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SILURIAN AND DEVONIAN CORALS OF JAPAN

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Coral assemblages and their faunal sequence for the Silurian and Devonian in four major regions of Japan are reviewed. In Yokokurayama the G_2 fauna with *Halysites* is Early to Middle Silurian and the G_3 fauna with *Schedohalysites* is mainly Late Silurian. The Kawauchi Formation of Hikoroichi corresponds to G_3 and a part of G_2. The Okuhinotsuchi Formation of Arisu is mainly correlatable with the G_2. The Ohno fauna of Hikoroichi with *Xystriphyllum* and the Fukuji fauna are both Early Devonian in age, but their composition is quite different from each other. The Nakazato fauna of Hikoroichi is Middle Devonian. These faunas are composed mostly of cosmopolitan genera. The development of coral faunas may indicate the strong contrast in litho- and biofacies between the Pacific side (outer zone of Southwest Japan and Northeast Japan) and the Japan Sea side (inner zone of Southwest Japan) during the Silurian and Devonian.

K e y w o r d s: coral biostratigraphy, paleogeography, Silurian, Devonian, Japan.

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INTRODUCTION

In terms of geotectonics, Japan has customarily been divided into Northeast and Southwest Japan, the latter being divided into the inner zone and outer zone.

Silurian and Devonian sediments have been known to develop in all of the three tectonic blocks mentioned above (fig. 1), but their actual distributional areas are usually very narrow. Apart from the non-metamorphosed, fossil-bearing Silurian and Devonian rocks, there are some metamorphic rocks which have been stratigraphically and lithologically inferred as Devonian.

Our own research on the Silurian and Devonian has been directed on the Arisu and Hikoroichi regions in the Kitakami Mountains, Northeast Japan, the Fukuji region of the Hida Mountains in the inner zone of

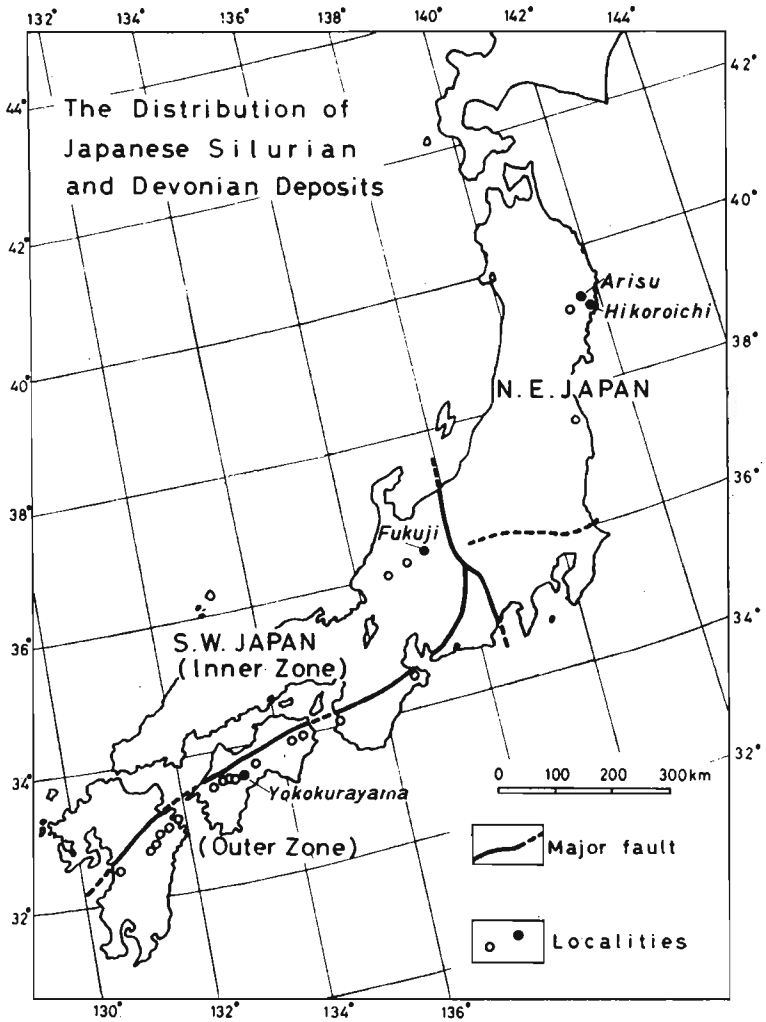

Fig. 1. The distribution of Japanese Silurian and Devonian deposits. Localities where geological columns are shown in fig. 2 are encircled black.

Southwest Japan, and the Yokokurayama in Shikoku of the outer zone of Southwest Japan. In these regions, sediments are more or less continuous, and fossils are relatively common.

The Silurian is the oldest fossil bearing formation in Japan and it might have originally covered the Precambrian basement. It is composed mainly of limestone with shallow-water marine fossils. As a whole, it is epicontinental in character. No graptolite facies has been found.

The Devonian in Northeast Japan and in the outer zone of Southwest Japan is very rich in pyroclastic sediments in which fossils are very scarce. It is thick and may be generally eugeosynclinal in character. In marked contrast to the outer zone, the Devonian of the inner zone of Southwest

Japan is represented by limestone facies with abundant fossils, although it is also intercalated by a small amount of tuff at the horizons.

Where fossils are found, corals are the main component of the fossil assemblage in the Japanese Silurian and Devonian. But they are mostly unfavourably preserved. They are largely recrystallized and fragmental. Therefore not many paleontological studies are available on them. Hamada (1961) and Minato (1975) reviewed the Japanese Silurian and Devonian coral faunas, citing in each review faunal lists taken mostly from a number of stratigraphical papers. Many of the corals listed have been left undescribed so far.

It is the purpose of the present article, although preliminary in nature, to summarize the present knowledge on the Japanese corals in the Silurian and Devonian, and to give a general account of coral faunas, based mainly on our own collection of fossils.

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CORAL FAUNAS
(fig. 2 and fig.3)

In the Hikoroichi region of the Kitakami Mountains, Northeast Japan, the Silurian and Devonian deposits are relatively well developed. The Silurian has been called the Kawauchi Formation and consists mainly of black, massive or bedded limestone. Fossils are abundant at places. Corals were first described by Sugiyama (1940) in his monograph on the Kawauchi fauna. Hamada (1958) revised the halysitids which Sugiyama described, and Kato and Minato (1977) recognized *Amsdenoides* amongst Sugiyama's corals. Recently Murata (1977) added a new species of *Phaulactis*, which is however in our opinion better transferred to *Neocystiphyllum*. We have newly found *Multisolenia*. The following genera have thus far been recognized: *Schedohalysites, Falsicatenipora, Halysites, Favosites, Multisolenia, Heliolites, Propora, Plasmoporella, Alveolites, Tryplasma, Cystiphyllum, Nipponophyllum, Rhizophyllum, Spongophyllum, Amsdenoides, Pilophyllum*? and *Neocystiphyllum*. Among them *Halysites, Multisolenia* and *Neocystiphyllum* occur in the lower horizon, whereas *Schedohalysites, Spongophyllum, Rhizophyllum* and *Nipponophyllum* occur in the upper horizon. When we compare the occurrence of the genera enumerated above with that on the island of Gotland, the upper part of the Kawauchi Formation may be Ludlovian, while the lower part may be Wenlockian. No definitely Llandoverian corals are known. Sugiyama established *Kitakamiia* as a stromatoporoid genus, but this is only *Alveolites* (Mori 1973). *Maia* Sugiyama was later renamed as *Kitakamiphyllum* by Hill (1956). But the form appears to be a recrystallized, finger-like,

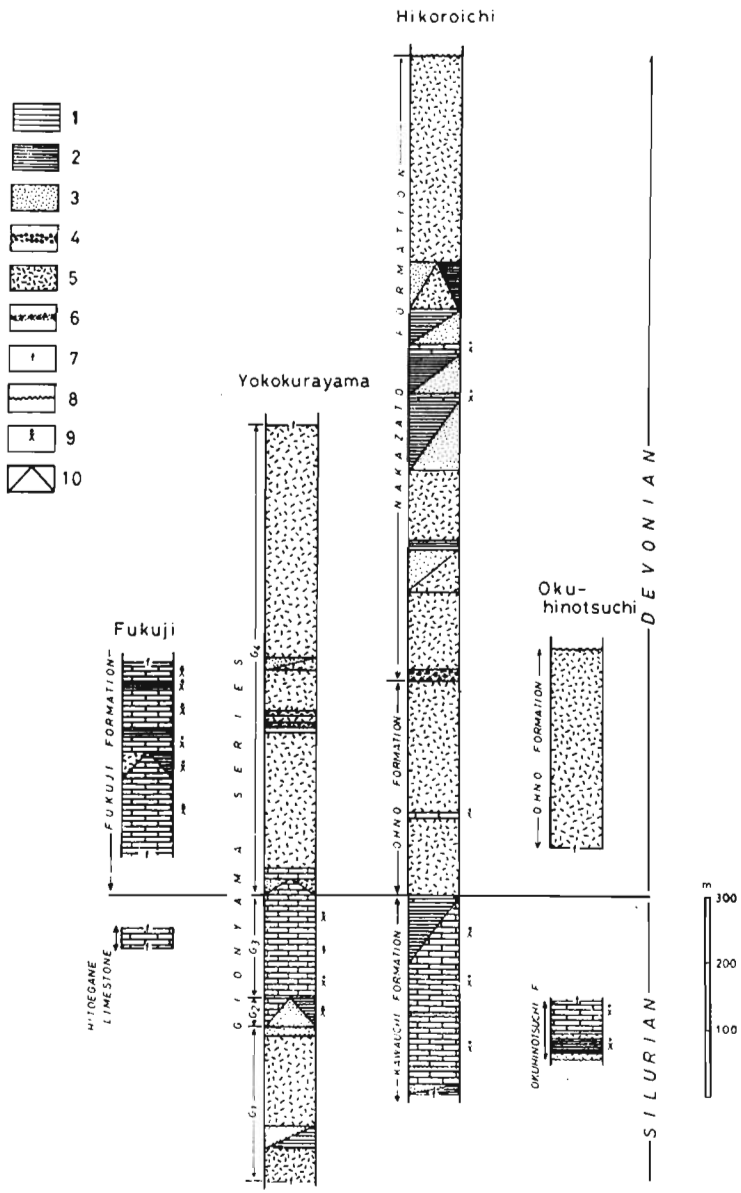

Fig. 2. Geological columns showing lithological succession of the Silurian-Devonian deposits in major localities in Japan, also showing horizons in which corals have been found.

stromatoporoid (?), covered by another stromatoporoid (?). *Nipponophyllum* may be simply termed as a fasciculate *Holmophyllum*, and is now known to occur in central Asia, Australia, Gotland etc. Thus, as a whole, there is no strong evidence for endemism in the Kawauchi fauna except for *Schedohalysites* which is said to be indicative of the connection between Australia and Japan during the Silurian.

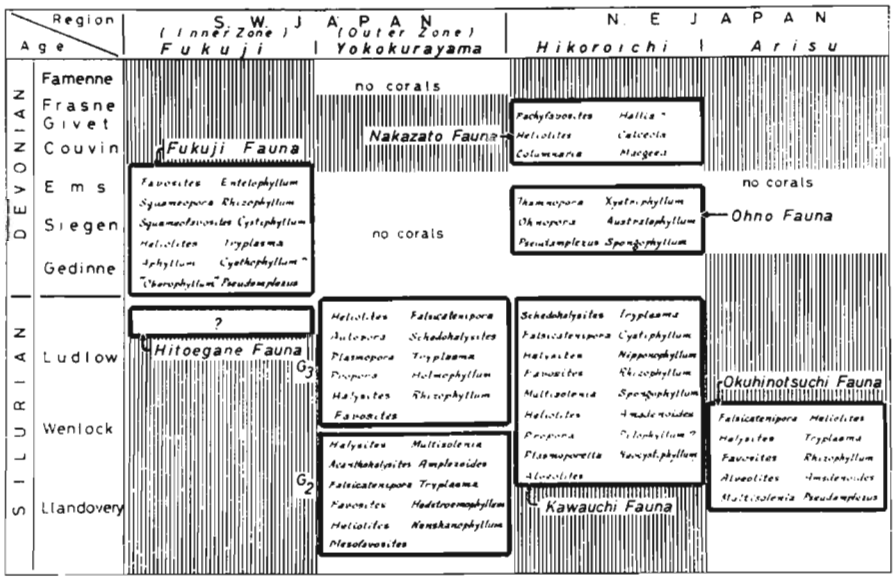

Fig. 3. Stratigraphical relationship and contents of Silurian and Devonian coral faunas of Japan. Vertical shading means the lack of strata. The existence of Lower Llandoverian in Japan is still questionable.

Conformably overlying the Silurian Kawauchi Formation is the Ohno Formation chiefly composed of tuffs. Pale green, vitric tuff is the most characteristic rock of the formation. Small limestone lenses intercalated in the lower part of the formation yield some corals. *Xystriphyllum* (ex. gr. *interlineatum*) is common, together with *Australophyllum*, *Spongophyllum*, *Thamnopora* and *Pseudamplexus*. A peculiar tabulate, *Ohnopora*, was described from this horizon by Minato and Minoura (1977). According to oral information given by Y. Fujiwara of Hokkaido University, a bed of porphyrite tuff in the upper part of the Ohno Formation reveals rock magnetism with normal paleomagnetic polarity which may correspond to the Emsian mixed zone. Since the Ohno Formation lies directly on the Wenlockian-Ludlovian Kawauchi Formation, it would be Lower Devonian in rough estimation. *Xystriphyllum*, *Australophyllum*, *Spongophyllum* and *Pseudamplexus* appear to be related to "Coblenzian" corals of Europe and Australia.

The Nakazato Formation conformably supersedes the Ohno Formation in the Hikoroichi region. It begins with beds of tuff breccia, and is also rich in pyroclastics throughout the sequence. Only in about the middle of the sequence the alternation of slate and sandstone develops. Limy slate yields some trilobites, brachiopods, corals etc. Such coral genera as *Pachyfavosites, Heliolites, Macgeea, Hallia*? and *Columnaria* (Ma 1956; Murata 1972) have been discriminated. They may be Middle Devonian, but precise age cannot be determined by corals only. Trilobites are *Thysano-*

peltella, Phacops and *Dechenella.* Brachiopods contain *Undispirifer* (*Nakazatothyris*). As a whole, the coral assemblage may be late "Eifelian" to early Givetian, if we are to take other faunal elements into consideration.

The Devonian described above in the Kitakami Mountains is eugeosynclinal in character as a whole.

Quite recently Kawamura discovered a new locality for Silurian fossils in Okuhinotsuchi, the Arisu region of the Kitakami Mountains, Northeast Japan, where we collected many fossils which occurred in two major horizons (fig. 2). From the lower part of the Okuhinotsuchi Formation *Halysites, Favosites, Alveolites, Amsdenoides* and *Pseudamplexus* were obtained with the other fossils. From the upper horizon *Falsicatenipora, Halysites, Favosites, Multisolenia, Heliolites, Alveolites?, Pseudamplexus, Tryplasma* and *Rhizophyllum* were collected. Domination of tabulate corals is significant, and the coral assemblage as a whole correlates very well with the G_2 fauna of Yokokurayama which will be later mentioned. We call the whole assemblage the Okuhinotsuchi fauna, which may be late Llandoverian to Wenlockian in age.

In spite of the close distance from the distribution of the Kawauchi Formation, the Okuhinotsuchi Formation is lithologically and faunistically different from the former. The latter is definitely older than the upper part of the Kawauchi Formation with the *Schedohalysites* fauna, and may be partially equivalent to the lower part of the Kawauchi Formation which yields *Halysites* and *Multisolenia.* However, in the lower part of the Kawauchi Formation, stromatoporoids are much more abundant than in the Okuhinotsuchi Formation. Halysitids from the Okuhinotsuchi Formation resemble those of Southwest Japan, Australia and North America.

In the outer zone of Southwest Japan Yokokurayama supplies a good section for Silurian and Devonian succession. There, the basal member, G_1, being rich in pyroclastics, produces only fragments of unidentifiable corals. The G_2 member is an alternation of slate, sandstone and limestone. Fossils are abundant in G_2, and we recognized the following coral genera: *Halysites, Acanthohalysites, Falsicatenipora, Favosites, Heliolites, Mesofavosites, Multisolenia, Amplexoides, Tryplasma, Hedstroemophyllum* and *Nanshanophyllum.* Among them *Halysites, Falsicatenipora* and *Multisolenia* are conspicuous.

Recently Kuwano (1976) made a conodont study of the G_2 member, and stated that it was late Llandoverian to early Wenlockian in age, with which the lower part of the Kawauchi Formation and the Okuhinotsuchi Formation afore mentioned are correlatable.

G_3 comes on the G_2, and is mainly composed of massive, gray limestone. It yields corals at several horizons in which we found *Heliolites, Aulopora, Plasmopora, Propora, Halysites, Favosites, Falsicatenipora. Schedohaly-*

sites, Tryplasma, Holmophyllum and *Rhizophyllum.* The most common and characteristic genus is *Schedohalysites.* G_3 is, also by a conodont study by Kuwano (1976), Middle Wenlockian to Middle Ludlovian in age, and is well correlatable with the upper part of the Kawauchi Formation with *Schedohalysites.* As a matter of fact, some corals from the Yokokurayama have not been identified with the hitherto known forms, owing to poor preservation and to their peculiarity. However, they may eventually reveal resemblance with Chinese corals. Similar limestone bodies with the G_3 of Yokokurayama have been known along a structural belt in Kyushu and Shikoku. Sugiyama (1944) described a species of *Multisolenia* as *Dania* from Kyushu.

Thick succession of tuffs follows the G_3 in Yokokurayama. It is called G_4, which stratigraphically as well as lithologically corresponds to the Ohno Formation and perhaps to a part of the Nakazato Formation in the Hikoroichi region of the Kitakami Mountains. Therefore we see that the lithologic development of the Silurian and Devonian sediments of Southwest Japan in the outer zone was quite in harmony with that of Northeast Japan. Similar eugeosynclinal conditions must have prevailed on the Pacific side of the Japanese island, especially in the Devonian.

In Fukuji of the Hida Mountains, belonging to the inner zone of Southwest Japan, the Devonian limestone is fairly well developed. The so-called Fukuji Formation is not very thick, steeply dipping, and fault bounded with younger rocks. It consists of black, bedded limestone. But in the middle of the sequence, pale-green tuff beds are intercalated with limestone and slate. The lithology of tuff reminds one of the Lower Devonian Ohno Formation or its correlatives.

Corals may be collected abundantly from scree, but they are difficult to find and extract from actual exposures. Therefore we have been unsuccessful in obtaining fine biostratigraphy of the Fukuji Formation, although such an attempt was repeatedly made by Kamei (1955, 1961). Kamei (1955) described some favositids, one of which was later revised by Hamada (1959). Several corals were illustrated by Kamei (1961) from the formation, but none of them has been described. Hamada (1971) recorded an operculum of *Calceola* from the formation, and Research Group for the Palaeozoic of Fukuji (1973) discovered *Rhizophyllum enorme.* We could recognize the following genera: *Favosites, Squameopora, Squameofavosites, Heliolites, Aphyllum, "Oborophyllum", Entelophyllum, Rhizophyllum, Cystiphyllum, Tryplasma, Cyathophyllum* ? and *Pseudamplexus. Oborophyllum* was established by Ozaki (1956, 1957) from the Fukui Prefecture on a tryplasmatid coral with epithecal scales. It may be congeneric either with *Pholidophyllum* or *Thecapsinellum.* Corals appear to be indicative of Early Devonian age as a whole. In fact Igo, Koike and Igo (1975) found some conodonts from the lower part of the Fukuji Formation and concluded that the part was Gedinnian in age. Whether the formation ranges

until "Eifelian" or not is unsettled. The Fukuji coral fauna is in general Gedinnian to Emsian. For paleoecological condition of Fukuji corals, strong seasonal growth seen in favositids is noteworthy (Hamada 1961). Although the Fukuji fauna should roughly correspond to the Ohno fauna, not a single common species has been found among these two faunas. This is probably due to the difference of facies between the two regions during the Early Devonian.

Depositional conditions in the inner zone of Southwest Japan might have been epicontinental in the Early Devonian, when the Pacific side of the Japanese islands underwent changes to the eugeosynclinal condition as stated above.

Slightly apart from the distributional area of the Devonian Fukuji Formation, the Hitoegane limestone crops out as an isolated block in younger rocks. The limestone is banded and black in colour, and is lithologically quite similar to that of the Fukuji Formation. But it yields *Encrinurus* (Kobayashi and Hamada 1974), and thus is considered to be late Silurian in age. Tabulate corals are common, but no halysitids. They have not been studied in any detail. Rugose corals are scarce, but *Rhizophyllum* is present. At any rate character of this fauna is quite different from the other Silurian faunas.

The Upper Devonian has been known only from three localities in Japan. Lithology of the Upper Devonian is mostly slate, and the occurrence of corals is very rare, except for fragmental pleurodictiids and streptelasmatids. No corals have been descibed as yet.

CONCLUSIONS

1. The Silurian and Devonian corals are not very diverse in Japan. They are represented so far only by 40 genera.
2. At least four coral assemblages are chronologically discernible. They are the G_2 fauna of Early to Middle Silurian, the G_3 fauna of Late Silurian, the Fukuji fauna and the Ohno fauna of Early Devonian and the Middle Devonian Nakazato fauna. Others are wholly or partially assignable to the faunas listed above. The Late Devonian coral fauna is practically absent.
3. Corals are mostly represented by cosmopolitan types. No particular endemism is apparent. Only halysitids (e.g. *Schedohalysites*) could indicate a faint paleozoogeographical feature of the Japanese Silurian.
4. In general, tabulate corals are abundant, compared to rugose corals. And some of the corals reveal seasonal growth.
5. The Silurian was epicontinental in the Japanese islands. But litho- and biofacies were clearly differentiated in the Devonian, where the eugeosynclinal condition prevailed on the Pacific side.

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