85. Colonial Corals in the Geological Formations of the Japanese Islands.¹⁾

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In the Japanese Islands where no fossiliferous Older Palaeozoic deposits exist, the oldest coralline rocks are those of the Chichibu System which is Lower Carboniferous-Permian in age at least in its fossiliferous parts. Our common Lower Carboniferous corals, *Lithostrotion*, *Lonsdaleia*, *Diphyphyllum* and *Chaetetes*, are found for instance in profusion in certain limestone zones interbedded in clayslates of the Chichibu System in the middle part of the Kitakami Mountainland. Permian coral fauna is much simpler, prevailing types being *Waagenophyllum*, *Michelinia* and *Pachypora*; *W. akasakense* is a form frequent in a zone of the limestone of Akasaka in the province Mino, while this species and its close ally *W. indicum-virgalense* as well as *M. multitabulata* are three very common corals in the Lower Permian limestone of the southern Kitakami Mountainland. An interesting occurrence of two species of *Pachypora* in an aggregate growth is known from another locality of this district.

Lately J. Iwai discovered a limestone full of *Clathrodictyon* in the northern part of the Abukuma Mountainland; this rock is interesting by bearing an aspect hardly distinguishable from certain Gotlandian and Devonian stromatoporid limestones of Europe, though decidedly much younger (Permian).

The Kitakami Mountainland (N. 38° 15'–40° 30' L.) is the northernmost tract in the Japanese Islands with evidences of colonial corals having enjoyed a more or less prolific growth during the Lower Carboniferous and Permian Periods.

Coralline rocks are not yet discovered in our Triassic formations; we have at present very few corals from a Lower Triassic limestone in the province Iyo and Upper (partly Middle?) Triassic ones in the province Tosa. It is almost certain that limestones and corals are rather negligible elements of our Triassic rocks and faunas respectively.

Lower and Middle Jurassic deposits, partly marine and partly

1) This article is devoted to a short description of the geological occurrence of colonial corals in the Japanese Islands for the purpose of comparison with the present distribution of reef corals in the adjacent seas summarised in a previous paper (Proc. 7 (1931), 357).

terrestrial in origin, are almost free from calcareous rocks, and corals are extremely rare. On the contrary, the Japanese Islands of the Upper Jurassic time seem to have been under a climatic condition favourable for the growth of corals, and coral limestone is an important element of the Upper Jurassic Torinosu Series. The Torinosu limestone usually in small irregular masses is sometimes massive and sometimes stratified; it often abounds in hexacorals, hydrozoa, tabulata and calcareous algae. A locality in the Abukuma Mountainland near N. $37^{\circ}50'$ L. is the northernmost occurrence now known of the limestone.¹⁾ Genera of the corals found in the Torinosu limestone are:

Hexacorals: *Acanthogyra**,²⁾ *Amphiastraea*, *Aulastraea*, *Calamophyllia**, *Cladocoropsis*, *Cladophyllia*, *Comoseris*, *Convexastraea**, *Dendrogyra**, *Diplaraea*, *Diplocoenia*, *Dimorpharaea*, *Dimorphastraea**, *Hydnophora*, *Isastraea*, *Latimeandraea*, *Leptoria*, *Microsolenia**, *Montlivaultia*, *Orbicella*, *Placocoenia*?, *Pleurosmilia*, *Spongiomorpha* (*Hexastylopsis**), *Stephanocoenia*, *Stromatomorpha**, *Stylina*, *Thecosmilia*, *Thamnastraea**.

Tabulata: *Chaetetopsis**, *Pachypora**, and two other genera*.

Hydrozoa: *Actinostromaria*, *Milleporella*, *Milleporidium*, *Stromatopora* (*Epistromatopora*, *Parastromatopora**), *Tosastroma*.

An unusual case of the northern extension of warm water organisms in the Japanese geology is shown by *Orbitolina*-rocks in Lower Cretaceous formations. The *Orbitolina*-rocks cover small areas in the middle part of Hokkaidô and the northern part of the Kitakami Mountainland. The *Orbitolina*-rock of Hokkaidô is limestone and that of the Kitakami Mountainland highly calcareous sandstone; in both cases the tests of the foraminifera form the bulk of the rocks and accompany reef corals, calcareous algae and certain types of thick shelled molluscs similar to those characterising the Urgon facies of the Mediterranean Lower Cretaceous. The corals belong to the genera:

Amphiastraea, *Astrocoenia*, *Diplogyra* (nov. gen.)*, *Eugyra**, *Heterocoenia*, *Hydnophora*, *Orbicella*, *Pleurosmilia*, *Thamnastraea*, *Thecosmilia**, *Latiphyllia**; besides, *Heliopora*.

The northernmost exposure of the *Orbitolina*-limestone of Hokkaidô lies at a little north of N. $43^{\circ}50'$ L.

Corals are also rich in a Lower Cretaceous sandy shale exposed on a small islet Ôshima opposite Kesenuma in the Kitakami Mountainland; corals from this layer belong to the following genera and subgenera:

Astrocoenia, *Enallohelix**, *Eugyra*, *Rhabdophyllia*, *Thamnastraea*, *Centrastraea*, *Polyphyastraea*.

1) Reef corals are reported from the Middle Jurassic Hinchman tuff and sandstone of Plumas County, California, near N. 40° L.

2) Genera with an asterisk are common.

The later Cretaceous deposits are almost, if not entirely, free from limestones as well as colonial corals.

Tertiary rocks abound with large sized foraminifera are very limited in distribution; nevertheless, *Nummulites*- and *Orthophragmina*-rocks extend up to N. 32° 40' L., *Eulepidina*-limestone up to N. 30° L. and *Nephrolepidina* and *Miogyopsina*-limestone up to N. 40° 50' L. Coral stocks are common in some parts of these foraminiferal rocks, but they rarely aggregate together so densely as to form typical coralline rocks.

An almost unique examples of the typical coral limestone in the Tertiary of Japan is that very recently found by T. Sugiyama in the limestone series exposed on a small islet Minami-jima at the southern end of Chichi-jima, Ogasawara Group. The coral limestone, according to him, is straightway a lithified mass of crowded coral stocks, mostly in upright position and hence probably showing their original growth in situ. The limestone series, with *Eulepidina* in other parts, is Aquitanian in age; the corals belong to:

Alveopora, *Astrocoenia*, *Favia*, *Favites*, *Lamellastraea* (?)*, *Orbicella**, *Porites**, *Psammocora* (?).

A good deal of coral stocks are found in a *Nephrolepidina*-limestone exposed near Ôishi, in the province Kai; among them we can discriminate species belonging to the genera:

Favia, *Favites* (*Prionastraea*), *Hydnophyllia*, *Maeandra*.

This limestone is Burdigalian in age and the locality (N. 35° 30' L.) marks the northernmost limit of reef coral growth in the Japanese Islands during the Tertiary period.

The Riukiu limestone of the Riukiu Islands and Taiwan is a limestone formation of an immense extension; it extends over 6 degrees of latitude covering widely separate areas between the southernmost point of Taiwan, Cape Garanbi, N. 22° L. and the islands Ôshima and Kikaiga-shima of the Ôsumi Subgroup of the Riukiu Islands, N. 28° 30' L. in thickness it seldom exceeds 80 m. In the majority of cases it is fairly well stratified, often with interbedded foraminiferal limestones; at places it comprises massive coralline limestone composed almost solely of coral stocks. In a recent trip to Kikaigashima S. Hanzawa found numerous coral stocks weathered out under a favourable condition of a coral limestone, which are well preserved and are determined as follows:

Acanthastraea cfr. *hemprichii*, *Acropora* sp., *Alveopora* cfr. *verrilliana*, *Antillia japonica*, *Astraeopora* cfr. *regalis*, *Cyphastraea chalcidicum*, *C. microphthalma*, *Euphyllia fimbriata*, *Favia amplior*, *F. speciosa*, *F. valenciennes*, *Fungia cyclolites* var., *Goniastrea pectinata*, *Hydnophora exesa*, *Leptoria phrygia*, *Maeandra* cfr. *lamellina*, *M.* cfr. *stricta*, *Orbicella curta*, *O.* sp., *Ulophyllia* cfr. *aspera*, *Tubipora rubicola*.

Most of the Riukiu limestone corals from other localities in our collection are usually not in good preservation and difficulty always arises as to their specific and generic determination. The corals other than those from Kikaiga-shima cited above are:

Acropora spp., *Antillia* spp., *Coscinaraea*? sp., *Cyphastraea serailia*, *Favia pallida*, *F.* spp., *Favites* cfr. *virens*, *F.* spp., *Fungia* spp., *Goniopora* spp., *Hydnophora microconos*, *H.* spp., *Hydnophyllia*? sp., *Leptastraea*? sp., *Leptoria gracilis*, *L. tenuis*, *L.*? sp., *Maeandra astraeformis*, *M.*? sp., *Mussa*? sp., *Orbicella* spp., *Pachyseris* cfr. *rugosa*, *P.* cfr. *speciosa*, *Pavona* sp., *Porites* spp., *Symphyllia*? sp., *Turbinaria* sp.

As a whole, the fossil coral fauna does not seem to be much different from the living one of the region concerned.

The Riukiu limestone is certainly neither younger nor much older than the Pleistocene and it was thought by us to be the youngest Neogene on several reasons as stated elsewhere.¹⁾

Post-Pleistocene raised coral reefs and raised beach deposits with corals are recorded by Hanzawa from various places in Taiwan; these are also developed in the Riukiu Islands. To the north of the island group, there exists no more raised coral reefs except the remarkable growth of fossil reef corals at Noma near Tateyama in the province Awa (Honshu), approximately N. 35° L., which forms a subject to be treated separately.

In short, colonial corals extended their distribution beyond the present northern limit of their growth farther northwards once in the Lower Carboniferous Period, to the second time in the Permian and to the third in the Jurassic and Lower Cretaceous; also at least once during the Miocene and lastly in a post-Pleistocene time reef corals lived nearly as north as now are.

Reef coral growth is generally regarded by geologists as an indicator of warm climate in the geological ages; this admitted, we have geological evidences before us which are in disharmony with the change of position of the earth's poles as claimed by Wegener and the consequent change of latitude, for instance, of Tokyo through the geological ages as stated by Köppen and Wegener,²⁾ unless it is assumed at the same time that the general temperature on the earth was higher in the Upper Jurassic and Lower Cretaceous than in the later ages.

1) H. Yabe and S. Hanzawa: A Geological Problem Concerning the Raised Coral Reefs, etc. Sci. Rep. Tōhoku Imp. Univ., Ser. Geol., VII, 2 (1925).

2) W. Köppen and A. Wegener: Die Klimate der geologischen Vorzeit (1924), p. 127.