 (-N 12) of Blow zone), the second is the late Middle Miocene (N 14-N 15 of Blow zone) and the third is the latest Miocene (N 17 of Blow zone). They are always accompanied by tropical or subtropical marine molluscs. These 3 ages correspond to the remarkable warnings of marine climate (Climatic Optimum 1-3 of Barron and Baldauf, 1990, in chronologic order).

Conclusions

1) Neogene *Aturia* consists of 5 species, *aturi*, *cubaensis*, *complanata*, *formae* and *coxi*. From Japan, four species except *aturi* locality exactly unknown, have been reported.

2) *Aturia aturi* (Basterot) is distinguished from *Aturia cubaensis* (Lea) by the different suture lines not only in the adult stage but in the juvenile stage. *Aturia minoensis* Kobayashi seems to be synonymous with *Aturia cubaensis* (Lea).

3) *Aturia complanata* Sturani is small in size and has a suture line similar to an adult of *Aturia cubaensis* (Lea). While *Aturia formae* Parona is small in size and has a suture line similar to a juvenile of *Aturia cubaensis* (Lea). *Aturia cubaensis* (Lea) is known from the Burdigalian Stage of Lower Miocene in age, but *Aturia complanata* and *Aturia formae* are known from the Langhian Stage of lower Middle Miocene in age. These facts suggest that *Aturia cubaensis* (Lea) may be an ancestral form of these two species. For example, *Aturia formae* Parona seems to have derived from *Aturia cubaensis* (Lea) on the basis of phenomenon of progenesis accompanying a prococious maturation.

4) *Aturia coxi* Miller seems to have been an Indo-Pacific element ranging from the Middle Miocene to the Latest Miocene in age. This species is characterized by the presence of a ventral lobe, but it has no ventral lobe in its juvenile stage. Therefore this seems to have derived from *A. aturi* or *A. cubaensis* which has no ventral lobe in its juvenile and adult stages.

5) The occurrences of the Neogene *Aturia* in Japan are concentrated in 3 ages. These 3 ages correspond to the remarkable warmings of marine climate (Climatic Optimum 1-3).

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Plate 24

Figs. 1a-f. *Aturia cubaensis* (Lea); Ogai's collection, Nagura Fm.
fig. 1a Left lateral side; fig. 1b Right lateral side; fig. 1c Adoral side; fig. 1d Posterior side; fig. 1e Ventral side; fig. 1f Dorsal side, ×0.4.

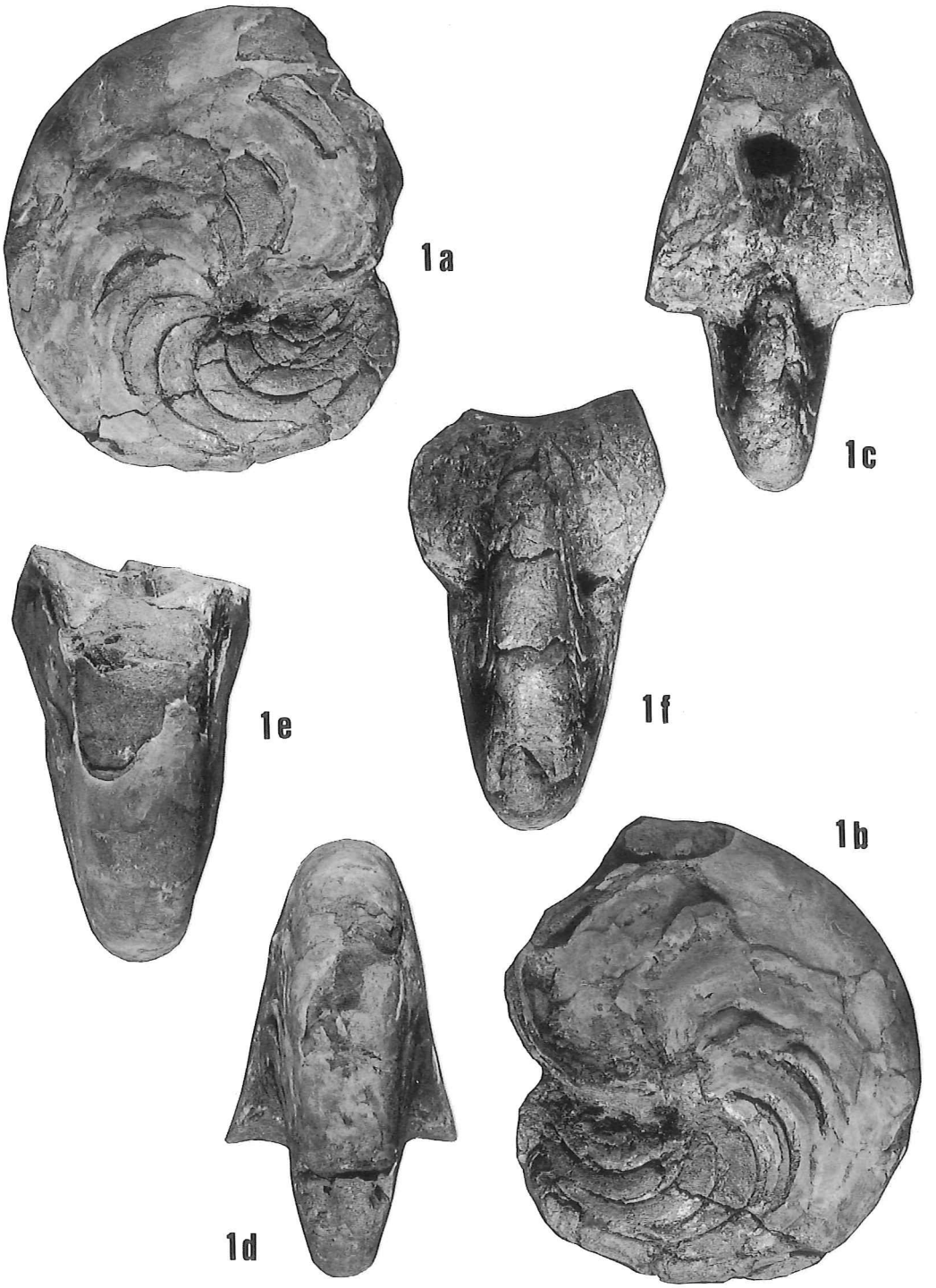

1a
1c
1e
1f
1b
1d

Plate 25

Figs. 1a,b *Aturia* cf. *cubaensis* (Lea); MFM 41003; Kinone Fm.
fig. 1a Lateral side, fig. 1b Ventral side, ×1.2.

Fig. 2 *Aturia* cf. *cubaensis* (Lea);MFM 41004; Kinone Fm.
Lateral side of a fragment, ×1.5.

Fig. 3 *Aturia cubaensis* (Lea); MFM 41005; Amatsu Fm.
Lateral side, ×1.4.

Fig. 4 *Aturia cubaensis* (Lea); MFM 41006; Amatsu Fm.
Lateral side, ×1.

Figs. 5a-c *Aturia cubaensis* (Lea); MFM 11033; Shukunohora Facies, Mizunami Gr.
fig. 5a Right lateral side; fig. 5b Left lateral side; fig. 5c Posterior side, ×0.8.

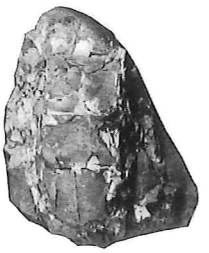
Figs. 6a,b *Aturia cubaensis* (Lea); MFM 11034; Shukunohora Facies, Mizunami Gr.
fig. 6a Left lateral side; fig. 6b Right lateral side, ×0.9.



3



2



1b



1a



5a



6a



6b



4



5c



5b

Plate 26

Figs. 1a-d *Aturia cubaensis* (Lea); MFM 11026; Tsukiyoshi Mem.
fig. 1a Left lateral side; fig. 1b Right lateral side; fig. 1c Adoral side; fig. 1d Dorsal side, ×0.9.

Figs. 2a-c *Aturia cubaensis* (Lea); MFM 11027; Yamanouchi Mem.
fig. 2a Left lateral side; fig. 2b Right lateral side; fig. 2c Adoral side, ×0.6.

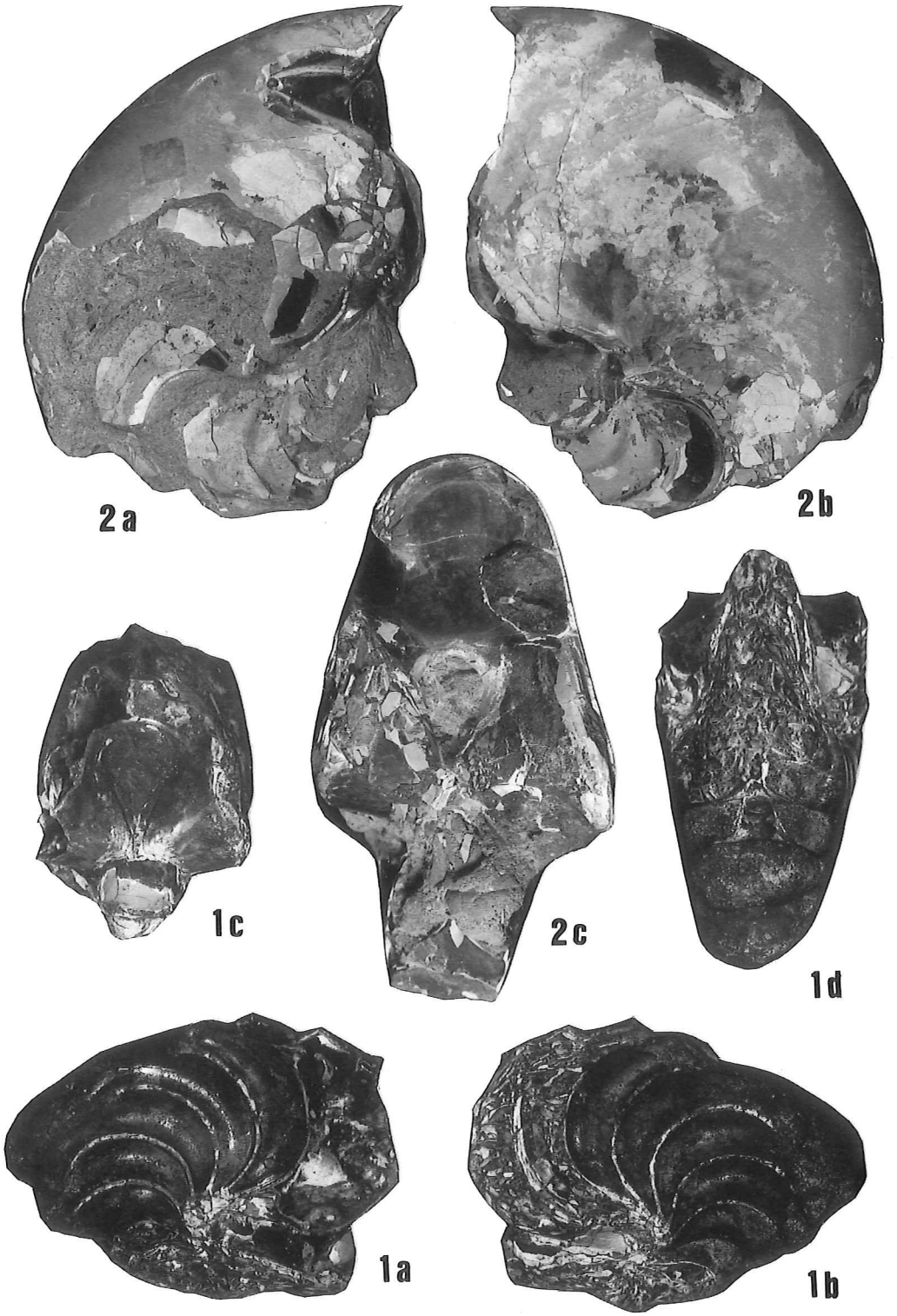

2a
2b
1c
2c
1d
1a
1b

Plate 27

Figs. 1a-c *Aturia cubaensis* (Lea); MFM 11028 Yamanouchi Mem.
fig. 1a Enlarged Left lateral side; ×2.2, fig. 1b Adoral side; fig. 1c Right lateral side, ×1.5.

Figs. 2a,b *Aturia cubaensis* (Lea); MFM 11029; Sakuradô Facies, Mizunami Gr.
fig. 2a Left lateral side; fig. 2b Adoral side, ×1.

Fig. 3 *Aturia cubaensis* (Lea); MFM 11030; Sakuradô Facies, Mizunami Gr
Left lateral side, ×1.5.

Fig. 4 *Aturia cubaensis* (Lea); Mizuno's collection; Toyohama Fm.
Right lateral side, ×2.3.

Figs. 5a,b *Aturia complanata* Sturani; MFM 11031; Yamanouchi Mem.
fig. 5a Right lateral side; fig. 5b Sectioned view, ×1.4.

Fig. 6 *Aturia complanata* Sturani; MFM 11032; Yamanouchi Mem.
Right lateral side, ×1.4.

Fig. 7a,b *Aturia formae* Parona; MFM41001 ; Kokozura Fm.
fig. 7a Sectioned view; fig. 7b Right lateral side, ×1.2.

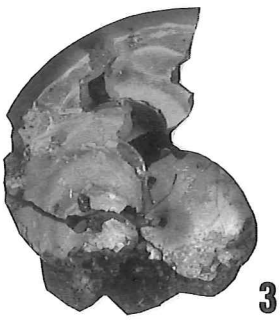

1a

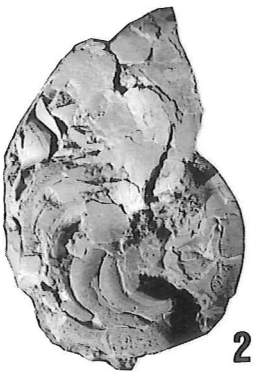

1b

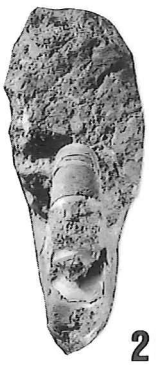

1c


5a


5b


3


2a


2b


6


4


7a


7b

Plate 28

Figs. 1a,b *Aturia cubaensis* (Lea); MFM41002 ; Kokozura Fm.
fig. 1a Whorl view of *Aturia*-bearing nodule, ×0.8, fig. 1b Enlarged inner view, ×2.5.

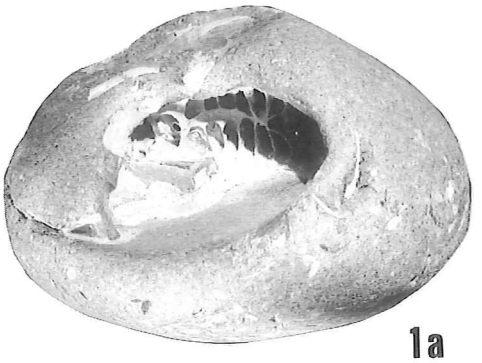
Fig. 2 *Aturia coxi* Miller; MFM 112110; Senhata Fm.
Lateral side of a juvenile specimen, ×3.

Figs. 3a,b *Aturia coxi* Miller; Inoue's collection; Senhata Fm.
fig. 3a Ventral side; fig. 3b Lateral side, ×1.3.

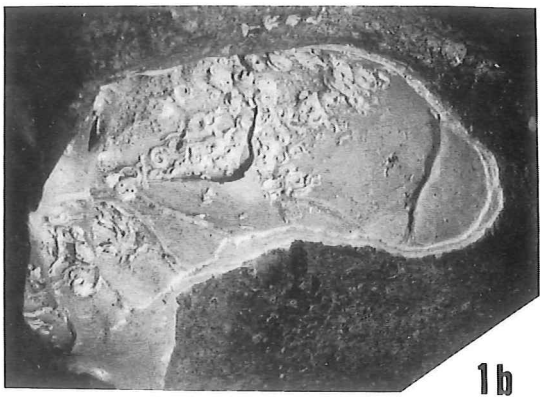
Figs. 4a,b *Aturia coxi* Miller; MFM 112111; Senhata Fm.
fig. 4a Ventral side of a fragment, showing ventral lobes; fig. 4b Lateral side, ×1.5.

Fig.5 *Aturia coxi* Miller; MFM 112112; Senhata Fm.
Lateral side of a fragment, ×2.

Fig. 6 *Aturia coxi* Miller; MFM 112113; Senhata Fm.
Lateral side of a juvenile specimen, ×1.5.



1a



1b



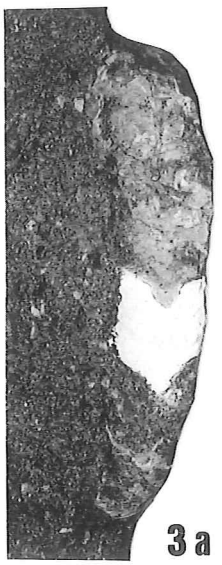
2



4a



4b



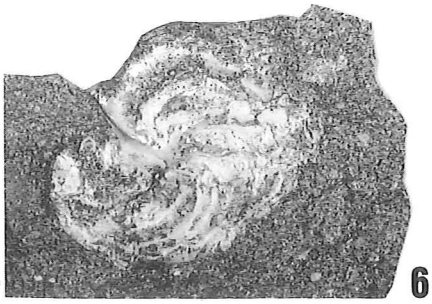
3a



3b



5



6