Quaternary Geologic History of the Ryukyu Islands

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Hiroyasu FURUKAWA*

Abstract

In this paper the Quaternary geologic history of the Ryukyu Islands has been made clear on the grounds of the field data of regional stratigraphy and also the results of the geochronology by ^{14}C measurements. The Quaternary System in the Ryukyu Islands is divided in ascending order into the Upper Shinzato Formation and Chinen Sandstone Member of the Shimajiri Group, Ryukyu Limestone and Terrace Deposits of the Ryukyu Group in the Pleistocene, Alluvial Deposits, Younger Dune Sands and Recent Coral Reef Sediments in the Holocene. The correlation of the Quaternary strata among various islands of Ryukyu Arc is shown in Table 1. The Shimajiri Group was deposited during the transgression from Upper Miocene to Lower Pleistocene, consisting mainly of thick mudstone with some intercalated sandstones and tuffs. The Ryukyu Limestone was deposited with a distinct unconformity on the Shimajiri Group and other basement rocks. Sand and gravel beds are found locally to replace part of the limestone. The Ryukyu Limestone is a continuous series of strata in which no great unconformity intervenes. It is generally 40 to 60 m thick and scarcely exceeds 100 m at the maximum. Faulting was remarkable after the deposition of the Ryukyu Limestone, cutting perpendicularly the island arc with accompanied uprise of the basement rocks. The terraces are generally divided into higher, middle, and lower groups, and the sediments forming these terraces comprise mainly sand and gravel and partly silt and limestone. In the Latest Pleistocene the land-area was much enlarged, owing to the lowering of ancient sea level and reddish brown soil was distributed on the subaerial flat place during that time, which now lies mostly under the sea. The sediments accompanied by the transgression during the period from the Latest Pleistocene to Holocene are distributed on the reddish brown soil with an unconformity, wheras the reef sediments were deposited around these islands. This redords a slight uprise of sea level, at least one meter higher than the present position at the peak phase of the transgression during at about 5,000 to 4,000 Y.B.P. There was the lowering of sea level down to two meters lower than the present position during the period of 3,000 to 2,000 Y.B.P. Accompanied by it Younger Dune Sands were formed along the present coast lines. The correlation of the geologic history from the latest Pleistocene to Holocene between Ryukyu and Kyushu is shown in Tables 3 and 4.

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* Dept. of Mar. Sci., Sci. & Eng. Div.

I. Introduction

The Ryukyu Islands forms an arc which connects Kyushu with Taiwan (Formosa) with the extension of about 1200 km. Especially the Okinawa Region forming the southern half of this arc is composed of more than 70 islands of various dimensions. In these islands the Quaternary System is distributed. The Quaternary System has hitherto been studied by many researchers including TOKUNAGA (1901), and YABE and HANZAWA (1925).· Especially HANZAWA (1935) described the general geology of all the islands of the Ryukyus, and this gives a base for the succeeding geologic studies of the Ryukyu Islands. However, there has been difficulty to make accurate geologic map, because the available topographic maps were rough, and because islands are more or less isolated and separated far from the center of Japan. For these reasons, stratigraphical study on the Quaternary System in the Ryukyu Islands has been much delayed.

On the other hand, after World War II some American geologists studied the Ryukyus from the viewpoint of mililary geology, and the results were published by CEDERSTROM (1947), ELINT *et al.* (1953), MACNEIL (1960), and FOSTER (1965). Succeeding to them, in the decades of 1960, KONISHI (1963, 1964, 1965 and 1973), NAKAGAWA (1964, 1967, 1969 and 1975) studied the Pre-Quaternary and the Quaternary Systems of the Ryukyus including the Amami Islands. In addition a group of scientists of the National Science Museum have recently worked under the title of "Natural History Researches of the Islands of Ryukyu", and palaeontological results among many others have been given for Cenozoic fossils. However, no systematic report has been given for the Quatermary geologic history of the Ryukyu Islands. To fulfil this deficiency the writer have been engaged in the stratigraphical study of the Quaternary System in selected eleven islands of Ryukyus. In addition to the field evidence obtained by current stratigraphic mothods, results of radiocarbon dating have been used for the correlation. In this paper the result of writer's study are described for individual areas and then a comprehensive summarization is given on the Quaternary geologic history of the Ryukyu Islands.

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II. Regional Stratigraphy

In this chapter the stratigraphy of the Quaternary system in the Ryukyu Islands is described. Here 13 disricts of 11 islands are selected. They are distributed in the area of 350 km from north to south and 400 km from east to west, that is from Iheya-jima, at the northeastern end of the Okinawa Prefecture to Kuro-shima of the Yaeyama archipelago at the southwestern end (Fig. 1). The geologic maps and their cross-sections in the individual islands are shown in the following sections.

1 Miyako-jima Island

1) The outline of Topography and Geology.

Besides the older works by TOKUNAGA (1901), AOKI (1932) and HANZAWA (1935), there are many recent studies, on the topography and geology of the island such as DOAN *et al.* (1960), KAMEI (1970), YAZAKI (1970), OMURA (1973), HASEGAWA *et al.* (1973), UJIIE and OKI (1974) and KAMEYAMA (1975).

As was described repeatedly the ridge and cuesta topography is characteristic of the Miyako-jima island. The ridges run in parallel with a direction of NW to SE or NWW to SEE with an interval several kilometers, and the cuestas dicline gently southward. The general topgrahgy becomes higher in the northeast. The topography of the Miyako-jima island well reflects the reliefs of the basement rocks as revealed not only from the observations of the cliffs in the southern coast but also from the results of boring and electric survey in the inland areas.

Observing the submarine topography, flat planes extend at the depths shallower than 150 m, these being extensive particularly off the northeastern coast of the island. From the outer edges of these planes steeper slopes descend down to the depth of more than 500 m. Several islets such as the Irabu-jima, Ikema-jima, Ohgami-jima and Shimoji-jima, are scattered around the main island. They are all linked with the main island by the shallow waters with a depth less than 40 m.

The strata composing the Miyako-jima island are mainly the Shimajiri Group of Late Miocene to Early Pleistocene age and the Ryukyu Limestone that overlies the former with a clino-unconformity. The Shimajiri Group sporadically crops out along the northeastern sea cliffs of the island, while the Ryukyu Limestone widely covers the almost whole area of the island. In addition there are Terrace Deposits I & II, Dune Sand and Recent Coral Reefs.

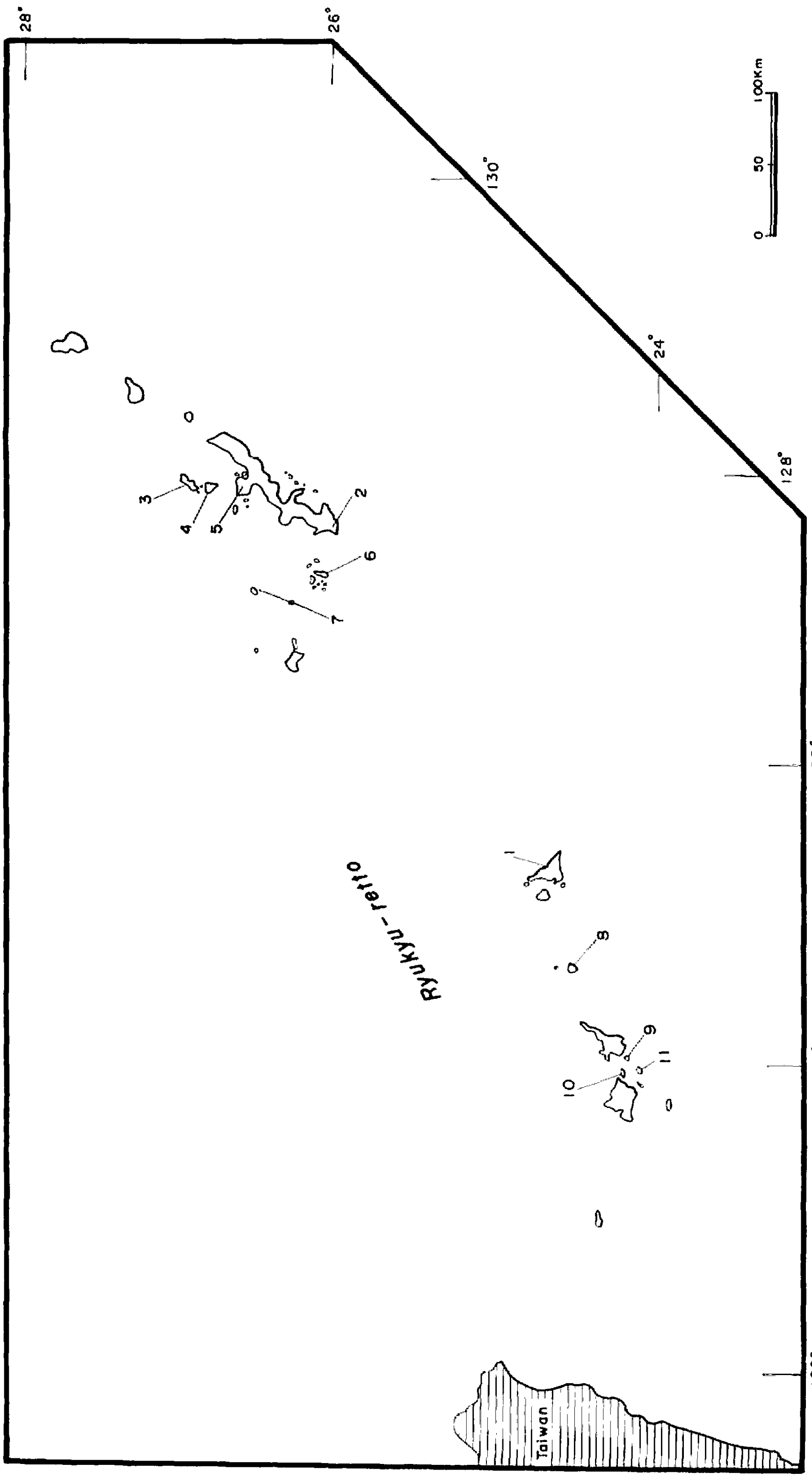
2) Stratigraphy

(a) Shimajiri Group

The Shimajiri Group is exposed along the northeastern coast of the island and the innermost part of the Yonaha Bay. It consists mainly of stratified mudstone with tuff, sandy mudstone and sandstone, which are unconsolidated. The heavy mineral assemblage of the intercalated tuffs are of the two pyroxenes and the common hornblende types (MITSUSHIO, 1972).

In the Ohgami-jima islet adjacent to the north of the main island, and in the environs of Shimajiri at the northern end of the main island, the lower member crops out showing a monoclinal structure with a gentle southward dip.

The Shimajiri Group is covered by the overlying Ryukyu Limestone everywhere with a remarkable clinounconformity.



1. Miyako-jima 2. Southern Okinawa-jima 3. Ineya-jima 4. Izena-jima 5. Motobu Peninsula
6. Kerama-retto 7. Aguni-jima 8. Tarama-jima 9. Taketomi-jima 10. Kahama-jima 11. Kuro-shima

Fig. 1 Index Map

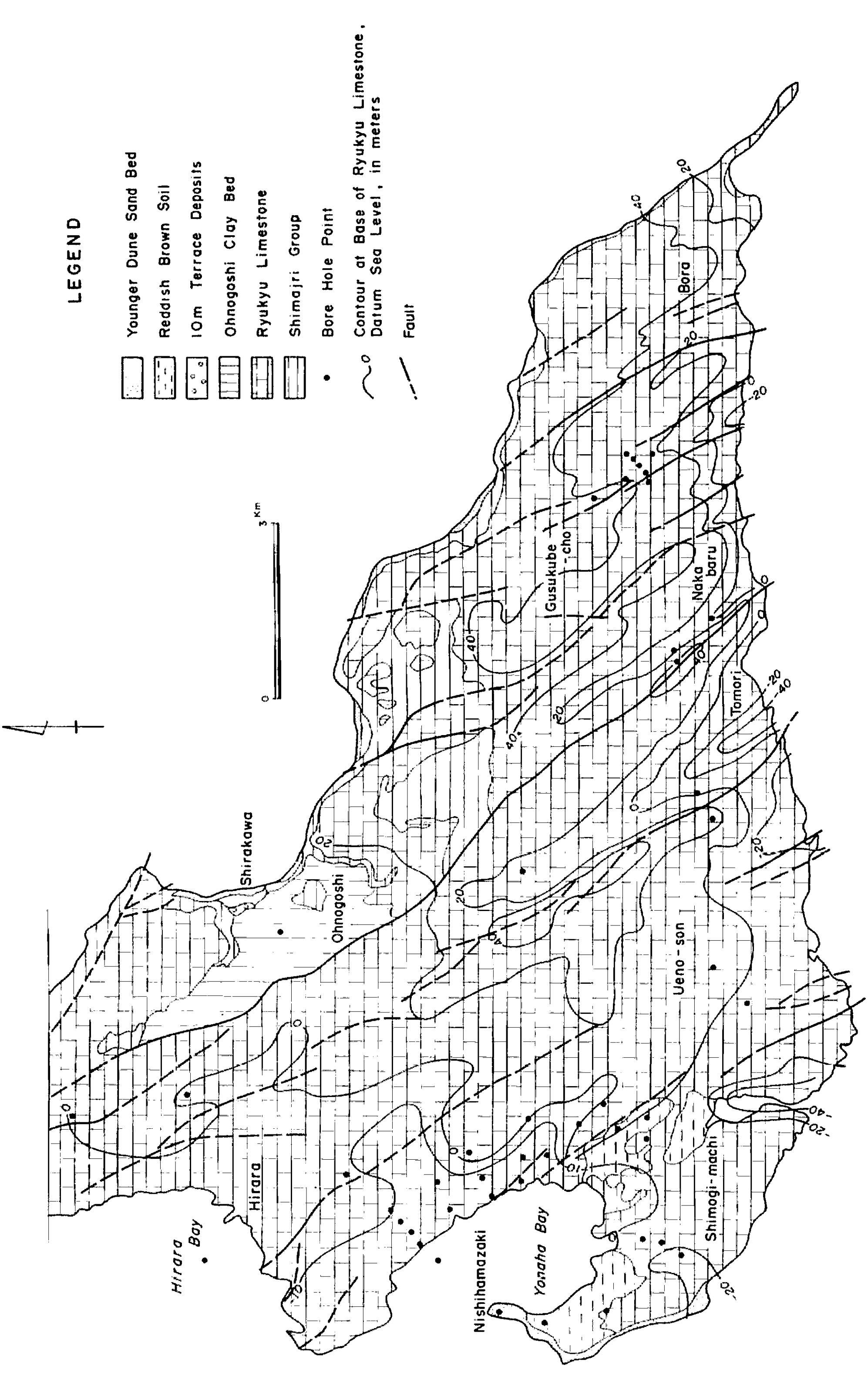


Fig. 2 Geologic Map of Miyako-jima

(b) Ryukyu Limestone

The Ryukyu Limestone attains more than 60 to 70 m in its total thickness. It is subdivided into four lithostratigraphic units, which are successively exposed along the southern coast of the main island, as described below.

(1) Basal Pebble-bearing Muddy Limestone

This covers the underlying Shimajiri Group directly. The thickness is generally 20 To 30 cm and three m at its maximum. It is mainly composed of consolidated muddy limestone or calcareous mudstone, associated with the fragments of muddy rock probably derived from the underlying Shimajiri Group. These rock fragments subangular with a size of three to four cm. The basal unit of the Ryukyu Limestone is presumed to have been deposited as a result of mixing of the limy components precipitated from the sea water and the muddy materials washed out from the sea bottom by active wave action that prevailed during the initial phase of the marine transgression.

(2) Coral Limestone

This is characterized by the abundant occurrence of reef-building corals which often keep their original growth position. However, the limestone has generally a brecciated texture, which shows that it was broken and secondarily deposited. The matrix is composed mainly of foraminifer sand and bioclastic fragments, the latter being extremely loose with very rough features. In the lower part of the coral limestone unit sandy facies is predominant and weakly developed laminae are sometimes observed. The coral remains contained in this part are remarkably abraded. The coral limestone and the sandy limestone described below are laterally grading into each other. The coral limestone consititutes a dome- or mound-like sedimentary body. This suggests that the corals have growed here and there to build up the reefs of various extent and the foraminifer sand deposited burying the gaps or voids between these reefs as in the present reef flat.

(3) Sandy Limestone

The sandy limestone is slightly more fragile and composed mainly of foraminifer sand. Besides, it contains corals, calcareous algae and molluscs as main organogenic components. The sandy limestone generally changes into the coral limestone laterally as stated above, but it covers the latter in the southern coastal area as a thick sequence. The sandy limestone is covered by algal ball-bearing muddy limestone unit described below throughout the whole area of the island. The sandy limestone is generally well stratified and characterized by a remarkable lamination.

The organic remains other than foraminifers are all broken into fragments and abraded in many cases, but their absolute amount is small.

(4) Muddy Limestone

The muddy limestone is widely distributed from Sunagawa in Gusukube Town to the west of Shinzato in Ueno Village along the southern coast. Around the western part of the island the limestone is developed thinly under the landcovering deposits.

The muddy limestone covers the sandy limestone unit in some places, but in other places it lies directly on the coral limestone unit.

The diagnostic features of the muddy limestone are that its matrix is slightly denser than the limy slants limestone, hence being more muddy. The limestone is predominantly rich in foraminifers and ball-shaped lumps of calcareous algae. Other organic components include molluscs, corals, etc., which occur in mass in some places. The muddy limestone is in general massive, but in some places weak lamination is developed.

From the succession exposed on a cliff along the southern coast a generalized column was made. The relief of the basal surface of the Ryukyu Limestone in the Miyako-jima island is shown in Fig. 2 as revealed from the results of geologic survey, etc. From these figures the following can be pointed out with respect to the stratigraphy of the Ryukyu Limestone.

A general sequence of the Ryukyu Limestone comprises the coral limestone in the middle and the muddy limestone in the upper. Thus there is a general vertical faciess change from the basal conglomerate through the coral and sandy limestones to the muddy limestone, which is considered to have resulted from a single phase of transgression. As evidently shown in Fig. 4 no unconformity is found between these lithologic unit. The successive deposition of the Ryukyu Limestone can also be estimated from the results of drilling at 150 points in the island. Consequently, it can be concluded that these sediments correspond to a single phase of transgression, so far as this island is concerned. Several topographic surfaces developed in the Ryukyu Limestone terrain in this island are then estimated to be of later, erosional origin evidently after the deposition of the Ryukyu Limestone.

(c) Ohnogoshi Clay Bed (Terrace Deposits I)

A unit of reddish brown clay overlies the Ryukyu Limestone and constitutes a flat topographic surface of 25 to 30 m high in the island. Its type locality is designated as the environs of the Tropical Botanic Garden in Ohnogoshi, its clay bed has 10 to 15 m in thickness. It lacks any distinct stratification and contains partly small manganese nodules with a diameter of several centimeters. No calcareous material is contained, which suggests that the clay may have been washed out from the weathered part of the mudstone of the Shimajiri Group. A similar reddish brown clay with a thickness of 3 to 5 m is distributed around Sugama, along the western coast of the Yonaha Bay, forming a flat surface of five m high a.s.l. It covers The Ryukyu Limestone but its exact stratigraphical position is yet unknown.

(d) Terrace Deposits II

The sediments composed of silt, coral gravel, algal ball and sand are distributed near Shirakawa spring along the eastern coast of the island, constructing a flat topographic surface of about 10 m high a.s.l. These are considered to be terrace deposits. Similar deposits probably constituting the 10 m terrace are found near the Kadekaru Inlet in the southwest of the island. They are represented by loose limestone that contains abundant corals lying in situ.

(e) Younger Dune Sand Bed

The dune sand is distributed sporadically along the eastern coast of the island and in the west of the Yonaha Bay. It is composed of calcareous dune sand, covering the reddish brown clay or directly the Ryukyu Limestone. It contains grey pumices of pebble size and is correlatable to the Younger Dune Sand in other islands.

(f) Recent Coral Reef Sediments

The present coral reefs are well developed around the Miyako-jima island. They construct a submarine flat surface of five to 30 m deep in the waters between the western coast of the main island and the Irabu islet. This surface is covered by sandy sediments with patchy reefs sporadically developed thereon. This submarine flat represents the depositional surface of the sand and silt beds containing coral gravels with a total thickness of 20 to 30 m. The information obtained from submarine drilling reveals that reddish brown clay is widely developed on the surface of the Ryukyu Limestone and is covered by these Recent sediments. The Recent Coral Reef Sediments are interbedded with patchy reefs at their lower horizon. A ^{14}C date of 5,600 ± 100 Y.B.P. has been obtained from the coral recovered from this patchy reef horizon at the depth of 20.60 m in the B-6 bore hole (Fig. 3). From these facts it may be mentioned that these Recent sediments have resulted from the sea level rise during the Holocene.

3) Geologic Structure

The Shimajiri Group is deformed to form an anticlinorium plunging gently southwestward with axis of the NE to SW direction which is parallel to the trend of the Ryukyu arc repeating the folding with an interval of four to six km. The inclination of the limbs is 10 to 20 degrees, thus the structure is rather gentle.

In contrast the general structure of the Ryukyu Limestone is discordant to that of the underlying Shimajiri Group and controlled by a large anticline with its axis along the line from Fukutou to Hika in Gusukube Town trending in the NW to SE direction. A group of well extending faults with downthrow less than 30 m, runs parallel to the folding structure at an interval of about 2 km, and makes step-like depressions along the axial part of the folding.

Considering that these two stratigraphical sequences are separated by a remarkable clino-unconformity as evidenced from the surface outcrops, it can be estimated that after the deposition of the Shimajiri Group there was a period of denudation and tectonic deformation and the Ryukyu Limestone was deposited on the erosional surface of the deformed Shimajiri Group. That this unconformity is of considerably large scale has been proved throughout the Ryukyu Islands from the Yaeyama-gunto Archipelago in the south to the Kikaigashima island in the north. Here the writer intends to propose the Miyako-jima Disturbance by designating the Miyako-jima island as its type locality. Its diagnosis is the tectonic disturbance that took place after the deposition of the Shimajiri Group and before that of the Ryukyu Limestone.

The Uruma Disturbance defined by the OKINAWA QUATERNARY RESEARCH GROUP (1974) is in contrast characterized by a dominance of NW to SE faulting that extends across the Ryukyu Arc at right angle and ocurrel after the deposition of the Ryukyu Limestone

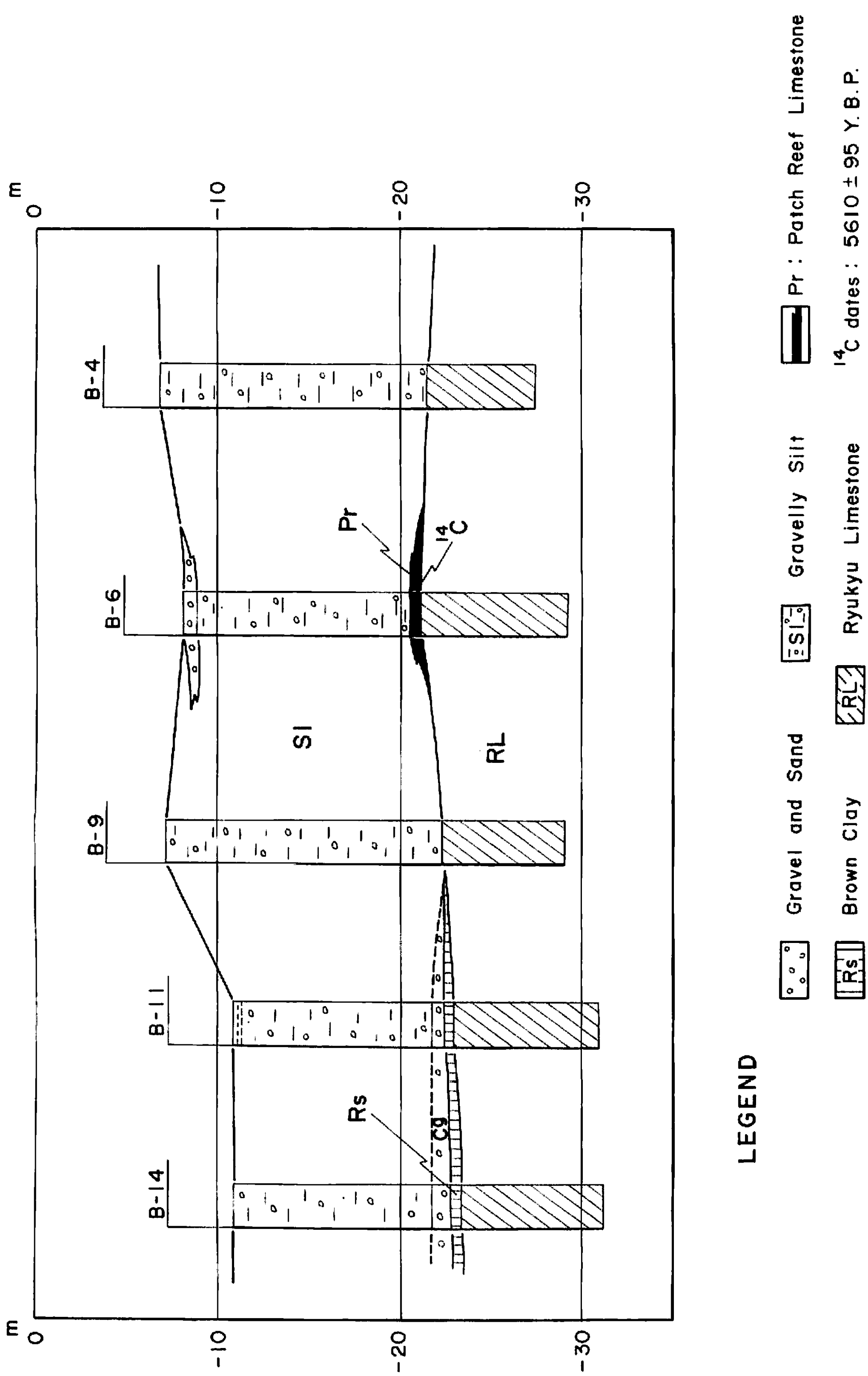


Fig. 3 Submarine Columnar Section off the Hirara Port, Miyako-jima Island

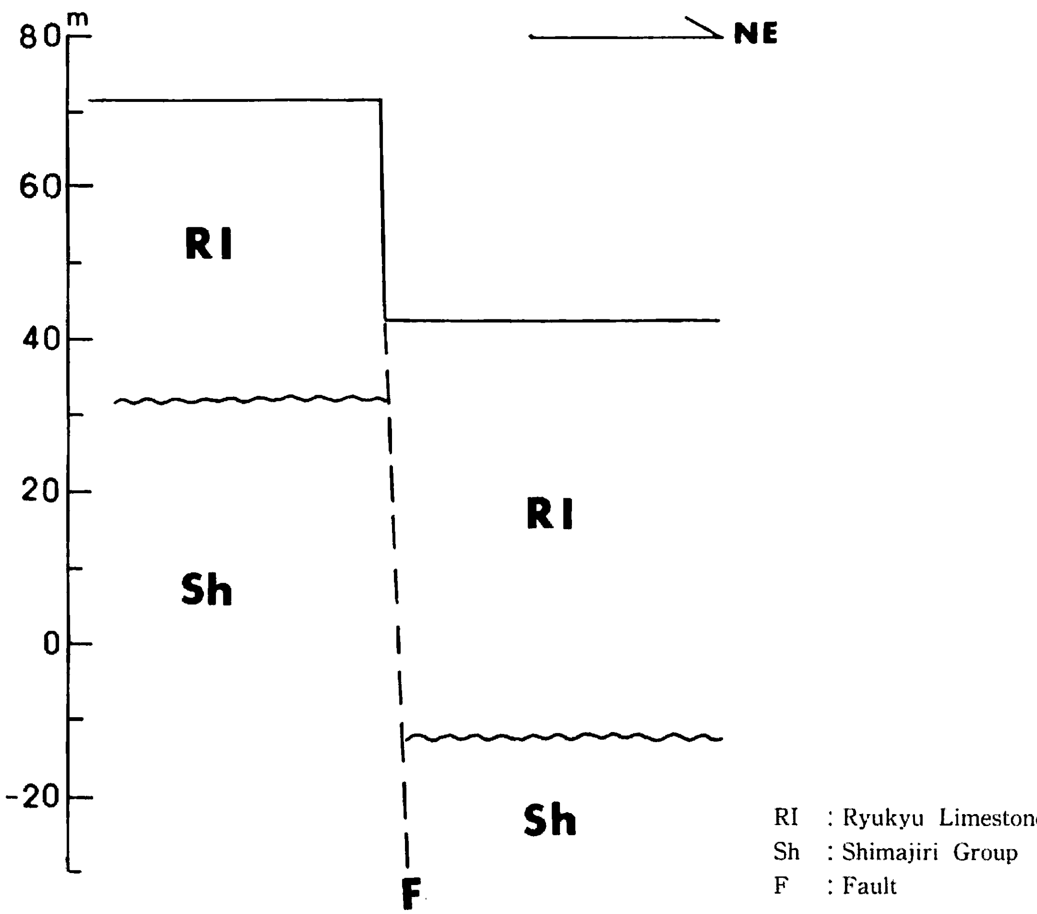


Fig. 4 Geologic Section of the Limestone Wall near Sunagawa, Miyako-jima Island

accompanied by a dome-like upheaval of the basement. This anticlinal structure seems to correspond to the so-called "Miyako Positive" be DOAN *et al.* (1960). In the Miyako-jima island sheared zones are recognized along the faults of NW to SE direction, whereas the faults with a direction of NE to SW or E to W are less developed. The latter are all of small scale not disturbed by the former. These observations suggest that a fault movement in minor scale has followed after the Urama Disturbance.

4) **Geologic Age**

As for the Shimajiri Group several schemes of biostratigraphic subdivision by use of planktonic foraminifers have been prescented by HUANG (1968), NATORI *et al.* (1972), UJIIE and OKI (1974) and KAMEYAMA (1975). Especially UJIIE and OKI (1974) examined the whole section of the Shimajiri Group exposed along the eastern coast of the Miyako-jima island and reported the existence of Blow's (1969) N17 through N22 zones with the conclusion that the age of the Group is the Late Miocene to Early Pleistocene. Moreover, HASEGAWA *et al.* (1973) reported *Trilophodon* sp. from the lower part of the Shimajiri Group and assigned it to the *Mastodon* group of the Pliocene age.

Concerning the Ryukyu Limestone no direct evidence of dating has been obtained. A fossil elephant was found from the cave deposits that filled a fissure in the Ryukyu Limestone in the west of Ohnogoshi, Hirara City. TOKUNAGA (1940) indentified it with *Palaeoloxodon namadicus* and OTUKA (1941) refered it to *Palaeoloxodon.* KAMEI (1970) reemamined the specimen and has concluded that it may belong to the *Elephas meridionalis-trogntherii* group. HASEGAWA *et al.* (1973) found fossil vertebrates auch as *Rattus* cf. *legata, Testudo* cf. *emys*, etc. from the limestone breccia beds in the Amakawa cave situated on the southern coast of the Miyako-jima island and named them the Tomori vertebrate fauna. The OKINAWA QUATERNARY RESEARCH GROUP (1974), who examined the age of caves in the Miyako-jima island, concluded that the age of the Amakawa and Tanahara caves was correlative with the age of the topographic surface of 30 to 40 m high a.s.l.. This flat plane is correlatable to the depositional surface of the Ohnogoshi clay bed in age, and according both of them are the equivalent of the Ryukyu Group II a or II b, i. e. Middle to Late Pleistocene.

On the basis of these facts, the Ryukyu Limestone in the Miyako-jima island is estimated to be younger than the N22 zone (early Pleistocene) of the uppermost Shimajiri Group and older than the Late Pleistocene.

2 Southern part of Okinawa Main Island

1) The outline of Topography and Geology

The southern part of the Okinawa Main Island is occupied mainly by the Shimajiri Group made up mainly of mudstone with sandstone and the unconformably overlying Ryukyu Limestone. The Holocene sediments are sporadically distributed in small areas.

The Ryukyu Limestone is distributed along the southern coast with width of five to six km, and is faulted in blocks. In more island areas, it covers the Shimajiri Group with an erosion unconformity, and is sporadically distributed as monadonocks. It lies at the altitude of 180 m a.s.l. in the mountain areas of Yaedake and Yozadake. This is the highest elevation on the Ryukyu Limestone. The same is seen in the island of Kikaiga-jima and Okino-erabu-jima, as well. Around the Yozadake, the Ryukyu Limetone forms a flat terrace at 150 to 180 m a.s.l. with a steep cliff along its margin.

The Shimajiri Group forms hilly areas of a gentle relief at the elevation of 30 to 100 m a.s.l., surrounding the terraces of the Ryukyu Limestone. The faults cutting the Ryukyu Limestone are mostly of the NW-SE to E-W directions and subordinately of the NE-SW.

Previous studies on the geography, pedology, Quaternary geology and palaeontology of the island the numerous: YABE and HANZAWA (1925), HANZAWA (1935), CEDERSTROM (1974), CAMERON *et al.* (1958), FLINT *et al.* (1953,1959), MACNEIL (1960), MOTOJIMA *et al.* (1970), FUKUTA *et al.* (1970 a and b) MATSUZAKA *et al.* (1971), SHOJI (1971), FUKUTA *et al.* (1972), NATORI *et al.* (1972), NOHARA and HASEGAWA (1973), TAKAMIYA and MEIGHEN (1973), and KIZAKI and TAKAYASU(1975), of which the first two are basic for the stratigraphy.

2) Stratigraphy

(a) Shimajiri Group

The name of Shimajiri Beds was proposed by HANZAWA (1935), and MACNEIL (1960) called it the Shimajiri Group. It consists predominantly of mudstone with intercalated sandstone in the lower member. FUKUTA *et al.* (1972) divided the Shimajiri Group into three formation: Tomishiro, Yonahara, and Shinzato Formations in ascending order. Through the study of planktonic foraminifer (NATORI *et al.*, 1972) the age of the group has been detemined to range from the upper Miocene to lower Pleistocene. LEROY (1965) pointed out from the results of his paleoenvironmental study of the benthonic foraminifers that the Shimajiri Group changed gradually from a semi-bassyal environment in the lower part to a shallow sea in the upper one and finally to the uppermost Shinzato Formation of a sublittoral sea under subtropical to tropical climate. Besides, according to the results of pollen analysis by NISHIDA *et al.* (1976), the Yonabaru Formation contains *Abies* and *Tsuga*, and the Shinzato Formation predominantly the warm temperate floral elements such as *Fagus* and *Alnus.*

In the surveyed area the outcrops of the Shimajiri Group are narrow. Near Itoman the outcrop includes tuff at some horizon, and the heavy imnerals in the tuff shows the two pyroxenes assemblage (MITUSHIO, 1974).

The geologic drilling and electric survey has revealed that the uppermost of the Shinzato Formation and Yonabaru Formation are extensively distributed below the Ryukyu Limestone.

(b) Ryukyu Limestone

The Ryukyu Limestone of the southern part of the Okinawa main island was divided by MACNEIL (1960) into three, i.e., Pliocene Naha Limestone, Pleistocene Yontan Limestone and Machinato Limestone in ascending order, which were considered as unconformable with one another. He thought that the upper two units of limestones defined as the Pleistocene are the terrace deposits. His division has been generally accepted, but the writer is skeptical about his scheme of subdivision, because the writer observes the facts described below. The limestone is distributed in a higher range of 230 m from 180 m a.s.l. around Mt. Yozadake down to about 50 m a.s.l. The thickness attains 80 to 90 m, and it can be classified broadly into two; pleateau-like massive limestone which forms geographically the flat plane of 150 to 180 m a.s.l., and the alternation type limestone which is distributed around the plateau with gentle inclination of 5° to 10° toward the coast. The former is generally rich in massive limestone and scarcely stratified. There is a muddy and brecciated limestone on the plane of unconformity with the Shimajiri Group, containing pebbles of mudstone derived from the Shimajiri Group. The sandy limestone with clear laminae of several centimeters characteristically occurs in this lower member which is 8 to 10 m thick as measured along the coast of Mabuni to Minatogawa. Above this Lower Member comes the massive sandy limestone consisting of the fragments of corals, calcareous algae, and shells, with thickness of 10 to 20 m.

The alternation type limestone is sandy, made up of algal ball, and foraminifer with

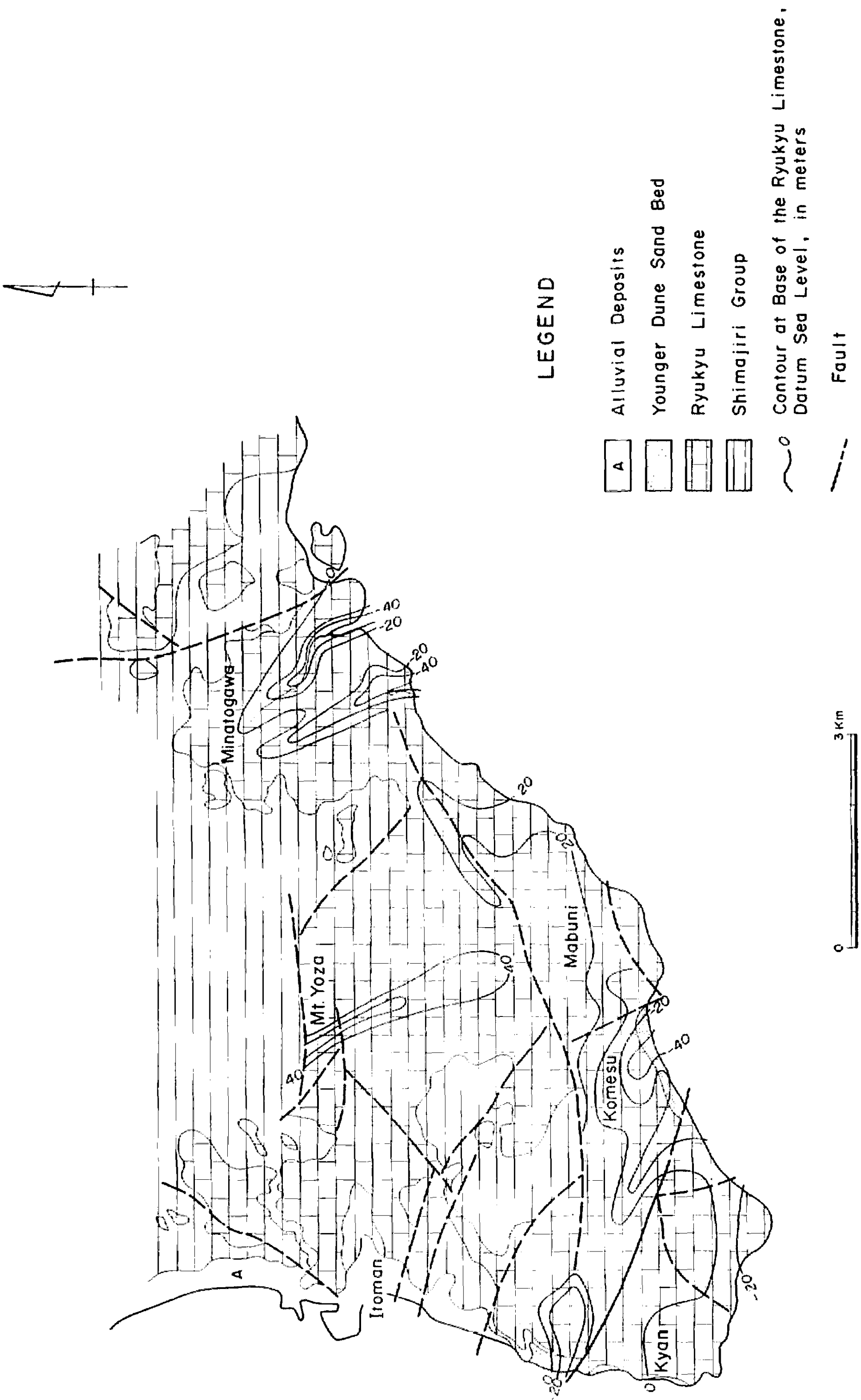


Fig. 5 Geologic Map of the Southern Part of the Okinawa-jima Main Island

some fragments of corals and shells and also pebbles in some parts. The alternation is manifested by that of dense and loose layers, each with 50-70 cm thickness and partly by interbeds of accumulated corals.

The relationship between the major two types of limestone is not clear, but a distinct unconformity has not been recognized.

The calcarenite which MacNeil (1960) once defined as the type locality of Machinato Limestone at Minatogawa (Fig. 5), is a facies in the uppermost part of the limestone of 70 m thick. This calcarenite facies itself is 10 to 20 m thick, but the so-called unconformity with the lower coralline limestone is nowhere exposed. The relation is merely a gradual change of sedimentary environment.

Thus, the Ryukyu Limestone in the southern part of the Okinawa main island shows facies changes both vertically and horizontally, owing to the variation in sedimentary environment. The unconformity dividing the Ryukyu Limestone is nowhere recognized. A remarkable unconformity is between the Shimajiri Group and the Ryukyu Limestone. The relief of the basal plane of the Ryukyu Limestone is shown in Fig. 5. Three buried vallies which open toward southeast near Minatogawa and Komesu, and another narrow one which opens northward in front of Mt. Yozadake are examples of the relief. The relief may imply a divide of roughly NE-SW trend. Anyhow a tectonic movement evidently took place after the sedimentation of the Shimajiri Group and before that of the Ryukyu Limestone. The strata of the Shimajiri Group show the strike of NEE-SWW and the dip of 10° to SEE, suggesting a monoclinal tilting in this area. Faulting may have also occurred. As a result were formed vallies of NW-SE trend, cutting across the Ryukyu Arc, which where then burried by the Ryukyu Limestone.

Faulting of the same trend occurred after the deposition of the limestone. An interesting record of the downthrow of the strata has been obtained by a geological drilling near Itoman (Fig. 6). The amount of downthrow of the Shimajiri Group is larger than that of the present topographic plane on the Ryukyu Limestone.

This indicates that the faulting across the Ryukyu Arc started before the formation of the sedimentary plain of the Ryukyu Limestone and again became active after its deposition. The flat planes cutting the Ryukyu Limestone are 50 to 60 m, 30 to 40 m, 20 to 25 m, 10 to 15 m, and 5 to 10 meters a.s.l., all of them have no sediments and are of erosional origin, except the last one on which a thin new limestone is sticked.

(c) Younger Dune Sand Bed

Sand dunes of 10-20 m height are sporadically distributed along the coast of southern part of the Okinawa-jima main island. The largest among them exists near Komesu, and covers unconformably the reddish brown soil on the flat plane of five to10 m a.s.l.

The eolian calcareous sand bed is made up mainly of foraminifer tests.

The buried rotten plant peaty soil is intercalated in the Dune Sand Bed, containing the Nanto type porcelain earths. Judging from this character, the Dune Sand Bed can be correlated with that which contains the Uhutobaru shell-mound remains at Toya.

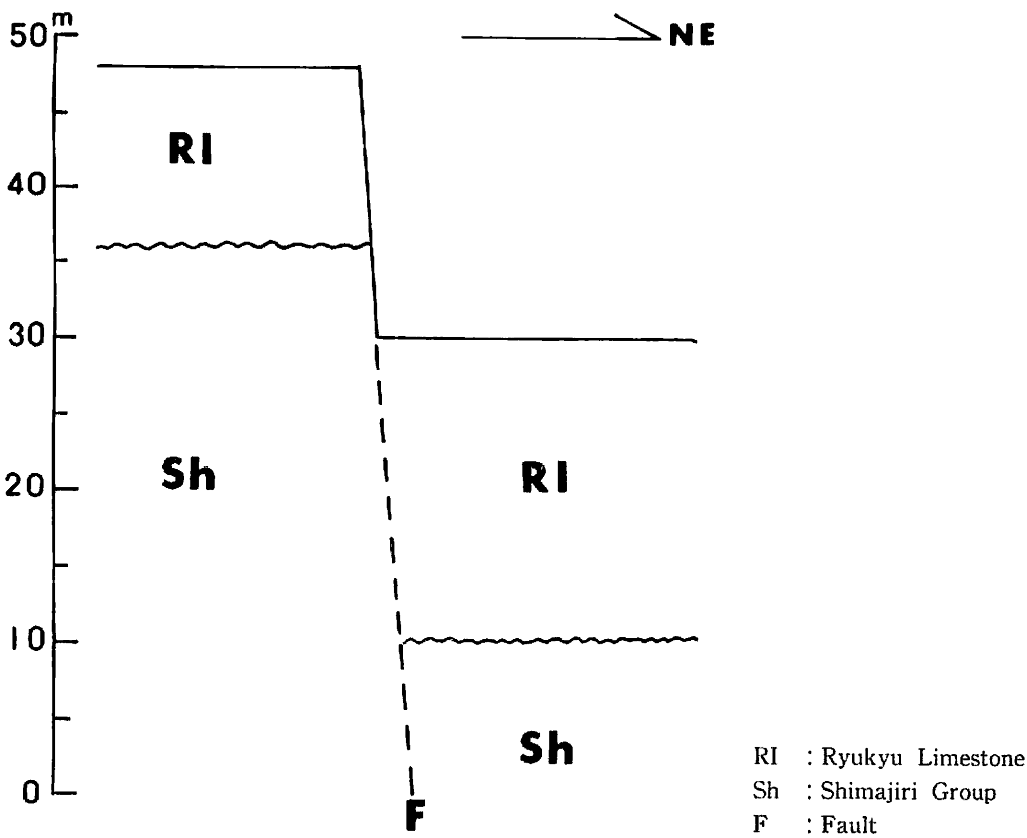


Fig. 6 Geologic Section of the Limestone Wall near Kyan, Itoman City, Southern Okinawa Main Island

3 Iheya-jima Island

Iheya-jima island, locating at the northernmost part of the Okinawa Prefecture, has an elongate shape of 14 km in length and one to three km in width.

KONISHI (1965) reported the geology of the basement rocks. TAKENAGA (1973) studied the Quaternary System, who discussed the history of the geographic development from his topographic study. Here the writer describes the Quaternary stratigraphy with special reference to two plains of Tana and Gakiya.

1) Topography

The steep mountains of 100 to 200 m a.s.l., with the highest summit at 239.9 m, extend from northeast to southwest, along the trend of this island. Alluvial coastal plains are distributed discontinuously near Tana-Maédomari and Gakiya, being cut by these mountains.

There are a terrace of 10 to 20 m a.s.l. around the plains and a chain of sand dunes along the coastline. Talus deposits are found at a gently inclined piedmont on the mountain slopes.

Thus the topographical features are mainly divided into three: (a) Talus slope, (b)

Terrace I and (c) Alluvial lowland.

(a) Alluvial slope

This is a gentle slope, from 15 m to 40 m a.s.l. around the plains of Tana and Gakiya.

(b) Terrace I

There is a flat terrace of 10 to 20 m a.s.l. around the plains of Tana-Maedomari and Gakiya. This is composed of terrace sand and gravel.

This terrace is fairly wide. Besides them, the flat plains of 25 m, 10 m and 5 m a.s.l. are distrubuted very narrowly, but all of them are the erosional plains.

(c) Alluvial lowland

A very flat lowland of one to three m a.s.l. are found at Tana, Gakiya and Shimajiri. Sand dunes run parallel to the coast line along this flat plain. This plain may be correlated with the Senbaru lowland of the Izena-jima island. The elongated direction of this plain, however, is different from each other between places as follows: north-east trend at Tana, east-west at Shimajiri and Gakiya, and north-west direction at the lowland of the Izena-jima island. This phenomenon may be effected by the difference of the structures of the basement rocks, that is prepared by the erosion of those rocks along the faults and sheared zones.

2) **Stratigraphy**

The Quaternary System, covering uncomformably the basement rocks is divided as follows: (a) Paleotalus deposits, (b) Maedomari Formation, (c) Alluvial sand and silt, and (d) Dune Sand.

(a) Paleo-talus deposits (Older debris)

These are distributed at the altitude from 40 m to 15 m a.s.l., forming a piedmont slope around the Alluvial plains. They comprise angular to sub-angular gravels of chert, sandstone and shale deribed from the basement rocks. The size of the abundant pebbles ranges from two to ten cm in diameter. The matrix is composed of sand and silt weathered to reddish brown. As a whole, it is yellowish brown to reddish brown. The terrace deposits are distributed cutting these paleo-talus deposits.

(b) Maédomari Formation

This formation is named for the sediments of the Terrace I, about 10 to 20 m a.s.l. in the Maedomari district. Its subsurface extension is widely distrubuted underneath the Alluvial lowland. The valley which cuts the basement is about 40 m deep near the coast line under the lowland of Tana and Gakiya. The narrow valley extends southward in the underground of this lowland at the depth of 30 to 20 m. The stratigraphic sequence in this burried valley is fine sand, silt with the gravels of chert, and blue grey silt with shell fragments in ascending order, and attains 25 to 35 m in total thickness. These sediments are covered by a bed of sand and gravel, which are distributed for continuously forming the terrace plain. This sand and gravel bed is 15 m thick at the maximum but in general two to five meters in other places. The pebbles are rounded, with diameters of about five to ten cm. The bed is intercalated occasionally with thin layers of coarse sand and silt. The matrix is sandy and reddish brown in color. This bed is solid as a whole and covered

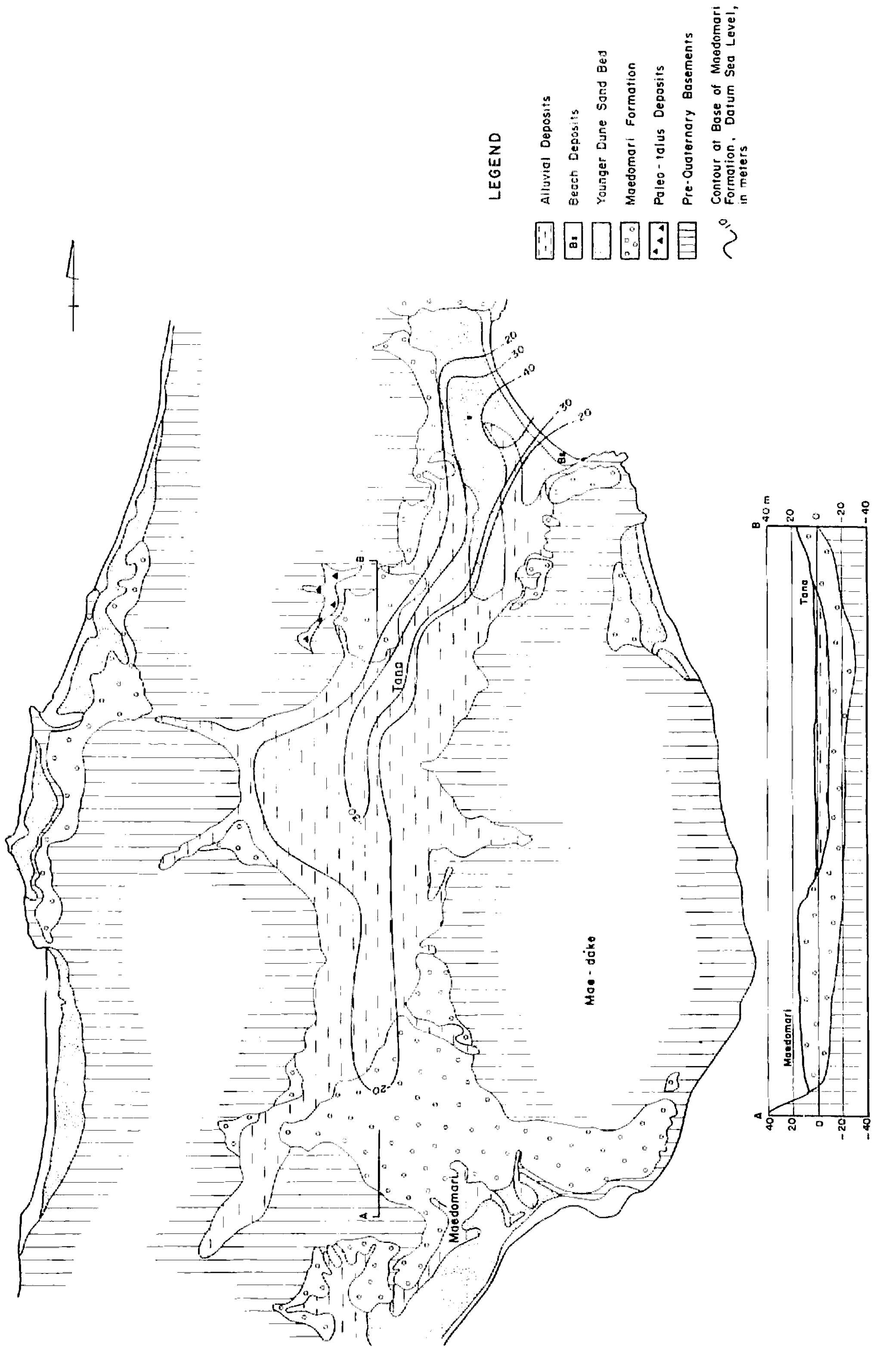


Fig. 7 Geologic Map of the Central Part of the Iheya-jima

with the reddish brown soil at its top.

The Maedomari Formation is evidently a continuous series of sediments which were deposited during the transgression commenced at about 40 m depth from the surface, and the upheaval of the sea level probably attained at about 20 m a.s.l. The Maedomari Formation can be divided roughly into two parts: The lower muddy facies, and the upper one of sand and gravel. A profile of this formation is shown in Fig. 7.

(c) Alluvial Silt and Sand

Loose sand and silt are distributed in the Tana plain with the thickness of six or seven m, and in the Gakiya plain with about 15 m thick. The sediments contain many fragmental shells and corals, and form a feeble swampy ground. This bed may be correlated with the Alluvial Silt and Sand of the Senbaru lowland in the Izena-jima island.

(d) Younger Dune Sand Bed

The Sand Dune, with height of three to seven meters as compared with the surface of three to seven meters as compared with the surface of the lowland, is distributed along the coast line of Tana, Gakiya, Shimajiri etc.

It is generally composed of limy sand consisting mainly of foraminifers, intercalated with greyish pumice of gravel size. It is probably correlated with the Younger Dune Sand Bed of the northern coast of Izena-jima island.

3) Interrelation between the Quaternary Strata and the Submarine topography around the Iheya-jima island.

As to the submarine topography around the Iheya-jima island, the following may be regarded as characteristic features: The present coral reef and the flat plain of 60 to 80 m deep surround the two islands of Iheya-jima and Izena-jima, with a narrow plain of 40 m deep in front the reef. The latter is continuously distributed especially off the east coast of the Iheya-jima island and off the west one of the Izena-jima.

It is to be noted that the submarine flat plain of the two places mentioned above is the extension of the burried valleys which form the Alluvial lowlands in two islands. As for the deeper topography, there is narrow flat plain at about 120 m depth, and steep slope is observable between the flat plain of 120 m and that of about 130 m depth. The flat plain of 300 m deep is observed between the two islands of Iheya-jima and Izena-jima, and Motobu Peninsula.

The interrelation between the submarine flat plains and the Quaternary Strata is shown in a profile of Fig. 7. The flat plain of 60 to 90 m depth may have been formed before the sedimentation of the Maédomari Formation.

4 Izena-jima Island

1) Topography

The Izena-jima island is located at four km south of the Iheya-jima, having a rectangular outline of 14 km^2. It has a small undulating hills of 100 to 120 m extending from northeast to southwest around which there are three terraces and the Alluvial plain forming the alluvial coastal plains.

Terrace I, flat plain of 45 to 55 m a.s.l., is distributed in the southwestern part of Mt.

Chijin and the southeastern part of Mt. Ohno. Terrace I near Mt. Ohno declines gently northeastward to the Senbaru lowland.

In general, this terrace plain has only thin sediments at its top, and has a character of an erosional plain.

Terrace II, 30 to 45 m a.s.l., is distributed on the northeastern mountain slope of the central mountain and near Mt. Mennah, northeastern part of the island. This Terrace II also declines to the Senbaru lowland. This is distributed more widely but has thinner sediments than Terrace I. It has a character of an erosional flat plain like Terrace I.

These two flat plains, Terrace I and II, resemble each other in their distribution, the difference of the compared height, and the declination after their deposition. Terrace II may have been formed at time interval immediately after the formation of Terrace I.

Terrace III, 8 to 17 m a.s.l., is mainly distributed around the northeastern part of the island. It has also thin sediments in most parts like Terraces I and II, and a character of the erosional flat plain.

The Alluvial Plain, distributing around the Senbaru lowland of the northern part and near Serikyaku and Izena, west of the island, has has the flat plain of three to five m a.s.l. It is divided into two: one is formed by burying with sediments the old valley in the deeper basement rocks like that near Senbaru and Serikyaku, and the other has thin sediments on the surface of the erosional plain of the basement near Izena.

It is noted that the burried valleys in the vasement rocks generally extend from northwest to southwest in parallel to the faults which run across the Ryukyu Arc.. The depth of the burried valleys attains 50 m and 30 m under the Senbaru and Hanakiri lowlands respectively. They show a steeper on the southeastern side. This may suggest that there existed a fault along the steep slope. The faulting must have been before the formation of Terrace III.

2) Stratigraphy

(a) Basement Rocks

The strata mainly composed of sandy to shaly flysh and thick chert are distributed with its lowest part intercalated by chert. Their strike is generally N60° to 80°E, and their dip 30° to 90° apparently northward.

Faults cut these strata frequently in the same trend as the strike. There is an anticline with 1000 m amplitude, plunging southwestwards in the central part of the island. The general trend of these basement rocks is parallel to the elongated mountains of the Iheya-jima island located to the north of the Izena-jima. Moreover, this trend coincides also with the direction of the Ryukyu Arc.

These basement rocks are assigned to a unit of the Motobu belt by Konishi (1965).

(b) Terrace I, Sand and Gravel Bed Type locality: Sahta quarry of the Izena Village

This unit is typically exposed at the Sahta quarry located on the northern slope of Mt. Ohno, central part of the islands.

Sand and gravel are well stratified, comprising mainly pebbles of chert and subordinately those of sand and shale. Grading of the gravels is recognized with the interval of 20 to 80 cm. The coarser part of the bed is composed of the sub-angular blocks of four

Fig. 8 Geologic Map of Izena-jima

or five cm in the averaged diameter, and the maximum one 30 cm in the elongated direction, and the finner part of the sub-angular one to the two cm on the average.

Both the two parts have the matrix of reddish brown clay. The strike of the bedding plane is N10°W to N15°W degree, and declines to the Senbaru lowland. The plane of unconformity at the base has extremely rough and irregular reliefs. Its height is so variable as to range from 25 to 45 m a.s.l.

The red coloured sand and gravel bed mainly composed of the sub-angular pebble to cobble of chert, is distributed at about 55 m a.s.l. in the southwestern part of Mt. Chijin and the southern part of the Izena Middle School. The thickness of the bed is about 3 to 5 m.

(c) Terrace II, Sand and Gravel Bed

This is widely distributed on the ffat plain of 30 to 40 m a.s.l., and the thickness of the bed is generally thin, about one to two m in many places. It consists of sand and gravel comprising reddish brown coarse sand, covering unconformably the sandstone of the basement. The gravel contains abundantly the rounded to sub-angular pebbles and cobbles of chert.

In the east of Serikyaku, it contains the pebbles of sandstone and shale. Its thickness generally increases towards the Senbaru lowland, and attains more than 5 m near the Dainigo Dam. Judging from these facts, it may be considered that the present topographic pattern of the Senbaru lowland trending northwest to southwest was originally formed before the deposition of the sand and gravel bed of Terrace I and II, and that the same pattern was retained untill at the time of the deposition of the Terrace sand and gravel bed of Terrace II.

(d) Terrace III, Uchihana Formation

This is distributed near Uchihana, northeast of the island, forming a depositional plane. It has become clear that this formation also extends to the Senbara lowland and is extensively concealed beneath the Alluvial plain there, as is shown in Fig. 8. The base of the formation lies at the depth of 36 m below the Alluvial Plain of the Senbaru lowland. The lowest part is 1.5 m thick, and is mainly composed of subangular gravels of chert. The main part comprises carbonaceous silt containing fragments of shells and foraminifers below and grey to pale brown limy silt with limestone gravels above. It sthickness attains 25 m at the central part of the lowland, but decreases rapidly towards the island side, being only 5 m at the site of bore-hole No. 5.

Limestone gravels in the silt member are white to pale yellow and dense, and resemble those forming a flat plane at a level of 8 m a.s.l. in the small isles lying west of the island. In some part of the limestone fragments, dendroid corals are found fairly abundantly.

The limestone is similar in sedimentary facies to the Recent sediments of an innerbay in the Okinawa district. It may be assigned to the sediments in a bay with a barrier reef in front of it.

Near Uchihana there occur a sand and gravel bed of two or three m thick in the uppermost part of the silt member forming a flat plane. It becomes thicker near Yabe at the island side, and attains four to five m. The gravels contained are sub-angular to rounded pebble and cobble of chert. Near Yabé the gravels become larger, and there the sandy matrix becomes lesser in amount as atratigraphically going upwards, and in the upper part it is almost lacking. The upermost gravel bed is red coloured.

The Uchihana Formation is the thickest in the Senbaru lowland, and rapidly thins towards the inland side. It shows a cycle sedimentation represented by a change from a coarse, through a fine, to a coarse-grained facies. It is the sediments of a transgression phase in a drowned valley opened in the northwest direction. It is considered that the sea-level at the regression time must have been about 20 m higher that of the present day. As is shown in Fig. 8, the relief of the basal plane of the Uchihana Formation attains 50 m at the deepest place in the Senbaru lowland.

The quite flat lying of the formation indicates that during and after the deposition of the formation neither faulting nor other crustal deformations have taken place.

(e) Older Dune Sand Bed

There is a small monadonock is about 10 to 15 m a.s.l. in the inner per of the Senbaru lowland. It is made up of a terrace sand and gravel bed of the uppermost part of the Uchihana Formation. It is covered by a reddish brown and well-sorted medium- to fine-grained sand bed. This bed contains calcareous nodules of several centimeters in diameter, and is overlain by a well-sorted sand and gravel bed in part.

It attains 8 m at the maximum thickness, and is cosidered to be a dune sand formed at the regression phase just after the deposition of the Uchihana Formation.

(f) Alluvial Deposits

The Alluvial deposits are distributed in the lowlands of Senbaru and Serikyaku, forming a flat plane of 2 to 3 m a.s.l..

The Alluvial deposits of the Senbaru lowland consist of limy silt that covers the silt that covers the silt member of the Uchihana Formation. It is locally variable in thickness: 20 m at W-3 borehole located at 300 m inland from the present seashore, 10 m at B-1 borehole and 10 m at W-a.

It is divided into parts by its sedimentary facied: The upper and lower. The lower part exists 6 m below the alluvial plain at the boreholes of B-1 and W-1, and 11 m below at W-3. It is made up of soft and limy silt containing shell debris and fragments of corals of various kinds including dendroid forms. It is considered to be the sediments probably of the transgression phase in the Holocene Epoch that invaded into valleys dissected the Terrace Deposits II. The upper part is predominantly composed of sands that gradually change from the silt of the lower member. It contains abundant foraminifers tests and some other bioclastic materials, and in its lower part are contained finegrained gravels of chert and fragments of dendroid corals and shells. It may be referable to inner-bay sediments at the zenith phase of the Holocene transgression.

The upper surface of the Sand bed forms a flat sedimentary plane at about 3 m above seal-level. It probably indicates the level of the high-tide at the Holocene Epoch in

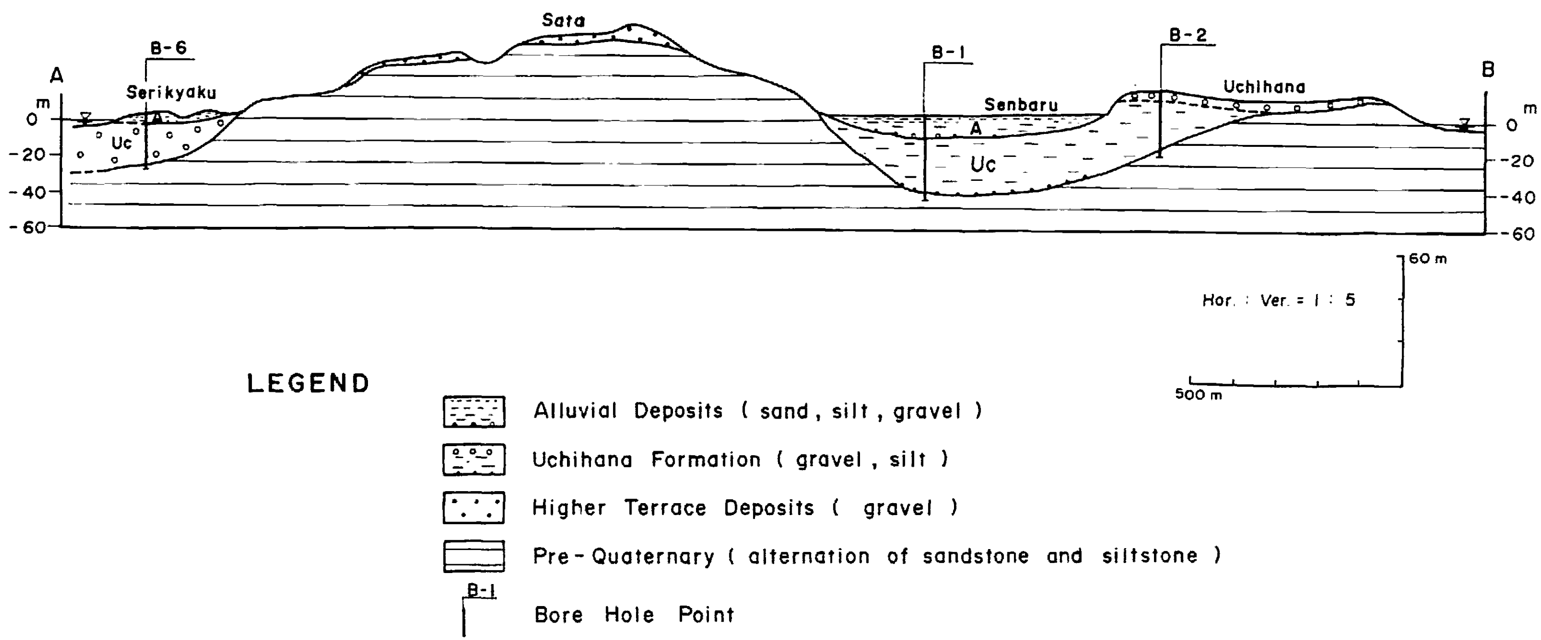


Fig. 9 Geologic Section of Izena-jima along Line A–B

this island. As described before, the Alluvial deposit shows the change of facies from the lower muddy sediments to upper sandy ones. This phenomenon is a characteristic feature of the Alluvial formations in Japan, and is explained by the eustatic changes of sea-level, as FURUKAWA (1972) already pointed out. .

The maximum phase of the Holocene transgression which is shown by the sediments at about 3 m a.s.l. in the Senbaru lowland of this island, and this level is quite the same as those clarified in the plains and etc.

(g) Younger Dune Sand Bed

This is recognized along the present shoreline including that of the Senbaru lowland. It is generally at the elevation of 10 m along the northeast and east coast, but it is slightly lower along the west coast. The dune is made up of limy sand mainly of foraminifer tests, with some grey pumices. Judging from the cultural remains contained in it, the dune was formed about 1,500 to 2,000 years ago.

5. Motobu Penisula of the Okinawa-jima Main Island

1) Topography

The Motobu Penisula extends for about 60 km northwestward from the main part of the Okinawa main island. The Quaternary System is mainly distributed along the northern to northeastern coast.

The pre-Quaternary basement rocks form a mountanous area including Mt. Yae (451 m) and Mt. Otowa (271 m) and comprise slate, chert and limestone of the Permian Motobu Formation, and limestone, slate and sandstone of the Triassic Nakijin Formation. They are refered to the Motobu Belt (KONISHI, 1965).

Around the mountains some terraces are found. Near the northern part of the peninsula three terraces, besides the Alluvial Plains along some river, are distinguished flat planes of 80 to 180 m a.s.l., 30 to 70 m a.s.l. and 10 to 15 m a.s.l. The highest plane extends northward from the mountains of the central part of the penisula, and slightly declines to the northwest side. It is separated by a linear cliff of NW-SE trend.

The upheaval of and the declination of the basement mountains to the north were taken place after the formation of the terrace. After this movements the plane was separated by block faulting of the northwest direction.

The Middle plane is distributed sporadically, forming a flat plane of 30 to 50 m a.s.l. outside the highest terrace and around the sedimentary basin in which the thick sediments equivalent to the Ryukyu Group Ib. The sediments forming this plane is thin, and in many cases it represents an erosion plane.

The lower terrace is widely distributed around Nakoshi and Sakiyama in the Nakijin Village, and forms a very flat plane of 10 to 15 m a.s.l.

The sediments which burried valleys in the upper reaches of rivers in the penisula, form the middle plane. This plane is formed by the sediments burried the lowland defined by the faults of the NW to SE and EW directions.

Juding from these facts, the main faulting of the NW-SE and EW trends took place after the formation of the highest plane and before the middle one.

2) Stratigraphy

(a) Terrace I, Sand and Grave Bed

This bed forms terrace of 80 to 180 m a.s.l. and comprises sand and gravel with intercalated silt and sand in some part. The gravels are mostly made up of rounded to sub-angular pebbles and cobbles of chert, sandstone, slate and limestone which are derived from the basement rocks. In many cases the matrix is composed of deep reddish clay. The thickness is 1 to 2 m in some places and 10 to 15 m in some other places. This unit was called the Kunigami Gravel Bed by HANZAWA (1935).

(b) Ryukyu Limestone

This is widely distributed along the northern to northwestern coast of the Motobu Penisula, and is made up of a conformable sequence mainly of carbonate sediments: calcareous muddy sand and silt, limestone characterized by larger forminifers such as *Operculina* and *Cycloclypeus*, limestone mainly composed of calcareous lagae, and calciludite with indistinct stratification, in ascending order.

In the lowest part, fine-grained gravels of the basement rocks are commonly included, and boulders of more than 1 m in size are contained at the base.

These strata gently decline to north-west, and exceed in the thick part, 100 m as revealed by the electric survey and boring.

The sediments are deposited in a valley which declines and widenes northwestwards from the downstream of the Oh-i River, and continues to the submarine part to the north of the penisula. This sedimentary basin is 1 to 2 km width, and the Ryukyu Limestone is in many cases abut against the basement rocks.

The exposed line of the unconformity is linear in many cases with the NW-SE direction, and is well concordant with the trend of the fault system cutting Sand and Gravel Bed and Ryukyu Limestone. This fact indicates that the formation of the sedimentary basin of the Ryukyu Limestone was controlled by the tectonic movement accompanied with the faulting of the NW-SE direction and that the movement occured after the deposition of the Sand and Gravel Bed. There are outcrops of the basement below the Ryukyu Limestone near the coast from the mouth of the Oh-i river. Moreover it has been clarified that limestone of more than 90 m thick is distributed in the Kouri Isle, about 2 km north of the Penisula. This limestone also belongs to the Ryukyu Limestone.

(c) Terrace Deposits I

This is the sediments forming a flat terrace of 30 to 50 m a.s.l.. It is narrowly distributed in the downstream areas of the rivers and in the sedimentary basin of the Ryukyu Limestone at Nakijin.

It is made up of reef limestone mainly composed of corals, and sand and gravel. The limestone lies in the area facing the sea surrounding the sedimentary basin of the Ryukyu Limestone. That of the area to the sourth of Kaneshi and Serikyaku of Nakijin village is caracterized by corals and mat-form coralline algae of in situ position. In many places the thickness is as 4 to 5 m.

Small basins trending are aligned along the rivers of the Oh-i and Manna. The sediments which burried the basins are sand and gravel with lenticular bodies of mud. The sand and gravel bed forms a flat plane of 30 to 50 m a.s.l.. Its thickness attains 20 to 30 m. The basins mentioned above are defined by faults of the NW-SE and E-W direction. The carbon fourteen age of a carbonized wood chip in this sand and gravel is older than 34,000 years B.P. The elevation of the terraces are, however, is different between the north and south sides of the NW-SW fault running near Kaneshi in Nakijin Village, i.e. that of the south side is higher than the north. This shows that the activities of faulting of the NW trend lasted to a small extent in this stage, too.

(d) Terrace Deposits II

This is the sediments forming a flat plane of 10 to 20 m a.s.l., and is widely developed dissecting the Ryukyu Limestone near Nakoshi and Sakiyama in Nakijin Village of the north coast of the Peninsula. It consists of sand and gravel beds of at most 10 m thick with intercalations of silt bed containing gravels in some places, and shell fossils and plant remains in some other places is distributed. It may be inner-bay sediments. The gravels are mainly composed of rounded pebbles of chert, sandstone and limestone derived from the basement rocks, and the matrix is sandy to silty. Reddish brown soil thickly covers the uppermost part of the sand and gravel bed.

The altitude of the sedimentary plane, the degree of erosion of the plane, and the lithofacies of the sediments evidently indicate that the Sand and Gravel Bed is correlated with the Maédomari Formation of the Iheya island and the Hanakiri Formation of the Izena island.

(e) Terrace Deposits III

The submarine geology off the west coast of the Motobu Peninsula was reported by AKIYAMA(1975). He pointed out that there were three submarine burried flat planes on the older limestone and the Ryukyu Limestone, and that there were weathered beds accompanied with reddish brown clay on these places. It is known from the dating on ^{14}C that the sediments covering these flat planes range from the maximum stage of the Würmian glacial age to the Holocene age. There are also a sand bed in the upper part and soft sediments characterized by sandy silt with intercalated patch reef limestones in the lower part. Gravels of corals are found throughout these beds. These strata are 10 to 15 m thick, and rest disconformably in local on the reddish brown clay bed of the lower member, which is extensively and horizontally distributed, 10 to 15 m thick, and is accompanied by sand beds with gravel in its lower part. The reddish brown clay forms a flat plane of about 20 m below sea level, and can correlated with that of the Middle flat plane off the west of the Motobu Peninsula. It is the terrestrial sediments at the stage of the lowering of the sea level during the Würmian glacial age of the latest Pleistocene.

(f) Alluvial Deposits

These comprise sediments spread by modern rivers such as Oh-i and Manna, etc. in the lowland areas, and descend below sea level as described before.

Those of the submarine bottom were subdivided by AKIYAMA (1975) into three parts, A, B and C members, and their absolute ages were also clarified.

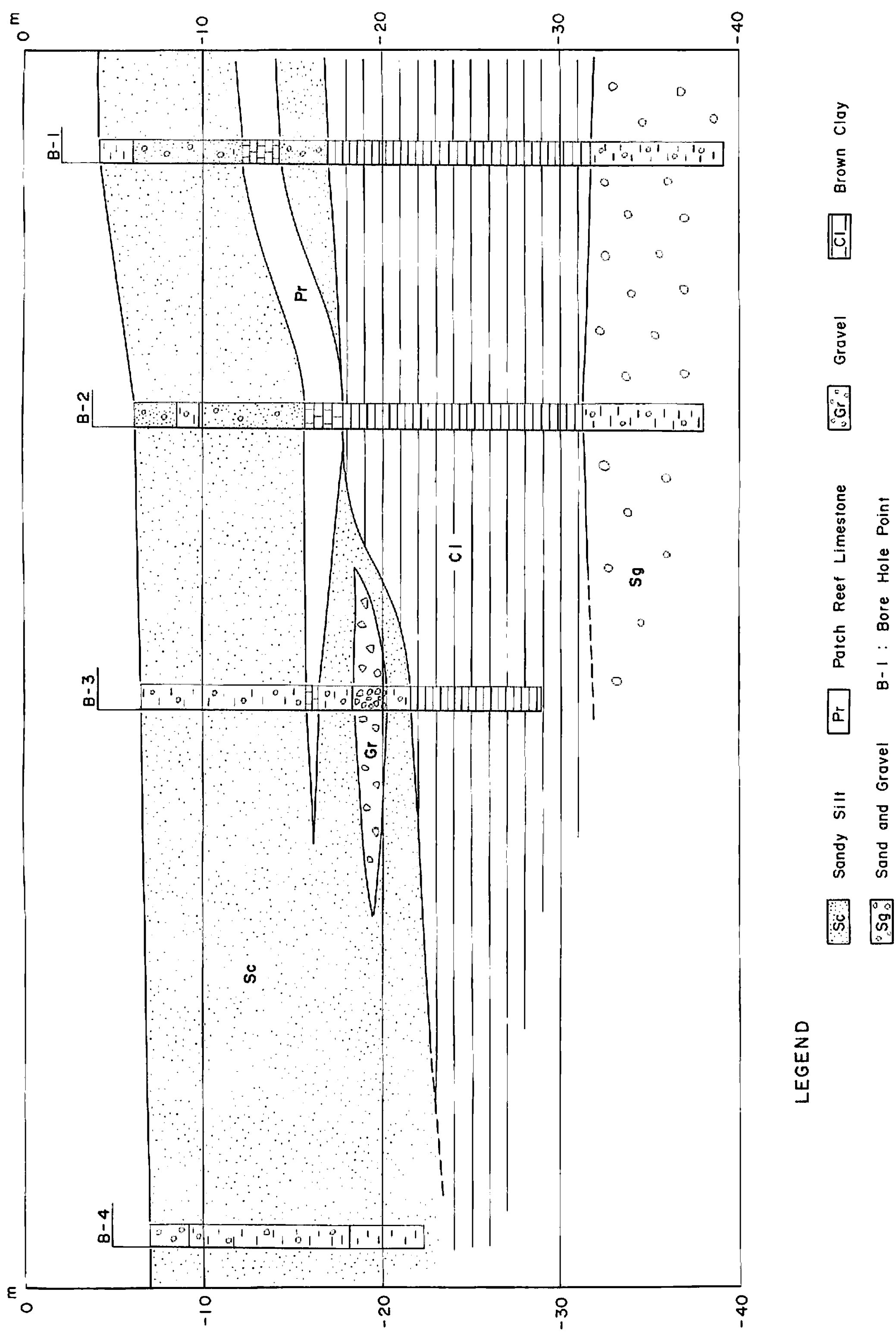


Fig. 10 Submarine Columnar Section of the Sesoko Channel, Motobu Peninsula, Okinawa Main Island

6 Kerama-retto Islands

The Kerama-retto islands, located at about 40 km west of Naha City of the Okinawa main island comprise 13 islands. The Quaternary System is distributed only in the two, Tokashiki-jima and Zamami-jima. They are otherwise made up of the pre-Miocene basement complex which belongs to the Kunigami belt (KONISHI, 1963).

The Quaternary System and the topography in the two islands are described here.

1) Topography

(a) Tokashiki-jima island

This island is mountainous, with the highest peak at 223.5 m a.s.l. Generally mountains about 200 m a.s.l. extend in the NNE-SSW trend. The valley is controled by faulting and other geologic structures. It is narrow even near the coast and its bottom plane is long and narrow. There is a narrow Alluvial plain near Aharen and Tokashiki.

(b) Zamami-jima island

This island is likewise mountainous with the highest peak at 160.7 m a.s.l. Its north side has a steep slope with many cliffs, and narrow Alluvial plains exist sporadically on the north side.

Sand dunes are distributed along the coast of the Alluvial plains.

(c) Submarine Topography

On the Kerama-retto islands, the Ryukyu Limestone is nowhere recognized and there is no erosional plane either. Accordingly the islands may have been subsided almost all-through the Quaternary Period. On this account, the writer has examined the submarine topography.

The results of the submarine geologic investigations are as follows:

(1) The Kerama Straits dividing the islands of Tokashiki-jima and Zamami-jima in the NNE-SSW direction have a submarine flat plane of 50 to 60 m deep, on which sediments are mainly sands and gravels without limestone.

(2) The Kerama Straits are divided into two submarine valleys which extend straightly from NNE to SSW, leaving the above flat plane as a submarine ridge.

(3) The isles of Zamami-jima are unified into a topographical unit bordering the 45 m depth, in which several parallel valleys extend from NE to SE.

(4) No remarkable submarine valley is recognized around Tokashiki-jima, except for the inlet of Aharen Port. However, many small valleys run from NW to SE. They seem to have a close connection with the on-land ones on the view-point of the geologic structures.

(5) All the islands of Kerama-retto are unified into a topographic unit on a submarine flat plane of 65 to 80 m deep. Pebbles of limestone are collected from this plane.

(6) Recent coral reefs develop around the most of the islands of Kerama-retto.

(7) The buried valley of the Tokashiki Plain meanders sharply and extends to a submarine valley. The flat plane of 50 to 60 m deep is not found here, and the valley runs directly to the 60 to 70 m deep.

To sum up there are many valleys formed by the faulting of the NW-SE trend, and many of them and flat planes were formed newly during the Quaternary Period.

There is, furthermore, a great depression of the same trend, cutting across the Ryukyu Arc at the immediate southwest of the Kerama-retto. It is called the Miyako Depression (KONISHI, 1963). It seems to have been formed by the tectonic movement after the deposition of the Shimajiri Group and is closely related with the formation of the Ryukyu Basin, a trough on the inner-side of the Ryukyu Arc. The subsidence of the Kerama-retto islands may have a reation with these movements.

2) Stratigraphy

(a) Basement

The pre-Quaternary basement is referred to the Nago Formation. It consists of phyllite, schistose sandstone, and alternation of them in the lowest part at the northern end of the Tokashiki-jima island. The strata show the strike of N20°–40° and the dip 20–40°NE. Many faults cut the basement with the systems of (1) E-W, (2) NEE-SWW, (3) NE-SW, (4) NNE-SSW, and (5) NW-SE.

Among them, (1) to (3) are concordant with the extension of the Kunigami Belt. (4) is concordant with the topographic trend of the island and a also the extension of the Kerama Straits, cutting (1), (2) and (3). (5) is the most remarkable fault in this area, cuts all other systems, and coinsides with the faults which cut the Ryukyu Limestone in the southern part of the Okinawa-jima, and also the direction of the Miyako Depression.

(b) Quaternary System

The Alluvial Plains are distributed near Tokashiki and Aharen of the Tokashiki-jima, and near Ama, Zamami, Furuzamami and Asa, southern coast of the Zamami-jima. They are flat planes of three to five meters a.s.l., and on the frontal margin of them dunes are distributed.

(1) Alluvial Formation

This forms a flat semimentary plane of about five m a.s.l. in each Alluvial Plain. At Furuzamami, it extends from NW to SE, and is located on the extension of the structural submarine valley opening to SE.

This submarine valley extends to the flat plane of 45 to 50 m in depth. It corresponds to the submarine flat beneath the Alluvial Formation off the west coast of the Motobu Penisula.

The Alluvial Formation is divided into the Upper and Lower Members. The Upper Member consists of greyish white coarse dune sands from the surface to 1.3 m depth, containing the fragments of shells and corals, with some interbeds of sand and gravel. The sand is calcareous, mainly composed of foraminifer tests, loose unconsolidated. The Lower Member is mainly made up of gravels containing cobble size coral fragments, and partly intercalated with gravels without matrix. The matrix is loose medium to coarse sands made up of the small fragments of foraminifers, corals and shells.

The thickness of the Formation attains 25 m at Furuzamami, 35 m at Ama, 43 m at Zamami, 28 m at Aharen, and 34 m at Tokashiki respectively.

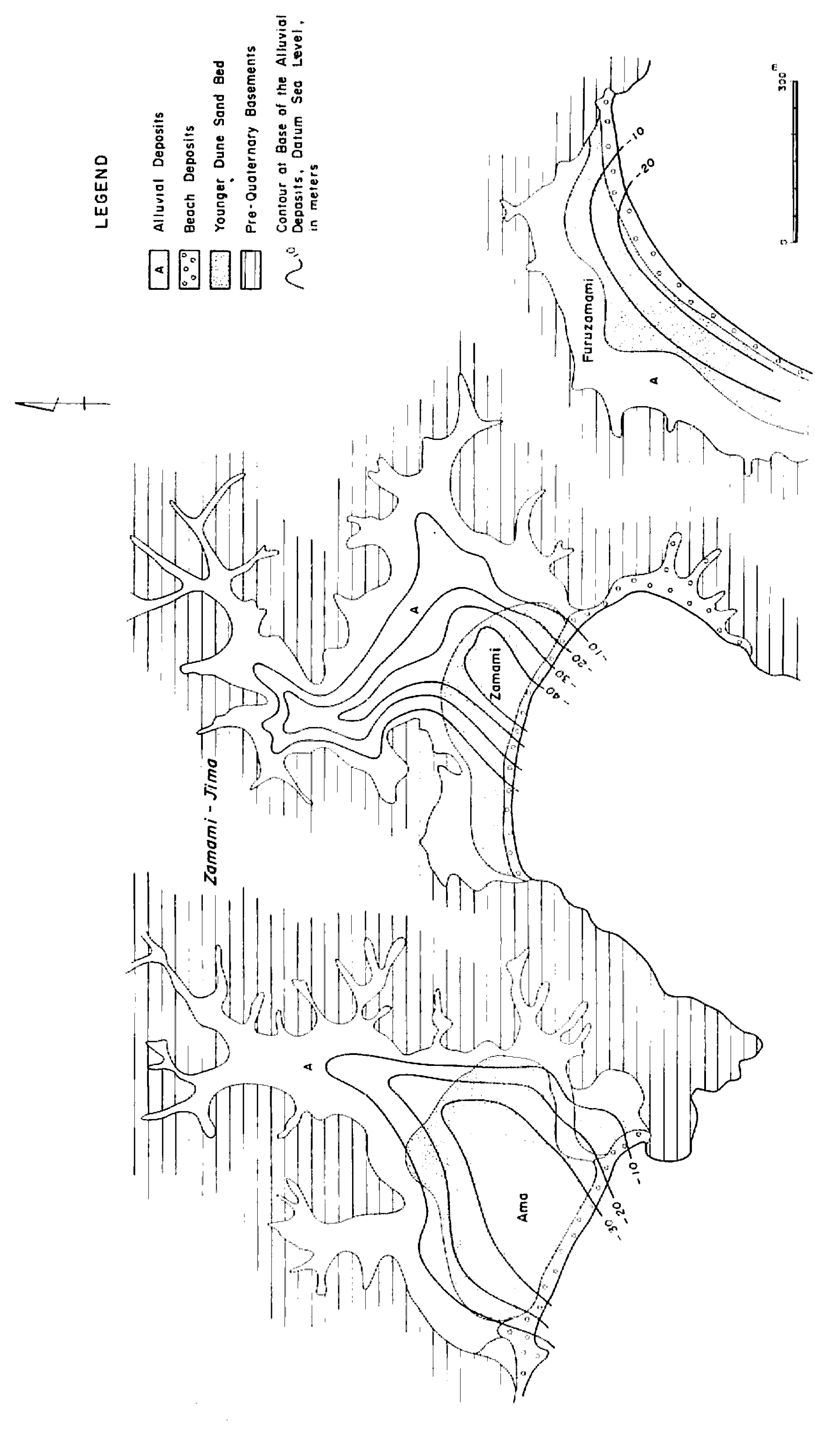


Fig. 11 Geologic Map of the Western Part of the Zamami-jima, Kerama-retto

(2) Younger Dune Sand

Sand dune is distributed along the coastline on the margin of each Alluvial plain. It is generally four to five m a.s.l. in height. It is composed of well-sorted medium to coarse calcareous sand, containing fragments of foraminifers, coral and shells. In the uppermost part a layer of grey to dark grey pumice is intercalated. Moreover, the Late-Nanto type porcelains of archaeological remains were found in the dune sand.

Judging from all these characters, the dune sand is correlated with the Younger Dune Sand which is distributed in Okinawa-jima and other islands.

7 Aguni-jima Isle

Aguni-jima isle, located at about 70 km west of Okinawa-jima, has the length of 3 km from north to south and the width of four km from east to west, with its highest peak at 97.3 m a.s.l. The isle consists mainly of Tertiary volcanic rocks like Kume-jima isle 22 km to the southwest, and belongs to the older volcanic belt (KONISHI, 1965; NAKAGAWA, 1967). They were described by WAKIMIZU (1906) and KAMIYA (1973). The Ryukyu Limestone and dune sand bed rest unconformably on them.

1) Topography

Generally, the topography of this island shows a gentle inclination to the east and northeast, with some terrace-like flat planes, which are all composed of limestone except the highest one at the southwestern end.

A fault cliff of the NE-SW trend with a steep slope to SE, extends in the central part of the isle. It has 20 m downthrows at the maxmum. Its downthrow becomes smaller towards NE, where the cliff becomes vague and is not expressed topographically on the flat plane of 20 m a.s.l. It is the most remarkable fault in the Aguni-jima isle and is called here the "Aguni Fault".

A long and narrow ridge of several meters difference in compared height runs along the outer margin of each flat plane. On the inner side of the ridge which is presumably an ancient reef, exsists a flat depression of lagoon like form. A sand dunes, which attain 15 m at the highest level, extend from north to south along the eastern coast of the isle. The present coral reef also is remerkably developed along the eastern coast.

On the west side of the Aguni Fault, six flat planes are distinguished: 80 to 95 m, 60 to 75 m, 25 to 50 m, 15 to 25 m, 7 to 15 m, and 4 to 10 m a.s.l. On the east side of the fault, there are also six flat planes, which correspond to these on the west side, i.e., 55 to 75 m, 35 to 45 m, 20 to 30 m, 15 to 20 m, 5 to 14 m and 4 to 5 m a.s.l. Among them, the highest plane is an irosion flat plane of basement volcanic rocks, and the red soil developes remarkably on the surface. The flat planes of 60 to 75 m and 7 to 15 m have reddish brown clayey soils on their surface. There is tendency that the lower the plane is, the lighter the red color. The lowest flat plane of four to 10 m has no surface soil, and the limestone crops out directly. This is the topographical plane of the so-called "raised coral reef". Thus these are the topographical planes surrounding semi-circularly the erosion at surface of the basement rocks. In other words, the ancient land seems to have extended to the southwest of the isle.

2) Stratigraphy

(a) Tertiary Volcanic Rocks

The volcanic rocks which make the basement of the isle are extensively distributed, although they are covered unconformably by the Ryukyu Limestone is some places. They are the best exposed on steep cliffs along the western and southern coasts from the Fuden Cape. They comprise dacitic lava in the lower part, white pyroclastic rocks in the middle, and andesite lava in the upper part, accompanied by tuff and tuff breccia. The fossil shells of gastropods and pelecypods occur in the pyroclastic rocks, by means of which KAMIYA (1973) correlates the Aguni Volcanics with the Pliocene Volcanic (Uegusukudake Volcanics) of the Kumé island.

(b) Ryukyu Limestone

The Ryukyu Limestone is more than 70 m thick. It is roughly divided into three facies.

(1) Pebbly limestone

The basal part of several meters thick above the plane of unconformity consists of muddy limestone containing well rounded granules and small pebbles of the Tertiary andesite and tuff breccia. At the borehole of B-1 near the east coast of the isle, pebble bearing clay is distributed between 40.30 to 43.00 m deep, and the included limestone becomes brecciated and fragile.

(2) Sandy and muddy limestone

Muddy limestone comes above the basal pebble bearing muddy limestone mentioned above, and sandy limestone generally deposits above the muddy one. The muddy limestone is 15 to 25 m thick, and mainly contains calcareous algae and foraminifer tests, with some calcareous algae, corals, etc.

(3) Coral limestone

This limestone is generally abundant in the uppermost part of five to 10 meters. It is mainly made up of corals, and contains very abundantly a fossil assemblage of calcareous algae, pelecypods, echinodermarta, gastropods, etc. The corals are large dendritic massive, and show nearly in situ deposition. This limestone has five to 10 m thick and 10 to 20 m long, and is sporadically distributed like a knoll in many cases.

The change of the above three facies is transitional. The Ryukyu Limestone is a successive series of sediments from the basal pebble bearing limestone to the uppermost coral limestone through sandy and muddy ones, without remerkable unconformity within it. Moreover, the stratigraphy is the same between the eastern and western parts on both sides of the Aguni Fault. That means the faulting occured after the deposition of the limestone.

(c) Post-Ryukyu Limestone terraces

The main fault activity was at least after the formation of the flat plane of 60 to 70 m a.s.l., and partly it occured again after the formation of the 25 to 50 m flat plane. The planes of 80 to 95 m and 60 to 75 m a.s.l. are sedimentary plane of the Ryukyu Limestone and the lower one are probably of erosional origin. On the 20 to 25 m plane in the eastern part of the isle, there is a thin gravel bed of 10 to 15 cm thickness, with granules

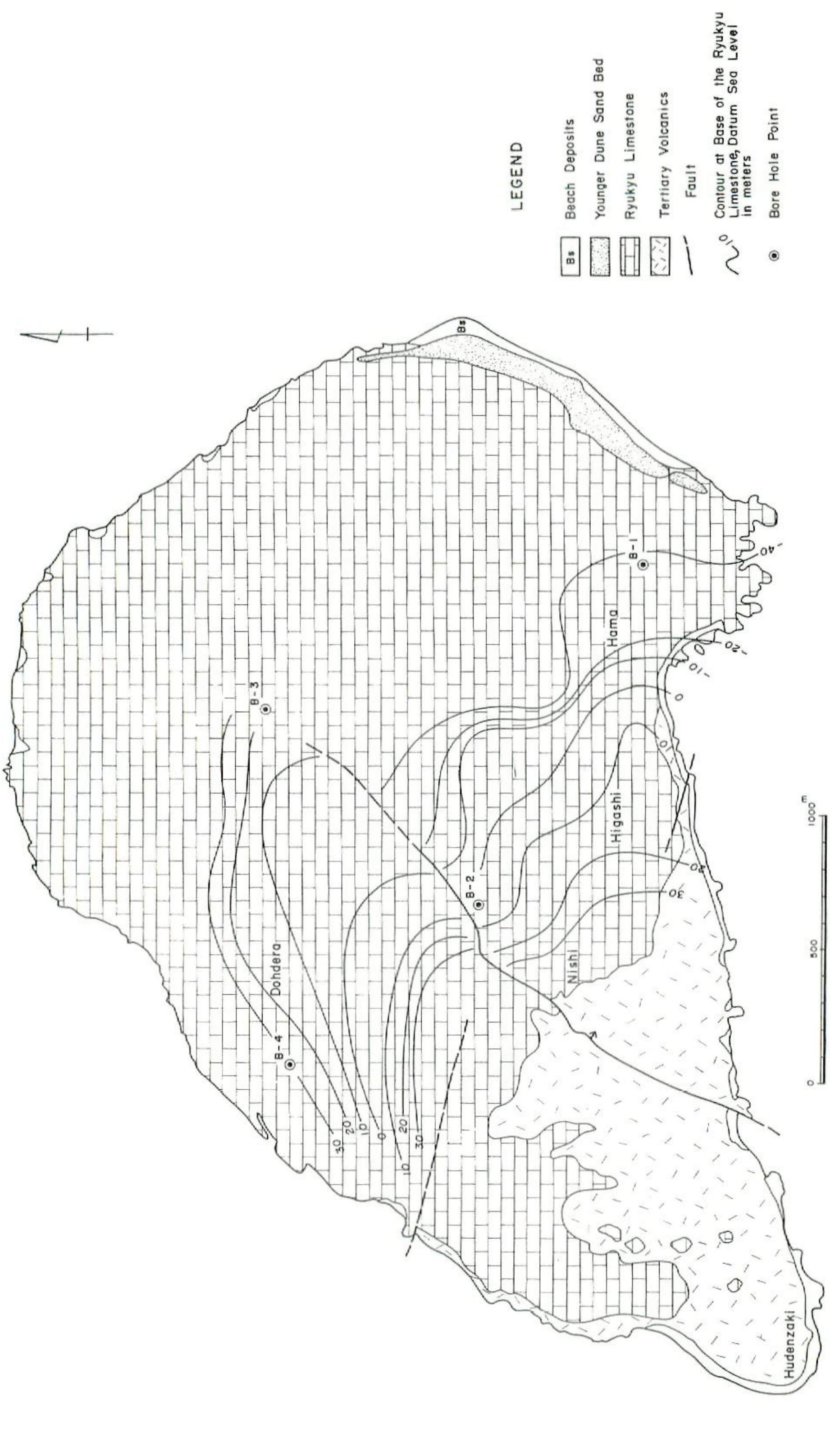


Fig. 12 Geologic Map of Aguni-jima

of greyish white to greyish brown volcanic rocks in the weathered red soil of the Ryukyu Limestone. It may have been formed during the erosional stage of this topographical plane.

(d) Younger Dune Sand Bed

There is a dune sand bed along the west coast of the isle with the maximum width of 2000 m, the length of 1300 m from north to south, and the sedimentqry plane of the maximum height 15 m. It is made up of calcareous medium sands of mainly foraminifer tests, including the fragments of corals and shells. In the sands grey pebbles of pumice are abundantly contained. It covers unconformably the reddish brown soil on the Ryukyu Limestone. It can be correlated with the Younger Dune Sand Bed distributing in various areas in the Okinawa Prefecture, considering the distribution, the faces, and the character of the contained pumice.

3) Geologic Structure

The Aguni Fault cuts across the isle from NE to SW, dividing the isle into two parts. The fault has the strike N50°E and the dip 70° to N. A group of minor fault trending NWW-SEE, E-W is found along the western to northwestern. The NWW fault is cut by the Aguni Fault. The EW fault is recognized also on the four to 10 m plane, cutting the Ryukyu Limestone. This minor fault group agree well in the direction with the fault group cutting the Ryukyu Limestone in the southern part of the Okinawa-jima. It is noted that the scale of the faulting was smaller inside the Ryukyu Arc.

8. Tarama-jima Isle

1) The outline of Topography and Geology

The Tarama-jima isle is localed at about the middle between the islands of Miyako-jima and Ishigaki-jima, having the ellipsoidal form, 5 km long from east to west and 4 km wide from north to south. It is low and flat. The heighest point, being 32.8 m a.s.l. is on the hill at the northern end of the isle. The hills are generally 8 to 15 m a.s.l. in height and their surface is covered thinly by brown to reddish brown soil. The isle is composed wholly of limestone, which continues down to 50 to 60 m b.s.l. This is referred to the Ryukyu Limestone. Around the isle sand dunes are distributed, and moreover the present coral reef surrounds the outer side of the isle with 300 to 700 m. Faults extend from the Futenma Port to the NWW direction in the eastern part of the isle and some of them cut the present reef at the southern end. Moreover, boring data have revealed the subsurface distribution of a bed of quartzose sand immediately below the limestone.

The Tarama-jima isle continues eastward to the Miyako-jima island, if we follow the bathymetric line of 200 m deep. Around the isle, the bathymetric line of 100 m deep extends to the southeast and north of the isle, and especially a submarine flat plane of 60 to 80 m b.s.l. is distinguished. At about 10 km north of the Tarama isle, crops out the Minna-jima isle whose highest top is 10 m a.s.l. On the submarine bottom between the two isles there is a flat plane of 30 m b.s.l. And the frontal steep slope around these isles inclines to the flat plane of 60 to 80 m b.s.l. which extends to another steep slope untill the deeper flat plane of 200 to 300 m b.s.l..

The relationship between the submarine topography and the subsurface geologic system of the Tarama-jima isle is shown in Fig. 14. As shown in this figure, the Ryukyu Limestone in the Tarama-jima isle has its base at the flat plane of 60 to 80 m b.s.l.

2) Topography

a) Terrace I

There is a topographic plane at 20 to 35 m a.s.l., which is rich in small relief near Nakasuji, the northern end of the isle. It is composed of foraminifer sands with developed cross-bedding. The sands are possibly interpreted as paleo-dune sands, and the topographic relief of the dune. The extension of the dune is from east to west along the north coast, and the orientation of the cross- bedding from northeast to southwest.

b) Terrace II

This is the topographic plane which occupies the most part of the isle. It is extremely flat and five to 15 m a.s.l. Its highest place is near the Terrace I of the northern end, and declines gently southward with about one-four hundredth. This suggests the tilting from north to south. The surface of the terrace is covered with reddish brown soil. The patch reef as recognized in the modern reef, knoll-like reef, minor relief, and linear sedimentary structure by tidal current are not found. This means that the flat plane is not of the sedimentary origin but of the erosional one.

The sedimentary plane seems to have exsisted at a higher position. On this flat plane, caves were formed at some localities, and their base attains to the present sea level. They seem to have been formed in a considerably recent age. Cutting this flat plane, there is a fault scarp with a strike N20°W and a dip westward 70° in the eastern part of the isle. The vertical downthrow of the topographical plane is less than two m, but the right lateral horizontal displacement is recognized with the amount of heave not less than 100 m. Here the writer calls this fault "Futenma Fault". It cuts the present reef also, and it may be an active fault.

c) Sand Dune

Sand dunes are aligned along the present coast line, surrounding the isle. Especially those along the north coast becomes high. Around the isle they cover the flat plane of about three meters along the present ocast line. Their height is 10 m at the highest plane and generally five to six m.

d) Recent Coral Reef

The present coral reef is developed around the Tarama-jima isle well in the eastern sea-area but poorly in the west. On the eastern side, its width is 300 to 500 m, and the flat shallow lagoonal part is composed of sandy sediments of mainly foraminifer tests. Patch reefs are in spots along the outer margin of this lagoonal part, showing a concentric alignment around the isle. And the reef edge further encircles the isle. The concentric structure of the reef seems to record a successive enlargement along with the growth of corals. The steep front slope of this edge extends to the flat plane of 60 to 80 m b.s.l. Futenma Fault mentioned above is cut by the fault of N70°E trend on the reef flat in the northeastern part of the isle, and the E-W liniations are abundantly found on the parallel cleavages.

3) Stratigraphy

To examine the stratigraphic sequence in the Tarama-jima isle the outcrops are too much limited because of flatness of the surface topography. Therefore a geologic boring was drilled, which has newly given a sequence as described below.

a) Tarama Sand Bed

This is named to the quartzose sand bed which has been found by drilling to lie extensively under the central part of the isle. This seems to be covered unconformably by the Ryukyu Limestone, although the contact plane does not crop out on the surface of the isle. The upper limit of the Tarama Sand Bed is lower than 36 m b.s.l. at the bore-hole of B-1 and 43 m at that of B-2, and the thickness of the bed itself is at least 10 m.

This bed is dark brown to brown and made up of semi-consolidated muddy sand to coase sand. The sand is almost wholly made up of quartz grains with a small amount of greenrock fragments. Arround the isle, the drilling did not reach the Tarama Sand Bed even at 50 or 61 m b.s.l., which seems to exsist at deeper place.

As is illustrated clearly in Fig. 14 the structure of this sand bed rises up like a mound at the central part under the isle. This bed is distributed below the Ryukyu Limestone and located to the west of Miyako-jima. Therefore it is most probably correlated with the Lower Sandstone Member (Ohgami Sandsone Member) of the Shimajiri Group.

b) Ryukyu Limestone

This is the limestone which composes nearly the whole isle of the Tarama-jima with the thickness of 50 to 60 m. In its basal part sandy limestone is predominant in which three facies are generally distinguished: facies of mainly foraminifer tests, that of mainly algal balls, and the intermediate type of the two. The lowest sandy limestone covers unconformably the Tarama Sand Bed at about 36 to 45 m b.s.l. under the central part of the isle. Its thickness is about five meters. In the superjacent part, it is about 20 m thick, and the thin alternation of algal ball, coral, and foraminifer limestone is seen, one to seven cm thickness of each unit. A reef facies of mainly corals occurs as patch reef in some parts. And at a still higher horizon a thick algal limestone occurs characteristically around the central part and the foraminifer limestone in the northern and southern parts of the isle respectively. The thickness of this limestone is 10 to 20 m. The uppermost part, 10 m thick, consists of foraminifer sandy limestone. Coral limestone a.s.l.

The Ryukyu Limestone of this isle which altogether attains more than 80 m thick has characters of lagoonal sediments, and, accordingly, the antient reef around this lagoonal limestone must have been larger than the present Tarama-jima isle and the reef edge may have existed at the still outer side of the isle.

c) Nakasuji Sand Bed (Older Dune Sand Bed)

This is a unit of sediments forming a small relieved flat plane of 20 to 35 m a.s.l. which extends from the east to west in the northern part of the isle. It covers the brown paleo-soil of the weathered Ryukyu Limestone at the level of 17 to 19 m with a distinct unconformity. The soil is 15 cm thick and contains many fossil shells of Plutolamella, a

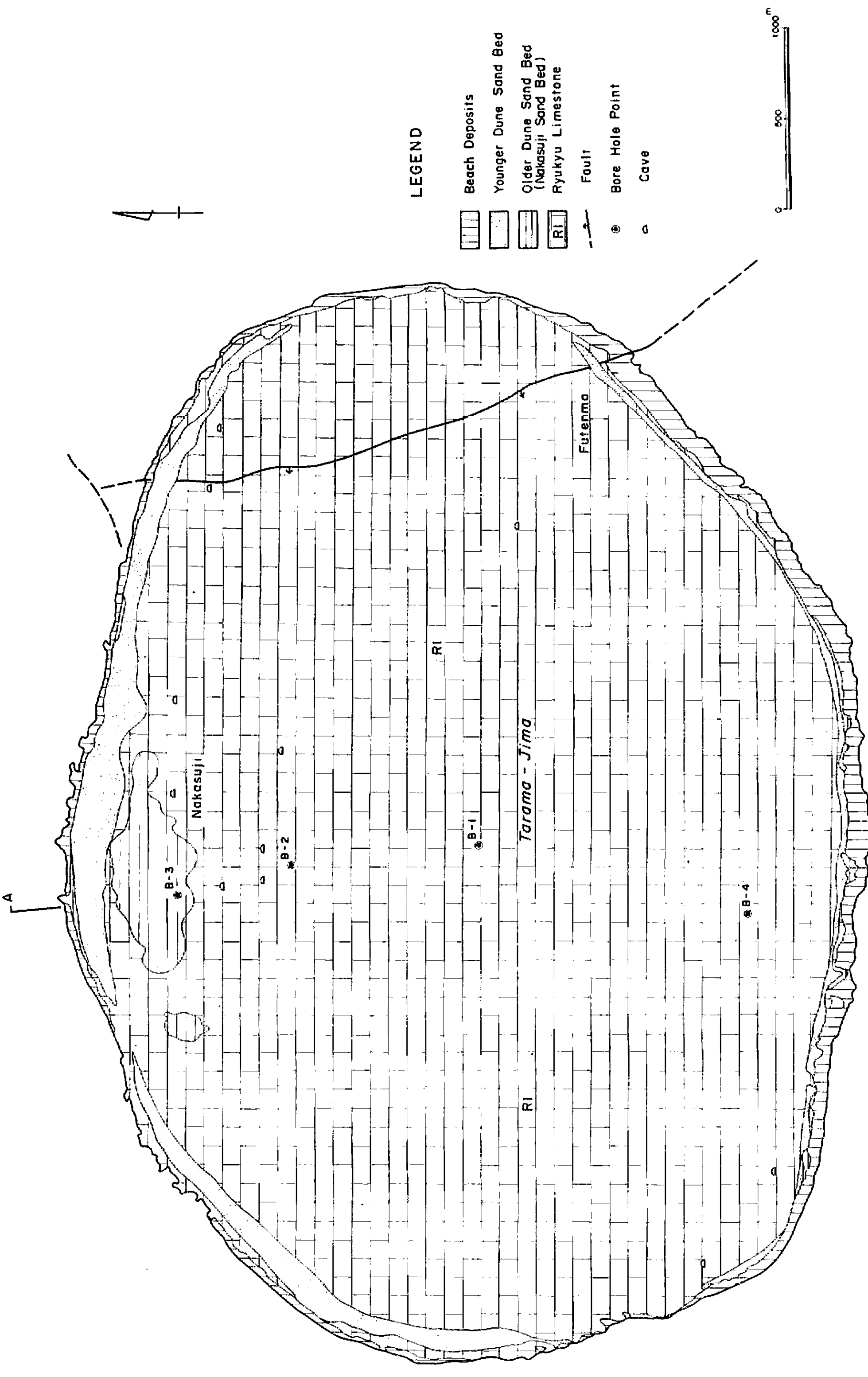


Fig. 13 Geologic Map of Tarama-jima

land-smail. Its uppermost part is dark brown and forms an independent soil unit.

The sand is well-sorted, loose, calcareous, and coarsed-grained, consisting mainly of foraminifer tests. It is cross-laminated with southward inclination of about 30°. It is covered with a reddish brown soil at the top. This reddish brown soil is in turn, covered with the Younger Dune Sand Bed.

The Nakasuji Sand Bed looks like the eolian sand which covered the erosional plane of the Ryukyu Limestone.

d) Younger Dune Sand Bed

The Sand Bed is distributed long and narrowly, with width of 50 to 100 m, on the flat plane of three to five m a.s.l. around the isle and itself two to three m thick. The sand is well abraised, well-sorted, coarse and calcareous, consisting mainly of foraminifer tests, with some fragments of corals and shells. The fine pebbles of grey to greysh brown purmice are contained at three horizons in this sand bed.

The top is covered with black to dark brown soil, but the weathering has not yet been so much progressed as to make it reddish and clayey.

9. Taketomi-jima Isle

Taketomi-jima is a small isle located at about four km south of the Ishigaki-jima island. It is extremely low and flat. The highest point shows 21 m a.s.l. in its central part. HANZAWA (1935) mentioned that the older rocks exsisted in the central part and that the Ryukyu Limestone circumferenced around them.

This stratigraphical relationship is confirmed by the present investigation. The present reef is formed around this isle, and moreover a larger outer reef is also formed, surrounding all the islands of Ishigaki-jima, Kohama-jima, Iriomote-jima, Kuro-shima and Shinjo-jima. Around each of these island there is a reef flat of two to three m in depth and several kilometers in width.

1) Topography

The isle has the flat planes in three steps at 15 to 20 m, 10 to 15 m, and five to eight m in descending order. The higher plane, 100 to 200 m in length and 30 th 50 m in width, is distributed sporadically in the central part of the isle, being five meters higher than other parts. This is an erosional plane of the older rocks such as chert, etc. There is no exposure of the Ryukyu Limestone. A part of it, the monadonock to the south of a power station, was removed by the fault of the E-W trend, rising up to several meters.

The middle plane of 15 to 20 m occupies the main part of the isle. The plane is composed of the Ryukyu Limestone. The plane is composed of the Ryukyu Limestone. The air-photograph shows a linear structure of N-S trend on this plane, which closely resembles the structure found on the reel flat of the present reefs. But it is not yet certain whether this plane is a sedimentary structure of the Ryukyu Limestone or an erosional plane. Although the writer inclines to prefer the latter interpretation, further investigation is necessary for the final conclusion. The lower plane of five to eight m surrounds the middle one.

Sand dunes and beach rocks are distributed along the coast around the isle, and on the southern and eastern coast there are notches. Dunes are distributed long and narrowly, with width of 50 to 100 m, at about 4 m a.s.l. along the coast. And beach rocks are distributed

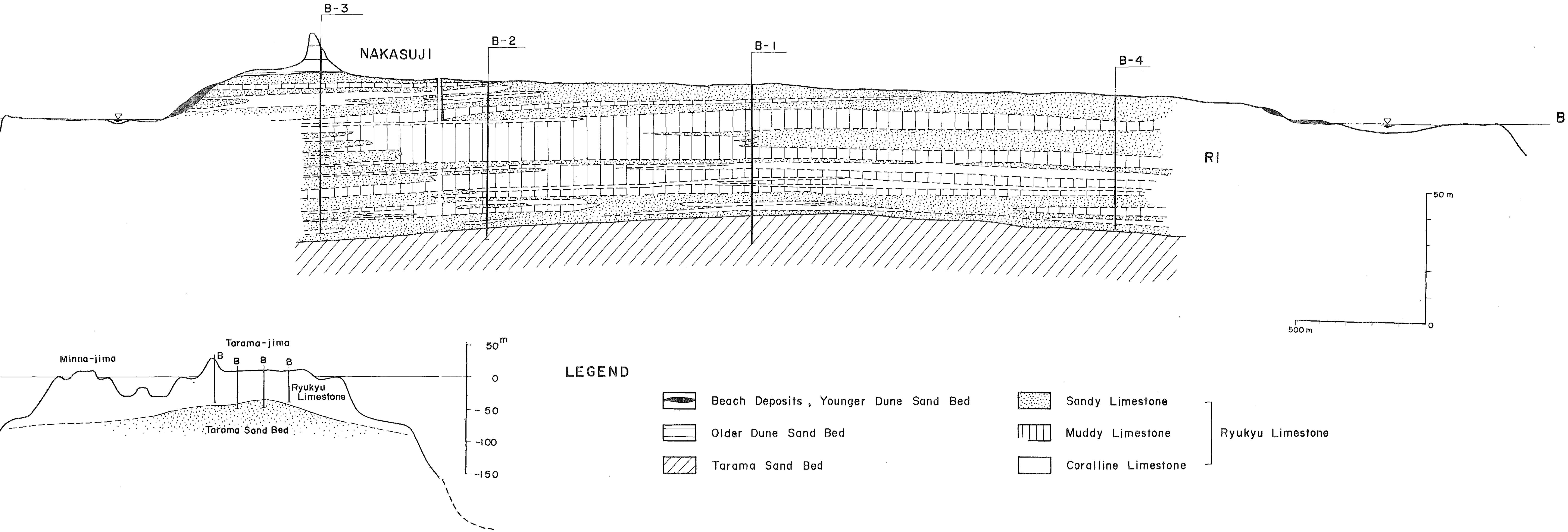


Fig. 14 Geologic Section of Tarama-jima along line A—B

along the northern coast line from the east piet to the west piet and the cape of Kondoi. Among them, the beach rocks exposed from the west piet to Kuramoto-ato, are about one meter higher than the present intertidal zone. The upper flat plane inclines eastward with five to six degree. The beach rock along the eastern coast is limited nearly to the present intertidal zone.

This suggests that an eastward tilting has taken plane since the formation of the beach rocks.

2) Stratigraphy

(a) Basement Rocks

The weakly metamorphosed sandstone and slate in alternation, chert and conglomerate are distributed in the central part, at the tip point of the northern part, and near Kuramoto-ato of the west coast in the Taketomi-jima isle. The bedded chert exposed at the center shows the strike of N70-80°E and the dip of 20°-30° to the north. The conglomerate exposed on the playground of Taketomi school, has mainly angular to subangular cobbles of chert and sandstone, and intercalated with the bedded chert. The matrix is fine sandy, and is not good at its continuity. Alternating sandstone and slate are exposed at the north cape, intercalated with the lenticular or irregularly shaped chert. The strata show the strike of N70°-80°E and the dip of 30 degree to the north. They seem to correspond to the upper part of the chert bed of the central part.

(b) Ryukyu Limestone

This covers unconformably the basement rocks and occupies the alomst whole part of the Taketomi-jima isle. Its limestone attains more than 70 m in thickness being as thick as that in the Kuro-shima isle, and thicker than that in the Ishigaki-jima island. According to the submarine boring cores at the straits between this isle and Ishigaki-jima, this limestone is widely distributed underneath the submarine bottom around the straits. It continues evidently to that of the southern part of the Ishigaki-jima. It can be correlated with the Ryukyu Limestone of the islands of Kuro-shima, Taketomi-jima and south of Ishigaki-jima, according to the results of both on land and submarine bottom. Examining the results of electric survey and geologic borings, it has become clear that there is a deep valley of the E-W direction in the besement rocks around the south of this isle. It should be noticed that the directoin of this buried valley is parallel with that of the Ryukyu Arc. Stratigraphically the Ryukyu Limestone consists of muddy limestone with chert gravels for several meters near the basal part.

The lower part is made up of coralline limestone interbedded with thin sandy foraminiferal limestone and the upper part is of biocalcirudite including the fragments of forminifer and coral. The uppermost part of five m includes the limestone of mainly algal ball, as exposed in the central part of the isle. The outcrops around the southern coast contain larger foraminifers such as *Cycloclypeus* sp. and *Maginopora* sp. According to HANZAWA (1951), Recent *Cyclocrypeus* can be collected from the depth of about 80 to 100 m b.s.l. around the islands of Iriomote-jima and Tarama-jima. This suggests that the uppermost part of the present Ryukyu Limestone in the Taketomi-jima isle is the sediments of considerable depth b.s.l.

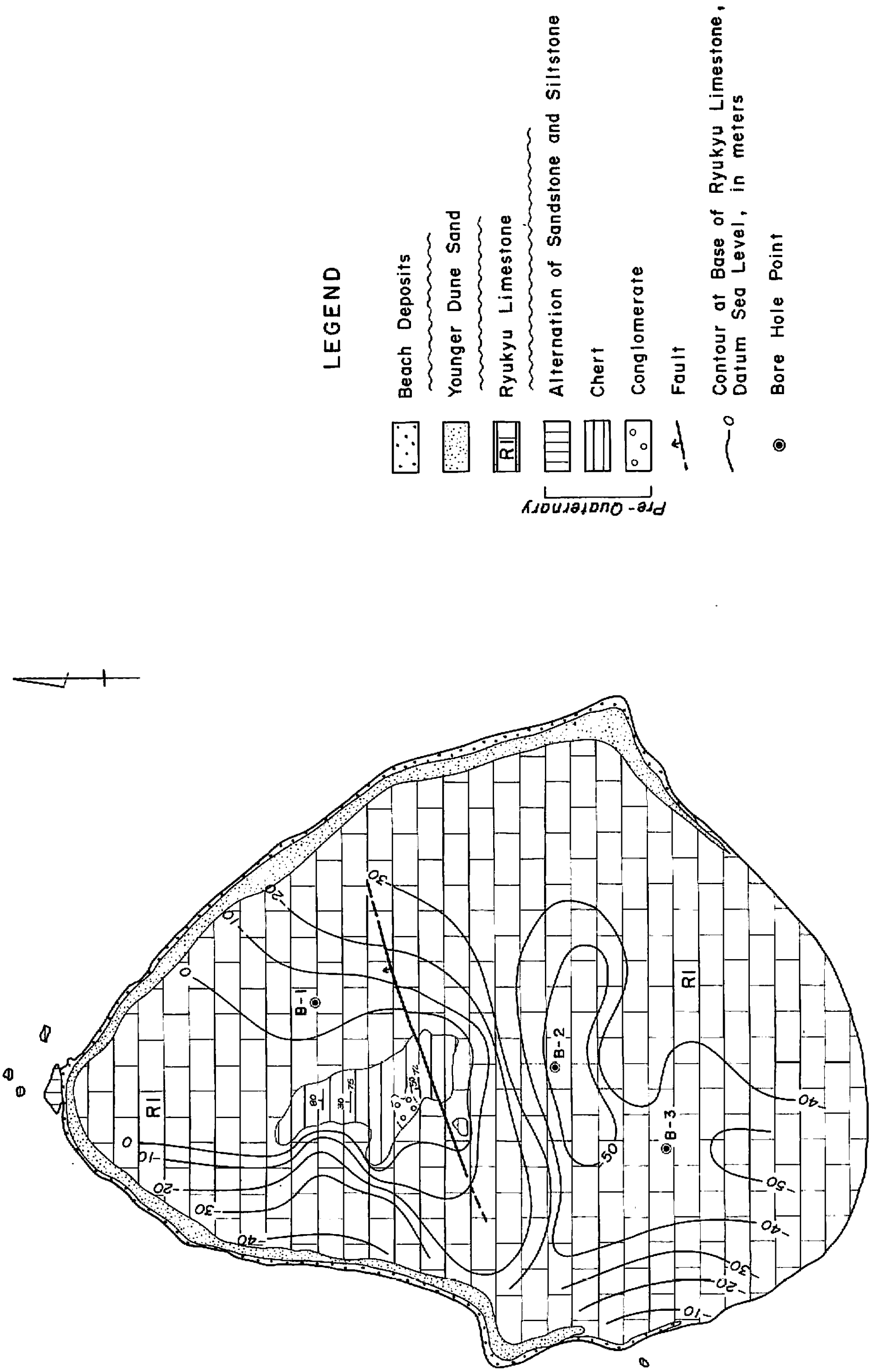


Fig. 15 Geologic Map of Taketomi-jima

The Ryukyu Limestone, more than 70 m thick, is the successive and continuous sediments, and no unconformity can be found within them in the Taketomi-jima isle. This limestone is cut by the fault with the strike N70°W, and the dip 70° to the north. The vertical downthrow on the surface of the isle is small, i.e. about three meters. Some caves are observable spottedly along this fault. The fault does not cut the dune sand bed and present reef, and it records the pre-Holocene tectonic activity.

(c) Younger Dune Sand Bed

This Bed is distributed along the coast of the northern harf of the isle. The Dune Sand is medium-grained, calcareous, and made up of well-rounded and abraded foraminifer tests. It covers unconformably the weathered soil of the Ryukyu Limestone and is intercalated with thin gravel of grey to greyish white pumices.

10. Kohama-jima Isle

The Kohama-jima isle is located at 15 km west of Ishigaki-jima, two km off the west coast of Iriomote-jima island, seven km northwest of Taketomi-jima, seven km of north of Kuroshima isle, and two km southwest of Kayama-jima. The neighbouring sea-area around all of these islands and islets is very shallow, and the reef are well developed. Kohama-jima is five km from east to west, two km from north to south. There is Mt. Ohdake, 99.4 m a.s.l. at the highest, around which several terraces are concentrically distributed. They mostly show the erosional topography on the pre-Quaternary basement rocks and partly that on the limestone, and sand and gravel bed. The Alluvial Plain extends along the eastern and southern coasts, forming the low marsh land, and sand dune is long and narrowly distributed at its end. HANZAWA (1935) pointed out the existence of the Ryukyu Limestone, and Terrace Sand and Gravel Bed in this isle, describing the outline of the Quaternary System.

1) Topography

The hilly area, including Mt. Ohdake, is over 60 m a.s.l. which consists of the pre-Quaternary basement rocks and there is no flat plane on it. The flat terraces are distributed at heights of 50 to 60 m, 30 to 50 m, 20 to 30 m, 15 to 20 m, 10 to 15 m, five to 10 m, and two to five m a.s.l. in descending order, which may be grouped into two, I and II.

(a) Terrace Group I

This terrace group I includes two minor terraces, 50 to 60 m and 30 to 50 m a.s.l.. The former is distributed in a small area, surrounding Mt. Ohdake, and the sediments on it are generally less than three m thick, and it has a character of an erosional plane. The latter occupies a wider area in the central part of the isle, and around it the limestone and limestone gravel are sporadically distributed. When it was formed, the place at about 30 m a.s.l. corresponded to its reef edge. On this flat plane, a long and narrow, irregular depression is found, which runs along the dip of the gently inclined topographical plane. The depression seems to have been formed before the deposition of the limestone, because it extends to a buried valley under the limestone, from the results of electric survey and geologic drilling. On the flat plane formed by this limestone, a long and narrow minor relief with about one m height extends from north to south. It resembles the structure in the present reef.

(b) Terrace Group II

This lower terrace group is mainly developed in the southern part of the isle, and partly along the west coast. This group includes four flat plane; 20 to 30 m, 15 to 20 m, 10 to 15 m, five to 10 m a.s.l. The long and narrow flat plane formed by limestone at the base of the west slope of Birumazaki is divided distinctly into three terraces, although the boundaries of them are indistinct in some palces. These flat planes are 18 to 20 m, 12 to 15 m, and eight to nine m a.s.l. Above them the flat plane of 20 to 30 m a.s.l. is widely distributed. The same relationship is alos recognized at the Hosozaki Cape, southwestern end of the isle, where the 18 to 20 m plane shows the best contibuity.

Terrace II corresponds to that which is distributed most widely around Ishigaki-jima island and on the east coast of Iriomote-jima island and Taketomi-jima isle, etc.

(c) Alluvial Plain and Sand Dune

There is the Alluvial Plain of average height three m a.s.l. around the lowland except the northern coast of the isle. Sand dunes are distributed long and narrowly with about five m a.s.l. along the coast line.

2) **Stratigraphy**

(a) Basement Rocks

(1) Metamorphic rocks

The metamorphic rocks are distributed zonally from east to west, forming mountainous area from Funazaki to Akayazaki. In the southern part they are in contact with the Tertiary strata by an E-W fault. In the northern part they are covered with Eocene limestone and tuffaceous rocks. They show generally the strike of NWW to SEE and the dip of 20-30° to the south. The liniation and minor folding are generally north to south, with southward plunge of about 30°.

They comprise the black schist, green and diabasic schists and are probably correlated with the Tsumuru Formation in the Ishigaki-jima.

(2) Tertiary Limestone (Miyara Formation)

This limestone covers the metamorphic rocks with unconformity on the northern side of Mt. Ohdaké. It is compact and greyish white to grey, and probably correlated with the limestone of the Eocene Miyara Formation in the Ishigaki-jima from the lithologic similarity.

(3) Volcanic Rocks (Yubu Volcanics)

These are distributed mainly in the southern half of the isle and narrowly in the northern part with the belt of metamorphic rocks in between them. In the southern area, tuff, tuff-breccia, tuffaceous sandstone and agglomerate are distrubuted zonally with the strike N60°-70°E and the dip 10-15° north. Moreover, black and compact two pyroxenes andesite is distributed in the Hosozaki Peninsula. The strata are cut by a fault of NNW-SSE trend. In the northern area, tuff and agglomerate are exposed.

The volcanic series seem to be correlated with the Tertiary Yubu Volcanics of SAITO *et al.* (1973) of the Iriomoté-jima, located to the west of the Kohama-jima isle.

(4) Yaéyama Group

This is distributed around the Birumazaki Peninsula of the southeastern end of

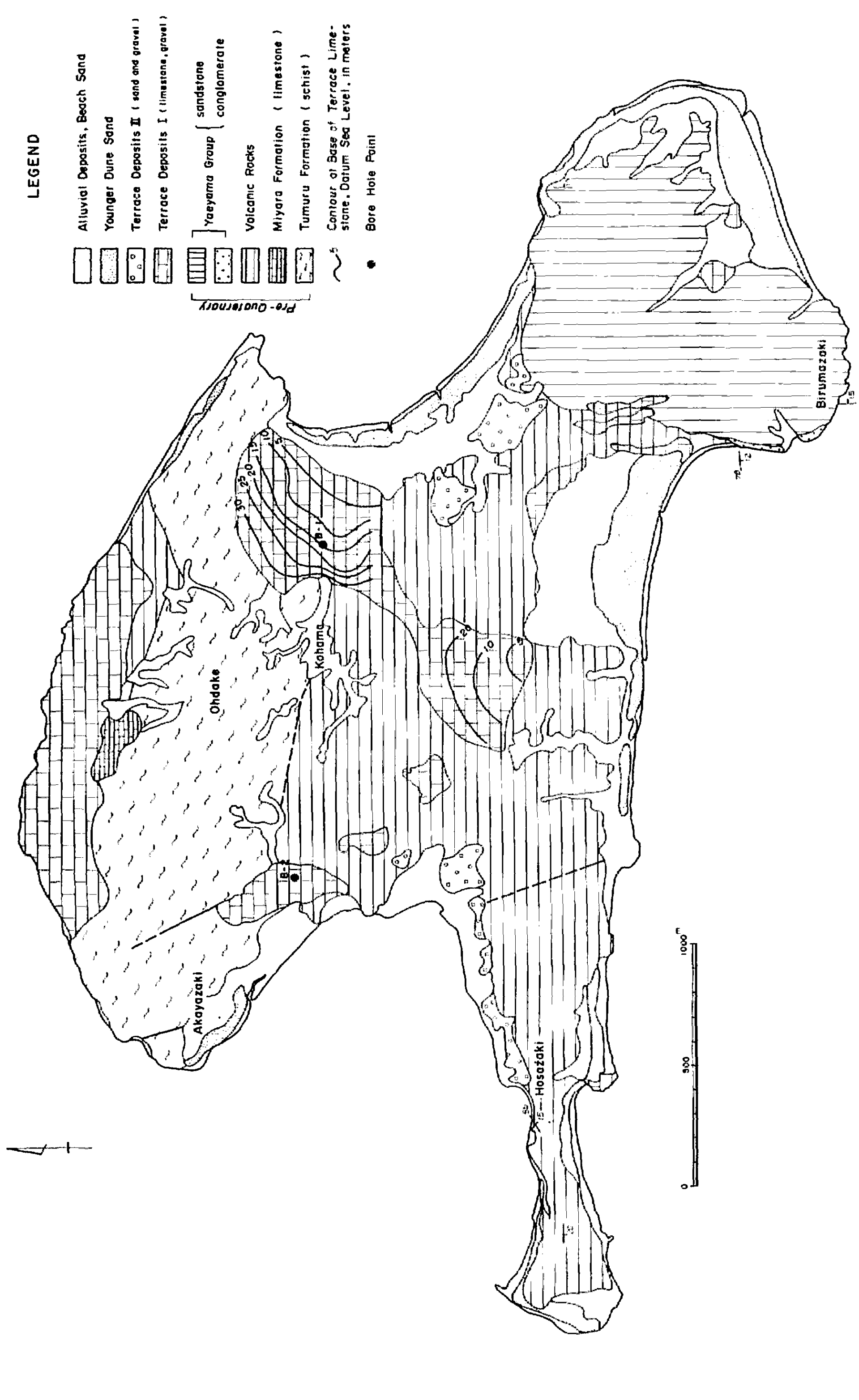


Fig. 16 Geologic Map of Kohama-jima

the isle and covers unconformably the volcanic rocks, as is exposed at Nishizaki. It is composed of basal conglomerate, alternation of sandstone and siltstone, and sandstone. The general strike is N25°E and the dip 15°SE.

(b) Quaternary System

(1) Terrace Deposits I

These are the sand and gravel bed of one to two m thickness resting on the planes of 50 to 60 m and 30 to 50 m a.s.l.. The bed on the plane of 50-60 m contains rounded small pebbles of chert and quartz. The pebbles of limestone are not found. The distributional area is limited around Mt. Ohdake, and in other areas the basement rocks crop out directly.

The gravel bed covering the plane of 30 to 50 m contains in the main part angular to subangular pebbles of chert,quartz and crystalline schists, and in the northern part of Mt. Ohdake rounded gravels and pebbles. Occasionally contained boulders of 30 to 100 cm of green schists seems to be the fallen-down blocks from the mountainous hinterland. The matrix of the gravel is reddish brown sandy clay, and contains abundautly quartzose coase sand. Subangular limestone fragments with diameter of 5 to 30 cm are scattered on the central parts of this plane. The sand and gravel bed and the limestone show the relation of the contemporaneous heterotopic facies.

The limestone is distributed from the 30 to 50 m plane to the slope of the terrace, showing characters of the outward reef slope (MERGNER, 1971).

It does not exsist in the higher part above 35 m a.s.l. As a whole, it is porous and mainly made up of table and massive corals, containing shell fragments and many subangular to angular granules, and small pebbes of green and black schists. In some places breccia is formed. The gravel is abundant in the northern part and few in the southern part of the isle. The limestone exsists down to 16.80 m b.s.l. at the borehole of B-1, eastern part of isle, and from the deeper part the calcareous sandstone is distributed continuously down to 30.90 m b.s.l.. In this calcareous sandstone the pebbles of crystalline schists are contained, and at the base it becomes a conglomerate. In the western part of the isle the limestone is 13.50 m thick in the upper part, its lower part becomes muddy and it becomes conglomeratic near the basal part.

These calcareous rocks are a series of transgressional sediments which deposited on the flat plane of 30 to 50 m and which also buried the valley of the basement.

(2) Terrace Deposits II

Among four planes divided as the lower Terrace Group the plane of 5 to 10 m has the best developed sediments.

The sediments composing the five to 10 m plane are mostly sand and gravel. The surface is covered with red soil. This bed is three m thick on the on the average and maximum 5 m, and contains well-rounded pebbles and granules of tuff, quartz, etc. The matrix is reddish brown sandy clay. At some horizons quartzose coarse sand is concentrated. The lower part contains mainly cobbles and boulders of two pyroxenes andesite and tuff with diameters of normally about five to 20 cm, but sometimes over one m. Quartz gravel is occasionally contained. The rounded pebbles of green schist, sandstone and chert are contained in the basal part of the Birumasaki Peninsula.

This sand and gravel bed seems to be correlated with the Lower Terrace Sand and Gravel Bed near Yubu of the Iriomoté-jima, western side of this isle, judging from the height of the sedimentary plane, kinds of gravels, colour tone, and the existence of the pebbles coated with manganese oxide, etc.

The sediments on the other topographic planes are mostly gravels and partly porous coral limestone. The pebbles are rounded, coated with manganese oxide, and mainly of volcanic rocks and quartz, with small fragments of corals.

(3) Raised Coral Reef Limestone

This is distributed in a small amount in the southwestern part of the Higashi-hosozaki Village and along the coast one km east of it. The limestone is composed of the fragments of foraminifers, corals, and molluscs. The lower part has the gravel bed with one to five cm pebbles of crystalline schist, quartz and andesite.

It possibly shows a high level of an ancient sea in the Holocene.

(4) Younger Sand Dane Bed

The sand dune of about five m a.s.l.. is developed along the coast line of the Alluvial Plain. The dune bed is made up of unconsolidated medium to coarse calcareous sand, containing pebbles of greyish white pumice.

11 Kuro-shima Isle

1) The Outline of Topography and Geology

The kuro-shima isle, located at 15 km southwest of the Ishigaki-jima island, is roughly heart-shaped, four km from east to west and four km from north to south. It is lower than 10 m a.s.l. in the main part forming an extremely flat plane. It is highest point is 12.5 m a.s.l.. Along the margin of the isle sand dunes are distributed, and especially on the north coast some of them attain 12 m at the highest. All of these sand dunes are distributed on the flat plane of five m a.s.l.. Notches develope cutting the sea cliffs around the isle. The isle is wholly composed of limestone, except the Holocene dune sands and beach rocks. This limestone certainly exceeds 64 m in its thickness. It is composed of the alternation of coral, sandy foraminiferal, algal ball, and muddy limestone. Faults are observable on the southern and western coasts, cutting the limestone.

Their directions are mainly NW-SE and N-S, with a small vertial throw and a large horizontal heave. The present reef surrounds the isle with 500 to 1000 m width, and at some places it is displaced by the fault of the NW-SE trend.

2) Topography

The topography of the isle can be classified into three: three flat planes of 10, 5, and 2 m, sand dunes, and the present reef. The flat plane of 10 m extends northwestward from a point a little northwest of the center of the isle, forming an ellipsoidal outline of 10 m a.s.l. It is extremely even, without perceptible relief. At one place, near the center of this plane, blocks of limestone are sporadically distributed with the compared height of about one meter. The blocks seem to have been brought as flats during the formation of the erosional plane.

The flat plane of three to six a.s.l. occupies the widest area in the isle. Upon it there are some ridges of one to two m height which extend from north to south at the eastern end of the isle. They closely resemble the emerged knolls or patch reefs which are found on the present reef flat off the east coast.

This plane is probably an erosional plane on the thick limestone. It also forms the basal plane of the sand dunes around the isle.

The flat plane of two meters exsists near Kitanobaru, Nakanobaru and Sakihara, eastern part of the isle, extending from north to south with width of 600 m and with the averaged flat level of, 2.5 m a.s.l. Its surface is not weathered and has no soil. In other words, the smooth and flat plane of the limestone is exposed directly. In the central area a part of this plane has a bed (one m thick) of calcareous, medium to coase grained sands containing loose fossil shells, and it may show an ancient wave-cut terrace plane. A similar plane as this is distributed in small areas near Miyari and Hori, western part of the isle.

Sand dunes are distributed along the margin of the isle, covering the flat plane of five m a.s.l.. The highest place attains 12.4 m a.s.l., which is the highest point in the isle. The long and narrow rows of sand dunes are generally formed with six m a.s.l. Three rows of dunes are found along the northern coast, and two rows are distributed along the western coast.

The present reef circumfering the isle is distribued with width of 500 to 1000 m. In its lagoonal part the irregular patch reefs and banded structures are well recognized, wheras another patch is covered with sandy sediments. Off the Kyan Cape, the reef is cut by a reef edge which represents a fault of the NW trend, and becomes discontinuous. A horizontal heave of 150 m is found. On the outer side of the reef edge there is a reef slope, which extends to the flat plane of 60 to 80 m b.s.l.. At a still outer side of the plane there is another steep slope which extends to the plane of 300 to 500 m b.s.l..

3) **Stratigraphy**

(a) Ryukyu Limestone

As described in the above section of topography, this low and even side is almost wholly composed of limestone, except for thin dune sands and the present reef sediments.

To make clear the basement of this isle, the bore-hole drilling was taken place down to 67 m deep. However, the boring cores are all limestone, without reaching the basement. On the other hand, in the submarine topography around the Kuroshima isle, the reef slopes down to the flat plane of 60 to 80 m deep, which could possibly correspond to the basal plane of the limestone, as is suggested by the facts observed in many other island. In other words the bore-hole point of 67 m deep is probably located at the basal part of the limestone. A result of two bore-holes at the northeastern end and the central part in the isle shows that the investigated part consists of the alternation of coral and forminiferal limestone. The ratio of sandy foraminiferal limestone is larger in the bore-hole at the northwestern end, and that of coral limestone is larger in the bore-hole at the center of the isle. This may suggest that the ancient reef may have been on the southern side, and that the northern part may have been of lagoonal environment. The limestone

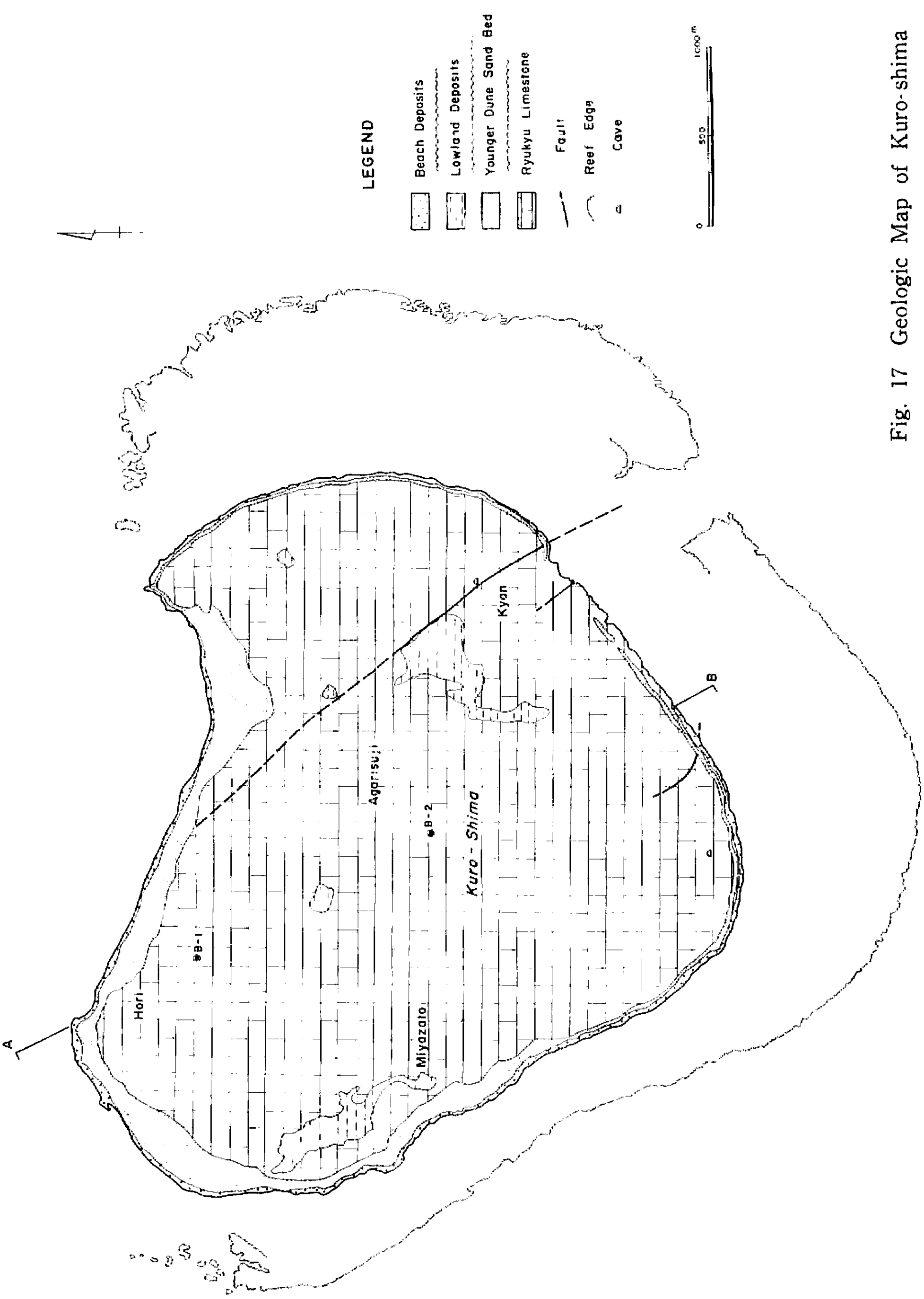


Fig. 17 Geologic Map of Kuro-shima

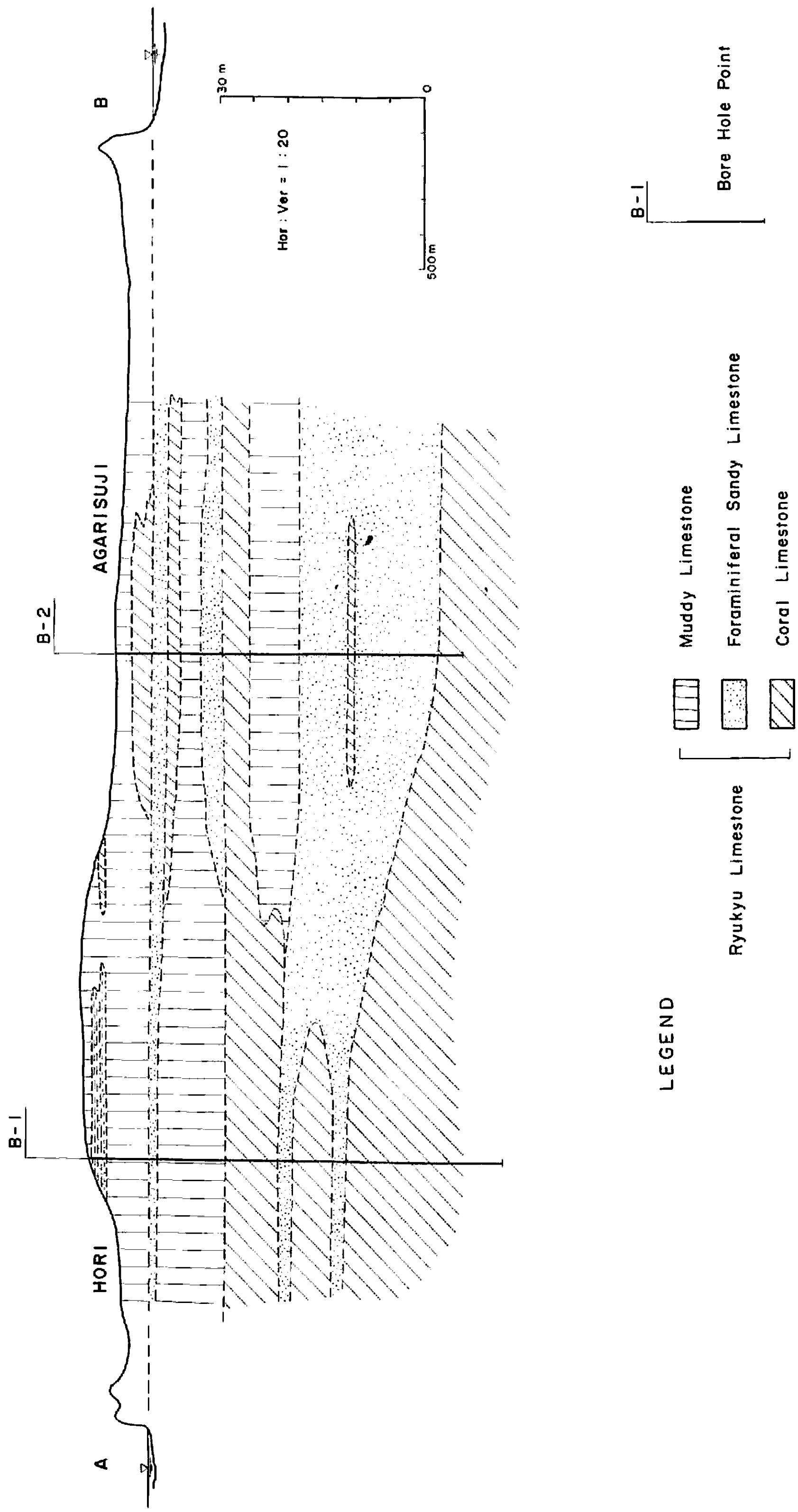


Fig. 18 Geologic Section of Kuro-shima along line A-B

formation of 67 m thick is a series of continuous transgressional sediments and no unconformity intervenes then, so far as the deta of boring cores are concerned. The topographical plane formed by this limestone in the Kuroshima isle is flat and 10 m a.s.l., and this hight also is possibly an erosional plane. This limestone is comparable with the Ryukyu Limestone of the Taketomi-jima isle, about 10 km north of this isle.

(b) Younger Dune Sand Bed

This is distributed along the coast line, surrounding alomst entirely the isle, but it especially developes well in the northern and northeastern coastal area. It is made up of loose calcareous coase sand, consisting mainly of fragments of foraminifers, corals and molluscs. In the lower part, it is frequently intercalated with thin layers, about 4 cm thick, of reddish brown scoria of pebble size, which shows a horizontal stratification.

In the upper part it contains abundantly test of Plutolamella molluscs.

4) Geologic Structure

The faults cut the Ryukyu Limestone in the NNW-SSE and N-S direction. The former is exposed on the southeastern coast where the reef edge becomes discontinuous. Its vertical displacement, however, is small. The latter is exposed on the southern coast. It is small with little extention. The time relationship between the two faults is yet unknown.

III. Geologic History

1. Pleistocene geologic history in the Ryukyu Islands.

Three major sedimentary cycles can be recognized in the Pliocene and Pleistocene of the Ryukyu Islands. They are represented by the Shimajiri Group, the Ryukyu Limestone, and the terrace deposits in ascending order.

The Shimajiri Group consists mainly of mudstone with intercalation of sandstone and tuff at some horizons in its middle and upper parts. It s thickness attains 2,000 m in the Okinawa-jima main Island.

The northern limit of the group is found at the Kikaiga-jima isle and extends to the outer zone of the Archipelagoes of the middle and southern parts of the Okinawa-jima main Island, Kume-jima, Jiyako-jima, Tarama-jima, and Hateruma-jima.

Planktonic foraminifers indicate that it ranges in age from the upper Miocene to Lower Pleistocene in Okinawa-jima (NATORI *et. al.*, 1972) and Miyako-jima (UJIIE and OKI, 1974). Volcanic rocks are accompanied with the group in the Kume-jima, the innermost side of the Ryukyu arc, and these rocks are probably related with tuff in the Shimajiri Group of Okinawa main Island and Miyako-jima.

The result of pollen analysis of the Shimajiri Group in the Okinawa main Island by NISHIDA and ITOKAZU (1975) shows that the upper Yonabaru Formation includes *Abies* and *Tsuga* and that the Shinzato Formation is predominant in the temperate elements such as *Fagus* and *Alus*.

Moreover according to the study of smaller foraminifer by LEROY (1965), the upper part of the Shimajiri Group shows the fairly shallow sea deposits of subtropical to tropical climatic zone.

After the deposition of the Shimajiri Group, there came a stage of upheaval and erosion. A valley topotraphy of the NW trend which cut the Shimajiri Group is found in the islands of Miyako-jima and Okinawa-jima. This was formed at the erosional stage after the deposition of the Shimajiri Group.

The sedimentation of the Ryukyu Limestone started on this erosional plane by the second transgression caused by an extensive subsidence. The Ryukyu Limestone overlies the Shimajiri Group with a distinct clino-unconformity in the islands of Miyako-jima and Okinawa-jima.

A part of the Ryukyu Limestone may have deposited at the depth of 100 m or so as indicated by the occurrence of *Cycloclypeus* etc. As the main part of the Ryukyu Limestone is of very shallow sea environments, this somewhat deeper part may have been caused by block movement.

At first, the Ryukyu Limestone was named after the foraminifer limestone in the southern part of Taiwan (Formosa) by YABE and HANZAWA (1930), who distinguished it from the Holocene Raised Beach Deposits. HANZAWA (1935) found the Kunigami Gravel Bed as the terrace deposits which covered the Ryukyu Limestone in the Ryukyu Islands. MACNEIL (1960) called the Ryukyu Group including in it both the Ryukyu Limestone and Kunigami Gravel Bed of HANZAWA (1935), and pointed out that it ranged in age from the Pliocene to Pleistocene. NAKAGAWA (1967, 1969, 1975) and FUKTA *et. al.* (1970) also used the name of the Ryukyu Group.

In this paper the writer defines the Ryukyu Group as the deposits after the Shimajiri Stage, excluding the Holocene sediments. This definition nearly agrees with that of NAKAGAWA and FUKTA *et. al.* The strata composing the Ryukyu Group are roughly divided into two as is described in each island, Ryukyu Stage I and II, which are separated by an unconformity representing a crustal movement.

Ryukyu Stage I comprises mainly the Ryukyu Limestone. The Ryukyu Limestone covers the basement rocks up to the Shimajiri Group with a distinct unconformity in every island, and it is generally 40 to 60 m thick attaining 110m at the maximum. Although the thickness varies locally in other islands, it is kept constant in the Okinawa-jima.

The coral reef limestone itself is very poorly developed, while the limestone is mostly made up of clastic one.

The distinct terrigeneous sediments such as reddish brown soil or sand and gravel beds are not intercalated in the Ryukyu Limestone in the surveyed islands. This is a successive series of limestone, and no great unconformity can be found. The Ryukyu Group was divided by MACNEIL (1960) into Naha Limestone, Yontan Limestone, and Machinato Limestone in ascending order, which he erroneously considered to be separated by a plane of unconformity. KIZAKI and TAKAYASU (1976) divided the Ryukyu Limestone into two; upper Member and Lower one.

The writer however considers from his survey that MACNEIL's division depended only upon the difference of individual sedimentary environments under which the members of Limestone deposited.

Because of the reasons mentioned above, the writer does not divide the Ryukyu Limestone, treating it as one unit.

A bed of sand and gravel is distributed along with the Ryukyu Limestone. In the Okinawa-

Table 1. Correlation of the Quaternary System in the Ryukyu Islands

Geologic Age	Stratigraphic Subdivision	Iheya – Jima	Izana – Jima	Motob – Pen.	Southern Okinawa Jima	Kerama – Retto	Aguni – Jima	Miyako – Jima	Tarama – Jima	Ishigaki – Jima	Kohama – Jima	Taketomi – Jima	Kuro – Shima
Holocene	Younger Dune Sand Bed Alluvial Deposits	Younger Dune Sand Bed Alluvial Deposits (sand & silt)	Younger Dune Sand Bed Alluvial Deposits (sand & silt)	Youger Dune Sand Bed Alluvial Deposits (gravel, sand & silt)	Younger Dune Sand Bed	Younger Dune Sand Bed Alluvial Deposits (sand & gravel)	Younger Dune Sand Bed	Younger Dune Sand Bed Reef Flat Sedime-nts (sand, gravel & silt)	Younger Dune Sand Bed	Younger Dune Sand Bed Alluvial Deposits (gravel, sand & silt)	Younger Dune Sand Bed Alluvial Deposits	Younger Dune Sand Bed	Younger Dune Sand Bed
Pleistocene – Late; Ryukyu Stage II; Ryukyu Group	II c: Reddish Brown Soil Older Dune Sand Bed Lower Terrace Deposits	Reddish Brown Soil Older Dune Sand Bed	Reddish Brown Soil Older Dune Sand Bed	Reddish Brown Soil Lower Terrace Dep-sits (gravel, sand & silt)	Reddish Brown Soil	? Reddish Brown Soil	Reddish Brown Soil	Reddish Brown Soil	Reddish Brown Soil Nakasuji Sand Bed (Older Dune Sand)	Reddish Brown Soil	Reddish Brown Soil	Reddish Brown Soil	Reddish Brown Soil
Pleistocene – Late; Ryukyu Stage II; Ryukyu Group	II b: Middle Terrace Deposits	Maedomari F.	Uchihana F.					10m Terrace Deposits (sand & silt)			Terrace Deposits II (sand & gravel)		
Pleistocene – Middle; Ryukyu Stage II; Ryukyu Group	II a: Higher Terrace Deposits	Paleo – Talus Deposits	Higher Terrace Deposits I. II. (sand & gravel)	Higher Terrace Deposits (coralline l.s)				Ohnogoshi Clay Bed			Terrace Deposits I. (Limstone) (sand & gravel)		
Pleistocene – Early; Ryukyu Stage I; Ryukyu Group	I: Ryukyu Limestone Ib Kunigami Gravel Bed Ia			Ryukyu Limstone ? Kunigami Gravel Bed	Ryukyu Limstone		Ryukyu Limstone	Ryukyu Limstone	Ryukyu Limstone	Nagura Gravel Bed Ryukyu Limstone Siltstone Menber		Ryukyu Limstone	Ryukyu Limstone
Early – Plio; Shimajiri Stage; Shimajiri Group	Chinen Sand Bed Shinzato Formation			Nakoji Sand Bed ?	Chinen Sand Bed ? Shinzato Formati-on			Shimajiri Group	Tarama Sand Bed				

jima main island, the bed is mostly distributed at the level higher than 80 to 100 m a.s.l., and the highest place is near 250 m a.s.l. This bed seems to be deposited nearly with the Ryukyu Limestone, judging from its distributional altitude and the phenomenon that the bed was affected by crustal movement. The direct relationship of this bed with the Ryukyu Limestone is not yet fully clarified.

The Ryukyu Limestone is distributed at the highest position on the outermost side of the Ryukyu Islands such as Kikaiga-shima, southern part of the Okinawa-jima, and Miyako-jima,

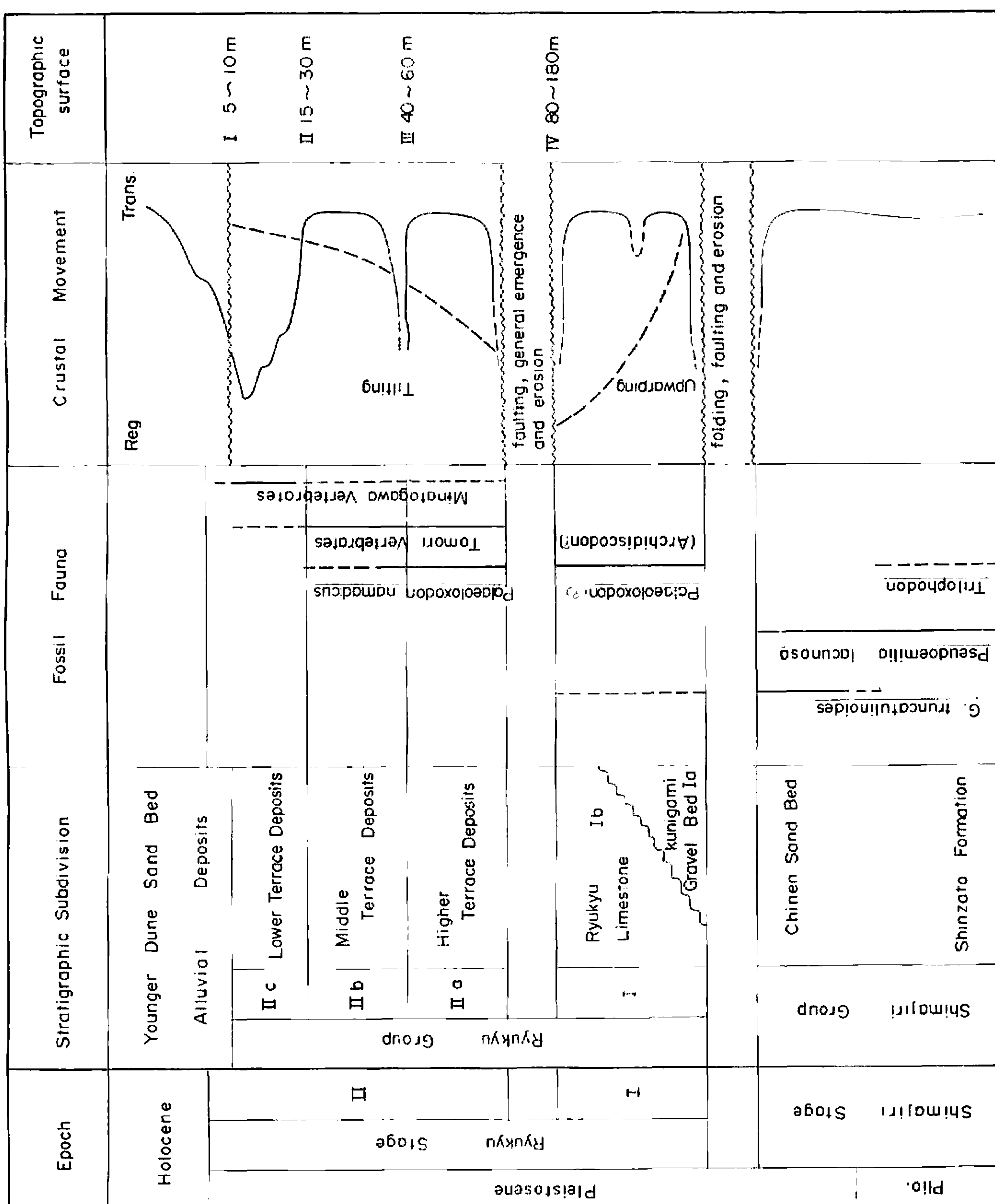


Table 2. Summarized Quaternary Geologic History of the Ryukyu Islands

and at the lowest position in the inner side in many cases. This seems to imply the uprise along the outer side of the Ryukyu Arc as represented by upwarping of the dome in the middle area of the Okinawa-jima and Gusukube anticline in the Miyako-jima (FLINT *et. al.*, 1959), whereas the subsidence occurred in the inner zone.

At the same stage the Ryukyu Trough on the northwest side of the Ryukyu Islands and also the Miyako Depression were probably formed as pointed out by KONISHI (1965). The faulting parpendicular to the island arc, with formation of blocks, was also most remarkable at this stage.

Thus, a remarkable tectonic movement took place after the deposition of the Ryukyu Limestone in the Ryukyu Islands. This is a later part of what is called the Uruma movement by the OKINAWA QUATERNARY RESEARCH GROUP (1974), which includes in it, earlier part the tectonic movement immediately after the deposition of the Shimajiri Group.

From the Ryukyu Limestone in the southern part of Okinawa-jima NOHARA and HASEGAWA (1973) reported *Paleoloxodon* which was allied to *Archidiskodon*. This indicates together with the fact that terraces unconformably overlies the limestone, a probably latest Early to early Middle Pleistocene age of the Ryukyu Limestone.

After the end of the Uruma Movement, several terraces were formed. This means that the age of terraces came after the age of Ryukyu Limestone. The terraces are divided into higher, middle and lower groups.

The higher one shows the horizon up to 60 m a.s.l., and the middle 15 to 30 m, the lower ten to five m respectively.

Among the three, the former two were declined by the effect of local tectonic movement. The strata forming the terraces are mainly composed of sand and gravel and partly silt and limestone.

In many cases these are marine terraces. In general sand and gravel are distributed on the inner side, and limestone on the outer side.

The sediments are thin, except those of the inner-bay in a part of such islands as Iheya-jima and Izena-jima.

After the age of terraces, a land area was much enlarged owing to the lowering of sea level in the latest Pleistocene, and the reddish brown soil was formed. Finally some subsidence has given rise to the Holocene sediments which unconformably cover the Pleistocene and older rocks.

On the basis of the foregoing descriptions, a correlation chart is given in Table 1 and the major geologic history is summarized in Table 2.

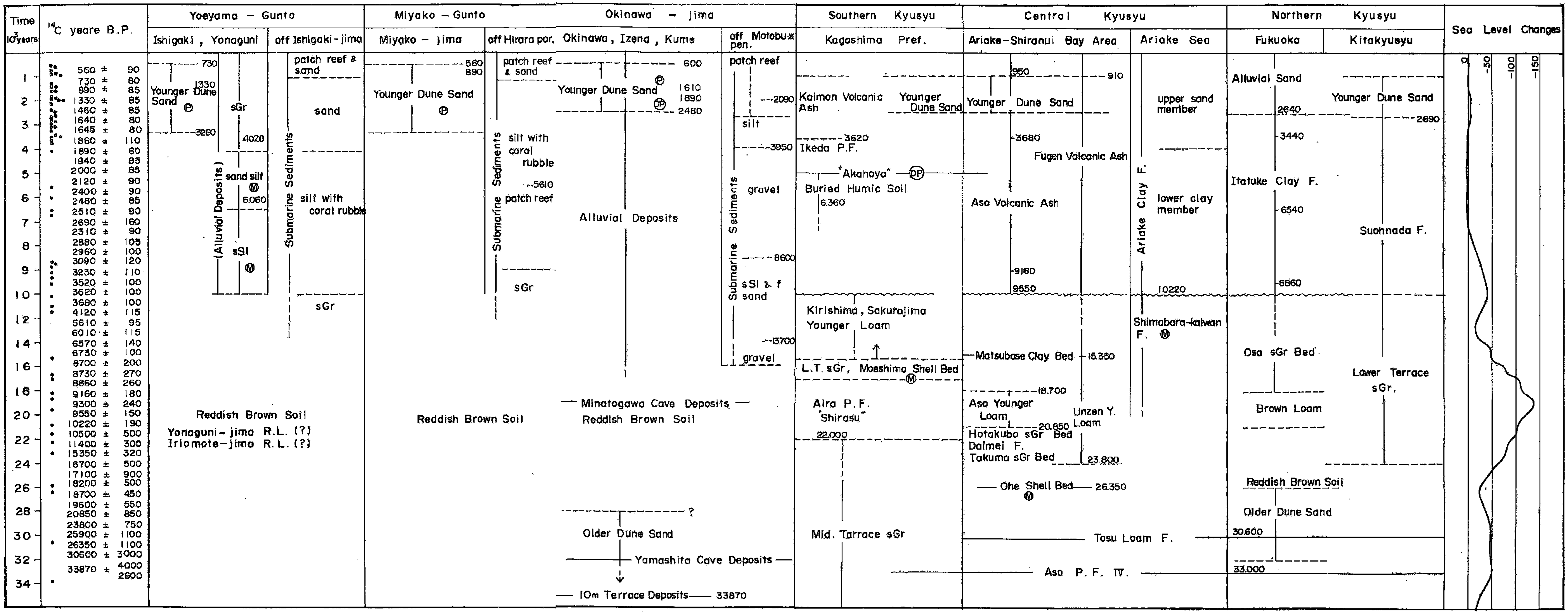
2. Holocene History of the Ryukyu Islands

The development of the Alluvial deposits in the Okinawa Region is not so remarkable because of narrowness of the land area.

As compared with the Alluvial deposits of the various areas in Japan, especially Kyushu, which form mainly the coastal plains and the inner part of the present bays, the exsistence of the reef sediments developing as fringing reefs and/or barrier reefs around the islands is characteristic of the Alluvium of the Islands.

Knowledge about the Alluvial deposits of mainly coastal plains in many areas of Japan has

Table 3. Late Pleistocene-Holocene Sequence in the Ryukyu Islands and Kyusyu Region



by J. Akiyama (1975) ※

• 14C sample collected in the surveyed areas by H. Furukawa and measured by K. Kigoshi

Abbreviations : F – Formation ; sGr – Sand and Gravel ; sSl – Sand and Silt ; Ⓟ – pumice ; ⓄⓅ – orange pumice ; P.F. – pumiceflow ; Ⓜ – marine unit ; Loam means weathered tephra member ; R.L. – Ryukyu Limestone been accumulated to a great extent, but that of the islands in the Ryukyu Islands has been rather poor. The sediments corresponding to a cooler climate of the latest Pleistocene and those of a warmer one of the Holocene has been distinguished in the coastal plains of various areas (FURKAWA, 1972; etc.). The Holocene series is divided into three from the results of pollen analysis: RI to RIII.

It is moreover ascertained by NAKAMURA (1972) and YASUDA (1974) that division can apparantly be applied to almost the entire area of Japan from Hokkaido to the northern part of Kyushu. But this division cannot be directly applied to the Holocene of Kyushu because of the difference in climate. In other words, the climate is subtropical in the Ryukyu Islands. Then how can the stratigraphy of the Alluvial deposits and the Holocene geologic history be expressed in such a different climatic zone as in the Ryukyu Islands? From this viewpoint the writer has stressed importance to the results of carbon fourteen age determination for the chronological classification of the Alluvial deposits in the Ryukyu Islands. By means of this radiometric dating the writer has attempted the compilation of the stratigraphic data of the sediments under the Alluvial plains along the coastal one, and the Alluvial lowlands along the various streams and rivers, and under the reef around various islands. A result of writer's correlation of the Holocene deposits between the Ryukyu Islands and Kyushu is shown in Table 3.

The geologic history may thus be explained as follows:

(a) *Enlargement of the land-area with lowering of the sea-level with eustatic movement of the latest Pleistocene*

There are layers of reddish brown soil which form the flat plains of 10, 20 and 40 m below sea level, as clarified under the submarine bottom off the Hirara and Yonaha bays of the Miyako-jima island and off the west coast of the Motobu Peninsula, Okinawa-jima main island. This soil is most probably a product of subaerial weathering formed on the Ryukyu Limestone during the lowering of the sea-level. The soil must be found hereafter on some buried submarine flat planes, moreover. It is known that at the maximum Würmian glacial stage of the latest Pleistocene the sea level lowered 130 m b.s.l. in the Ariake Inland Sea of Kyushu and that the age was during 18,000 to 20,000 Y.B.P. It can be assumed that at the age of the lowering of 130 m b.s.l. there must have been an extensive land area around the Okinawa main island including the neighbouring isles of Kerama-retto, Tonaki-jima and Kume-jima.

Also around the Yaéyama Archipelagoes, there may have existed a land-area including the site of islands of Ishigaki, Iriomoté, Kohama, Kuroshima and Taketomi-jima and similarly around the Miyako-jima island, a wide land-area may have extended to its north-east, including the isles of Irabu-jima and Ikema-jima.

The sediments which overly this reddish brown soil are deposited during the interval of the latest Pleistocene to Holocene, i.e., from 13,700 to 5,610 Y.B.P., so far as the age was made clear. Besides the reddish brown soil, there are the sediments which bury the caves and fissures formed in the Ryukyu Limestone in a number of islands, such as Okinawa main island and Miyako-jima, etc. These sediments are celebrated for their rich content of fossil mammals (TOKUNUGA, 1940; OTSUKA, 1941; HASEGAWA, *et al.*, 1973; NOHARA, 1971; NAKAGAWA, 1971; SHIKAMA, *et al.*, 1971). Certain parts of these cave and fissure sediments show the age of enlarging land-area from 32,000 to 18,000 Y.B.P. on the grounds of radicarbon chronological measurements.

(b) Reduction of the land-area and islanding during the period from the late Pleistocene to Holocene

A wide land-area subsided and many islands and isles were formed in nearly the same outline as the present shape by the rapid uprise of the sea level from the late Pleistocene of about 18,000 Y.B.P. till the middle Holocene. The sediments formed during this period show a cycle sequence beginning with sand and gravels, followed by silt, and terminating with sand and gravel, representing a marine transgression. Around these islands the present reefs are distributed. Beneath the submarine bottom of these reefs a sedimentary sequence is recognized which consists of sand and gravel and/or sand in its lowest part, silt with coral gravels of 20 to 30 m thick in its middle part, and sandy sediments interbedded with patch reefs in its upper part. This quite resembles the characteristic sedimentary cycle in the coastal plains of Japan, except for existense of calcareous gravels and reefs in Ryukyu (see also FURUKAWA, 1972).

Under the Alluvial plains along the River Miyara in the Ishigaki-jima island, silty marine deposits of more than one meter thick are found. The absolute age of carbon fourteen on a sample from these deposits is 4,120 ± 115 Y.B.P., which seems to show the maximum of the Holocene transgression in this island.

These facts well agree with those which have been made clear in Kyushu by FURUKAWA and MITSUSHIO (1965), the ARIAKE BAY RESEARCH GROUP (1965) and FURUKAWA (1969, 1972). Some of the notches found in various islands of the Ryukyu Arc are evidently formed at the maximum phase of the Holocene transgression.

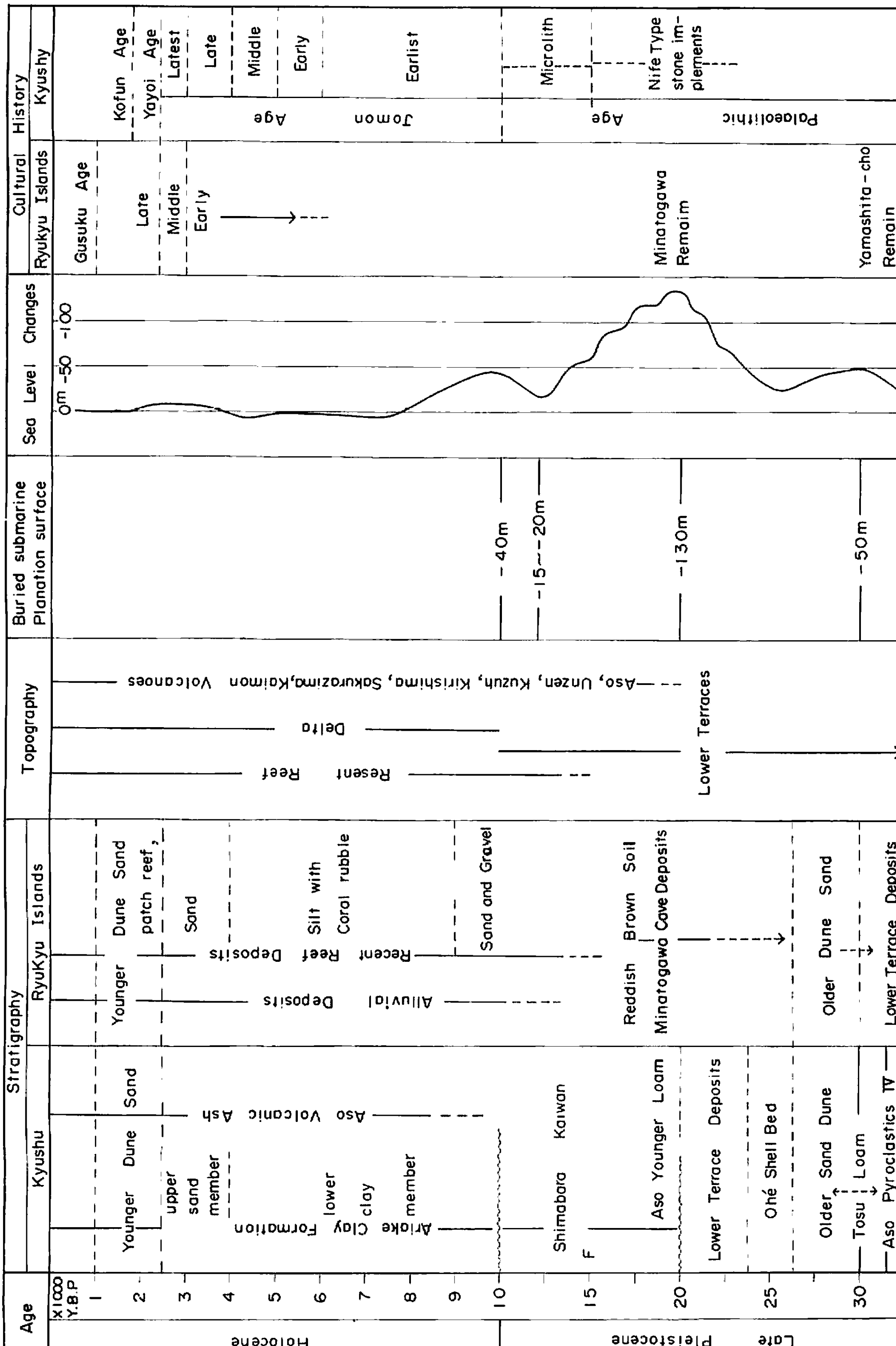
Thus the Alluvial deposits in the Ryukyu Islands have remarkable uniformity in the sedimentary cycle, the stage of sedimentation, and the age of the maximum of the transgression. This may show the geologic history corresponding to the sea-level change during the late Pleistocene to the Holocene.

(c) The Yayoian Regression and the Formation of Dunes

The dunes well develop in various islands of the Ryukyu Arc. Some of these dune sands bury the notches locating at two to three meters a.s.l. At the Uhutobaru shell-mound remains locating on the coast of Toya, Okinawa main island, the eolian sands are distributed, burying the notches of two to three meters a.s.l. which cut the Ryukyu Limestone, and earth porcelains of the late Nanto type are contained in the sands which show the age from 2,400 to 1,800 Y.B.P. by the carbon fourteen chronology.

And also it becomes clear from the archaeological remains and carbon fourteen of absolute age that the dune sands comparable to these are distributed in the other islands of the Ryukyu Arc. A pumice bed is intercalated in them, which records a volcanic activity somewhere in the neighbourhood. The deposition of these dune sands commenced at about two meters b.s.l. at Nishihama-zaki, Miyako-jima island. From this fact and the results of measurement of carbon fourteen, it may be concluded that there was about two meters lowering of sea level during the time-interval from 3,000 to 2,000 Y.B.P. as compared with the present position.

Table 4 Late Pleistocene-Holocene Chronology of the Ryukyu Islands and Kyusyu Region



This period corresponds to what was called "the Yayoian Regression" in the Nohbi plain of central Japan by FURUKAWA (1972) and to the same regression recognized in Kyushu by FURUKAWA and MITSUSHIO (1965), and FURUKAWA (1969, 1972).

Thus, the lowering of the sea level commenced at the peak phase of the Holocence transgression about 4,000 years ago, and it was about two meters b.s.l. during the period of 3,000 to 2,000 Y.B.P. On account of this, the reef flats which were formed along the coast lines of the various islands in the Ryukyu-retto Archipelagoes, have mostly cropped out and probably become the main source of delivery of the dune sands.

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Appendix

Aguni	粟国	Komesu	米須	Taketomi	竹富
Bora	保良	Kyan	喜屋武	Tana	田名
Chinen	知念	Mabuni	摩文仁	Tarama	多良間
Futenma	普天間	Maédomari	前泊	Tokashiki	渡嘉敷
Gusukube	城辺	Motobu	本部	Uchihana	内花
Hirara	平良	Nakasuji	仲筋	Uhutobaru	大当原
Iheya	伊平屋	Nakijin	今帰仁	Yaéyama	八重山
Itoman	糸満	Ohnogoshi	大野越	Yonaha	与那覇
Izena	伊是名	Senbaru	千原	Zamami	座間味
Kerama	慶良間	Serikyaku	勢理客		
Kohama	小浜	Shimajiri	島尻		