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Geology and Paleontology of Yonaguni-jima

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Abstract

Yonaguni-jima is one of the southern islands of the Ryukyu-retto, extending from southern Japan southwestward nearly to Taiwan. About a half of the island's area is hilly, and most of the remainder consists of slightly tilted lowlands.

The oldest rocks, Miocene in age, are Yayeyama coal-bearing beds, which consist principally of greenish to brown sandstone and black shale. The Yayeyama coal-bearing beds have an exposed thickness of about a hundred meters at Arakawabana. It is overlain unconformably by the Ryukyu Limestone.

The Ryukyu Limestone is a fringing reef limestone that crops out mostly north and southwest of the island and is at altitudes of sea level to about eighty meters. It consists of foraminiferous, coralliferous, and algal limestones. The maximum exposed thickness is about twenty meters.

Recent deposits include sand and gravel of the present day beaches, sand dunes, and alluvium.

Most of the faults that cut the Yayeyama coal-bearing beds and Ryukyu Limestone are of high angle and east-west trending faults which make northward facing escarpments.

Seven types of ichnofossils and two species of fossil plants are reported for the first time from the Yayeyama coal-bearing beds.

At least 9 species of corals and 34 species of molluscs are reported for the first time from the Ryukyu Limestone.

One species of corals and 12 species of molluscs from the Ryukyu Limestone of Tobaru more or less keep their natural color.

1. Introduction

(1) Location and size of the island

Yonaguni-jima is one of the southern islands of the Ryukyu-retto, extending from southern Japan southwestward nearly to Taiwan (fig. 1). It extends from about lat 24°26' to 24°28' N and from about long 122°56' to 123°03' E. It is the westernmost island of the groups of islands called the Sakishima-gunto.

Yonaguni-jima has a maximum length of about eleven kilo-meters and a maximum width of about four kilometers. It has an area of only 31.46 square kilometers.

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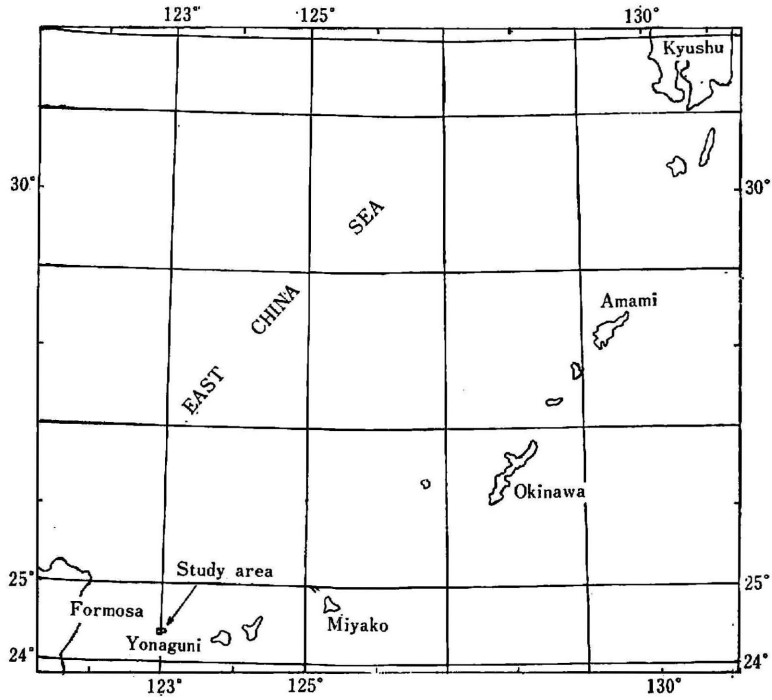

Fig. 1. Location of Yonaguni-jima

(2) Purpose of the report

This report describes some geological and paleontological aspects of Yonaguni-jima.

(3) Collection of data

The data presented in this report were acquired from Sept. 3 to Sept. 13, 1969 and from March 21 to March 30, 1970.

(4) Acknowledgment

Appreciation is extended to Mr. M. Nakamoto, mayor of Yonaguni-cho, and his assistants for their help in the field work. Special acknowledgment is extened to Drs. K. Chinzei, Y. Iwasaki, K. Yamazato, K. Hayami, Messrs. Y. Nakasone, and S. Tamaki for their help in identification of some specimens.

2. Physical Geography

(1) Geography

Yonaguni-jima is rhombic in shape. It has two mountains in the south. Most of the remainder consists of limestone terraces which were caused by fault scarps. The highest mountain, Urabu-yama, which is 231.3 meters high, is in the south-eastern section of the island. The next highest mountain, Kubura-dake, which is 188 meters

high, is in the south-western section of the island.

Except these two mountains Yonaguni-jima consists of many flat-topped ridges and table lands, mostly trending east and west. In the south of Urabu-yama the E-W trending high ridges from 100 to 150 meters in height occur. A flat topped hill about sixty meters high at Hoan is bordered by an E-W trending low scarp in the north and slopes southward. A table land 30 meters in height at the east of Sonai ends at a fault trending N-S. Two parallel ridges trending east to west occur at south of Kubura-dake and they consist of limestone at the tops and dips southward.[1]

A broad plateau, 60 meters in height, occurs at south of Simanaka and the plateau ends as a fault scarp of 60 meters high at Kenzabana. The fault scarp diminishes westward in height. Below the fault scarp, a terrace occurs between Tobaru and Sonai. The terrace from 20 to 40 meters in height extends about five kilometers east to west and dips slightly southward.

The terraces range from a few meters in altitude above the sea level to above eighty meters. Limestone terraces are most extensive in the northern part of the island, but they are also conspicuous in the south-western part. In some places the surface is somewhat smoothed by local deposits of sand and gravel. The limestone terraces generally slope landward with conspicuous scarps.

Few short streams that have small drainage areas flow seaward from the mountains.

(2) Coasts

The extensive coasts of Yonaguni-jima are of a few different types. In general, all coastal area except a few sand beaches at Kubura, Higawa,and the air field near Sonai is rocky and cliffed.

The cliffed cosatlines are mostly in limestone, shale, and sandstone. The cliffs range in height from 1.5 to 100 meters. Limestone cliffs are extremely rough and irregular; they have pitted surfaces and projecting ridges.

Beaches of Yonaguni-jima are composed of foraminiferal sands and range in size from small pockets of sand, only ten meters wide, to sand beaches several hundred meters. A beachrock dredged from Kubura harbor includes a fragment of bottle which indicates fast lithification.

(3) Coral reefs

Coral reefs fringe several coasts of Yonaguni-jima. The width of the reef ranges from tens to several hundred meters. The shoreward sides of reef flats are fairly smooth but contain a few shallow pits. And a few barrier reefs, which are good wind breaks, develop at Kubura, Sonai, and Higawa. The tidal pools make natural harbors.

(4) Climates

Yonaguni-jima has a subtropical oceanic climate that is considerably influenced by the Kuroshio. Humidity on Yonaguni-jima is high throughout the year, and cloudiness

and rain are frequent.

The mean summer temperature on Yonaguni-jima is 27.9°C, and the mean winter temperature is 18°.2 C. The highest air temperature occurs in June, July, August,and September. The mean maximum air temperature for these months is 30°C. The highest air temperature ever recorded was 33.5°C on September 2, 1963. The lowest air temperature on Yonaguni-jima occurs throughout the months of January and February. The mean maximum air temperature recorded for these months were 19.5°C and 20.1°C, respectively, and the mean minimum air temperatures were 15.6°C and 16.1°C, respectively. The coldest temperature ever recorded was 7.7°C on January 16, 1967. Freezing temperatures have never been recorded.

Rainfall is fairly well distributed throughout the year. The yearly average is 2393.7 millimeters. March, May, September, and November are usually the months of highest rainfall because of Bai-u rains and the frequent occurrence of typhoons.

The dominant wind on Yonaguni-jima is from NNE, September to March and from S, April to August. The mean surface wind velocity is 5.9 meters per second. Typhoons are common from July to September. The monthly distri-bution of typhoons which had wind velocities of more than 20 meters per second on Ishigaki-jima and might affect Yonaguni-jima from 1897 to 1967 are shown below.

(Yayeyama Weather Bureau, 1968)

Month	1897—1967 Frequency
May	2
June	8
July	24
August	32
September	27
October	7
November	5
	Total 105

Some weather data obtained over a period of 10 years at the Yonaguni weather station are summarized in table 1.

(5) Fauna

The fauna of Yonaguni-jima[2),3)] includes at least 31 species of insects of which a Yonaguni-moth, *Attacus atlas* Linne, is the largest throughout the Japanese islands; nonmarine molluscs of which *Katayama formosana* Shine is a new species; 2 species of reptiles; 24 species of birds; and 3 species of mamals of which mice, *Mus yonakuni* Kuroda, are only known from Miyako-jima and Yonaguni-jima. Interesting is that no venomous snake is reported from Yonaguni-jima.

(6) Vegetation

About forty-one percent of the area of Yonaguni-jima is a forest and scrub, 29

Table—1 Meterological data from Ryukyu Weather Bureau

Data millibars	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual	period of record
Monthly mean atmospheric pressure at sea level mb +1000 mb	20.6	19.4	16.8	14.4	10.2	06.9	06.9	06.0	08.6	14.6	17.7	19.2	13.4	1957—1968
Mean atmospheric temperature °C	17.4	18.0	20.1	22.8	25.3	27.1	28.5	28.3	27.1	24.7	22.5	19.7	23.4	〃
Mean maximum atmospheric temperature °C	19.5	20.1	22.4	25.2	27.6	29.2	30.9	30.8	29.4	26.9	24.6	21.7	25.7	〃
Mean minimum atmospheric temperature °C	15.6	16.1	18.2	20.9	23.4	25.1	26.5	26.0	25.1	23.0	20.8	17.8	21.5	〃
Mean monthly precipitation mm	179.1	173.6	200.6	179.9	261.7	192.4	142.3	168.1	246.9	193.4	263.4	192.5	2393.7	〃
Mean relative humidity %	75	77	78	81	83	85	82	82	81	74	76	76	79	〃
Mean monthly evaporation mm	107.7	94.1	122.2	149.8	151.3	164.6	227.2	206.1	178.9	184.3	134.4	109.1	1829.6	1957—1966
Mean wind velocity m per second m/s	6.9	9.3	6.4	5.3	4.7	4.4	6.2	4.1	6.4	6.4	5.4	4.9	5.9	1957—1968
Dominant wind direction	NNE	NNE	NNE	S	S	S	S	S	NNE	NNE	NNE	NNE	NNE	〃
Mean number of clear days	0.9	1.3	1.7	2.7	0.7	0.7	4.7	4.2	4.9	3.4	3.0	1.6	29.7	〃
Mean number of cloudy days	24.7	22.5	22.3	18.5	20.6	18.3	9.2	11.0	11.5	14.3	16.8	22.2	211.8	〃

percent a grassland, and 30 percent a farm. Yonaguni-jima, though small and low in altitude, has a variety of plants growing in accordance with the change of altitude. Grass areas occur mostly on terraces at altitudes just a few meters above sea level to about sixty meters. Forest areas occur mostly along fault scarp and mountain slopes.

Five hundred ninety-four species of plants are listed from Yonaguni-jima[3]. Pteridphyta consists of 59 species which belong to 16 families. Gymnospermae consists of only 3 species which belong to 3 families. Angiospermae consists of 356 species of Dictyledonae and 176 species of Monotyledonae. It has a forest of *Livistona chinensis* R. B. var. *subglobosa* Bec. which is rarely seen in other islands, along the southern to south-western slope of Kubura Mt.

A large group of *Acrostichum aureum*, which belongs to typical tropical flora and grows only in Yayeyama-gunto, grow near Kubura Village.

(7) Soils

Shallow acid, dark, brown, yellow, and red brown soils are the most common types developed on Yonaguni-jima. In general, the surface soils are mostly dark to yellow brown, and the subsoils are red brown. The soil horizons are deep near the mountain slope and valley, but thin on limestone terraces. The soil profile (pl. 1, fig. 1) at about one kilometers south-east of Sonai consists of 20 cm A_2 horizon which is poor in organic contents, 7 cm of yellowish A_3 horizon, 10 cm of yellowish brown B_1 horizon, 3 to 5 cm of manganese horizon (B_2), and red-brown soils (C_1). The manganese horizons are found at two localities.

(8) Previous geological study

Though Yonaguni-jima was visited by many geologists, probably Hanzawa[1] was the first one whe did extensive work and published a comprehensive description of the geology of Yonaguni-jima. No detailed work was done until present.

3. Stratigraphy

Yonaguni-jima has a few variety of rock types. The stratigraphic succession of these rocks was established by Hanzawa[1] as follows:

Recent Deposits
Ryukyu Limestone
Yayeyama Coal-Bearing Beds

Neither paleozoic nor mesozoic rock is known (fig. 2). The present study has produced a few additional information about geology and paleontology. The stratigraphic sequence, as presently interpreted by the author, is shown in figure 3.

(1) Yayeyama coal-bearing beds

The Yayeyama coal-bearing beds were named by Hanzawa[1], but no type section was designated. Complete sections on Yonaguni-jima are not available because much of the formation is covered and the lower contact is not exposed. The top of the formation

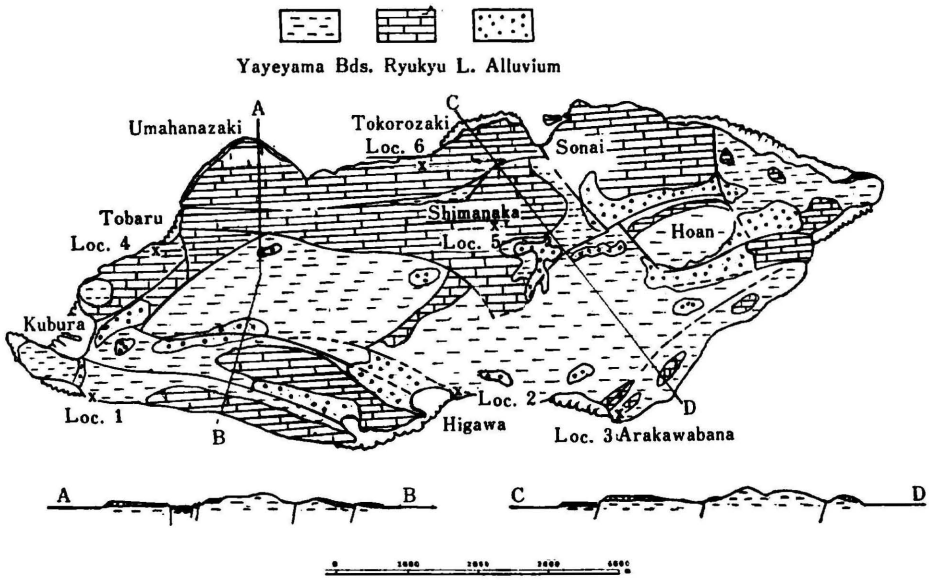

Fig. 2. Geologic map of Yonaguni-jima
(After Hanzawa, 1935; partly modified)

is an irregular erosion, in places covered by Ryukyu Limestone as unconformity.

The exposed thickness of the Yayeyama coal-bearing beds on Yonaguni-jima is estimated to be about a hundred meters at Arakawabana. A thin coal seam, 30 cm thick, interbedded in the sandstone is reported by Hanzawa[1]. The Yayeyama coal-bearing beds crop out in the southern and eastern parts of the island, chiefly in mountains and at the base of cliffs.

The Yayeyama coal-bearing beds consist of brown and gray, fine grain, massive sandstone, thin-bedded sandstone withnumerous sandpipes, grayish blue shales, and black shales. The beds dip slightly in different directions in which east and southward directions are dominant.

The sandstones are cross-bedded in some places (pl. 1, figs. 2 & 3) and contain poorly preserved molluscs and echinoids. Black shales include some plants (pl. VI, figs. 6 & 7).

On the sandstone at the south-west coast of the island, ripple marks are found (pl. II, fig. 4).

(2) Age and correlation

The Yayeyama coal-bearing beds are reported from other islands such as Iriomote, Hatoma, Kobama, Ishigaki, Hateruma, and Nakanogan and they are correlated with the lower part of the Kaizan, which is Burdigalian in age[1]

Era	Period	Epoch	Formation	Type of rock	Thickness (in meters)
CENOZOIC	Quaternary	Recent	Beach deposits	Forams, Sands, & Gravel	0—1
		Pleistocene	Ryukyu Limestone	Alagal, Coralliferous, & Gravelly limestone	0.5—20+
	Tertiary	Pliocene	Unconformity		
		Miocene	Yayeyama Coal-Bearing Beds ?	Sandtone, Shale	200(?)
		Oligocene			
		Eocene			
		Paleocene			

Fig. 3. Stratigraaphy of Yonaguni-jima

4. Ryukyu Limestone

The Ryukyu Limestone unconformably overlies the Yayeyama coal-bearing beds. The Ryukyu Limestone ranges in altitude from the sea level to more than 80 meters above sea level. Two principal types or facies of the Ryukyu Limestone occur on Yonaguni-jima ; soft sandy foraminiferal limestone and massive coralliferous, algal limestone. Boulders of sandstone origin are common near the base of the formation where boulders, 2 meters in diameter, are common. In some places the pebbles in limestone range in size from 2 mm to a few centimeters in diameter. The larger boulders are common in the limestone near Kubura (pl. 1, fig. 4) and in the limestone along the valley near Arakawabana.

The Ryukyu Limestone crops out the northern to western part of the island. Topographically this is an area of slightly landward sloping terraces that range in altitude from several meters near the coast to 80 meters or more inland(pl. III, fig. 3). On the coast behind Kubura Junior High School the Ryukyu Limestone occurs as stripes bordering the coast (pl. II, fig. 2). The thickness of the Ryukyu Limestone ranges from less than 1 meter to more than 20 meters.

(1) Soft sandy foraminiferal limestone

The foraminiferal limestone consists of sand-sized particles loosely cemented together by calcium carbonate. It is white, light tan, or creamy : it is so soft that it can be dug by hands. At the top of the limestone quarry of Yonaguni-cho, 20 cm of hard limestone covers the soft white limestone. In the soft limestone, well rounded sandstones from several millimeters to a few centimeters in size are included. The limestone contains corals, foraminifers, and molds of molluscs.

(2) Coralliferous limestone

The coralliferous limestone is mostly a well-lithified, bioclastic, recrystallized limestone composed of tests or fragments of foraminifers, pieces of corals which are found in their natural position of growth (pl. III, fig. 4 & pl. V, fig. 1), pieces of algal balls from 5 to 10 cm in diameters at Tobaru and 30 cm in diameter on the west side of Sonai where the cores of algal ball consist of sandstones and sponges, and molluscs in a groundmass of fine calcareous organic debris and crystalline calcite.

It is mostly light gray on weathered surfaces and white or cream on fresh surfaces. Color changes slightly laterally or vertically in outcrops. The limestone is massive and porous. And irregular cavities are scattered through the rock. The fossils, particularly molluscs, are well preserved.

(3) Origin

The most of the Ryukyu Limestone originated as fringing reefs like those that border the island at the present time. They were widest on the northern side of the

island. They commonly grew on bedrock shelves of sandstone or shale and in places extended over gravels that accumulated along the margin of the then-existing island. The over all trend was for the northern reef to become wider by growing northward. In general, the younger parts of the reef limestone are those lowest in altitude and nearest the coast.

(4) Age and correlation

Fossils alone are inconclusive in determing the age of both sandy foraminiferal and coralliferous facies of the Ryukyu Limestone since they are Recent species. However, its distribution, thickness, degree of recystallization or solution, and close similarity to Yontan Limestone of Okinawa may conclude that most of the Ryukyu Limestone is Pleistocene in age.

Some limestone found along the coast at low altitudes may be younger than sandy foraminiferal limestone since molluscs including in coralline limestone keep their original colors on shells, water does not percolate in it enough to solve molluscs shell, and the limestone at the coast behind Kubura Junior High School overlies Tertiary sandstone thinly (pl. II, fig. 2). However, no definite age distinctions can be made between limestones because no unconfor mities were found.

The Ryukyu Limestone of Yonaguni-jima probably correlates with the Ryukyu Limestone of Ishgaki-jima (fig. 4). The limestone of Yonaguni-jima is considerably thinner than Yontan Limestone of Okinawa-jima the northeast.

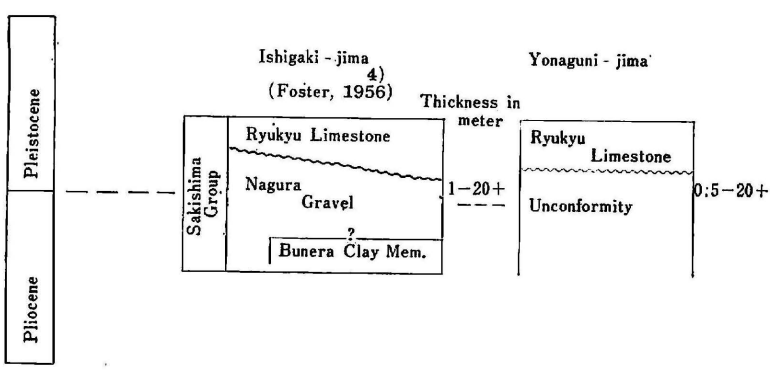

Fig. 4. Stratigraphic relations between Ishigaki and Yonaguni-jima

5. Recent Deposits

Recent deposits include sand and gravel of the present day beaches, sand dunes, and alluvium flooring river valleys.

The sediments composing the present beaches range in size from fine calcareous

sand to accumulations of large boulders. The most abundant deposits are calcareous sand and gravel. These deposits are typically fine to coarse sand consisting largely of calcareous debris including many pieces of coral and fragments of marine shells. Test of foraminifers are numerous in some of the deposits.

Sand from the beaches has been blown inland to form sand dune in the east of Yonaguni air field. The sand is largely calcareous and includes foraminifers, corals, and shell fragments. The sand is fairly well anchored by grass and other vegetation. The dune is less than 5 meters high and is fairly recent in origin because it includes a shell heap in younger age and pumice which might originate in a recent eruption of a submarine volcano.

Beachrock which develops well on the beach of the north-west of Okinawa-jima is not found on Yonaguni-jima. However, gravels dredged from Kubura harbor include some recent glass fragments which indicate that process of beachrock is occurring at present.

Alluvial deposits range from accumulations of large boulders of sandstone and coral fragments to sands, silt, and clay. Alluvial deposits occur in the south of Sonai, South Hoan, the west of Higawa, and about 1 kilometer south of Kubura, most of which are used for rice fields or sugar cane fields at present.

6. Structural Geolgy

The rocks of Yonaguni-jima have been acted upon by a succession of tectonic forces which have produced faults and joints (pl. I, fig. 3, pl. III, figs. 1 & 2). Both the Yayeyama coal-bearing beds and the Ryukyu Limestone at the east coast(pl. III, fig. 2) of Sonai are indicative of recent movements and strains.

Strikes of the most faults are east-west and the north sides are downthrown. Others are NE-SW trend or NW-SE trend. Most of these faults are high angle (pl. III, fig. 2). Faults that cut the Ryukyu Limestone are conspicuous on Yonaguni-jima.

(1) Joints

Joints are abundant in rocks at Arakawabana (pl. I, fig. 3). Fractures are closely spaced and extend in many directions, but do not show a particular pattern.
Vertical joints perpendicular to the strikes of the beds are present in interbedded sandstone with shale at Arakawabana, but in most exposures joint sets are not conspicuous.

7. Geologic History

The geologic history of Yonaguni-jima is summarized as follows:

1) In Miocene time, Yonaguni region was the site of deposition of hundreds of meters of sandstone sand shales in the rather shallow sea.
2) Uplifts of the region.
3) Local submergence. Beginning of reef development in the shallow sea in Pleistocene time. Conditions gradually became favorable around much of the island for deposition of limestone and the growth of fringing coral reefs. Some of the Ryukyu Limestone was deposited, mostly around the margins of gravel deposits.
4) Local Uplift.
5) Successsions of faulting in late Pleistocene and Recent time. In late Pleistocene or early Recent time, high angle faulting and some tilting occurred.

8. Paleontology

(1) Ichnofossils

Seven types of ichnofossils are found from the Yayeyama coal-bearing beds.

Type-I. This type has been found from locality 2 of the east of Higawa(pl. IV, fig. 2). The type develops horizontally to bedding and is found in brown or greenish sandstone. The type is essentially sinuous to meandering trails. It takes different shapes (fig. 5)

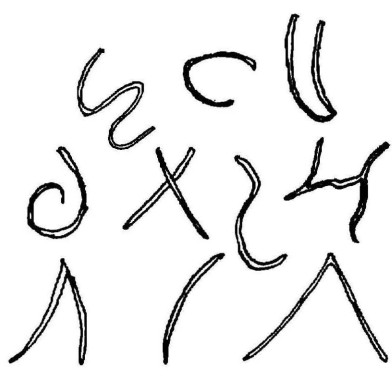

Fig. 5. Ichnofossils from the Yayema coal-bearing beds (Type-I)

and has a diameter of 5 millimeters wide and 12 cm to 20 cm long. The type resembles ichnofossils of Webby[5] from?Cambrian Fowler Gap Beds, New South Wales, Australia, but is far wider and longer than ichnofossils of Webby. The type is similar in size to Webbys' ***Planolites***? sp. from Lintiss Vale Beds(? Lower Cambrian) of New South Wales. However, the type differs from ***Planolites***? sp. in lacking prominent transverse annulations, 3-7 mm apart. The type is in part, similar to trails of ***Helminthoida molassica*** Heer of Seilacher[6]. However, the type has a close similarity of ***Helm-***

inthoida--type B of Konishi[7] from Kayo Formation though the type is larger in diameter.

Type-II. This type has been found from localities 1 and 2 of Kubura and Higawa so far. It takes dendritic patterns in general. The forms develop horizontally to bedding of sandstone. They are about 30 cm long, 5 cm wide, and 4 cm thick (pl. IV, figs. 1 & 2). This may be due to crabs (Nakasone, oral communication). However, the type has a close similarity of *Spongites* sp. of Seilacher.[6]

Type-III. This type has been found from localities 1 and 2. The types consist of numerous sandpipes which occur in the brown thin bedded sandstone (pl. II, fig. 1). Most of sandpipes are about 10 to 15 cm long and 2 cm in diameter, and develop vertically to bedding. However, a sandpipe, horizontal to bedding which occurs on a rippled surface of sandstone, is relatively longer (pl. II, fig. 4). A longer sandpipe, 1.5 cm in diameter and 60 cm long, is found in sandstone from Kubura beach. The type may owe to burrowing Polychaeta rather than burrowing shells because of no impression of the shell and lack of roundness of bottom. The type is similar to a sandpipe made by *Corophium volutator* of Seilacher.[6]

Type-IV. This type has been found from locality 1. The type develops vertically to bedding. It is 20 cm in depth and 9 cm in diameter. At the bottom of the sandpipe, it becomes U-shaped and broader (pl. II, fig. 1). The type may owe to a crab.

Type-V. This type has been found from locality 1. It develops in sandstone vertically or horizontally to bedding and rather takes complex forms (pl. II, fig. 3). As they seem to be too big, long, and irregular shapes to be called as coprolites, they are tentatively included in those of unknown origin.

Type-VI. This type is essentially in dendritic patterns and develops in pararrel to bedding (pl. IV, fig. 3). All trails consist of successions of depressions. The only specimen is known from locality 1.

Type-VII. This type is elongated and develops horizontally to bedding (pl. IV, fig. 4). The type is preserved in convex semirelief in sandstones and chains of triangular depressions develop along both sides of the relief. Only specimen is known from locality 1.

(2) Plants

Fossil plants are found from locality 3 of Arakawabana. The Yayeyama coal-bearing beds there consist of interbedded sandstones and black shales. The plants are included in thinly laminated black shales which consist of the lower part of the outcrop. The plants are included along laminae. Though they are bulky, they are restricted mostly to leaves and only four species have been recognized. Here, two species are listed in this paper since the other two are poorly preserved.

Machilus sp. (pl. VI, fig. 6)

The figured specimen is 2.5 cm wide and 7.5 cm long. The leaf is slender-pointed. The leaf has a conspicuous midrib, but nerves are not apparent, though slightly preserved. The leaf belongs to Lauraceae (Tamaki, oral communication). The family is a large and important family of temperate and tropical genera and species[8]. The identification of genera and species is difficult because of poor preservation and lack of a flower part. The specimen looks like a leaf of recent genus *Listea* and *Machilus* sp. of Kotaka and Noda[9] from Miocene deposits of Aomori Prefecture. So, the specimen is assigned to *Machilus* sp.

? *Quercus* sp. (pl. VI, fig. 7)

The figured specimen has a conspicuous midrib and nerves. Its width is 2.8 cm, but its length is not apparent. This looks like Fagacear in outline, and in number and arrangements of nerves.

The leaf is more close to genus *Quercus* than to other genus. So, the figured specimen is assigned to ?*Quercus* sp. However, the specimen is different from *Quercus* sp. of Kotaka and Noda[9] in arrangements of nerves.

(3) Corals

Corals in the Ryukyu Limestone are mostly of modern forms poorly preserved in general. They are listed as follows.

Euphyllia fimbriata (Spengler)
Favia sp.
Fungia repanda (Dana)
Fungia sp.
Leptoria phrygia (Ellis and Solander)
Pachyseris speciosa (Dana)
Plesiastrea sp.
Porites sp.
Tubipora musica Linnaeus

They are species which live on a shallow reef.

(4) Molluscs

Molluscs in the Ryukyu Limestone are mostly of modern forms, in general poorly preserved except molluscs from Tobaru, locality 4 where most specimens are extremely well preserved. They are listed as follows.

Arca sp.
Avestorides sp. Ind.
Chlamys sp. A
Chlamys sp. B

Chlamys sp. C
Chlamys sp. D
Chlamys irregularis (Sowerby)
Columbella (*Euplica*) *turturina* Lamarck
Conus cf. *C. vitulinis* Hwass
Conus sp.
Darioconus sp. A
Darioconus sp. B
Erosaria (*Ravitrona*) cf. *E. captserpentis* (Linne)
Gloripallium pallium (Linne)
Latirus sp.
Lima sp.
Lischkeia alwinae Lischke
Lithophaga sp.
Littoraria sp.
Notoacmea fuscovirides Teramachi
Oliva cf. *O. annulata amethystina* (Rodine)
Oliva sp.
Puncticulis pulcarius Bruguire
Rhizoconus aff. *R. mustelinus* Hwass
Rhizoconus tectile (Linne)
Spondylus candidus Lamarck
Spondylus cf. *S. anacanthus* Mawe
(?) *Siphonalia* sp.
Tridacna (*Chametrachea*) *crocea* (Lamarck)
Tridacna (*Flodacna*) *squamosa* (?) Lamarck
Turbo (*Lunatica*) *marmoratus* Linne
Turbo petholatus Linne
Turbo sp.
Vexillum cf. *V.* (*Vexillum*) *gruneri* (Reeve)

(5) Color retention

One species of corals, that is, *Tubipora musica* Linnaeus and 12 molluscs collected from Tobaru (loc. 4) are interesting from the point ofiew of color retention.

In general, fossils in the Ryukyu Limestone at other localities are poorly preserved because of wearing and recrystallization. However, the 13 fossils keep slightly or almost natural colors. The fact that 12 species of 34 molluscan species keep their natural color indicates that fossilization is in good condition or the limestone which includes the fossils may be younger than the limestone distributed over localities at higher altitude.

The most dominant species is *Turbo petholatus* Linne which originally has red

brown color but is turned out light brown.

(6) Paleocurrent (?)

One valve of *Tridacna* (*Flodacna*) *squamosa* (?) (pl. V, fig. 3) was found in the Ryukyu Limestone 5 meters higher from Tahara water garden along a roadcut. The length of the valve is 63 cm. and the thickness is 6 cm.

Another valve (pl. V, fig. 4) was found at less than a hundred meters north-west of Tahara water garden. The length of the valve is 48 cm. and the thickness of the valve is 5.5 cm.

If these valves compose the left and the right valve of a shell, they may be indicative of the current direction (east to north- west) in Pleistocene time.

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