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Geology of the Kudoyama area in the western Kii Peninsula, Southwest Japan, with reference to disappearance of the Chichibu terrane

Chikao Kurimoto*

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Abstract: The western Kii Peninsula is situated in the Outer Zone of the Southwest Japan which is generally characterized by E-W trending zonal structure and it is underlain by the rocks of the Sambagawa, Chichibu and Shimanto terranes from north to south. However, rocks of the Chichibu terrane are not croped out on the land surface in the central part of the Kii Peninsula, and the zonal structure is incomplete here. In this paper, geology of the Kudoyama area of Wakayama Prefecture, where the Chichibu terrane is absent on the land surface, is described. Particularly the process of uplift and disappearance of the Chichibu terrane in the western Kii Peninsula is presented.

In the Kudoyama area metamorphic rocks of the Sambagawa terrane are distributed to the north of Cretaceous rocks of the Shimanto terrane. Because the rocks of the Shimanto terrane correspond with the northeastern extension of the Upper Cretaceous Hanazono Formation which occupies the northern-most part of the Shimanto terrane, they are also called the Hanazono Formation in this paper. The Hanazono Formation is in fault contact with the Sambagawa Metamorphic Rocks through the Aridagawa Tectonic Line. The formation is divided into the Northern and Southern Units by a fault (Kamiya Fault) and the Northern Unit is characterized by existence of more obvious foliation as compared with the Southern Unit. This paper presents description of lithology, radiolarian and K-Ar ages, distribution of metamorphic minerals in greenstones and characteristics of the Aridagawa Tectonic Line.

On the basis of these geologic data, process of disappearance of the Chichibu terrane in the western Kii Peninsula is considered as follows. After the sedimentation of Cretaceous strata of the Chichibu terrane, the Chichibu terrane was thrust over the Sambagawa terrane to the north and the Shimanto terrane to the south respectively. Subsequently, the Aridagawa Tectonic Line evolved, accompanied with deformation of the low-angle pile structure of these terranes and a relative uplift took place on the southern side of the Aridagawa Tectonic Line. As the extent of the uplift was larger in the eastern part of the region, the Chichibu terrane, a part of the Sambagawa terrane and the uppermost Shimanto unit were eroded out in this eastern part and the Hanazono Formation which was underthrust far north and deeper under the Chichibu terrane uplifted up to the land surface.

1. Introduction

Recently, stratigraphy, geologic structure and geologic ages of the Paleozoic and Mesozoic rocks in Japan have been reexamined on the basis of detailed mapping, occurrence of conodonts and radiolarians, and measurement of radiometric ages of white mica from weakly metamorphic rocks.

Since 1976, the author has been engaged in the research of the Paleozoic and Mesozoic rocks in the western Kii Peninsula. The study area is situated in the Outer Zone of the Southwest Japan which is generally characterized by the E-W trending rocks of the Sambagawa,

* Geology Department

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Chichibu and Shimanto terranes from north to south. However, rocks of the Chichibu terrane are not croped out on the land surface for about 50 km from east to west in the central part of the Kii Peninsula and the zonal structure which characterizes the Outer Zone of Southwest Japan is incomplete here because of a later structural disruption.

For discussing the Late Mesozoic tectonism and geologic evolution of the Sambagawa, Chichibu and Shimanto terranes, the Kii Peninsula is a suitable area. The purpose of this paper is to clarify the geology of the Kudoyama area in the western Kii Peninsula and to discuss the process which causes disappearance of the Chichibu terrane.

The Chichibu terrane is divided into the Northern Chichibu, Kurosegawa and Southern Chichibu terranes on the basis of lithology and geologic age (Ichikawa *et al.*, eds., 1990). In this paper, however, the term, the Chichibu terrane is applied for a general name which includes the Northern Chichibu, Kurosegawa and Southern Chichibu terranes. Various tectonic models of the Kurosegawa terrane have been proposed by many geologists. For example, microcontinent collision model (Hada and Kurimoto, 1990), strike-slip model (Taira *et al.*, 1981) and the tectonic outlier originated from the Inner Zone (Isozaki and Maruyama, 1991). The author considers that the Kurosegawa terrane has close relation to the Northern and Southern Chichibu terranes and that a strike-slip faulting played an important role in tectonic modification of these terranes.

2. Outline of geology

In the Kii Peninsula, absence of the Chichibu terrane is recognized in three areas, such as the Hanazono area, Kudoyama area and central part of Kii Peninsula from west to east (Fig. 1A). Outline of geology of these three areas is as follows.

(1) Hanazono area : Kurimoto (1982) discovered Late Cretaceous radiolarians from the complex formerly referred to the "Chichibu System", and introduced the new name "Hanazono Formation" for the exposed geologic unit. Furthermore, he showed that this formation belongs actully to the Shimanto terrane and that any member of the Chichibu terrane is not recognized on the land surface, consequently Sambagawa terrane is in direct contact with the Shimanto terrane along the Aridagawa Tectonic Line. Rocks of the Chichibu terrane are bounded on the east by the Itao Fault, mapped in the northern part by Kurimoto (1982) and the southern part by Saka (1969) and Saka and Takagi (1983).

(2) Kudoyama area (present study area) : This area is located northeast of the Hanazono area. Here the Sambagawa Metamorphic Rocks are in direct tectonic contact with the Cretaceous rocks of the Shimanto terrane, and phyllitic rocks are exposed along the northern margin of the Shimanto terrane. Here the rocks of the Shimanto terrane are composed of the northern extension of the Hanazono Formation of Kurimoto (1982). The Aridagawa Tectonic Line significantly changes its trend from NE-SW to N-S trend and consequently the Sambagawa terrane suddenly becomes narrower (Fig. 1A and B). Kanai *et al.*(1990) reported the geology and K-Ar age of the Kudoyama area and its adjacent area. Kurimoto (1993) reported K-Ar ages of white micas from pelitic rocks and a greenstones of the Sambagawa, Chichibu and Shimanto terranes in the Hanazono and Kudoyama areas and discussed its geological significance.

(3) Central part of the Kii Peninsula : Here the distribution of the Sambagawa Metamorphic Rocks is extremely narrow, and only the rocks of the spotted zone, which is characterized by appearance of albite porphyroblast, are recognized. In some places, the Sambagawa Metamorphic Rocks are even absent, consequently the geologic units of the Inner Zone are in direct contact with rocks of the Shimanto terrane along the Median Tectonic Line (Yamato Omine Research Group, 1981; 1989; 1992).

Activity of the Aridagawa Tectonic Line played an important role in the disappearance of the Chichibu terrane in these areas. This line corresponds to the "Mikabu Tectonic Line", which was regarded as the boundary fault between the Sambagawa and Chichibu terranes.

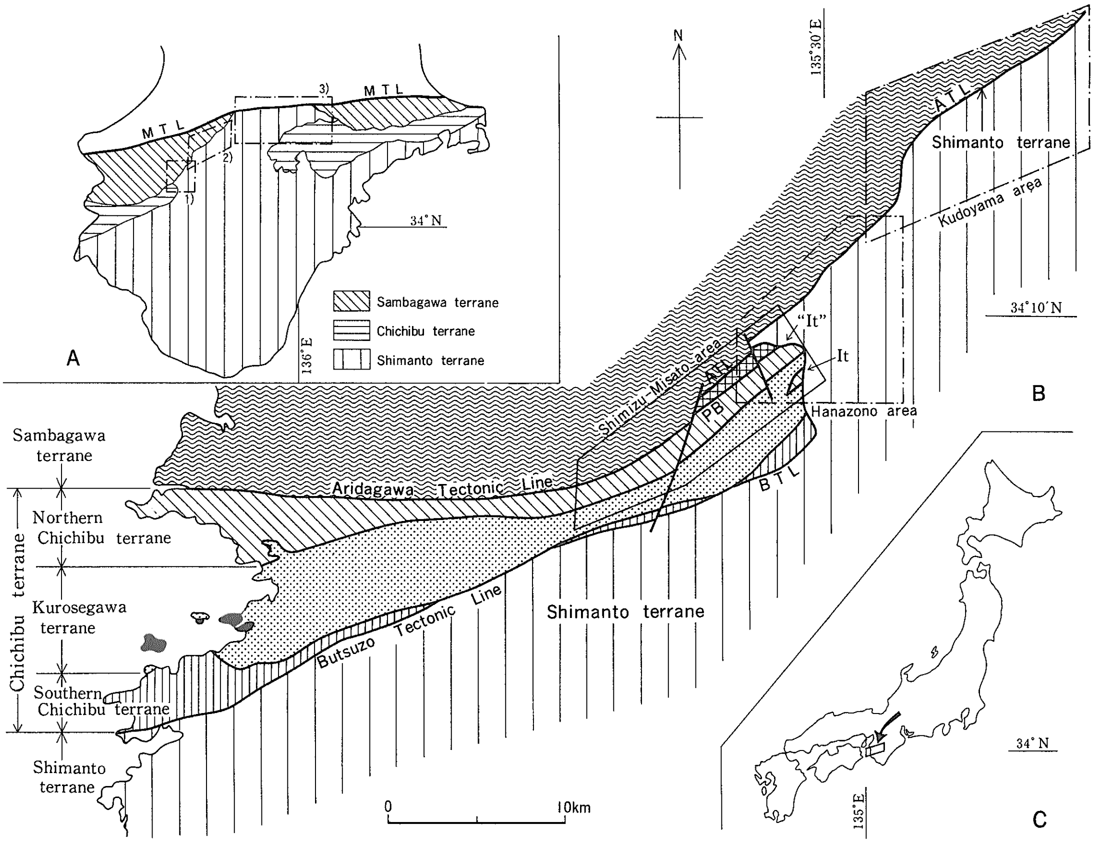

Fig. 1 Geologic outline of the western Kii Peninsula.
Fig. 1A is based on 1:1,000,000 Geological Map of Japan (3rd edition) by Geological Survey of Japan (1992). (1) Hanazono area, (2) Kudoyama area, (3) Central part of Kii Peninsula.
Fig. 1B : ATL; Aridagawa Tectonic Line, BTL; Butsuzo Tectonic Line, It; Itao Fault, PB; primary boundary of the Sambagawa and Chichibu terranes. Cross stripes part between the ATL and PB in the Shimizu-Misato area shows the Kebara Formation of the Sambagawa terrane (Kurimoto, 1986a). Solid parts within the Kurosegawa terrane show the lenticular bodies of the Kurosegawa Tectonic Zone which are interpreted as part of an exotic ancient mass of continental affinity.

The "Mikabu Tectonic Line" was traced in the "Kainan" District (Hirayama and Tanaka, 1956b), "Todorogi" District (Hirayama and Tanaka, 1956a), "Koyasan" District (Hirayama and Kambe, 1959) and "Yoshinoyama" District (Hirayama and Kishimoto, 1957) from west to east in the western Kii Peninsula. Ichikawa and Hada (1966) and Hada (1967) called the "Mikabu Tectonic Line" in the middle-Aridagawa district, the Aridagawa Tectonic Line and referred to the post-Cretaceous activity of this line. Iwahashi (1970) called the northeastern extension of the Aridagawa Tectonic Line the "Hase-Kebara Fault" in the upper-Kishigawa district which corresponds to the Kudoyama area in this paper. Kurimoto (1982, 1986a, b) traced the Aridagawa Tectonic Line in the Shimizu-Misato and Hanazono areas from west to east (Fig. 1B).

3. Geology of the Kudoyama area

The study area covers at Kudoyama-cho, Koya-cho, and the southern part of Hashimoto-shi, Wakayama Prefecture. Structural division by Hirayama and Kambe (1959) and a new division by the author are shown in Fig. 2. Geologic map of the area is shown in Fig. 3.

The Sambagawa Metamorphic Rocks are distributed to the north of the Hanazono Formation and are separated from the Hanazono Formation by the Aridagawa Tectonic Line. The Hanazono Formation is divided into the Northern and Southern Units on the basis of difference in development of foliation. Both units are separated by a fault named the Kamiya Fault, which is considered to be a subsidiary fault of the Aridagawa Tectonic Line.

3.1 Sambagawa terrane

The Sambagawa Metamorphic Rocks are bounded by the Aridagawa Tectonic Line on the south. The Sambagawa terrane in the area almost corresponds to the Shiga Zone of Hirayama and Kambe (1959) and non-spotted zone of Iwahashi (1962).

3.1.1 Lithology

The rocks of the Sambagawa terrane consist mainly of pelitic schists and greenschists associated with psammitic, siliceous and quartz schists. Pelitic schists are black to grayish black and are interbedded with psammitic, siliceous and quartz schists. Quartz veins are usually present parallel or slightly oblique to schistosity. Greenschists are green, dark green, purple or dark red and are occasionally associated with red quartz schists and red pelitic schists. Greenschists are composed of basic lava and volcaniclastic rocks, and the latter is composed of hyaloclastite, pillow breccia and tuff. Sometimes greenschists can be traced for a distance of several kilometers, but are generally mapped as lenticular bodies in pelitic schists (Fig. 3). Interbedded psammitic and pelitic schists are occasionally observed.

3.1.2 Geologic structure

Schistosity strikes ENE-WSW and dips 30°

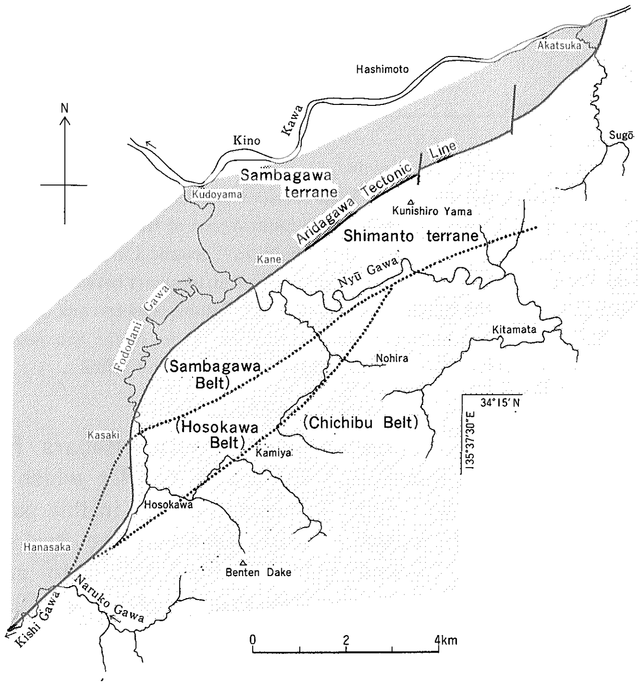

Fig. 2 Structural divisions of the Kudoyama area, Wakayama Prefecture.
Dense and sparse dotted areas show the Sambagawa and Shimanto terranes respectively, and the Aridagawa Tectonic Line is newly defined by the author. Parenthesized words (Sambagawa, Hosokawa and Chichibu Belts) and dotted lines show old division by Hirayama and Kambe (1959) where the Hosokawa Belt was regarded as a northern marginal zone of the Chichibu Belt.

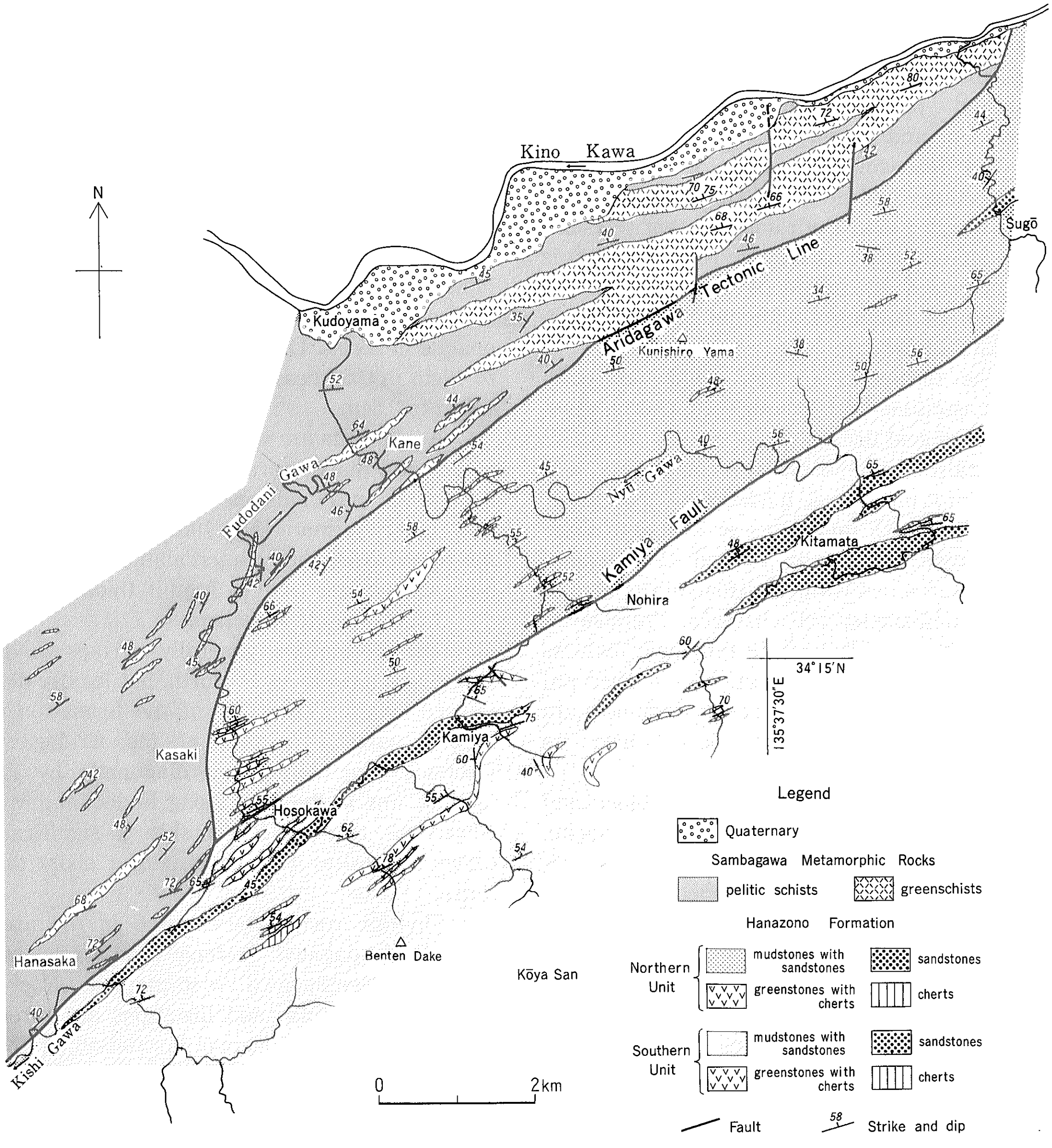

Fig. 3 Geological map of the Kudoyama area.

to 80°north. The ENE-WSW strike is generally sub-parallel to that of the Aridagawa Tectonic Line. Toward the Aridagawa Tectonic Line, the strike becomes convergent to that of the tectonic line in the area along the Fudodanigawa where this tectonic line trends N-S. Lineations are well developed on the bedding schistosity. Lineations on schistosity surface generally strike between NE-SW and E-W and plunge 10°to 30°west. Microfolds frequently occur in pelitic schists and in the alternation of pelitic and psammitic schists.

3.2 Shimanto terrane

The rocks of the Shimanto terrane in the Kudoyama area correspond to the northeastern extension of the Hanazono Formation (Kurimoto, 1982). The area here referred to the Shimanto terrane was formerly included in the Chichibu Belt, Hosokawa Belt and the southern marginal part of the Sambagawa Belt (Hirayama and Kambe, 1959 : Fig. 2).

The Hanazono Formation is divided into the Northern and Southern Units separated by the Kamiya Fault. Both units present the similar lithologic features, but the Northern Unit is characterized by existence of more obvious foliation as compared with the Southern Unit.

3.2.1 Lithology

The formation consists mainly of mudstones assciated with greenstones, cherts, sandstones and acid tuffs.

Stratified mudstones are not sheared and grade into tuffaceous mudstones. Mudstones, interbedded with sandstones or including sandstone lenses, are usually sheared. Occasionally pebbly mudstones with sandstone clasts of 1cm or less in diameter are observed. Presence of red mudstones is one of the lithologic features that characterize this formation. Stratified red mudstones having several meters thick-ness are exposed. Red mudstones occur also as mudstone film in red bedded cherts.

Sandstones are gray to grayish black and belong to medium- to fine-grained lithic wacke. There are two types of the occurrence of sandstones. i) Sandstones interbedded with mudstones are several centimeters to more than 50cm thick, and occasionally showed graded bedding. The sandstones are frequently in slip contact with mudstones and show boudinage structure. ii) Sandstones which show lenticular shapes in mudstones range generally from several centimeters to more than 1m thick, and sometimes are more than 5m in thickness.

Greenstones are green, dark green or light green in color and are composed of basic lava and volcaniclastic rocks. Lava is basaltic or microgabbroic and often shows pillow structure. One of basaltic lavas is porphyritic and others are variolitic. The former is composed of plagioclase and clinopyroxene as phenocryst with plagioclase and opaque minerals as groundmass. The latter contains spherulites that are made of plagioclase and felsic minerals growing in glass. Microgabbroic lava is subophitic and is composed mainly of plagioclase and clinopyroxene associated with small amount of brown hornblende and opaque minerals. Volca-niclastic rocks are composed of hyaloclastite, pillow breccia and tuff. Greenstones are contained in mudstones as lenticular bodies and are associated with red cherts and red mudstones.

Most of cherts are red, others are white or light green. Cherts are generally bedded and are composed of fine-grained quartz and opaque minerals. One bed of cherts ranges 1cm to 10cm in thickness and mudstone film ranges 0.1cm to 0.5cm.

Acidic tuffs are white, light yellow or light green and have parallel lamination. Acidic tuffs grade into mudstones and range from several meters to more than 10m in thickness. On the other hand, thinly intercalated acidic tuffs in mudstones are 1mm to 3mm in thickness.

3.2.2 Geologic structure

The formation generally strikes ENE-WSW and dips 30° to 70° north, but locally dips toward south. The strike of the formation is usually parallel to that of the Aridagawa Tectonic Line, but is cut diagonally by the tectonic line in the area along Fudodani-gawa, where the tectonic line makes a significant curve and takes N-S trend, for a short distance.

Phyllitic rocks are exposed in the area near the Aridagawa Tectonic Line. Compared with the Sambagawa Metamorphic Rocks, however, microfolds and lineations are rarely observed in the Hanazono Formation in this area.

4. Metamorphic minerals in greenstones

Metamorphic minerals in greenstones collected by the author were examined by Mitsuoka *et al.* (1984). Occurrence of lawsonite, actinolite, pumpellyite and chlorite is examined as follows. Distribution of representative minerals in greenstones sampled from about 100 localities in the area is shown in Fig. 4. The Sambagawa Metamorphic Rocks are characterized by the occurrence of pumpellyite and

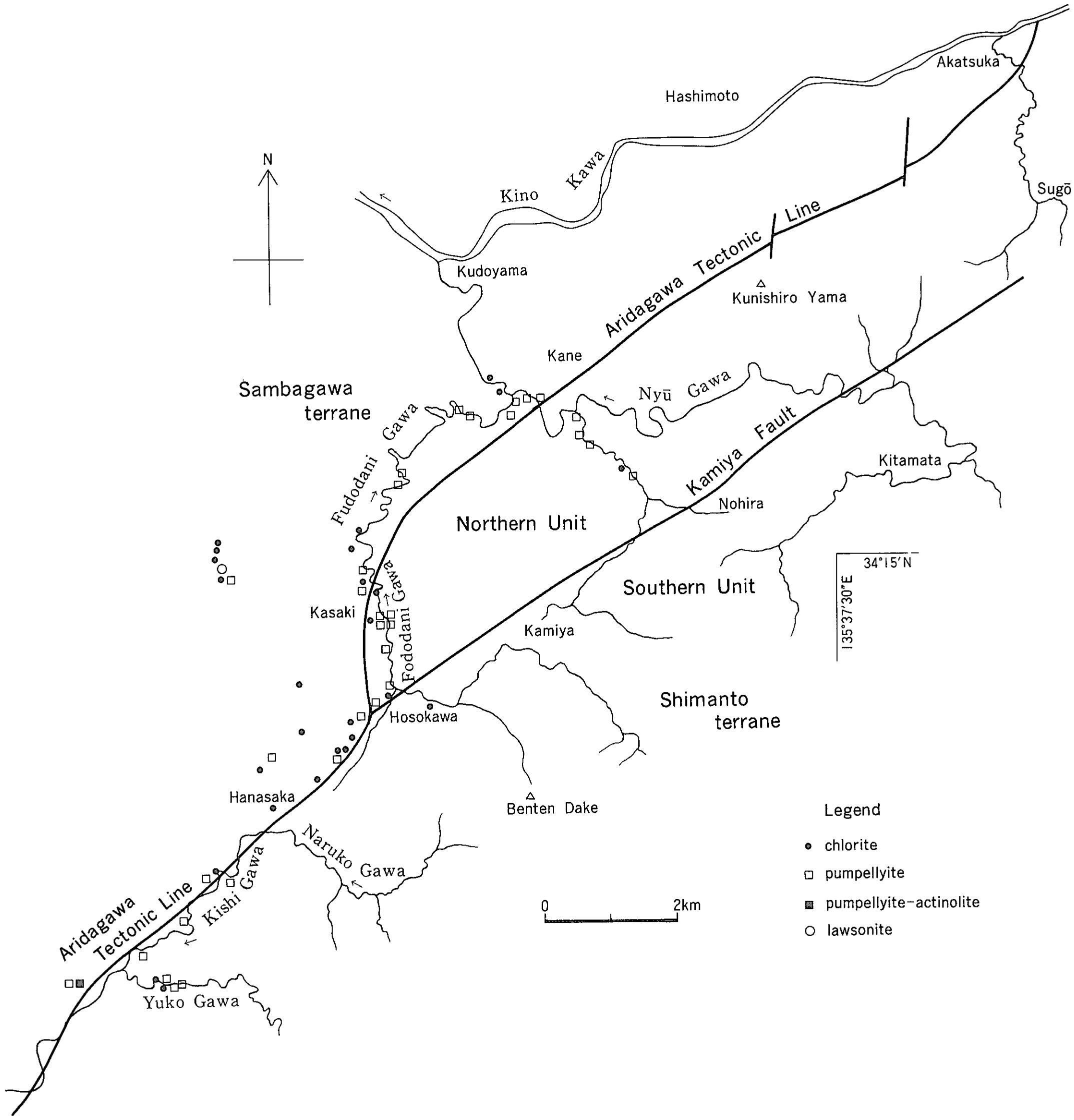

Fig. 4 Distribution of metamorphic minerals in greenstones of the Kudoyama area, Wakayama Prefecture.

chlorite. Assemblage of pumpellyite and actinolite is found in one sample of the Sambagawa Metamorphic Rocks which was collected at the southwestern part of the area (Fig. 4). Lawsonite is found in two samples which are located in the non-spotted zone near the spotted zone with albite porphyroblasts (Hirayama and Kambe, 1959 ; Akimoto, 1962). On the other hand, the Hanazono Formation is also characterized by occurrence of pumpellyite and chlorite. Therefore, in the Kudoyama area there is no distinctive difference in metamorphic minerals between the Sambagawa and Shimanto terranes in the area along the Aridagawa Tectonic Line. However microstructure shows a remarkable difference between the Sambagawa and Shimanto terranes as mentioned in Chapter 3.

5. Geochronology

5.1 Radiolarian age

Mudstones, siliceous mudstones, acidic tuffs and cherts were treated in hydrofluoric acid for extracting radiolarians. Radiolarians from the area are usually poorly preserved. Localities of 18 samples which contain identifiable radiolarians are shown in Fig. 5 and a list of

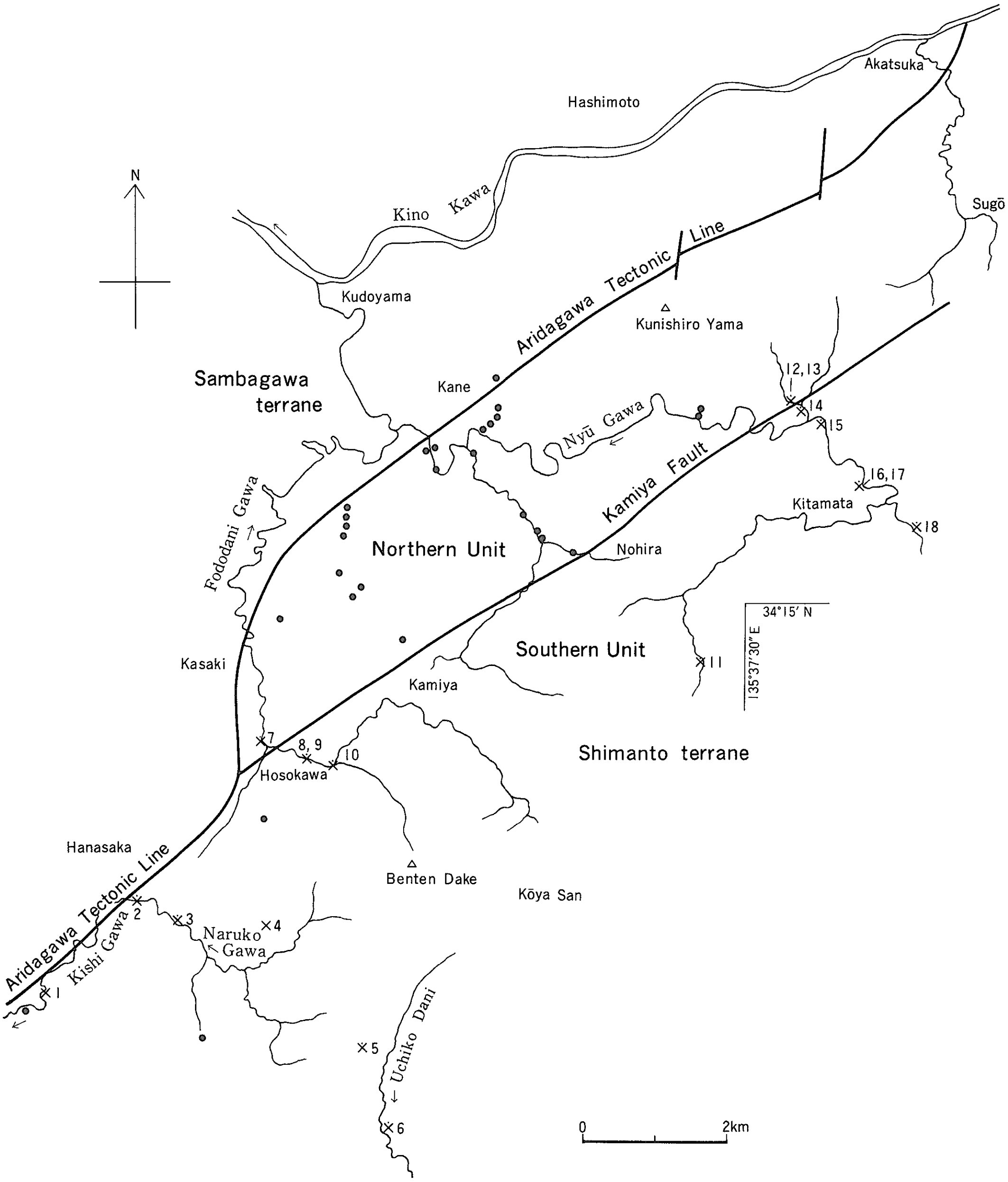

Fig. 5 Map showing the fossil localities of the Kudoyama area, Wakayama Prefecture.
Locs. 1-18 correspond to those of Table 1. Sample locations marked by solid circle yielded spherical unidentifiable radiolarians.

Table 1 Radiolarians from the Kudoyama area, Wakayama Prefecture.

locality numbers / species	Northern Unit			Southern Unit														
	7 ch	12 ms	13 si	1 ms	2 si	3 rc	4 ms	5 at	6 si	8 ch	9 ch	10 at	11 ms	14 ms	15 ms	16 ms	17 at	18 ms
Alievium sp.				+			+	+	+						+			
Archaeospongoprunum sp.		+							+									
Paronaella sp.							+											
Praeconocaryomma sp.									+									
Pseudoaulophacus sp.								+	+									
Amphipyndax stocki							+	+	+			+						
Amphipyndax sp.		+	+	+			+		+			+	+		+			
Archaeodictyomitra sp.						+	+	+			+	+	+		+			
Diacanthocapsa sp.												+						
Dictyomitra formosa							+	+	+									
Dictyomitra cf. *formosa*												+						+
Dictyomitra koslovae								+	+									
Dictyomitra cf. *koslovae*												+						
Dictyomitra sp.		+	+	+			+	+	+			+			+	+	+	
Holocryptocanium sp.		+				+	+		+		+	+			+			+
Theocapsomma sp.												+						
Nassellaria gen. and sp. indet.	+				+					+	+			+				

ms:mudstone, si:siliceous mudstone, at:acidic tuff, ch:chert, rc:red chert

radiolarians is shown in Table 1. Localities of samples containing uni-dentifiable spherical radiolarians are also shown in Fig.5. Characteristic radiolarians are shown in Plate I.

Sambagawa terrane

Only spherical unidentifiable radiolarians were obtained from one sample of siliceous schists near the Aridagawa Tectonic Line (Fig. 5). Thus, geologic age of the rocks is unknown.

Northern Unit of the Hanazono Formation

Radiolarian assemblages from Locs.12 and 13 contain *Dictyomitra* sp. and *Amphipyndax* sp. and are Cretaceous in age. From Loc.7, nassellarians of probably Cretaceous age were obtained.

Southern Unit of the Hanazono Formation

Radiolarian assemblages from Locs.5, 6, and 10 contain *Dictyomitra koslovae* and are compared with those of *D. koslovae* Assemblage Zone (Teraoka and Kurimoto, 1986) of Santonian age. Radiolarian assemblages from Locs.4 and 18 contain *Dictyomitra formosa*, and are compared with those of *D. formosa* to *D. koslovae* Assemblage Zones (Teraoka and Kurimoto, 1986) of Turonian to Santonian age. Radiolarian assemblages from Locs.1, 11 and 15 contain *Alievium* sp., *Amphipyndax stocki* or *Amphipyndax* sp. and are Late Cretaceous in age. Radiolarian assemblages from remaining localities (Locs.2, 3, 8, 9, 14, 16 and 17) are probably of Cretaceous age. Thus, radiolarians obtained from rocks of the area are roughly comparable with those from the Hanazono Formation in the Hanazono area (Kurimoto, 1982), although radiolarians which characterize *Amphipyndax enesseffi* zone are not discovered in the Kudoyama area.

5.2 K-Ar age

In the northeastern part of the Wakayama Pre-fecture including the Kudoyama area, the K-Ar ages of recrystallized white micas from mudstones and greenstones have been recently reported (Kanai *et al.*, 1990 ; Kurimoto, 1993).

From the study area (Kurimoto, 1993), K-Ar ages of samples from the non-spotted zone of the Sambagawa terrane on the north of the Aridagawa Tectonic Line range from 68.7 to 78.6 Ma. On the other hand, the K-Ar age from the Northern Unit of the Hanazono Formation is 66.8 Ma and it is very close to the youngest age of the non-spotted Zone. As only one sample is analyzed from the Hanazono Formation, it is difficult to conclude about significance of the K-Ar age. But the K-Ar age possibly indicates a metamorphic age because it is younger than radiolarian age which indicates sedimentary age. Judging from metamorphic grade and closure temperature of K-Ar system in white mica, it is considered that the K-Ar ages from the non-spotted zone and the Hanazono Formation show the time of the metamorphism (Kurimoto, 1993).

6. Aridagawa Tectonic Line

The Aridagawa Tectonic Line is traced by the author from the Shimizu-Misato area through the Hanazono area to the Kudoyama area (Fig. 1B). The tectonic line passes between the Sambagawa and Chichibu terranes in the Shimizu-Misato area and farther western area, but in the eastern part of the Shimizu-Misato area it passes between the Sambagawa Metamorphic Rocks and the Kebara Formation (Kurimoto, 1986a; Fig. 1B). In the Hanazono and Kudoyama areas where the Chichibu terrane is absent on the land surface, the tectonic line passes between the Sambagawa and Shimanto terranes.

The Aridagawa Tectonic Line in the western Kii Peninsla strikes ENE-WSW and dips 60°north in general. The tectonic line is a shear zone of 50m to 60m in width and includes several faults which are running parallel to each other within the shear zone. The Aridagawa Tectonic Line is traced from the westernmost part of the Kii Peninsula to the Kudoyama area as a bended line (Fig. 1) and general strike of the Sambagawa Metamorphic Rocks is oblique to this tectonic line.

The Aridagawa Tectonic Line in the Kudoyama area separates the Sambagawa Metamorphic Rocks from the Hanazono Formation. The tectonic line, which trends NE-SW in the westernmost part in the Kudoyama area, changes its orientation to N-S along the Fudodani-gawa. Further eastward it trends again NE-SW (Fig. 3). In the area along the Fudodani-gawa, the tectonic line almost corresponds to the "Mikabu Tectonic Line" by Iwahashi (1979).

Outcrops of the Aridagawa Tectonic Line are observed at 18 localities in the Kudoyama area (A-1 to A-18 in Fig. 6). Geologic features at each locality are sum-marized in Appendix. As mentioned in the Chapter 3, the Sambagawa Metamorphic Rocks are characterized by well-developed schistosity, micro-folds and lineations. On the other hand, microfolds and lineations are rarely observed in the Hanazono Formation.

The fault at A-1 to A-5 and A-9 to A-18 strikes between NE-SW and ENE-WSW and generally dips either steeply to the north or vertically, almost concordant with the geologic structure of the rocks distributed on both sides of the tectonic line.

The Aridagawa Tectonic Line branches at Hosokawa in the Kudoyama area (Fig. 6) and the branch fault runs from Hosokawa through Kamiya to Nohira within the Shimanto terrane (Kamiya Fault). Furthermore, a few minor faults nearly parallel to the Aridagawa Tectonic Line are also recognized within the Sambagawa and Shimanto terranes and may be regarded as subsidiary faults of the tectonic line.

Judging from pattern of the fault system as shown in Fig. 6, the Aridagawa Tectonic Line and the subsidiary faults indicate left-handed en echelon arrangements in the western part of the Kudoyama area. It is considered that the Aridagawa Tectonic Line has shifted abruptly northward at locations A-5 to A-9 and that the portion around Kasaki corresponds to the shift interval of the tectonic line. Faults at locations A-6, A-7 and A-8, situated in the interval part, strikes N-S trend and gently dips to the west, cutting diagonally the geologic structure of the both sides. Possibly the faults at locations A-6 to A-8 have different sense from the other

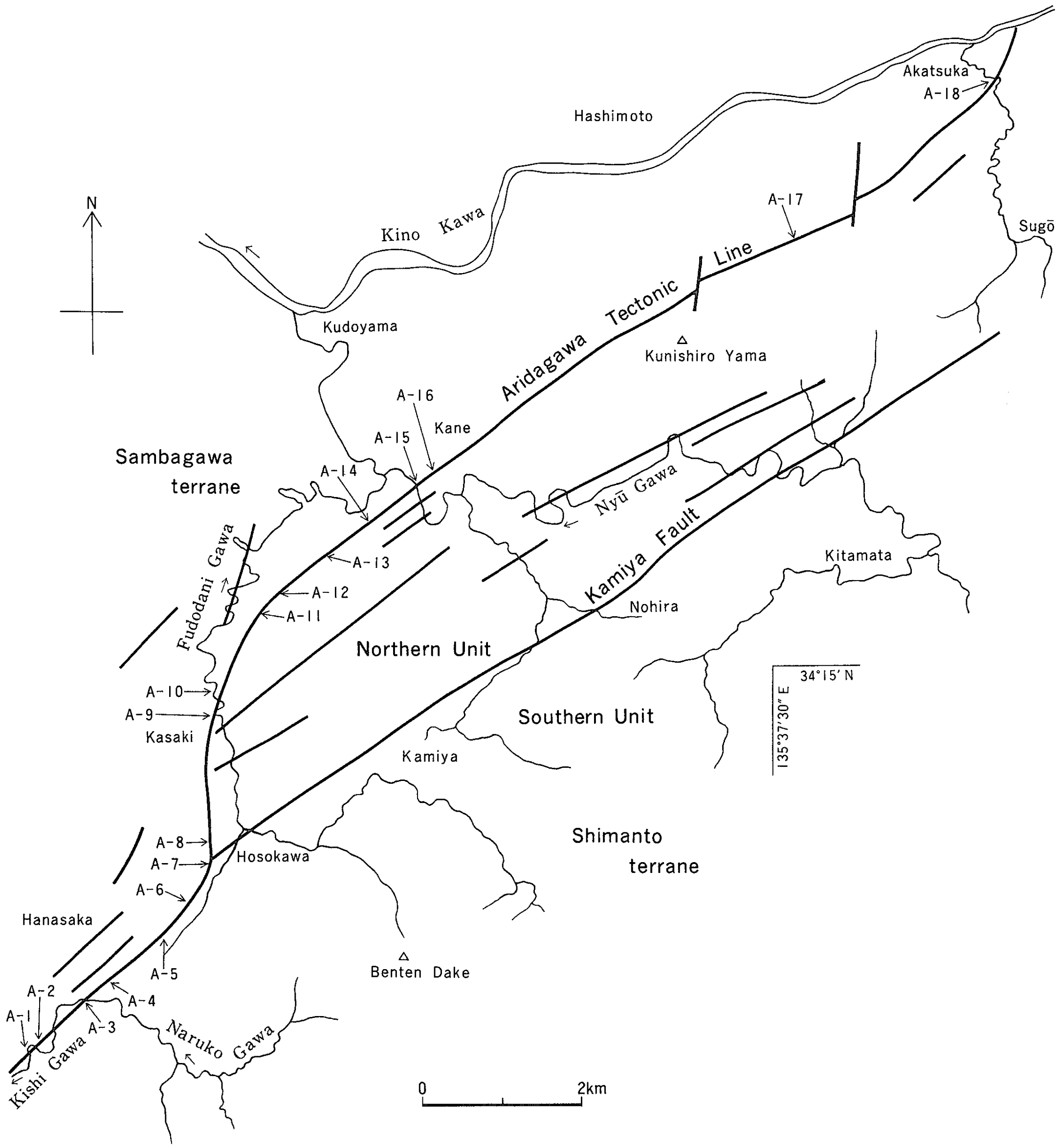

Fig. 6 Aridagawa Tectonic Line and subsidiary faults in the Kudoyama area, Wakayama Prefecture.

parts. As a whole, however, the Aridagawa Tectonic Line is traced as a boundary between the Sambagawa and Shimanto terranes in the area.

7. Discussion

In the Hanazono area where the Chichibu terrane is absent on the land surface, the Sambagawa terrane is in fault contact with the Shimanto terrane along the Aridagawa Tectonic Line (Kurimoto, 1982). Therefore, the Aridagawa Tectonic Line was active after the sedimentation of the Turonian to Campanian Hanazono Formation of the Shimanto terrane. Prior to the activity of the Aridagawa Tectonic Line the structural relationship among the Sambagawa, Chichibu and Shimanto terranes was different from the present state. The initial state of the relationship is discussed in the following lines.

The primary boundary between the Sambagawa and Chichibu terranes (PB in Fig.1B) corresponds to the boundary between the Kebara Formation of the Sambagawa terrane and Jurassic sedimentary complex of the Northen Chichibu terrane in the Shimizu-Misato area (Fig. 1B). This boundary fault is high-angle fault at present and is generally parallel to the Aridagawa Tectonic Line. The apparent high-angle is considered to be due to later folding which involved the Futakawa Formation of Santonian to Campanian age with high angle axial planes in response to N-S shortening. The Futakawa Formation is marine sedimentary strata in the Kurosegawa terrane and belongs to the Sotoizumi Group (Hirayama and Tanaka, 1956a). Unfolding of the Upper Cretaceous Futakawa Formation suggests that the primary boundary between the Sambagawa and Chichibu terranes was a low-angle fault and the Chichibu terrane was set tectonically above the Sambagawa terrane.

The boundary between the Chichibu and Shimanto terranes is marked by the Butsuzo Tectonic Line and Itao Fault in the Hanazono area and south of the Shimizu-Misato area (Fig. 1B). It is considered that the initial boundary between the two terranes was a low-angle thrust which became high angle in the shallower level because of post-Cretaceous folding.

On the other hand, the Itao Fault is considered to reflect the initial low-angle thrust between the Chichibu and Shimanto terranes in the deeper level before the appearance of the Aridagawa Tectonic Line. In the central part of the Kii Peninsula, the rocks of the Chichibu terrane are thrust over those of the Shimanto terrane with horizontal or low-angle fault (Yamato Omine Research Group, 1976; 1979) and the initial relationship between the two terranes is considered to be preserved in that part.

The Cretaceous rocks of the Shimanto terrane in the Kii Peninsula, which are called the Hidakagawa Group, are divided into the Hanazono, Yukawa, Miyama, Ryujin and Nyuno-kawa Formations from north to south (Kishu Shimanto Research Group, 1986). Concerning geologic age of the clastic rocks, younging polarity from north to south is generally recognized except for the Hanazono Formation, which occupies the northernmost part of the Shimanto terrane in the Kii Peninsula (Fig. 7).

The geologic age of the Hanazono Formation is younger than that of the Yukawa Formation and is situated between those of the Miyama and Ryujin Formations. This apparently anomalous situation of the Hanazono Formation is interpreted to be due to a subsequent uplift of the Hanazono area, which not only resulted in erosion of the tectonically overriding rocks of the Chichibu terrane but also of the equivalent of the Yukawa Formation which existed tectonically above the Hanazono Formation.

Kurimoto (1982, 1986a) assumed that the Chichibu and Sambagawa terranes were initially structurally piled up in ascending order by thrusting prior to the activity of the Aridagawa Tectonic Line, and presented schematic block diagrams showing process of the disappearance of the Chichibu terrane. However, the Chichibu terrane is considered to have been originally thrust over the Sambagawa terrane as suggested already. So, in this paper the author presents schematic N-S cross sections showing the activity of the Aridagawa Tectonic Line and the process of the disappearance of the Chichibu terrane in Fig. 8.

In Fig. 8I the initial relationship among the geologic units of the Sambagawa, Chichibu and Shimanto terranes are shown. After that, the Aridagawa Tectonic Line started and a N-S shortening occurred (Fig. 8II). Fig. 8II corresponds to the present state of the Shimizu-Misato area (Fig. 1B) where the zonal structure is pre-served and the rocks of the Chichibu terrane are distrib-uted on the land surface. With the appearance of the Aridagawa Tectonic Line and Yanase Fault (mentioned later), a relative uplift took place in the southernmost part of the Sambagawa terrane (*i.e.* area of the Kebara Formation), Chichibu terrane and northern part of the Shimanto terrane

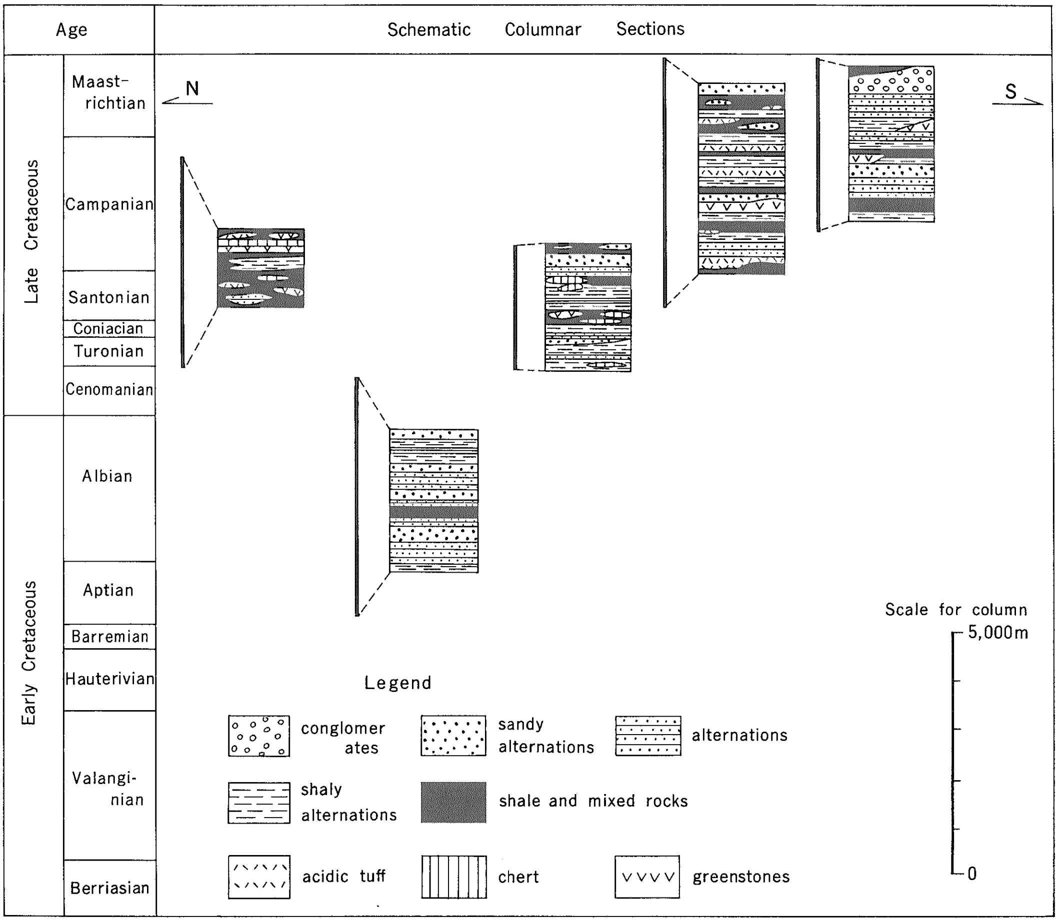

Fig. 7 Generalized stratigraphy and lithology of the Cretaceous Hidakagawa Group of the Shimanto terrane in Kii Peninsula. From Kishu Shimanto Research Group (1986) with slight modification of age of the Hanazono and Yukawa Formations. The bar at the left of each column indicates geologic age.

(Fig. 8III). In Fig. 8II and III the Yanase Fault may have appeared at the same time as the Aridagawa Tectonic Line. As the extent of the uplift was larger in the eastern part of the western Kii Penin-sula, the Chichibu terrane and a part of the Sambagawa terrane were eroded out in this part. Consequently, the Chichibu terrane is absent on the land surface, and the Sambagawa terrane is in fault contact with the Shimanto terrane through the Aridagawa Tectonic Line (Fig. 8IV).

In Fig. 8IV the Hanazono Formation is in contact with the Yukawa Formation through a south dipping fault (Nakazawa, 1967). Recently, this fault was named the Yanase Fault by Kishu Shimanto Research Group (1991).

In the Northern Unit and northern margin of the Southern Unit of the Hanazono Formation in the Kudoyama area, mudstones become phyllitic and linea-tions and microfolds are observed near the Aridagawa Tectonic Line. This fact is consistent with the model that the Hanazono Formation was underthrust far north and deeper, tectonically below rocks of the Chichibu terrane and the adjacent uppermost Shimanto unit com-posed of the equivalent of the Yukawa Formation.

Takeuchi and Yamato Omine Research Group (1984) showed that not only the Chichibu terrane but also the Sambagawa terrane are

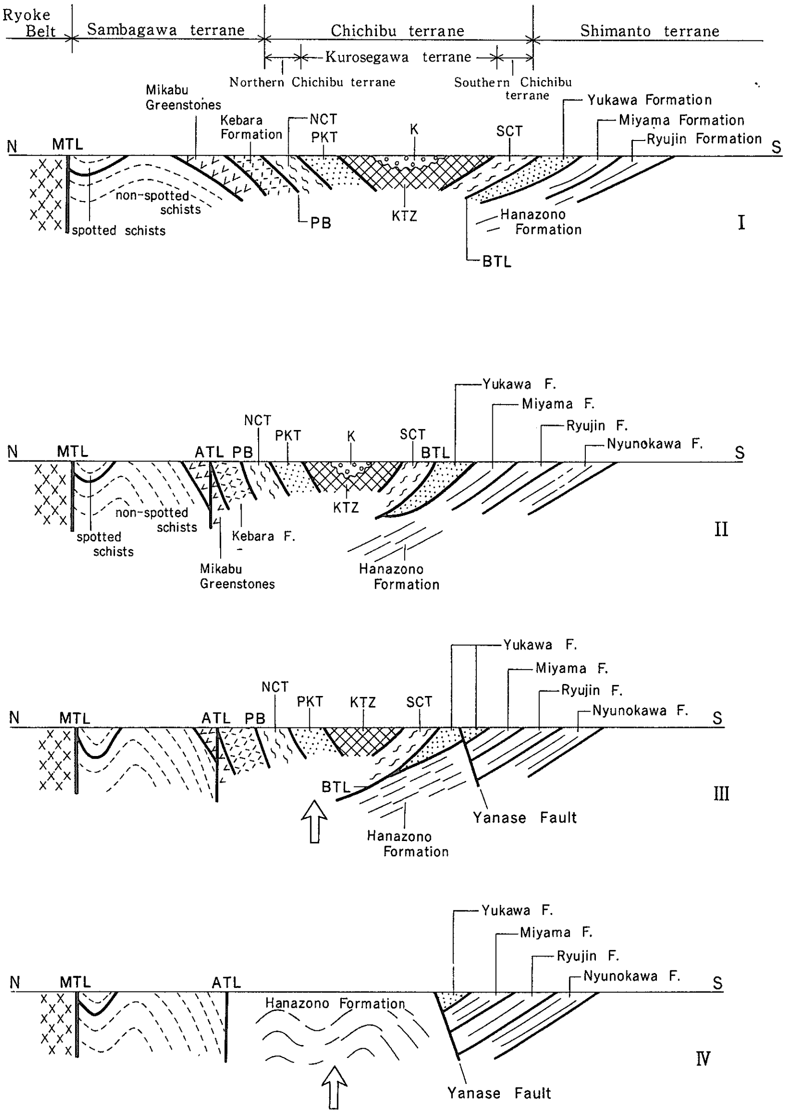

Fig. 8 Highly schematic N-S cross sections showing the tectonic evolution in the area where the Chichibu terrane is absent on the land surface (not to scale).

I : After sedimentation of the Cretaceous strata (Futakawa Formation *etc.*) on the Kurosegawa terrane and before appearance of the Aridagawa Tectonic Line.

II: Appearance of the Aridagawa Tectonic Line.

III: Appearance of the Yanase Fault and beginning of uplift of the zone between the Aridagawa Tectonic Line and the Yanase Fault.

IV: After uplift and erosion. Consequently the Chichibu terrane bacame absent on the land surface.

MTL: Median Tectonic Line, PB: primary boundary between the Sambagawa and Chichibu terranes, BTL: Butsuzo Tectonic Line, ATL: Aridagawa Tectonic Line, KTZ: rocks of Kurosegawa Tectonic Zone, NCT: Jurassic complex of Northern Chichibu terrane, K: Cretaceous strata in Kurosegawa terrane, PKT: Permian complex of Kurosegawa terrane, SCT: Jurassic to Early Cretaceous complex of Southern Chichibu terrane. Open arrows show uplift.

absent on the land surface in the central Kii Peninsula. They mentioned that the northern part of the Shimanto terrane was weakly metamorphosed. Amount of the uplift in this area is considered to be larger than that in the Kudoyama and Hanazono areas, consequently phyllitic or schistose rocks are more widely exposed there.

8. Summary

(1) The Kudoyama area is located in the western part of the region where the Chichibu terrane is absent in the Kii Peninsula.

(2) The Sambagawa Metamorphic Rocks which belong to the Sambagawa terrane consist mainly of pelitic schists and green-schists associated with psammitic, siliceous and quartz schists. The Hanazono Formation of the Shimanto terrane consists mainly of mudstones and interbedded sandstones and mudstones with greenstones, cherts, sandstones and acidic tuffs.

(3) The Hanazono Formation is divided into the Northern and Southern Units separated by the Kamiya Fault, and the Northern Unit is characterized by existence of more obvious foliation as compared with the Southern one. Radiolarian fossils from the Southern Unit are assigned to Late Cretaceous and those from the Northen Unit are probably of Cretaceous age.

(4) The Aridagawa Tectonic Line is traced as the southern boundary of the Sambagawa Metamorphic Rocks in the Kudoyama area. This line changes its orientation from E-W to NE-SW trend and at some places to N-S trend toward the east and dips steeply to the north up to vertical in the area.

(5) The Chichibu terrane was originally thrust over the Sambagawa terrane (Kebara Formation) to the north and Shimanto terrane to the south. Subsequently, the Aridagawa Tectonic Line appeared and a relative uplift took place on its southern side. As the extent of the uplift was larger in the eastern part of the western Kii Peninsula, the Chichibu terrane, a part of the Sambagawa terrane and uppermost Shimanto unit were eroded out in the Kudoyama area, and the Hanazono Formation which was underthrust far north and deeper under the Chichibu terrane was exposed on the land surface (Fig.8). Consequently, the Chichibu terrane is absent on the land surface and the Sambagawa terrane is in direct fault contact with the Shimanto terrane through the Aridagawa Tectonic Line.

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(* in Japanese with English abstract, ** in Japanese)

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紀伊半島西部，九度山地域の地質－秩父帯の欠如に関連して－

栗本史雄

要　旨

紀伊半島西部は東西性の帯状配列によって特徴づけられる西南日本外帯に位置し，三波川・秩父・四万十の3帯にまたがる．秩父帯は岩相と地質年代により秩父北帯・黒瀬川帯・秩父南帯に3分され，特徴の異なった3帯が複合した地帯といえる．紀伊半島西部の東半分では秩父帯が地表において欠如し，三波川帯と四万十累帯が有田川構造線を介して接している．本論文では秩父帯が欠如する和歌山県九度山地域の地質を記述し，これらの資料に基づいて紀伊半島西部において秩父帯が欠如する原因となった上昇過程を考察する．

九度山地域では北から南へ三波川変成岩類と四万十累帯の白亜系が分布し，有田川構造線を介して接する．四万十累帯の岩石は花園地域の上部白亜系花園層の北東延長にほぼ相当し，本論文でも花園層と呼ぶ．花園層は片状構造のより発達した北部ユニットと発達の弱い南部ユニットから構成され，両ユニットは断層によって境される．本論文では岩相・構造・放散虫及びK-Ar年代・緑色岩の変成鉱物・有田川構造線の特徴を記載する．

九度山地域の地質情報に加え，有田川構造線とその分岐断層の分布状況や隣接する地域の知見に基づいて，紀伊半島西部における秩父帯欠如の過程を次のように推定した．秩父帯の構成岩類は秩父帯白亜系堆積後，北の三波川帯及び南の四万十累帯の構成岩類に低角度で衝上していた．その後，有田川構造線が三波川帯の南限においてこの累重構造を切って出現した．有田川構造線の活動に伴う上昇の程度が紀伊半島西部の東半部でより大きかったため，秩父帯全体と三波川帯の一部，それに四万十累帯の中で構造的上位の部分が削剝され，秩父帯の下位により深く入り込んでいた花園層が地表に出現するに至った．

(受付：1993年9月6日；受理：1994年1月10日)

Appendix : Outcrops of the Aridagawa Tectonic Line

(Localities are indicated in Fig. 6)

A - 1, 2, 3, 4, 5, 9 and 12 : Mudstones including sandstone lenses are generally sheared. Shear plane usually strikes parallel to bedding plane.

A-6 : Fault strikes N10° E and dips 23° west. On the west of the fault, pelitic schists of the Sambagawa Metamorphic Rocks strikes E-W and dips 23° north, and are cut by the fault diagonally. On the eastern side of the fault, mudstones of the Hanazono Formation are distributed and their strike and dip are parallel to those of the fault.

A-7 : The Hanazono Formation generally strikes N60° E and dips 72° north. Near the Aridagawa Tectonic Line, sheared mudstones and cherts are observed, and their strikes and dips are N25° E, 52° NW and N32° E, 28° NW, respectively. On the western side of the tectonic line, pelitic schists of the Sambagawa Metamorphic Rocks are exposed and strike E-W and dip 50° north.

A-8 : A shear zone having an orientation of N28° W, 35° W is observed. On the east of this shear zone, mudstones and interbedded sandstones and mudstones of the Hanazono Formation are exposed, having strikes of N65° E and N78° E and dips of 35° N and 45° N respectively. On the west, pelitic schists of the Sambagawa Metamorphic Rocks strike N26° W and dip 32° west.

A-10 : Black mudstones about 20m thick include sandstone lenses and are generally sheared. Within the mudstones, greenish siliceous rocks, 2 to 10cm thick, are interbedded with mudstones and are folded. These mudstones occupy the northern marginal portion of the Shimanto terrane.

A-11 : Shear zone of 50m in width is exposed. Siliceous rocks and sandstones are included in mudstones as lenticular bodies. Mudstones with schistosity and those without schistosity are distributed alternately by fault.

A-13 : Shear zone of 50m in width is observed. Several faults of 1m in width being parallel to each other, strike N60° E to N85° E and dip 50° to 70° north. Bedding plane strikes NE-SW and dips 50° north is cut by high-angle faults. Mudstones with schistosity and those without schistosity are distributed alternately in the same way as at A-11.

A-14 : The fault observed here strikes N66° E and dips 74° N. Mudstones without schistosity belonging to the Hanazono Formation are distributed south of this fault. Pelitic schists of the Sambagawa Metamorphic Rocks are exposed towards north several meters away from the fault zone.

A-15 : Near the southern marginal portion of thick greenschists, about 15m wide shear zone is observed. Greenschists and mudstones which are distributed towards the south of greenschists are sheared. Fault gouge containing clay and cataclasite strikes N65° E and dips 64° north. Greenschists are associated with red cherts and red mudstones and have intercalation of pelitic schists. These pelitic schists are characterized by well developed schis-tosity, microfolds and lineations. Mudstones south of these fault zone include lenticular bodies of sandstones which exceed 0.5×3m in maximum size. Microfolds and lineations within the mudstones are rarely observed.

A-16 : Schists and non-schistose rocks occur alternatively. However, geologic relationship between the both rocks is not clear and actual fault zones are not exposed.

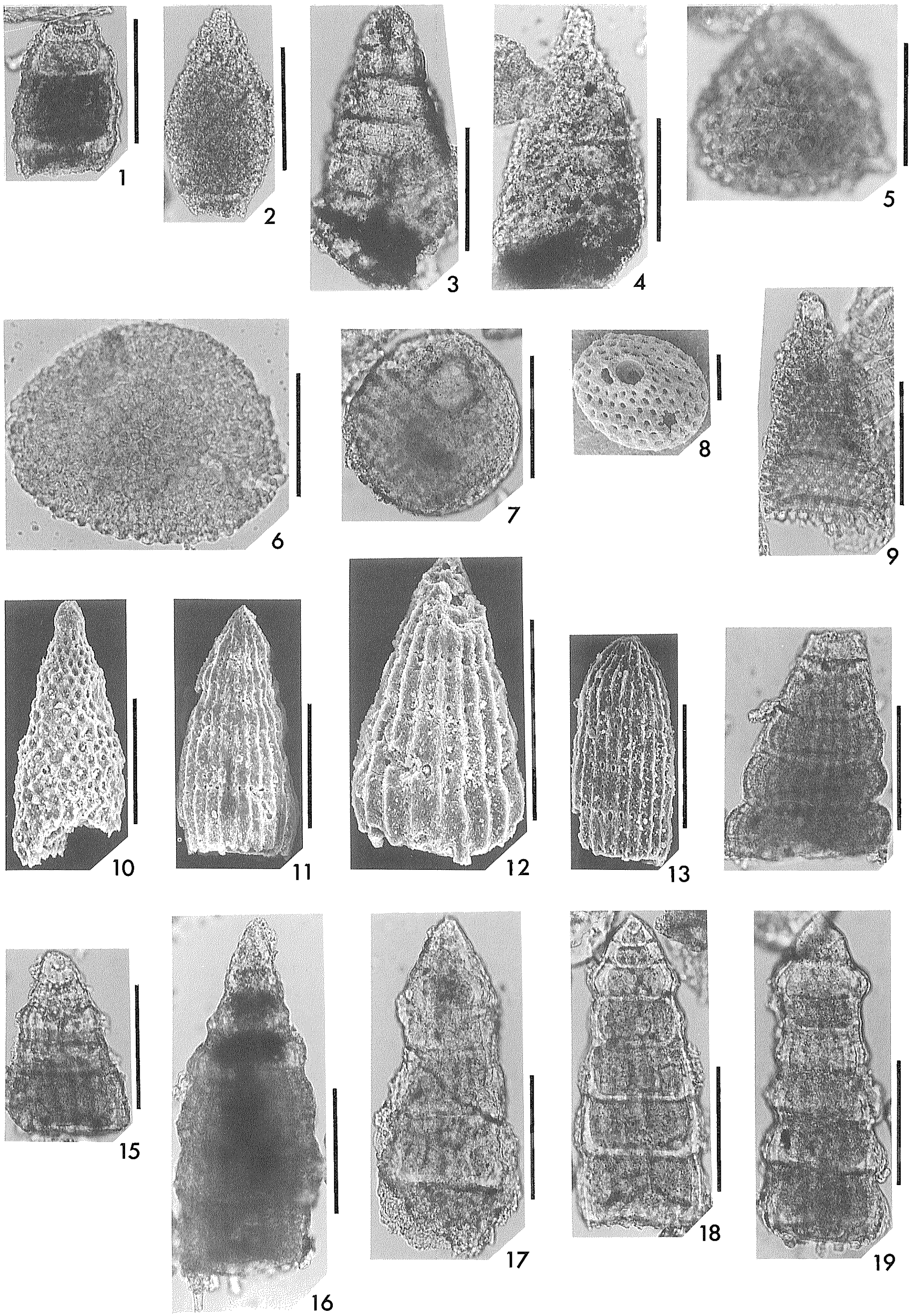
A-17 : Shear zone of 30m in width is observed. The fault observed here strikes N75° E and dips 70° N.

A-18 : Black mudstones about 20m thick are sheared and they have strike of N50° E and dip of 30° N.

Plate I Cretaceous radiolarians from the Hanazono Formation of the Kudoyama area

Fig.1	*Dictyomitra* sp.	Loc.13
Fig.2	*Amphipyndax* sp.	Loc.12
Fig.3,4	Nassellaria gen. and sp. indet.	Loc.14
Fig.5	*Alievium* sp.	Loc.6
Fig.6	*Pseudoaulophacus* sp.	Loc.6
Fig.7	*Holocryptocanium* sp.	Loc.6
Fig.8	*Holocryptocanium* sp.	Loc.10
Fig.9	*Amphipyndax stocki*	Loc.6
Fig.10	*Amphipyndax* sp.	Loc.11
Fig.11-13	*Archaeodictyomitra* sp.	Loc.11
Fig.14,15	*Dictyomitra formosa*	Loc.5
Fig.16	*Dictyomitra formosa*	Loc.6
Fig.17	*Dictyomitra koslovae*	Loc.5
Fig.18,19	*Dictyomitra koslovae*	Loc.6

Figs. 1 and 2 are from the Northern Unit and Figs. 3 to 19 from the Southern Unit. Figs.1 to 7, 9 and 14 to 19 are photographs under ordinary microscope and Figs. 8 and 10 to 13 are under scanning electron microscope. Each scale bar shows 0.1mm.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