花井哲郎先生

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TAXONOMIC NOTES ON *CARDINIA* WITH DESCRIPTION OF A NEW SPECIES FROM THE LIAS OF WESTERN JAPAN

By

Itaru HAYAMI

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With One Plate

In 1956, I collected several specimens belonging to a new species of *Cardinia* from the basal part of the lower Liassic Higashinagano formation of the Toyora group in Yamaguchi Prefecture, West Japan. The cardiniid occurs in a small fossil bank together with many other pelecypods including *Prosogyrotrigonia inouyei* (YEHARA), gastropods, an ammonite, a brachiopod, two hexacorals (*Chomatoseris cyclitoides* and an isastraeid) and a crinoid. MATSUMOTO and ONO (1947) reported *Rhacophyllites* (*Harpophylloceras*) sp. from this horizon and suggested Hettangian for the fauna.

Cardinia AGASSIZ has been regarded as an important pelecypod genus especially for Liassic stratigraphy and chronology. The genus shows quite variable outlines and ornamentations, but no attempt to divide the genus into groups of lower category has been done. On this occasion I discuss the taxonomy and morphological relationship among *Cardinia* and its related genera. As I could observe only a few foreign specimens besides Japanese ones, I do not here divide it into subgenera but into several groups which consist of morphologically intimate species.

Before discussion, I wish to express my sincere thanks to Prof. Teiichi KOBAYASHI of the University of Tokyo for his kind advices and encouragements, and also to Dr. Leslie R. Cox of the British Museum for his kind and instructive informations about this genus.

Taxonomic Notes on *Cardinia*

Since SOWERBY had described several species under the generic name of *Unio* in his Mineral Conchology, many Liassic species of *Cardinia* were reported in Western Europe by GOLDFUSS (1836), KOCH and DUNKER (1837), STUTCHBURY (1842), AGASSIZ (1843), D'ORBIGNY (1850), DUNKER (1851), CHAPUIS and DEWALQUE (1853), TERQUEM (1855), QUENSTEDT (1856), CHAPUIS (1858), MARTIN (1859), DUMORTIER (1867, 1869), TERQUEM and PIETTE (1868), COSSMANN (1904), JOLY (1908, 1936), TROEDSSON (1951) and some others, and several Rhaetic species by DITTMAR (1864), DUMORTIER (1864), LEVALLOIS (1865), PLÜCKER (1868), OOSTER (1869) and REYNOLDS and VAUGHAN (1904). So far as I am aware, the occurrence of *Cardinia* is restricted to the Rhaetic to Dogger in Europe, but in some other continents older forms were reported. McCOY (1847), SWALLOW (1858), WAAGEN (1881), STUCKENBERG (1898) and some others described several species** from the Permian

* Received June 9, 1958.

** Many Permian "*Cardinias*", which are omitted in my synoptic list, were referred to some other Palaeozoic suitable genera by BRANSON (1948, *Geol. Soc. America, Mem. 26*).

of Australia, North America, India and Russia. Their generic references are, however, not warranted, because their hinge and other principal characters are unknown or seemingly different from Mesozoic true *Cardinia*. It is, therefore, quite doubtful if such Palaeozoic species are actually ancestral to Mesozoic forms. Two undoubted species of *Cardinia* appeared at first in the Carnic of Japan (KOBAYASHI and ICHIKAWA, 1952a; ICHIKAWA, 1954; NAKAZAWA, 1955, 1956). In North America SMITH (1927) reported also a Carnic species. Other Triassic cardiniids occur in the Noric of Japan (KOBAYASHI and ICHIKAWA, 1952b), Upper Triassic of Northern Siberia and Elleresmereland (KITTL, 1907; VORONETZ, 1936, KIPARISOVA, 1937) and Rhaetic of New Zealand (MARWICK, 1953; FLEMING, 1957).

But *Cardinia* show as a whole an acmaic development in lower Liassic times. As shown in Table 1, lower Lias yields more than 80 species which occupy more than 70 percent of true cardiniids. In outside of Western Europe,

Table 1. Number of Species of *Cardinia* in each geological Stage.

Stage	Undoubted occurrence	Doubtful occurrence
Dogger	2	1
Upper Lias	6	0
Middle Lias	7	2
Lower Lias	88	0
Rhaetic	8	0
Noric	1	3
Carnic	2	2

Liassic *Cardinia* is distributed in Eastern Greenland (ROSENKRANTZ, 1934), Ferghana, Caucasus (PČELINCEV, 1937), Northern Siberia (VORONETZ, 1936), Japan, Indochina (MANSUY, 1914, 1919), Alberta (WARREN, 1932, Bajocian?), California (HYATT, 1894) and the southern Andes (JAWORSKI, 1915; FERUGLIO, 1934; LEANZA, 1942). A few species are found in the European Dogger, but none survived until Malm.

About 100 species hitherto described from the Upper Triassic and the lower half of Jurassic have actually a fairly persistent hinge-structure composed of a more or less obsolete cardinal (3b) and a pair of characteristic remote laterals (AI–III, PI–III), and should be included in one genus. Only a few species such as *Cardinia listeri* show complete obsolescence of the cardinal tooth and are slightly different in hinge aspect from normal ones. But it is not considered of generic importance. Musculature is of primitive heterodont type, also very persistent and composed of strongly impressed anisomyarian adductors, clear posterior pedal scar and entire pallial line. Ligament is subinternal and sunk profoundly between subvertical escutcheons, and the character makes it easy to distinguish *Cardinia* from Schizodont and more primitive Heterodont genera. However, the external aspect and ornamentation of *Cardinia* are quite variable, and the genus can be divided into several groups of lower category. Some of them may require subgeneric distinction, but I do not propose here new subgeneric names, because their differences and phylogenetical relationship must be further studied.

Chief criteria for the subdivision of *Cardinia* are considered to exist in shell-outline, umbonal position, ventral sinuation, development of lunule and surface-ornamentation. There is certain relationship among these characters: for instance, *Cardinia concinna* and its related species (i. e. *Cardinia* s. s.) with comparatively large and elongated shells do not show strong concentric ornamentation, while smaller and cuneiform species such as *Cardinia hybrida* are provided with deep lunule, very prosogyrous umbo and strong concentrics. In view of these characters most species of *Cardinia* can be classified into the following five groups.

1. *Concinna*-group (*Cardinia* s.s.) (Pl. XI, Figs. 12a–b)

Diagnosis:—Shell large, very elongated, usually twice or more as long as high, not strongly inflated; umbo more or less prosogyrous, lying very anteriorly, not projected anteriorly; surface smooth without any strong concentric ornaments, marked only with weak irregular lamellae and numerous fine growth-lines.

Distribution:—Noric (?), Rhaetic to middle Lias of Western Europe, Greenland, Ferghana, Northern Siberia and Indochina.

List of Species:—*Cardinia angustata* (?), *concinna*, *copides*, *elongata*, *eveni* (?), *fischeri* (?), *gigantea*, *hennocquii*, *infera*, *kullensis*, *lanceolata* (?), *philea*, *porrecta* (?), *scapha* and *secuiformis* (?).

2. *Crassissima*-group (Pl. XI, Figs. 13a–b)

Diagnosis:—Shell medium to large, ovate or subelliptical, not elongated, well inflated; test thick; umbo prosogyrous; lunule fairly deeply excavated below beak, sometimes folded; surface marked with concentric lamellae of variable strength, but lacks any strong ribs or imbrications.

Distribution:—Rhaetic to lower Dogger of Western Europe, Northern Siberia (?), South America (?) and Indochina (?).

List of Species:—*Cardinia acuminata*, *breoni*, *brevis*, *collenoti*, *contracta*, *crassissima*, *crassiuscula*, *deshayesi*, *desoudini*, *insignis*, *minor*, *moreana*, *obovata*, *ovum* (?), *quadrangularis*, *regularis*, *siberica* (?), *sinemuriensis*, *sublamellosa*, *subovalis*, *tas-aryensis* (?) and *trapezium*.

3. *Piriformis*-group (Pl. XI, Figs. 14a–b)

Diagnosis:—Shell medium to large, highly inequilateral, pyriform with a posteriorly rostrated part and distinct postero-ventral sinuation; test very thick; hinge-plate heavy with more or less tubercle-like lateral teeth: umbo slightly prosogyrous; surface marked only with weak growth-lamellae.

Distribution:—Lower Lias of Western Europe.

List of Species:—*Cardinia chillyensis*, *piriformis* and *plana*.

4. *Hybrida*-group (Pl. XI, Figs. 1–11, 15–17).

Diagnosis:—Shell small to large, only slightly inflated, not very elongated but more or less expanded postero-ventrally, often more or less cuneiform with slight ventral sinuation and anteriorly protruded prosogyrous umbo; test not very thick; lunule deep; surface marked with strong and often imbricated concentric lamellae.

Remarks:—*Hybrida*-group consists of the following three subgroups.

4a. *Hybrida*-subgroup (Pl. XI, Figs. 15a–b, 16) with small to medium size, cuneiform outline, distinct ventral sinuation, very prosogyrous and anteriorly protruded umbo, profoundly excavated lunule which is covered upwards with beak and vertically depressed, and strong concentric ribs whose interspaces are often striated by many fine secondaries or growth lines.

Distribution:—Rhaetic to middle Lias of Western Europe, Greenland and Northern Siberia.

List of Species:—*Cardinia abducta, amygdala, angustiplexa, aptycha, cuneata, depressa, dunkeri, gibba, gibbosula, hybrida, idalia, imbricata, itea, lamellosa, latiplexa, listeri, morisi, nilssoni, quadrata* and *sulcata*.

4b. *Toriyamai*-subgroup (Pl. XI, Figs. 1–11) with comparatively small size, more elliptical outline, less prominent and more posterior umbo and more strongly imbricated and widely spaced concentric lamellae with smooth or only faintly striated intervals than in the preceding subgroup.

Distribution:—Carnic to lower Lias of Western Europe, Northern Siberia, Arctic (?) and Japan.

List of Species:—*Cardinia elliptica, misawensis, ovalis, ovula* (?), *regularis* (in VORONETZ, 1936), *similis, toriyamai* and *triadica*.

4c. *Densestriata*-subgroup (Pl. XI, Fig. 17) with large size, similar outline to the preceding subgroup, obscure ventral sinuation, strong concentric ribs or lamellae whose intervals are striated by fine secondaries or growth-lamellae.

Distribution:—Middle to upper Lias of South America.

List of Species:—*Cardinia andium, densestriata*.

5. *Unioides*-group (Pl. XI, Fig. 18)

Diagnosis:—Shell medium to small, subequilateral, trigonal; ventral sinuation absent, umbo only slightly prosogyrous, lying submesially; surface lacks any strong concentric ornamentation.

Distribution:—Lower Lias of Western Europe.

List of Species:—*Cardinia cyprina, subaequilateralis, trigona* (?) and *unioides*.

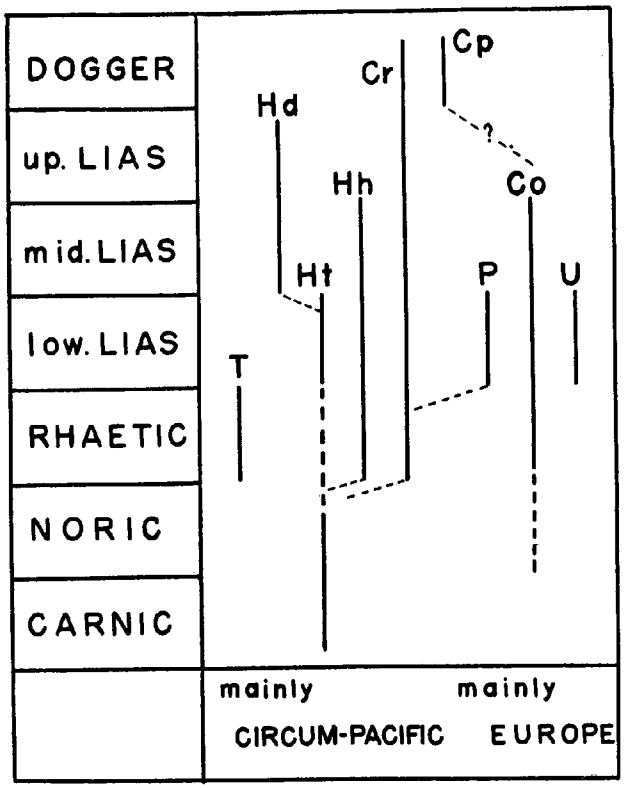
6. Other groups

Besides, it is presumed that there are several species of *Cardinia* belonging to other groups, such as *Cardinia attenuata, exigua, expansa, follini, ingelensis, oblonga* and *lucinaeformis*. MARWICK (1953) established *Torastarte* for a Rhaetic species from New Zealand and took it for a genus of the Astartidae. Subsequently FLEMING (1957) included it in the Cardiniidae, and considered that it differs from *Cardinia* in its rounder less elongated outline, coarse regular concentric sculpture and gerontically in-grown escutcheon and nymph which have been carried down completely across the cardinal area, presumably by the descent of ligament. The outline of the species is, in fact, fairly unique but other characters are also seen to a certain extent in many species of *Cardinia*, and I am inclined to regard it as a subgenus of *Cardinia*. Besides the above mentioned groups, TORNQUIST (1898) proposed *Cardiniopsis* for a *Cardinia*-like Bajocian species from Argentina. Although the generic name was preoccupied by *Cardiniopsis* STANTON (1895) by three years, it may be related to *Cardinia* (especially to *Concinna*-group), judging from its exterior. *Cardinia gleimi* SMITH (1927) and *Cardinia ponderosa* GABB (1869) respectively from the Carnic and Noric of North America do not belong to any of my five groups. The two species are interesting ones for the consideration of the phylogeny of *Cardinia* but their generic references were doubted respectively by KOBAYASHI and ICHIKAWA (1952a) and SMITH (1927).

Among the above mentioned groups of *Cardinia*, *Unioides*- and *Piriformis*-groups are composed comparatively of a few species, and considered two specialized small branches from certain main trunks of the genus in Europe. Judging from the geological occurrences, *Toriyamai*-subgroup flourished already in the Carnic of Eastern Asia and Arctic regions prior to many other European

groups. In Europe *Concinna*- and *Crassissima*-groups and *Hybrida*-subgroup appeared almost coevally at first in the Rhaetic, and it is difficult to say which group is the oldest and forms the main stock. These three groups are very different in outline from one another, but *Hybrida*-subgroup and *Crassissima*-group may be related in many other characters. *Hybrida*-subgroup is morphologically related to *Toriyamai*-subgroup and may be a derivative from the latter. The differentiation among the two groups and the subgroups occurred anyhow already in the lower Liassic. The former subgroup flourished chiefly in Europe, while the latter prospered mainly in the Circum-Pacific and Arctic regions. *Densestriata*-subgroup is probably also a specialized branch from a certain subgroup of *Hybrida*-group, and very characteristic in the middle and upper Lias of South America (Neuquen, Patagonia and Chile). In outline the subgroup is very similar to *Toriyamai*-subgroup. Text-fig. 1 shows the possible phylogeny of *Cardinia*.

The origin of *Cardinia* has not yet been clarified. As mentioned above, some Upper Palaeozoic "*Cardinias*" could not be ancestral to the Mesozoic species. According to DIENER (1923) and KUTASSY (1931), no Lower or Middle Triassic species was reported, and the ancestor of this genus should be sought in other pelecypod genera of the age. WAAGEN (1907) discussed the phylogeny



Text-fig. 1. Evolution of *Cardinia*. Abbreviations:—T: *Torastarte*, Hd: *Densestriata*-subgroup, Ht: *Toriyamai*-subgroup, Hh: *Hybrida*-subgroup, Cr: *Crassissima*-group, Co: *Concinna*-group (*Cardinia* s. s.), Cp: *Cardiniopsis*, P: *Piriformis*-group, U: *Unioides*-group.

of *Cardinia* and concluded that the genus is a descendent group from *Trigonodus* SANDBERGER (1864). He regarded that the cardiniid hinge was introduced by the shifting of ligament from external to internal. But I think that *Cardinia* is quite different from *Trigonodus* and its related genera (i.e. *Pachycardia*, *Heminajas*, etc.) in dentition, ligament structure and external aspects which are fundamental for the classification of pelecypods. NAKAZAWA (1956) and I (1957) included *Cardinioides* KOBAYASHI and ICHIKAWA (1952a) in the Cardiniidae ZITTEL laying special weight on the presence of remote lateral teeth of *Cardinia*-type. The musculature of *Cardinioides* is also fairly similar to *Cardinia*, but the two genera differ from each other in some other fundamental characters, as shown below.

Characters	*Cardinia*	*Cardinioides*	*Trigonodus*
Outline	ovate or cuneiform	ovate or trigonal	trigonal
Umbonal direction	prosogyrous, often projected anteriorly	orthogyrous	slightly prosogyrous
Ligament	subinternal	external	external
Cardinal teeth	obsolete 3a only	pseudocardinal teeth	*Myophoria*-like teeth
Ant. lateral teeth	strong, short	absent	absent
Pos. lateral teeth	strong, remote	rounded, if present	thin, elongated
Pos.-dorsal carina	absent	absent or weak	present
Ventral sinuation	sometimes present	absent	absent
Lunule	deeply excavated	absent	absent or weak
Escutcheon	nearly vertical	absent	absent

Therefore, I am now inclined to consider that *Trigonodus*, *Pachycardia*, *Heminajas* and *Cardinioides* should be excluded from the Cardiniidae and included in a certain schizodont family. *Palaeopharus* (*Minepharus*) *triadicus* TOKUYAMA* (MS) from the Carnic of West Japan shows *Pleurophorus*-like posterior radial ornamentation and elongated outline, and at the same time *Cardinia*-like dentition composed of obsolete cardinal and incipient anterior lateral teeth, similar musculature and ligament structure. The excavated lunule in *Cardinia* is very similar to that of the Carnic species as well as other Japanese Carnic palaeopharids**. The crenulated pseudocardinal teeth in *Palaeopharus* correspond as a whole probably to the anterior lateral teeth of *Cardinia*. Although the phylogenetical relationship between *Palaeopharus* and "*Pleurophorus*" has not yet been clarified, it is possible that *Cardinia* was originated in such primitive heterodont groups with more or less elongated shells. In comparison with primitive heterodonts which were lately discussed by NEWELL (1957), *Cardinia* differs from "*Pleurophorus*" and its related genera in having a distinct anterior lateral teeth and subinternal ligament. In many respects, direct descendants

* I could observe its well-preserved specimens through his courtsey.

** NAKAZAWA (1955) regarded the pre-umbonal excavation in *Palaeopharus maizurensis* KOBAYASHI and ICHIKAWA as an anterior ligament area.

from the pleurophorids are found in *Myoconcha* SOWERBY (1824) and *Kalentera* MARWICK (1953) in the Jurassic. But it is certain that *Cardinia* is more phylogenetically related to such primitive heterodonts than *Trigonodus* and other Triassic Schizodont genera. It is notworthy that the musculature, lunule and escutcheon of *Cardinia* are fairly similar to those of the Astartidae, typical Diagenodonta, especially to *Coelastarte* BOEHM (1893) as discussed before (HAYAMI, 1958), although the dentition of *Cardinia* is quite different from astartids.

Another problem adhering to *Cardinia* is the phylogeny of unionids. POHLIG (1880–1881) noted that Carboniferous *Anthracosia*, Triassic *Uniona* and Jurassic *Cardinia* form a transitional series from najadids to cyprinids, and that *Uniona* and *Cardinia* are at the same time ancestral to recent *Unio*. The internal characters of *Cardinia* (especially European thick forms as Pl. XI, Fig. 13b) remind at a glance one of the similarity to the Unionidae. But *Cardinia* differs from any unionid genera in having the subinternal ligament, distinct lunule and escutcheon which appear in advanced forms of pelecypods. Such a regressive evolution cannot be considered. Although the Unionidae may have polyphyletic origins, cardiniids are most certainly not ancestral to any group of unionids.

Systematic Description

Family **Cardiniidae** ZITTEL

Genus *Cardinia* AGASSIZ, 1841

=*Sinemuria* DE CHRISTOL, 1841; *Pachyodon* STUTCHBURY, 1842; *Thalassites* QUENSTEDT, 1856

Type species:—*Unio concinnus* SOWERBY, 1821, lower Lias and Rhaetic, England, Paris basin, Greenland and Northern Siberia. (Opinion 292)

The decision of the International Commission on Zoological Nomenclature relating to the generic name *Cardinia* was published as Opinion 292 which was rendered as the result of Cox's application (1951) entitled "Validation, under the Plenary Powers, of the generic name *Cardinia* as from AGASSIZ (1841), for use in its accustomed sense". Therefore, *Sinemuria*, *Pachyodon* and *Thalassites* are regarded as its synonyms.

MM2913-11-1
MM2914-11-2
MM2915-11-3
MM2916-11-4
MM2917-11-5
MM2918-11-6
MM2919-11-7
MM2920-11-8
MM2921-11-9
MM2922-11-10
MM2923-11-11

Cardinia toriyamai HAYAMI, new species

Plate XI, Figures 1–11.

1938, *Cardinia* sp. listed by TORIYAMA, *Jour. Geol. Soc. Japan, Vol. 45, No. 533*, p. 251.
1958, *Cardinia* n. sp. listed by HAYAMI, *Japan, Jour. Geol. Geogr., Vol. 29, Nos. 1-3*, p. 107.

Description:—Shell medium to small for genus, equivalve, inequilateral, ovate to cuneiform in outline, expanded postero-ventrally, not strongly inflated, about 1.6 times as long as high; test very thick; antero-dorsal margin deeply excavated below umbo; postero-dorsal one gently arcuate, passing gradually into venter; both margins form as apical angle of about 50 degrees at beak, although it is not observable in external view; ventral margin slightly sinuated mesially in early stage but the sinuation gradually diminishes later; umbo very prosogyrous, protruded forwards, lying at about two-sevenths of shell-length from front; surface marked with strongly imbricated concentric lamellae, whose intervals are fairly regular but more or less narrow in early and full-grown stages; growth-lines very weak, frequently indiscernible; lunule small but ex-

tremely deep (generally impressed on internal mould), overlain by anteriorly protruded umbo, larger in left valve than in right due to a thickening of pre-umbonal margin in left valve, circumscribed and clearly defined by a sharp ridge in each valve; escutcheon subvertical, marked with oblique growth-lamellae; ligament subinternal, sunk deeply. Right valve provided with an obsolete cardinal 3b and a pair of laterals of *Cardinia*-type (AIII and PIII); 3b fairly stout, prosocline and linearly elongated in early stage, but almost degenerated later; AI and PI undeveloped, represented by slight marginal thickenings respectively; AIII elongated, gradually strengthened anteriorly; PIII short, weak, isolated from cardinal; left valve with a shallow cardinal groove (3b′) and a pair of stout isolated laterals (AII and PII); AII short but extremely strong; PII moderate in length, very strong, originated in a post-umbonal hinge-plate near the posterior end of escutcheon; all laterals abruptly interrupted at the ends by deeply sunk adductor scars; anterior scar gibbose, wedge-like, strongly impressed; posterior one orbicular and also well marked; pallial line weakly marked and most certainly entire; umbonal cavity shallow.

Measurement in mm.	Length	Height	Thickness
Holotype (MM2918) Left internal mould	44.0	29.0	6.5+
Paratype (MM2917) Right valve	44.5+	32.5	7.5+
Paratype (MM2921) Right valve	19.5	12.0	4.0

Observation and comparison:—About 20 specimens are at hand, but most of them more or less broken except for several immature individuals. The holotype (Fig. 6) and some other specimens (Figs. 1–4, 7) show typical dentition of *Cardinia*. Two paratypes (Figs. 5 and 9) and some other external moulds (Figs. 8, 10, 11) reveals splendidly imbricated concentric surface-markings. The concentrics are very widely spaced but sometimes irregular at intervals. The outline is more or less cuneiform with a slight ventral sinuation in early stage (Figs. 8, 9), but becomes more elliptical in adult. An elongated cardinal tooth 3b is seen in a juvenalium (Fig. 4), but when grown up, it is almost completely obsolete.

Cardinia was most flourished in the Liassic, especially in the Hettangian and Sinemurian of Europe, where many species have been described. Insofar as I am aware, there is no foreign species having such a magnificent imbricated surface. This species seems more related to the cardiniids hitherto known from the Upper Triassic of Japan in external features. More precisely, this is fairly similar to *Cardinia triadica* KOBAYASHI and ICHIKAWA (1952a) (NAKAZAWA, 1955) from the Carnic Nabae group in Central Japan and may be a derivative of such species. But in *triadica* the cardinal tooth 3b is more distinct and bordered by a shallow depression on each side which corresponds with a tooth-like projection of the counter valve. If considered that the cardinal was degenerated in this genus, this is a more advanced form than *triadica*. The surface of the Carnic species is marked also with more or less imbricated lamellae, but they are more irregular at intervals and obviously weaker than the present species. The length of *triadica* is 36 mm. at the largest, while it often exceeds 45 mm. in this species. *Cardinia misawensis* KOBAYASHI and ICHIKAWA (1952b) (ICHIKAWA, 1954; NAKAZAWA, 1955, 1956) from the Noric Nariwa and Carnic Nabae and Kochigatani groups are different from this in the slightly more anterior umbo and more

irregularly and densely spaced concentrics.

As to foreign species, *Cardinia regularis* TERQUEM in VORONETZ (1936) from the lower Lias near the mouth of Lena, Northern Siberia may be an ally to this, judging from the concentric lamellae, their smooth intervals and general outline. Typical *regularis* in TERQUEM (1855) from the lower Lias of Paris basin has an ovate outline and finely striated surface, and the Siberian form may be specifically different from the species. If the much larger dimensions of this species are ignored, it is not easy to find specific distinction between this and the Siberian form. But the concentric lamellae are probably still stronger in this species. The ventral sinuation, which is slightly seen in some young specimens of this species, develops in *Cardinia hybrida* (SOWERBY) (1818; STUTCHBURY, 1842; AGASSIZ, 1843; CHAPUIS and DEWALQUE, 1853; QUENSTEDT, 1856; DUMORTIER, 1867, etc.), a well known lower Liassic species from Western Europe and also in several allies which form *Hybrida*-subgroup in this paper. But the outlines of such European forms are more cuneiform with very anteriorly projected umbones, and the concentrics are much weaker, not imbricated and more densely spaced with insertions of numerous growth lamellae. In this species growth-lines are very weak and often indiscernible. *Cardinia latiplex* GOLDFUSS (1836), *C. idalia* D'ORBIGNY and *C. itea* D'ORBIGNY (BOULE, 1907) show almost smooth intervals, but their outlines are more cuneiform. *Cardinia elliptica* AGASSIZ (1843; QUENSTEDT, 1856), *C. similis* AGASSIZ (1843; TERQUEM, 1855) and *C. ovalis* (STUTCHBURY) (1842) have similar outlines to this, but their surface-ornaments are less imbricated. The ratio of length to height varies in this species to some extent. A right internal mould (Fig. 1) has a fairly elongated outline more or less similar to that of *Cardinia elongata* DUNKER (1851; DOUVILLÉ, 1921) which I include in *Concinna*-group. But it is certainly due to variation within this species, because wide-spaced concentric foldings are weakly impressed in the internal surface.

Occurrence:—Common in a fossiliferous lenticular sandstone bed belonging to the basal part of the lower Liassic Higashinagano formation at a small valley southeast of Higashinagano, Toyoda town, Toyora County in Yamaguchi Prefecture. The locality corresponds with Loc. 97 of Nbs by MATSUMOTO and ONO (1947). TORIYAMA (1938) listed *Cardinia* from this horizon at a valley of Higashinakayama, and his juvenile specimen (Fig. 4) is here identified with this species.

List of *Cardinia**

Abbreviations:—Co: *Concinna*-group (*Cardinia* s.s.), Cr: *Crassissima*-group, P: *Piriformis*-group, Hh: *Hybrida*-subgroup, Ht: *Toriyamai*-subgroup, Hd: *Densestriata*-subgroup, U: *Unioides*-group.

Unio abductus PHILLIPS, 1836, low.-up. Lias, Europe, (Hh); STUTCHBURY (1842).

Cardinia acuminata MARTIN, 1859, low. Lias, Europe, (Cr); JOLY (1936).

Cardinia amygdala AGASSIZ, 1843, low. Lias, Europe, (Hh); TERQUEM and PIETTE (1868).

Cardinia andium GIEBEL, 1861, mid.-up. Lias, South America, (Hd); PHILIPPI (1899), BURCKHARDT (1901), JAWORSKI (1915), JAWORSKI (1926), FERUGLIO (1934), WAHNISH (1924), LEANZA (1942).

* It is beyond my ability to make a complete synonymic list among many forms only from descriptions and figures. This list is, of course, synoptic one showing homonymic relations among hitherto reported species which I could refer to for this study.

Cardinia angustata AGASSIZ, 1843, low. Lias, Europe, (Co?); TERQUEM (1855).
Cardinia angustiplexa CHAPUIS and DEWALQUE, 1853, low. Lias, Europe, (Hh); TERQUEM and PIETTE (1868), JOLY (1936).
Cytherea aptychus MÜNSTER, low. Lias, Europe, (Hh); GOLDFUSS (1836).
Cardinia? aritiensis STUCKENBERG, 1898, Artinskian, Russia, (not *Cardinia*).
Pachyodon attenuatus STUTCHBURY, 1842, low.-mid. Lias, Europe; JOLY (1936).
Cardinia authelini JOLY, 1908, low. Lias, Europe.
Torastarte bensoni MARWICK, 1953, Rhaetic, New Zealand, (subgenus of *Cardinia*); FLEMING (1957).
Cardinia breoni MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia brevis MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia chillyensis TERQUEM and PIETTE, 1868, low. Lias, Europe, (P).
Cardinia collenoti MARTIN, 1859, low. Lias, Europe, (Cr).
Unio concinnus SOWERBY, 1819, Noric (?), Rhaetic-low. Lias, Europe, Northern Siberia and Greenland, (Co); ZIETEN (1830), GOLDFUSS (1836), AGASSIZ (1843), CHAPUIS and DEWALQUE (1853), TERQUEM (1855), QUENSTEDT (1856), CHAPUIS (1861), DUMORTIER (1867), TERQUEM and PIETTE (1868), POHLIG (1880–1881), VAUGHAN (1904), ROSENKRANTZ (1934), JOLY (1936), KIPARISOVA (1937).
Cardinia conjugensis WAAGEN, 1881, low. *Productus* Limestone of India, (not *Cardinia*?).
Cardinia contracta MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia copides RYCKHOLT, 1850, low. Lias, Europe, (Co); CHAPUIS and DEWALQUE (1853), TERQUEM (1855), DUMORTIER (1867), TERQUEM and PIETTE (1868).
Cardinia cordata SWALLOW, 1858, low. Permian, North America, (not *Cardinia*).
Unio crassissimus SOWERBY, 1817, low. Lias,-low. Dogger, Europe, South America (?) and Indochina (?), (Cr); STUTCHBURY (1842), QUENSTEDT (1856), TERQUEM and PIETTE (1868), DUMORTIER (1869), MANSUY (1919), DACQUÉ (1933–1934), FERUGLIO (1934), JOLY (1936).
Unio crassiusculus SOWERBY, 1817, low. Lias, Europe, (Cr), STUTCHBURY (1842), DUMORTIER (1867), TERQUEM and PIETTE (1868).
Pachyodon cuneatus STUTCHBURY, 1842, low. Lias, Europe, (Hh).
Cardinia cyprina AGASSIZ, 1843, low. Lias, Europe, (U).
Cardinia densestriata JAWORSKI, 1915, mid.-up. Lias, South America, (Hd); WEAVER (1931), LEANZA (1942).
Unio depressus ZIETEN, 1830, low. Lias, Europe, (Hh); QUENSTEDT (1856); DACQUÉ (1933–1934).
Cardinia deshayesi TERQUEM, 1855, low. Lias, Europe and South America (?), (Cr), TERQUEM and PIETTE (1868), MÖRICKE (1894).
Cardinia desoudini TERQUEM, 1855, low. Lias, Europe (Cr).
Cardinia dormali JOLY, 1908, low. Lias, Europe; JOLY (1936).
Cardinia dunkeri CHAPUIS and DEWALQUE, 1853, low. Lias, Europe, (Hh); KOCH and DUNKER (1837, *Unio trigonus*), JOLY (1936).
Cardinia elliptica AGASSIZ, 1843, low. Lias, Europe, (Ht); QUENSTEDT (1856).
Cardinia elongata DUNKER, 1851, low. Lias, Europe, (Co); TERQUEM and PIETTE (1868), PHILIPPI (1897), DOUVILLÉ (1921).
Cardinia eveni TERQUEM, 1855, low. Lias, Europe, (Co?); DUMORTIER (1864), JOLY (1936).
Cardinia exigua TERQUEM, 1855, low. Lias, Europe; DUMORTIER (1864), TERQUEM and PIETTE (1868), JOLY (1936).
Cardinia? exilis MCCOY, 1847, Permian, Australia, (not *Cardinia*).

Pholadomya expansa LUNDGREN, 1878, low. Lias, Europe, (*Cardinia*?); LUNDGREN (1881), TROEDSSON (1951).

Cardinia fischeri TERQUEM, 1855, low. Lias, Europe, (Co?); TERQUEM and PIETTE (1868).

Cardinia follini LUNDGREN, 1878, low. Lias, Europe; LUNDGREN (1881), TROEDSSON (1951).

Cardinia gibba CHAPUIS and DEWALQUE, 1853, low. Lias, Europe, (Hh); TERQUEM and PIETTE (1868).

Cardinia gibbosula D'ORBIGNY, 1850, low. Lias, Europe, (Hh); BOULE (1906).

Cardinia gibbosum HYATT, 1894, up. Lias, North America.

Thalassites giganteus QUENSTEDT, 1858, low. Lias, Europe, (Co), TERQUEM and PIETTE (1868).

Cardinia gleimi SMITH, 1927, Carnic, North America, (*Cardinia*?).

Cardinia gottingensis PLÜCKER, 1868, Rhaetic, Europe, OOSTER (1869).

Cardinia hennocquii TERQUEM, 1855, low. Lias, Europe, (Co), DUMORTIER (1864), TERQUEM and PIETTE (1868).

Unio hybridus SOWERBY, 1817, low.-mid. Lias, Europe, Greenland and Northern Siberia (?), (Hh); STUTCHBURY (1842), AGASSIZ (1843), CHAPUIS (1869), DEWALQUE (1853), QUENSTEDT (1856), DUMORTIER (1867), DUMORTIER (1869), WAAGEN (1907), ROSENKRANTZ (1934), JOLY (1936), VORONETZ (1936).

Cardinia idalia D'ORBIGNY, 1850, low. Lias, Europe, (Hh); BOULE (1906).

Pachyodon imbricatus STUTCHBURY, 1842, low. Lias, Europe, (Hh); JOLY (1936).

Cardinia inexpectans WARREN, 1932, low.? Dogger, Canada.

Cardinia infera AGASSIZ, 1843, low. Lias, Europe, (Co); TERQUEM and PIETTE (1868).

Cardinia ingelensis TROEDSSON, 1951, low. Lias, Europe.

Cardinia insignis MARTIN, 1859, low. Lias, Europe, (Cr).

Cardinia itea D'ORBIGNY, 1850, low. Lias, Europe, (Hh); BOULE (1906).

Cardiniopsis jurensis TORNQUIST, 1898, low. Dogger, South America, (*Cardinia*?).

Cardinia keuperiana DITTMAR, 1864, Keuper (?) and Rhaetic, Europe.

Cardinia kullensis TROEDSSON, 1951, low. Lias, Europe, (Co).

Cardinia laevis AGASSIZ, 1843, low. Lias, Europe.

Cytherea lamellosa GOLDFUSS, 1836, low. Lias, Europe, (Hh); CHAPUIS and DEWALQUE (1853), TERQUEM and PIETTE (1868), JOLY (1936).

Pachyodon lanceolatus STUTCHBURY, 1842, low. Lias, Europe, (Co?); AGASSIZ (1843).

Cytherea latiplex MÜNSTER, low. Lias, Europe, (Hh); GOLDFUSS (1836), QUENSTEDT (1856).

Cardinia latitruncata MANSUY, 1919, mid.? Lias, Indochina.

Cardinia lerichei JOLY, 1908, low. Lias, Europe; JOLY (1936).

Unio listeri SOWERBY, 1817, Rhaetic-low. Lias, Europe, and Northern Siberia, (Hh); GOLDFUSS (1836), STUTCHBURY (1842), CHAPUIS and DEWALQUE (1853), DUMORTIER (1864), DUMORTIER (1867), TERQUEM and PIETTE (1868), OOSTER (1869), POHLIG (1880–1881), WINKLER (1886), WAAGEN (1907), JOLY (1936), VORONETZ (1936).

Cardinia lucinaeformis COSSMANN, 1904, low. Lias, Europe.

Cardinia lycetti CHAPUIS, 1858, low. Lias, Europe.

Cardinia mactroides LEVALLOIS, 1864, Rhaetic-low. Lias, Europe.

Cardinia minor AGASSIZ, 1843, low. Lias. Europe, (Cr), TERQUEM and PIETTE (1868).

Cardinia misawensis KOBAYASHI and ICHIKAWA, 1952b, Carnic, Noric (?), Japan, (Ht); ICHIKAWA, (1954), NAKAZAWA (1955), NAKAZAWA (1956).

Cardinia moreana MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia morisi TERQUEM, 1855, low. Lias, Europe, (Hh).
Cardinia nachamensis MANSUY, 1919, mid.? Lias, Indochina.
Unio nilssoni KOCH and DUNKER, 1837, low. Lias, Europe, (Hh); CHAPUIS and DEWALQUE (1853), JOLY (1936).
Cardinia oblonga AGASSIZ, 1843, Lias-mid. Dogger, Europe.
Cardinia obovata MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia oppeli CHAPUIS, 1858, low. Lias, Europe; JOLY (1908), JOLY (1936).
Pachyodon ovalis STUTCHBURY, 1842, low. Lias, Europe, (Ht); CHAPUIS (1858), JOLY (1936).
Cardinia ovula KITTL, 1907, Carnic?, Bayfjord and Northern Siberia, (Ht?), VORONETZ (1936).
Cardinia ovula KITTL, var. *polaris* VORONETZ, 1936, Carnic?, Northern Siberia; (Ht?).
Cardinia ovum MARTIN, 1859, low, Lias, Europe, (Cr?); COSSMANN (1904).
Cardinia philea D'ORBIGNY, 1850, low.-mid. Lias, Europe, Caucasus (?) and Indochina (?), (Co), DUMORTIER (1869), DUMORTIER (1869), BOULE (1906), MANSUY (1914), PČELINICEV (1937).
Cardinia piriformis TERQUEM and PIETTE, 1868, low. Lias, Europe, (P).
Cardinia plana AGASSIZ, 1843, low. Lias, Europe and Indochina (?), (P); TERQUEM and PIETTE (1868), MANSUY (1919), JOLY (1936).
Cardinia? plana STUCKENBERG, 1898, non AGASSIZ, 1843, Artinskian, Russia, (not *Cardinia*).
Cardinia ponderosa GABB, 1869, North America, (*Cardinia*?); SMITH (1927).
Cardinia porrecta CHAPUIS and DEWALQUE, 1853, low. Lias, Europe, (Co?), TERQUEM and PIETTE (1868), JOLY (1936).
Cardinia quadrangularis MARTIN, 1859, low. Lias, Europe, (Cr).
Cardinia quadrata AGASSIZ, 1843, low. Lias, Europe, (Hh); CHAPUIS (1858), JOLY (1936).
Cardinia regularis TERQUEM, 1855, low. Lias, Europe, (Cr); TERQUEM and PIETTE (1868), JOLY (1908).
Cardinia regularis VORONETZ, 1936, non TERQUEM 1855, low. Lias, Siberia, (Ht).
Cardinia scapha TERQUEM, 1855, low. Lias, Europe, (Co), TERQUEM and PIETTE (1868).
Cardinia secuiformis AGASSIZ, 1843, low. Lias, Europe, (Co?), TERQUEM and PIETTE (1868).
Cardinia siberica VORONETZ, 1936, low. Lias, Siberia, (Cr).
Cardinia similis AGASSIZ, 1843, low. Lias, Europe, (Ht); TERQUEM (1855), TERQUEM and PIETTE (1868).
Cardinia sinemuriensis D'ORBIGNY, 1850, low. Lias, Europe, (Cr); BOULE (1906).
Cardinia subaequilateralis CHAPUIS and DEWALQUE, 1853, low. Lias, Europe; (U); JOLY (1936).
Cardinia? subangulata SWALLOW, 1858, Permian, North America, (not *Cardinia*).
Cardinia sublamellosa D'ORBIGNY, 1850, low. Lias, Europe, (Cr).
Cardinia subovalis MARTIN, 1859, low. Lias, Europe, (Cr); JOLY (1936).
Cardinia subtrapezoides VORONETZ, 1936, low. Lias, Northern Siberia.
Cardinia sulcata AGASSIZ, 1843, low. Lias, Europe, (Hh); DUMORTIER (1867).
Cardinia tas-aryensis VORONETZ, 1936, low. Lias, Northern Siberia, (Cr?).
Cardinia toriyamai HAYAMI, 1958, low. Lias, Japan, (Ht).
Cardinia trapezium MARTIN, 1859, low. Lias, Europe (Cr).

Cardinia triadica KOBAYASHI and ICHIKAWA (1952a), Carnic, Japan, (Ht), NAKAZAWA (1955).

Cardinia trigona DUNKER, 1851, low. Lias, Europe, (U?); MARTIN (1859), PHILIPPI (1897).

Cardinia unioides AGASSIZ, 1843, low. Lias, Europe, (U); CHAPUIS and DEWALQUE (1853), TERQUEM and PIETTE (1868), JOLY (1936).

Cardinia wyomingensis LOGAN, 1900, Jurassic, North America.

Cardinia zeilleri JOLY, 1908, low. Lias, Europe; JOLY (1936).

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Postscript

After the manuscript of this paper had been completed, Dr. L. D. KIPARISOVA sent me a copy of her paper entitled "New Lower Jurassic Fauna near Amur. *Trans. All Soviet Union Sci. Geol. Inst.*, 1952". It comprises *Cardinia amurensis* KIPARISOVA, *C. nostra* KIPARISOVA, *C.* aff. *subacuminata* TCHERNYSHEW, *C.* aff. *collenoti* MARTIN, *C.* aff. *hennocquii* TERQUEM and *C.* ex gr. *concinna* (SOWERBY). Thus some of them were compared with European species from the lower Lias. But so far as I can judge from the illustrations, most of them appear to belong to the *toriyamai*-subgroup in my classification which is characterized by the more or less widely spaced concentric imbrications on the surface. *Toriyamai* actually resembles the Amur forms in outline, but specifically different in the stronger surface-ornamentation. (August 28, 1958)

I. HAYAMI

Taxonomic Notes on *Cardinia* with Description of a New Species
from the Lias of Western Japan

Plate XI

Explanation of Plate XI

Figs. 1–11. *Cardinia toriyamai* HAYAMI, new species p.121

Fig. 1. Right internal mould (MM2913) × 1.

Fig. 2. Left internal mould (MM2914) × 1.

Fig. 3. Gypsum cast of right internal mould (MM2915) × 1.

Fig. 4. Juvenile right internal mould (MM2916) × 2. (TORIYAMA coll.)

Fig. 5. Gypsum cast of right external mould (MM2917) × 1. Paratype.

Fig. 6. Gypsum cast of left internal mould (MM2918) × 1. Holotype.

Fig. 7. Gypsum cast of right internal mould (MM2919) × 1.

Fig. 8. Gypsum cast of right external mould (MM2920) × 3/2.

Fig. 9. Gypsum cast of right external mould (MM2921) × 3/2. Paratype.

Fig. 10. Gypsum cast of right external mould (MM2922) × 1.

Fig. 11. Gypsum cast of right external mould (MM2923) × 1.

Figs. 12–18. Foreign species of *Cardinia*.

Figs. 12a–b. *Cardinia copides* RYCKHOLT × 2/3, after TERQUEM (1855, pl. 19, figs. 10, 10a).

Figs. 13a–b. *Cardinia crassissima* (SOWERBY) × 1/2, after TERQUEM and PIETTE (1868, pl. 10, figs. 3, 4).

Figs. 14a–b. *Cardinia piriformis* TERQUEM and PIETTE × 4/9, after TERQUEM and PIETTE (1868, pl. 8, figs. 1, 2).

Figs. 15a–b. *Cardinia hybrida* (SOWERBY) × 2/3, after AGASSIZ (1843, pl. 12′, figs. 10, 12).

Fig. 16. *Cardinia latiplex* (MÜNSTER) × 2/3, after GOLDFUSS (1836, pl. 141, fig. 6a).

Fig. 17. *Cardinia densestriata* JAWORSKI × 1/2, after JAWORSKI (1915, pl. 5, fig. 6a).

Fig. 18. *Cardinia unioides* AGASSIZ × 2/3, after AGASSIZ (1843, pl. 12″, fig. 7).

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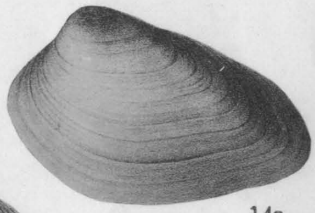
13a


13b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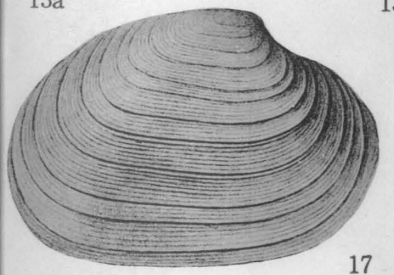
18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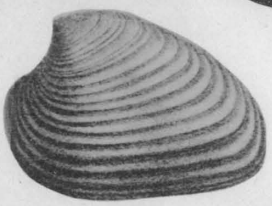
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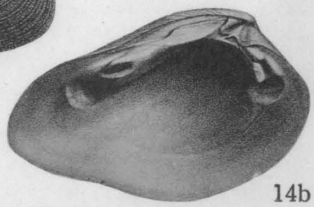
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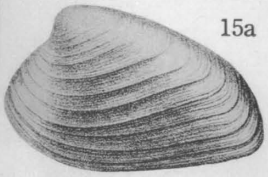
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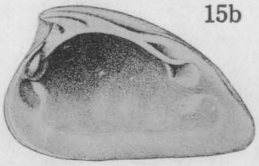
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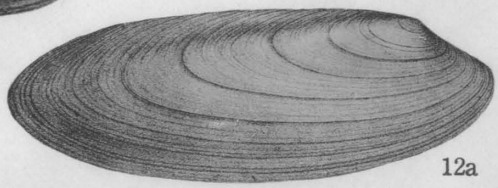
12a

12b