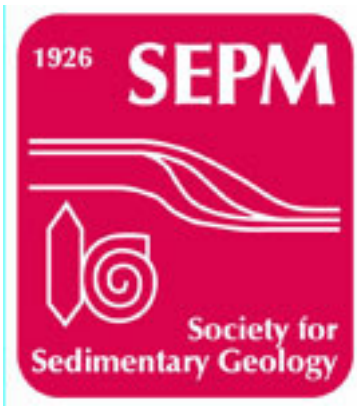

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GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF REEF-CORALS IN JAPAN[1]

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ABSTRACT

In the pre-Pleistocene formations of the Japanese Islands corals occur at several horizons. The Chichibu system, Lower Carboniferous to Permian, contains them in abundance as far north as lat. 40°. Corals are negligible in the Triassic and Lower and Middle Jurassic deposits. The Upper Jurassic Torinosu limestone contains corals as far north as lat. 37°. The Lower Cretaceous rocks contain reef organisms as far north as lat. 43°. The Upper Cretaceous deposits have few corals. So also the Tertiary for the greater part, though some coralline limestones are known. The Riukiu limestone (probably late Pliocene) of the southern islands contains extensive coral reefs as far north as lat. 28°. From these 68 species, in 38 genera, are listed. The fauna is not greatly different from the living fauna of the same region. Calcareous algae were important in all of the pre-Pleistocene coral-bearing formations. In the Pleistocene as a whole the Japanese Islands were at a lower level and the climate was cooler than at present. Few corals are found. In post-Pleistocene time coralline deposits are abundant both as raised reefs and as living reefs. From raised reefs of Taiwan (Formosa) and the Riukiu Islands 31 genera are listed. A raised reef near Tateyama (Awa, Honshû), representing the last submergence, has yielded a large fauna, including 46 species, in 27 genera. In the present seas reef corals are growing on the southern margins of Honshû, Shikoku, and Kiûshû; on the Riukiu Islands, on the Ogasawara group, and on Taiwan. These sites are interpreted as rocky bottoms submerged in Recent time. The northernmost reef-coral growth is at lat. 35°. Conditions affecting corals on these reefs are discussed, and comparisons are made with other regions. It is inferred that the present fauna is derived from more southerly regions by migration in Recent time. Three subfaunas of Recent corals are recognized and their relationships shown. Contrary to expectation, the northern subfauna, as now known, does not show fewer species than the southern subfaunas, but this is believed to be due to accidental circumstances. A list of the Recent corals in 22 geographic areas is presented as the basis for part of the discussion.

I. COLONIAL OR REEF-BUILDING CORALS FOUND IN THE PRE-PLEISTOCENE FORMATIONS OF THE JAPANESE ISLANDS

Stromatoporoids are reef-building organisms of the Ordovician, Gotlandian and Devonian periods. Remains of these organisms are found in the Ordovician limestones of North China, Manchuria and northern Korea,[2] where, however, we have not any case recorded of their occurrence as actual reefs.[3] In the Japanese Islands, where no fossiliferous older Palaeozoic deposits exist, the older coralline rocks are those of the Chichibu system, the Japanese Palae-

[1] Manuscript received April 1, 1934.

[2] Yabe, H., and Sugiyama, T., On some Ordovician stromatoporoids from South Manchuria, North China and Chôsen (Corea), with notes on two European forms: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 14, no. 1, 1930; Notes on two stromatoporoids from Chôsen (Corea): *Jap. Jour. Geol. Geogr.*, vol. 8, nos. 1–2, 1930.

[3] The term "reefs" is here used in the broad sense long in use among geologists, without defining that structure, so much disputed in the current discussions of "coral reefs and coral islands."

zoic, which is Lower Carboniferous to Upper Permian in geological age, at least in its fossiliferous parts. Genera of coralline organisms prevailing in our Lower Carboniferous limestones are *Lithostrotion*, *Lonsdaleia*, *Diphyphyllum*, and *Chaetetes*. The Chichibu system in the middle part of the Kitakami Mountainland[4] in northeast Japan consists of clay-slates with several interbedded limestone zones, some of which contain in profusion Lower Carboniferous corals, such as *Lonsdaleia japonica* Yabe and Hayasaka, *Lithostrotion pseudomartini* Yabe and Hayaska, *Lithostrotion densitabulata* Yabe and Hayasaka, *L. peculiare* Yabe and Hayasaka, *Diphyphyllum flexuosum* Yabe and Hayasaka, *D. equiseptatum* Yabe and Hayasaka, and *Syringopora reticulata* Goldfuss. A Lower Carboniferous coralline limestone is found also in the southern part of the Abukuma Mountainland, near Hitachi-machi, where it is interbedded in a series of metamorphosed rocks.

In the Inner Zone of southwest Japan there are two well known localities of Lower Carboniferous corals: (1) Ômi in the province of Echigo and (2) Akiyoshi and Ofuku Plateaux in the province of Nagato. The steeply inclined Ômi limestone, of considerable thickness, more than 2000 m. by estimation, and destitute of distinct stratification, has a coral zone of Lower Carboniferous age in its apparently upper, but stratigraphically lower part. Corals collected by Hayasaka from this zone are *Lonsdaleia floriformis crassiconus* M'Coy, *Waagenophyllum omiense* (Yabe and Hayasaka), *Echigophyllum giganteum* Hayasaka, *Axonophyllum gracilis* Hayasaka and *Chaetetes* sp.[5] Likewise the overturned younger Palaeozoic complex of the Akiyoshi district comprises a series of massive limestones, more than 500 m. thick, in its apparently upper, but stratigraphically lower, half; and a series of shales and hornstones, with interbedded limestone lenses, in all 300 to 400 m. thick, in the other half. A Lower Carboniferous limestone zone exposed along the southern border of the Akiyoshi plateau contains many corals, among which the late Y. Ozawa discriminated *Lonsdaleia floriformis crassiconus* M'Coy, *L. enormis* Ozawa, *Nagatophyllum satoi* Ozawa, *Polycoelia japonica* Ozawa and *Chaetetes* sp.[6] It is worthy of note that the Lower Carboniferous coral faunas of Japan and western Europe have several closely allied elements in common.

Upper Carboniferous limestones of southern Manchuria and northern Korea have a peculiar coral fauna, of which the principal elements are colonial *Arachnastraea* and *Cystophora*, and the solitary *Caninia*. This

[4] Endô, R., Palaeozoic stratigraphy of southern Kitakami Mountainland (in Japanese): *Geol. Soc. Tokyo, Jour.*, vol. 31, 1925. Yabe, H., and Hayasaka, I., Palaeozoic corals from Japan, Korea and China: *Idem*, vol. 22, 23, 1915–16.

[5] Hayasaka, I., On the fauna of the Anthracolithic limestone of Ômi-mura in the western part of Echigo: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 8, no. 1, 1924.

[6] Ozawa, Y., Palaeontological and stratigraphical studies on the Permo-Carboniferous limestone of Nagato, Pt. II, Palaeontology: *Coll. Sci. Imp. Univ. Tokyo, Jour.*, vol. 45, art. 6, 1925.

fauna is not found in the Japanese Islands, while the nearly contemporaneous limestone zone of the Akiyoshi district has, according to Ozawa, not only *Dibunophyllum rugosum* M'Coy var. *ofukuense* Ozawa, but also *Lonsdaleia floriformis crassiconus* M'Coy, *Lonsdaleia enormis* Ozawa and *Chaetetes* sp. in common with the lower zone.

Our Permian coral fauna is much simpler, prevailing types being *Waagenophyllum*, *Michelinia* (*Michelinopora*), and *Pachypora*. The Permian limestones of the Akiyoshi district contain several species of corals, and Ozawa distinguished two species of *Lonsdaleia*, s. str.; five species of *Waagenophyllum*, including *Waagenophyllum akasakense* Yabe; and *Chaetetes* sp. Lately we have described a hydrozoan, *Lophiostroma ozawai*.[7] *Waagenophyllum akasakense* Yabe is very common in a zone of the limestone of Akasaka (province of Mino), which is some 600 m. or less by estimated thickness; *Romingeria* (*?*) *kotoi* Yabe and Hayasaka, a rare form, also occurs. A hydrozoan, *Stromatopora* (*Parallelopora*) *minoensis* Yabe and Sugiyama, occurs in a lower zone.[8] The same species of *Waagenophyllum* and its close ally, *Waagenophyllum indicum virgalense* Waagen and Wentzel, as well as *Michelinia* (*Michelinopora*) *multitabulata* Yabe and Hayasaka, are very common corals in the Lower Permian of the Kitakami Mountainland, the last species often forming large stocks.

An interesting case of an aggregate growth of two Permian species of *Pachypora* is known from a small rock, Yakejima, off the coast of Obama, Jûgohama-mura, Rikuzen (in the southern part of the Kitakami Mountainland).

Recently J. Iwai, of our Geological Institute, has discovered in the northern part of the Abukuma Mountainland, northeast Japan, a peculiar limestone, full of stromatoporoid remains belonging to the genus *Clathrodictyon*. This rock is in general aspect hardly distinguishable from certain Gotlandian or Devonian stromatoporoid limestones of Europe, though decidedly much younger (Permian).[9]

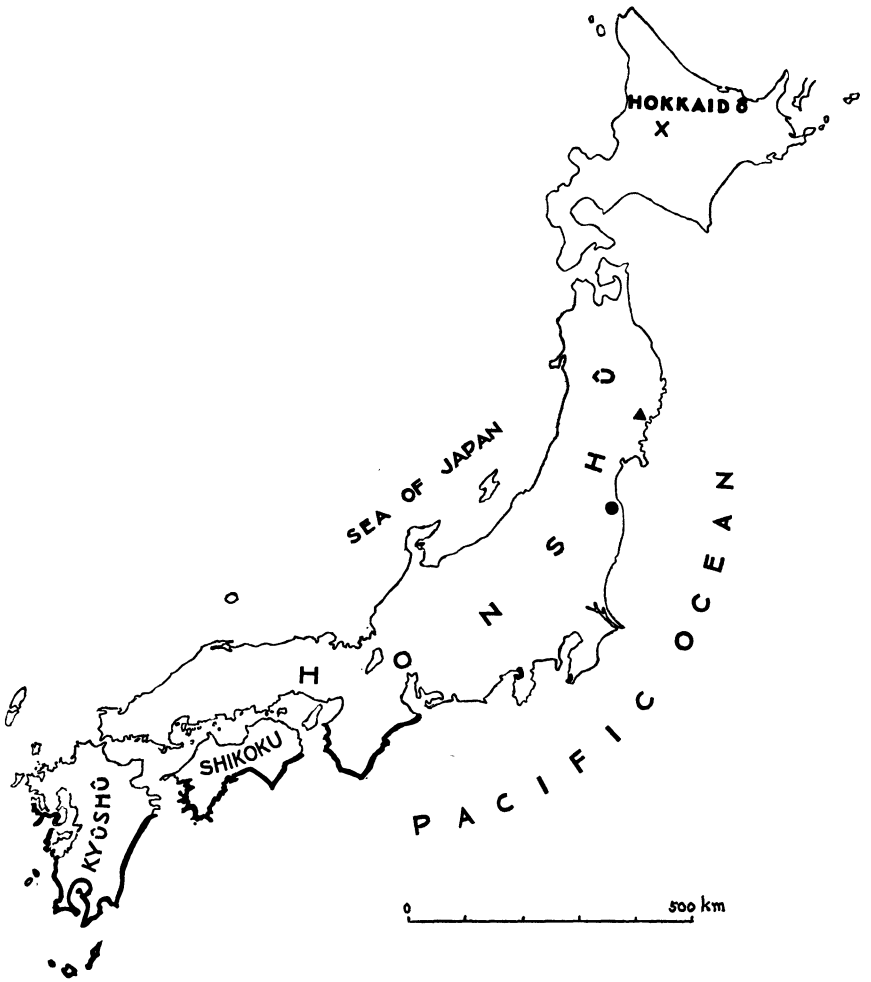
The Kitakami Mountainland (lat. 38°15′ to 40°31′ N.) of northeast Japan is the northernmost tract in the Japanese Islands where colonial corals enjoyed a more or less prolific growth in the Lower Carboniferous and Permian periods (Text-Fig. 1, triangle).[10]

[7] Yabe, H., and Sugiyama, T., Note on a new form of *Lophiostroma* from the Permian of Japan: *Jap. Jour. Geol. Geogr.*, vol. 9, no. 1–2, 1931.

[8] Yabe, H., and Sugiyama, T., Note on a Lower Permian Stromatoporoid from Japan: *Jap. Jour. Geol. Geogr.*, vol. 8, no. 1–2, 1930.

[9] We have now five species of stromatoporoids from the Chichibu system, all found in limestone. Three of them have already been cited above. The other two are *Sphaerostromella shikokuensis* Yabe and Sugiyama, from Shikoku, and *Amphipora* cfr. *A. asiatica* Cowper-Reed, from the northern part of the Abukuma Mountainland. The former is a small subspherical hydrozoan abundant in a limestone of either Upper Carboniferous or Permian age. (See Yabe, H., and Sugiyama, T., Note on a new hydrozoa *Sphaerostromella shikokuensis*, gen. et sp. nov., from the Upper Palaeozoic limestone of Shikoku, Japan: *Jap. Jour. Geol. Geogr.*, vol. 8, no. 2, 1931.) A note on the latter is now in preparation.

[10] *Waagenophyllum virgalense* var. *mongoliense* Grabau is stated to be a dominant fos-



TEXT-FIG. 1—Distribution of the recent reef corals along the coasts of Kiushû, Shikoku, and Honshû (black line), in comparison with the northernmost localities of Lower Carboniferous and Permian (△), Upper Jurassic (○), and Lower Cretaceous (×) reef corals.

Coralline rocks have not yet been discovered in our Triassic formations, which are seldom calcareous. Lower Triassic limestones occur to a very limited extent in the provinces of Iyo and Tosa (both in the Outer Zone of southwest Japan), Musashi and Rikuzen (both in northeast Japan); cephalopods are contained in some of the limestones and lamellibranchs in others, but corals are extremely rare or almost absent. Limestones

sil of the *Waagenophyllum* bed of the Jisu Honguer limestone of Jisu Honguer, Mongolia (Grabau, A. W., *The Permian of Mongolia*, 1931). The locality is situated between 42° and 43° of North Latitude.

and corals are even more negligible elements of our Middle and Upper Triassic rocks.[11]

Our Lower and Middle Jurassic deposits, partly marine and partly terrestrial in origin, are almost free from calcareous rocks. Of corals there are known only two forms, a solitary coral of the genus *Anabacia*,[12] from the Lower Jurassic sandstone of Higashi-Nagano, province of Nagato; and a colonial form of the genus *Latimaeandra*, from the Lower Jurassic *Trigonia*-sandstone of Hosoura, province of Rikuzen (Kitakami Mountainland). On the other hand, the Japanese Islands of Upper Jurassic time seems to have been under climatic conditions favourable for the growth of corals, and coralline limestone is an important element of the Upper Jurassic Torinosu series. The so-called Torinosu limestone of the series, which usually forms small masses or lenses of irregular outline, is at some places massive and at others more or less stratified. It abounds in places in hexacorals, stromatoporoids, milleporoids, milleporelloids, tabulates, and calcareous algae, and it has been sometimes suggested that these organisms formed reefs. The northernmost locality of the Torinosu limestone lies in the northern part of the Abukuma Mountainland, lat. 37°50′ N. (Text-Fig. 1, circle).

Genera of coralline organisms found in the Torinosu limestone are, those with an asterisk being common:

Hexacorals: *Acanthogyra*,* *Amphiastrea*, *Aulastrea*, *Calamophyllia*,* *Cladocoropsis*, *Cladophyllia*, *Comoseris*, *Convexastrea*,* *Dendrogyra*,* *Diplarea*, *Diplocoenia*, *Dimorpharea*, *Dimorphastrea*,* *Hydnophora*, *Isastrea*, *Latimeandrea*, *Leptoria*, *Microsolena*,* *Montlivaultia*, *Orbicella*, *Placocoenia?*, *Pleurosimilia*, *Spongiomorpha* (*Heptastylopsis*),* *Stephanocoenia*, *Stromatomorpha*,* *Stylina*, *Thecosmilia*, *Thamnastrea*.*

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

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

An unusual northern extension of warm-water organisms in Japan is shown by *Orbitolina* in the Lower Cretaceous formations. *Orbitolina* beds are developed, though limited in their areal extent, in the province of Ishikari, Hokkaidô, and in the province of Rikuchû (Kitakami Mountainland). The *Orbitolina*-rock exposed at several places along the upper course of the Sorachi-gawa, and at a hill in the northern part of the Asahikawa basin, in the first province, is limestone. That in the second, the Miyako Cretaceous district, is highly calcareous sandstone. In both cases the tests of the Foraminifera form the bulk of the rock and accompany reef corals, calcareous algae, and certain types of or-

[11] Yabe, H., and Sugiyama, T., Note on an Upper Triassic spongiomorphoid coral from Sanpozan, Province of Tosa: *Jap. Jour. Geol. Geogr.*, vol 10, no. 1, 1932; A new form of the Genus *Omphalophyllia* collected from Yamanba near Sakawa-machi, Province of Tosa (Shikoku). Idem.

[12] Yabe, H., and Eguchi, M., *Anabacia cycloliloides* sp. nov. from Japan, with remarks on the Genus *Anabacia*: *Jap. Jour. Geol. Geogr.*, vol. 10, 1933).

ganisms similar to those characterising the Urgonian facies of the Mediterranean Lower Cretaceous. The basal Raga conglomerate of the Miyako Cretaceous has many rolled stocks of hexacorals together with well rounded boulders of older rocks, on which it rests unconformably. The corals belong to the genera *Amphiastrea*, *Astrocoenia*, *Diplarea?*, a new genus,* *Eugyra*,* *Heterocoenia*, *Hydnophora*, *Orbicella*, *Pleurosmilia*, *Thamnastrea*, *Thecosmilia*, *Latiphyllia*,* and *Heliopora* (identified in a preliminary study by M. Eguchi, a member of our Institute). Those with an asterisk are common. The northernmost exposure of the *Orbitolina* limestone is a little north of lat. 43° 53′ N. (Text-fig. 1, ×).

Corals are also abundant in a certain zone of the Lower Cretaceous formation of Ôshima, opposite Kesennuma, province of Rikuzen (Kitakami Mountainland). The coralline rock is a sandy shale, and the corals found in it belong to the genera and subgenera *Astrocoenia*, *Enallohelia*,* *Eugyra*, *Rabdophyllia*, *Thamnastrea*,* *Centrastrea*, *Polyphyllastrea*.

The later Cretaceous deposits are almost, if not entirely, free from limestone as well as stock-building corals. Disc-shaped corals are occasionally found in the Upper Cretaceous (Senonian) deposits of Saghalin and Hokkaidô. They belong to the genera *Cyclocyathus*, *Platycyathus*, and *Trochocyathus*.[13]

In the Japanese Islands, rocks composed of large-sized tests of highly organised Tertiary Foraminifera are very limited in distribution. Beds containing *Camerina* and *Orthophragmina* extend, however, to lat. 32° 30′ N.; those with *Eulepidina* to lat. 30° N.; and those with *Nephrolepidina* and *Miogypsina* to lat. 40° 50′ N. Coral stocks are common in some parts of these foraminiferous rocks, but they rarely aggregate together so densely as to form typical coralline rocks.

An almost unique example of typical coral limestone in the Tertiary of Japan is that very recently found by one of us (Sugiyama) in the limestone series exposed on a small islet Minami-jima, opposite Minami-zaki, the southernmost point of Chichi-jima (Ogasawara Group). The coral limestone is a lithified mass of crowded coral stocks, mostly in upright position and hence probably indicating their growth *in situ*. The limestone series contains *Eulepidina* and is assigned by us approximately to the Aquitanian stage, as stated elsewhere.[14] The identification of the fossil corals has not yet been completed, but the genera *Alveopora*, *Astrocoenia*, *Favia*, *Favites*, *Lamellastrea(?)*,* *Orbicella*,* *Porites*,* and *Psammocora(?)*, are likely to be represented among them.

Many coral stocks are found in a *Nephrolepidina*-bearing limestone exposed near Ôishi, on the north shore

[13] Eguchi, M., Three new turbinarian corals from the Upper Cretaceous of Saghalin and Hokkaidô: To be published in *Jap. Jour. Geol. Geogr.*

[14] Yabe, H., Tertiary rocks with higher Foraminifera from Japan (in Japanese): *Geol. Soc. Tokyo, Jour.*, vol. 27, 1920. Hanzawa, S., Foraminiferal rocks of Okinawa Islands and Ogasawara Islands (in Japanese): *Geol. Soc. Tokyo, Jour.*, vol., 32, 1925.

of the Lake Kawaguchi in the province of Kai. Among the corals collected at this locality we can distinguish several species of the genera *Favia*, *Favites* (*Prionastrea*), *Hydnophyllia*, and *Maeandra*. Two small hills, Megami-yama and Ogami-yama, near Sagara-machi in the province of Tôtômi, are an immense accumulation of coralline algae, Melobesiae and Corallinae in numerous species. This limestone is rather poor in corals, the commonest forms being *Stylophora*, *Mussa*, and *Montipora*. The *Nephrolepidina* limestone of Ôishi is approximately Burdigalian in age and that of Ogamiyama and Megami-yama may be a little younger. The former (lat. 35° 30′ N.) 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 immense extent. It extends over 8 degrees of latitude, occupying widely separate areas between the southernmost point of Taiwan, Cape Garambi (lat. 22° N.), and the islands Ô-shima and Kikai-shima of the Ô-shima Subgroup of the Riukiu Islands, (lat. 28° 30′ N.). In thickness it seldom exceeds 80 meters. At most places it is fairly well stratified, often with interbedded foraminiferal limestones. At places it includes massive coralline limestone, composed almost solely of coral stocks—*Porites* at an exposure in a quarry once open near Shuri, Okinawa-jima. In a recent trip to Kikai-shima, S. Hanzawa found numerous coral-stocks weathered out, under favorable conditions, from a coral limestone. These are well preserved and are determined as follows:

Acanthastrea cfr. *hemprichii* (Ehr.), *Acropora* sp., *Alveopora* cfr. *verrilliana* Dana, *Antillia japonica* Yabe and Sugiyama, *Astraeopora* cfr. *gracilis* Bernard, *Cyphastrea chalcidicum* Klunzinger, *Cyphastrea microphthalma* (Lam.), *Euphyllia fimbriata* (Spengler), *Favia amplior* (M.-Edw. and H.), *Favia speciosa* (Dana), *Favia valenciennesii* (M.-Edw. and H.), *Hydnophora exesa* (Pallas), *Leptoria phrygia* (Ell. and Soll.), *Maeandra* cfr. *lamellina* Ehr., *Maeandra* cfr. *stricta* (M.-Edw. and H.), *Orbicella curta* Dana, *Orbicella* sp., *Oulophyllia* cfr. *crispa* (Lam.), *Tubipora musica* L.

Most of the Riukiu limestone corals from other localities in our collection are not in good preservation, and difficulty always arises as to specific and generic determinations. The annexed Table 1 shows a list of the Riukiu limestone corals hitherto examined by us, including 68 species in 38 genera. The fossil coral fauna, as a whole, seems to be not much different from the living one of the region concerned.[15]

The precise geological age of the Riukiu limestone is still unsettled. Certainly it is neither younger nor much older than the Pleistocene. It was thought by us to be the youngest Neogene or pre-Pleistocene, partially on the grounds, first, that the large-sized foraminiferal fauna of the

[15] *Tubipora*, *Oulophyllia*, and *Antillia* occur in the Riukiu limestone of the Riukiu Islands, but are not represented in our collection of recent corals from the same islands.

TABLE I.—List of the Reef-Corals from the Riukiu Limestone (Late Pliocene?) of the Riukiu Islands and Taiwan

SPECIES \ LOCALITIES	RIUKIU					TAIWAN			
	Kikai-shima	Ishigaki-jima	Miyako-jima	Yonakuni-jima	Hateruma-jima	Hanpei-zan	Kotobuki-yama	Taikô-zan	Shôriukiu
Galaxes clavus (Dana)	—	—	x	—	—	—	—	—	—
fascicularis (Linné)	—	—	x	—	—	—	—	—	—
Euphyllia fimbriata (Spengler)	x	—	—	—	—	—	—	—	—
Cyphastrea chalcidicum Klunzinger	x	—	—	—	—	—	—	—	—
microphthalma (Lam.)	x	—	—	—	—	x	—	—	—
serailia (Forskål)	—	—	x	x	—	x	x	—	—
Leptastrea ? sp.	—	—	x	x	—	—	—	—	—
Orbicella cfr. *curta* Dana	x	—	—	x	—	—	x	—	—
sp. (A)	x	—	—	—	—	—	—	—	—
sp. (B)	—	—	x	—	—	—	x	—	—
sp. (C)	—	—	—	x	—	—	—	—	—
Favia cfr. *amplior* (M.-Edw. and H.)	x	—	—	—	—	—	—	—	—
cfr. *pallida* (Dana)	—	—	—	x	—	—	—	—	—
speciosa (Dana)	x	—	x	x	x	—	—	—	—
cfr. *speciosa* (Dana)	—	—	—	—	—	x	—	—	—
valenciennesii (M.-Edw. and H.)	x	—	—	—	—	—	—	—	—
sp. (A)	—	—	x	—	—	—	—	—	—
sp. (B)	—	—	x	—	—	—	—	—	—
Favites cfr. *virens* (Dana)	—	—	—	x	—	x	—	—	—
sp. (A)	—	—	x	—	—	x	—	—	—
sp. (B)	—	—	—	—	—	—	x	—	—
? sp. (C)	—	—	x	—	—	—	—	—	—
Goniastrea parvistella (Dana)	—	x	—	—	—	—	—	—	—
cfr. *pectinata* (Ehr.)	x	—	—	x	—	—	—	—	—
retiformis (Lam.)	—	—	—	x	x	—	—	—	—
? sp.	—	—	—	—	—	—	—	—	x
Leptoria gracilis (Dana)	—	—	—	—	—	—	—	—	x
phrygia (Ell. and Soll.)	x	—	x	x	—	—	—	—	—
tenuis (Dana)	—	—	x	—	—	—	—	—	—
? sp.	—	—	x	—	—	—	—	—	—
Maeandra astreiformis M.-Edw. and H	—	—	—	—	—	—	x	—	—
cfr. *lamellina* Ehr.	x	—	—	—	—	—	—	—	—
cfr. *stricta* (M.-Edw. and H.)	x	—	—	—	—	—	—	—	—
? sp.	—	—	x	—	—	—	—	—	—
Hydnophora exesa (Pallas)	x	—	—	—	—	—	—	—	—
microconos Lam.	—	—	x	—	—	—	—	—	—
sp. (A)	—	—	x	—	—	—	—	—	—
sp. (B)	—	—	x	—	—	—	—	—	—
Hydnophyllia ? sp.	—	—	—	—	—	x	—	—	—
Antillia japonica Yabe and Sugiyama	x	—	—	—	—	—	—	—	—
? sp. (A)	—	—	—	—	—	x	—	—	—
? sp. (B)	—	—	—	—	—	—	—	x	—
Fungia cyclolites Lam. var.	x	—	—	—	—	—	—	—	—
cfr. *granulosa* Klunzinger	—	x	—	—	—	—	—	—	—
sp. (A)	—	x	—	—	x	—	—	—	—
sp. (B)	—	—	—	x	—	—	—	—	—
Oulophyllia cfr. *crispa* (Lam.)	x	—	—	—	—	—	—	—	—
Mussa ? sp.	—	—	x	—	—	—	—	—	—
Symphyllia ? sp.	—	—	—	x	x	—	—	—	—
Acanthastrea cfr. *hemprichii* (Ehr.)	x	—	—	—	—	—	—	—	—

TABLE I. (*Continued*)

SPECIES \ LOCALITIES	RIUKIU					TAIWAN			
	Kikai-shima	Ishigaki-jima	Miyako-jima	Yonakuni-jima	Hateruma-jima	Hanpei-zan	Kotobuki-yama	Taikô-zan	Shôriukiu
Coscinarea ? sp.	—	—	x	—	—	—	—	—	—
Pavona sp.	—	—	—	—	—	—	—	—	x
Pachyseris cfr. *rugosa* (Lam.)	—	—	x	—	—	—	—	—	—
cfr. *speciosa* (Dana)	—	—	—	—	—	x	—	x	—
Turbinaria sp.	—	—	—	—	—	—	—	x	—
Astraeopora cfr. *gracilis* Bernard	x	—	—	—	—	—	—	—	—
Goniopora sp. (A)	—	x	—	—	—	—	—	—	—
sp. (B)	—	—	—	x	—	—	—	—	—
sp. (C)	—	—	—	—	—	x	—	—	—
Acropora sp. (A)	—	—	x	—	—	—	—	—	—
sp. (B)	—	—	—	x	—	—	—	—	—
sp. (C)	x	—	—	—	—	—	—	—	—
Porites sp. (A)	—	—	x	—	—	x	—	—	—
sp. (B)	—	—	x	—	—	—	—	—	—
Alveopora cfr. *verrilliana* Dana	x	—	—	—	—	—	—	—	—
sp.	—	—	x	—	—	—	—	—	—
Tubipora musica L.	x	—	x	x	—	—	—	—	—

limestone has several features distinct from the present fauna of the same region and approaches that of more southern seas; second, that the deposition of such an extensive calcareous formation by direct or indirect contribution of organisms identical with those which now haunt the tropical and subtropical seas is hardly expectable during the Pleistocene. We have no good reason at present to believe that a climate warmer than that of the present prevailed over the Japanese Islands during the Pleistocene. On the other hand, we have no positive evidence against the view that the limestone may be a product of one, especially an earlier one, of the interglacial stages. Other collateral evidence, however, geological and morphological data from the Riukiu Islands and Taiwan, derived from the peculiar configuration of the adjacent sea bottom, the extensive submerged surfaces at 2 different levels, seem to be more favorable to the assumption of youngest Pliocene age for the Riukiu limestone.[16]

We can not close this chapter without again referring to the important role of calcareous algae in our geological formations, for they took an important part in the building of limestones, in association with corals and Foraminifera. To mention conspicuous examples, there are *Mizzia japonica* Karpinsky (?=*Mizzia velebitana* Schubert) in the Permian; *Solenopora rothpletzi* Yabe, *Nipponophycus ramosus* Yabe and Toyama,

[16] Yabe, H., and Hanzawa, S., A geological problem concerning the raised coral reefs, etc.: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 7, no. 2, 1925.

Pycnoporidium lobatum Yabe and Toyama, *Girvanella tosaensis* Yabe and Toyama in the Upper Jurassic (Torinosu limestone); *Nipponophycus ramosus* Yabe and Toyama, *Stenoporidium chaetetiformis* Yabe and Toyama, *Petrophyton miyakoense* Yabe in the Lower Cretaceous. Melobesiae, Corallinae and *Halimeda* were active in the construction of some of our Tertiary limestones already mentioned in the foregoing paragraphs, as they are for the building of reef rocks in the present tropical and subtropical seas.[17]

II. PLEISTOCENE DEPOSITS

In the northern and middle parts of Taiwan, plateau gravel covered by red lateritic earth is unconformably underlain by two Neogene series, the Shokkôzan and Byôritsu, whereas in the southern part it is underlain by the youngest Neogene Riukiu limestone.[18] The plateau gravel is barren of marine fossils, though mammalian remains are occasionally found in it. Very similar plateau gravel occurs also on Okinawa-jima and several other islands of the Riukiu group, and Hanzawa believes it contemporaneous with that of Taiwan.[19] Both plateau gravels may possibly be terrestrial sediments either of the "Latest Continental Stage" of the Japanese Islands, transitional from the Pliocene to the Pleistocene, or of the Pleistocene, or of both of them.[20]

A representative example in the main island (Honshû) of Pleistocene marine deposits is the Narita series of the Kwantô region, while one of terrestrial origin is the fossil lake deposit of Shiobara, in the volcanic district of the same name in the Shimotsuke Mountainland.[21]

The Narita series admits of numerous minor subdivisions according to the nature of sediments and of the faunas they contain. These can be grouped into 3 larger divisions; the upper Narita, or Narita proper, is conformable on the middle Narita, or Kiyokawa group, which in turn rests

[17] Nishiwada, K., On some organic remains from the Tertiary limestone near Sagara, Tôtômi: *Coll. Sci. Univ. Tokyo, Jour.*, vol. 7, pt. 3, 1894. Yabe, H., Ueber einige Gesteinbildende Kalkalgen von Japan und China: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 1, no. 1, 1912. Yabe, H., andToyama, S., On some rock-forming algae from the younger Mesozoic of Japan: *Idem*, vol. 12, no. 1, 1928.

[18] Yabe, H., and Hanzawa, S., Tertiary foraminiferous rocks of Taiwan (Formosa): *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 14, no. 1, 1930; Stratigraphical studies of the Tertiary foraminiferous rocks of Taiwan (in Japanese): *Memorial Volume for the 60th Birthday Celebration of Professor T. Ogawa*, 1929.

[19] It was stated by Yabe and Hanzawa in 1930 that in Okinawa-jima, the plateau gravel is older than the Riukiu limestone. Recent observations of Hanzawa have shown that the former is actually younger than the latter, just as in Taiwan. A conglomerate underlying the Riukiu limestone is now proved to be different from the plateau gravel. The Cenozoic stratigraphy of the Riukiu Islands and Taiwan are thus no longer discrepant.

[20] The plateau gravel is often difficult to separate from certain gravel beds of younger terraces in the valleys incised through the plateau, and a part of what we now call plateau gravel may better be separated from the typical deposit.

[21] Yabe, H., Relation of the volcano Shiobara to the local geotectonic (in Japanese): *Jap. Assoc. Adv. Sci., Proc.*, vol. 4, 1928.

unconformably on the lower Narita, or Sanuki with Sasage sand and gravel at the base.[22]

The molluscan fauna as a whole is very rich in cool water elements or northern types. A number of warm water elements or southern types are found in the lower Narita, or Sanuki, subfauna, whereas nearly all of them disappear in the middle Narita, or Kiyokawa, subfauna. In the upper Narita subfauna, northern types are slightly reduced in number, as compared with the Kiyokawa, but not so much as in the Sanuki. In short, the lowering of the temperature of sea water reached its climax in the middle Narita time.

Plant remains are abundant in the fossil lake deposits of Shiobara, more than 65 species being discriminated, most of them broad-leaved plants. All the specifically determined forms are still living in Japan. The fossil vegetation differs from the present one in the vicinity of the fossil lake, but is very similar to that around the well known Lake Chûzenji of Nikkô, another volcanic district lying to the south of Shiobara. Lake Chûzenji has an altitude of 1500 m. above the present sea level, being at least 800 m. higher than the site of the fossil lake.

The Shimotsuke Mountainland, with the two volcanic districts of Shiobara and Nikkô, is bordered on the east by the broad platform of eastern Shimotsuke incised by the valleys of the Naka-gawa and the Kinu-kawa, which discharges its water into the Tone-gawa near the center of the Kwantô tectonic basin. River terraces well developed along the border of the mountainland descend gently southwards to the uplifted platform of the basin, through which they can be traced more or less continuously to the coastal land. It is therefore thought possible to make by estimation a rough approximation of the altitude of the site of the fossil lake of Shiobara above the sea-level of the past age, and the result of our trial is some 500–600 meters.

The uplifted platform of the tectonic basin is built in greater part of the marine sediments of the Narita series, as well as its equivalent, the marine Tokyo series; and in lesser part of contemporaneous semiterrestrial deposits in the marginal belt of the basin. The surface layer, resting unconformably upon the foundation rocks of the platform, is the Kwantô loam, which also covers the surface of the higher river terraces of the Kinu-kawa. Consequently the terraces on the eastern border of the Shimotsuke Mountainland can be called in to aid in a chronological correlation between the fossil lake deposits of Shiobara on one side and the marine Narita of the Kwantô region on the other side. Apart from palaeontological data, the approximate contemporaneity of the former at least to a part (the upper) of the latter is believed to be manifest.

All the facts stated above agree in

[22] In the guide-book for excursion C6 of the 3rd Pacific Science Congress, the Narita series was divided into two. Recent progress of our stratigraphical knowledge has shown that three divisions of it mentioned above are more practically convenient.

respect to the geographical condition of the Japanese Islands during the Pleistocene: namely, the land as a whole was probably lower and the climate was cooler than now.

By future detailed studies of the fossils from the different zones of the Narita series, it will be possible to bring out evidence of faunal changes reflecting those of climate during the alternate glacial and interglacial stages of the glaciated areas.

Corals found in the Narita and Tokyo series are few, all being either solitary forms or simply branching colonies of relatively deeper waters. They are *Balanophyllia* sp., *Caryophyllia* sp., *Ceratotrochus* sp., *Deltocyathus lens* Alcock, *Deltocyathus* sp., *Dendrophyllia* sp., *Discotrochus ?* sp., *Flabellum transversale* Moseley and var. *kazusaense* Yabe and Eguchi, *Endopachys japonicum* Yabe and Eguchi, *Heterocyathus* sp., *Oulangia stockesiana* (Milne-Edwards and Haime) var. *miltoni* Yabe and Eguchi, *Sabinotrochus?* sp., and *Stephanophyllia fungilus* Alcock.[23]

III. POST-PLEISTOCENE CORALLINE DEPOSITS

Post-Pleistocene raised coral reefs and raised beach deposits with corals are recorded by Hanzawa from various places in Taiwan, and are also well developed in the Riukiu Islands.

The raised coral reefs are well developed along the coast of the southernmost part of Taiwan, as well as around the coast of the small islets Kôtô-sho, Kashô-tô and Shôriukiusho; everywhere they assume a former coastal terrace: besides, they are feebly developed on the raised abrasion benches near Kiirun and Cape Fukkikaku in the northernmost part of Taiwan. On an average, the coastal terraces of raised coral reefs are 100 m. wide and 15 m. high whereas the reefs themselves are 3 m. or slightly more thick. The raised reefs are essentially composed of the stocks of reef corals mostly in upright position and have in association Mollusca, Bryozoa, Foraminifera and calcareous algae; all the organic remains are usually excellently preserved, though sometimes metamorphosed almost to a coralline limestone. On the other hand, layers of calcareous sand and shingles are rare.[24]

At other places, the raised coral reefs are replaced by abrasion platforms with or without a thin cover of raised beach deposit with coral shingles.

In another paper the same author stated that all the islands of the Yaeyama subgroup of the Riukiu Islands are encircled by narrow terraces, some 5 m. high, covered at places by a thin beach deposit of coral sand or shingles and foraminiferal sand.[25] In his recent visit to Kikai-shima and Amami-Ô-shima of the Ôshima subgroup he found

[23] Yabe, H., and Eguchi, M., Some Recent and fossil corals of the Genus *Stephanophyllia* H. Michelin from Japan: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 15, no. 2, 1932; A new species of *Endopachys, Endopachys japonicum* from a younger Cenozoic deposit of Japan: *Jap. Jour. Geol. Geogr.*, vol. 10, no. 1, 1933; Fossil and Recent *Flabellum* from Japan: To be published in *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.;* Fossil and Recent *Deltocyathus* and *Discotrochus* from Japan: *Jap. Jour. Geol. Geogr.*

[24] Hanzawa, S., Notes on the raised coral reefs and their equivalent deposits in Taiwan (Formosa) and adjacent islets: *Rec. Oceanogr. Wks. Japan*, vol. 3, no. 2, 1931.

[25] Hanzawa, S., A brief sketch of the geology and geological history of the Yaeyama subgroup (in Japanese): *Geogr. Review, Tokyo*, vol. 8, no. 2, 1932.

TABLE II.—LIST OF THE REEF-CORALS FROM THE RAISED CORAL REEFS AND RAISED BEACH DEPOSITS OF THE RIUKIU ISLANDS AND TAIWAN

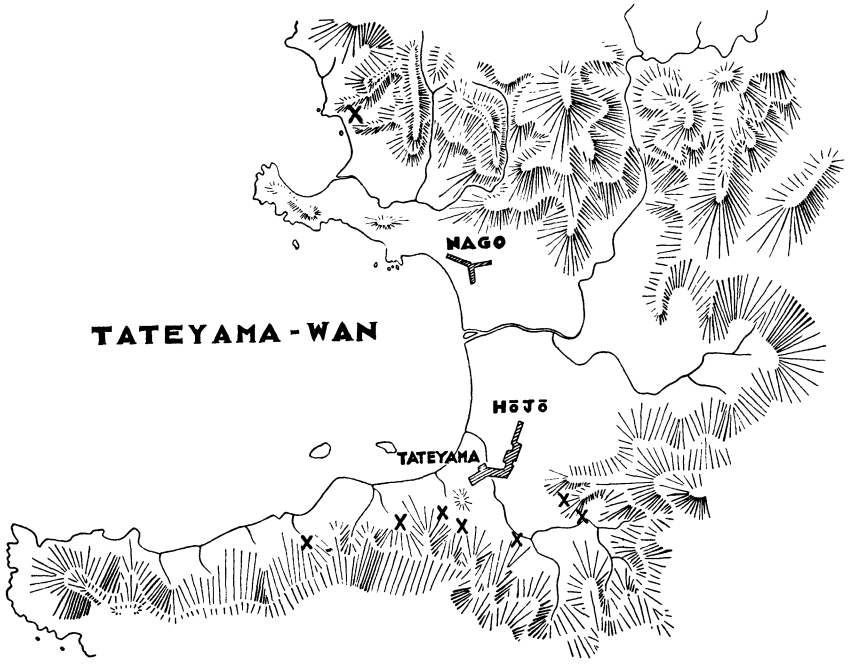
SPECIES \ LOCALITIES	RIUKIU: Sakishima subgroup	RIUKIU: Kikai-shima	TAIWAN
Stylophora imperatoris Vaughan	—	—	x
pistillata (Esper)	—	—	x
sp.	—	x	—
Pocillopora informis Dana ?.	—	—	x
cfr. *maeandrina* Dana var. *nobilis* Verrill?	—	x	—
sp.	—	—	x
Galaxea			
clavus (Dana)	—	—	x
fascicularis (L.)	x	x	x
Cyphastrea			
chalcidicum Klunzinger	—	x	x
cfr. *gardineri* Matthai	—	—	x
serailia (Forskål)	—	—	x
microphthalma (Lam.)	x	x	—
Orbicella			
curta Dana	—	x	—
spp.	x	x	—
Favia			
magnistellata M.-Edw. and H.	—	x	—
pallida (Dana)	—	—	x
speciosa (Dana)	x	x	x
valenciennesii(M.-Edw. and H.)	—	x	—
sp.	—	—	x
Favites			
abdita (Ell. and Soll.)	—	—	x
virens (Dana)	—	—	x
sp.	—	—	x
Goniastrea			
pectinata (Ehr)	—	x	x
planulata M.-Edw. and H.	—	—	x
reliformis (Lam.)	—	—	x
sp.	—	—	x
Leptoria			
phrygia (Ell. and Soll.)	—	x	x
cfr. *tenuis* (Dana)	—	—	x
sp.	—	—	x
Maeandra			
astreiformis M.-Edw. and H.	—	—	x
daedalea (Ell. and Soll.)	x	—	—
lamellina Ehr.	—	x	—
cfr. *sinensis* M.-Edw. and H.	—	—	x
cfr. *stricta* (M.-Edw. and H.) sp.	—	x	—
	—	—	x
Hydnophora			
microconos (Lam.)	—	x	—
exesa (Pallas)	—	—	x
Fungia			
cyclolites Lam. var.	—	x	—
cfr. *granulosa* Klunzinger	x	—	x
cfr. *paumotensis* Stutchberg	x	—	—
Herpetolitha			
cfr. *stricta* (Dana)	—	—	x
Coelocoenia			
cfr. *vacua* Gerth	—	—	x
? sp.	—	—	x
Symphyllia			
cfr. *cactus* Quelch	x	—	—
cfr. *nobilis* (Dana)	—	x	—
Oulophyllia			
cfr. *aspera* Quelch	—	x	—
Acanthastrea			
echinata (Dana) var. ?	—	x	—
hemprichii (Ehr.)	—	x	—
Agaricia			
cfr. *forskåli* M.-Edw. and H.	—	—	x
Pachyseris			
cfr. *speciosa* (Lam.)	—	—	x
Pavona			
sp.	x	—	—
Podabacia			
sp.	—	—	x
Coeloseris			
sp.	—	—	x
Astraeopora			
cfr. *gracilis* Bernard	—	x	—
Turbinaria			
peltata (Esper)	—	x	—
sp.	—	—	x
Goniopora			
sp.	—	x	—
Montipora			
sinensis Bernard	—	—	x
cfr. *informis* Bernard	—	—	x
cfr. *ramosa* Bernard	x	—	—
spp.	—	x	x
Acropora			
cfr. *haimei* (M.-Edw.)	x	—	—
hebes (Dana)	x	—	—
cfr. *muricata* (L.)	x	—	—
pulchera (Brook)	—	—	x
smithi Brook	—	x	—
spp.	x	x	x
Porites			
cfr. *compressa* forma *tumida* Vaughan	—	—	x
cfr. *lanuginosa* Studer	—	—	x
sp.	—	x	—
Alveopora			
cfr. *verrilliana* Dana	—	x	—
Heliopora			
caerulea M.-Edw. and H.	—	—	x

raised coral reefs well developed around the former island to a breadth of about 1 km., and raised abrasion benches, 1 to 2 m. above the high water mark, around the latter.

The corals of these young geological formations of Taiwan and the Riukiu Islands are listed in Table 2; they belong to 31 genera and constitute a fauna quite indistinguishable from the Recent fauna of the adjacent seas.[26]

To the north of the Riukiu Islands there exist no more raised coral reefs except the remarkable growth of semifossil reef corals at Noma, near Tateyama, in the province of Awa (Honshû), approximately lat. 35° N. On the other hand one good example of raised beach deposits with coral shingle is observable at Mera, a little west of Tanabe, province of Kii.

The coral bed, or more correctly, coral reef, of Noma near Tateyama on the coast of the Tateyama-wan, one of the 15 m. beaches, is the most instructive of all. There an alluvial plain has its surface some 20 m. higher than the present sea level. Many excavations at Okanoma and several other places nearby have shown that there is in a more or less extended distribution beneath the alluvial silt an incipient fringing reef or reef corals that grew in drowned



TEXT-FIG. 2—Extent of the raised coral reef of Noma near Tateyama (×). 1:200,000.

[26] *Oulophyllia* occurs in the coral fauna of the raised coral reefs of Kikai-shima. It is also found in the Riukiu limestone fauna as stated sbove. It is, however, not represented in our collection of recent corals from the Riukiu Islands.

valleys cut into Neogene rocks at the time of the last submergence of the Japanese Islands.

The semifossil coral reef is 2 to 3 m. thick and consists of coral heads or stocks in upright position, the basal stocks resting directly on the rocky floor (Neogene tuffs of the Miura series), or on angular and subangular blocks of the same rocks torn from the floor, and more or less rolled.

Other common organic remains in association with these corals are thick-shelled Mollusca, found in fresh condition, often with color pattern, the bivalves having both valves usually intact. The corals are likewise well preserved, even delicate spinules of the septal margins usually showing no trace of damage. Worthy of special note is further the circumstance that there are almost no rolled coral stocks around the reefs; at least these were not seen in an excavation at Okanoma which Yabe had an opportunity personally to examine a score of years ago, and in another one very recently opened by members of our Geological Institute. All these facts seem to support the view that we have here an incipient fringing reef grown in rather calm water immediately after the land submerged. Subsequent copious settling of mud at the heads of the submerged valleys, and probably also the simultaneous slight lowering of the temperature of the sea water, soon prevented further growth of the coral reefs, and the mud penetrated and filled up the interspaces between the coral stocks.

There is divergence of opinion as to the geological age of the semifossil coral reef of Noma. M. Yokoyama at first maintained a Pleistocene warm age, instead of glacial, in Japan on the evidence of this coral bed, but later assigned it to the youngest Pleistocene. In our opinion[27] it is post-Pleistocene (early Holocene), nearly equivalent to the Neolithic beaches of England.

S. Nomura distinguished 470 species of Mollusca from the raised beach deposits in the Kwantô region, including the semifossil coral reef of Noma, and concluded "the temperature of the sea-water in the time when the raised beach deposits were laid down may have been nearly as warm as that of Central Japan at present; at the most, it may have been as warm as the present coast of Kii, being in no way warmer." As to the geological age of them, he stated, "from the faunal and climatological as well as from the geographical situation, the raised beach deposits seem to have been laid down in the youngest age, ranging from the Neolithic time to the early historic age—the Holocene.[28]

Corals obtained from the semifossil reef are listed on Table 3.[29]

[27] Yokoyama, M., Climatic changes in Japan since the Pliocene Epoch: *Coll. Sci. Univ. Tokyo, Jour.*, vol. 32, art. 5, 1911; Mollusca from the coral bed of Awa: *Idem.*, vol. 45, art. 1, 1924. Yabe, H., Recent stratigraphical and palaeontological studies of the Japanese Tertiary: *First Pan-Pac. Sci. Congr., Proc.*, vol. 3, 1921.

[28] Nomura, S., Mollusca from the raised beach deposits of the Kwantô Region: *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 15, no. 2, 1932.

[29] These semifossil corals, as well as Recent ones, from Japan will be described in a series

TABLE III.—REEF-CORALS FROM THE RAISED CORAL REEF OF NOMA AND THE RAISED BEACH DEPOSIT OF MERA

SPECIES \ LOCALITIES	HONSHÛ	
	Noma	Mera
Stylophora cfr. *danae* M.-Edw. and H	x	x
sp.	x	—
Pocillopora damicornis (Pallas)	x	—
Cyphastrea chalcidicum Klunzinger	x	x
japonica Yabe and Sugiyama nov. sp.	x	—
serailis (Forskål)	x	—
Leptastrea purpurea (Dana)	x	?
Echinophyllia spp.	x	x
Orbicella cfr. *felixi* Gerth	x	—
versipora (Lam.)	x	?
sp.	x	—
Favia magnistellata M.-Edw. and H	x	—
pallida (Dana)	x	—
speciosa (Dana)	x	x
Favites abdita (Ell. and Soll.)	x	—
virens (Dana)	x	—
Maeandra astreiformis M.-Edw. and H	—	x
sp.	x	—
Hydnophora exesa (Pallas)	x	x
Antillia constricta Brüggeman	x	—
japonica Yabe and Sugiyama	x	—
nomaensis Yabe and Sugiyama sp.	x	—
Fungia cfr. *patella* (Ell. and Soll.)	x	—
Caulastraea yokoyamai Yabe and Sugiyama	x	—
yokoyamai Yabe and Sugiyama var. *gracilis* Y. and S.	x	x
Mussa cfr. *regalis* Dana	x	—
Tridacophyllia sp.	x	x
Acanthastrea hemprichii (Ehr.)	x	—
Psammocora paponica sp. nov.	x	—
profundacella Gardiner	x	x
superficialis Gardiner	x	—
Coscinarea sp. nov.	x	—
Pavona danae M.-Edw. and H	x	—
spp.	x	—
Podabacia lobata Van der Horst	x	?
lobata forma *nomaensis* Yabe and Sugiyama	x	—
lobata forma *vanderhorsti* Yabe and Sugiyama	x	—
Turbinaria contorta Bernard	x	?
peltata (Esper)	x	x
Goniopora sp.	x	—
Montipora cfr. *ramosa* Bernard	x	—
Acropora sp.	x	x
Porites cfr. *bernardi* Vaughan	x	—
cfr. *hawaiensis* Vaughan	x	—
Alveopora cfr. *verrilliana* Dana.	x	—
Gen. sp. indet	x	—

They belong to 46 species in 27 genera, excluding one generically as well as specifically indeterminable form, of excellent preservation, which is rare and represented by a single specimen. Dominant above all is *Favia speciosa;* next are *Caulastraea yokoyamai* and variety, *Cyphastrea chalcidicum*, *Echinophyllia* sp., *Leptastrea purpurea*, *Orbicella* sp., *Podabacia lobata* and varieties, and *Turbinaria contorta*. The generically indeterminable form excluded, nearly all the species are now living in the adjacent seas. A comparison of this fauna with the Recent one of the adjacent seas brings out the following result: no coral of the genus *Coscinarea* was found in our collection of Recent corals from Honshû and Shikoku, though living in the seas of the Riukiu Islands and Ogasawara-jima. Of the genus *Fungia*, we have only 1 species, *Fungia cyclolites*, from the adjacent seas, while *Fungia patella* is not yet known living in the Riukiu Archipelago and north. *Pocillopora* is richly represented by only 1 species in the seas of Misaki (Shikoku) and Kushimoto (Kii), but very poorly in the Noma fauna. Finally, most characteristic of it is the absence of *Goniastrea* and the great rarity of *Montipora*, *Acropora* and *Porites* in it as compared with the abundance of species of these genera in the adjacent seas.

The beach deposit of Mera is far less important. Some 2 km. west of Tanabe, province of Kii, there is the

of papers under the title *A study of Recent and semifossil corals of Japan*, of which the first part (*Antillia* and *Caulastraea*) has already been published in *Sci. Rep. Tôhoku Imp. Univ., Geol. Ser.*, vol. 14, no. 2A, 1931.

small peninsula of Mera. In the upper 1.5 to 2 m. of a 5 m. sea-cliff cut into a low terrace is exposed a beach deposit of sand and clay with shingles 2–3 cm. in diameter, which rests unconformably on the abraded surface of the underlying Neogene sandstones. Molluscan shells and coral shingles are common in the beach deposit. The corals specifically discriminated are listed in Table 3. They represent 15 species in 14 genera, including 4 doubtful ones. All the species are living now in the Tanabe-wan, as mentioned in the next chapter, and also occur in the Noma reef.

IV. REEF CORALS FOUND IN THE JAPANESE SEAS

A list of the reef corals in the Japanese seas is given in Table 4. The specific determination is rather tentative in certain forms and these will be revised later. The first step of our study was to make a rapid reconnaissance of the general aspect of the fauna as to its constituents.[30] The present list is by no means complete, because the number of collecting grounds visited by our collaborators is limited, and the collection made in many cases is far from being exhaustive; among others, we felt particularly the deficiency of material from Taiwan and some other semitropical islets of Japan. The present list of corals will certainly be much enlarged by acquisition of new materials.

The collecting grounds for reef corals visited by our collaborators may be grouped in the 22 fields enumerated below:

Pacific coast of Honshû (the Main Island: Tateyama-wan, Enoura-wan, Yura-wan, Tanabe-wan, Kushimoto.

Pacific coast of Shikoku: Murotozaki, Tei, Susaki, Misaki (all in the province of Tosa), Uwajima-wan.

Kiushû and dependent islets: coast of Hiuga, coast of Ôsumi, Kagoshima-wan, southern coast of Satsuma, coast of Hizen, Amakusa, Koshiki-jima.

Riukiu Group: Ôshima, Okinawa, and Sakishima subgroup.

Ogasawara Group: Chichi-jima, and Haha-jima.

Taiwan (Formosa): Sharyô-tô near Taihoku.

The geographical distribution is shown on the Text-Figure 1.

In the Japanese Islands, the reef corals are growing on rocky sea bottoms along coasts submerged in post-Pleistocene time. In the Enoura-wan and Tateyama-wan as well as in the somewhat southerly Tanabe-wan of Kii Peninsula, the coral stocks are never crowded and rarely overgrown one upon another. They are found at depths from 5 to 40 m., and are never exposed, even at the low spring tide. In the southern part of Kiushû, on the other hand, the coral stocks are more or less densely crowded, at places entirely covering the rocky sea bottoms, but never assuming a reef-like structure. Their growth ex-

[30] Yabe, H., and Sugiyama, T., Reef building coral fauna of Japan: *Imp. Acad., Proc.*, vol. 7, no. 9, 1931; Reef corals found in the Japanese seas: *Sci. Rep Tôhoku Imp. Univ., Geol. Ser.*, vol. 15, no. 2, 1932.

TABLE IV.—List of the Reef-Corals Found Living in the Japanese Seas

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. Coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
Stylophora cfr. *danae* M.-Edw. and H.	—	x	—	x	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
pistillata (Esper)	—	—	—	—	—	—	—	—	x	—	x	—	—	x	—	—	—	—	—	x	—	—
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
nov. sp. ?	x	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Seriatopora angulosa Klunzinger	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
hystrix Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—	—
Pocillopora damicornis (Pallas)	—	—	—	—	x	—	—	—	x	—	x	x	x	x	—	—	—	—	—	—	x	x
damicornis var. *cespitosa* Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	—	—	—
ligulata Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
cfr. *elegans* Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
maeandrina Dana var. *nobilis* Verrill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	x
modumanensis Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
verrucosa (Ellis and Sollander)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	x
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
Galaxea fascicularis (L.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	x	x
clavus (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—
Euphyllia fimbriata Spengler	—	—	—	—	—	—	—	—	x	—	x	—	—	x	—	x	—	—	x	x	x	x
glabrescens (Chamisso and Eysenhardt)	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
Cyphastrea chalcidicum Klunz. incl. C. *ocellina* (Dana)	—	x	x	x	x	x	—	x	x	—	x	—	x	x	x	x	x	—	x	—	x	—
chalcidicum var. *tanabensis* Y. and S. nov.	—	—	x	x	x	—	—	—	—	x	—	—	x	—	x	—	—	—	—	—	—	—
japonica Y. and S. nov. sp.	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
microphthalma (Lam.)	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	—	—
serailia (Forskål)	—	x	—	x	x	x	x	—	—	x	—	—	x	x	—	—	—	x	—	x	x	—
cfr. *gardineri* Matthai	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
Stylocoenia japonica Y. and S. nov. sp.	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Leptastrea purpurea (Dana)	x	x	—	x	x	x	—	x	x	—	x	—	x	x	—	x	—	—	—	—	x	x
Echinopora lamellosa (Esper)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
Echinophyllia cfr. *contorta* (Quelch)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
sp. A	—	x	x	x	x	—	—	x	x	x	x	—	—	x	x	x	x	—	x	—	—	—
sp. B	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Orbicella curta Dana	—	—	—	—	x	—	x	—	—	—	—	—	—	x	—	—	—	—	—	—	x	x
gravieri Vaughan	—	—	—	x	—	—	—	—	—	x	—	—	—	—	x	x	—	—	—	x	—	—
cfr. *praehaliopora* Gregory	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
versipora (Lam.)	—	—	—	x	—	—	x	x	x	—	x	—	x	x	x	—	—	—	—	—	—	—
sp.	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	x	—	—
Favia cfr. *amplior* (M.-Edw. and H.)	—	x	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	x
cfr. *danae* Verrill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
magnistellata M.-Edw. and H.	—	—	x	x	—	x	x	x	x	x	x	—	x	x	—	—	—	—	—	x	x	—
cfr. *matthai* Vaughan	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
speciosa (Dana)	—	x	—	—	—	x	—	x	—	x	x	—	—	—	—	x	—	—	x	—	x	x
pallida (Dana)	—	x	x	x	x	x	—	x	—	x	—	—	—	x	x	—	—	x	—	x	x	

A=Riukiu; B=Taiwan; C=Ogasawara Group

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
Favites abdita (Ellis and Sollander)	—	x	—	—	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	—	—
virens (Dana)	—	—	—	—	—	—	—	—	x	—	x	—	—	x	—	—	—	—	x	—	—	—
sp.	—	—	—	—	—	—	—	—	x	—	x	—	—	x	—	—	—	—	—	—	—	—
Goniastrea aspera Verrill	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	x	—	—	—	—
parvistella (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
pectinata (Ehrenberg)	x	x	—	—	x	x	x	x	x	x	—	—	—	—	—	x	—	x	x	—	x	x
retiformis (Lam.)	—	—	—	—	x	—	x	x	x	—	x	—	—	x	—	—	x	—	x	—	x	—
sp.	—	—	—	—	x	—	x	x	x	—	x	—	—	x	—	—	—	—	—	—	—	—
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
Leptoria gracilis (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—
phyrygia (Ellis and Sollander)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—
sp. nov. ?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Maeandra daedalea (Ellis and Sollander)	—	—	—	x	x	—	x	—	x	—	x	—	x	x	—	—	—	?	—	—	x	—
edwardsi (Gardiner)	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—	—	—	x	—
esperi (M.-Edw. and H.)	—	—	—	—	x	—	x	x	x	x	x	—	—	x	—	x	—	—	—	—	—	—
lamellina Ehrenberg	—	x	—	x	x	x	?	x	x	—	x	x	—	—	—	x	x	—	x	—	x	x
stricta (M.-Edw. and H.)	—	—	—	x	x	—	—	—	x	—	—	—	—	—	—	—	—	—	x	—	x	—
sp. A	—	—	—	—	x	—	—	—	x	—	—	—	—	x	—	—	—	—	—	—	—	—
sp. B	—	x	—	—	—	—	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—
sp. C	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	x	—	—	—	—	—
sp. D	—	x	—	x	x	—	—	—	—	x	—	—	—	x	x	—	—	—	—	—	—	—
sp. E	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trachyphyllia amaranthus (Müller)	—	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—
Hydnophora exesa (Pallas)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	—	x	—	—	—
sp.	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sp.	—	—	—	x	—	—	x	—	—	—	x	x	—	—	—	—	—	—	—	—	—	—
Antillia constricta Brüggemann var. *kiiensis* Y. and S.	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
flabelliformis Y. and S.	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—
japonica Y. and S.	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fungia cfr. *costulata* Ortmann	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
cyclolites Lam. var.	x	x	—	x	x	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
fungites (L.) var. *haimei* Verril	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
granulosa Klunzinger	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
echinata (Pallas)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
paumotensis Stutchbury	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
rapanda Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
cfr. *scruposa* Klunzinger	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
scutaria Lam. var. *danae* Verrill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	x
scutaria Lam. var. *placunaria* Klunz.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—
sinensis M. Edw. and H.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
subrepanda Döderlein	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
Herpetolitha limax (Esper)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—

A=RIUKIU; B=TAIWAN; C=OGASAWARA GROUP

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
Döderleinia irregularis Gardiner.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Caulastrea aiharai Y. and S., nov. sp.	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
conglobata Y. and S., nov. sp.	—	—	—	x	x	—	—	x	x	—	x	—	—	—	—	—	—	—	—	—	—	—
multiseptata Y. and S.	—	—	—	x	x	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	—	—
yokoyamai Y. and S.	—	—	—	—	?	—	—	—	—	—	x	—	—	—	x	—	—	—	—	—	—	—
yokoyamai var. *gracilis* Y. and S.	—	?	—	x	—	—	—	—	x	—	—	—	—	x	—	—	x	—	—	—	x	x
Mussa cfr. *sinuosa* (Lam.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
cfr. *regalis* Dana	—	x	—	—	—	—	—	—	x	—	—	—	—	x	—	x	—	—	x	—	—	—
cfr. *tenuidentata* M.-Edw. and H.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
sp. A	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sp. B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
Symphyllia cfr. *acutus* Quelch	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
nobilis Dana	—	—	—	—	—	—	—	x	—	—	x	—	—	x	—	—	x	—	x	—	x	x
sp. nov. ?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Tridacophyllia laciniata M.-Edw. and H.	—	—	—	x	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—	x	—	—
laciniata var. *japonica* Y. and S., nov.	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cfr. *paeonia* (Dana)	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—
symphylloides M.-Edw. and H.	—	?	—	x	—	—	—	—	x	?	x	—	—	—	x	—	—	—	—	—	—	—
Acanthastrea cfr. *echinata* Dana	—	—	—	—	—	—	—	x	x	—	x	—	—	x	—	x	—	—	—	—	—	x
hemprichii (Ehrenberg)	—	x	—	—	x	x	x	x	x	—	x	x	x	x	—	x	x	—	x	—	—	—
Merulina ampliata (Ellis and Sol.)	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	x	—	x	—	x	x
laxa Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
Psammocora profundacella Gardiner	—	x	—	x	x	—	—	x	—	—	x	—	—	—	—	—	—	—	—	—	—	—
superficiales Gardiner	—	x	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
cfr. *gonagra* Klunzinger	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
sp.	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—
Agaricia ponderosa Gardiner	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
Pavona danai M.-Edw. and H.	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
decussata Dana	—	x	—	x	x	—	—	x	—	—	x	—	x	x	—	—	x	—	x	?	—	—
decussata Dana var. *minor* Y. and S., nov.	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	x	—	—
divaricata Lam.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
varians Verrill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
cfr. *frondifera* Lam.	—	—	—	—	—	—	—	—	—	—	x	—	x	x	—	—	—	—	x	x	—	—
Coscinarea columna (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
monile (Forskål)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—
Podabacia crustacea (Pallas)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
lobata Van der Horst	—	?	—	x	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—	—	—	—
lobata forma *kiiensis* Y. and S., nov.	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—
lobata forma *numaensis* Y. and S., nov.	—	—	—	—	—	—	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—

A = RIUKIU; B = TAIWAN; C = OGASAWARA GROUP

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
lobata forma *vanderhorsti* Y. and S., nov.	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
lobata var. *elegans* (Van der Horst)	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
lobata var. *elegans* forma *pilicata* Y. and S., nov.	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
lobata var. *elegans* forma *setoensis* Y. and S., nov.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–
lobata var. *elegans* forma *variians* Y. and S., nov.	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
formosa Y. and S., nov. sp.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	x	–	–
Coeloseris mayeri Vaughan	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
Astraeopora cfr. *gracilis* Bernard.	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	x	–	–	x	–	–	–
cfr. *incrustana* Bernard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
Turbinaria cfr. *auricularis* Bernard	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
brüggemanni Bernard	–	–	–	?	–	–	–	–	–	–	x	–	–	–	–	–	–	x	–	–	–	–
contorta Bernard	x	–	–	x	x	x	x	x	x	–	x	x	x	x	x	x	x	–	x	–	–	–
elegans Bernard	–	–	–	x	–	–	–	–	x	–	–	–	–	x	–	–	x	–	x	–	x	x
peltata (Esper)	–	x	–	x	x	x	–	–	x	–	x	x	x	x	–	x	x	–	–	–	–	–
sinensis Verrill	–	–	–	?	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
tubifera Bernard	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	x	–	x	–
undata Bernard	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
sp.	–	–	–	x	x	–	–	x	–	–	x	–	–	–	x	–	–	–	–	–	–	–
Goniopora sp. A	–	–	–	–	–	–	–	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–
sp. B	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
sp. C	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–
sp. D	–	x	–	–	x	–	–	x	x	–	–	–	–	x	–	x	–	–	–	–	–	–
sp. E	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Montipora cactus Bernard	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
calcarea Bernard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
challengeri Bernard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	x
cfr. *effusa* (Dana)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	–
cfr. *ehrenbergi* Verrill	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–
cfr. *elschneri* Vaughan	–	–	–	x	x	–	–	–	x	–	–	–	–	x	–	–	–	–	–	–	–	–
foliosa (Pallas)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	x
hispida Dana	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	x	x	–
informis Bernard	–	–	–	–	–	–	–	–	x	–	x	–	–	–	–	–	–	–	x	–	x	x
lanuginosa Bernard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
levis Quelch	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–
patula Verrill	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
pulcherima Bernard	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	–
ramosa Bernard (in the sense of Vaughan including *compressa*)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	x	x
cfr. *squamosa* (Lam.)	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
nov. sp. ?	–	–	–	x	–	–	x	–	x	–	–	–	–	x	–	–	–	–	–	–	–	–
cfr. *venosa* (Ehr.)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x

A = RIUKIU; B = TAIWAN; C = OGASAWARA GROUP

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
verrilli Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	x	—
verrilli Vaughan var. *auaensis* Hoffm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	x	x
verrilli Vaughan var.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
verrucosa (Lam.)	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	x	—
sp. A	—	—	—	—	—	—	—	—	x	—	x	—	—	—	—	x	x	—	—	—	—	—
sp. B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
Acropora (*Eumadrepora*) cfr. *abrotanoides* (Lam.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Eumadrepora*) *formosa* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Eumadrepora*) *formosa* (Dana) var. *gracilis* (Dana)?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Eumadrepora*) *formosa* var. *brachiata* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	—
(*Eumadrepora*) *gravida* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	—
(*Eumadrepora*) *haimei* (M.-Edw. & H.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	x	—
(*Eumadrepora*) cfr. *muricata* L.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Eumadrepora*) *muricata* L. forma *plamata* Lam.	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
(*Eumadrepora*) cfr. *smithi* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
(*Eumadrepora*) *tutuilensis* Hoffmeister	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
(*Isopora*) *nobilis* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
(*Isopora*) *palifera* (Lam.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Lepidocyathus*) *hehes* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—	—
(*Lepidocyathus*) *squamosa* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Lepidocyathus*) cfr. *studeri* (Brook)	x	—	—	x	x	x	x	—	x	—	x	—	x	x	—	x	x	—	—	—	—	—
(*Lepidocyathus*) *sublata* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Polystachys*) cfr. *anthocervis* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Polystachys*) *cerealis* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
(*Polystachys*) cfr. *conferta* (Quelch)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Polystachys*) cfr. *hyacinthus* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	x	—
(*Polystachys*) cfr. *latistella* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
(*Polystachys*) cfr. *pectinata* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
(*Polystachys*) cfr. *quelchi* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—

A=RIUKIU; B=TAIWAN; C=OGASAWARA GROUP

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHÛ					SHIKOKU					KIUSHÛ								A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
(*Polystachys*) cfr. *quelchi* (Brook) var. *paradoxa* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Polystachys*) *sinensis* (Brook)	—	—	—	—	x	—	—	—	x	—	—	—	—	—	—	—	—	—	—	x	—	—
(*Rhabdocyathus*) *hemprichi* (Ehr.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Rhabdocyathus*) cfr. *hemprichi* (Ehr.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Rhabdocyathus*) *squarrosa* (Ehr.)	—	x	—	x	x	x	—	—	—	—	x	—	—	x	—	x	x	—	—	—	—	—
(*Rhabdocyathus*) *valida* (Dana)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	x
(*Rhabdocyathus*) *variabilis* (Klunz.)	—	—	—	—	?	—	—	—	—	—	x	—	—	—	—	—	—	x	—	x	x	—
(*Rhabdocyathus*) sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
(*Tylopora*) *gemmifera* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
(*Tylopora*) *leptocyathus* (Brook)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	x	—	x	—
(*Tylopora*) cfr. *pagoensis* Hoffmeister	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—
(*Tylopora*) *scherizeriana* (Brüggemann)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
sp. A	—	—	—	x	x	x	—	—	x	—	x	—	x	x	—	x	—	—	—	—	—	x
sp. B	—	—	—	—	x	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—
sp. C	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
sp. D	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
sp. E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	x	—	—
sp. F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
sp. G	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—
Porites andrewsi Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
cfr. *australiensis* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—
cfr. *ceylonica duodecima* Bernard	—	x	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—
compressa Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
compressa Dana forma *abacus* Vaughan	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	x	—	x	—	—	—	—
cfr. *compressa* forma *fragilis* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
convexa (Verrill)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
cfr. *haddoni* Vaughan	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	x	—	—	—	—
lanuginosa Studer	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
latistellata Quelch var. ?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
lichen Dana	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
cfr. *lobata* Dana forma *centralis* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
cfr. *lobata* Dana forma *centralis* subforma *alpha* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	—

A = Riukiu; B = Taiwan; C = Ogasawara Group

TABLE IV. (*Continued*)

SPECIES \ LOCALITIES	HONSHU					SHIKOKU					KIUSHÛ							A		B	C	
	Tateyama-wan	Enoura-wan	Yura-wan	Tanabe-wan	Kushimoto	Muroto-saki	Tei	Susaki	Misaki	Uwajima-wan	Hiuga coast	Ôsumi coast	Kagoshima-wan	So. coast of Satsuma	Hizen coast	Amakusa	Koshiki-jima	Sakishima Subgroup	Ôshima Subgroup	Sharyôtô	Chichi-jima	Haha-jima
cfr. *lobata* Dana *centralis* subforma *epsilon* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
cfr. *lutea* M.-Edw. and H.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
cfr. *murrayensis* Vaughan	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
nigrescens Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	—	—	—
cfr. *purpurea* Gardiner	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—
cfr. *quelchi* Studer	—	—	—	x	—	—	x	x	—	x	x	x	—	—	—	—	—	—	—	—	—	—
salomonis quarta Bernard	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—
schauinslandi Studer	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
sinensis noma Bernard ?	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
singaporensis quinta Bernard	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—
cfr. *somaliensis* Gravier	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	x	x
tenuis Verrill	—	—	—	—	x	—	—	—	—	—	—	—	x	—	—	—	—	x	—	x	x	x
sp. A	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—
sp. B	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—	—
sp. C	—	—	—	—	—	—	—	—	—	x	—	—	—	—	—	—	—	—	—	—	—	—
sp. D	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
sp. E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x
Alveopora cfr. *verrilliana* Dana	—	—	—	x	—	—	—	—	—	—	x	—	—	—	—	x	—	—	—	—	x	x
Heliopora coerulea (Pallas)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x	x	—	—
Tubipora musica L.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
Millepora cfr. *platyphyllia* Ehr.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—
tortuosa Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	?	x	—	—
truncata Dana	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	x
sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	—

A=RIUKIU; B=TAIWAN; C=OGASAWARA GROUP

tends up to the shallower sea floor, where they are exposed at the low neap tide. As to how deep the coral growth extends along these coasts, we have at present no information. Certain corals seem to be markedly tolerant of mud. For instance, several species of *Podabacia*, *Favia*, *Cyphastrea*, *Hydnophora*, and *Acropora* are living in calm water inside the Tanabe-wan, where influx of muddy water from land is frequent (Text-Fig. 3).

The northernmost localities of reef corals are in Tateyama-wan, lat. 35°10′ N., long. 139°50′ E., and Enoura-wan, lat. 35°05′ N., long. 138°12′ E. The monthly temperature and specific gravity of the sea water at Tateyama, on Tateyama-wan, in 1921 and those at Seto, on Tanabe-wan, in 1929 are as shown on page 207.

The Riukiu Islands, Ogasawara Islands and Taiwan have coral reefs, fringing reefs or bank barriers, where the conditions for growth are favorable.

Monthly Temperature and Specific Gravity of Sea Water at Tateyama and Seto

Tateyama, Tateyama-wan			Seto, Tanabe-wan		
1921	Temp. C°	Sp. Gr.	1929	Temp. C°	Sp. Gr.
1	13.0	24.95	1	12.1	25.5
2	12.1	25.39	2	15.3	25.8
3	13.5	25.22	3	16.6	25.5
4	14.8	24.70	4	18.8	24.5
5	18.1	24.82	5	22.1	23.3
6	19.6	24.79	6	23.5	22.4
7	23.2	25.26	7	26.8	21.5
8	24.2	24.70	8	27.7	20.3
9	23.6	23.76	9	27.0	20.1
10	20.8	23.96	10	23.0	21.6
11	17.0	25.37	11	21.3	23.0
12	14.2	24.90	12	15.0	23.4

S. Hanzawa, of our Geological Institute, who visited several times the Riukiu Islands for geological study gave us the following information about the coral reefs of Okinawa-jima and the islands of the Sakishima subgroup (Miyako-jima, Ishigaki-jima, Yonaguni-jima, Iriomote-jima), where he had opportunities to make observations on these structures.

Coral reefs along the coasts of these islands are fringing reefs; some of them may better be called bank barriers. They vary in breadth even about the same island—for instance, having a breadth of 2000 to 2500 m. along the northeastern coast of Iriomote-jima and of 250 to 1500 m. along its southwestern coast; 1000 to 1600 m. along the eastern coast of Ishigaki-jima and 200 (or less) to 900 m. along its western coast.

Around Okinawa-jima fringing reefs are well developed, broadest near Itoman and near Naha, where they are 4000 and 3000 m. broad, respectively, though at certain places they are reduced to a narrow belt of hardly 150 m. width. Northeast of Guschichan, coral reefs occupy a narrow off-shore belt some 4000 m. from shore, within which the water has an average depth of 2 m. and a maximum depth of 9 m.

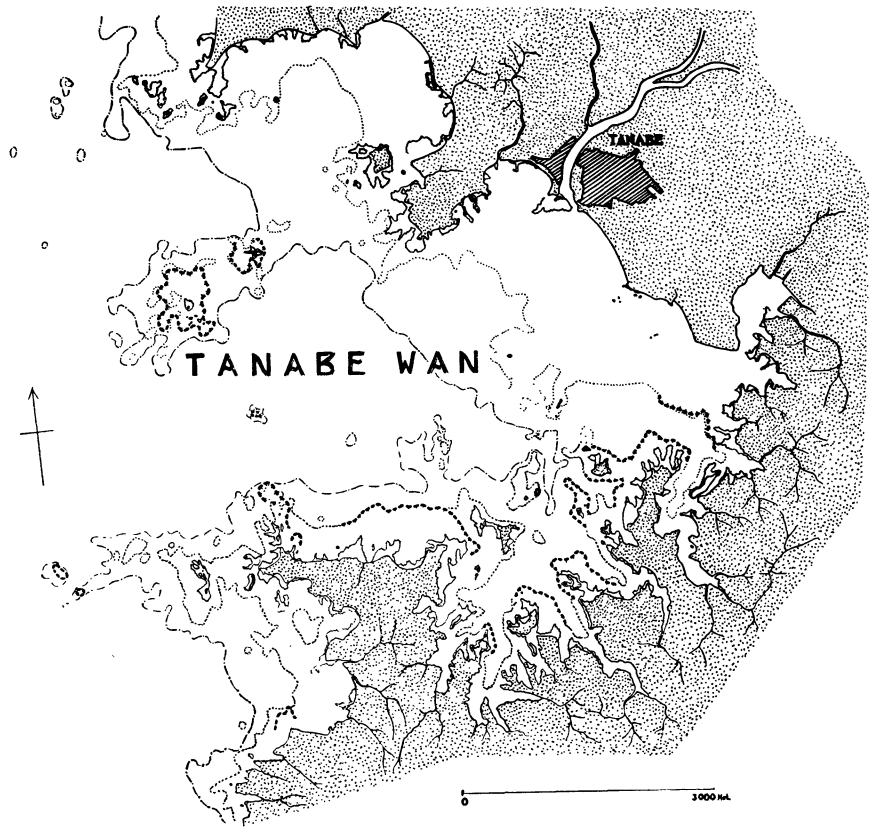
The breadth of the coral reefs around Okinawa-jima seems to depend on various factors. Among them two factors are believed to be especially important: (1) the breadth of the higher submarine terraces,[31] with their outer boundary slope descending steeply from 40 m. to 80 m., or occasionally from 30 m. to 60 m.; (2) the rate of the latest land submergence. The island being divided into many geological blocks by dislocations younger than the building of the submarine terraces, the coral reefs built or being built on the higher terraces are very variable in breadth from place to place.

The fringing reefs of Okinawa-jima as well as the islands of the Sakishima subgroup have the so-called boat channel inside the outer rim, which is slightly exposed above

[31] The island is surrounded by terraces of 2 different depths; the lower terraces are limited seaward by the steep slope between 100 m. and 140 m.

sea level at low water as dark brown bars several meters broad running subparallel to the shore. At low water the boat channels are transformed almost to lagoons. The bottom of these boat channels, or reef flats lying beneath a thin sheet of sea water, is usually covered by foraminiferal sands over a considerable area, and is often quite free from living coral stocks. At places it is covered by dense groves of staghorn-shaped stocks of *Acropora*, or at other places with massive heads of *Favia*, *Favites*, *Goniastrea*, *Porites*, etc., in groups.

The reefs are traversed more or less radially by many passages and numerous furrows. The latter are narrower and shorter than the passages and of a quite different nature, being deep transverse clefts extending from the reef-margin and only in narrow reefs reaching near to the shore. The furrows are narrow, 1 m. or less to 2 or 3 m. broad, and are bordered by steep or even overhanging side-walls.



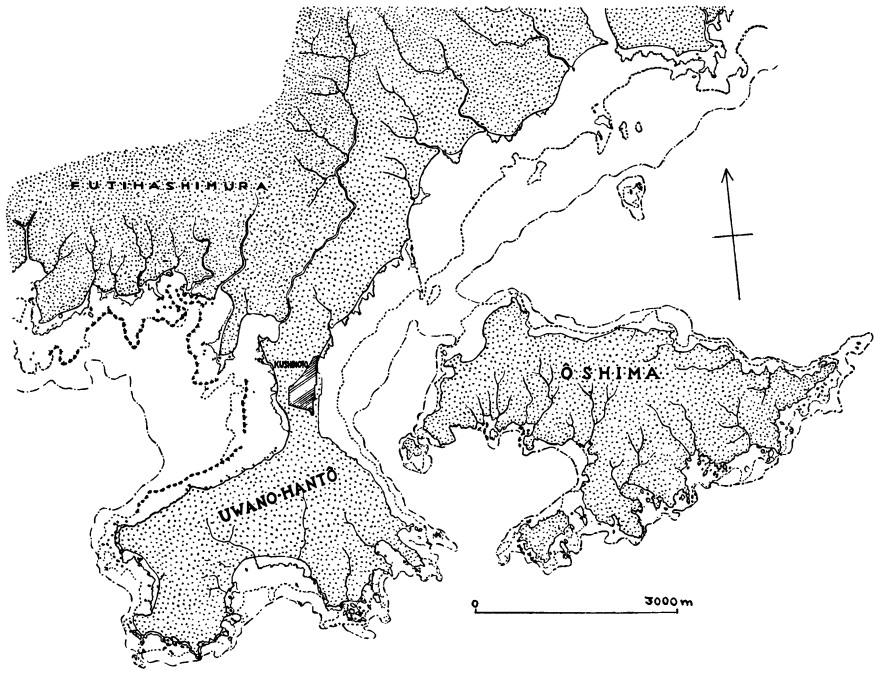
TEXT-FIG. 3—Tanabe-wan: distribution of reef corals; dotted line, 10 m. depth; chain line, 20 m. depth; heavy broken line, outer margin of reef area.

Some of the passages were antecedent to the building of coral reefs, possibly being drowned valleys, though other passages, as well as all the furrows, have no relation to the drowned valleys.

The furrows are sometimes interpreted as a product of erosion by streamlets of sea water dashing on and withdrawing from the surface of the reefs, but Hanzawa looks on them rather as chasms left between the lateral borders of lobes into which the growing outer margins of the reefs are divided. In this explanation the furrows on the reef surface from their heads outwards gradually become shallower and are finally abolished by growing organisms, instead of being gradually enlarged by erosion. Reef corals enjoy luxuriant growth along and near the margin of reefs and in the furrows.

The mean monthly temperature and specific gravity of sea water at Ishigaki-jima, Sakishima subgroup, is as shown on page 210.

On the other hand, the more northerly islands—Kiushû, Shikoku and Honshû—have no well developed coral reefs, although reef building corals thrive along the Pacific coasts of Shikoku and Honshû and along the Pacific as well as Genkai-



TEXT-FIG. 4—Kushimoto: distribution of reef corals; dotted line, 10 m. depth; chain line 20 m. depth; heavy broken line outer margin of reef area.

Monthly Temperature and Specific Gravity of Sea Water at Ishigaki-jima

1931	Temp. C°	Sp. Gr.
1	19.4	24.98
2	21.2	25.18
3	20.7	25.18
4	22.7	25.50
5	26.1	25.12
6	27.5	25.00
7	28.8	24.85
8	28.8	24.83
9	28.5	23.86
10	25.9	24.45
11	24.0	25.03
12	21.4	25.31

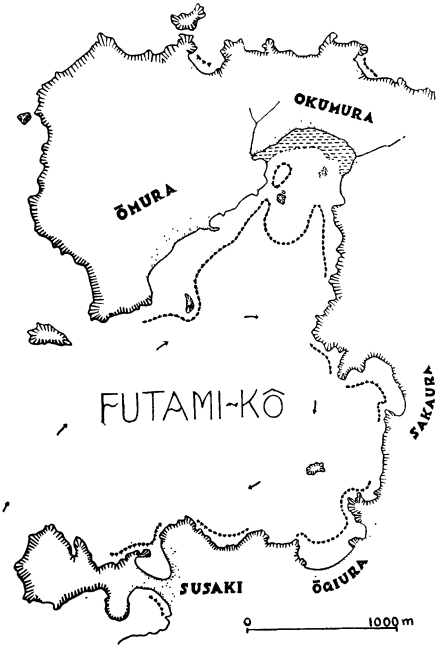
nada coasts of Kiushû under the influence of the warm-water current, Kuroshiwo, from the south, and its branches. The northernmost points on the Japanese coasts where the coral growth is more or less vigorous are Enoura, on Suruga-wan, and Tateyama-wan of the Sagami-nada, in lat. 35°10′ N.

The Ogasawara (Bonin) group is situated some 15° of longitude east of Okinawa-jima. Sugiyama made the following observation about the coral growth along the coasts of Chichi-jima and Haha-jima, the two largest islands of the group.

Reef corals are not flourishing along the east coast of the islands, which is directly exposed to strong winds and violent oceanic waves, owing to the rapid descent of the sea bottom off shore. They seem to prefer the more sheltered places in these islands, as their growth is most vigorous, for instance, in Futami-wan, Miyanohama, Tsurihama, and Susaki on Chichi-jima, and the coast of Okimura, Nishiura and Nankinhama on Haha-jima.

Futami-wan, of Chichi-jima (Text-Fig. 5), almost the only harbour of the island group, is an inlet open to the west. Its dimensions are 2 km. east-west and 1.5 km. north-south, apart from a northeastern extension 1.5 km. long. The water is shallow, some 80 m. at the deepest (middle) part. It is deeper along the line diametrically traversing the bay from the head of its northeastern section southwestwards.

North-east and south-west gales prevail, but at no time is the water of the northeastern section of the bay much disturbed. This part is well



TEXT-FIG. 5—Futami-wan, Chichi-jima; distribution of reef corals; arrows show currents; heavy broken line, outer margin of reef area.

sheltered from the wind and is the only place where reef corals are luxuriant.

Reef corals, especially branching *Acropora haimei* (M.-Edw. and H.)

and *A. formosa* (Dana) var., thrive in the northeastern section of the bay to a depth of about 25 m. and there a kind of fringing reef has been built. The coral reef is 150 m. broad along the coast of Byôbudani and Ômura and has grown to a lobe prolonged southwestwards just over the deep median part between the 2 coasts; the lobe is 800 m. long and 1.5 m. high at its distal, outgrowing edge. In front of it the sea bottom is muddy.

Fifteen meters is an estimated thickness of the coral reef, estimated on the mean slope of the sea bottom off shore at this place; a well dug through the sandy plain of the coast of Byôbudani passed through a reef rock 12 m. thick and from this the above estimation is verified.

Along the western half of the coast of Ômura the coral growth is less vigorous, the sea bottom being overgrown by numerous stocks but with their interspaces left bare. The coral fauna is, however, more varied in this part than in the reef within the northeastern section. In the latter we see an extensive grove of branching *Acropora haimei* covering the entire surface of the reef, while in the former, *Montipora*, several species, and *Pocillopora*, especially *Pocillopora maeandrina*, are most abundant among many other corals. *Millepora* and *Porites* like more agitated water and are common along the outer margin of the belt of growing corals; the former is especially flourishing at Sakaura on the eastern coast of the bay.

Miyanohama is rich in *Tubipora musica*. The coral fauna of this place is much like that of the coast of Oki-mura in Haha-jima. *Fungia* is also common in both places.

Coral growth is not so luxuriant along the coast of Nankinhama and Oki-mura, Haha-jima, as to cover the entire surface of the sea bottom, the foundation being always more or less exposed between the coral stocks.

Coral growth in the Ogasawara Group differs essentially from that along the coasts of Kiushû, Shikoku and Honshû in that corals are living in shallower waters and their stocks

Monthly Temperature and Specific Gravity of Sea Water at Kanameiwa

Kanameiwa, Futami-wan
April, 1930 to March, 1931

	Surface		−10 m.		−25 m.	
	Temp. C°	Sp. Gr.	Temp. C°	Sp. Gr.	Temp. C°	Sp. Gr.
1	21.5	25.29	21.3	25.46	21.2	25.58
2	21.5	25.16	21.2	25.00	21.2	24.82
3	21.2	25.35	21.3	25.33	20.9	25.35
4	21.3	25.85	20.9	25.89	20.6	26.16
5	23.9	26.00	23.5	26.01	23.3	26.18
6	25.5	26.37	24.6	26.15	24.6	26.25
7	26.4	25.98	24.8	26.07	23.5	26.19
8	24.9	25.31	23.8	25.32	23.9	25.35
9	26.2	25.95	25.9	25.82	25.0	25.98
10	25.9	25.54	25.6	25.73	25.0	25.71
11	24.3	25.14	24.1	25.57	23.3	25.43
12	22.2	25.63	22.2	25.58	21.8	25.61

are exposed above the water at neap tides (Pl. 21).

The mean temperature and specific gravity of water at Kanameiwa on Futami-wan is as follows:

Some 2000 samples of reef coral stocks have been collected from Taiwan, the Riukiu Islands, the Ogasawara Islands, Kiushû, Shikoku and Honshû, and 249 species, including varieties and formae, in 44 genera were provisionally discriminated among them, as follows:

Reef Corals from Taiwan, Riukiu Islands, Ogasawara Islands, Kiushû, Shikoku and Honshû.

Stylophora, 4 sp.
Seriatopora, 2 sp.
Euphyllia, 2 sp.
Cyphastrea, 5 sp., 1 var.
Stylocoenia, 1 sp.
Leptastrea, 1 sp.
Echinopora, 1 sp.
Echinophyllia, 3 sp.
Orbicella, 5 sp.
Favia, 6 sp.
Favites, 3 sp.
Goniastrea, 6 sp.
Leptoria, 3 sp.
Maeandra, 10 sp.
Trachyphyllia, 1 sp.
Hydnophora, 3 sp.
Antillia, 3 sp.
Fungia, 13 sp.
Herpetolitha, 1 sp.
Döderleinia, 1 sp.
Caulastraea, 4 sp., 1 var.
Mussa, 5 sp.
Symphyllia, 3 sp.
Tridacophyllia, 3 sp., 1 var.
Pocillopora, 7 sp., 1 var.
Galaxea, 2 sp.
Acanthastrea, 2 sp.
Merulina, 2 sp.
Psammocora, 5 sp.
Agaricia, 1 sp.
Pavona, 5 sp., 1 var.
Coscinarea, 2 sp.
Podabacia, 3 sp., 7 var. and forma
Coeloseris, 1 sp.
Astraeopora, 2 sp.
Turbinaria, 9 sp.
Goniopora, 5 sp.
Montipora, 23 sp., and var.
Acropora, 42 sp., var. and forma
Porites, 30 sp., var. and forma
Alveopora, 1 sp.
Heliopora, 1 sp.
Tubipora, 1 sp.
Millepora, 4 sp.

Our reef coral fauna is exceedingly varied, contrary to our expectation, as is evident in a comparison with the fauna of the Philippine seas, where coral reefs of varied types are well developed. From this region Faustino[32] enumerated 154 well established species and varieties in 40 genera; in detail he had:

Reef Corals from the Philippine Seas

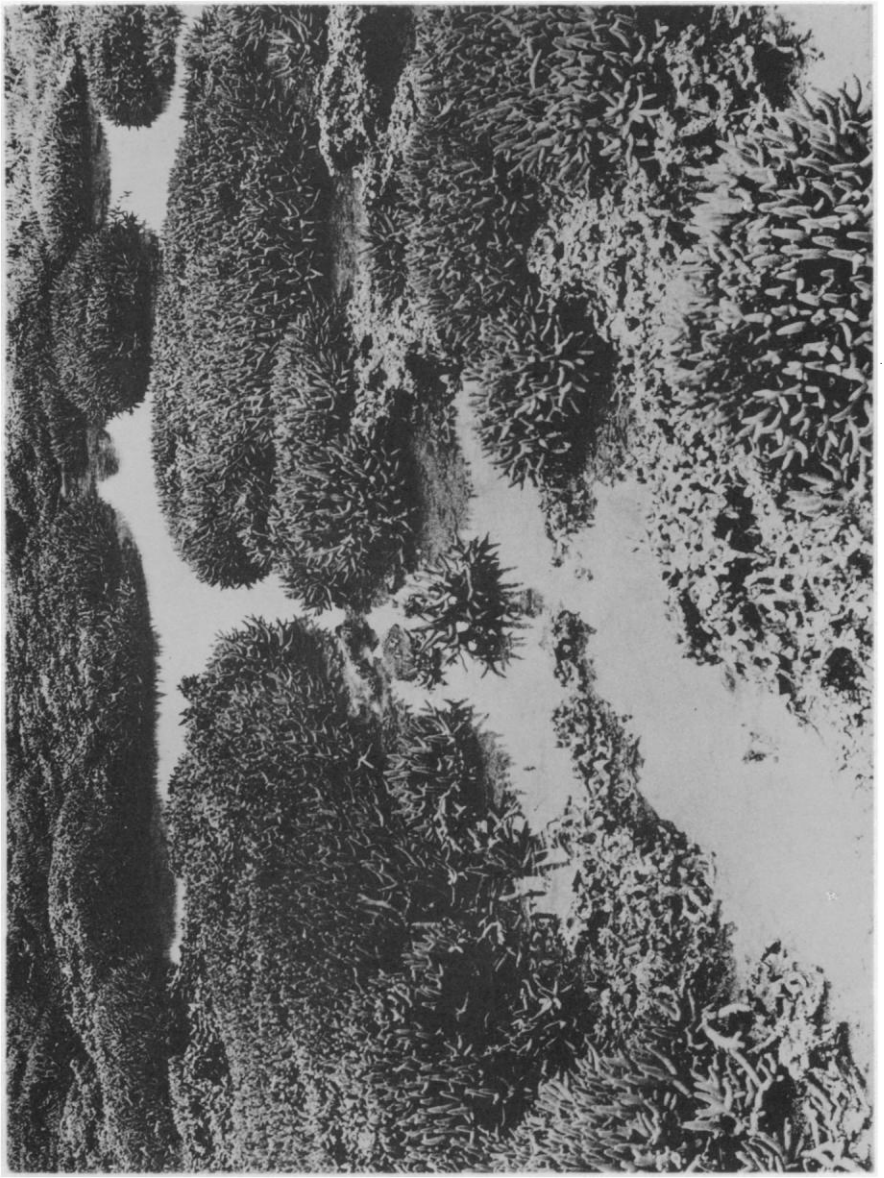
Stylophora, 4 sp.
Seriatopora, 8 sp., 1 var.
Pocillopora, 4 sp.
Euphyllia, 1 sp.
Cyphastrea, 4 sp.
Leptastrea, 2 sp.
Echinopora, 2 sp.
Galaxea, 3 sp.
Favia, 4 sp.
Favites, 4 sp.
Goniastrea, 3 sp.
Leptoria, 2 sp.
Maeandra, 4 sp.
Trachyphyllia, 1 sp.
Hydnophora, 3 sp.
Antillia, 1 sp.
Mussa, 4 sp.
Symphyllia, 1 sp.
Pectinia (=*Tridacophyllia*), 4 sp.
Acanthastrea, 1 sp.
Merulina, 4 sp.
Fungia, 16 sp., 2 var.
Halomitra, 4 sp.
Herpetolitha, 1 sp.
Polyphyllia, 1 sp.
Agaricia, 1 sp.
Pachyseris, 1 sp.
Pavona, 3 sp.
Podabacia, 1 sp.
Haloseris 1 sp.
Leptoseris, 1 sp.
Coeloseris, 1 sp.
Aulastraea, 1 sp.
Turbinaria, 1 sp.
Montipora, 6 ap.
Acropora, 29 sp., 1 var.
Goniopora, 5 sp.
Porites, 9 sp.
Heliopora, 1 sp.
Millepora, 3 sp.

In his papers Faustino made no mention of *Caulastraea*, *Orbicella*, *Echinophyllia*, and *Astraeopora*, which are well represented in the Japanese seas. The Philippine seas also seem to be characterised by the paucity of species of *Turbinaria*, *Podabacia* and *Antillia*, which are common in the Japanese seas.

In the Atlantic Ocean reef corals enjoy vigorous growth 1 to 3 ft. below tide around the Bermuda Islands, lying in lat. 32°15′ to 32°23′ N. and hence approximately in the same latitude as Hosojima, on the coast of Hiuga (Kiushû). The islands are situated amid the Gulf stream, and the

[32] Faustino, L. A., Coral reefs of the Philippine Islands: *Philippine Jour. Sci.*, vol. 44, no. 3, pp. 291–305, 1931; *Recent Madreporaria of the Philippine Islands*, 1927.

EXPLANATION OF PLATE 21—*Acropora haimei* grove exposed at low tide, Ô-mura, Futami-wan (northwestern coast), Chichi-jima.



Yabe and Sugiyama, Reef Corals

temperature of the surface sea water is higher than in the southern part of Kiushû.

Mean Monthly Surface Temperature of Sea Water (after Verrill)[33]

January	15° –17°.2
February	15° –17°.2
March	16°.6–18°.8
April	18°.8–21°.6
May	21°.1–24°.4
June	23°.8–26°.6
July	26°.1–28°.3
August	27°.7–29°.4
September	18°.3–23°.8
October	23°.8–20°.5
November	20°.5–18°.3
December	18°.3–16°.1

Coral reefs which are sometimes called pseudatolls cover an extensive area between 32°30′ to 32°12′, and mark the northern limit of the typical coral reefs in the Atlantic.

The reef coral fauna of Bermuda is remarkably poor in the number of genera and species represented. Verrill once distinguished in the shallow water around the islands 22 species and varieties of corals, which belong to the following 10 genera: *Maeandra* (2 species), *Favia* (1), *Mussa* (including *Isophyllia*) (5), *Orbicella* (1), *Stephanocoenia* (1), *Oculina* (4 and 1 variety), *Madracis* (1), *Porites* (2), *Siderastrea* (2), and *Agaricia* (1). In addition there is a species of *Millepora*.

It is stated that the reef coral fauna of Bermuda was probably derived from that of the West Indies in post-Pleistocene time. There is an essential and striking difference between the two faunas, namely, the total absence in Bermuda of corals belonging to the genera *Cyphastrea* and *Acropora*. A similar difference in the constitution of reef coral faunas exists between the Hawaiian Islands and the Philippines-East Indies.

We are well informed concerning the reef-building coral fauna of the Hawaiian Islands through the elaborate work of T. W. Vaughan.[34] According to him, there are 86 species and varieties in 16 genera. The dominant types of coral found there are *Pocillopora*, *Porites*, and *Montipora*, which are well represented in the number of species and abundant in the number of individuals. On the other hand, the absence or rarity of *Acropora*, *Orbicellidae*, *Favidae*, and *Mussiidae* is worthy of special notice. These genera being represented by a number of species in the Japanese seas, their absence or rarity in the Hawaiian seas can not be attributed solely to the lower temperature of sea water as compared to that of the more southern or southwestern tropical coral seas. This fact is considered by us as evidence rather favorable to the explanation suggested by Vaughan for the absence or rarity of *Acropora* in the Hawaiian Islands in the middle of the Pacific, as well as in the Bermuda Islands in the middle of the Atlantic. Each of them lies some distance from the chief areas of reef corals in its own region.

A. G. Mayor and C. Crossland[35]

[33] Verrill, A. E., The Bermuda Islands: *Conn. Acad. Arts Sci., Trans.*, vol. 11, part 2, p. 503, 1901–1902.

[34] Vaughan, T. W., *Recent Madreporaria of the Hawaiian Islands and Laysan*, 1907. Temperature of the surface sea water in the Hawaiian seas is February, 23° to 24°; May, 24°; August, 25°; November, 25°. Daly, R. A., The glacial-control theory of coral reefs: *Am. Acad. Arts Sci., Proc.*, vol. 51, no. 4, p. 168. 1915.

[35] Crossland, C., Notes on the ecology of the reef-builders of Tahiti: *Zool. Soc. London, Proc.*, (1928), part 2, p. 718.

Composition of Japanese Reef Coral Faunas

Genera	Number of species in each genus	Northern		Riukiu	Ogasawara
		Honshû and Shikoku	Kiushû		
Stylophora	4	3	1	1	0
Seriatopora	2	0	0	2	0
Pocillopora	8	1	1	5	5
Galaxea	2	0	0	2	2
Euphyllia	2	2	1	2	1
Cyphastrea	6	5	3	2	3
Stylocoenia	1	1	0	0	0
Leptastrea	1	1	1	0	1
Echinopora	1	0	0	0	1
Echinophyllia	3	2	1	1	1
Orbicella	5	4	4	1	1
Favia	6	5	3	3	5
Favites	3	3	3	1	0
Goniastrea	6	3	4	5	2
Leptoria	3	0	0	3	2
Maeandra	10	9	7	3	4
Trachyphyllia	1	1	0	0	0
Hydnophora	3	3	2	1	0
Antillia	3	3	0	0	0
Fungia	13	1	2	10	2
Herpetolitha	1	0	0	1	0
Döderleinia	1	0	0	1	0
Caulastrea	5	5	4	0	1
Mussa	5	2	1	1	3
Symphyllia	3	1	1	2	1
Tridacophyllia	4	4	3	0	0
Acanthastrea	2	2	2	1	1
Merulina	2	0	1	2	1
Psammocora	5	2	3	0	1
Agaricia	1	0	0	0	1
Pavona	6	2	3	2	2
Coscinarea	2	0	1	0	1
Podabacia	10	7	5	1	0
Coeloseris	1	0	0	1	0
Astraeopora	2	1	1	1	1
Turbinaria	9	8	7	4	2
Goniopora	5	2	3	1	0
Montipora	23	8	6	10	16
Acropora	42	8	6	22	20
Porites	30	7	8	17	9
Alveopora	1	1	1	0	1
Heliopora	1	0	0	1	0
Tubipora	1	0	0	0	1
Millepora	4	0	0	2	2
Total No. of Species	249	105	92	112	94
Total No. of Genera	44	31	29	33	30

have shown that the coral fauna becomes gradually poorer eastwards in the southwestern Pacific. The former author estimated that of Samoa at only two-thirds of that of northern Australia, and the latter found 11 genera present in Samoa which are absent in Tahiti.

Crossland listed the following 16 genera absent from Tahiti, of which those marked F are recorded from Fiji (or Rotuma) and those marked S from Samoa:

Seriatopora	F	*Goniastrea*	FS
Acrohelia	F	*Leptoria*	FS
Euphyllia	FS	*Maeandra*, i.e. *Coeloria*	FS
Echinophora	F	*Hydnophora*	FS
Galaxea	FS	*Symphyllia*	FS
Favites	FS	*Merulina*	S
Diploastrea	FS	*Turbinaria*	F
Astraeopora	FS	*Goniopora*	

Furthermore, it is stated that *Heliopora* and *Tubipora* are also lacking in Tahiti, and 5 genera, *Lobophyllia* (*Mussa*), *Stylophora*, *Favia*, *Cyphastrea* and *Pachyseris* are in process of disappearance.

Our Japanese reef coral fauna is geographically separable into three sub-faunas, the Ogasawara, the Riukiu, and the northern (Honshû, Shikoku and Kiushû) subfauna. Taiwan is for the present excluded from consideration, as the material now available is very scanty and is from the northernmost part only. From the geographical position of the island, however, it may not be misleading to assume that its coral fauna is intermediate in composition between that of the Philippines and that of the Riukiu.

The number of genera and species of corals constituting the subfaunas are shown on preceding page.

The number of genera common to each pair of these subfaunas is:

Reef Coral Genera Common to Subfaunas

	N.		R.	O.
	H.-S.	K.		
H.-S.	31	28	22	22
K.	28	29	24	25
R.	22	24	33	22
O.	22	25	22	30

The number of species common to each pair of these subfaunas is:

Reef Coral Species Common to Subfaunas

	N.		R.	O.
	H.-S.	K.		
H.-S.	105	63	24	27
K.	63	92	32	29
R.	24	27	112	35
O.	27	29	35	94

Gradual reduction of reef corals in number of species and genera is expected in passing from the central area of coral growth in the tropical regions toward the northern and southern seas of the temperate regions, as physical conditions adverse to the life of reef corals gradually appear. Superficially just the reverse is, however, shown by the above list of genera, the number of species being inferior in the Riukiu and Ogasawara subfauna to that in the northern subfauna. This is, we believe, partly ascribable to the following circumstances:

(1) *Podabacia* and *Caulastraea* living along the coasts of Honshû and Shikoku are very variable, and they have contributed much toward multiplying the number of species, varieties, and formae.

(2) Where reef-corals are most prosperous and the dominant types are found in overwhelming number of individuals, the collecting of less numerous elements is a task of greater difficulty than at places where corals are less flourishing.

Nevertheless, it is marvellous that 105 species, in 31 genera, are found along the coasts of Honshû and Shikoku, and the conclusion seems inevitable that the reduction of genera and species in passing from the tropical Pacific to our latitudes is but slight.

The three subfaunas of the Japanese reef corals, in comparison with one another, show interesting differences.

The northern subfauna has the following characteristics: (1) Absence of *Tubipora*, *Millepora*, *Heliopora*, *Galaxea*, *Coeloseris*, *Echinopora*, *Seriatopora*, *Leptoria*, and *Agaricia;* (2) relative rarity of *Mussa*, *Symphyllia*, *Pocillopora*, and *Porites*, and great rarity of *Fungia;* (3) abundance of *Hydnophora* and *Turbinaria*, and richness in varieties of *Caulastraea* and *Podabacia*.

The characteristic aspect of the Riukiu subfauna consists in (1) the absence(?) of *Tubipora*, and the absence or rarity of *Hydnophora*, *Antillia*, and *Podabacia;* (2) presence of *Heliopora*, *Millepora*, *Seriatopora*, *Galaxea*, and *Leptoria;* (3) great abundance of *Fungia*, *Acropora*, *Montipora*, and *Porites*.

The Ogasawara subfauna is distinguished by (1) the absence(?) or great rarity of *Heliopora*, *Seriatopora*, *Hydnophora*, *Antillia*, and *Podabacia*, and rarity of *Turbinaria;* (2) presence of *Echinopora* and *Agaricia*, the presence in profusion of *Tubipora*, *Millepora*, *Mussa*, *Symphyllia*, *Fungia*, *Pocillopora*, and *Porites*, and the great abundance of *Montipora;* (3) abundance in number of individuals of *Acropora haimei* and *Acropora formosa* (Dana) var., as compared with other species of the same genus.

In regard to the reduction of genera from west to east in the southwestern Pacific, mentioned above, it is interesting to note that corals of the genera *Seriatopora*, *Coeloseris*, *Galaxea*, *Millepora*, *Leptoria*, and *Heliopora*, which are common in the coral reefs of the Riukiu Islands, Taiwan, and the Ogasawara Islands, do not occur in the present collection from Kiushû, Shikoku, and Honshû; and also that other genera are represented in the latter areas by fewer species than in the former areas, namely, 1 out of 7 species and varieties of *Pocillopora*, 2 out of 13 species of *Fungia*, 8 out of 22 species and varieties of *Montipora*, 8 out of 42 species and varieties of *Acropora*, and 12 out of 30 species and varieties of *Porites*.

In the following list are enumerated the species of reef corals living in the Enoura-wan and Tateyama-wan, the northernmost localities

Reef Corals Living in the Enoura-wan and Tateyama-wan

	Tateyama-wan	Enoura-wan
Stylophora cfr. *danae* M.-Edw. and H.	—	c
Stylophora sp. nov.?	—	x
Cyphastrea chalcidicum Klunzinger	—	c
Cyphastrea serailia (Forskål)	—	c
Stylocoenia japonica Yabe and Sugiyama	—	x
Leptastrea purpurea (Dana)	x	x
Echinophyllia sp. (A)	—	c
Echinophyllia? sp. (B)	—	x
Favia cfr. *amplior* (M.-Edwards and Haime)	—	x
Favia cfr. *matthai* Vaughan	—	x
Favia pallida (Dana)	—	x
Favia speciosa (Dana)	—	c
Favites cfr. *abdita* (Ellis and Soll.)	—	x
Goniastrea pectinata (Ehrenberg)	x	x
Maeandra lamellina Ehrenberg	—	x
Maeandra sp. (A)	—	c
Maeandra sp. (B)	—	x
Hydnophora exesa (Pallas)	c	x
Hydnophora sp.	x	—
Antillia japonica Yabe and Sugiyama	—	x
Fungia cyclolites Lam. var.	x	x
Caulastraea aiharai Yabe and Sugiyama, sp. nov.	—	x
Caulastraea yokoyamai var. *gracilis* Yabe and Sugiyama	—	x
Mussa cfr. *regalis* Dana	—	x
Tridacophyllia cfr. *symphylloides* M.-Edw. and H.	—	x
Acanthastrea hemprichii (Ehrenberg)	—	x
Psammocora profundacella Gardiner	—	x
Psammocora sabigniensis Gardiner	—	x
Pavona decussata Dana	—	x
Podabacia lobata Van der Horst (?)	—	x
Turbinaria contorta Bernard	c	—
Turbinaria peltata (Esper)	—	x
Goniopora sp.	—	x
Acropora squarrosa (Ehernberg)	—	c
Acropora cfr. *studeri* Brook	x	—
Porites sp.	—	x

(x = species present; c = common)

known on the western side of the Pacific, where they are thought to be under most adverse conditions.

As an indication of the vigor of the corals at these places we may mention that stocks of *Turbinaria contorta* attain a size of 4 square meters, and those of *Hydnophora exesa* 2 square meters in surface extension in the Tateyama-wan, while those of *Cyphastrea chalcidicum*, *Favia speciosa* and *Echinophyllia* sp. as large as 1 square meter are by no means rare in the Enoura-wan.

Stylophora and *Cyphastrea*, which are in process of disappearance in Tahiti, exist in the Enoura-wan; and *Favites*, *Goniastrea*, *Maeandra*, and *Hydnophora*, absent in Tahiti, are found, some fairly common, in the Tateyama-wan or at Enoura.

These differences and another fact, pointed out by Crossland, that certain genera absent in Tahiti are found still farther eastward in the Taumotu Atolls are sufficient to show that the gradual decrease of the coral genera and species outwards from their centers of distribution is not simply due to the relative ability of their floating larvae to pass over considerable distances. Much depends on various other factors, partly intrinsic in each species, and partly local in origin and physico-chemical in nature.

Finally we call attention to a marvelous element of our coral fauna, a living species of the genus *Stylocoenia*,[36] which has been hitherto known only as a fossil, at horizons from the Neocomian to the Miocene.

[36] Yabe, H., and Sugiyama, T., A living species of *Stylocoenia* recently found in Japan: *Jap. Jour. Geol. Geog.*, vol. 9, no. 3, 1932.