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Stratigraphy of the Triassic Formation in Okinawa-jima, Ryukyus

By

Takeshi ISHIBASHI

Abstract

Distinctive Triassic deposits are discovered in the Motobu Peninsula of Okinawa-jima. Though the older rocks of this area have been generally regarded as Paleozoic, the strata are at least in part Carnian in age, as evidenced by the occurrence of numerous characteristic ammonoids and *Halobia*. The deposits named here the Nakijin Formation are 450–500 m thick, composed mainly of limestone and basaltic lava with a subordinate amount of calcareous siltstone, and tuffaceous and calcareous mudstone. This formation is divided into two members in accordance with the stratigraphic and lithologic features. The limestones of the Lower Member are massive semi-crystalline, bearing calcareous algae, sponge (?), bryozoans (?), while those of the Upper one are of pelagic facies, containing numerous cephalopods, halobiids and microfossils. The Upper Triassic ammonoids collected from the Upper Member not only provide reliable evidence for the interregional correlation of the Nakijin Formation but also present an interesting clue to the facies analysis of the pelagic carbonate rocks in which the ammonoids occur.

Introduction and Acknowledgments

The Motobu Peninsula pushing out into the East China Sea is situated at the northwestern coast of the central part of Okinawa-jima (Fig. 1) which is a major island in Ryukyu Geanticline (KONISHI, 1963, 1965). The basement complex of the Motobu Peninsula together with Hedo-misaki, Akamaru-saki and scattered areas along the western coast of Okinawa-jima and also Iheya Islands (ISHIBASHI, 1968), Ie-jima, Tonaki-jima (KONISHI, 1964) are geotectonically referred to the Motobu Belt (KONISHI, 1963, 1965) and are characterized with the weakly metamorphosed Paleozoic sediments. This belt is in contact with the Kunigami Belt (KONISHI, 1965) in the south by a major fault named the Hedo Thrust Fault (FLINT *et al.*, 1959).

I have been engaged in the study of the Paleozoic and Mesozoic formations in Ryukyu Islands since 1964. The distribution of Triassic deposits in the Motobu Peninsula and a nearby islet, which is named here the Nakijin Formation, was first recognized by the occurrence of a halobiid, as orally communicated previously (ISHIBASHI and KONISHI, 1967). The age of this formation as well as the stratigraphic sequence has been further clarified by the prolific occurrence of Upper Triassic ammonites and halobiids at many localities. This paper is a

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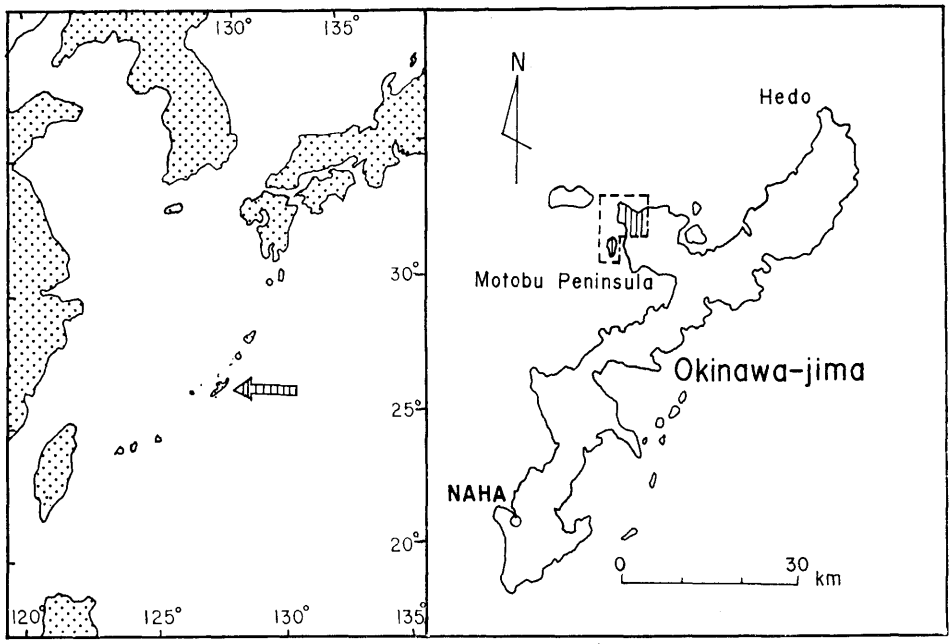

Fig. 1. Index maps of Okinawa-jima and studied area.

stratigraphic note on the Nakijin Formation. A detailed sedimentology of the Nakijin Formation and paleontological studies on the ammonites and halobiids will be published in separate papers.

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Historical review

As the previous works on the geology of the Ryukyu Islands were summarized by KONISHI (1963, 1965) in some details, only those on the Motobu Peninsula of

Okinawa-jima are reviewed in this paper.

KOTO (1897) divided the Ryukyu Islands (KOTO's Riukiu Curve) into three geotectonic belts, the middle of which was treated as either Archeozoic or Paleozoic. YOSHIWARA (1901) reported the occurrences of an indeterminable molluscan fossil from the limestone of Sesoko-jima and a single species of coral from the Motobu Peninsula. He considered the older rocks in the central and northern districts of Okinawa-jima and its annexed islets as Paleozoic. Later, HANZAWA (1933) discovered some Permian fusulinaceans, *Neoschwagerina* sp., *Verbeekina douvillei* (DEPRAT), and *Pseudofusulina* sp. from the limestone of the Motobu Peninsula. The existence of the Paleozoic formation was confirmed with the paleontological evidence in the Ryukyu Geanticline for the first time. Geological history of the Ryukyu Islands was summarized by him (1935a, 1935b).

HATAE (1955) segregated the palaeo-Ryukyu Volcanic Zone in the KOTO's Inner Belt. FLINT *et al.* (1959) made a geological map of Okinawa-jima in scale of 1 : 50,000 and divided the Paleozoic into four units as Kayo, Nago, Yonamine and Motobu Formations in ascending order. The geological ages of the Kayo and Nago Formations were revised by KONISHI (1963), based on the discovery of the Late Mesozoic fossil assemblage in the former and also on comparative geotectonics. He (1965) divided the Ryukyu Geanticline (nearly corresponding with the Middle Belt of KOTO and HATAE) into six belts. The Motobu Peninsula and Hedo Limestone plateau area of Okinawa-jima were located in his Motobu Belt. Having found halobiid shells and other Late Triassic fossils in the Motobu Peninsula, ISHIBASHI and KONISHI (1967) proved that a part of the older rocks in this area was actually Triassic in age instead of Paleozoic as considered by previous authors. ISHIBASHI (1967 MS) revised the stratigraphic successions of the Paleozoic Motobu and Yonamine Formations in the Motobu Peninsula on the basis of the Permian fusulinaceans and field evidence.

Outline of Geology of the Motobu Peninsula

A tongue-shaped peninsula of Motobu is situated in the northern part of Okinawa-jima, stretching about 18 km. from southeast to northwest, and about 15 km. in breadth. There are steep mountains, Yae-dake (457 m), Katsuu-dake (451 m) and Awa-dake (419 m) etc., made up of limestone, in the southern part of the peninsula. Annexed islets, such as Sesoko-, Minna-, Yagaji- and Kourijima, surround the peninsula at a distance of about 0.5 to 2 km.

The Permian, Triassic, Tertiary and Quaternary sedimentary rocks constitute the Motobu Peninsula, with some igneous rocks intruded in the pre-Tertiary strata. The Permian Motobu and Yonamine Formations are most widely distributed in the peninsula as basement complex, whereas the Triassic Nakijin Formation is distributed only at a locality in Sesoko-jima and in at the northwestern area of the peninsula. The Early Pliocene Guga Formation (FLINT *et al.*, 1959) crops out in the eastern area. The Quaternary rocks are mainly represented by the Ryukyu (Riukiu) Limestone (HANZAWA, 1935b) subordinated with the Kunigami Gravel, Nakoji Sand (MACNEIL, 1960) and Holocene deposits.

The Paleozoic formations in the Motobu Peninsula are bounded to the Mesozoic formations by the Nago Fault (nomenclature after FLINT *et al.*, 1959) which extends to the Hedo Thrust, both running along the western coast of Okinawa-jima.

Stratigraphy of the Triassic Nakijin Formation

The Nakijin Formation is distributed in Sesoko-jima and the northwestern area of the Motobu Peninsula. Its thickness is estimated at 450–500 m. This formation is in contact with the underlying Permian Yonamine Formation by a reverse fault. The upper limit of the Nakijin Formation is concealed in the East China Sea. The lower part is rich in limestone and the upper part consists of basaltic lava and argillaceous limestone, with a subordinate amount of calcareous siltstone and mudstone (Fig. 2). Based on the lithofacies and paleontological evidence, the Nakijin Formation is divided into two members, the Lower and Upper as described below.

I. Lower Member

Type locality:—The route between Toguchi and Ufudo at the Motobu Peninsula, Okinawa-jima.

Thickness:—150–200 m.

The Lower Member is distributed in the northern area and in the greater part of the southern area of Ufudo, Motobu-cho. It is in contact with the Upper Member of the Nakijin Formation by a reverse fault. This member is composed of thick massive limestone which is white grey to grey in color and compact in texture. The lower part of the limestone is white, semi-crystalline, jointed and unfossiliferous, being in contact with intrusive rock. A band of nodular chert, about 2 m. in thickness, is contained in the limestone. The growth of dolomite crystals is recognized along the cracks of quartz-grains in thin section (Pl. 53, Fig. 6).

The middle part of the limestones is white to grey, faintly bedded, micritic, in which presumably organic matters of various shapes are observed in thin section. On the other hand, the upper part is white grey to dark grey, bedded in layers 20 to 50 cm. thick, and intercalates a layer of limestone breccia 5 m. thick. No index fossils have been discovered, although the radiolarian tests, crinoid-stemjoints, sponge (?), and bryozoans (?) have been recognized.

II. Upper Member

Type locality:—The northern coast of Yamakawa, at Kamimotobu-son, Okinawa-jima.

Thickness:—ca. 300 m.

The Upper Member is exposed as inliers at two localities of Sesoko-jima (Fig. 3) and in the Ishikawa area of Kamimotobu-son, and more extensively in the northern part of Motobu-cho (Fig. 4) and is covered with the Tertiaty and Quaternary sediments.

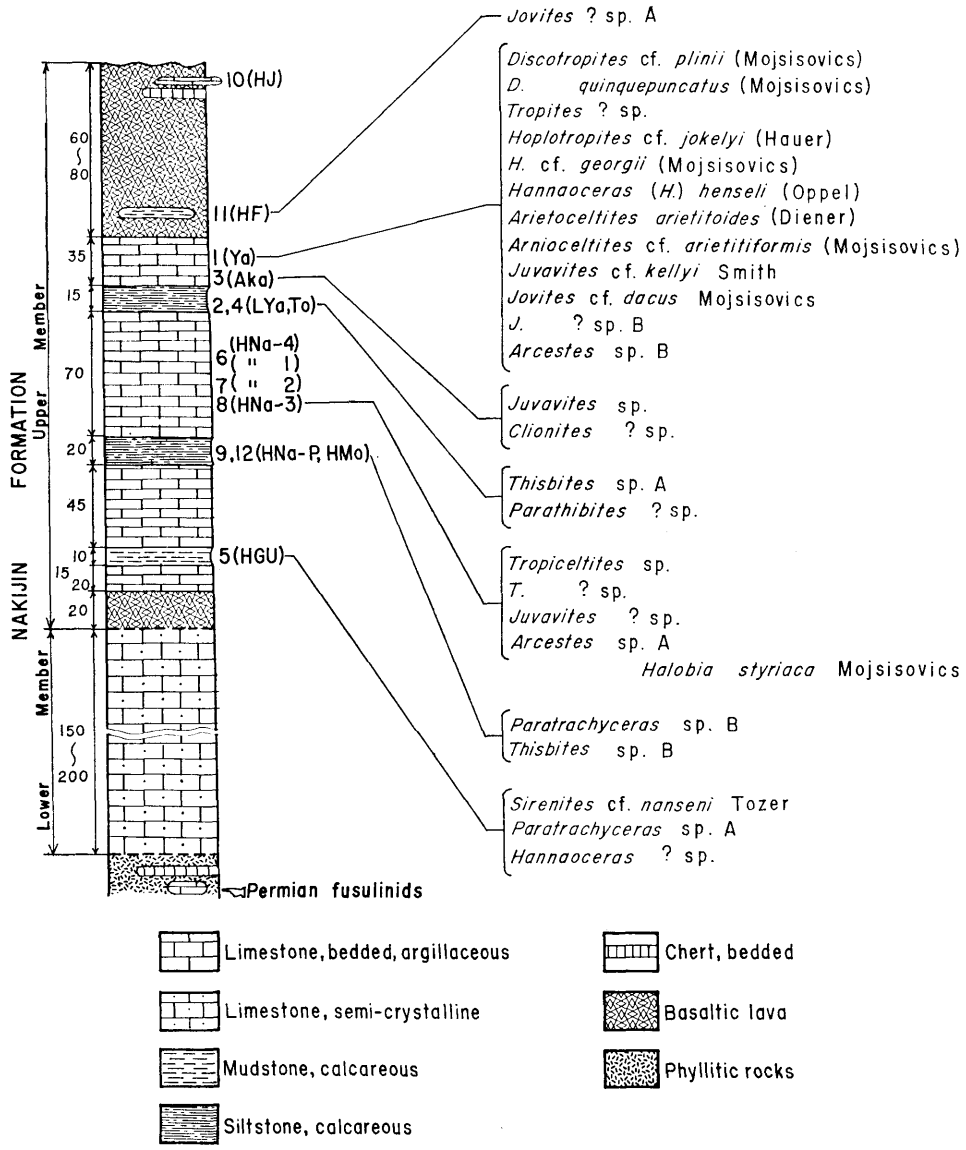

Fig. 2. Generalized columnar section and fossil occurrences of the Nakijin Formation.

The lower part of this member consists mainly of limestone, with a subordinate amount of calcareous siltstone and mudstone beds. The upper part is composed of basaltic lava, tuffite in association with lenticular or thin layer of limestone, chert and calcareous mudstone. The limestone is bedded in layers of about 5 to 30 cm. thick, intercalated with thin layers of tuffite between limestone beds. It shows a tendency to increase the tuffaceous material upwards.

The limestone including thin tuffaceous mudstone layers crops out as inliers at Ishikawa and Yamakawa areas. This limestone is the upper unit of the Nakijin Formation, and is black, argillaceous, bedded in layers of 5 to 60 cm. thick,

being rich in carbonaceous materials and insoluble residues. A grey, compact, slightly bedded limestone is intercalated in the black, argillaceous one which was mentioned above. It contains bands of fossiliferous, biomicritic öolitic (Pl. 53, Fig. 1), bioclastic (Pl. 53, Fig. 4), and dolomitic layers. The fossiliferous limestone layer displays graded bedding by the tests of small gastropods, ammonites, foraminifers, crinoid-stems and microfossils. Thus fossiliferous layers are found in the limestone at several horizons. Small very thin shelled bivalves (*Posidonia* ?) (Pl. 53, Figs. 5 and 7) are concentrated at particular horizons. Dolomitic limestone and dolostone are predominant in the upper part and are banded in layers of about 5 to 10 cm. thick, which are alternated with similarly thin layers of compact, hard micritic limestone (Pl. 53, Fig. 3).

The silt- to mudstone beds are found at least in three stratigraphic units. Fresh calcareous siltstone bed of about 20 m. in thickness is only exposed at loc. 9 (NHa-P), west of the Nakijin Castle, and loc. 12 (MHo), ground of Motobu Senior High School. It is bluish grey, hard and laminated. Bivalves such as *Halobia, Lima* and *Palaeoneilo,* ammonoids, gastropods, bryozoans and crinoid-stems and other occur in this bed (Pl. 53, Fig. 2).

Basaltic lava beds are contained both in the lower and upper parts; the upper one is 60 to 80 m. thick and interbeds several layers of calcareous fossiliferous mudstone, chert, limestone and tuffite. The basaltic lava is greenish grey, hard, massive, well-jointed and weathers to brown to reddish brown and friable.

Two layers of chert, about 2 m. and 4 m. thick respectively are interbedded in the upper part. The chert is bedded, and white in color and limited in distribution. Besides, some 5 m. layer of bedded chert is known along the boundary between the Nakijin and the Paleozoic Yonamine Formation. This chert layer is considered to belong to the Yonamine Formation. Also the huge boulder gravels of chert in the basaltic lava unit are found on the top of a hill at Nagatakibaru area.

III. Paleontological notes

The Nakijin Formation contains Triassic marine fossils. In the Lower Member, which is composed of semi-crystalline limestone, occur poorly preserved fossils such as crinoid stems, bryozoans (?) and sponge (?). In the Upper Member fossils occur in a greater number and in a better condition of preservation. They are gastropods, bivalve shells (*Halobia, Lima, Palaeoneilo* and others), ammonites, a nautiloid, belemnoids, bryozoans, radiolarians, conodonts, smaller foraminifers and algae. The cephalopods are intimately bound up with halobiid shells. About 200 individuals of cephalopods have been obtained at several stratigraphic horizons.

Although almost all the ammonites are secondarily deformed and compressed, the following species have been preliminarily identified.

Tropitidae

Discotropites cf. *plinii* (MOJSISOVICS)
Discotropites quinquepunctatus (MOJSISOVICS)
Hoplotropites cf. *jokelyi* (HAUER)

Hoplotropites cf. *georgii* (MOJSISOVICS)
Tropites ? sp.
Choristoceratidae
Hannaoceras (*H.*) *henseli* (OPPEL)
Hannaoceras ? sp.
Tropiceltitidae
Arietoceltites arietitoides (DIENER)
Arnioceltites cf. *arietitiformis* (MOJSISOVICS)
Tropiceltites sp.
Tropiceltites ? sp.
Haloritidae
Haloritinae
Jovites cf. *dacus* (MOJSISOVICS)
Jovites ? sp. A
Jovites ? sp. B
Juvavites cf. *kellyi* SMITH
Juvavites sp.
Juvavites ? sp.
Trachyceratidae
Paratrachyceras sp. A
Paratrachyceras sp. B
Sirenites cf. *nanseni* TOZER
Thisbitidae
Thisbites sp. A

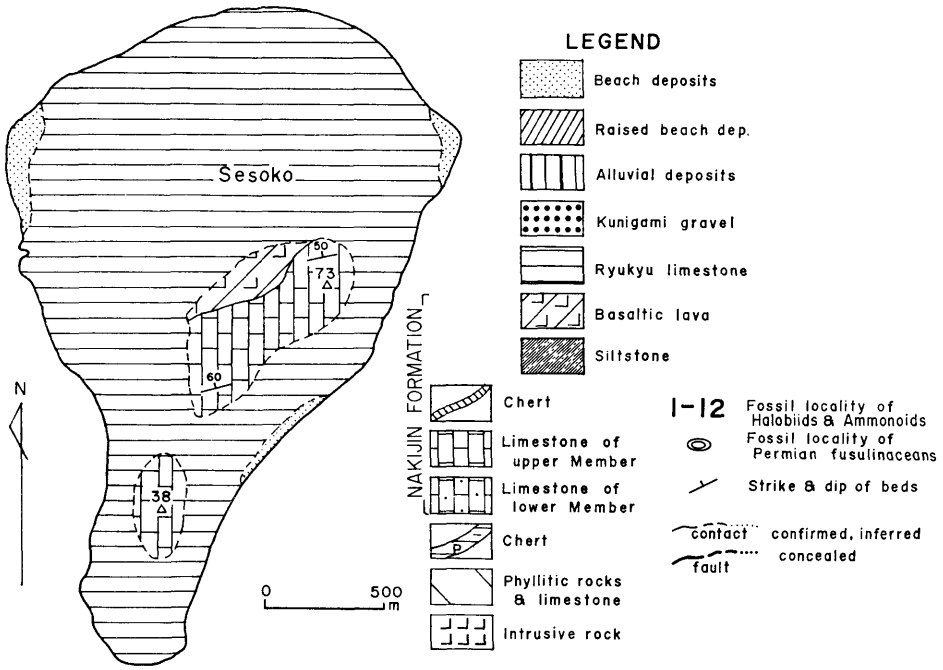

Fig. 3. Geologic map of Sesoko-jima.

Thisbites sp. B
Clionites ? sp.
Arcestidae
Arcestes sp.

The bivalve shells occur together with ammonites except for the localities of 10 (HJ), 6 (HNa-4) and 7 (HNa-2). The halobiid shells at the locality of 9 (HNa-P) were identified as *Halobia styriaca* MOJSISOVICS. Some species of calcareous algae in grey limestone of the Upper Member belong to the genus *Parachaetites* and *Cayeuxia*. The microfossils occur abundantly in the grey limestone.

IV. Sedimentary environment

Because little information is available at present to interpret the sedimentary environment under which the Lower Member of the Nakijin Formation was deposited, the following discussions are limited mainly to the subject about the Upper Member.

The Upper Member is characterized by black, bedded and tuffaceous limestone. Each limestone bed is more tuffaceous in the lower part. Thin layers of tuffite are found between the limestone beds. It may be presumed that the volcanic activities were continued through the sedimentation of the Upper Member. These tuffaceous materials supplied from the rhythmical volcanisms were responsible for the stratification of limestone beds and concentration of planktonic and benthonic organisms in thin layer.

While the primary terrigenous materials and fossils except for radiolarians are rare in the lower part of the Upper Member. The upper limestone of the Upper Member is fossiliferous, partly exhibiting a microscopic brecciated structure. Furthermore, there occur öoids, together with calcareous algae, gastropods and other microfossils at two horizons of the upper part.

Many authors tend to believe that the öoids were formed by wavy agitations, but FRIEDMAN (1962) and BATHURST (1967), for example, reported that the öoids were possibly grown also under quiet water or slight flow environment. The presence of terrigenous material of siltstone and mudstone, and thin layers of dolostone may not be conclusive to prove a shallow water environment. Although the brecciated structure and calcareous algae are considered as indicating a relatively shallower environment, these breccias and calcareous algae from 0.2 to 2 mm. in size could be transported for a long distance. There is no positive evidence to indicate that the sedimentary environment was either very shallow, coastal one or of very deep sea. The plausible interpretation is proposed for the sedimentary environment of these sediments that a barrier or a bank may be laid between a land and sedimentary basin, which tapped the sediments including silts, muds and benthonic animals and filled the inner side of the barrier. The sediments were sometimes over-flowed across the barrier and supplied into the basin, where they were mixed with calcareous and tuffaceous materials.

Correlations

Although the paleontological study is preliminary, the ammonites of the Nakijin Formation are comparable with those from other regions of the world.

Many species of *Sirenites* have been reported from the Carnian of various regions of the world. *Sirenites nanseni* was referred by TOZER (1961) to the Lower Carnian. SILBERLING and TOZER (1968) recognized that *Sirenites nanseni* was useful for the correlation with upper zone of the Lower Carnian. Also *Halobia styriaca* MOJSISOVICS has been reported from the Lower Carnian of the Hallstatt Limestone in Austria, Greece, Sicily and Indonesia (DIENER, 1925). Therefore, the lower part of the Upper Member of the Nakijin Formation is probably correlated with the upper part of the Lower Carnian.

At a horizon represented by loc. 1 (Ya) in the upper part of the limestone of the Nakijin Formation, the Tropitidae and Haloritidae are abundant. The ammonoid assemblage listed at this level (Fig. 2) indicates an Upper Carnian. To explain more precisely, *Juvavites kellyi* was described by SMITH (1927) from the Hosselkus Limestone in California, where it occurs in the upper horizon of the *Tropites subbullatus* zone. *Jovites dacus* is the type species of the genus and is known from the Carnian Alps (MOJSISOVICS, 1893), Greece, Himalaya and Timor. In this zone many species referable to the genus *Discotropites* occur very commonly, and they are well known in the Carnian stage of Sicily, Northern Alps, Bosnia, Himalaya and Tonkin. *Hoplotropites jokelyi*, the type species of the genus, was described by HAUER (1855) from the Hallstatt Limestone of Austria and is also known from Sicily, California and Alaska. *Arietoceltites arietitoides* was reported by DIENER (1906) from the Upper Triassic beds of Himalaya. *Arnioceltites arietitiformis* was described by MOJSISOVICS (1893) from the Carnian Hallstatt Limestone together with numerous allied species and *Juvavites*, *Discotropites* and *Tropites*, etc.

In the Japanese Islands the Upper Triassic ammonites are inferior in the number of species and individuals to the Lower and Middle Triassic ones. The following are the Upper Triassic ammonites which have hitherto been described:

Arpadites sakawanus MOJSISOVICS	YEHARA (1926)
Paratrachyceras cf. *hofmanni* (BOECKH)	SHIMIZU (1930)
Paratrachyceras sp. nov. ?	SHIMIZU (1930)
Paratrachyceras n. sp.	BANDO (1964)
Thisbites orientalus SHIMIZU	SHIMIZU (1930)
Arcestes aff. *oligosurcus* MOJS.	SHIMIZU & MABUCHI (1932)
Arcestes sp.	NAKAZAWA (1964)
Proarcestes aff. *hanieli* WELTER	SHIMIZU (1931)
Proarcestes aff. *bicarinatus* MÜNSTER	SHIMIZU (1931)
Stenarcestes sp.	NAKAZAWA (1959)
Placites aff. *oxyphyllus* MOJS.	SHIMIZU & MABUCHI (1932)
"Monophyllites" arakurensis NAKAZAWA	NAKAZAWA (1958)
Monophyllites ? sp.	NAKAZAWA (1958)
Rhacophyllites sp.	NAKAZAWA (1964)

Among the species listed above, only three species of *Paratrachyceras* and each two species of *Monophyllites* and *Proarcestes* are Carnian in age.

The Triassic sediments are known from Kitakami and Kanto massives, Maizuru Zone, Yamaguchi Prefecture, Shikoku, Southern Kyushu and other areas in the Japanese Islands. The Triassic marine fauna is prolific bivalves such as Halobiidae, Monotidae and Pectinidae etc. However, such a rich ammonite fauna has not been reported in those regions.

The Triassic sediments have not been found in the Ryukyu Geanticline except in the area under consideration. However, it is noted here that there is a possibility of finding Triassic sediments in the Naon Formation (HATAE *et al.*, 1959) of Amami-o-shima. The Naon Formation is presumed to be in the same tectonic zone to which the Nakijin Formation belongs (KONISHI, 1965). MATSUMOTO *et al.* (1966) proposed a tentative correlation of the Naon Formation with the Konose Group (KANMERA and FURUKAWA, 1964) of Permian and Triassic ages. In my preliminary field work of Amami-o-shima, I found in the Naon Formation Permian fusulinaceans of *Neoschwagerina* and *Yabeina* from the limestone pebbles and the matrix of tuffite at several stratigraphic horizons. Therefore, at least a part of the Naon Formation is referable to the Permian, as KONISHI (1963, 1965) suggested, and to the Lower Konose Group. The upper part of the Naon Formation, composed of thickly bedded chert, thin layers of limestone and basaltic lava and silicious shale, can be presumed to be Triassic in age.

Concluding remarks

The Triassic Nakijin Formation is confirmed at the Ryukyu Geanticline for the first time. The Nakijin Formation is divided into the Lower and Upper Members by the lithological and paleontological characteristics; the former is composed of semi-crystalline limestone containing doubtful fossils, while the latter consists of black, bedded fossilierous limestone with subordinate amounts of basaltic lava, calcareous siltstone, calcareous mudstone and tuffite.

The numerous cephalopods and pelecypods are found in the limestone, calcareous siltstone and mudstone of the Upper Member. According to the preliminary study of the ammonite fauna obtained, they are referred to the Lower to Upper Carnian in age. Therefore, the Upper Member of the Nakijin Formation has proved to be approximately of the same age as the previnously known Carnian formations of Japan, such as the Mine, Lower Nariwa, Nabae, Lower Kochigatani, Upper Members of Sambosan and Konose Group.

However, the faunal assemblage of ammonites of the Nakijin Formation resembles that of Alps, the Arctic region and British Columbia of Canada, Timor, Himalaya rather than that of Japan proper. This may be due to the sedimentary facies rather than to the faunal province.

The sedimentary environment of the Upper Member is presumed to have been bounded by a barrier or a bank from the land. The volcanic activities frequently near and/or in the basin, resulting that the tuffite and the tuffaceous

materials in the limestone were formed in the basin. The terrigenous materials were often transported from the land beyond a barrier. As a whole, the Nakijin Formation bears rather pelagic sedimentary facies which was defined by PETTIJOHN (1957, p. 400).

It is pointed out that there is a similarity in tectonic configurations, biofacies and lithofacies between the suite of the Nakijin Formation, and that of the Naon Formation of Amami-o-shima, Konose and Sambosan Groups of Southwest Japan, in both of which basaltic lava and tuffaceous material are considerably predominant. The concept of the *Early Mesozoic Outerside Submarine Volcanic Belt* (KANMERA and FURUKAWA, 1964) can be extended to the Ryukyu Geanticline (KONISHI *et al.*, 1966).

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Appendix

Alphabetical list of place names

Akamaru-saki	赤丸崎	Minna-jima	水納島
Amami-o-shima	奄美大島	Motobu	本部
Awa-dake	安和岳	Nabae	難波江
Bise	備瀬	Nagatakibaru	長滝原
Furujima	古島	Nago	名護
Guga	呉我	Nakijin	今帰仁
Gushiken	具志堅	Nakōji	仲尾次
Hedo	辺戸	Naon	名音
Higashiuebaru	東上原	Nariwa	成羽
Ie-jima	伊江島	Okinawa-jima	沖縄島
Iheya	伊平屋	Oyadomari	親泊
Ishikawa	石川	Ryukyu	琉球
Jyahana	謝花	Sakimotobu	崎本部
Kamimotobu-son	上本部村	Sambosan	三宝山
Kantō	関東	Sesoko-jima	瀬底島
Katsuu-dake	嘉津宇岳	Shikoku	四国
Kayo	嘉陽	Toguchi	渡久地
Kitakami	北上	Tonaki-jima	渡名喜島
Kitazato	北里	Toyohara	豊原
Kochigatani	河内ケ谷	Ufudo	大堂
Kōnose	神瀬	Yae-dake	八重岳
Kouri-jima	古宇利島	Yagaji-jima	屋我地島
Kunigami	国頭	Yamaguchi	山口
Kyushu	九州	Yamakawa	山川
Maizuru	舞鶴	Yamazato	山里
Manna-gawa	満名川	Yonamine	与那嶺
Mine	美称		

Takeshi ISHIBASHI

Stratigraphy of the Triassic Formation in Okinawa-jima, Ryukyus

Plate 53

Explanation of Plate 53

Photomicrographs of calcareous sediments of the Nakijin Formation

Fig. 1. Öolitic limestone;—contains fragments of crinoid columnals as a nucleolus of öoid. The Upper Member. Loc. 2 (LYa). ×20.

Fig. 2. Calcareous siltstone;—contains tests of bryozoa ?, and small calcite spheres. The Upper Member. Loc. 9 (HNa-P). ×10.

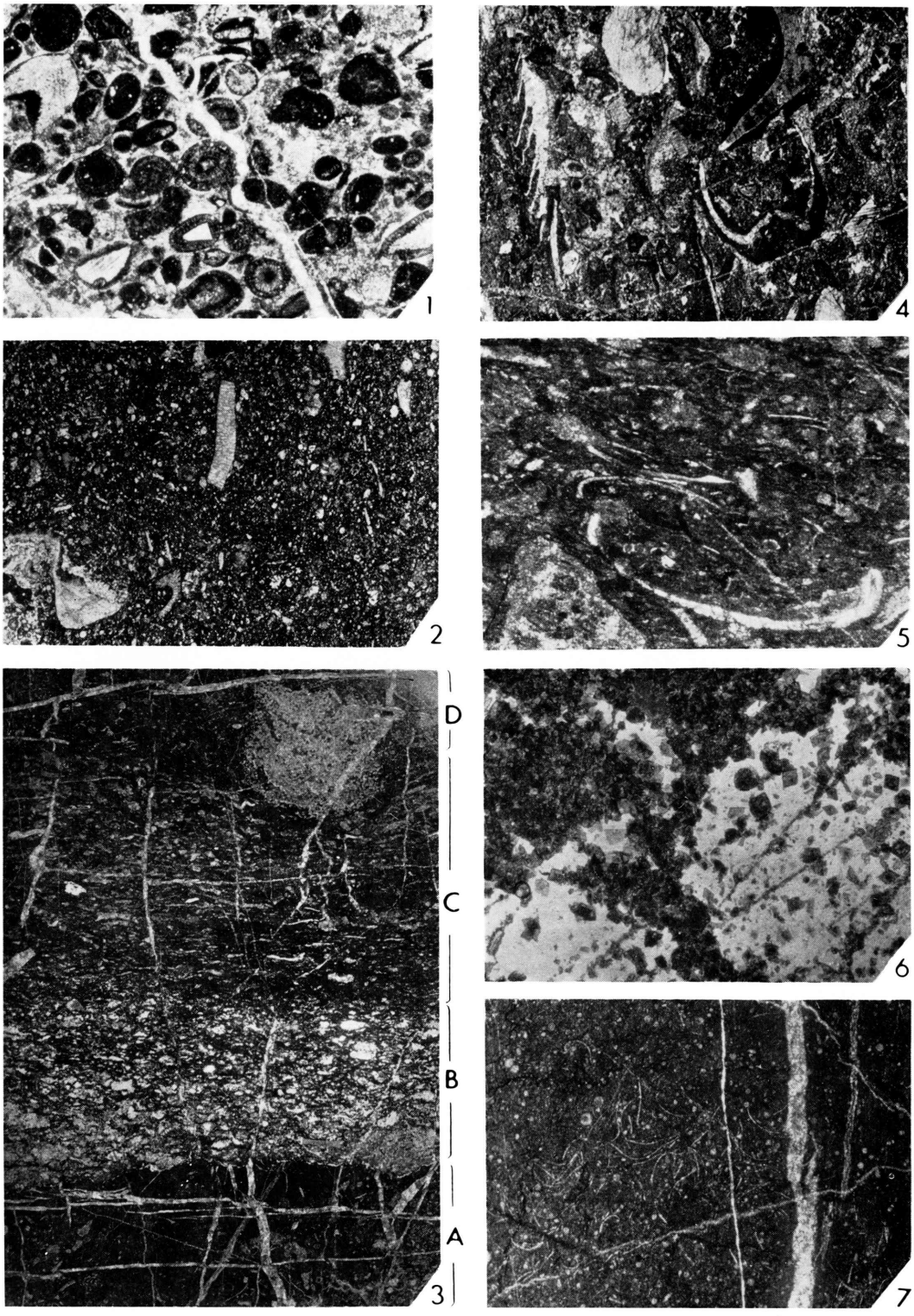
Fig. 3. Dolomitic limestone.
A. Micritic layer;—contains tests of thin shell and radiolaria.
B. Dolostone layer;—contains radiolarians.
C. Dolomitic layer;—contains tests of thin shell and radiolaria.
D. Micritic layer;—contains fragments of alga ?, or bryozoa ?.
The Upper Member. Loc. 3 (Aka). ×3.

Fig. 4. Bioclastic limestone;—contains debris of mollusca, crinoid-stems and coral ?. The Upper Member. Loc. 6 (HNa-2). ×10.

Fig. 5. Micritic skeletal limestone;—contains fragments of shell. The Upper Member. Loc. 6 (HNa-2). ×20.

Fig. 6. Dolomitic chert;—contains euhedral dolomite. The Lower Member. Loc. Higashiuebaru. ×20.

Fig. 7. Micritic limestone;—contains radiolarians and filaments of shell. The Upper Member. Loc. Nagatakibaru, neibourhood of HGU. ×10.



T. ISHIBASHI: Triassic Formation in Okinawa-jima.

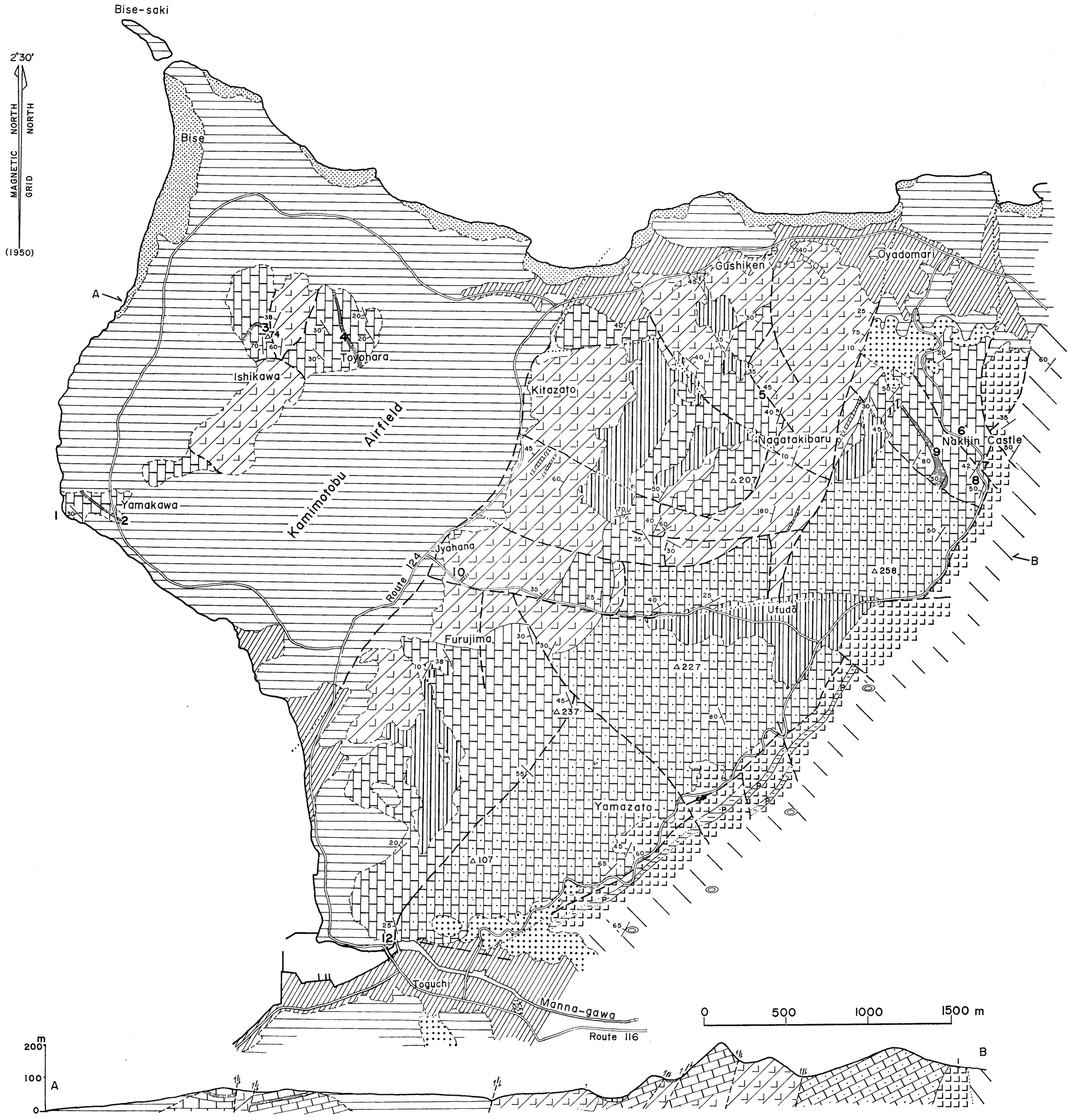


Fig. 4. Geologic map of northwestern area of the Motobu Peninsula. (See Fig. 3 for the legend.)