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Tectonic Development of the Chichibu Belt, Southwest Japan

By

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with 28 Text-figures, 5 Tables and 5 Plates

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ABSTRACT

Tectonic development of the Chichibu belt, Southwest Japan was discussed in this paper, on the basis of analysis of tectonostratigraphic units and tectonic development of individual units of the Chichibu belt in Shikoku, clarifying following points.

The Chichibu belt in Shikoku consists of three terranes, the Sawadani Terrane, the Kurosegawa Terrane and the Sambosan Terrane. The Sawadani Terrane is composed of three tectonostratigraphic units, which develop as nappes separated by southward dipping thrusts and show the northward younging age polarity. They in Eastern Shikoku correspond to the Sawadani unit of early to middle Early Jurassic time, Higashiura unit of middle to late Early Jurassic time and Kenzan unit of Middle Jurassic time in descending order, respectively. The Ohnogahara and Kanogawa nappes in Western Shikoku are correlated with the Sawadani and Higashiura nappes respectively. The ages of the constituent rocks of the nappes show following rules: (1) In each unit the age of the constituent rocks arrange in the order of limestone, chert, siliceous mudstone and mudstone from older to younger. (2) Each pair of limestone and chert, chert and siliceous mudstone and siliceous mudstone and mudstone of individual units tends to show the overlap of age. (3) The rocks of a kind in the lower unit are younger in age than those of the same kind in the upper unit. (4) The same sort of rocks in the different units tend to show the overlap of age. The Sawadani Terrane in Shikoku is defined as a belt occupied by Early to early Middle Jurassic accretionary prism formed along the northern (inner) front of the Kurosegawa Island-arc. The Kurosegawa Terrane is defined as a realm converted through Jurassic diastrophism from an older island-arc (Kurosegawa Island-arc), which consists of the Siluro-Devonian basement comlex of continental crust type, Permo-Triassic continental shelf type sediments, Permo-Triassic accretionary prism etc. The Sambosan Terrane of the Hiradani - Shiraishi area, Eastern Shikoku, has been divided from north to south into the Torinosu Group and the A, B1, B2 and C tectonostratigraphic units. The A, B1, B2 and C units have lithological and chronological sequences regarded as accretionary prisms which show a younging age polarity from north to south. The Sambosan Terrane is defined as a belt which is occupied by Middle Jurassic to Early Cretaceous accretionary prism formed along the southern front of the Kurosegawa Terrane.

Late Paleozoic to Mesozoic tectonic development of the Chichibu belt, Southwest Japan, is divided into nine stages. The initial structure of the Sawadani Terrane and the Sambosan Terrane were built up during the stages from 2 to 4 and the stages 5 to 7, respectively. And the diastrophism throughout the Chichibu belt had a climax at the change of the accretionary site from the northern (inner) side to the southern (outer) side across the Kurosegawa Terrane.

CONTENTS

I. Introduction

Southwest Japan is geologically divided into the Inner Belt on the Sea of Japan side and the Outer Belt on the Pacific Ocean side by the Median Tectonic Line. The Outer Belt has further been subdivided, from north to south, into the Sambagawa-Mikabu belt which consists of high-pressure type metamorphic rocks, the Chichibu belt and the Shimanto belt which is mainly composed of only weakly metamorphosed and non-metamorphic rocks of Cretaceous and Paleogene ages.

The Chichibu belt consisting of weakly metamorphosed rocks has commonly been so far defined as the belt between the Sambagawa and the Shimanto belt, that can be traced from Kanto Mountains to Okinawa Island for about 1500 km. In order to define a geologic province as a belt, however, it is necessary that there is a clear difference in formation process between the province and the surrounding provinces. Standing on this view point, we may notice that the previous expression does not adequetely define the Chichibu belt as a belt.

A model for the tectonic framework and evolution of Southwest Japan was proposed by Kobayashi (1941). His geotectonic division of Southwest Japan has been perfomed by the analyses of the sedimentary facies characteristics, the tectonic movement phases defined by unconformities in geological sequences and the styles of tectonic movements. Such a method of the determination of geotectonic units is still effective. From our present knowledge, however, there are various evidences to deny his conclusions. For instance, he regarded the constituent rocks of the belts excluding the Shimanto belt as a series of sediments deposited within the Chichibu geosyncline, and attempted to distinguish the belts by the difference in tectonic movement phase. And he explained that the northern half part of the Chichibu geosyncline had been deformed by the Akiyoshi orogenic movement of Permian-Triassic age and the remaining southern half part had been deformed only by the Sakawa orogenic movement of Cretaceous age. Although Mesozoic (Triassic and Jurassic?) radiolarian fossils, together with Paleozoic fusulinids, had already been reported by Hujimoto (1938) and Yehara (1927) from the Sambagawa and Chichibu belts which have been regarded as belonging to the southern half part of Chichibu geosyncline, Kobayashi denied such the ages of radiolarian fossils, considering that only Paleozoic age of fusulinids is significant and so that these belts belong to the Paleozoic Chichibu geosyncline. It has recently been, however, clarified by many authors (e.g. Isozaki et al., 1981; Suyari et al., 1983; Yao, 1984; Sashida et al., 1982) that most of constituent rocks of the Chichibu belt are of Jurassic age.

Ichikawa et al. (1953, 1956) first doubted Kobayashi's opinion that the Chichibu belt had not been subjected to a vigorous diastrophism during the age ranging from Late Paleozoic to Early Cretaceous, stressing a diastrophism during the age from the end of Paleozoic to the begining of Mesozoic which is shown by the Sakashu unconformity of Triassic time. The subdivision of the Chichibu belt into the northern, middle and southern subbelts was proposed by them. In the middle subblet, Silurian and Devonian rocks together with granitic and gneissic rocks, which were considered to be the fragments of basement complex of the Chichibu geosyncline, develop. Ichikawa et al. (1956) called the uplifting zone of such basement fragments the Kurosegawa (tectonic) zone, pointing out that the uplifting movement of the Kurosegawa zone (Kurosegawa movement) during Late Paleozoic to Early Triassic time induced the differentiation of the Chichibu geosyncline into three subbelts.

Miyashiro (1961) introduced the concept of the paired metamorphic belts, which consist of the metamorphic belt of low pressure-high temperature type on the continental side and the metamorphic belt of high pressure-low temperature type on the ocean side in parallel arrangement. It has farther been pointed out by many authors (e.g. Uyeda and Miyashiro, 1973) that the paired metamorphic belts develop commonly along the converging plate boundaries between the continent and the ocean, and that the Hida and Sangun belts are the paired metamorphic belts of Late Paleozoic-Early Triassic time while the Ryoke and Sambagawa-Chichibu belts are those of Late Mesozoic time following the Late Mesozoic radiometric dates of the Ryoke and Sambagawa metamorphic rocks. Such a way of thinking that the orogenic movement in Japan had successively shifted from the continental side (Hida belt) to the ocean side (Shimanto belt) has first been shown by Kobayashi (1941).

Recently, however, conodont and radiolarian biostratigraphical studies have been perfomed on the sedimentary rocks of the Chichibu geosyncline by many authors. The results have provided that the concept of the Chichibu geosyncline after Kobayashi (1941) is no longer effective: many of sedimentary rocks of the Chichibu belt have been referred to as olistostrome of Jurassic age, showing that many of limestone blocks containing fusulinids are only olistoliths (e.g. Tominaga et al., 1979; Yokoyama et al., 1979; Ichikawa et al., 1979; Isozaki et al., 1981; Suyari et al., 1979; 1982; Sashida et al., 1982). While it has been clarified that in the Kurosegawa zone occur the high-pressure type metamorphic rocks of ca. 400 Ma (Maruyama and Ueda, 1975), the granitic rocks and the high-temperature type metamorphic rocks of the same age (e.g. Hayase and Ishizaka, 1967; Hayase and Nohda, 1969), together with continental shelf type sediments of Silurian to Triassic age.

On the basis of such progress of age determination about the rocks of the Chichibu belt, some plate tectonic hypotheses on its development were proposed (e.g. Hada et al., 1979; Kanmera, 1980; Ichikawa et al., 1981). Nevertheless, their structural divisions seem to have been made following the traditional paradigm. For instance, although the structural division of the Chichibu belt into three subbelts, the northern, the middle and the southern subblet, has been authorized, the stratigraphics of sedimentary sequences of those subbelts have not been analysed to explane in terms of accretion process. Then, the purpose of this study is to re-examine the tectonic development of the Outer Zone of Southwest Japan.

A belt as a tectonic unit developed in the converging plate boundary has to be recongnized through understanding of the diastrophic movements to which the belt was subjected during the time from appearance of sedimentary environment (=begining of plate subduction), through sedimentation (=sediment accumulation by accretion process) and metamorphism of accreated

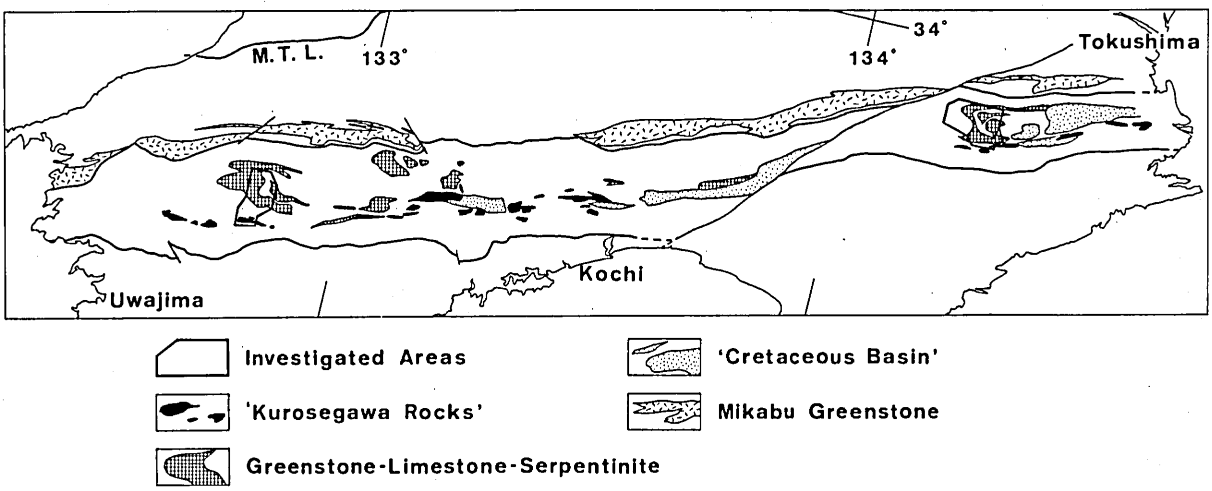

FIG. 1. Index map showing the investigated areas and the distribution of greenstone-limestone-serpentinite complexes, Kurosegawa rooks, Cretaceous basins and Mikabu greenstones in Shikoku, Southwest Japan.

materials (=subduction zone metamorphism), to emplacement of metamorphosed rocks into shallow tectonic position. In the Sambagawa belt just on the north of the Chichibu belt, the picture of the orogenesis has been drawn only for its later half process that corresponds to the uplifiting of the Sambagawa metamorphic rocks, while in the Chichibu belt there is a possibility that the main process of orogenesis including the earlier half could be understood, because the constituent rocks of the Chichibu belt contain fossils, as well as metamorphic minerals.

One of the important works to clarify the tectonic development of a belt may be to discriminate the tectonostratigraphic units based on the structural and stratigraphical analyses. Because a belt may consist sometimes of some tectonostratigraphic units but not of only one tectonostratigraphic unit, like the case of the Sangun metamorphic belt (Hara et al., 1985).

Another essential requirement for the tectonic analysis of a belt is the elucidation of the relationship between the belt and surrounding belts during the period of the diastrophic process. The relationship between the Chichibu belt and the Sambagawa belt (and the Shimanto belt) and even mutual relations among three subbelts of the Chichibu belt must be questioned. The tectonic framework for the formation of the Chichibu belt will be understood only through the study of such relationships.

Since 1976, the author has studied the Chichibu belt with his collaborators in order to understand the abovementioned problems (Tominaga et al., 1979; 1981; Tominaga and Hara, 1980; Yokoyama et al., 1979; Tsukuda et al., 1981a, b, c; Miyamoto et al., 1983, 1985). In this thesis, the tectonic development of the Chichibu belt is discussed on the basis of investigation of the geological structure of the Chichibu belt in both Eastern and Western Shikoku, namely the Sakashu-Sawadani area and Mt. Mitaki-Ohnogahara area. And a new geotectonic division of the Chichibu belt based on the discussion is proposed.

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II. Outline of Geologic Framework

The Outer Zone of Southwest Japan is generally subdivided into the Sambagawa-Mikabu, Chichibu and Shimanto belts arranged from north to south. The Mikabu belt sandwiched between the Sambagawa belt and the Chichibu belt is characterized by the development of greenstones of vast volume. The relationship between the Mikabu belt and the Chichibu belt is still indefinite, although, from a series of studies in Eastern Shikoku by Iwasaki (e.g. 1969, 1984), a set of strata which rest conformably on the Mikabu greenstones appear to be in southerly dipping fault contact with the strata of the Chichibu belt. In Shikoku the Sambagawa belt is considered to thrust over the Mikabu belt and the Chichibu belt (Takeda et al., 1977; Hara et al., 1977). The boundary between the Chichibu belt and the Shimanto belt is a reverce fault which commonly dips steeply to the north. This fault which is called the Butsuzo Tectonic Line has been regarded as the boundary between the Chichibu and Shimanto geosynclinal provinces (YAMASHITA, 1957). From the viewpoint of analysis of tectonostratigraphic units, however, the meaning of this fault must be re-examined in this papar.

It is well known that the Chichibu belt is composed of three kinds of rock groups which lie nearly parallel to the general trend of the Chichibu belt. In the middle line of the Chichibu belt in Shikoku characteristically developes such a unique rock group, called the Kurosegawa rocks, as granitic rocks, high-temperature type metamorphic rocks and high-pressure type metamorphic rocks of ca. 400 Ma, Silurian to Triassic continental shelf-type strata and a large quantity of ultramafic rocks (Fig. 1). It crops out as blocks of various scales, a few centimeters to some tens kilometers, in the Chichibu belt from Kii Peninsula, through Shikoku, to Kyushu. The knowledge of the Kurosegawa rocks has fairly been well accumulated, clarifying that most of them appear to be fragments of a continental crust of age of ca. 400 Ma (e.g. HAYASE and ISHIZAKA, 1967; HAYASE and NOHDA, 1969; MARUYAMA and UEDA, 1975).

While in the northern area of the Chichibu belt in Shikoku are known the complexes composed of greenstones closely accompanied by limestone and of gigantic serpentinite bodies containing blocks of the Kurosegawa rocks (Fig. 1). And these rocks are exotic blocks in Early Jurassic olistostromes (e.g. TOMINAGA et al., 1979; YOKOYAMA et al., 1979; ICHIKAWA et al., 1979; ISOZAKI et al., 1981; SUYARI et al., 1982; SASHIDA et al., 1982).

The southern area of the Chichibu belt is occupied by olistostromes of Late Jurassic and Early Cretaceous age composed mainly of chert and coarse grained crastic rocks (e.g. YAO, 1984; ISHIDA, 1987).

In this thesis, the areas occupied by such rock types are called, from north to south, the Sawadani Terrane, the Kurosegawa Terrane and the Sambosan Terrane for convenience. The definition for the Sawadani, Kurosegawa and Sambosan Terranes is newly given in this paper. And the name of the Chichibu belt is used as a general term for these three terranes in a customary usage.

The Lower Cretaceous system of the Chichibu belt, which has recently been considered by some authors (e.g. TAIRA et al., 1981) to correspond to the deposits in the fore-arc basin related to the formation of the Shimanto belt, unconformably overlies the pre-Cretaceous rocks of the Sawadani Terrane or the Kurosegawa Terrane or both (e.g. KOBAYASHI, 1941). Therefore, the Cretaceous strata should be used as a time-marker in analysis of the tectonic development of the Chichibu belt. The Cretaceous strata of the Chichibu belt in Western Shikoku show an isoclinal syncline with northerly dipping axial plane and are cut the northern extension by a northerly dipping thrust fault (ISHIZAKI, 1962). In the Ryoseki-Monobe Valley area, Central Shikoku, the Cretaceous strata are partly in unconformable contact with the pre-Cretaceous rocks of the Chichibu belt (KOBAYASHI, 1941) and partly thrust by them (MIYAMOTO et al., 1979). While the Cretaceous strata in Eastern Shikoku, according to OGAWA (1971, 1974), do not show any large displacement caused by thrust faults. These facts suggest that in Western Shikoku the pre-Cretaceous rocks of the Chichibu belt were strongly deformed after the deposition of the Cretaceous strata and that in Eastern Shikoku the pre-Cretaceous structure of the Chichibu belt may be fairly well preserved.

III. SAWADANI TERRANE

The Sawadani Terrane occupies the northern part of the Chichibu Belt and corresponds approximately to the terrane called the "northern Chichibu belt" (ICHIKAWA et al., 1956) or the "Chichibu belt proper" (TSUKUDA et al., 1981a, b, c). In this paper, however, this terrane was given a new name on the basis of the understanding of its evolutional process avoiding the confusion among the terms previously used. "Sawadani" is the name of an area in Eastern Shikoku investigated in this study, where the initial geologic structure of this terrane is well reserved. The geology of the Sawadani area as the type locality of the Sawadani Terrane will first be analysed.

A. GEOLOGY OF THE SAWADANI AREA

The Sawadani area, where the Sawadani Terrane develops most widely in Eastern Shikoku, is situated in the central part of Tokushima Prefecture. This area has been studied stratigraphically by KANMERA (1969) and petrographically by MARUYAMA (1976). MARUYAMA clarified the petrochemical characteristics of the Sawadani greenstones. KANMERA postulated the limestones yielding Carboniferous and Permian fusulinids to be embedded in constituent rocks of this area (the Sawadani Group), and considered that the large quantities of greenstone covering wide areas of Sawadani (Sawadani greenstones) were produced by the submarine volcanism. However, YOKOYAMA et al. (1979) showed that the chert lenses in pebbly mudstone underlying the Sawadani greenstones with the limestone lenses of Carboniferous to Permian ages contain Triassic conodonts, and provided that the limestone lenses in the Sawadani greenstones do not show a regular stratigraphical succession, pointing out that the limestone lenses and Sawadani greenstones are exotic blocks. The author has so far analyzed tectonostratigraphical units.

Figures 2, 3 and 4 illustrate the geology of the Sawadani Terrane of this area. As shown in Figs. 2 and 3, the strata of this area are divided by thrust faults into three geologic units, that is the Kenzan unit, the Higashiura unit, and the Sawadani unit in ascending order. And the nappes composed of their own units are called the Kenzan nappe, the Higashiura nappe, and the Sawadani nappe respectively.

This division differs from the KANMERA's, the Sawadani Group and the Kenzan Group (KANMERA, 1969). As compared with KANMERA's division, the Sawadani unit is correlated with the Takano Formation and with the part of Sawadani Formation in the vicinity of Sawadani, the Higashiura unit comprises the Higashiura Formation and the southern border part of the Kenzan Group in Kamagatani, and the Kenzan unit refers to the rest of the Kenzan Group and to the Sawadani Formation in and around Kawanaru.

From the traces of thrust faults or the trend of strata on the geologic map (Fig. 2), it is clear that a gentle synform (Takashiroyama synform) with eastward plung-

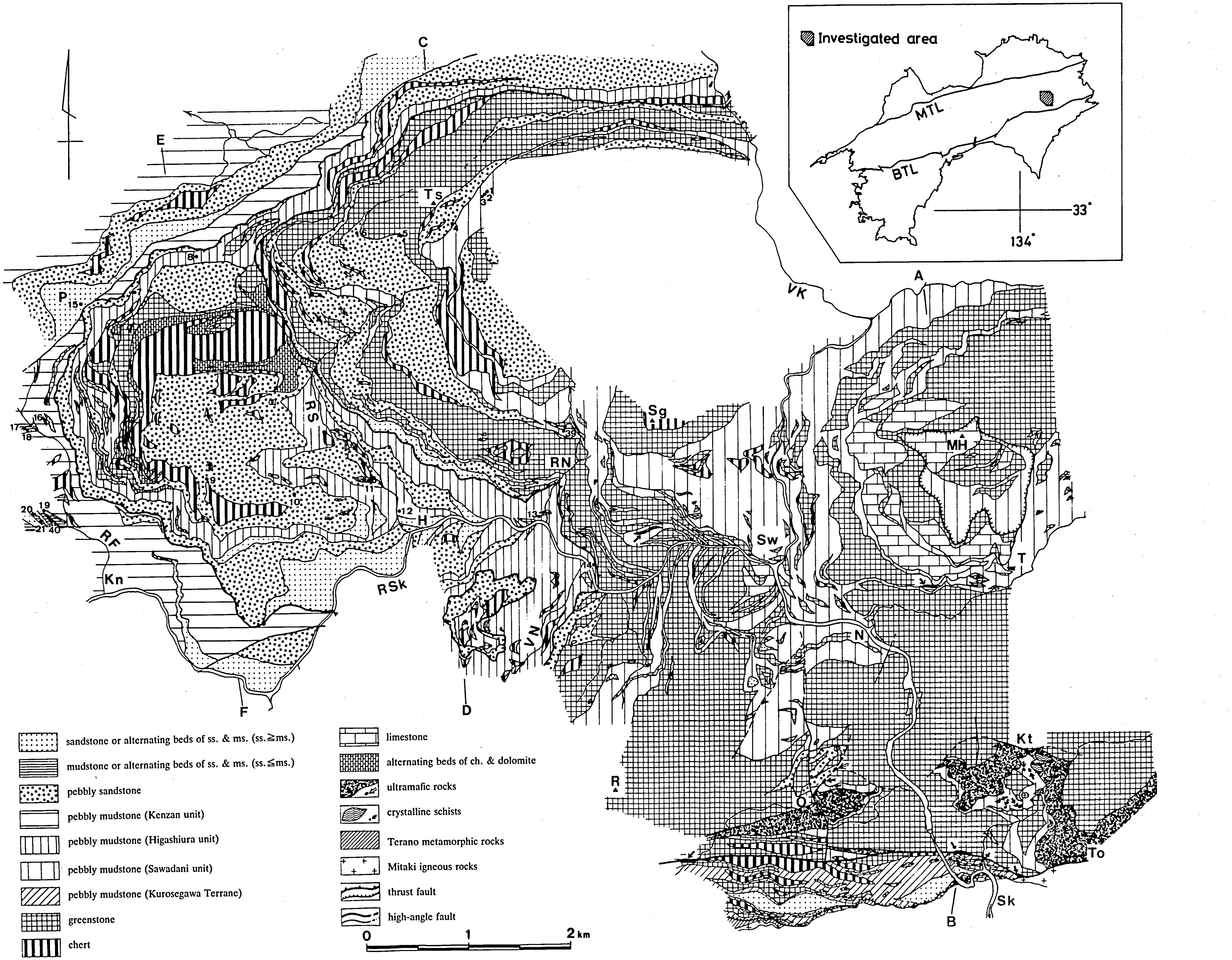


FIG. 2. Geological map of the Sawadani area (Sawadani Terrane), Eastern Shikoku.
H: Higashiura, Kn: Kawanaru, Kt: Kitohmyoh, N: Nagonose, O: Ohyohchi, P: Kawanarutohge Pass, Sk: Sakashu, T: Takano, To: Tohyama, MH: Mt. Hizuka, R: Mt. Rokuroh, Sg: Mt. Shigakinomaru, Ts: Mt. Takashiro, RF: Fujigauchidani River, RS: Shikibidani River, RSk: Sakashukitoh River, VD: Kamagatani Valley, VN: Natsugiri Valley.
Numbers mean the sample localities of the radiolarian fossils (1–21: Jurassic, 39: L. Triassic, 40: E. Permian).

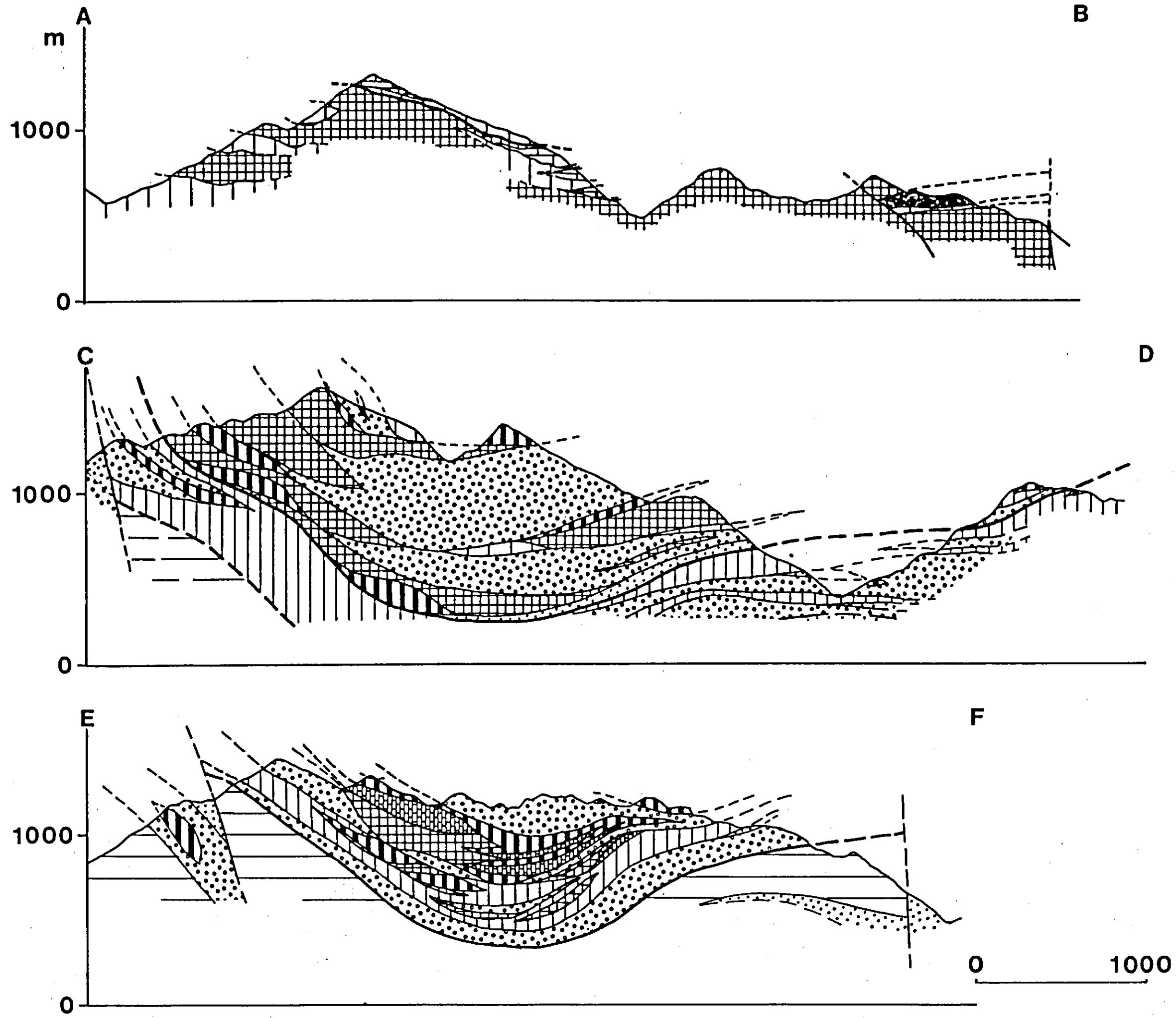


FIG. 3. Schematic geological profiles along the lines A-B, C-D and E-F on Fig. 2. See the legend of Fig. 2.

ing fold axis develops in the investigated area (Fig. 3). Therefore, the rocks of the Higashiura and Kenzan units crop out in discending order as traced westward along the southern border of the Sawadani Terrane (Fig. 13). The western extension of the Kenzan unit terminates along the Akuigawa fault, while the northern border of the Kenzan unit is considered to be in fault contact with the rocks of the Mikabu belt.

The thrust fault (Shikibidani thrust), which confines the bottom of the Sawadani nappe, is recognized in the upper stream of the Shikibidani River as the structural discontinuity between the alternating beds of sandstone and mudstone of the Sawadani unit and alternating beds of chert and dolomite which the Higashiura unit contains characteristically. Here the Shikibidani thrust shows strike of north to north-northwest and dip of about 40° eastward. Traced southeastward, the strike of this fault swings to northwest to west-northwest on the north of Higashiura and backs to north-northwest in the vicinity of the Natsugiridani River. The northeastern extension of the Shikibidani thrust strikes nearly north on the west of Mt. Takashiro and turns its strike to northeast on the northwest and north faces of Mt. Takashiro. At the Kamagatani River, the Shikibidani thrust leads to the fault which was regarded by KANMERA (1969) as the northern boundary of the Sawadani Group, strikes east and dips moderately south. Although the strata on the northern side of this fault was regarded by KANMERA (1969) as the member of the Kenzan Group, which corresponds to the northern half of the Kenzan unit, it belongs to the Higashiura unit according to the author's definition (Fig. 2).

The thrust (Kawanaru thrust), which limits the bottom of the Higashiura nappe, appears as the boundary between the althernating beds of sandstone and mudstone of the Higashiura unit and pebbly mudstone of the Kenzan unit at the Sakashukitoh River. The shear plane developed in the pebbly mudstone here generally strikes N80°W and dips about 60°N. The trace of the Kawanaru thrust shows a horseshoe-shape opening to the east, like the case of the Shikibidani thrust (Figs. 2, 4) The northern extension of the Kawanaru thrust has not been traced in details, though it is supposed that the Kawanaru thrust runs across the Kamagatani River near the Jizodani River according to the result of preliminary investigation by the author and to SUYARI et al. (1982).

The Shikibidani thrust cuts the alternating beds of sandstone and mudstone at the bottom of the Sawadani nappe on the north of Higashiura, chert and greenstone on the west of Mt. Takashiro and greenstone on the north of Mt. Takashiro, terminating the northward extension of more upper horizon of the Sawadani unit as traced

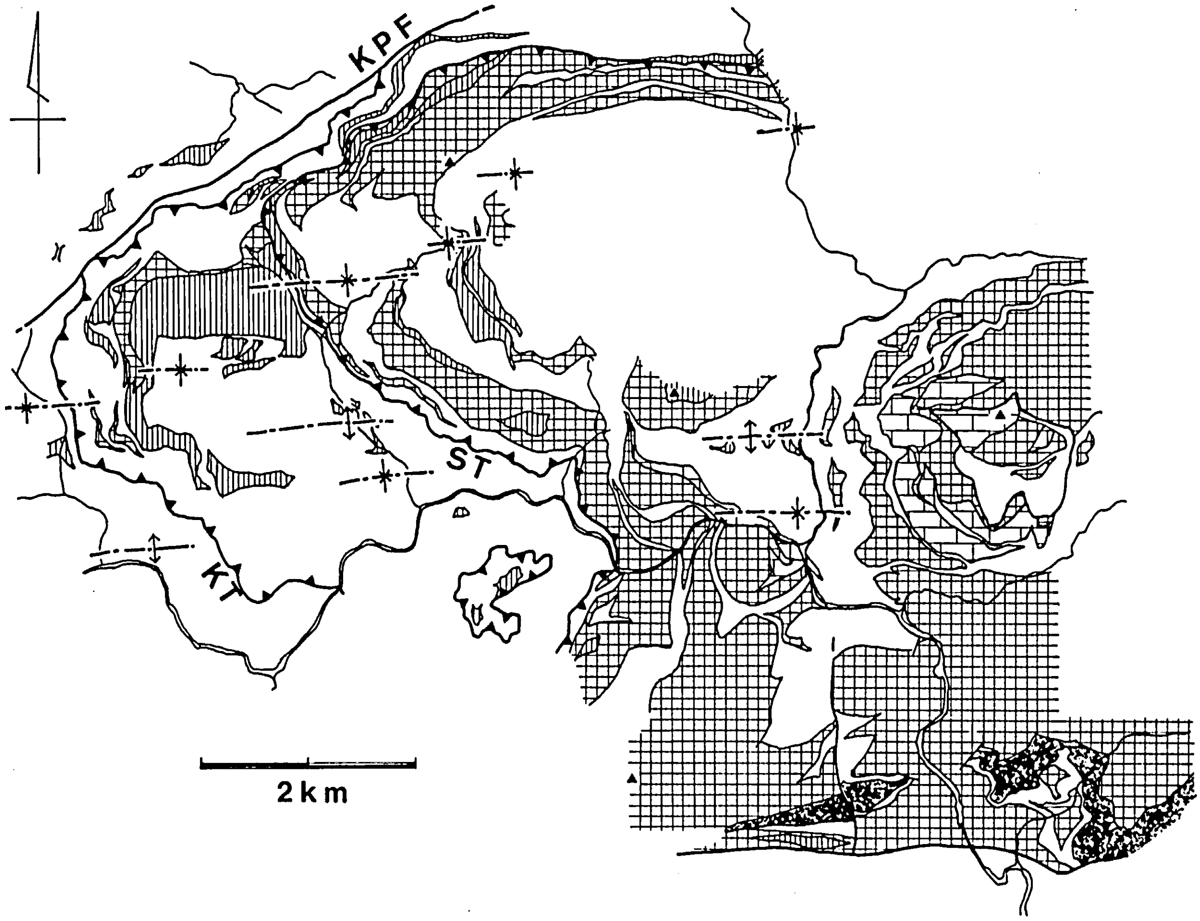


Fig. 4. Map showing the major structural features.
·—‡—· : antiform axes
··—+··— : synform axes
⌃⌃⌃: erosional fronts of nappes
ST: Shikibidani thrust
KT: Kawanaru thrust
KPF: Kawanarutohge fault

northward (Figs. 2, 3, 4). Like the case of the Shikibidani thrust, the Kawanaru thrust also cuts the more upper horizon of the Higashiura unit as traced northward. Such the style of relationship among the thrust faults and the strata of the upper unit on each thrust suggests that if the Takashiroyama synform had not be formed the Shikibidani thrust and the Kawanaru thrust would dip to the south.

1. The Sawadani unit

The Sawadani unit occurs as a nappe in the Sawadani area, occupying the uppermost part of the lithologic sequences and the largest domain. This unit mainly consists of greenstones of vast volume, their closely associated limestone, pebbly mudstone and relatively coherent coarse sandstone. And in the pebbly mudstone of this unit, serpentinite and associated crystalline shcists as blocks of various scales are also found characteristically. Besides them, pebbly mudstone and sandstone contain also chert, siliceous mudstone, phylitic sandstone and slate as exotic blocks which range in size from several millimeters to mappable scale.

Greenstones mainly consist of basaltic lava, which often show pillow structure, and of basaltic hyaloclastite with small amount of tuff to tuff breccia frequently alternated with clastic limestone. Greenstones occur mainly in three horizons as the accumulations of blocks of various sizes (Figs. 2, 5). The greenstones of the lower horizon are closely associated with coarse sandstone and fine conglomerate. The relationship between the former and the latters is generally sedimentary. The thick greenstone bed extending from the Niida River westward is chiefly composed of pillow lava with minor amount of chert and shows a large lenticular shape which is in harmony with surrounding rocks. The greenstone group of middle horizon exposes in the area from Kitohmyo-Ohyohchi to the west of Sawadani. In the west of Sawadani, the greenstones occur as the accumulation of small lenses surrounded by pebbly mudstone. Reddish purple tuff which occurs in the area from Nagonose to Sawadani interbeds with limestone, showing variation in lithology from tuff through tuffaceous limestone to limestone. The upper greenstone group, which overlies pebbly mudstone distributed in and around Sawadani, is accompanied by a large amount of limestone. In the Mt. Hizuka area where this group crops out widely, it has been clarified that the greenstone and limestone lenses are exotic blocks mixed into pebbly mudstones (Yokoyama et al., 1979).

Although the limestones are mostly crystalline, each of their texture are preserved is of clastic type. They mainly consist of oolitic grainstone accompanied by mudstone, bioclastic grainstone and bioclastic packstone (Fig. 6, Yokoyama et al., 1979). Such lithofacies are also observed in the present reef complexes. The limestone lenses of the Mt. Hizuka area are closely associated with

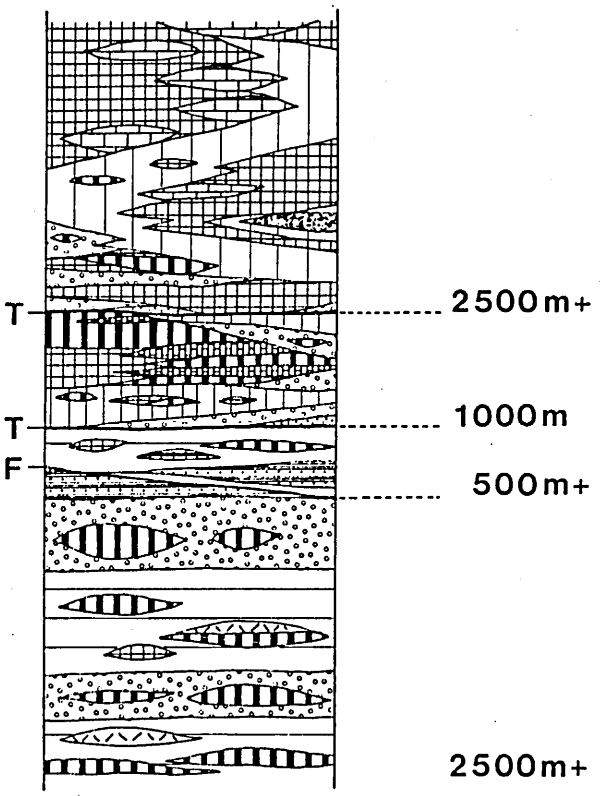


FIG. 5. Generalized columner section of the Sawndani, Higashiura and Kenzan units.

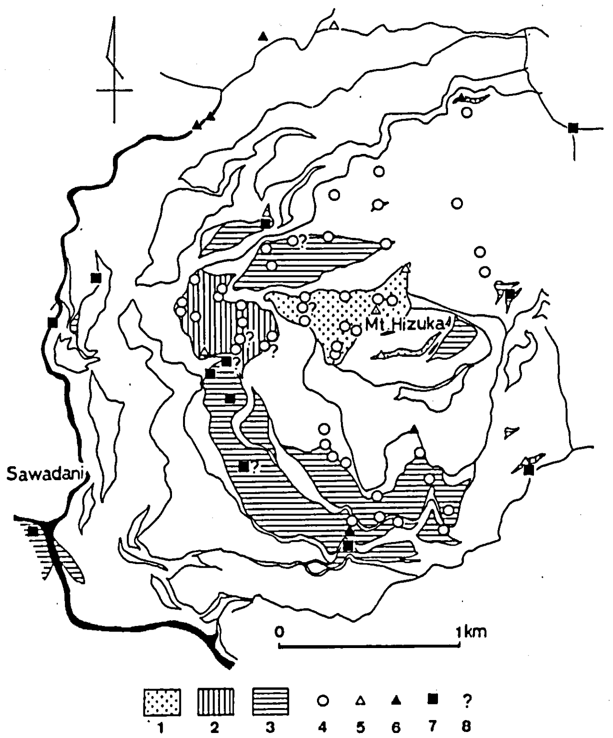


FIG. 6. Diagram showing the age and lithofacies of the limestone lenses in Mt. Hizuka area (after YOKOYAMA et al., 1979 and present study).
1–3: limestone lenses (1: Carboniferous, 2: Early Permian, 3: unidentified), 4: oolitic grainstone, 5: bioclastic grainstone, 6: bioclastic packstone, 7: mudstone, 8: recrystallized.

large quantities of greenstones (Fig. 2) which mainly consist of pillow lava. Therefore, the greenstone-limestone complex is considered to have been derived from a Paleozoic seamount and associated reef complex, as assumed by KANMERA (1969), MARUYAMA (1976) and YOKOYAMA et al. (1979). As shown in Figs. 2 and 6, however, the greenstones and limestones occur as large lenticular bodies surrounded by pebbly mudstone and the limestone lenses do not show any regular stratigraphic successions as analysed with foraminiferal fossils. These facts clearly indicate that the structural relationship between the greenstones and the limestones is not of any original reef complex.

It has been considered that the serpentinite bodies which contain crystalline schists of 402–445 Ma in age (MARUYAMA and UEDA, 1975) had intruded along a fault cutting the greenstones and pebbly mudstones around the serpentinite bodies (KANMERA, 1969; MARUYAMA and UEDA, 1975). As shown in the author's geological map and profile (Figs. 2, 3), however, the serpentinite bodies with the schists of 402–445 Ma appear to be in harmony with the layering of surrounding mudstones and greenstones, and to be extended from the border against the Kurosegawa Terrane northward in "tong shape" (TOMINAGA et al., 1981). Besides the pebbly mudstone contains not only lenses of sandstones, cherts, greenstones and crystalline schists but also of serpentinite. Such a mode of occurrence of serpentinite blocks suggests that these blocks are also sedimentary slide masses sandwiched in pabbly mudstones. The radiometric ages of the crystalline schists which occur as xenoblocks in serpentinites are correlative with those of the Kurosegawa Terrane. And also serpentinite itself is one of rock type which characteristically occurs in the Kurosegawa Terrane. Judging from the mode of occurrence and the correlations of the rocks with the Kurosegawa Terrane, it is most natural to assign the sause of the serpentinites to the Kurosegawa Terrane, and then a paleoslope which had been inclined from the Paleo-Kurosegawa Island-arc relatively northward may be assumed.

Chert, which is a minor component of the Sawadani unit, occurs in some extent in the north of Sawadani and around Mt. Takashiro. It is commonly of bedded type and contains abundant siliceous organic remains such as radiolarians and sponge spicules. It also yields poorly preserved conodonts occasionally. The cherts, as based on the ages of radiolarians and conodonts, are classified into two groups, Permian and Early Triassic (Fig. 11). Permian cherts, of which individual layers are usually 5–10 centimeters in thickness, are reddish at places and tend to be associated with greenstones. While Early Triassic cherts, of which individual layers are 1–2 centimeters in thickness, do not look ruddy, alternate occasionally with acid tuffaceous material, and often grade into bedded siliceous mudstone. Bedded siliceous mudstone ranges from Late Triassic to Early Jurassic in age. Such change in lithofacies may suggest that the sedimentary environment changed from pelagic to rather terrigenous with passing of time.

Pelitic rocks consist mainly of pabbly mudstone. Also ordinary black mudstone occasionally interbeds with pebbly mudstone, though its extensions are fairly restricted. Limestone and chert lenses contained in pebbly mudstone are Late Carboniferous to Late Permian and

Early Permian to Carnian in age respectively. While pelitic rocks yield Late Triassic(?) to Early Jurassic radiolarian fossils (Fig. 2, Table 1). Such a mode of occurrence of the constituent rocks of the Sawadani unit, that the older pelagic sediments such as limestones and cherts occur as lenses in the younger terrigenous sediments such as pelitic or psammitic rocks, suggests that the Sawadani unit is composed mainly of olistostromes. Summerizing the evidence afforded by the paleontological record (Fig. 11, Table 1) the Sawadani unit is considered to have been formed during the age between early and middle Early Jurassic time.

TABLE. 1. LIST OF JURASSIC RADIOLARIAN FOSSILS FROM THE SAWADANI AREA (SAWADANI TERRANE).

	Sawadani U.						Higashiura Unit								Kenzan Unit						
	siliceous shale	siliceous shale	shale	siliceous shale	siliceous shale	slate	pebbly mudstone	slate	siliceous shale	siliceous shale	siliceous shale	siliceous shale	shale	pebbly mudstone	shale	shale	shale	shale	shale	shale	shale
Samples Species	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
1. *Pantanellium tanuense* PESSAGNO & BLOME		+																			
2. *P. kluense* PESSAGNO & BLOME		cf.			cf.	cf.															
3. *Palaeosaturnalis* sp.	+	+				+				+											
4. *Bagotum erraticum* PESSAGNO & WHALEN					cf.																
5. *B. pseudoerraticum* KISHIDA & HISADA				+	+					+	+		+								
6. *B. moudense* PESSAGNO & WHALEN					#								cf.								
7. *B. modestum* PESSAGNO & WHALEN													cf.								
8. *B.* sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+							
9. *Droltus* sp.	+	+	+		+	+	+	+	+	+		+									
10. *Napora* sp.		+						+													
11. *Broctus selwynensis* PESSAGNO & WHALEN									cf.												
12. *B.* sp.	+				+	+					+	+		+							
13. *Stichocapsa* sp. B*					+		+														
14. *Noritus* sp.						+		+													
15. *Zartus* sp.									+												
16. *Natoba minuta* DE WEVER					+		cf.					+	+	+							
17. *Stichocapsa* sp. A*							+	+													
18. *Parahsuum simplum* YAO						cf.	+	+													
19. *P.(?)* sp. C*						+	+														
20. *Syringocapsa* sp. B*								+				+									
21. *Canoptum anulatum* PESSAGNO								cf.													
22. *C.* sp.	+		+		+	+	+	+				+	+	+							
23. *Gigi fustis* DE WEVER									cf.				+								
24. *G.* sp.									+				+								
25. *Katroma* sp.									+												
26. *Parahsuum* sp. D*							cf.	cf.								+					
27. *Spongocapsula* sp. C*																+					
28. *Stichocapsa convexa* YAO															+						
29. *S.* sp.			+		+				+							+					
30. *Hsuum* sp.									+						+	+	+	+	+		+
31. *"Spongosaturnalis" tetraspinus* YAO															+						
32. *Lupherium* sp.														+	+			+	+		
33. *Tricolocapsa(?) fusiformis* YAO																			+		
34. *Eucyrtidiellum unumaense* (YAO)								cf.							+	cf.			+	+	
35. *Unuma echinatus* ICHIKAWA & YAO															+				+		
36. *U. typicus* ICHIKAWA & YAO															+				+		
37. *U.* sp.															+		+	+	+		
38. *Cyrtocapsa mastoidea* YAO																	+	+	+		
39. *Diacanthocapsa(?) operculi* YAO																			+	+	
40. *Protunuma fusiformis* ICHIKAWA & YAO																	+		+		
41. *P.* sp.																	+	+		+	+
42. *Tricolocapsa plicarum* YAO															+		+		+		+
43. *T. parvipola* TAN																					cf.
44. *T.* sp.							+		+						+	+	+	+	+	+	+
45. *Parvicingula* sp. F*																	+	+	+	+	
46. *Archaeodictyomitra rigida* PESSAGNO															cf.					cf.	
47. *A.* sp.																	+		+		+
48. *Dictyomitrella(?) kamoensis* M & K**																					+

: affinity
* : YAO et al. (1982)
** : MIZUTANI & KIDO

2. Higashiura unit

The rocks of the Higashiura nappe, that is the Higashiura unit, can be traced from Higashiura, through the northwest of Mt. Takashiro, to the upper stream of the Kamagatani River. This means that the rocks found in Higashiura and in the area ranging from the north of Mt. Takashiro to the Kamagatani River are in succession, and that the Higashiura unit in the investigated area occurs both in the trough part and in the northern flank of the Takashiroyama synform.

The Higashiura unit also consists of the alternation of olistostromes with pelitic and psammitic matrices, and is characterized by the occurrence of olistolith of chert associated with dolomite.

The best exposure of the dolomite rocks is found in the area between the Shikibidani River and the Fujigauchidani River. In the alternating beds of chert and dolomite, commonly, dolomite beds are about ten centimeters in thickness. Massive dolomite frequently contains chert blocks of irregular shape. Besides, dolomite also occurs as breccia in basic tuffaceous matrix together with chert and limestone rubble. Such chert-dolomite beds have also been found in the Washinosu area, Kochi Prefecture, and the Okegoya and Tsuenose areas, Ehime Prefecture, showing lithofacies corelated with those of the Higashiura unit and yielding Late Carboniferous conodonts (Isozaki and Matsuda, 1980; Suyari et al., 1981).

Sandstone of the Higashiura unit is generally coarse and massive and occurrs commonly as the matrix of olistostrome. And it frequently passes into rudaceous facies. It also contains a large amount of pelitic material and/or microcrystals of phyllosilicate, and belongs to wacke. The rock fragments contained in sandstone are composed mainly of acid and intermediate pyroclastic rocks with minor amount of granitic rocks, chert and mudstone. Among the pebble-size rock fragments, chert is predominant and pyroclastic rocks and granitic rocks are rare. The latter two are well-rounded and have been observed only in some outcrops. No fossils have been discovered from the sandstone matrix.

Radiolarian fossils have been obtained from mudstone of four localities besides from siliceous mudstone closely related to chert (Fig. 2, Table 1). The Higashiura unit is assigned to middle to late Early Jurassic age based on radiolarian fossils.

3. Kenzan unit

The Kenzan unit is restricted in the northwestern part on the geological map (Fig. 2), though it occupies the area between the Higashiura nappe and the Mikabu belt on the north of the mapped area and its western extension is terminated along the Akuigawa fault. It was considered by Hirayama et al. (1956) that the Chichibu belt in Eastern Shikoku is covered by the Kenzan Group in the north and the Sawadani Group in the south and that these two groups are arranged in the east-west trend. It has been clarified, however, through this investigation that the rocks occurring in Kawanaru and its further west area (Kenzan Unit) continue to the Kenzan Group (Fig. 2). Thus it can be stated that the Kenzan unit is not only distributed on the north of the Higashiura and Sawadani units, but also underlies them (Figs. 2, 3).

The Kenzan unit is also composed chiefly of olistostrome with pelitic matrix. The rock types of the olistoliths are composed mainly of chert with small amount of acid tuff and alternating beds of sandstone and mudstone. Middle Jurassic radiolarian fossils have been discovered from mudstone of the Kenzan unit (Kenzan Group) on the north of the mapped area by Isozaki et al. (1981) and Suyari et al. (1982) and in the north of Kawanaru (Fig. 2, Table 1) by the author from mudstone which alternates with sandstone. This fact indicates that the continuity between the rocks exposing in Kawanaru (Kenzan unit) and the Kenzan Group is also paleontologically proved. The Kenzan unit can be dated as early Middle Jurassic age on the basis of fossil evidence (Fig. 2, Table 1).

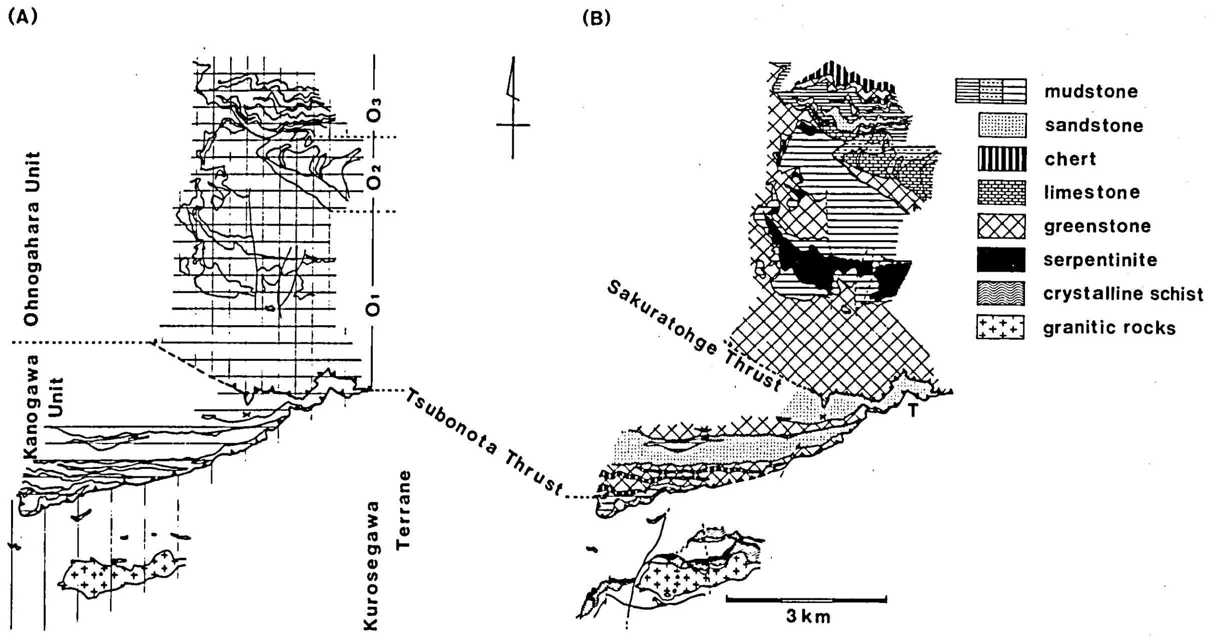


Fig. 7. (A) Distribution of structural units in the Mt. Mitaki-Ohnoganara area.
(B) Geological skech map showing the resional relation between the Mt. Mitaki and the Ohnogahara areas.

B. GEOLOGY OF THE OHNOGAHARA AREA

The Ohnogahara area selected to study on the Sawadani Terrane in Western Shikoku coveres to the north of Mt. Mitaki (Shirokawa Town) and Koya (Nomura Town), Ehime Prefecture, and Tsubonota (Yusuhara Town), Kochi Prefecture (Figs. 7, 8). The Sawadani Terrane in this area thrusts over the Kurosegawa Ter-

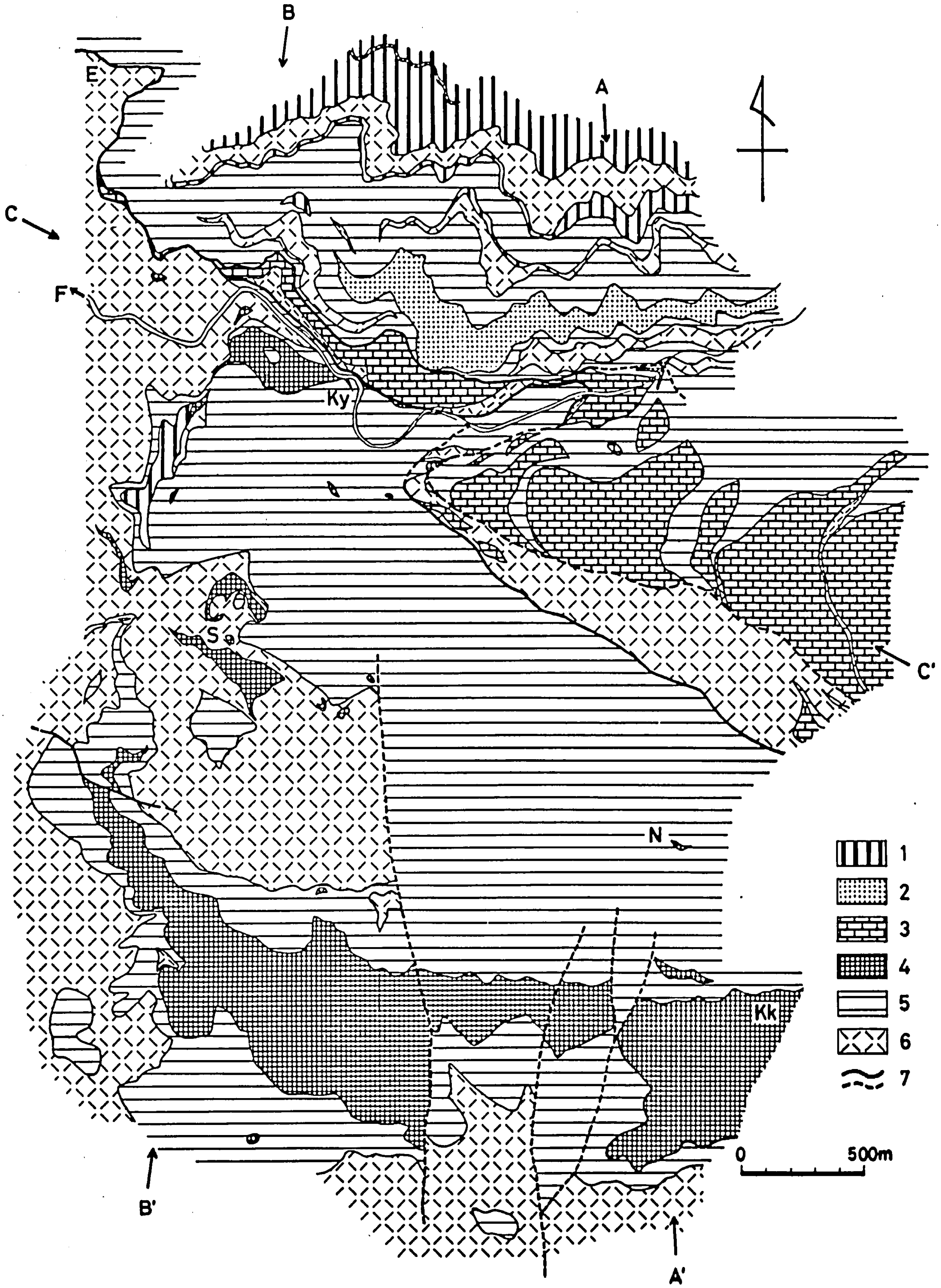


FIG. 8. Geological map of the Ohnogahara area (Sawadani Terrane), Western Shikoku.
1: chert, 2: sandstone, 3: limestone, 4: ultramafic rocks, 5: mudstone, 6: greenstone, 7: fault, E: Enoki, F: Funato River, Ky: Koya, S: Shohwa, N: Niragatonge Pass.

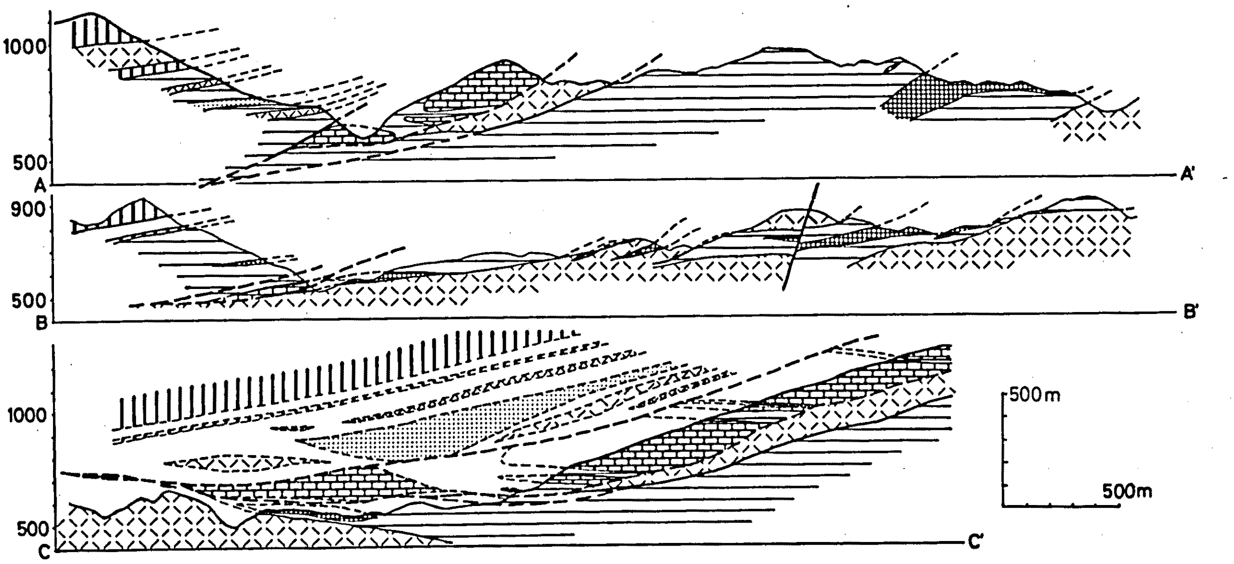


FIG. 9. Geological profiles along the lines A-A', B-B' and C-C' on Fig. 8. See the legend of Fig. 8.

rane. The thrust fault between the Sawadani and Kurosegawa Terranes can be traced from Tsubonota to the north of Nakanokawa (Shirokawa Town) and dips gently to the north. This fault is hereafter designated as the Tsubonota thrust because it is most obviously present in the west of Tsubonota (Fig. 7).

The strata of the Sawadani Terrane in Western Shikoku is divided into two units, the Ohnogahara unit at the top and the Kanogawa unit at the bottom. The nappes composed of the Ohnogahara unit and the Kanogawa unit are called the Ohnogahara nappe and the Kanogawa nappe respectively. The faults between those two nappes can be traced from Tsubonota through Sakuratohge Pass northwestward, and limits the northeastern border of the Noigawa Formation (TOMINAGA et al., 1979)(Fig. 7). This fault is named Sakuratohge thrust.

1. Ohnogahara unit

The Ohnogahara unit is structurally subdivided into three subunits, O1, O2 and O3 subunits in ascending order (Figs. 7, 8). The Sakuratohge thrust, which limits the bottom of the Ohnogahara nappe, extends from the north of Sakuratohge Pass, through the west of Mt. Amazutsumi, to Sohgawa (Nomura Town). As traced northward, the Sakuratohge thrust swings the strike to east in Kitahira (Kawabe Village), Ehime Prefecture (Fig. 13). The Kanogawa nappe exposes widely in Hijikawa Town and on the western side of the Ohnogahara nappe. And further it extends on the northern side of the Ohnogahara nappe (Fig. 13). The O2 subunit is limitted its bottom by the fault which runs from Enoki, through Koya, to about 500m northeast of Niragatohge Pass (Fig. 8). The top of the O2 subunit is cut by the fault in the north of Koya which runs between the limestone of the O2 subunit and pebbly mudstone of the O3 subunit. Therefore, the O2 subunit disappears between Koya and Enoki, and the O1 and O3 subunits are in immediate contact (Fig. 8).

The O1 subunit from the bottom upward, consists of the lower member of Sohgawa greenstones, pebbly mudstone, Kohkaino serpentinites, pebbly mudstone, the upper member of Sohgawa greenstones and pebbly mudstone (Fig. 10). The Sohgawa greenstones contain basaltic lava (in places pillowed), pillow breccia, hyaloclastite and tuff with intercalated pelitic rock, limestone and chert. Hyaloclastite, tuff and other rocks have weak foliation defined by parallel orientation of platy and prismatic minerals. The constituent rocks of both upper and lower members of Sohgawa greenstones are similar, although the upper portion of the upper member is interstratified with serpentinite lenses.

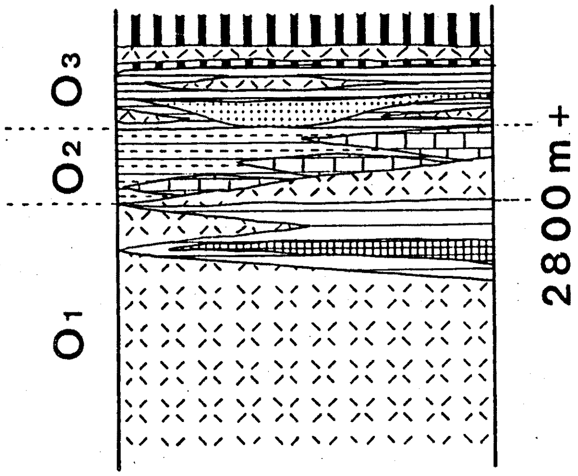


FIG. 10. Generalized columner section of the Ohnogahara Unit.

The Kohkaino serpentinite is sandwiched and stratified between pebbly mudstone beds (Fig. 8). The serpentinite body thins northwestward as the pebbly mudstone beds become thinner, and it disappears in the southwest of Shohwa. The original rocks of it are almost wholely serpentinized, though only clinopyroxenite can rarely be found. The Kohkaino serpentinite includes not only blocks of sandstone and mudstone but also high pressure type crystalline schists such as glaucophane schist (TOMINAGA and HARA, 1980; TSUKUDA et al., 1981c), similarly to the case of the serpentinite of the Sawadani unit in the Kitohmyoh-Ohyohchi area mentioned above.

The O2 subunit is structurally divided into the upper and lower members. The lower member consists mostly of greenstones but contains limestone, serpentinite and pebbly mudstone in small amount. The upper member is composed of pebbly mudstone and limestone with small amount of greenstones. Sandstone and chert are also found as blocks which can not be expressed on the geological map in size. Limestone is mostly recrystallized. Therefore, only mudstone and oolitic grainstone can be locally observed in it (Tominaga and Hara, 1980). Limestone of the upper member occurs as accumulation of small lenses in pebbly mudstone. These lenses appear to be comb's teeth which have come out from the greenstones of the lower member (Fig. 8).

The O3 subunit consists of pebbly mudstone and large-scale lenses of sandstone, greenstone and chert with small amount of limestone. The lithologic layers trend in east-west and dip gently northward.

The constituent rocks of the Ohnogahara nappe are quite similar in lithofacies to those of the Sawadani unit (Fig. 10).

2. Kanogawa unit

The Kanogawa unit which underlies the Ohnogahara unit is in contact with the Kubono Formation of the Kurosegawa Terrane across the Tsubonota thrust (Figs. 7 and 22). The Kanogawa unit in this mapped area is composed of the Noigawa Formation.

The Noigawa Formation (Tominaga et al., 1979) consists largely of greenstone, chert, sandstone and mudstone. Their beds are rather continous, strike in east-west trend and dip steeply northward (Fig. 22). Greenstones are mostly of basaltic lava, tuff and hyaloclastite. Basaltic lava which contains dolerite is generally massive but locally pillowed. Clinopyroxenes of basaltic lava are titaniferous augite or salite rarely accompanied by aegirine-augite. Tuffaceous rocks contain limestone lenses which yield fossils. Chlorite, epidote and pumpellyite are commonly observed as metamorphic minerals in greenstone.

Cherts are generally bedded. They are devided into two types in clour, red to reddish brown type and white to dark grey type, but change gradually to each other.

Sandstone is generally medium to coarse-grained and massive, and become occasionally into rudaceous. It frequently contains chert, siliceous mudstone and greenstone blocks or lenses. Namely, it appears to be the matrix of olistostrome with olistoliths of such kinds of rocks.

It is common that pelitic rocks are pebbly and contain greenstone, chert, siliceous mudstone, limestone and sandstone as blocks or fragments. Although greenstones are illustrated on the geological map as thick beds of good continuity (Fig. 22), as a matter of fact, they are frequently interbedded with thin pebbly mudstone layers. Thus it may be stated that the whole of the Noigawa Formation is composed of olistostromes which have both pelitic and psammitic matrices. The thick chert-dolomite beds have been reported by Kashima (1969) from Okegoya (Oda Town) on the north side of the Ohnogahara unit. They are correlative with those of the Higashiura unit. The constituent rocks of the Kanogawa unit are quite similar in lithofacies to those of the Higashiura unit.

Regarding with structural state and lithofacies, thus, it may be inferred that the Ohnogahara unit and the Kanogawa unit are correlated with the Sawadani unit and the Higashiura unit in Eastern Shikoku, respectively. In Central Shikoku, the Sawadani Terrane is widely covered by the correlatives of the Sawadani and Higashiura units as well as in Eastern and Western Shikoku as shown in Fig. 13. And the strata which seems to be correlated with the Kenzan unit, as a possibility, occur only along the Kamiyakawa-Ikegawa anticline. The order of arrangement of these units in Central Shikoku is essentially the same as that in Eastern Shikoku (Fig. 13).

C. DEVELOPMENT OF THE SAWADANI TERRANE

In order to make the recognition of a terrane, it is necessary to examine the accumulation process of its constituent rocks. Each of the Sawadani unit, the Higashiura unit and the Kenzan unit mainly consists olistostromes in which various rocks of different ages and facies are mixed. Judding from the radiolarian fossils obtained from pelitic matrices of olistostromes, the ages of the units are different each other. In Fig. 11 are complied the respective ages of constituent rocks of invividual units of the Sawadani Terrane in Eastern Shikoku. The following four items can be read from Fig. 11:

(1) In each unit, the ages of the constituent rocks arrange in the order of limestone, chert, siliceous mudstone and mudstone from older to younger.

(2) Each pair of limestone and chert, chert and siliceous mudstone and siliceous mudstone and mudstone of individual units tend to show the overlap of age.

(3) The rocks of a kind in the lower unit is younger in age than those of the same kind in the upper unit.

(4) The same sort of rocks in the different units tend to show the overlap of age.

In addition, it must be considered that each unit composes a nappe and that both two boundary thrusts of the nappes, the Shikibidani thrust and the Kawanaru thrust, have developed to dip gently to the south during pre-Cretaceous time (item-5).

The first item means that the change of deposits with the time may have caused by the passage of the sedimentary basement from pelagic to terrigenous. The second item proves that the different kinds of coeval rocks which deposited in different circumstances are involved in the same unit. The third item implies that the same kind of accumulation of the sediments had been performed in the order from the upper nappe downward. And the fourth item means that the coeval rocks accumulated in the same environment tend to be also involved separately in plural units.

It is known that in the Franciscan Group develops the landward dipping imbricate thrusts, which corresponds to the fifth item, and are also recognisable the above-mentioned items-1, -3 and -4 (Pessagno, 1973; Maxwell, 1974). In Japan, simillarly to the case of the Franciscan Group, many belt which are explained as the accretionary prisms are known to show such the five items (e.g. Kanmera and Sakai, 1975; Matsuoka, 1984; Yao, 1984; Ishida, 1985a; Otsuka, 1985; Ozawa et al., 1985). The item-2, however, has hardly been reffered or explicated in previous works.

For the understanding of the formation of the indi-

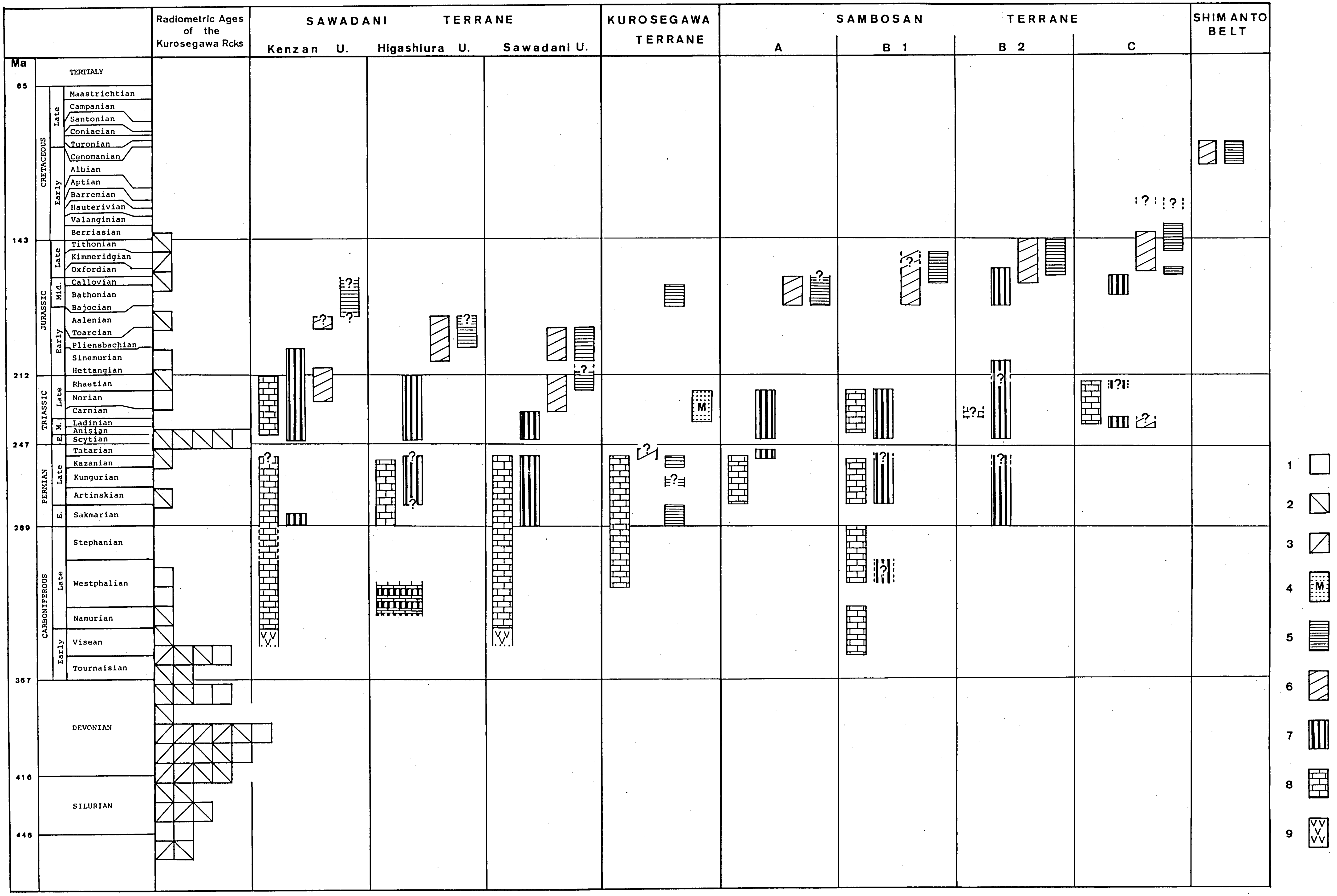


FIG. 11. Ages of the constituent rocks of the tectonostratigraphic units based on paleontological data of the Chichibu belt in Eastern Shikoku and frequency distribution of radiometric dates of the Kurosegawa rocks.
1: crystalline schists, 2: Mitaki igneous rocks, 3: Terano metamorphic rocks, 4: clastic rocks containing molluscan fossils, 5: mudstone, 6: siliceous or tuffaceous mudstone, 7: chert, 8: limestone, 9: greenstone.
Data are from followings: HAYASE and ISHIZUKA (1967), HAYASE and NOHDA (1969), HIRAYAMA et al. (1956), ICHIKAWA et al. (1953), ISOZAKI and MATSUDA (1980), ISOZAKI et al. (1981), KARAKIDA and STERN (1970), KAWANO and UEDA (1966), MARUYAMA and UEDA (1975), MARUYAMA et al. (1978), MATSUMOTO et al. (1968), ONO (1983), SHIBATA (1968), SHIBATA et al. (1979), SHIBATA et al. (1984), SHIMA et al. (1969), SUYARI et al. (1981, 1982), UEDA and ONUKI (1969), UEDA et al. (1980), UMEDA et al. (1986), WATANABE and SUZUKI (1978), YANAGI (1975), YOKOYAMA et al. (1979), YOSHIKURA et al. (1981) and this study.

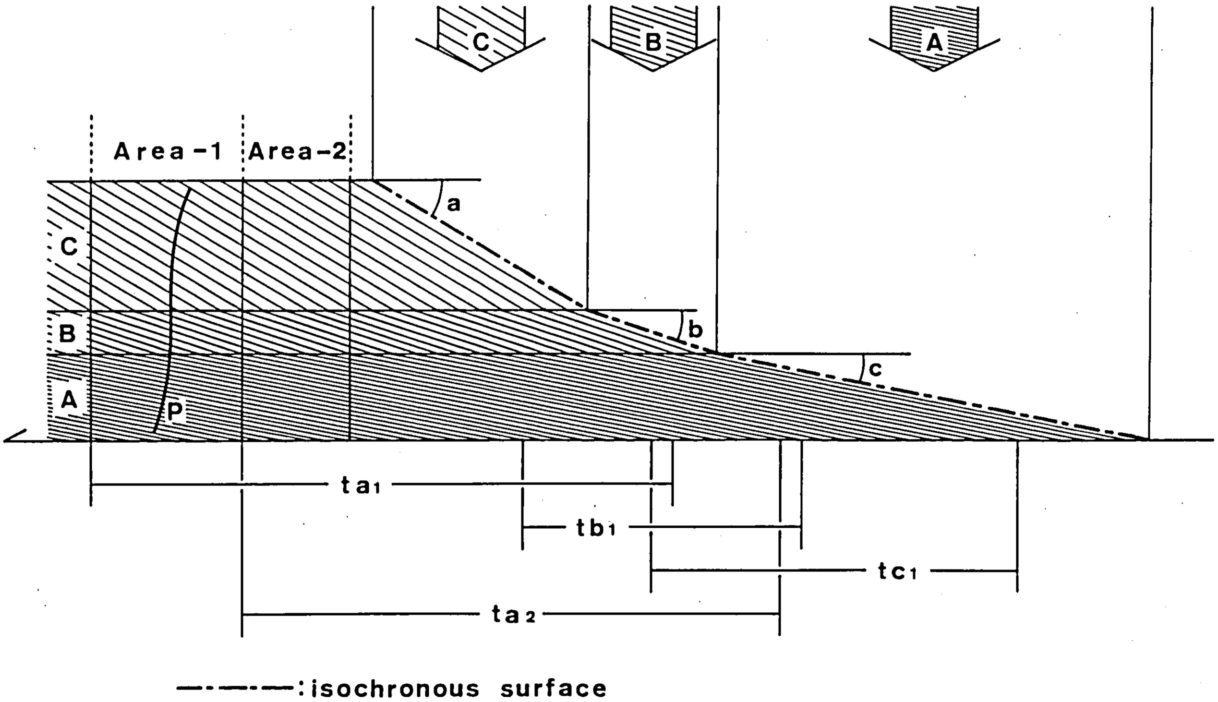


FIG. 12. Profile of simplified sedimentation process on the moving plate illustrating the intersection of the lithofacies boundaries and isocronous surfaces. The values **a**, **b** and **c** are defined by speed of both sedimentation and plate migration.

vidual units of the Sawadani Terrane, the accumulation process of constituent rocks has to satisfy all the above-mentioned items. The only following model, as shown in Fig. 12, satisfies these five items with no inconsistency.

The bacement of the constituent rocks of each unit may have been an oceanic plate which had relatively moved from the oceanic realm landward. Because, in each unit, the sedimentary environment gradually changed from pelagic to terrigenous (items-1 and -2), and the pelagic sediments in earlier stage are commonly associated with greenstone. If the oceanic plate moves at a constant speed, the time can be changed into the distance of the plate removal. In Fig. 12, the values a, b and c are related to the difference in the speed of both plate removal and sedimentation. In the sedimentary pile, the lithofacies boundary plane must intersect the isochronous surface. When a plate passes successively through depositional environments of A, B and C (item-1), A, B and C materials will be piled up on the plate in ascending order. Therefore, a succession of A, B and C materials in an outcrop is expressed as the line P in the figure. The expanse of the beds, however, is not expressed on the line P. Consequently the heteropic facies in a unit caused by the intersection of the lithofacies boundary plane and the isochronous surface (item-2) can not be represented only by the line P. The ranges in age of A, B and C materials in a certain unit are given as ta_1, tb_1 and tc_1 respectively (item-2). When we apply chert, siliceous mudstone and mudstone to A, B and C material respectively, the rocks which occupy the area-1 and the area-2 in Fig. 12 correspond well to those of adjacent two units in Fig. 11. If the adjoining two units were converted from the area-1 and the area-2, the sedimentation ranges of A material in the units would be given as the values ta_1 and ta_2 respectively. This suggests that both age polarity among the units (item-3) and duplication of sedimentary periods between the same type of rocks in the neighboring units (item-4) may result from the steady-state plate convergence, the continous accumulation and the episodic transformation of material to the accretionary prism.

Judging from the imbrication of the Shikibidani thrust and the Kawanaru thrust, the offscraping model (e.g. SEERY et al., 1974; SCHOLL et al., 1980; KAGAMI et al., 1983) may be applied to the process of transformation of the deposit to the accretionary prism.

If each unit of the Sawadani Terrane was formed by the above-stated process, they each may be regarded as the initial structural sequences at the stage of accretion.

Judging from the age polarity among the units in the Sawadani Terrane, the relative direction of movement of the oceanic plate may have been toward the south (from the inner side to the outer side), as stated on the tectonic framework of the present Japanese Islands. As metioned in the preceding pages, the rock fragments or pebbles of sandstone and pebbles of conglomerate of the Sawadani Terrane consist mostly of acid to intermediate pyroclastic rocks with minor amount of granitic rocks, chert and mudstone. These pyroclastic rocks and granitic rocks, as well as serpentinite and associated crystalline schists which occur in the Sawadani nappe and the Ohnogahara nappe as sedimentary slide masses, are correlative with the Kurosegawa rocks of the Kurosegawa Terrane (e.g. TOMINAGA et al., 1979, 1981; TSUKUDA, 1980). Besides, this rock group which corresponds to the supposed land in the direction of the oceanic plate during the accretional stage of the Sawadani Terrane is not distributed except for in the Kurosegawa Terrane at present.

From the above-described evidence and consideration, the Sawadani Terrane may be defined as the province covered by the rocks accumulated and accreted in

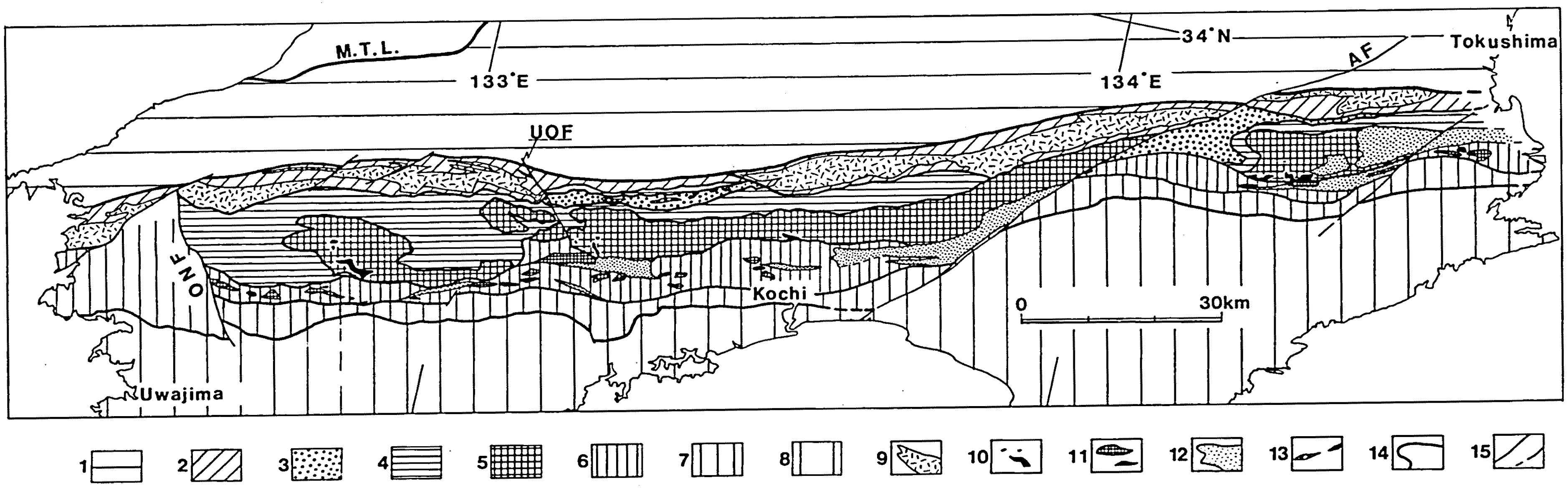


Fig. 13. Distribution of the tectonostratigraphic units of the Chichibu belt in Shikoku.
1: Sambagawa belt, 2: Mikabu belt, 3: Kenzan unit, 4: Higashiura-Kanogawa unit, 5: Sawadani-Ohnogahara unit, 6: Kurosegawa Terrane, 7: Sambosan Terrane, 8: Shimanto belt, 9: Mikaku greenstones, 10: serpentinite, 11: Kurosegawa rocks, 12: cretaceous basin, 13: dyke rock (Tertiary ?), 14: thrust fault, 15: high-angle fault.
AF: Akuigawa Fault, UOF: Uriuno-Ochi Fault, ONF: Ohzu-Nomura Fault.

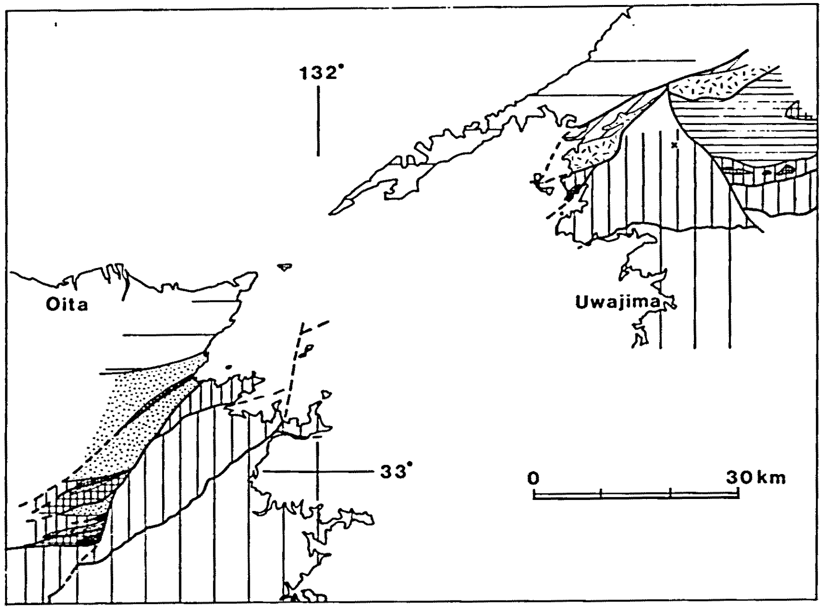


Fig. 14. Distribution of the tectonostratigraphic units of the Chichibu belt in the western part of Shikoku and Eastern Kyushu.
See the legand of Fig. 13.

the convergent plate junction along the northern fron of the Kurosegawa Island-arc during Early and Middle Jurassic time.

The southern boundary of the Sawadani Terrane corresponds to the northern border to the Kurosegawa Terrane. The geology of the Kurosegawa Terrane must be considered but will be analysed in the later pages. The limit of the northern extension of the Sawadani Terrane has not been clarified, though there appears to be a fault between the Sawadani Terrane and the Mikabu belt. Data for the discussion on the relation between them are as follows:

(1) Reddish muddy matrix of gabbro olistostrome of Mikabu greenstones yields Late Jurassic radiolarian fossils (IWASAKI et al., 1984).

(2) The boundary fault between the Sawadani Terrane and the Mikabu belt appears to diagonally cut the plural structural sequences of the Sawadani Terrane.

The first item may suggest that the age of the Mikabu belt lies on the trend of the younging age polarity of the Sawadani Terrane. However, because the age relationship of original rocks between the Mikabu belt and the Sambagawa belt has not yet been determined, it can not be concluded that the age polarity sucseeds from the Sawadani Terrane to the Mikabu belt. The second item means that the tectonic sequences of the Sawadani Terrane all together have been subjected to the later diastrophic movements, but the Mikabu belt seems to have behaved as a different and independent tectonic unit. Therefore it may be concluded that the northern limit of the Sawadani Terrane is placed on the boundary against the Mikabu belt.

In Kyushu, the rocks of the Sawadani and Kurosegawa Terranes occur in several lines repeated by thrust faults (Fig. 14). In eastern Kyushu the Kurosegawa rocks occur on the immediately south of the Sambagawa crystalline schists (KAMBE and TERAOKA, 1968). On the west of Kabunoki fault, however, the rocks of the Sawadani Terrane, together with those of the Kurosegawa Terrane, form pile nappe structure (SONODA, 1984, MS). And the rocks of the Sawadani Terrane usually underlie the Kurosegawa rocks (Fig. 14). This strongly suggests that the rocks of the Sawadani Terrane have already underlain the rocks of Kurosegawa Terrane prior to the formation of the pile nappe structure which appears to have controled the formation of Late Jurassic to Cretaceous basin. Therefore the diastrophism, through which the rocks of Sawadani Terrane have underlain those of the Kurosegawa Terrane, may correspond to the accretionary process inferred in Shikoku.

On the basis of observation of southerly dipping thrust piles developed in the Sawadani Terrane of Western Kii, ICHIKAWA et al. (1981) has also inferred the shortening and closure of the sea inside the Kurosegawa Arc during Early and Middle Jurassic time. They regarded the formation of thrust piles as "coeval" from the viewpoint that the age polarity may not be distinguished among those thrust piles. The initial structural conditions, which are rather well preserved in Eastern Shikoku, may have been changed by later tectonic process in Western Kii.

The geology of the Sawadani Terrane throughout Kanto Mts. still remains uncertain. Although the boundary differs among students, at least two geological sequences are distinguishable in the Mamba area (e.g. HUJIMOTO, 1935; SATO et al., 1977): One is characterized by large amount of greenstone and another by chert and associated carbonate rocks. The former lies on the latter. Judging from lithological features and spatial relationship, it may be inferred that the former is equivalent to the Sawadani unit and the latter is correlated with the Higashiura unit (Fig. 15).

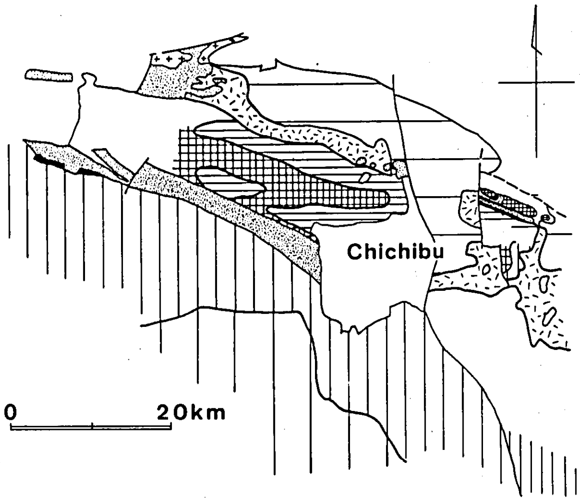


FIG. 15. Supposed distribution of the tectonostratigraphic units of the Chichibu belt in Kanto Mountains.
See the legend of Fig. 13.

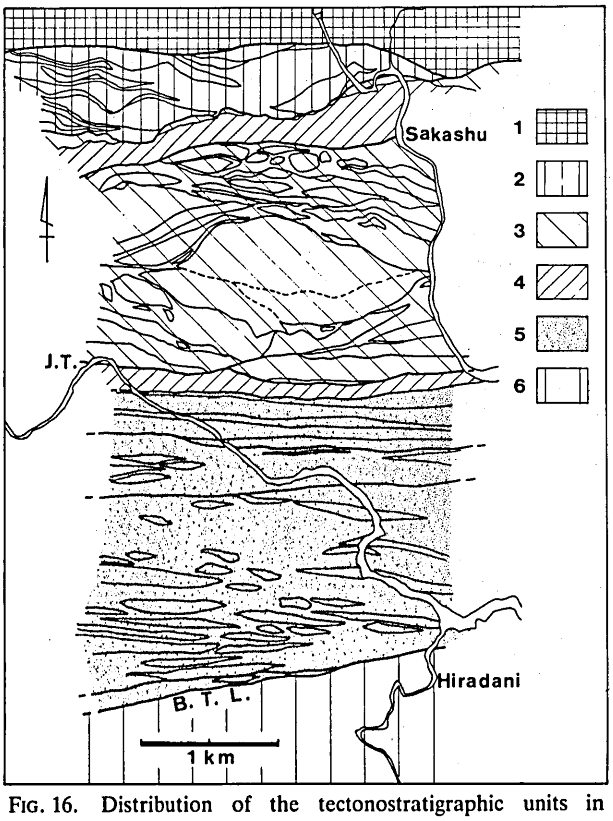


FIG. 16. Distribution of the tectonostratigraphic units in Sakashu-Hiradani area.
1: Sawadani Terrane, 2: northern Kurosegawa Terrane, 3: southern Kurosegawa Terrane, 4: Torinosu Group, 5: Sambosan Terrane, 6: Shimanto belt.
JT: Junisha Thrust, BTL: Butsuzo Tectonic Line.

IV. SAMBOSAN TERRANE

The Sambosan Terrane, which occupies the southern margin of the Chichibu belt, lies just on the southern outside of the Kurosegawa Terrane. Its northern and southern boundaries are in contact with the Kurosegawa Terrane across the Junisha thrust and with the Shimanto belt across the Butsuzo Tectonic Line respectively (Fig. 16).

A. GEOLOGY OF THE HIRADANI-SHIRAISHI AREA

A geological outline of the Sambosan Terrane of Eastern Shikoku has been clarified through a series of micropaleontological and stratigraphical studies by ISHIDA (1977a, 1979, 1981, 1983, 1985, 1986, 1987). He has divided the "South Zone of the Chichibu belt" (= Sambosan Terrane) into seven subzones, Ia, Ib, II, IIIa, IIIb, IIIc and IV subzones from north to south. The Hiradani-Shiraishi area, Kaminaka Town, Tokushima Prefecture, is placed just on the south of the Sakashu area. The author divided the Sambosan Terrane in this area into the Torinosu Group and the A, B1, B2, and C zones from north to south as shown in Fig. 17. The A, B1, B2, and C zones roughly correspond to the Ib, II, IIIa and IV subzones after Ishida (1986, 1987) respectively. The formations which cover the A, B, and C zones are herein called conveniently the A, B and C units respectively.

1. Torinosu Group

The Torinosu Group forms a narrow distribution (nearly 200 m wide) along the northern boundary of the Sambosan Terrane in the investigated area (Fig. 17). It consists mainly of thick silty laminated mudstone and alternating beds of mudstone and predominant sandstone, and occasionally contains lenses of limestone. Sandstone and mudstone are sometimes calcareous and traversed by white calcite veins. The beds generally strike in east-west trend and steeply dip northward.

Only this group yields molluscan fossils within the Sambosan Terrane of this area. Although they are fragments, bivalves fossils have been obtained from mudstone beds to the northwest of Matsukubo. *Trigonia* sp. cf. *toyamai* and *Propeamusseum* sp. are discovered from the roadside in the south of Shiraishi by HIRAYAMA et al. (1956). This group is considered to be Late Jurassic in age (HIRAYAMA et al., 1956).

2. A unit

The A unit is in fault contact with the Torinosu Group (Fig. 17). This unit is composed of the repetition of the pebbly mudstone beds and alternating beds of mudstone and predominant sandstone. The beds show west to east trend and have nearly vertical dips.

Pebbly mudstone contains chert, limestone and sandstone as lenses or blocks. No fossil has been discovered from the pelitic matrix of pebbly mudstone, although Late Permian radiolarian fossils have been obtained from a chert float in Matsukubo (Loc. 44 on Fig. 18, Table 2).

The alternating beds of sandstone and mudstone occur in two main horizons. Sandstone contains a large quantity of quartz and feldspars, and belongs to feldspathic wacke. Its grain size decreases northward. Early Middle Jurassic radiolarian fossils have been obtained from mudstone of two horizons (Figs. 17, 18, Table 2).

3. B unit

The B zone occupies the main part of the Sambosan Terrane in 1.5 km wide (Fig. 17). It is further divided into B1 and B2 zones by an eastwest trending fault running through rather northern position than center. The B1 unit consists of olistostromes whose matrices are largely of coarse to rudaceous sandstone, fine conglomerate or mudstone. As olistoliths are included blocks of chert and alternating beds of sandstone and mudstone, besides large limestone lenses accompanied by greenstone.

The B2 unit is also of olistostromes having coarse-grained clastic matrices. However, limestone lenses of this unit are not so large as those of the B1 unit. The limestone lenses occurring in the central part of the B2 zone are of the Torinosu type. And they are accompanied at places by calcareous sandstone or sandy limestone. The blocks of alternating beds of sandstone and mudstone occur rather frequently in the northern half of the B2 zone. On the other hand, chert lenses are abundantly included in the southern half.

A horizon which consists of chert conglomerate with limestone pebbles is observed along the boundary against the C zone in the western part of the mapped area. This horizon and C zone are absent in the eastern part. Therefore, the Shimanto belt and the middle horizon of the B unit are in direct contact across the Butsuzo Tectonic Line (Fig. 17).

The coarse-grained clastic rocks of the B unit are classified into two groups, the matrices of olistostromes and the olistoliths. Psammitic rocks as the matrices of olistostromes contain quartz, plagioclase and rock fragments in similar proportion and also mudy material (nearly 15%) at a distance from large olistoliths. And they have tendencies to become fine rudaceous and to grade into lithic arenite as nearing to the olistoliths (Plate 2 -1, -2). They especially around the chert olistolith are classified into chert-arenite or chert-breccia containing about 95% of chert to siliceous mudstone fragments. They are also accompanied by limestone pebbles around limestone olistoliths (Plate 2 -3). These chert and limestone pebbles may be regarded as minute olistoliths, although the gathering of them, chert-arenite or chert-breccia, appears to behave as a matrix against the larger olistoliths. Sandstone of olistoliths contains a large amount of quartz (about 40%) and its rock fragments consist mostly of granitic rocks (60%).

Chert is very poor in stratal continuity. The relationship between chert and coarse-grained clastic rocks is sedimentary but not to be expressed "conformable". On the basis of radiolarian fossils, the B1 unit ranges from late Middle to early Late Jurassic, and the B2 unit is considered to be Late Jurassic in age (Fig. 18, Table 2).

4. C unit

The C zone, which lies along the southern extremity of the Sambosan Terrane in this area, is in fault contact with the B zone on the northern side and with the Shimanto belt on the southern side. It forms a narrow outcrop (some 150 m wide) in the west of the mapped

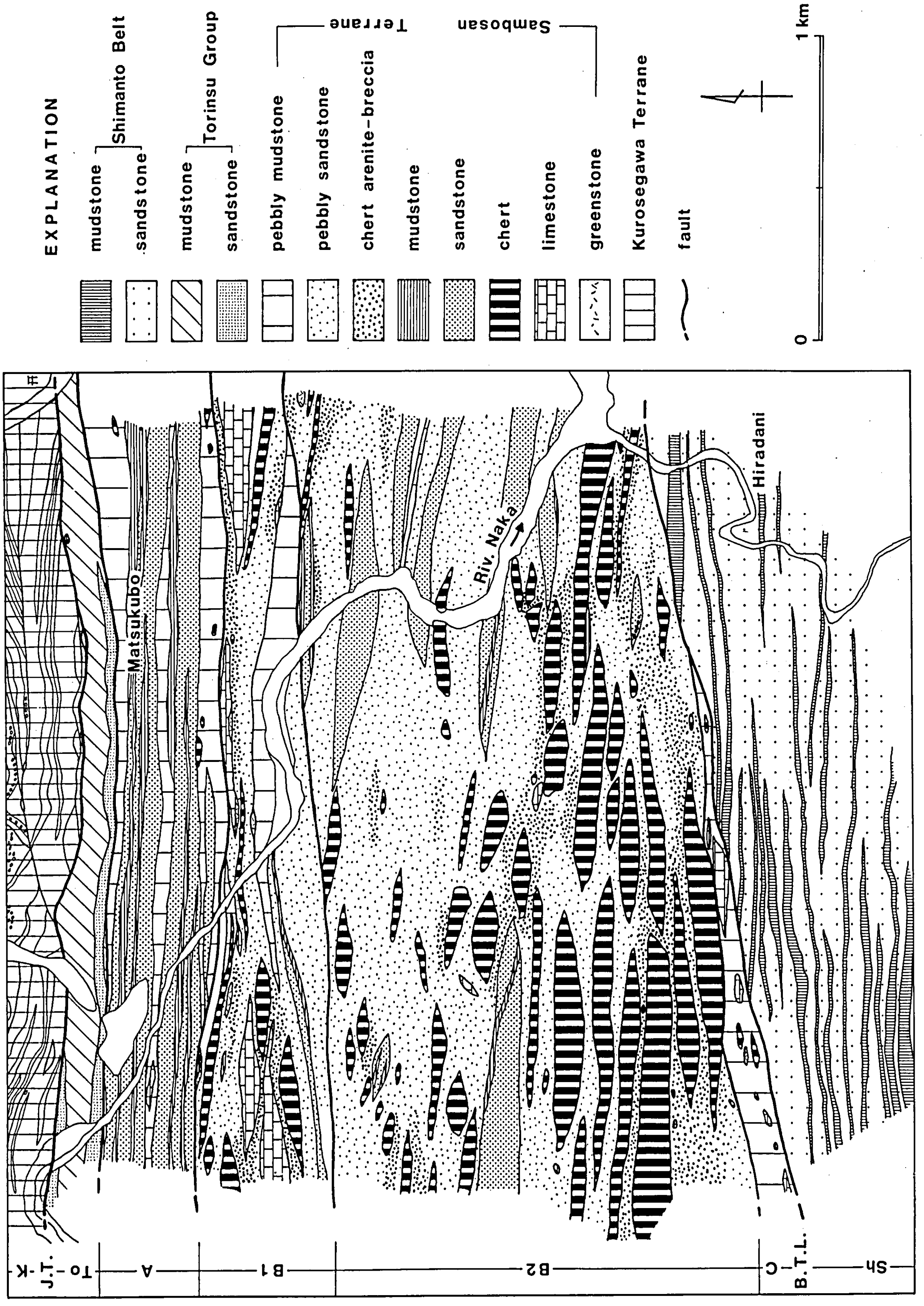


FIG. 17. Geological map of the Hiradani-Shiraishi area (Sambosan Terrane), Eastern Shikoku.

TABLE. 2. LIST OF JURASSIC AND CRETACEOUS RADIOLARIAN FOSSILS FROM THE SAKASHU-HIRADANI AREA (KUROSEGAWA AND SAMBOSAN TERRANES AND SHIMANTO BELT).
○: cf., #: aff.

Species \ Samples	22. sh.	23. sh. (type-2)	24. sh. (type-1)	25. type-2 nodule	26. sh.	27. sh.	28. siliceous sh.	29. ch.	30. siliceous sh.	31. siliceous sh.	32. ch.	33. siliceous sh.	34. tuffaceous sh.	35. red sh.	36. sh.
1. Canoptum sp.			+				+			+					
2. Parahsuum sp.		+	+		+		+				+				
3. Stichocapsa convexa	○	+		○	○	+	○				○				
4. Spongosaturnalis tetraspinus				+											
5. Tricolocapsa (?) fusiformis	+	○			+	+									
6. Andromeda praepodbielensis				○											
7. A. sp.	+			+											
8. Stichocapsa japonica	+	○			+	+			+						
9. Eucyrtidiellum unumaense	+	+				+									
10. Unuma echinatus		○													
11. U. sp.	+	+	+	+	+		+								
12. Stichocapsa tegiminis	+				+	○									
13. Cyrtocapsa mastoidea	○			○											
14. Podobursa sp.			+	+							+	+			
15. Tricolocapsa rüsti		○			○	○									
16. T. parvipora	○	○			○	○									
17. T. plicarum	+	+			○	○		+		+					
18. Parvicingula sp. F*		+					○								
19. P. sp.	+		+	+	+	+	+	+		+	+	+			
20. Nassellaria gen. and sp. indet. A				+											
21. Nassellaria gen. and sp. indet. B group	+	+													
22. Mirifusus fragiris			○	○											
23. Tricolocapsa tetragona								+							
24. Napola pyramidalis			○												
25. N. sp.	+		+												
26. Protunuma turbo								+							
27. Archaeodictyomitra sp. R*							+								
28. Dictyomitrella (?) kamoensis							+								
29. D. sp.	+	+		+						+		+			
30. Guexella nudata							+								
31. Dicolocapsa conoformis							+								
32. Hsuum (?) inexploratum											+				
33. Tricolocapsa conexa							+		+	+					
34. T. sp.		+			+		+			+		+			
35. Williriedellum crystallinum												+			
36. W. sp.		+					+	+		+	+				
37. Protunuma (?) ochiensis							+								
38. P. sp.	+	+	+	+	+	+	+	+			+	+			
39. Stichocapsa robusta							○				+				
40. Hsuum maxwelli										+					
41. H. sp.		+	+	+		+	+	+		+	+	+			
42. Mirifusus guadalupensis												+			
43. Cinguloturris carpatica										+	+				
44. C. sp.							+					+			
45. Gongylothorax sakawaensis											+				
46. Stilocapsa (?) spiralis											+				
47. Stichocapsa naradaniensis										○					
48. S. sp.		+						+	+		+	+			
49. Dictyomitra sp. C*												+			
50. Mirifusus mediodilatatus												+			
51. M. sp.	+		+	+	+						+				
52. Eucyrtidiellum ptyctum							#			+					
53. Xitus sp.							+					+	+		
54. Archaeodictyomitra vulgaris														○	
55. Pseudodictyomitra pentacolaensis															○
56. P. sp. D**													+		
57. Holocryptocanium barbui													+		+
58. Dictyomitra urakawaensis															○
59. Squinabolum fossilis															○
60. Hemicryptocapsa polyhedra														#	
61. H. sp.							+						+		
62. Cryptamphorella macropora													○		
63. Archaeodictyomitra sliteri													+	+	
64. A. sp.	+	+		+	+	+	+	+	+	+			+	+	+
65. Holocryptocapsa sp.													+		
66. Stichomitra sp.							+								+
67. Amphipindax sp.													+		
68. Pseudodictyomitra lodogaensis													○	○	
69. P. sp.													+	+	

*: cf. YAO et al.(1982)
**: cf. PESSAGNO (1977)

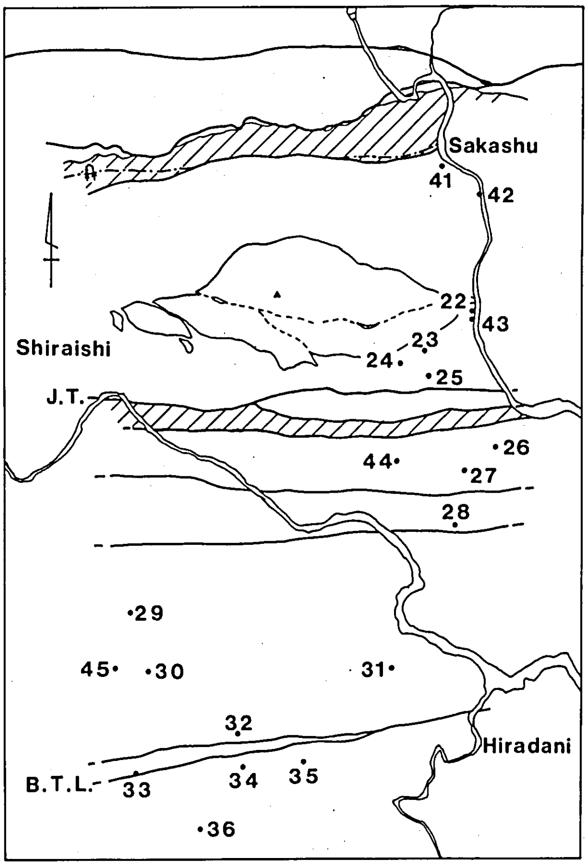


FIG. 18. Map showing the sample localities of the radiolarian fossils in the Sakashu-Hiradani area.

TABLE. 3. PERMIAN RADIOLARIAN FOSSILS FROM THE HIRADANI-SHIRAISHI AREA (SAMBOSAN TERRANE).

Loc.44 : chert (float)	
Albaillella triangularis	ISHIGA et al.
A. spp.	
Neoalbaillella optima	ISHIGA et al.
Na. sp.	
Loc.45 : chert	
Albaillella sp. D of	ISHIGA et al.
A. sp. cf. A. asymmetrica	ISHIGA and IMOTO
A. sp.	
Pseudoalbaillella sp.	

area, though it becomes narrower eastward and disappears at Hiradani. According to ISHIDA (1985), however, it appears to be exposed again on the east of the investigaed area. The Butsuzo Tectonic Line is considered to be winding through this area, whereas it dips steeply. The C unit ranges in age from Late Jurassic to Earliest Cretaceous on radiolarian fossils (Fig. 18, Table 2).

B. DEVELOPMENT OF THE SAMBOSAN TERRANE

As presented in Fig. 11, the constituent rocks of the Sambosan Terrane show quite similar characters to those of the Sawadani Terrane. Their younging age polarities are, however, opposed to each other. Therefore it may be inferred that the tectonic process responsible for the formation of the Sambosan Terrane was similar to that of the Sawadani Terrane but that the direction of the contemporaneous plate movement related to the formation of the Sambosan Terrane was relatively northward contrary to that of the Sawadani Terrane. This is a very interesting inference.

Thus the Sambosan Terrane may be defined as a province occupied by the rocks which were accumulated in the convergent plate junction and accreted along the southern front of the Kurosegawa Terrane, the southern margin of the non-subducted plate, during the period ranging from Middle Jurassic to probably Early Cretaceous time. Judging from the ages of constituent rocks and the formative mechanisms of the Sambosan Terrane and the Shimanto belt (e.g. KANMERA and SAKAI, 1975), there is a large possibility that the Sambosan Terrane and the Shimanto belt may be a set of geotectonic sequence.

V. KUROSEGAWA TERRANE

Since ICHIKAWA et al. (1956), the tectonic evolution of the Kurosegawa Terrane has been discussed by many authors (e.g. HORIKOSHI, 1972; SUZUKI, 1977; HADA et al., 1979; KANMERA, 1980; ICHIKAWA, 1981; MARUYAMA, 1981; TAIRA et al., 1981) on the basis of the geological, petrological and geochronological studies on the Kurosegawa rocks. Consequently, it has been clarified that the Kurosegawa rocks consist of granitic rocks of 350–450 Ma (e.g. HAYASE and ISHIZAKA, 1967; HAYASE and NOHDA, 1969), Siluro-Devonian acid volcanics (e.g. YOSHIKURA and SATOH, 1976), medium-pressure type metamorphic rocks (KARAKIDA, 1977), serpentinite, high-pressure type metamorphic rocks of 400 Ma (MARUYAMA and UEDA, 1975) and 208–240 Ma (MARUYAMA et al., 1978), Carboniferous, Permian and Triassic continental shelf type sediments (e.g. KANMERA, 1952, 1953; ICHIKAWA, 1954; ICHIKAWA et al., 1953) and Permian accretionary sediments (e.g. MIYAMOTO et al., 1985; ISOZAKI, 1985). On the other hand, from the parts of the Chichibu belt on the north and the south of the Kurosegawa Terrane (i.e. the Sawadani Terrane and the Sambosan Terrane in this paper) have been found cherts with Triassic conodont fossils (e.g. ISHIDA, 1977a; YOKOYAMA et al., 1979; SUYARI et al., 1980) and Triassic and Jurassic radiolarian fossils (e.g. YAO et al., 1982; KISHIDA and SUGANO, 1982). Owing to those informations, such the opinion that the Kurosegawa rocks correspond to the members of the basement complex of the Japanese Islands during Paleozoic time has been disappeared. And it has been recently proposed by some authors (e.g. ICHIKAWA, 1981; OZAWA et al., 1985) that the Kurosegawa Terrane may be a relict of an island-arc accreted to the Japanese Islands during Jurassic time. The geology and formational process, however, of the Kurosegawa Terrane and relationship in tectonic evolution between the Kurosegawa Terrane and the surrounding terranes are not so adequetely understood at present for Japanese geologists. The author has therefore analysed the geology of the Kurosegawa Terrane in some areas of Shikoku. The obtained results will be described and discussed in

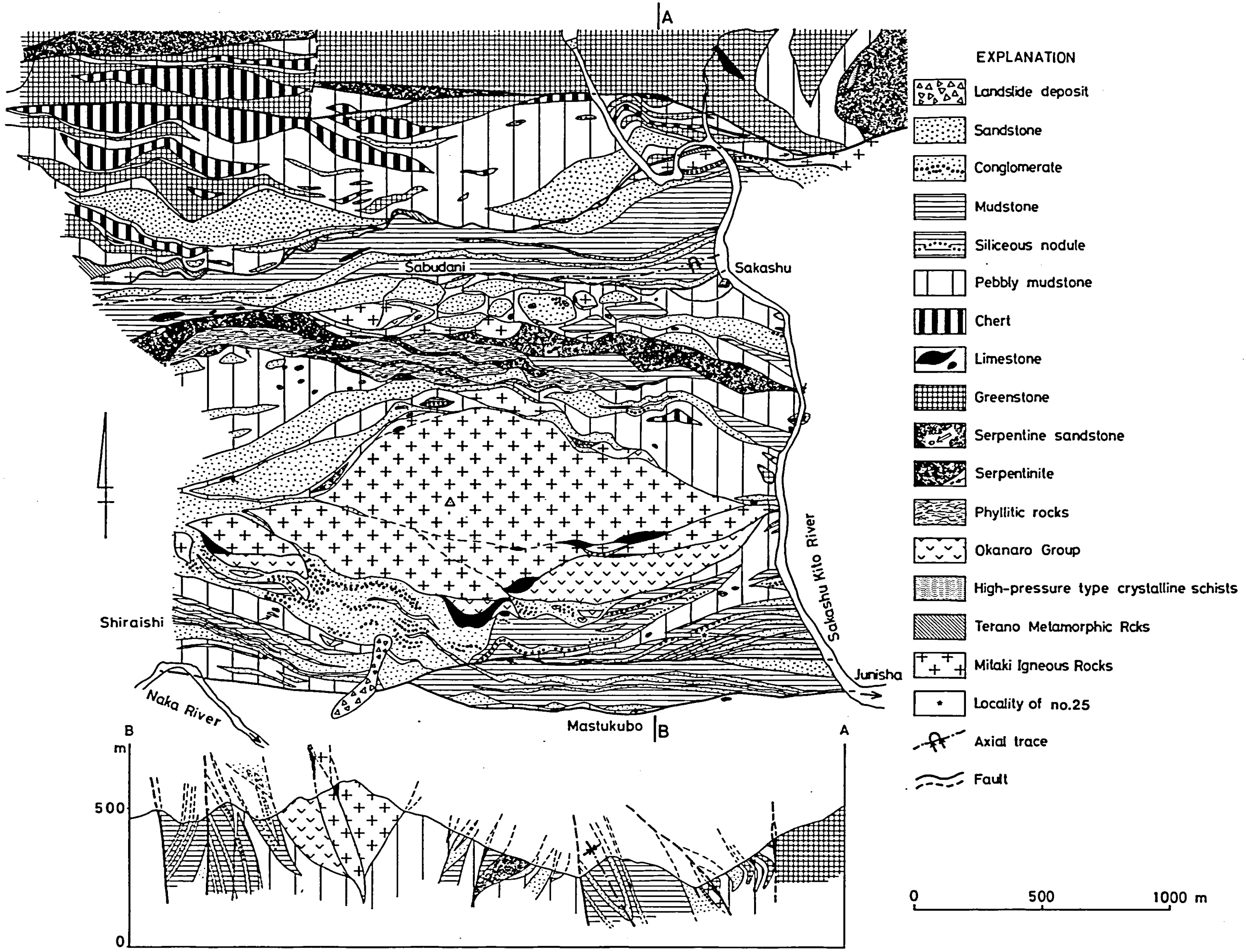


FIG. 19. Geological map and profile of the Sakashu area (Kurosegawa Terrane), Eastern Shikoku.

the following pages.

A. Geology of the Sakashu Area

The Sakashu area, which ranges in extension from Sakashu (Kisawa Village) to the vicinity of Shiraishi (Kaminaka Town), is adjacent on the south of the Sawadani area. In this area, although limited studies on the Permian strata have been presented (Ishii et al., 1975; Maejima, 1979), no general study on the Kurosegawa Terrane has been published since Ichikawa et al. (1953) described an unconformity between the Permian strata and the shallow water Triassic strata (the Sakashu unconformity) pointing out that the unconformity is regarded as an expression of vigorous diastrophism in the outer side of Southwest Japan during Late Paleozoic time. The Sawadani Terrane, however, is the fruit of Jurassic movements as discussed before. Therefore the ploblem on the Sakashu unconformity should be confined to the inside of the Kurosegawa Terrane.

Pebbly mudstone containing fairly sheared granitic rock on the north of Ottate lies between the southern margin of the greenstone-serpentinite complex of the Sawadani unit and the Sakashu thrust (Figs. 2, 19). A fault can be distinguished as a distinct structural discontinuity between this pebbly mudstone and the greenstone-serpentinite complex. Serpentinite exposes intermittently along this structural discontinuity (Figs. 2, 19). The southern boundary of the Sawadani Terrane, that is the northern boundary of the Kurosegawa Terrane, may be regarded as this discontinuity. Western extension of this fault appears to run through the vicinity of Iwakura. The boundary between the Kurosegawa Terrane and the Sambosan Terrane is the Jyunisha thrust which runs along the northern boundary of the Torinosu Group (Figs. 16, 19).

The Kurosegawa Terrane of this area is divided into two structural domains, which are herein referred to as the southern Kurosegawa Terrane and the northern Kurosegawa Terrane. The boundary between them is the Sakashu thrust (Fig. 19). The Sakashu thrust runs along the northern boundary of the distribution area of lenses of the Kurosegawa rocks and dips moderately northward (Fig. 19). Eastern extension of the Sakashu thrust is cut by the boundary fault between the Kurosegawa Terrane and the Sawadani Terrane on the north of Sakashu. Consequently, the northern Kurosegawa Terrane is terminated along the fault and the Sawadani Terrane is in direct contact with the southern Kurosegawa Terrane.

[Northern Kurosegawa Terrane]

The northern Kurosegawa Terrane is made up of pebbly mudstone containing large amounts of greenstone, chert and sandstone lenses. Although the stratal continuity is poor, the beds, as a whole, strike in east-west trend and dip moderately to steeply northward. Greenstones chiefly consist of basaltic lava and hyaloclastite. Chert is commonly bedded and it looks ruddy when it is associated with greenstone. The blocks of sheared granitic rocks occur also in the pebbly mudstone but very rarely than in the southern Kurosegawa Terrane.

Such lithologic sequence as that of the northern Kurosegawa Terrane has been documented in the northern part of the Kurosegawa Terrane from several areas of Shikoku. In Western Shikoku, the Kubono Formation (Tominaga et al., 1979) is comparable to that, and in Central Shikoku analogous lithologic sequence has been described by Tsukuda and Hara (1979) and Hada et al. (1985) on the north of Mt. Yokokura. Something in common among these lithologic sequences are that all of them lie in the northern part of the Kurosegawa Terrane and that the Kurosegawa rocks are hardly contained in them. Even if the Kurosegawa rocks occur in them, they are contained in pebbly mudstone as blocks.

No reliable index fossils have been discovered from the northern Kurosegawa Terrane here, though Late Triassic radiolarians have been reported from mudstone in Western and Central Shikoku (Nakatani and Yao, 1981; Hada et al., 1985).

[Southern Kurosegawa Terrane]

The southern Kurosegawa Terrane in this area is divided into two units, the Torinosu Group on the southern side of the Kurosegawa rocks along the Sakashu thrust and the rock unit which is overlain by the Torinosu Group. And the latter is herein defined as the southern Kurosegawa Terrane in a narrow sense.

1. Torinosu Group

The Torinosu Group consists of alternating beds of sandstone and mudstone with lenses of limestone and limestone-breccia. Limestone frequently grades into sandstone and mudstone through calcareous sandstone. Following calcareous algae were obtained from limestone.

Stenopolidium sphericum Endo
S. sp.
Pycnopolidium lobatum Yabe & Toyama
Lithothumnium sp.

Although the beds appear to show northerly dipping homoclinal structure, the northern half of this group is overturned by the overthrusting of the northern Kurosegawa Terrane along the Sakashu thrust (Fig. 19). This group is frequently in fault contact with the Kurosegawa rocks, though, as observed at the riverbed of the Sakashukitoh River, the original unconformable relation is still remained. Although this group is faulted against pebbly mudstones of the southern Kurosegawa Terrane, the boundary fault cuts also the axial plane developed in the Torinosu Group.

2. Southern Kurosegawa Terrane (s.s.)

The lithologic sequence of this terrane unconformably overlain by the Torinosu Group is characterized by the mingled occurrence of variously aged non-metamorphic clastic rocks and large volume of Kurosegawa rocks.

"Kurosegawa rocks"

a) Mitaki igneous rocks (Ichikawa et al., 1956)

The Mitaki igneous rocks consist mostly of tonalitic rocks. The tonalitic rocks are medium to coarse-grained and commonly looks pale greenish owing to low temperature alteration. They sometimes show weak gneissosity defined by the parallel orientation of biotite and hornblende and are composed essentially of plagioclase, quartz, potassium feldspars, biotite and green hornblende, with accessory zircon, apatite, allanite, sphene and opaque minerals. The Mitaki igneous rocks contain also granodiorite and adamelite in minor amount associating strongly altered diolitic to gabbroic rocks. They are generally subjected to intense cataclasis and/or mylonitization. Chlorite, epidote, prehnite and pumpellyite are sometimes found as secondary minerals.

The Mitaki igneous rocks are classified in modes of occurrence into two units, those along the Sakashu thrust and those irregularly mixed with clastic rocks about Mt. Takamaru (Fig. 19). The former is associated with Terano metamorphic rocks and Siluro-Devonian pyroclastic rocks, and they occasionally occur together as single lenticullar body. The latter, however, is not accompanied by Terano metamorphic rocks, but it is associated with Siluro-Devonian limestone and pyroclastic rocks.

The radiometric dates show clusters around about 400–430 Ma, 350–380 Ma and 250 Ma as presented in Fig. 20.

b) Terano metamorphic rocks (ICHIKAWA et al., 1956)

The Terano metamorphic rocks in this area consist of garnet-biotite gneiss and amphibolite with minor amount of epidote amphibolite. They expose as small blocks mainly along the Sakashu thrust and occasionally on the northern slope of Mt. Takamaru.

Radiometric dates of the Terano metamorphic rocks show a concentration around about 400 Ma (Fig. 20).

c) Siluro-Devonian rocks

The Siluro-Devonian rocks consist of rhyolitic to andesitic pyroclastic rocks and limestone. Although they are exposed in Mt. Takamaru typically, they occur as the accumulation of smaller lenticular bodies (Fig. 19). Therefore the details of their stratigraphy can not be clarified.

Pyroclastic rocks are mostly of tuff with small amount of lapilli tuff and tuffaceous sandstone to mudstone. Tuffaceous rocks contain large amounts of quartz and plagioclase crystals and rhyolitic to andesitic rock fragments. Granitic or granophyric rock fragments are rarely found. Pumpellyite, chlorite and sericite are commonly found as metamorphic minerals and prehnite and albite veins are rarely produced.

Limestone occurs as lenses in Mt. Takamaru. The limestone lenses are generally sandwiched between the Mitaki igneous rocks and pyroclastic rocks (Fig. 19). The marginal parts of the limestone lenses usually look like breccias which were cemented by tuffaceous material. Limestone tends to look pinky where it is in contact with dark reddish fine-grained tuff. Silurian fossils including *Schedohaysites kitakamiensis, Halysites* sp., *Favocites* sp., *Heliolites* sp. and others were discovered from limestone floats in Mt. Takamaru (ISHIDA, 1977b).

d) Crystalline schists

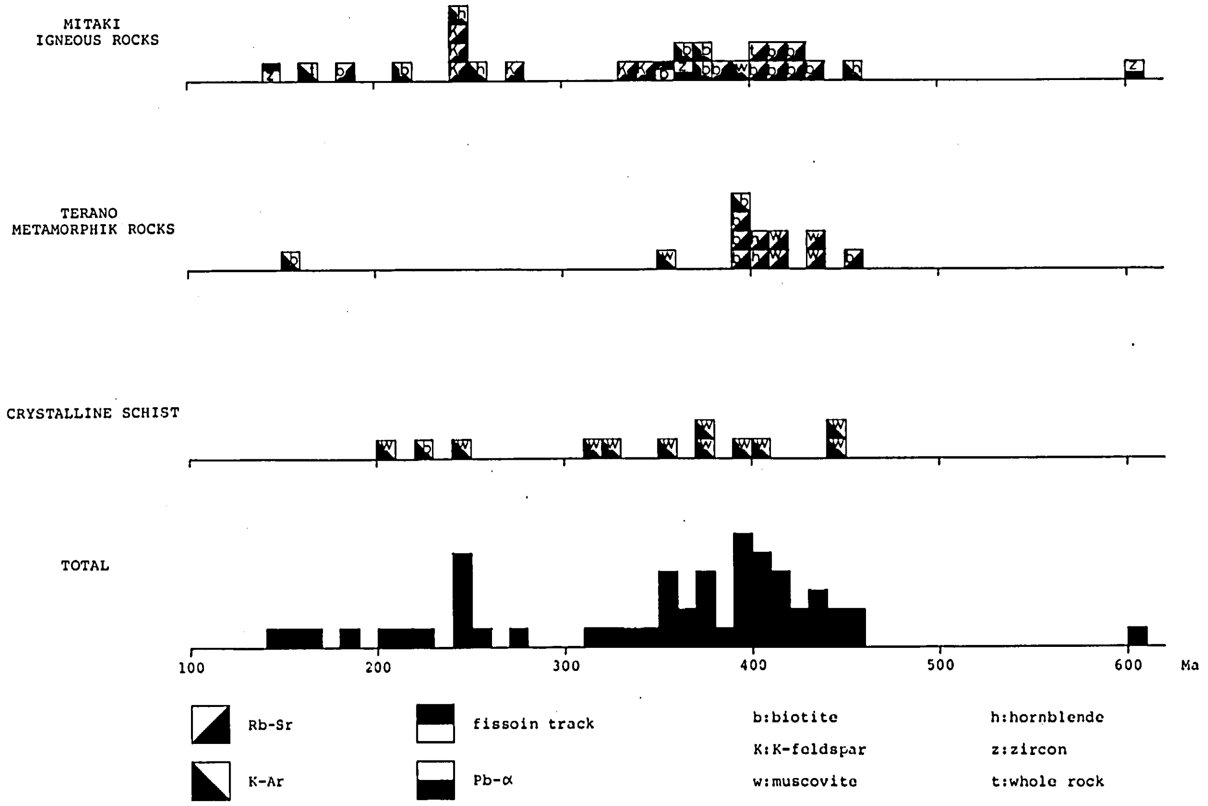


FIG. 20. Frequency distribution of the radiometric dates of the Kurosegawa rocks. The decay constants used in age calculation are:
$^{40}K\lambda\beta=4.962\times10^{-10}/y$, $^{40}K\lambda e=0.581\times10^{-10}/y$,
$^{40}K/K=1.167\times10^{-4}/y$, $^{87}Rb=1.42\times10^{-11}/y$.
Data are from followings: HAYASE and ISHIZUKA (1967), HAYASE and NOHDA (1969), KARAKIDA et al. (1978), KAWANO and UEDA (1966), MARUYAMA and UEDA (1975), MARUYAMA et al. (1978), MATSUMOTO et al. (1968), ONO (1983), SHIBATA (1968), SHIBATA et al. (1979), SHIBATA et al. (1984), SHIMA et al. (1969), UEDA and ONUKI (1969), UEDA et al. (1980), UMEDA et al. (1986), WATANABE and SUZUKI (1978), YANAGI (1975) and YOSHIKURA et al. (1981).

The crystalline schists described here do not belong to the Terano metamorphic rocks but one of high-pressure type. They occur as xenoblocks in east-west trending serpentinite on the south of Sabudani (Fig. 19). Only basic schists occur in the southern Kurosegawa Terrane of the Sakashu area. The crystalline schists found in the serpentinites of the Sawadani Terrane in Kitohmyoh, Ohyohchi (Fig. 2) and the west of Mt. Rokuroh are basic schists, pelitic to psammitic schists and siliceous schists in order of abundance and will be also described here.

Radiometric dates of those crystalline schists range from 208 Ma to 445 Ma (Fig. 20).

Basic schists: Basic schists are roughly classified into following two types: (1) A-type rocks which generally have albite porphiroblasts with diameter of less than several millimeters and belong to epidote-amphibolite facies and (2) B-type rocks which contain lawsonite and actinolite without albite porphyroblats.

The A-type basic schists expose on the south of Sabudani, and in Kitohmyoh and Ohyohchi. They are composed of hornblende, epidote, albite and muscovite with quartz, sphene, chlorite, stilpnomelane, apatite, calcite and opaque minerals as minor constituents. Garnet rarely observed as inclusions in albite porphiroblast. Hornblende is bluish green and often replaced by actinolite and chlorite along cleavages. Epidote is prismatic or porphiroblastic and shows zoning.

The B-type basic schists have been found in Ohyochi serpentinite body as a small block (Fig. 2). Although they have not been found in the southern Kurosegawa Terrane, lawsonite-bearing schists occur also in the Kurosegawa Terrane of other areas (e.g. Iwasaki and Shinoaki, 1959). Therefore, it is clear that the B-type schists belong to the Kurosegawa rocks. The B-type schists consist commonly mostly of actinolite and lawsonite with minor amount of chlorite, leucoxene and calcite. Actinolite is commonly fibrous or flaky and sometimes gives pseudomorph after hornblendes. Where lawsonite is fine-grained, it is rather dusty.

Table. 4. Chemical compositions of lawsonite in a basic schist block enclosed in Ohyohchi serpentinite body.

	1.	2.
SiO_2	38.23	37.93
TiO_2	0.13	0.28
Al_2O_3	31.43	31.29
FeO*	0.62	0.55
MnO	0.02	0.00
MgO	0.02	0.02
CaO	17.50	17.58
Na_2O	0.01	0.01
K_2O	0.03	0.04
Total	87.99	87.70
O=	8	8
Si	2.017	2.010
Ti	0.005	0.011
Al	1.956	1.955
Fe	0.027	0.024
Mn	0.001	0.000
Mg	0.002	0.001
Ca	o.990	0.998
Na	0.001	0.001
K	0.002	0.003
Total	5.001	5.004

* Total iron as FeO
Analyst : A. Minami

Pelitic to psammitic schists: They occur mainly in serpentinite of Kitohmyoh. A small block of psammitic schist, about 25 cm in diameter and 15 cm thick, was obtained from pebbly mudstone arround the Ohyohchi serpentinite body. They consist chiefly of quartz, albite, muscovite, chlorite, epidote and garnet with minor amount of sphene, stilpnomelane, tourmaline, apatite and opaque minerals. Garnet is usually fine grained, and when it is included in albite porphiroblast it is idiomorphic. Garnet is chloritized along cracks.

Siliceous schists: Siliceous schists occur in serpentin-

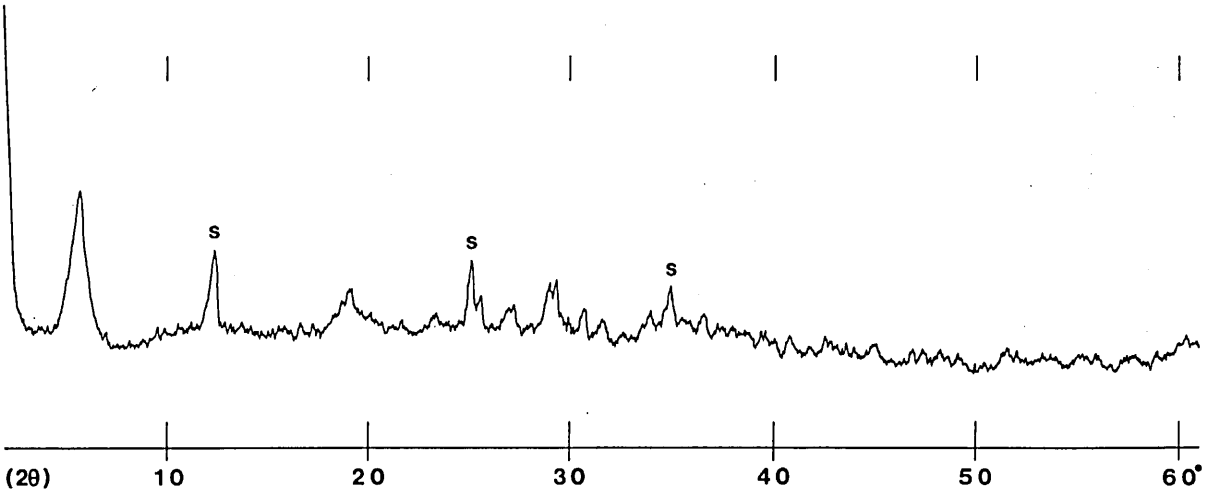


Fig. 21. X-ray diffraction pattern of serpentinite sandstone.
S: serpentine.

ite of Kitohmyoh and on the west of Mt. Rokuroh. They are composed of quartz, muscovite, chlorite, garnet and biotite with small amount of albite, sphene and opaque minerals. Biotite is largely replaced by chlorite. Garnet is commonly idiomorphic.

e) Ultramafic rocks

Ultramafic rocks mainly occur along the boundary fault between the Kurosegawa and Sawadani Terranes and on the south of Sabudani. They are almost completely serpentinized but pale grayish green coarse-grained clinopyroxenite is only rarely found as relicts.

f) Serpentinite sandstone (Plate I-1, 2, 3)

Serpentinite sandstone occurs as a small xenoblocks surrounded by serpentinite in the south of Sabudani (Fig. 19). The xenoblock consists of smaller blocks which are enveloped in serpentine-bearing mudstone. Although there are small differences among blocks, serpentinite sandstone is generally composed of serpentine (or serpentinite fragment), montmorillonite and carbonate minerals. Serpentinite sandstone contain abundant but poorly preserved smaller foraminifers, corals, sponge spicules and other fossils. Only *Glomospira* sp. (smaller foraminifer) is identified among them.

g) Phyllitic rocks

Phyllitic rocks occur as lenses closely associated with serpentinite blocks on the south of Sabudani. Their original rocks are mostly composed of pelite, which is occasionally pebbly, with small amount of sandstone. Pelitic phyllite has a cleavage defined by preferred orientation of flaky minerals. Although psammitic phyllite appears only slightly foliated under naked eyes, it is considerably recrystallized. Consequently, the boundaries between the matrix and the rock fragments, such as acid tuffaceous rock, chert and siliceous mudstone, are obscure.

"*Modes of occurrence of the Kurosegawa rocks*"

The Kurosegawa rocks of the Sakashu area occur in three modes, showing their characteristic gatherings: (1) A row of the Kurosegawa rocks along the Sakashu thrust (=Sakashu thrust row), (2) A row of serpentinite blocks on the south of Sabudani (=Sabudani row), and (3) A row of the Kurosegawa rocks about Mt. Takamaru (= Takamaru row) (Fig. 19).

The Sakashu thrust row is composed of lenses of Mitaki igneous rocks with small amount of Terano metamorphic rocks and Siluro-Devonian rocks. Serpentinite is only rarely observed. Terano metamorphic rocks tend to occupy on the northern side of Mitaki igneous rocks, while Siuro-Devonian rocks occur in the southern side. The lenses of this row are involved in displacement along the Sakashu thrust.

Crystalline schists, serpentinite sandstone and phyllitic rocks occur only in the Sabudani row. They are found together with large-scale serpentinite blocks (Fig. 19). The blocks of those Kurosegawa rocks appear to be surrounded by structurally continuous pebbly mudstone (Fig. 19). Small serpentinite blocks scattered on the west of mapped area are wholly enveloped by pebbly mudstone. Accumulation of smaller serpentinite lenses surrounded by pebbly mudstone is represented as a small block on the geological map (Fig. 19, Plate I-4). The serpentinite lens on the south of Sabudani is in harmony with lenses of other rock types and appears to be also a gigantic sedimentary slide mass in pebbly mudstone.

The Takamaru row of the Kurosegawa rocks has been regarded as a single lenticular composite mass so far (Hirayama et al., 1956). However, it has been clarified as shown in Fig. 19 that it is a gathering of smaller lenticular masses which consist of Mitaki igneous rocks and Siluro-Devonian rocks respectively. Granitic rocks occupy the northern part of each lens, while pyroclastic rocks occupy its southern part. Then limestone tends to occur between the former and the latter. Smaller lenses are surrounded by sandstone and/or conglomerate. Bedding planes of these sandstone and conglomerate gently dip northward and are at some angles with the contact plane to the surrounding pebbly mudstone. On the contrary, the bedding plane of pebbly mudstone is in harmony with the contact plane against the Kurosegawa rocks and such sandstone and conglomerate. This fact suggests that the sandstone-conglomerate sequence and Kurosegawa rocks are included together in pebbly mudstone as gigantic sedimentary slide masses. Analogous mode of occurrence of sandstone-conglomerate blocks are also found in the Sabudani row.

Above three modes of occurrence of the Kurosegawa rocks are summarized as follows:

(1) The occurrence of the Kurosegawa rocks along any fault is only the case of the Sakashu thrust row.

(2) Two types of process of mixing of the Kurosegawa rocks into pebbly mudstone are recognizable: 1) They are directly mixed into pebbly mudstone and 2) they were first mixed into sandstone and conglomerate and then they together with those sandstone and conglomerate were mixed into pebbly mudstone.

(3) Crystalline schists and phyllitic rocks occur individually as blocks in serpentinite, but they never form a composite mass with Mitaki igneous rocks, Terano metamorphic rocks and Siluro-Devonian rocks.

"*Nonmetamorphic clastic rocks*"

Nonmetamorphic clastic rocks consist of Permian, Triassic and Jurassic rocks dated on fossil evidences, and of unidentified pebbly mudstone which exposes around these dated rocks and the Kurosegawa rocks throughout the southern Kurosegawa Terrane.

a) Permian rocks

Permian rocks in the Kurosegawa Terrane in Eastern Shikoku have been classified into Middle Permian Hisone Group and Late Permian Haigyu Group (Hirayama et al., 1956). Their distributions, however, have not been clarified except for their type localities. Therefore, the pebbly mudstone-rich sequence in the Sakashu area has usually been called Hisone Group (Hirayama et al., 1956). The Haigyu Group was studied on its sedimentary environment by Maejima (1979) and dated as *Lepidolina kumaensis* zone of Late Premian on the basis of foraminifers described by Ishii et al. (1975). All fossils so far used for age determination, however, were obtained only from limestone gravels in clastic rocks. Therefore they do not represent the age of the group.

Although Permian radiolarian fossils have been obtained from three localities through this study (Fig. 18; Table 5), they all are from exotic blocks in pebbly mudstone. Pebbly mudstone itself does not yield reliable fossils. Judging from fossils and their modes of occurrence, there is a strong possibility that the age of pebbly

TABLE. 5. LIST OF PERMIAN RADIOLARIAN FOSSILS FROM THE SAKASHU AREA (SOUTHERN KUROSEGAWA TERRANE).

Loc.41:siliceous mudstone

Follicucullus scholasticus ORMISTON and BABCOCK

F. sp. cf. *F. chalveti* CARIDROIT and DE WEVER

Albaillella sp. cf. *A. levis* ISHIGA, KITO and IMOTO

A. spp.

Pseudoalbaillella sp. aff. *Ps. longicornis* ISHIGA and IMOTO

Ps. sp.

Neoalbaillella sp.

Pseudotormentus sp. cf. *P. kamigoriensis* DE WEVER and CARIDROIT

Loc.42:mudstone

Follicucullus scholasticus ORMISTON and BABCOCK

Pseudoalbaillella sp.

Loc.43:tuffaceous mudstone

Pseudoalbaillella sp.

Albaillella sp.

mudstone called the Hisone Group is placed in Late Permian or younger time. Consequently, the Permian rocks should be restricted to the olistoliths in pebbly mudstone. On the other hand, it is also a fact that the distribution of Permian clastic rocks in the Outer Zone of Southwest Japan are confined to the Kurosegawa Terrane (SURARI et al., 1983; MIYAMOTO et al., 1985; ISHIDA, 1985; ISOZAKI, 1985). Therefore, even though the age of pebbly mudstone itself is uncertain, it seems probable that the source area of the Permian clastic rocks was placed inside of the Kurosegawa Terrane.

b) Triassic rocks

Triassic rocks in Eastern Shikoku are commonly classified to the Late Ladinian Usugatani Formation, the Carnian Sabudani Formation and the Norian Umegatani Formation. In the investigated area the Sabudani Formation and Usugatani Formation were described by ICHIKAWA et al. (1953) and HIRAYAMA et al. (1956).

The Usugatani Formation in the Sakashu area is composed mainly of alternating beds of sandstone and mudstone. Sandstone is massive and fine-grained. Mudstone is black, massive, silty and rather micaceous. The beds in this area extend from Junisha westward for about 1.8 km in some 200 m wide. They are homoclinal and have east-west trend and intermediate to steep dips to the south. This formation is sandwiched by thin pebbly mudstone beds which contains acid tuffaceous rocks and serpentinite as blocks (Fig. 19). Its bedding planes are at some angles with the boundary planes against the pebbly mudstone beds. Nevertheless, this formation is in sedimentary contact with the pebbly mudstone. This indicates that the Usugatani Formation is also a block included in the pebbly mudstone. *Daonella sakawana* MOJSISOVICS, *D. kotoi* MOJSISOVICS and Torachyceras sp. have been reported from the Usugatani Formation by HIRAYAMA et al. (1956).

The Sabudani Formation is what was defined by ICHIKAWA et al. (1953) as the Triassic beds which unconformably overlie the Middle Permian Hisone Group and form a narrow distribution along the Sabudani Valley. Along the Sabudani Valley, however, develop the Torinosu Group (Late Jurassic) on the north side and pebbly mudstone on the south side (Fig. 19). The narrow distribution of the Sabudani Formation after ICHIKAWA et al. (1953) can not be recognizable. Coarse sandstone and fine conglomerate characterizing the Sabudani Formation appears to occur as blocks in the pebbly mudstone. At the junction of the Sabudani Valley and the Sakashukitoh River, where the most representative outcrop containing the southern boundary between the sandstone-conglomerate bed of the Sabudani Formation and the pebbly mudstone bed (cf. ICHIKAWA et al., 1953) is placed, the olistoliths in the pebbly mudstone are arranged nearly parallel to that boundary. The western and northern sides of the sandstone-conglomerate bed are also occupied by the pebbly mudstone. Consequently the sandstone-conglomerate bed appears to be surrounded by the pebbly mudstone. Such the relationship between the sandstone-conglomerate bed and the pebbly mudstone bed suggests that the former is also an olistolith in the latter. Thus, "the Sabudani Formation" should be recognized not as an individual formation but as a horizon in the pebbly mudstones where olistoliths of Triassic rocks are accumulated.

c) Jurassic rocks

Jurassic rocks in the southern Kurosegawa Terrane in a narrow sense are defined by radiolarian fossils (Fig. 18, Table 2) and are older than the Torinosu Group along the Sakashu thrust. They occur on the northwest of Junisha as some blocks, which are surrounded by pebbly mudstone (Fig. 19). They consist mainly of the alternating beds of sandstone, which contain poorly continuous conglomerate beds at places, and mudstone. Small blocks of limestone breccia are also rarely contained. In each block, the bed trends east-west and moderately to steeply dips northward.

The conglomerate beds range in thickness from several tens centimeters to several meters. The pebbles vary from a few millimeters to about 30 cm in diameter. They comprise mostly of rhyolitic rocks with andesitic rocks, granitic rocks, chert to siliceous mudstone, mudstone and limestone.

Sandstone is commonly fine to medium-grained and feldspathic, but it grades into coaser-grained and lithic facies around the comglomerate beds. Mudstone is black and massive, and yields radiolarian fossils. It occasionally shows following two facies characterized by nodules of different types: (1) facies having carbonate nodules, and (2) facies having siliceous nodules. The nodules of both facies yield the same age radiolarian fossils as the surrounding mudstone.

The carbonate nodules range in diameter from a few millimeters to 1cm and have irregular shape. Judging from the arrangement of the carbonaceous material in thin section, the nodules appear to have grown up excluding carbonaceous material from inside to outside (Plate II-7).

The siliceous nodules are generally spherical and ranges in diameter from one to several centimeters (Plate II-8). As a rule, they have a concentrically zoned structure composed of three parts. The most outer part is about 0.1 mm thick and contains concentrically arranged carbonaceous materials. The second layer, which looks like a mantle, is about 1mm thick and scarcely contains opaque materials and carbonate minerals. The remaining inner part is filled by microcrystalline silicate minerals. It contains also platy minerals with considerable amount of iron ore minerals but a little amount of carbonaceous materials. The platy minerals are randomly oriented in the inner part. The cores of larger nodules, which have fundamentally the same structure as the above-described, are often partly occupied by carbonate minerals.

Radiolarian fossils from mudstone contain representative species of the *Unuma echinatus* assemblage (Table 2). Therefore the alternating beds of sandstone and mudstone are considered to be dated as Bajocian to Bathonian. Judging from the modes of occurrence and fossil evidence, this formation should be distinguished from the Torinosu Group. In the Kurosegawa Terrane, this formation may correspond to the Kagio Group in Western Shikoku on the basis of radiolarian data (NAKATANI, 1981) and lithofacies.

A series of beds, which consist mainly of coarse sandstone and conglomerate with gigantic blocks of Kurosegawa rocks, occur in Mt. Takamaru (Fig. 19, Plate I-6). The sandstone of this series is greensih grey, medium- to coarse-grained and massive, and often grades into conglomerate. It is placed into lithic wacke by abundance in rock fragment. The conglomerate comprises well-rounded gravels, which range in diameter from a few millimeters to some 50 cm or more, and consist mainly of acid to intermediate pyroclastic rocks, granitic rocks and chert to siliceous mudstone with minor amount of mudstone and calcareous sandstone to siltstone. Granule conglomerate characteristically contains pebbles of rhyolitic to andesitic volcaniclastic rocks of 30% and of chert to siliceous mudstone of 35–40%. None of sequences have been known among the pre-Cretaceous formations in the Kurosegawa Terrnae to be correlative with such a conglomerate-rich succession but only with the coaser-grained facies of the Kagio Group around Mt. Mitaki, Ehime Prefecture as a possibility.

Sandstone and conglomerate of the Kagio Group in Mt. Mitaki area (Fig. 22) strongly resemble to those around Mt. Takamaru. In Mt. Mitaki area, the Kagio Group has a tendency to vary in lithofacies from coarser-grained near the Kurosegawa rocks to finer-grained away from the Kurosegawa rocks. This tendency apears to correspond to the relation between the sandstone-conglomerate beds around Mt. Takamaru and the alternating beds of sandstone and mudstone on the northwest of Junisha. The sandstone-conglomerate sequence on the southern slope of Mt. Takamaru may also be regarded as a correlative of the Kagio Group. The two correlatives of the Kagio Group, finer- and coarser-grained sequences, are conveniently termed the Junisha and Takamarusan (Mt. Takamaru) Formations respectively regarding the localities where each facies is particularly well developed.

d) Pebbly mudstone

Pebbly mudstone of the southern Kurosegawa Terrane has been considered to belong to the Hisone Group (HIRAYAMA et al., 1956). As stated so far, however, it contains not only the Permian rocks but also the Kurosegawa rocks and the Triassic and Jurassic clastic rocks. The youngest exotic block which is immediately in this pebbly mudstone is the Jurassic siliceous nodules derived from the Junisha Formation (Fig. 19; Table 2). And the pebbly mudstone bed is considered to unconformably underlie the Torinosu Group. Therefore, the formation of the southern Kurosegawa Terrane, which may have involved the collapse of the island-arc consisting of the Kurosegawa rocks, is considered to have occurred during the period ranging from Middle to Late Jurassic. The radiometric dates of 149±9 Ma, 154 Ma, and 163±13 Ma which have been obtained from the Kurosegawa rocks (WATANABE and SUZUKI, 1978; UEDA and ONUKI, 1969; SHIBATA, 1968) may also be reflections of such a series of diastrophism.

B. GEOLOGY OF THE MT. MITAKI AREA

The Mt. Mitaki area, Shirokawa Town, Ehime Prefecture is placed just on the southwest of the Ohnogahara area. In this area, ICHIKAWA et al. (1956) had tried the subdivision of the "Chichibu Belt", that is the northern, middle and southern subbelts, defining the "Kurosegawa Tectonic Zone". NAKAGAWA et al. (1959) and the author with his collaborators (1979) have also described the geology of this area and the surrounding areas.

The Tsubonota thrust, which is the boundary between the Kurosegawa Terrane and the Sawadani Terrane, is expressed as a low-angle thrust on the north of Nakanokawa (TOMINAGA et al., 1979) (Figs. 7, 22). In the mapped area (Fig. 22), the Kubono Formation corresponds to the northern Kurosegawa Terrane of the Sakashu area. The boundary between the northern and southern Kurosegawa Terranes is placed between the pebbly mudstone of the Kubono Formation and the serpentinite or crystalline schists on the north of Katahira. Although its eastern extension is cut by north-south treding fault, it seems to extend through the north of Katsura and Ohgaya Pass eastward.

[Northern Kurosegawa Terrane]

1. The Kubono Formation

The Kubono Formation corresponds to the southern half of the Yusukawa Group (ICHIKAWA et al., 1956), except for the crystalline schists along the southern border. It consists mainly of pebbly mudstone with variable sized blocks of greenstone, chert, limestone, sandstone and others. Sheared granitic rocks are also contained in the pebbly mudstone as small lenses. Pelitic rocks is generally foliated in variable degrees. Early Triassic conodonts were obtained from chert blocks (TOMINAGA et al., 1979), and Late Triassic radiolarian fossils were discovered from mudstone (NAKATANI and YAO, 1982).

[Southern Kurosegawa Terrane]

"*Kurosegawa rocks*"

The Kurosegawa rocks in this area contain Mitaki igneous rocks, Terano metamorphic rocks, Siluro-Devonian rocks, crystalline schists and ultramafic rocks.

a) Mitaki igneous rocks

Mitaki igneous rocks in the Mt. Mitaki area are composed mainly of tonalite and granodiorite with small amount of biotite granite and clinopyroxene gabbro. Biotite granite often has micrographic texture. It is hardly subjected to cataclasis, but tonalite and others are strongly cataclasized. Prehnite and pumpelyite are generally found in Mitaki igneous rocks.

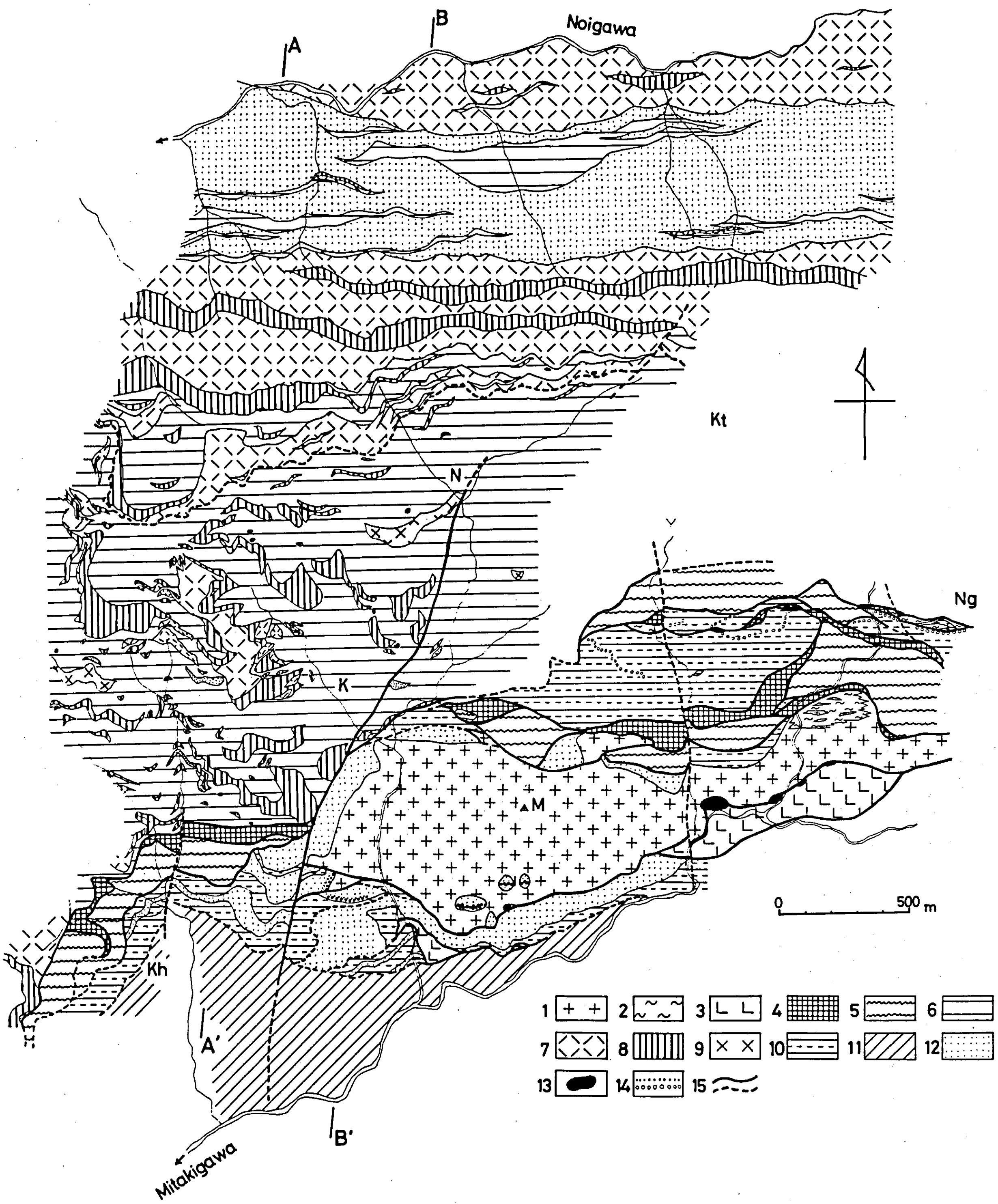


FIG. 22. Geological map of the Mt. Mitaki area (Kurosegawa Terrane), Western Shikoku.
1: Mitaki igneous rocks, 1: Terano metamorphic rocks, 3: Siluro-Devonian rocks (Okanaro Group), 4: serpentinite, 5: crystalline schists, 6: mudstone, 7: greenstone, 8: chert, 9: granitic rocks (block), 10: mudstone (Kagio Group), 11: Doi Group, 12: sandstone, 13: limestone, 14: conglomerate, 15: fault.
K: Kubokawa, Kh: Katahira, Kt: Katsura, M: Mt. Mitaki, N: Nakanokawa, Ng: Nagasaki.

b) Terano metamorphic rocks

Terano metamorphic rocks consist of garnet-biotite gneiss, amphibolite (or epidote amphibolite) and also garnet-clinopyroxene amphibolite. As shown in Fig. 22, they expose in two rows. In the southern row, garnet-biotite gneiss and amphibolite are exposed, while in the northern row occur amphibolite and garnet-clinopyroxene amphibolite. Garnet-biotite gneiss and garnet-clinopyroxene amphibolite never coexist in the same lenticular body.

Garnet-clinophyroxene amphibolite: Garnet-clinopyroxene amphibolite, which seems to be correlated with what is called garnet-clinopyroxene granulite (HADA et al., 1979), is medium to coarse-grained and shows a gneissose appearance. Amphibole is classified into bluish green and brown one. Bluish green amphibole is

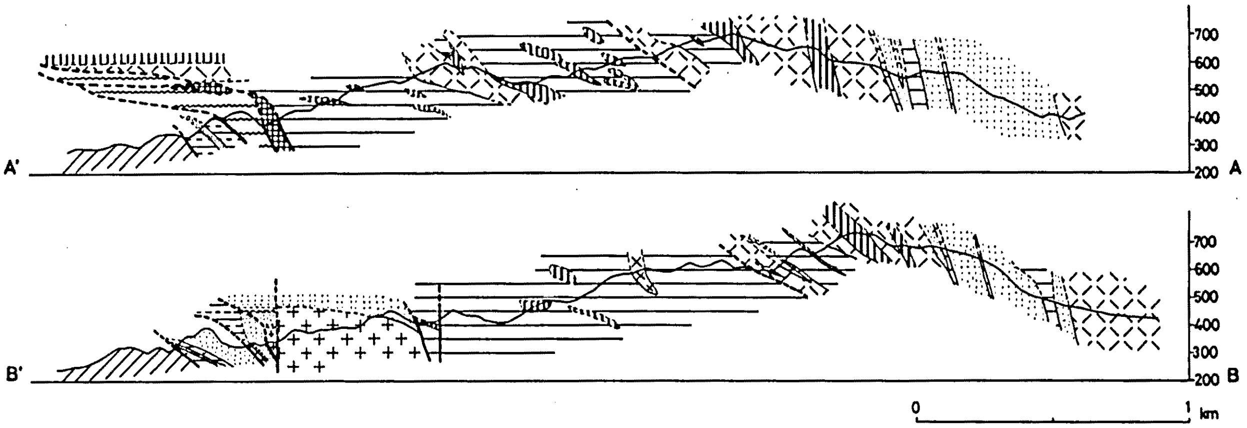


Fig. 23. Geological profiles along the lines A-A' and B-B' on Fig. 22. See the legend of Fig. 22.

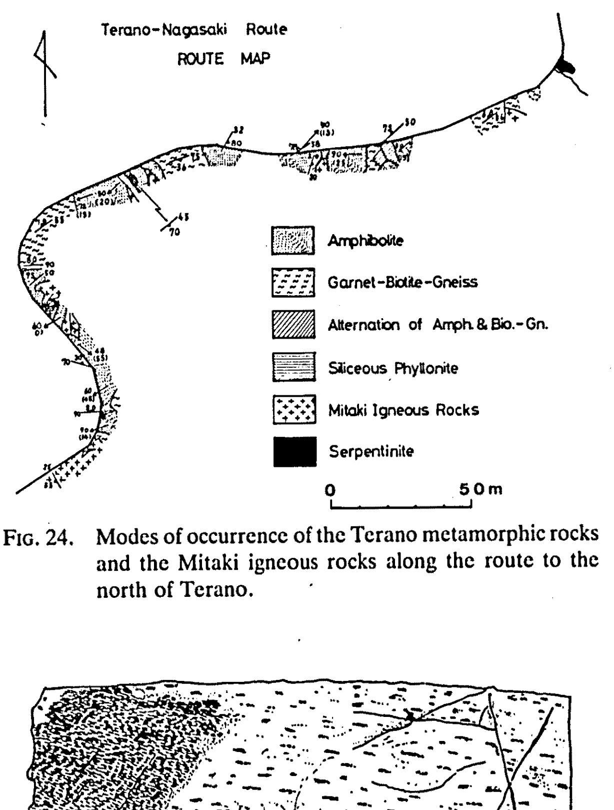


Fig. 24. Modes of occurrence of the Terano metamorphic rocks and the Mitaki igneous rocks along the route to the north of Terano.

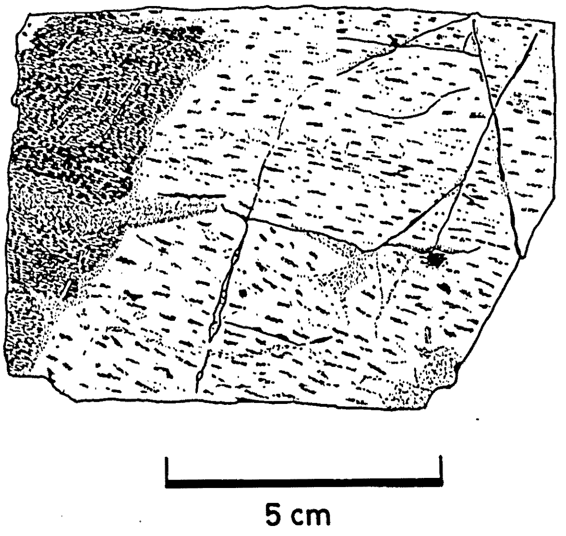


Fig. 25. Sketch showing the relationship between amphibolite (dark part) and quartz diolite (light Part). The gneissosity defined by preferred orientation of hornblende grains cuts across the lithofacies boundary.

found around clinopyroxene and brown hornblende, and is in places rimmed with fibrous actinolite. Garnet, which varies from a few millimeters to some 3 cm in diameter, is often altered to chlorite along cracks. Fine-grained (epidote) amphibolite and garnet-biotite gneiss are traversed by prehnite veinlets.

Terano metamorphic rocks and Mitaki igneous rocks are closely associated with each other. As shown in Fig. 24, Mitaki igneous rocks frequently occur among Terano metamorphic rocks. Although fault are generally observed between them, they rarely coexist not in fault contact, showing parallel arrangement of gneissosity and mineral lineation between them (Fig. 25). This suggests that a part of Mitaki igneous rocks were deformed and metamorphosed under high-temperature condition together with Terano metamorphic rocks.

c) Siluro-Devonian rocks (Okanaro Group)

Siluro-Devonian rocks, Okanaro Group, consist mainly of acid to intermediate pyroclastic rocks and limestone with minor amount of mudstone. Limestone yields corals including *Halysites* sp. and *Favosites* sp. (Ichikawa et al., 1956).

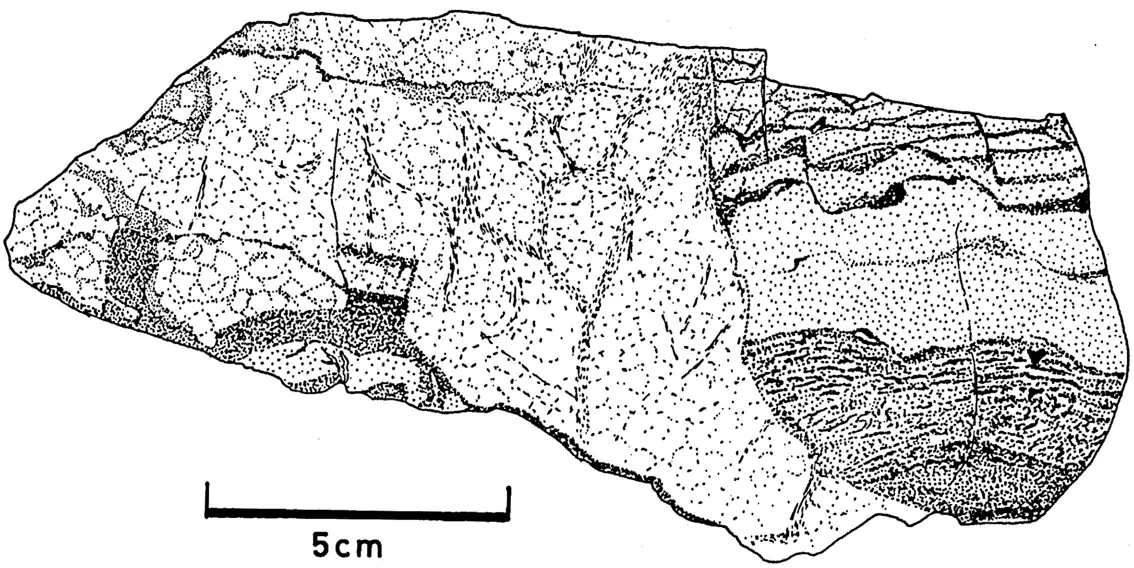
d) Crystalline schists

Crystalline schists are mainly composed of basic schists with subordinate pelitic, siliceous and calcareous schists and occur with serpentinite. Although Ichikawa et al. (1956) called both these crystalline schists and foliated parts of the Kubono Formation comprehensively "semischists", serpentinite and associated crystalline schists are regarded as members of the Kurosegawa rocks and belong to the different structural sequences from "the Yusukawa Group". The crystalline schists are always in fault contact with other structural sequences except serpentinite.

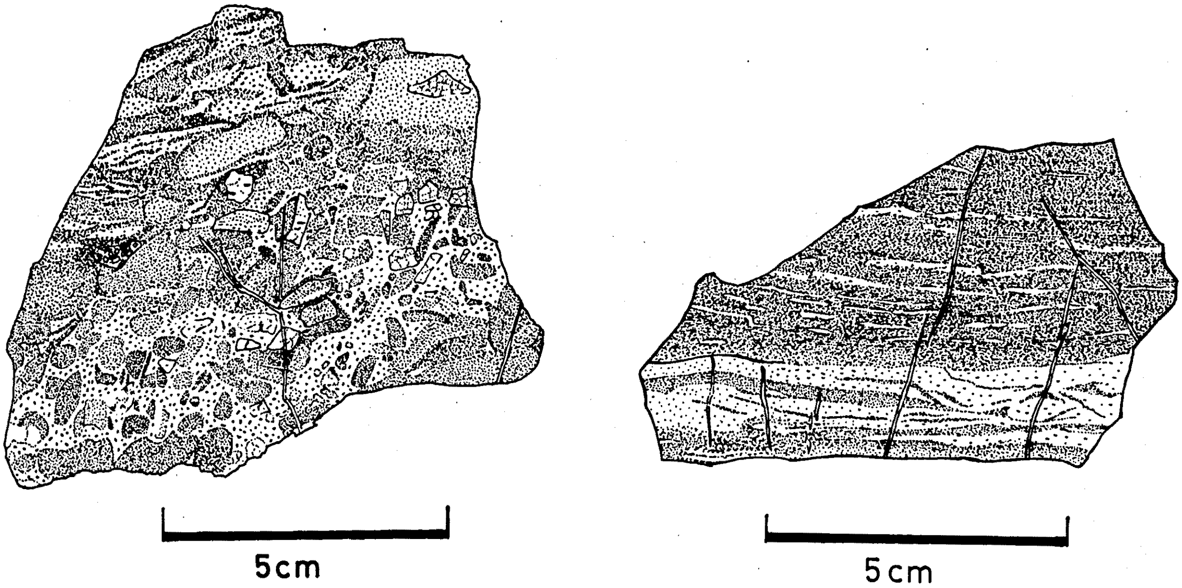
Basic schists are generally fine-grained and strongly foliated. They are composed of plagioclase, chlorite, epidote and actinolite with minor amounts of quartz, calcite, sphene and opaque minerals. Pumpelyite and glaucophane are sometimes found in them. Albite and epidote are often porphyroblastic.

e) Ultramafic rocks

Ultramafic rocks are almost completely serpentinized. They are in common strongly sheared and flaky. Chromite deposits rarely occur in them. Ultramafic rocks tend to occur on the northern side of Kurosegawa rocks of other kinds.



(A) bedded coarse sandstone containing tonalite rubble.



(B) Conglomeratic sandstone containing large amounts of mudstone chips and fragments of Mitaki igneous rocks.

(C) Ordinary beds of sandstone and mudstone.

FIG. 26. Sketch showing that the lithofacies of the Kagio Group varies in order of (A), (B) and (C) as passing away from the contact to the lenticular body of Mitaki igneous rocks.

"*Nonmetamorphic clastic rocks*"

In the mapped area (Fig. 22), nonmetamorphic clastic rocks in the southern Kurosegawa Terrane are classified into the Kagio Group and the Doi Group.

a) Kagio Group

The Kagio Group consists mainly of medium to coarse grained sandstone, mudstone and their alternating beds. Sandstone contains intercalated conglomerate. In general, coarse-grained facies tends to be dominant around the Kurosegawa-rock bodies.

This group occurs in two rows along the two rows of distribution of the Kurosegawa rocks: the southern row around the Mt. Mitaki body containing the Kubokawa Formation (cf. ICHIKAWA et al., 1956) and the northern row about the row of small lenses of Kurosegawa rocks which expose from Nagasaki westward.

Conglomerate and sandstone on the southern slope of Mt. Mitaki appear to unconformably cover Mitaki igneous rocks. In many outcrops along the northern to western border of the Mt. Mitaki lenticular body, rubbles of Mitaki igneous rocks are contained in sandstone or mudstone of this group. At the riverbed on the southeast of Kubokawa, tonalite rubbles are mingled in coarse-sandstone with neither disturbance of sedimentary structure nor distinct glide plane (Fig. 26A). Coarse sandstone grades into rather homogeneous mudstone with increasing of distance from the boundary between this group and the Mt. Mitaki lense, as illustrated in Figs. 26B and 26C. Also in the northern row, conglomerate occurs along the lenses of Kurosegawa rocks. Such relations between the Kagio Group and the Kurosegawa rocks indicate that the former covers unconformably.

This group yields Middle Jurassic radiolarian fossils (NAKATANI, 1981).

b) Doi Group

The Doi Group, which covers the southern part of the mapped area (Fig. 22) and extends southward, consists mainly of muddy olistostrome. As pebbles or blocks are found greenstone, chert to siliceous mudstone, limestone, sandstone and mudstone. Gigantic olistolith is rather rare in the Doi Group than in the Kubono Formation. Only a few chert to siliceous mudstone olistoliths can be expressed in the geological map (Fig. 22).

This group has been dated as Late Permian based on fusulinids from limestone lenses (Nakagawa et al., 1959). But they are only olistoliths. No reliable fossils for age determination has been obtained from the pelitic matrix of olistostrome. Judging from the mode of occurrence of limestone, the age of this group may be considered to be younger than Late Permian.

[Structural analysis]

Geological structure of the Kurosegawa Terrane is characterized by northward dipping low-angle thrusts (Fig. 22, 23). The Tsubonota thrust, which is the boundary between the Kurosegawa and the Sawadani Terranes in Western Shikoku, may also be an expression of this series of thrusting. The Kagio Group, the youngest rocks in this Terrane is involved in these thrust movements. Therefore, the pile nappe structure of this terrane is considered to have been formed after deposition of the Kagio Group, owing to southward overthrusting. In Western and Central Shikoku, it is known that the Cretaceous sediments on the Kurosegawa and Sawadani Terranes are also involved in this series of thrusts (Ishizaki, 1962: Kobayashi, 1941: Miyamoto et al., 1979).

The Kagio Group is in sedimentary contact with the Mitaki igneous rocks, though it is always in fault contact with the crystalline schists. Although the Mitaki igneous rocks, Terano metamorphic rocks and Siluro-Devonian rocks appear to be surrounded by the Kagio Group, the crystalline schists do not look so. From such structural relations among the Kagio Group, crystalline schsits and Mitaki igneous rocks, it may be inferred that the crystalline schists were not exposed near the sedimentary site of the Kagio Group, even though they had already been contained in serpentinite of the Ohnogahara nappe.

Before thrusting, the Doi Group, the Kurosegawa rocks and Kagio Group and the Kubono Formation seem to have been arranged in this order from south to north. In the west of Katahira, however, the Kubono Formation overlies the Doi Group (Fig. 22), showing that some nappes in this area had large-scale displacement. It may be said that the regional variation of the geological structure of the Chichibu Belt resulted from such diastrophic movements, because of similarity between Eastern and Western Shikoku with reference to the original arrangements of the above-mentioned tectonostratigraphic units.

C. Development of the Kurosegawa Terrane

The development of the Kurosegawa Terrane appears to have occurred in two stages, before and after the accretion of the Sawadani Terrane. It would be assumed that an island-arc consisting of the Kurosegawa rocks presented before the formation of the Sawadani Terrane, as stated by some authors (e.g. Ichikawa, 1981: Isozaki, 1985).

Permian and Triassic terrigenous clastic rocks have different lithofacies and modes of occurrence between the southern and the northern Kurosegawa Terranes respectively. In the southern Kurosegawa Terrane, Permian terrigenous clastic rocks, together with younger rocks, occur as blocks mixed in pebbly mudstone. In the northern Kurosegawa Terrane, however, it is known that any younger rock does not exist where Permian terrigenous clastic rocks occur, even though they are always blocks in pebbly mudstone (Suyari et al., 1983; Isozaki, 1985). Triassic clastic rocks in the southern Kurosegawa Terrane are shelly and have shelf facies. On the contrary, they in the northern Kurosegawa Terrane scarsely yield larger fossils but contain radiolarian fossils.

Almost all of the Kurosegawa rocks occur in the southern Kurosegawa Terrane, and they in the northern Kurosegawa Terrane are merely small olistoliths or pebbles in conglomerate.

Judging from the above-mentioned differences in constituent rocks between both terranes, it is inferred that the northern Kurosegawa Terrane is what has accreted against the antecedents (Permian Krosegawa Island-arc) of the southern Kurosegawa Terrane during Permian and Triassic time. Radiometric dates of some 200–250 Ma obtained from Mitaki igneous rocks and high P/T type crystalline schists seem to be in harmony with the time of formation of the northern Kurosegawa Terrane.

The tectonostratigraphic units which are considered to belong to the northern Kurosegawa Terrane usually lie in the norhtern part of the Kurosegawa Terrane. This suggusts that the northern Kurosegawa Terrane was accreted to Kurosegawa Island-arc from north side. Isozaki (1985) has also regarded the northern Kurosegawa Terrane in Central Shikoku (the Shingai Formation) as the Permo-Triassic accretionary prism to the north side of Kurosegawa Island-arc, but he has not shown any concrete evidence to decide the direction of relative plate motion.

It still remains unknown what happened during the end of formation of the northern Kurosegawa Terrane and before the begining of accretion of the Sawadani Terrane. The boundary fault between the northern Kurosegawa Terrane and the Sawadani Terrane is considered to have dated later than the boundaries between the accretionary units of the Sawadani Terrane because it evidently cuts the geological structure of the Sawadani Terrane. Large amounts of serpentinite and associated crystalline schists in the early deposits of the Sawadani Terrane, which were derived from the Kurosegawa Terrane, strongly suggests that the formation of serpentinite melange at the northern front of the Kurosegawa Island-arc occurred at the start of formation of the Sawadani Terrane giving rise to gravity-gliding of their blocks into the trench where the accretion of the Sawadani Terrane sediments was performed.

Early Jurassic terrigenous clastic rock has not been found in the Kurosegawa Terrane, though the accretion of the Sawadani Terrane appears to have begun during Early Jurassic. During early Middle Jurassic time the Kagio Group and its correlatives deposited. At the same time occurred the sedimentation of the Kenzan unit of the Sawadani Terrane and of the A unit in the

Sambosan Terrane mentioned above.

After the deposition of the Kagio Group had taken place the reorganization of the constituents of the Kurosegawa Terrane. Late Middle to Late Jurassic radiometric dates of the Kurosegawa rocks may be regarded as a reflection of such a movement.

VI. TECTONIC DEVELOPMENT OF THE CHICHIBU BELT

Judging from the above-stated tectonic development of the Sawadani, Kurosegawa and Sambosan Terranes, the tectonic history of the Chichibu belt is divided into following four phases:

1) phase before the formation of the Sawadani Terrane,
2) Phase of the formation of the Sawadani Terrane,
3) phase of the formation of the Sambosan Terrane,
4) phase after the formation of the Sambosan Terrane.

The tectonic history of the Chichibu belt would be grasped through the understanding of the correlation among three terranes. The major orogenic processes are of the second and the third phases. And the diastrophism appears to have had a climax at the change of the accretionary site from the northern (inner) side to the southern (outer) side across the Kurosegawa Terrane.

As will be read from Fig. 11, mudstones in the Chichibu belt show two younging age polarities. The one is of the northward direction within the Sawadani Terrane during Early and Middle Jurassic, and the other is of the southward diretion within the Kurosegawa Terrane and the Sambosan Terrane during Middle and Late Jurassic. The formation of the Sambosan Terrane started as soon as the accretion of the Sawadani Terrane stoped, and that a series of phenomena such as the stop of accretion of the Sawadani Terrane, collapse of the Kurosegawa Island-arc and beginning of formation of the Sambosan Terrane are related to the closure of the Sawadani Sea, which developed on the north of the Kurosegawa Island-arc, resulting in the formation of the Sawadani Terrane and appearance of a new subduction zone just on the south of the Kurosegawa Island-arc during Midle Jurassic age. Late Middle to Late Jurassic radiometric dates obtained from the Kurosegawa rocks may reflent such the series of phenomena.

The diastrophism after the completion of the three terranes is represented by the formation and successive collapse of the Cretaceous basins within the Kurosegawa Terrane, namely development of the pile nappe structure involving Cretaceous rocks. It may be inferred that the formation of Cretaceous basins is related to the movement of the geological sequence containing the Kurosegawa rocks, because the Cretaceous shelf sediments are closely associated with the Kurosegawa rocks.

The thrust faults, whose movement involves the Cretaceous sediments, are typicaly developed in Eastern Kyushu. According to SONODA (1984, MS), the Cretaceous basins in the Mikunitoge area appear to have developed on the nappes. And in plinciple, each nappe consists of the element of the Sawadani Terrane, the element of the Kurosegawa Terrane and the Cretaceous strata from the bottom upward. And the nappes together have thrusted over the Sambosan Terrane. Cretaceous basin sediments in Eastern Kyushu have a younging age polarity to the north in bulk (KAMBE and TERAOKA, 1968; TERAOKA, 1970). These suggest that the thrust faults have been formed not at the same time but episodically with sedimentation of related Cretaceous strata (Fig. 27).

Thus, Late Paleozoic to Mesozoic tectonic history of the Chichibu belt in Shikoku may be summarized as follows.

Stage 1 (Permian-Triassic; Fig. 28-A): This stage is represented by the accretion of the northern Kurosegawa Terrane around the Kurosegawa Island-arc and by the formation of Permian-Triassic shelly clastic rocks on the Kurosegawa Island-arc. The formation of high P/T type crystalline schists (e.g. Maruyama et al., 1978) appear to have also occured.

Stage 2 (early-middle Early Jurassic; Fig. 28-B): This stage is represented by the accumulation of Sawadani unit and its correlatives. Serpentinite melange was formed probably along the northern border of the Kurosegawa Island-arc, resulting in mixing of the serpentinite masses with high P/T type schists into the Sawadani unit.

Stage 3 (middle-late Early Jurassic; Fig. 28-C): This stage is represented by the accumulation of the Higashiura unit which is mainly composed of olistostrome characterized by sandy matrices and chart-dolomite olistoliths.

Stage 4 (early (-late) Middle Jurassic; Fig. 28-D): This stage is represented by the accumulation of the Kenzan unit of the Sawadani Terrane and by the sedimentation in the shelf and upper slope regions along the southern front of the Kurosegawa Island-arc, that is the Kagio Group of the southern Kurosegawa Terrane and the alternating beds of sandstone and mudstone of the A unit of the Sambosan Terrane.

Stage 5 (late Middle-early Late Jurassic; Fig. 28-E): This stage is represented by the reorganization of the constituents of the Kurosegawa Island-arc and by the accumulation of the B1 unit of the Sambosan Terrane. The shift of the subduction zone from the Sawadani Terrane to the Sambosan Terrane and the turn of direction of the subduction from southward to northward, may be attributed to the closure of the Sawadani Sea. Gabbro olistostrome of the Mikabu belt was formed at this stage.

Stage 6 (late Jurassic; Fig. 28-F): This stage is repre-

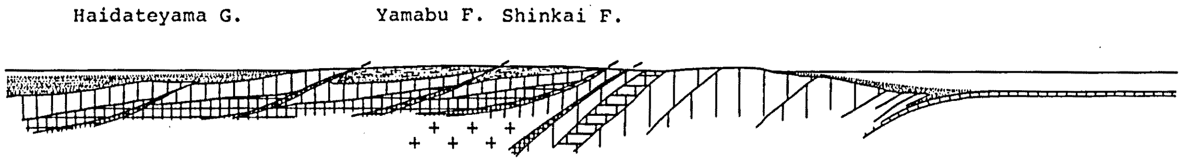


FIG. 27. Schematic paleogeographical profile during Early Cretaceous time across the Chichibu belt in Eastern Kyushu. Late Jurassic to Cretaceous sediments would be conveyed by thrust sheets in order each formation were deposited. (not to scale)

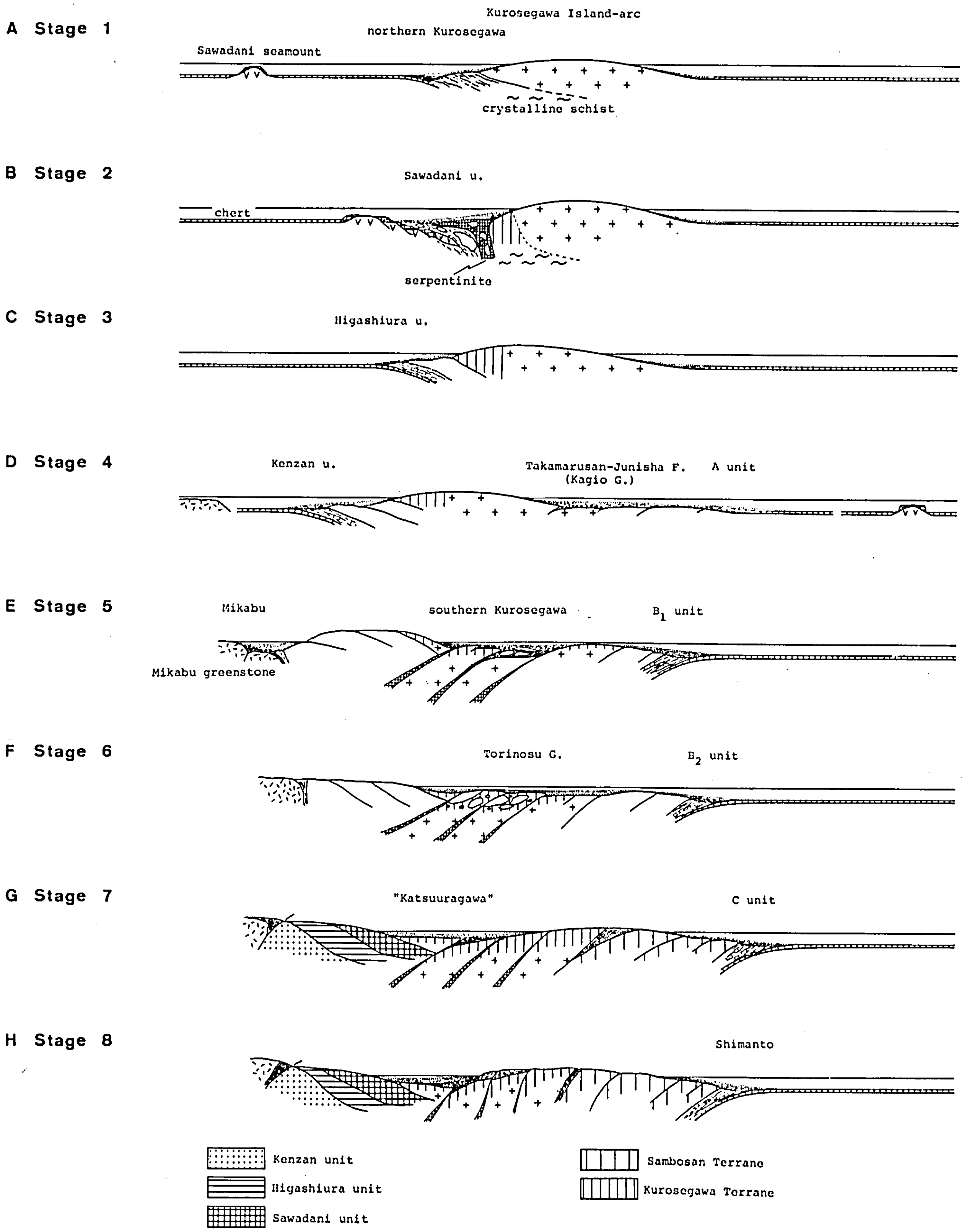


Fig. 28. Schematic paleogeographical profiles across the Chichibu belt in Eastern Shikoku during Mesozoic time. (not to scale)

sented by the sedimentation of the Torinosu Group whithin the Kurosegawa Terrane (=reorganized Kurosegawa Island-arc) and along the border between the Kurosegawa and Sambosan Terranes, and by the accumulation of the B2 unit of the Sambosan Terrane.

Stage 7 (late Late Jurassic-early Early Cretaceous; Fig. 28-G): This stage is represented by the accumulation of the Sambosan Terrane. The formation of basin deposits on the Kurosegawa and Sawadani Terranes began. The formation of Cretaceous basins may have been related to the south verging thrust movement.

Stage 8 (late Early Cretaceous; Fig. 28-H): This stage is represented by the accumulation of the constituent rocks of northern part of the Shimanto belt.

Stage 9 (Late Cretaceous): This stage is represented by the close of sedimentation in the structural basins on the Kurosegawa and Sawadani Terranes.

Each of stages from 2 to 7 is represented by the sedimentation of respective accretionary unit. Therefore the slight duplication of the ages between the successive two stages (=sedimentation of successive two units) is ascribed to the overlap of the sedimentary periods between adjacent accretionary units (Figs. 11, 12). The conversion of sediments into the accretionary units may have taken place at the end of stages.

Although nine stages have been distinguished throughout the development of the Chichibu belt, the initial structure of the Sawadani Terrane and that of the Sambosan Terrane were built up during the stages from 2 to 4 (phase-2) and the stages from 5 to 7 (phase-3) respectively. The change of the stage 4 to the stage 5 must be related to the closure of the Sawadani Sea by the probable collision of the Kurosegawa Island-arc and the geological body containing the Mikabu belt, Sambagawa belt and Paleo-Ryoke belt. The regional differences in the present geologic structure of the Chichibu belt are mainly due to the diastrophism during the stages from 7 to 9 or more later.

From its tectonic development analysed above, the Chichibu belt should be recognized as a general name of the following three independent terranes, the Kurosegawa Terrane, the Sawadani Terrane and the Sambosan Terrane.

The Kurosegawa Terrane may be defined as a realm converted from an older island-arc (Kurosegawa Island-arc) through Jurassic diastrophism. The Sawadani Terrane is a province occupied by Early to early Middle Jurassic accretionary prism which was formed along the northern front of the Kurosegawa Island-arc. The Sambosan Terrane is a province occupied by Middle Jurassic to Early Cretaceous accretionary prism which was formed along the southern front of the Kurosegawa Terrane.

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Note: Completed yet unpublished item is indicated by (MS) after the date.

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Explanation of Plate 1

1, 2. Microphotographs of serpentinite sandstone. 1: open nicol, 2: crossed nicols, scale bar: 1 mm.
3. Microphotograph of *Glomospira* sp. (smaller foraminifer) in serpentinite sandstone. Scale bar: 1 mm.
4. Serpentinite lenses in pebbly mubstone of the southern Kurosegawa Terrane to the south of Shiraishi.
5. Facies-2 mudstone of the Junisha Formation having spherical nodule.
6. Sandstone and conglomarate of the Takamarusan Formation (Kagio Group) in the southern slope of Mt. Takamaru.
7. Sandstone-conglomerate block surrounded by pebbly mudstone of the southern Kurosegawa Terrane at the riverbed of the Sabudani Valley.

Explanation of Plate 2

1. Thin section (crossed nicols) of sandy matrix of the olistostrome in the B zone of the Sambosan Terrane. scale bar=1 cm.
2. Thin section (crossed nicoles) of chert breccia of the B zone. scale bar=1 cm.
3. Thin section (crossed nicoles) of pebbly sandstone of the A zone. scale bar=1 cm, ls: limestone olistolith.
4. Thin section (crossed nicoles) of albite spotted basic schist contained in serpentinite in the south of Sabudani. scale bar=1 cm.
5. Microphotograph (open nicol) of high P/T type schist in the Ohyohchi serpentinite body. scale bar=0.1 mm, 1: lawsonite.
6. Thin section (crossed nicols) of psammitic schist block (sch) and surrounding pebbly mudstone which overlies the Ohyohchi serpentinite body. scale bar=1 cm, b: basaltic fragment.
7. Thin section (crossed nicols) of the facies-1 mudstone of the Junisha Formation. scale bar=1 cm, c: carbonate nodules.
8. Thin section (open nicol) of the facies-2 mudstone. scale bar=1 cm.

Explanation of Plate 3

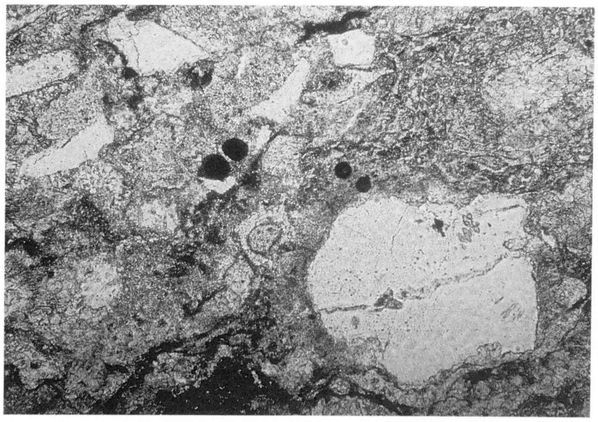
scales are 0.2 mm
1. *Follicucullus scholasticus* Ormiston & Babcock. Loc. 41.
2. *F.* sp. cf. *F. charveti* Caridroit & De Wever. Loc. 41.
3. *Neoalbaillella optima* Ishiga & Imoto. Loc. 44.
4. *Albaillella triangularis* Ishiga et al. Loc. 44.
5. *A.* sp. cf. *A. asymmetrica* Ishiga et al. Loc. 45.
6. *A.* sp. cf. *A. levis* Ishiga et al. Loc. 41.
7. *A.* sp. D Ishiga et al. Loc 45.
8. *Pseudoalbaillella* sp. aff. *Ps. longicornis* Ishiga & Imoto. Loc. 41.
9, 10. *Ps.* spp. Loc. 41.
11. *Pseudotormentus* sp. cf. *Ps. kamigoriensis* De Wever & Caridroit. Loc. 41.

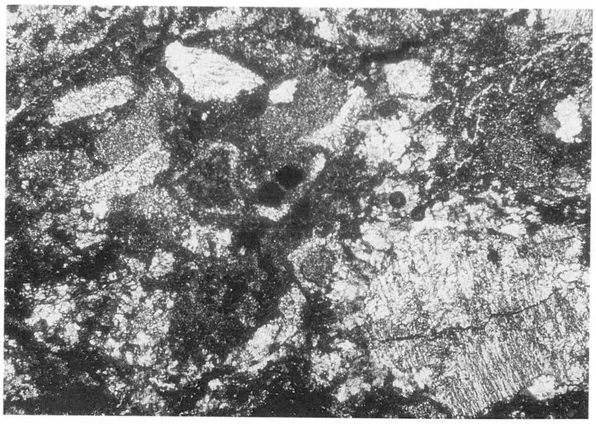
Explanation of Plate 4

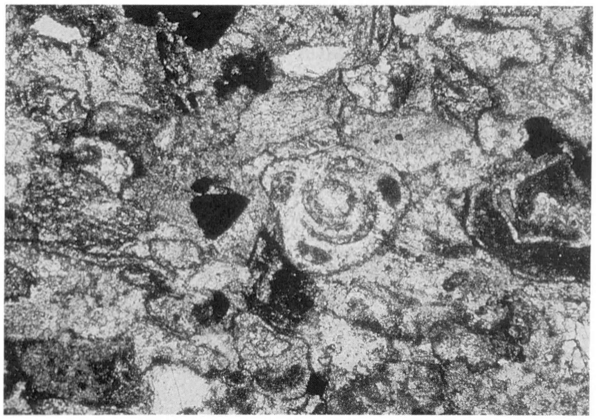
scales are 0.2 mm
1. *Pantanellium* sp. cf. *P. kluense* Pessagnd & Blome. Loc. 6.
2, 3. *Bagotum* spp. 2: Loc. 11, 3: Loc. 13.
4, 5 *Natoba minuta* De Wever. 4: Loc. 12, 5: Loc. 13.
6. *Parahsuum simplum* Yao. Loc. 7.
7. *Broctus* sp. Loc. 5.
8. *Canoptum* sp. Loc. 14.
9. *Parahsuum* sp. D Yao et al. Loc. 15.
10. *Gigi fustis* De Wever. Loc. 13.
11. *Spongosaturnalis tetraspinus* Yao. Loc. 25.
12. *Tricolocapsa* (?) *fusiformis* Yao. Loc. 22.
13. *Stichocapsa japonica* Yao. Loc. 22.
14. *Eucyrtidiellum unumaense* (Yao). Loc. 27.
15. *Unuma echinatus* Ichikawa & Yao. Loc. 15.
16–19. *U.* spp. 16: Loc. 18, 17 & 18: Loc. 22, 19: Loc. 23.
20. *Stichocapsa tegiminis* Yao. Loc. 22.
21. *Cyrtocapsa mastoidea* Yao. Loc. 17.
22. *C.* sp. *C. mastoidea* Yao. Loc. 22.
23. *C.* (?) sp. Loc. 25.
24. *Tricolocapsa* sp. cf. *T. rüsti* Tan. Loc. 27.
25. *T.* sp. cf. *T. parvipora* Tan. Loc. 27.

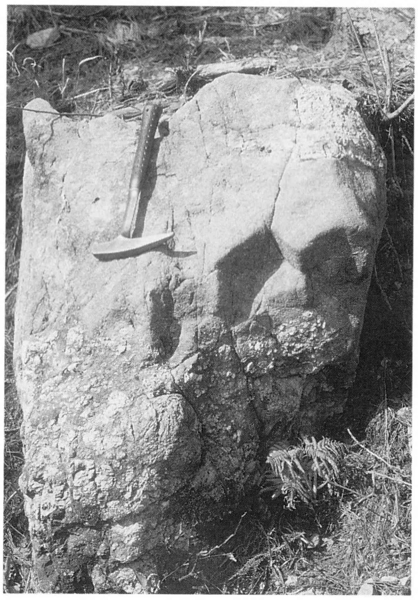
Explanation of Plate 5

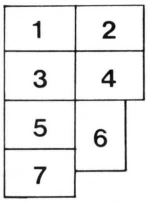
scales are 0.2 mm
1. *Tricolocapsa plicarum* Yao. Loc. 29.
2. Nassellaric gen. and sp. indet. A. Loc. 25.
3, 4. Nassellaria gen. and sp. indet. B. 3: Loc. 23, 4: Loc. 22.
5. *Parvicingula* sp. F. Yao et al. Loc. 23.
6. *Tricolocapsa tetragona* Matsuoka. Loc. 29.
7. *Protunuma turbo* Matsuoka. Loc. 29.
8. *Archaeodictyomitra* sp. R. Yao et al. Loc. 28.
9. *Dictyomitrella* (?) *Kamoensis* Mizutani & Kido. Loc. 28.
10. *Guexella nudata* (Kocher). Loc. 28.
11. *Dicolocapsa conoformis* Matsuoka. Loc. 28.
12. *Tricolocapsa conexa* Matsuoka. Loc. 28.
13. *Williriedellum crystallinum* Dumitrica. Loc. 33.
14. *Protunuma* (?) *ochiensis* Matsuoka. Loc. 28.
15. *Stichocapsa robusta* Matsuoka. Loc. 32.
16. *Mirifusus guadalupensis* Pessagno. Loc. 33.
17. *Cinguloturris carpatica* Dumitrica. Loc. 32.
18. *Gongylothorax sakawaensis* Matsuoka. Loc. 32.
19. *Stilocapsa* (?) *spiralis* Matsuoka. Loc. 32.
20. *Mirifusus mediodilatatus* (Rüst). Loc. 33.
21. *Stichocapsa naradaniensis* Matsuoka. Loc. 31.
22. *Eucyrtidiellum ptictum* (Riedel & Sanfilippo). Loc. 31.
23, 24 *Holocryptocanium barbui* Dumitrica. Loc. 34.
25. *Archaeodictyomitra sliteri* Pessagno. Loc. 35.
26. *Pseudodictyomitra lodogsaensis* Pessagno. Loc. 34.







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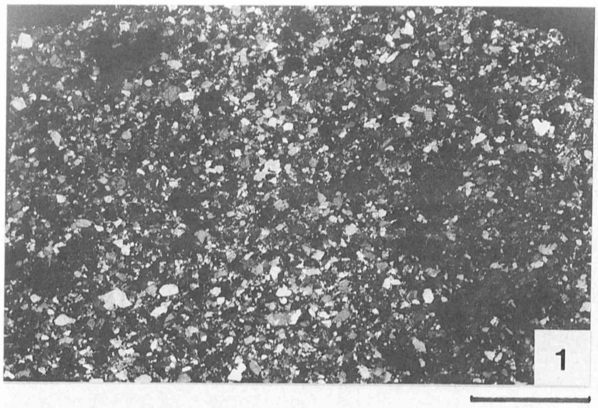
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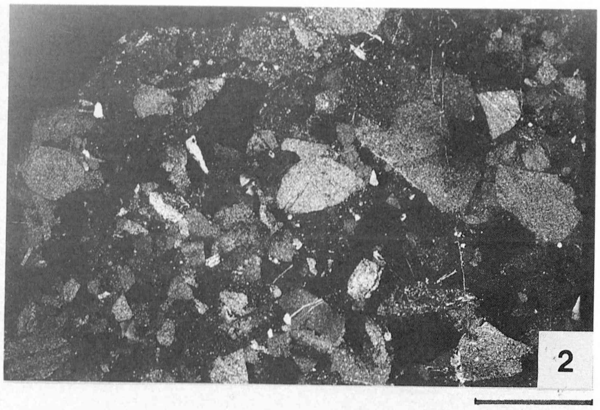
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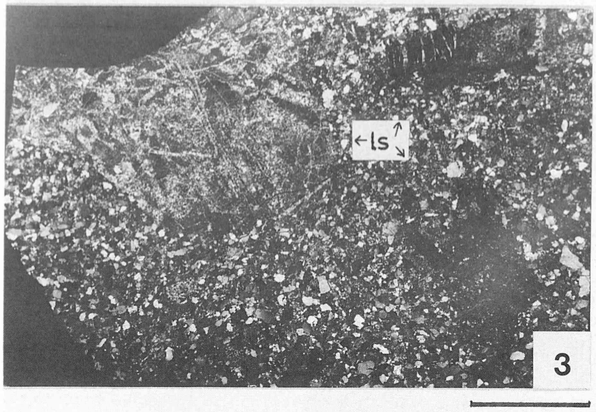
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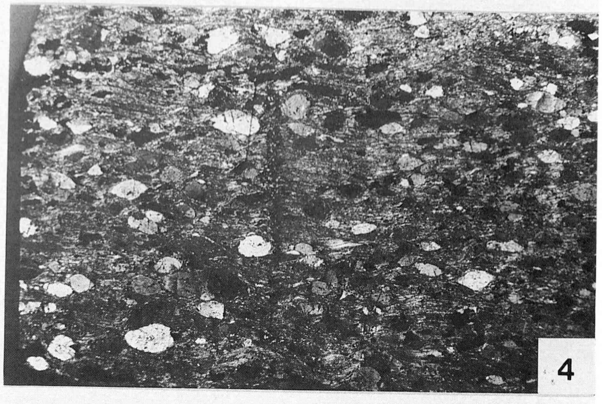
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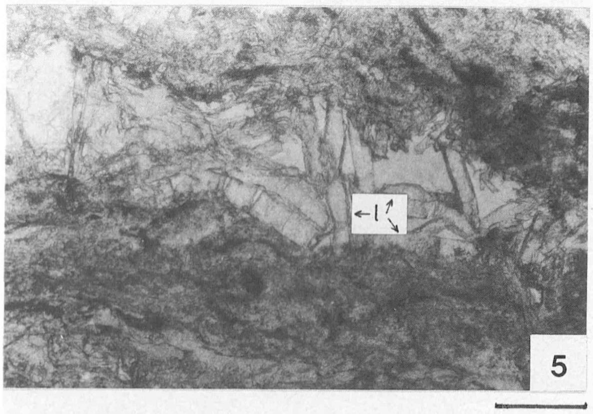
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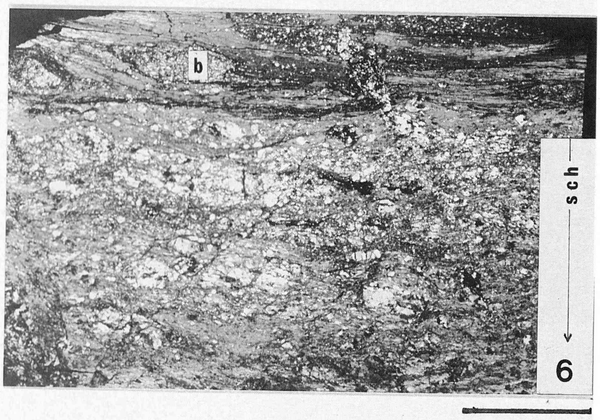
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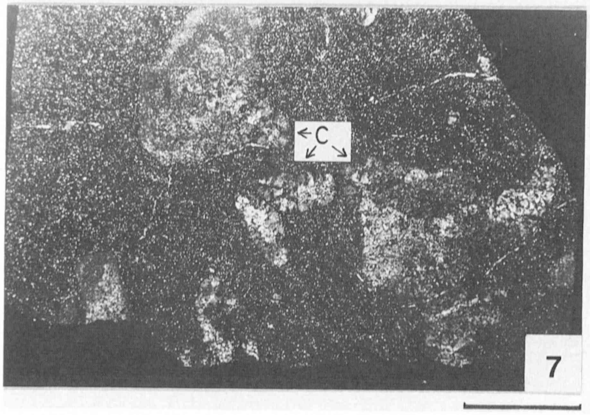
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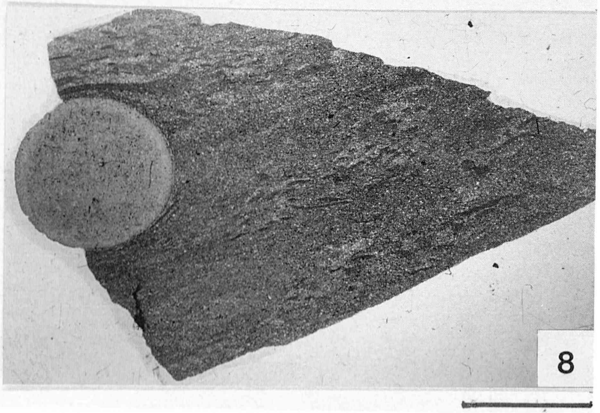
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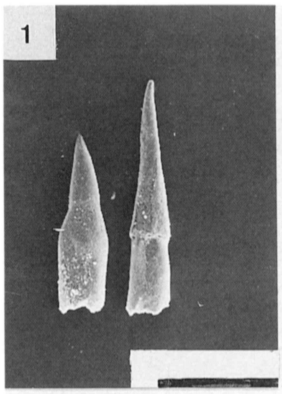
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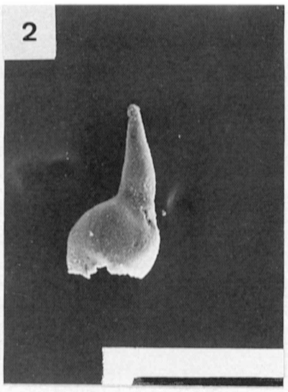
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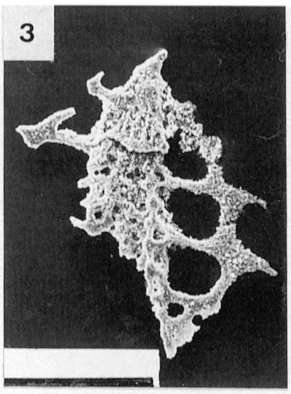
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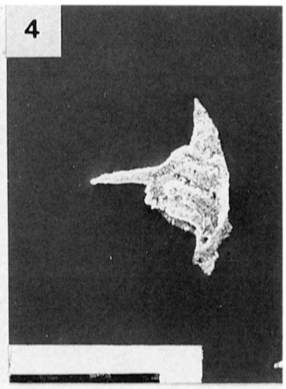
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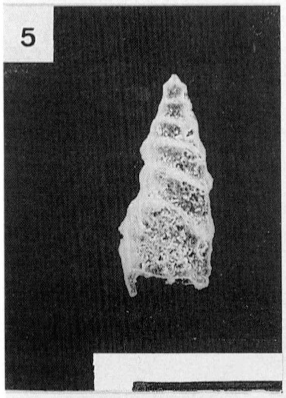
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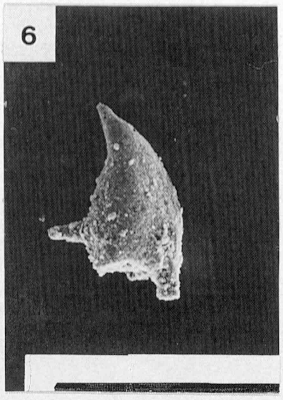
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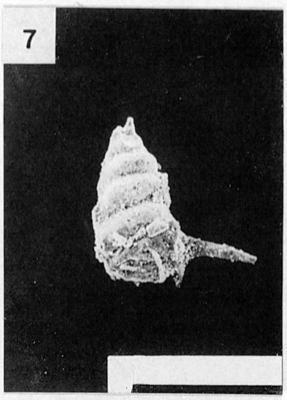
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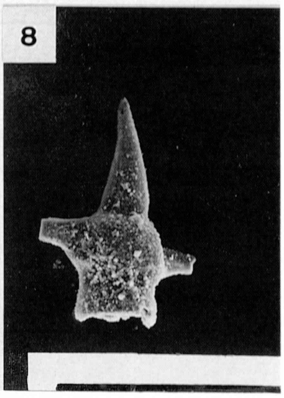
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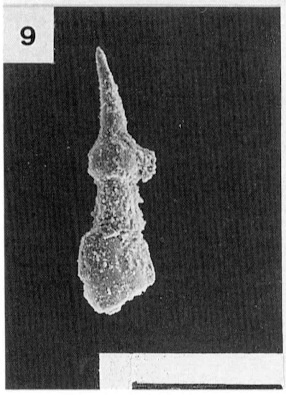
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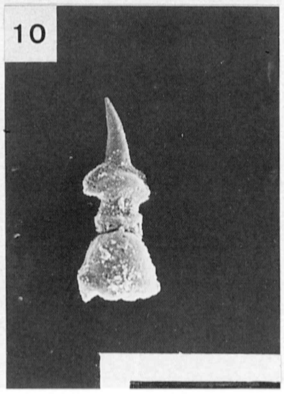
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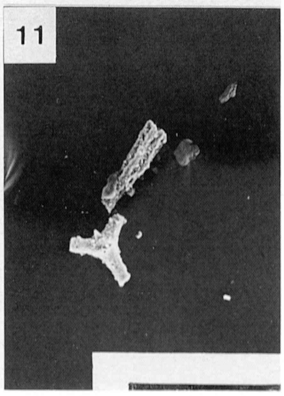
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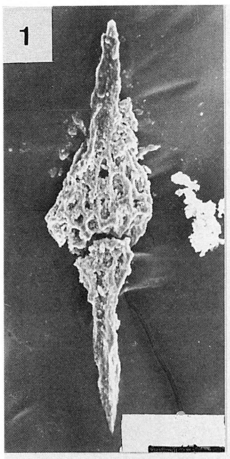
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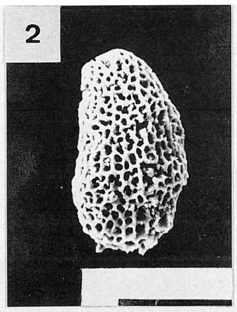
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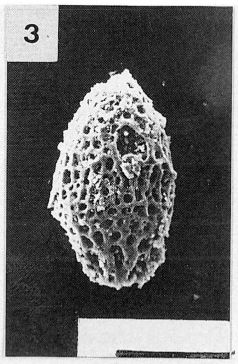
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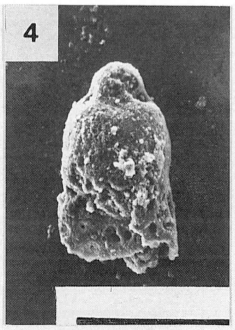
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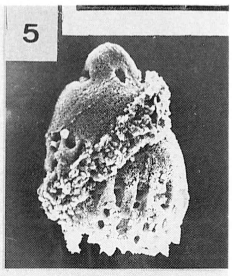
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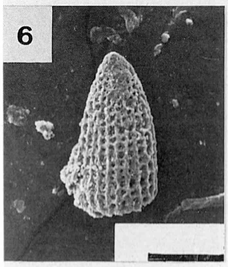
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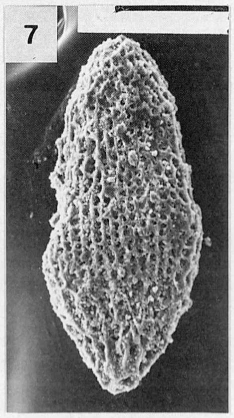
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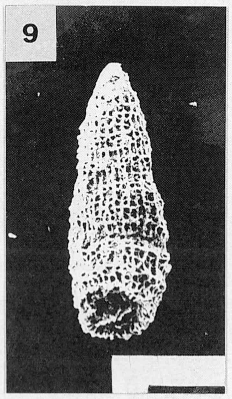
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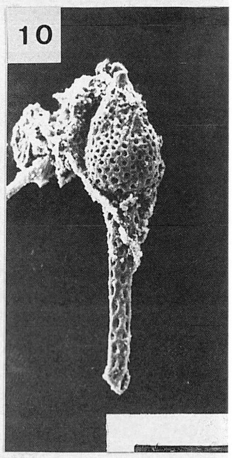
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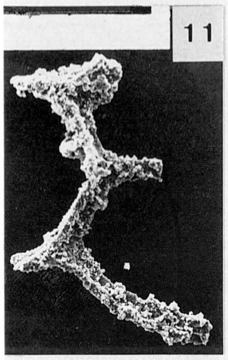
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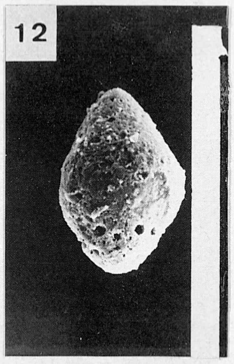
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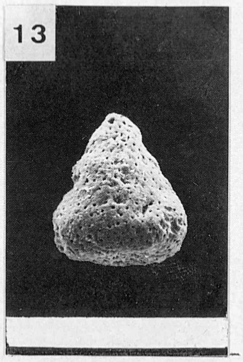
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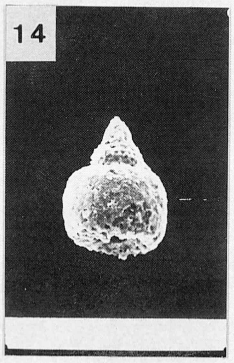
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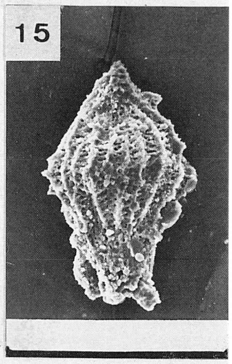
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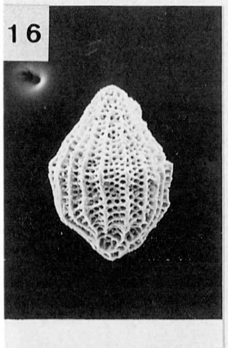
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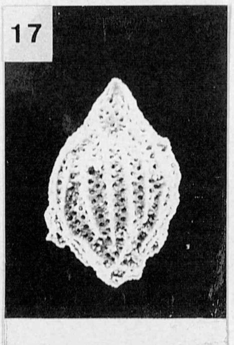
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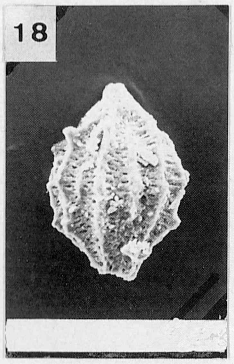
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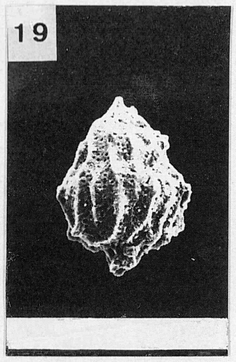
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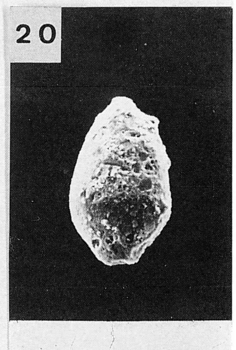
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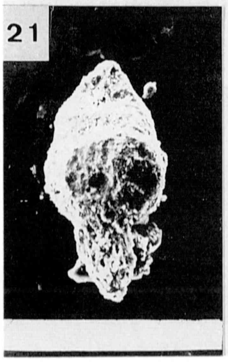
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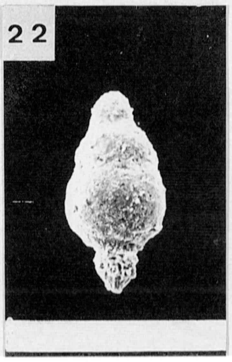
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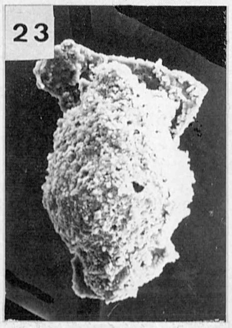
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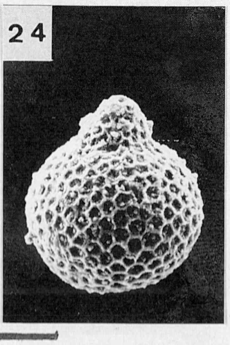
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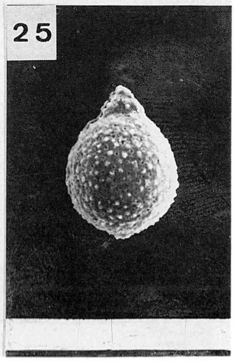
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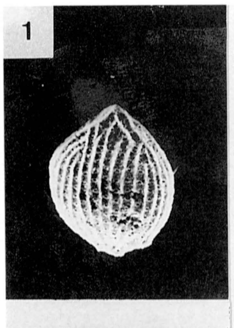
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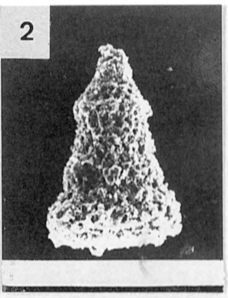
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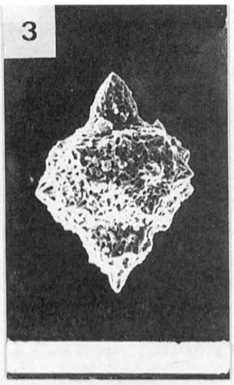
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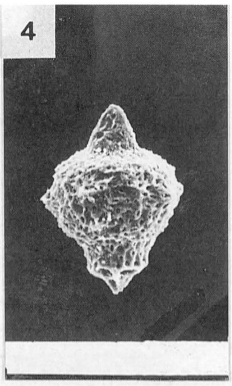
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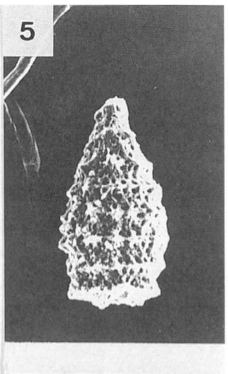
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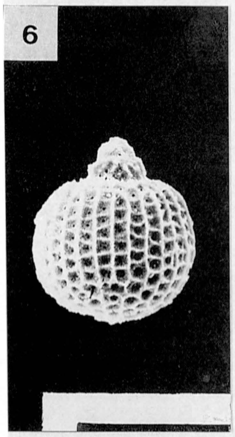
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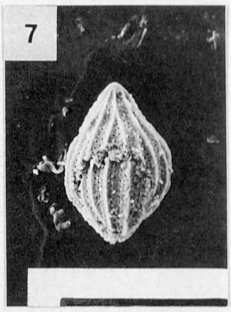
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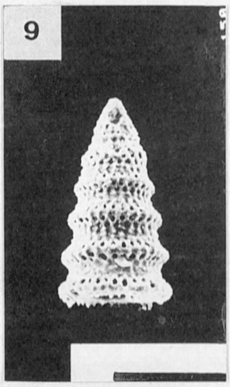
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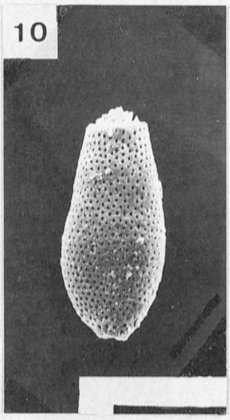
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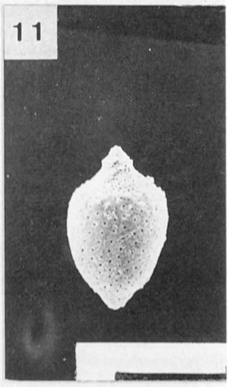
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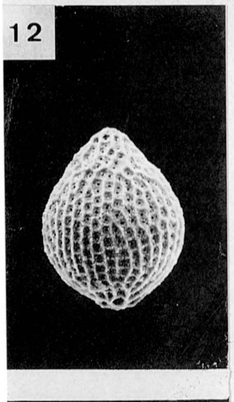
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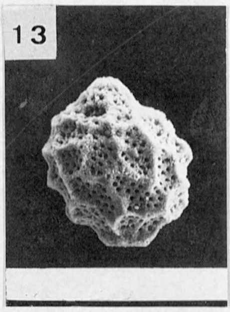
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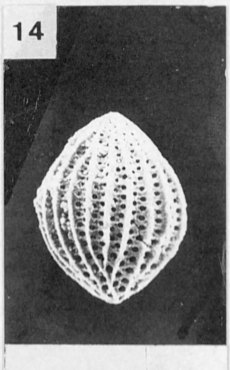
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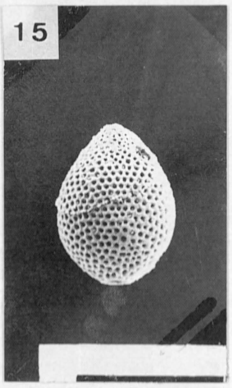
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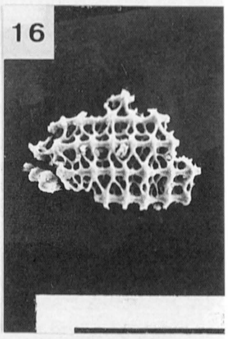
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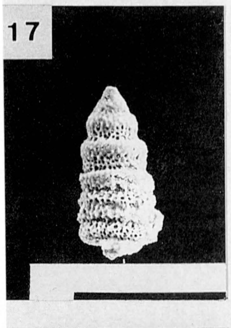
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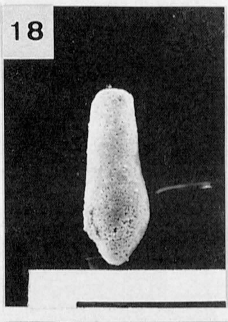
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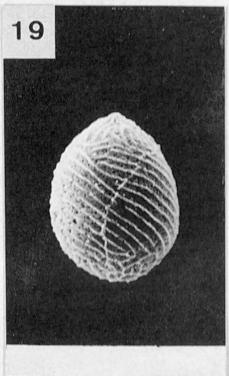
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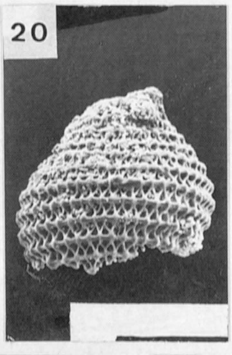
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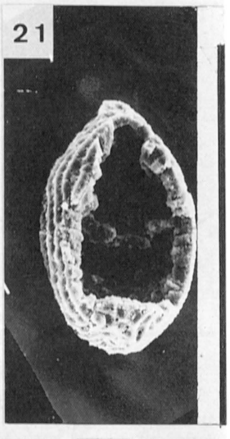
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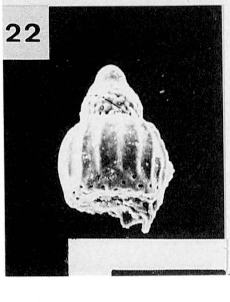
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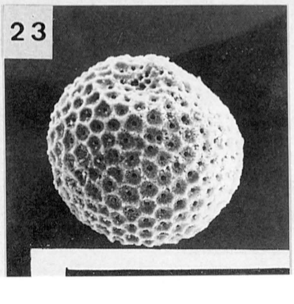
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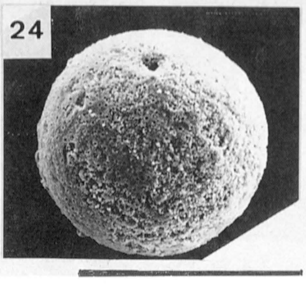
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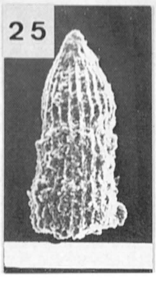
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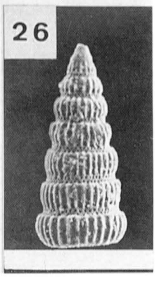
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