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Ultra-Tamba Zone of Southwest Japan

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(With 16 Figures and 1 Table)

Abstract

The Ultra-Tamba Zone is a tectonic unit between the Maizuru and the Tamba Bèlts of Southwest Japan. It consists of two tectonic units, namely, UT 1 and UT 2 sub-zones. The UT 2 sub-zone tectonically overlies the UT 1 sub-zone with southerly vergence. The Yakuno complex (southern sub-belt of the Yakuno complex) of the Maizuru Belt thrusts over the UT 2 of the Ultra-Tamba Zone, while the UT 1 thrusts over the Type II suite of the Tamba Group. These tectonic units, namely, the Yakuno complex, the UT 2 and the UT 1 sub-zones of the Ultra-Tamba Zone form the piling of nappes with a southerly vergence. The Ultra-Tamba Zone is distributed not only along the southern margin of the Maizuru Belt but also along the northern margin of the Kamigori Belt and is traceable for over 120 km in ENE-WSW direction.

The UT 2 sub-zone consists of the Oi Formation which is characterized by Late Permian clastic formation. In detail, it is composed of (1) thinly alternating beds of siliceous rock and pelitic rock, (2) alternating beds of sandstone and mudstone and (3) olistostrome in ascending order, and the total thickness of this sequence is estimated to be about 100 m. The lower member (1) yields early Late Permian *Follicucullus bipartitus-Fo. charveti* Assemblage. This assemblage is quite different from the contemporaneous assemblage in the bedded chert of the Tamba-Mino Belt in the main constituent species. *Neoalbaillella grypus* and others which are known in the upper part of the Late Permian *Neoalbaillella ornithoformis* Assemblage-zone occur from the middle member (2).

The UT 1 sub-zone consists of the Hikami Formation which is characterized by the thick green sandstone with intercalated black shale and green mudstone and the total thickness is estimated to be over 1000 m. The possible provenance of this sandstone is active magmatic arc region, according to the study of the mineral composition and composition of the lithic fragments by T. KUSU and the author.

The Oi Formation and the Hikami Formation of the Ultra-Tamba Zone have the different lithology and stratigraphy from the Permian of the Tamba and the Maizuru Belts, while the siliceous rock-clastic rock sequence of the Oi Formation and the sandstone with acid volcanic clasts of the Hikami Formation resemble those of the Permian of the Chugoku Belt of the A terrane-group.

The Oi Formation was widely developed in Late Permian time and successively the Hikami Formation was deposited on the outer side. In Latest Permian and Triassic times the Maizuru Belt thrust over the UT 2 (Oi Formation), which in turn was thrust over the UT 1 (Hikami Formation). Thus, the initial structure of the Ultra-Tamba Zone was formed. In Jurassic time, this zone thrust over the Early to Middle Jurassic Type II suite of the Tamba Group which in turn thrust over the Late Jurassic Type I suite of the Tamba Group. Present research on the stratigraphy, structure, and radiolarian biofacies of the Oi and the Hikami Formation reveals that the Ultra-Tamba Zone was constructed through the long and stepwise deformation process during Permian-Cretaceous time between the Maizuru and Kamigori Belts of the A terrane-group and the Tamba Belt of the B terrane-group of Southwest Japan.

Contents

I. Introduction

In Southwest Japan, three sets of terrane-groups, A, B and C are discriminated on the basis of timing of accretion of allochthonous elements to the paleoasiatic continent (Fig. 1a, ICHIKAWA, 1984). The A terrane-group consists of terrances of mainly Triassic accretion, while B terrane-group consists of terranes of Jurassic-earliest Cretaceous accretion. The C terrane-group (Shimanto) of still younger age is outside the scope of this paper. The A terrane-group and B terrane-group are regarded as two major groups of terranes in Jurassic time which are fundamentally different from each other.

The boundary between the A and the B terrane-groups coincides with that of the Maizuru and the Tamba Belts in a broad aspect. Along the southern margin of the Yakuno complex (southern sub-belt of the Yakuno complex) of the Maizuru Belt, strongly sheared, "Paleozoic" strata called the Oi and the Katsumi Formations are distributed, and they have been discriminated from the Tamba Group proper on the basis of field mapping (HIROKAWA *et al.*, 1957; HIROKAWA and KURODA, 1957; IGI *et al.*, 1961).

The author has been engaged in the research of (1) the stratigraphy and geologic structure of the Maizuru and the Tamba Belts on the basis of radiolarian and conodont biostratigraphy and (2) geologic relationship between the two belts. As a result, it has been deciphered that the characteristic strata having the different lithostratigraphy, structure and paleobiofacies from those of both Maizuru and Tamba Belts are distributed in a long and narrow zone between the Maizuru and the Tamba Belts (Fig. 1b, ISHIGA, 1985b). This zone forms a certain geo-tectonic unit which tectonically overlies the Type

II suite of the Tamba Group (Ishiga, 1983) and represents the third unit. Thus, it has been recently called the Ultra-Tamba Zone (Caridroit *et al.*, 1985). Through the examination of the boundary zone between the Maizuru and the Tamba Belts, another new fact has been clarified. The green sandstone formation (Caridroit *et al.*, 1985) zonally distributed along south of the "Ultra-Tamba Zone" also forms a distinct unit and does not belong to the Tamba Belt proper. With respects to the sandstone petrography (Kusu *et al.*, 1985; Kusu and Ishiga, in prep.), and fossil evidence (Kurimoto and Kimura, 1985; Kurimoto, 1986), the author thinks that the green sandstone should be included in the Ultra-Tamba Zone as one of the important components. Furthermore, concerning the western extension of this zone, it is now clarified that this zone is distributed along the north of the Kamigori Belt at Himeji, Hyogo Prefecture (Fig. 1b).

In this paper, the author describes the constituent rocks and distribution of the Ultra-Tamba Zone. Based on the description, he discusses the significance of the discerning of the Ultra-Tamba Zone between the A terrane-group (Maizuru and Kamigori Belts) and the B terrane-group (Tamba Belt) and suggests that the Ultra-Tamba Zone is better assigned to the A terrane-group.

II. Outline of Geology

It has been said that the Maizuru and the Tamba Belts are different from each other in lithofacies, age, distribution and geologic structure of the constituent rocks. The Maizuru Belt consists of Permian clastic rocks (for example the Maizuru Group), Yakuno igneous-metamorphic complex and Triassic clastic rocks. On the other side, the Tamba Belt are mainly represented by chaotic deposits of the Jurassic age, olistostrome. It has been recently clarified that the Tamba Group consists of two distinct suites of stratigraphic units, namely, Type I and II suites. The Type II suite with Paleozoic greenstone-bedded chert formation in the lower part tectonically overlies the Type I suite lacking Paleozoic strata (Ishiga, 1983).

The strata of the boundary zone between the Maizuru and the Tamba Belts can be grouped into two units in lithologic feature. One is characterized by pelitic rocks and the other is mainly composed of sandstone. The former, called the Oi and the Katsumi Formations (Hirokawa *et al.*, 1957; Hirokawa and Kuroda, 1957; Igi *et al.*, 1961) tectonically overlies the latter and as re-defined later in this paper, the formation is collectively called the Oi Formation. The latter includes the Kato Formation (Hirokawa *et al.*, 1957) and some part of the Kanbayashigawa Formation (Yoshida, 1977) and as will be redefined later, this formation is collectively called the Hikami Formation in this paper. The Ultra-Tamba Zone consists of the Oi and the Hikami Formations. Concerning the distribution of this zone, it varies in width in areas and is traceable over 120 km long from Obama, Fukui Prefecture to Sayo, western part of Hyogo Prefecture. Moreover, the author's recent study clarifies that the Ultra-Tamba Zone is developed not only on the south of the Maizuru Belt but also on the north of the Kamigori Belt (Fig. 1b).

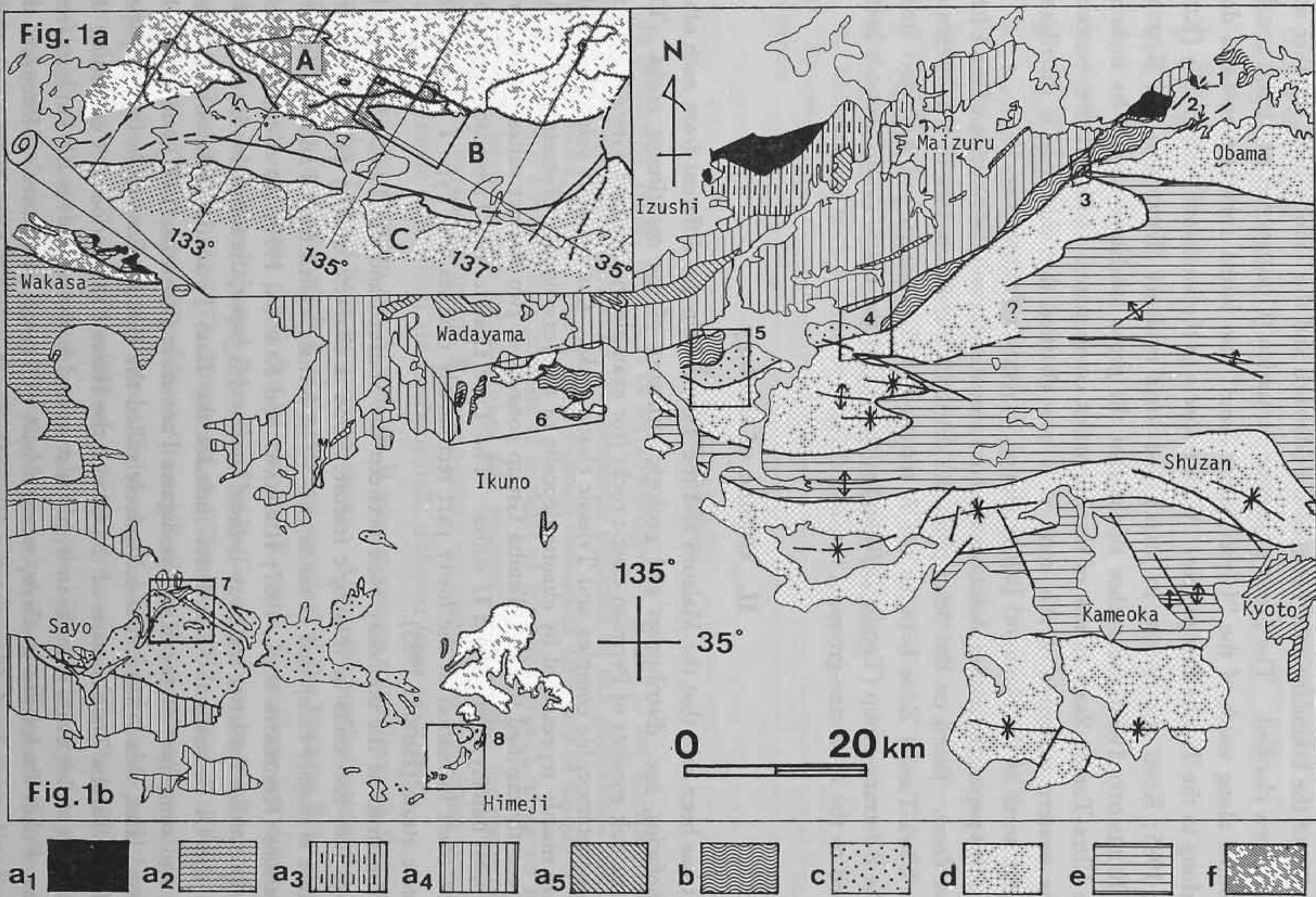
Fig. 1a
A
B
C
133°
135°
137°
35°
N
Izushi
Maizuru
Obama
Wakasa
Wadayama
Ikuno
Shuzan
Kameoka
Kyoto
Sayo
Himeji
1
2
3
4
5
6
7
8
?
135°
35°
0
20 km
Fig.1b
a1
a2
a3
a4
a5
b
c
d
e
f

Figs. 1a, 1b.

The study areas are as follows from northeast to southwest (see Fig. 1b); (1) Akaguri-saki, west of Obama City, Fukui Prefecture, (2) Shimokato, Oi-gun, (3) Oi, Oi-cho, (4) Ayabe, Kyoto Prefecture, (5) Fukuchiyama, southwest of Fukuchiyama City, (6) Aogaki, Hyogo Prefecture, (7) Yamasaki, and (8) Fukusaki. ISHIGA (1985b) reported the geology of the (1) Akaguri-saki area and the (3) Oi area. The eastern part of the (4) Ayabe area was also studied by CARIDROIT *et al.* (1985).

III. Geology of Study Areas

1. Akaguri-saki area

The study area is located at the eastern point of the Oura Peninsula, Oi-gun, Fukui Prefecture. The strata in this area, which is called the Katsumi Formation (HIROKAWA and KURODA, 1957) have the same lithology and biofacies with those of the Oi Formation of the Oi area (HIROKAWA *et al.*, 1957). Thus, the Katsumi Formation of the Akaguri-saki area is called the Oi Formation in this paper. The Katsumi Formation is typically distributed in the Uchitomi Peninsula located at the eastern bank of the Akaguri-saki and some part of the formation in this peninsula shows the same lithology with the Oi Formation. The radiolarian specimens belonging to the genus *Follicucullus* have been obtained from the Uchitomi Peninsula. However, whether the whole of the strata in this area belong to the Oi Formation or not remains to be solved in future.

A. Yakuno complex

According to ISHIGA (1985b), the Machinoyama ultrabasic rocks (HIRANO, 1969; ISHIWATARI, 1978, 1985) of the Maizuru Belt tectonically overlies the Katsumi Formation (Oi Formation) with a remarkable fault steeply dippnig northwest. The fault is represented by a sheared zone with 15 m width which is composed of sheared serpentinite and basic tuff including various scales of blocks of basic rocks and tuffaceous mudstones. The fault plane strikes N50°E and dips 45° to the northwest which is nearly parallel to the bedding plane of the Oi Formation.

B. Oi Formation

The Oi Formation in the area strikes N50°–70°E and dips 45°–80° to the north.

Fig. 1a. Index map and simplified map showing the distribution of the A, B and C terrane-groups in Southwest Japan after ICHIKAWA (1984) and ISHII *et al.* (1985).

Fig. 1b. Simplified geologic map showing the localities of the study areas and the distribution of the Ultra-Tamba Zone modified from KURODA ed. (1968), IGI ed. (1971), ISHIGA (1983) and CARIDROIT *et al.* (1985) on the basis of the author's survey. a, constituent rocks of the Chugoku and the Maizuru Belts (1, Ultrabasic rocks. 2, Sangun metamorphic rocks. 3, Shimomidani Formation. 4, Paleozoic rocks such as Maizuru Group, Yakuno complex and Tatsuno Group. 5, Triassic clastic rocks such as Shidaka Group, Yakuno Group, Nabae Formation). b, Oi Formation of the Ultra-Tamba Zone. c, Hikami Formation of the Ultra-Tamba Zone. d, Type II suite of the Tamba Group. e, Type I suite of the Tamba Group. f, equivalent of the Tamba Group. Legend of a–e is applied also to Figs. 4, 6, 7, 9, 11 and 12. Study areas: 1, Akaguri-saki (Fig. 2). 2, Shimokato (Fig. 3). 3, Oi (Fig. 4). 4, Ayabe (Fig. 6). 5, Fukuchiyama (Fig. 7). 6, Aogaki (Fig. 9). 7, Yamasaki (Fig. 11). 8, Fukusaki (Fig. 12).

Lithologically, it is divisible into four members in ascending order, namely, (1) red bedded siliceous shale-chert (more than 16 m thick), (2) grey to greenish grey siliceous shale (about 6.5 m thick), (3) black shale (about 14 m thick) and (4) black phyllitic shale (about 45 m thick) with many lenses or blocks of sandstone and chert (Fig. 2). They are strongly deformed and in some part, minor folding with nearly vertical fold axis is developed. They form a comformable sequence with gradual vertical change, but the lower half of the member (4) is strongly sheared and is represented by consolidated fault breccia or gouge with many quartz veins.

Concerning the radiolarians, the Late Permian *Follicucullus bipartitus-Fo. charveti* Assemblage has been reported from the members (1)–(3) as given in the chapter IV (ISHIGA, 1985b).

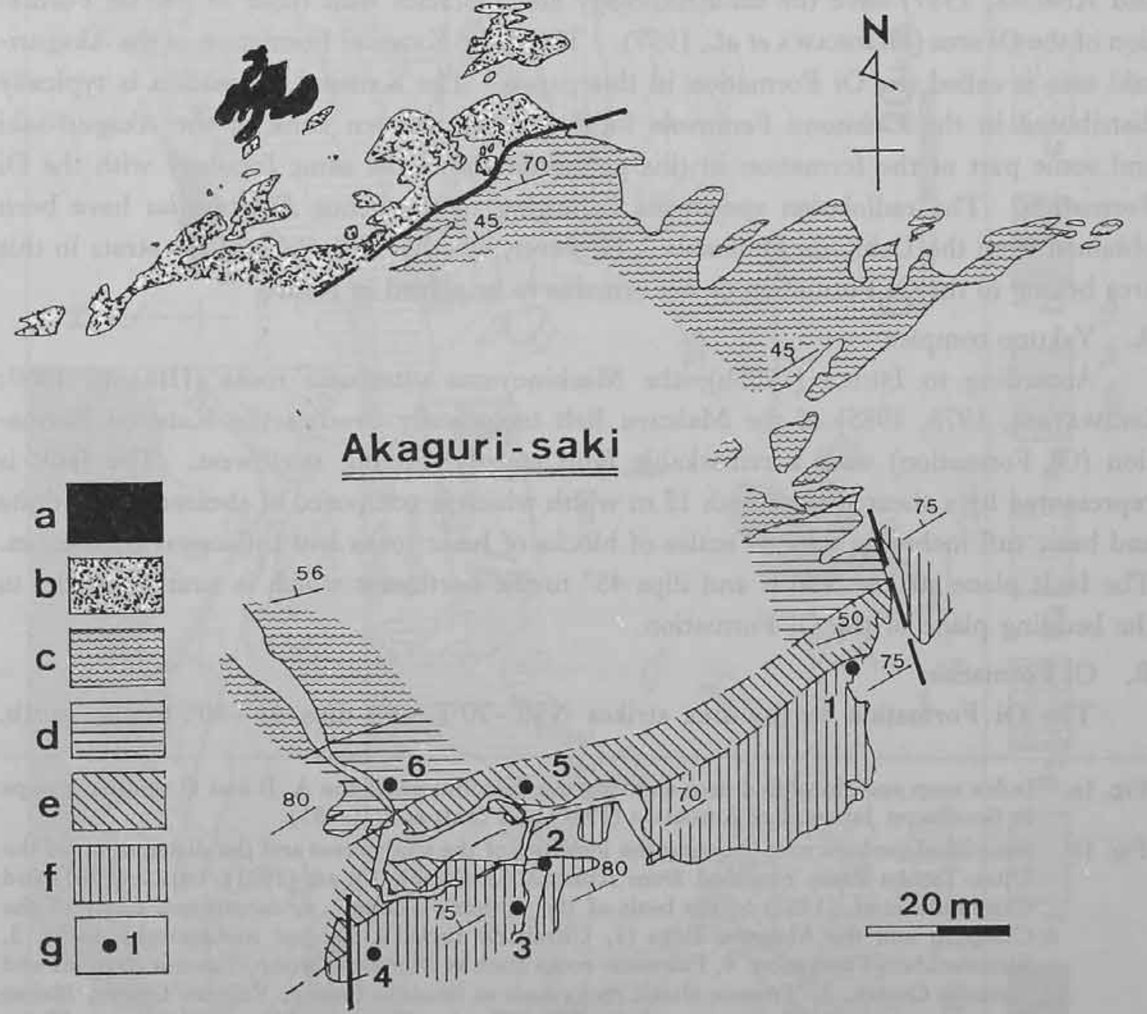

Fig. 2. Route map of the Akaguri-saki area after ISHIGA (1985b). a, Machinoyama ultrabasic rock of the Maizuru Belt. b, sheared zone. c–f, Oi Formation (c, black phyllitic shale with blocks of sandstone and chert. d, black shale. e, grey to greenish grey siliceous shale. f, red bedded siliceous shale-chert.). g, localities of occurrence of radiolarians after ISHIGA (1985b).

The member (1) is mainly composed of well-bedded red siliceous shale and occasionally includes thin beds (about 2–4 cm thick) of red chert. Near the boundary between (1) and (2) members, the lithology of the (1) member resembles that of the (2) member, but red color suddenly changes into greenish grey. The (2) member near the boundary includes also the chert layer occasionally in several horizons. Siliceous shale of the (3) member contains many radiolarian tests and fine clastic materials. The chert in the member (4) shows whity grey color and is strongly recrystallized. The sandstone is grey in color and is medium to coarse grained wacke which includes many lithic fragments. The lithic fragments are composed of volcanic rocks of which half are acid volcanic ones. The sandstone is generally cataclastic. Usually, the twinnings of the feldspar are strongly deformed and grains are crushed into small pieces.

2. Shimokato area

The study area is located at Kataebana coast, Shimokato, Obama City. The sandstone formation in the area was called the Oi Formation (HIROKAWA *et al.*, 1957), but it is correlative with the green sandstone (Hikami Formation) of the Ultra-Tamba Zone, which tectonically overlies the Type II suite of the Tamba Group (Fig. 3). The fault plane strikes N45°E and dips 75° to northwest. The fault has sheared zone with several centimeters thickness which is composed of black phyllitic shale. The sandstone of the hanging wall of this fault is strongly sheared and cataclastic. The Tamba Group of the foot wall is also sheared and is foliated by faulting. The Tamba Group includes various scales of blocks of green sandstone derived from the Hikami Formation of the Ultra-Tamba Zone. The fault is accompanied by a secondary fault which is developed in the green sandstone of the hanging wall.

The green sandstone consists of massive, coarse to medium grained sandstone which occasionally includes black shale as a lenticular bodies or clasts. The sandstone is

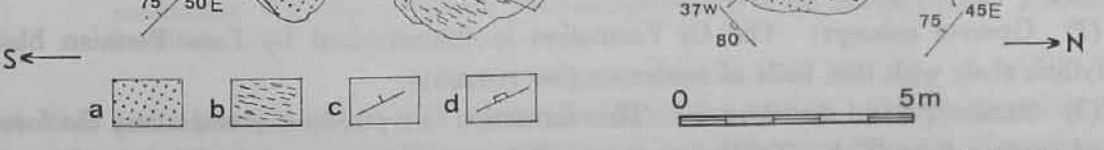

Fig. 3. Sketch at Kataebana showing the relationship between green sandstone of the Ultra-Tamba Zone and the Type II suite of the Tamba Belt. a, green sandstone of the Hikami Formation of the Ultra-Tamba Zone. b, black phyllitic shale of the Type II suite. c, strike and dip of the foliation. d, strike and dip of the joint. c, d; north is the upper side of the figure.

strongly sheared and cataclastic and grains of the sandstone are broken into small pieces. The twinning of feldspar grains is commonly deformed.

The Tamba Group in the area is also sheared and is mainly composed of phyllitic mudstone which contains elongated bodies of chert and sandstone. Mudstone is usually silty or sandy and partly alternates with sandstone. Although the rocks are strongly deformed, they belong to the Type II suite of the Tamba Group based on these lithology. The sandstone is greenish grey in color and consists of medium to coarse granied feldspatic wacke, which is regarded to be derived from the Hikami Formation of the hanging wall of the fault. The chert is grey to greenish grey bedded chert usually recrystallized by faulting.

3. Oi area

The study area is located at western part of Oi-cho, west of Obama City and covers 5 km longitudinally and 7 km latitudinally (Fig. 4). In this area, the Oi Formation is distributed along south of the Yakuno complex of the Maizuru Belt. The width of the distribution of the Oi Formation varies from 3 to 0.5 km and diminishes in the southwestern part. This area includes the stratotype of the Oi Formation (HIROKAWA *et al.*, 1957) which is re-defined below.

To the south of the Oi Formation, the Hikami Formation, Type II suite and Type I suite of the Tamba Group are distributed. The Tamba Group in this area was hitherto called the Kato Formation (HIROKAWA *et al.*, 1957) or the Kanbayashigawa Formation (YOSHIDA, 1977).

A. Yakuno complex

The Yakuno complex tectonically overlies the Oi Formation and they are in fault contact. The fault plane between them is steeply dipping northwest and is sometimes accompanied with sheared serpentinite. The Yakuno complex in the area conists mainly of metagabbro and peridotite (ISHIWATARI, 1976, 1985). Near the boundary with the Oi Formation, it is strongly sheared and is intruded by serpentinite and carbonate rocks. The carbonate rocks with 1–5 m thickness are emplaced along the fault and within the phyllitic shale of the Oi Formation near the boundary.

B. Oi Formation

(1) Name: This name was first used by HIROKAWA *et al.* (1957). Later the Oi Formation is reported in the Maizuru area, western neighborhood of this area, by IGI *et al.* (1961).

(2) General concept: The Oi Formation is characterized by Late Permian black phyllitic shale with thin beds of sandstone (see remarks).

(3) Stratotype and distribution: This formation is typically exposed along the forest road leading from Kobi, Takahama-cho to Fukutani, Oi-gun and is distributed in the middle part of the study area (Fig. 4).

(4) Description: The Oi Formation is mainly composed of black phyllitic shale, and alternating beds of green sandstone and greenish grey shale are intercalated. Red silice-

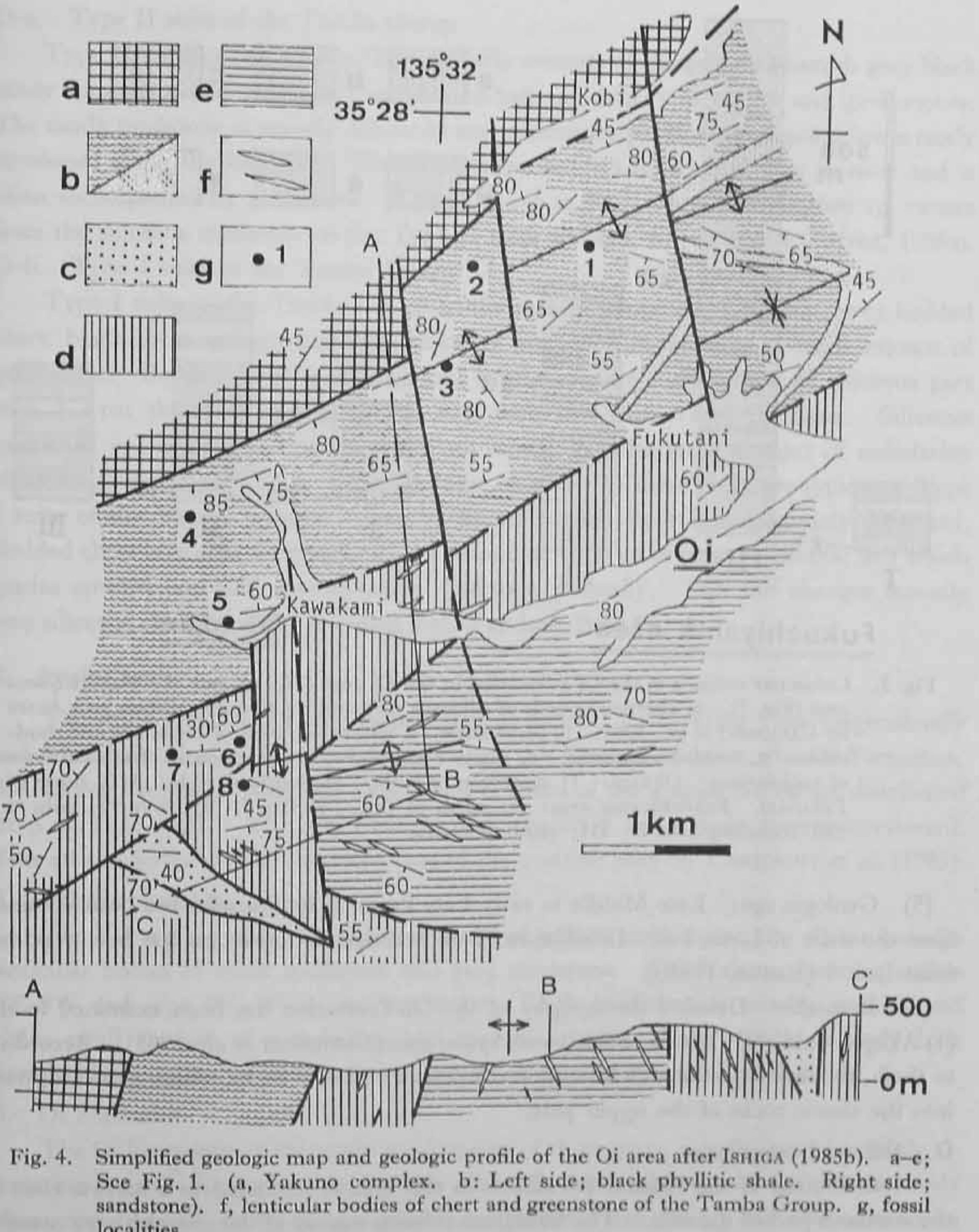

Fig. 4. Simplified geologic map and geologic profile of the Oi area after ISHIGA (1985b). a–e; See Fig. 1. (a, Yakuno complex. b: Left side; black phyllitic shale. Right side; sandstone). f, lenticular bodies of chert and greenstone of the Tamba Group. g, fossil localities.

ous shale and bedded chert are also included as lenticular bodies. The thickness of the formation is estimated at about 500 m in the type area (Fig. 5). The Oi Formation is folded with wave length of about 1 km and the axis gently dips southwest. The distribution of the sandstone is controlled by folding and shows the S-shape. The quartz veins are usually formed along the foliation of the phyllitic shale of the Oi Formation.

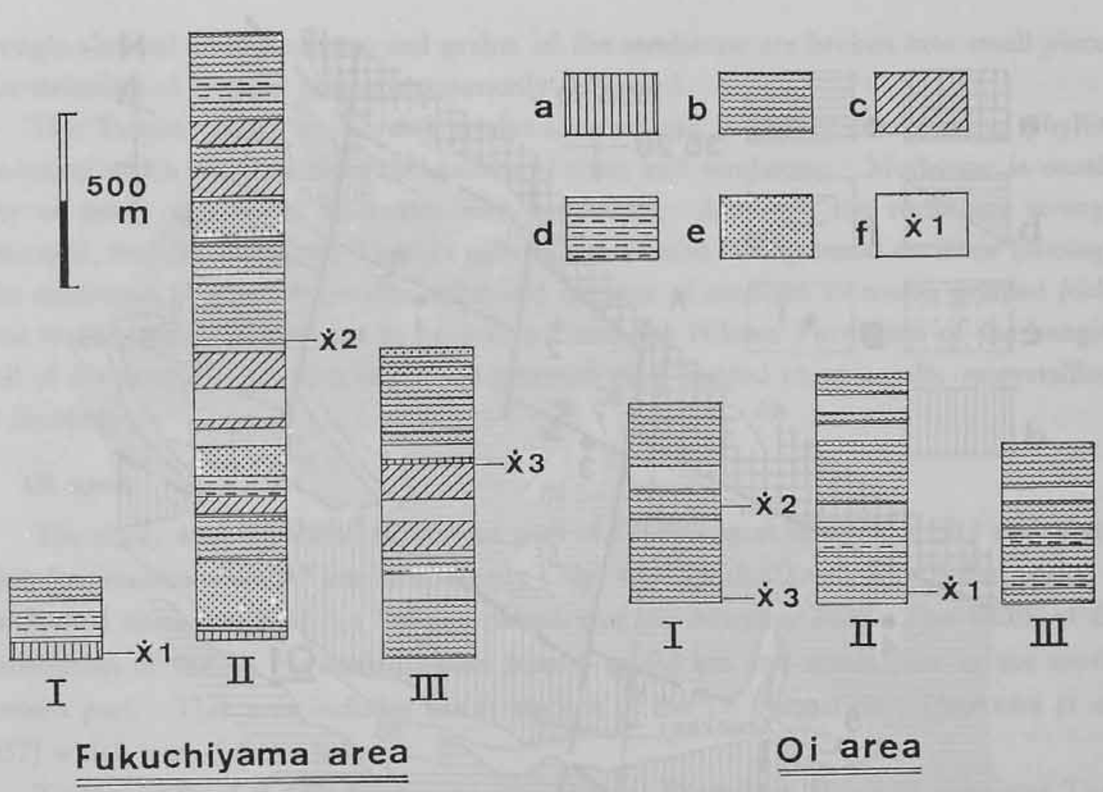

Fig. 5. Columnar sections of the Oi Formation in the Oi area (Fig. 4) and the Fukuchiyama area (Fig. 7). a, alternating beds of siliceous rock and pelitic rock (ribbon rock facies by CARIDROIT *et al.*, 1985). b, black shale. c, alternating beds of sandstone and mudstone. d, bedded sandstone. e, massive sandstone. f, horizons of the occurrence of radiolarians. Oi area: I; southwest of Kobi. II; south of Kobi. III; north of Fukutani. Fukuchiyama area: I; north of Loc. 1 in Fig. 7. II; from Kuroishi to SSE including Loc. 2. III; south of Ebara.

(5) Geologic age: Late Middle to early Late Permian *Follicucullus* has been obtained from the shale of Locs. 1–5. In addition, Late Permian *Fo. bipartitus* has been reported from Loc. 1 (ISHIGA, 1985b).

(6) Remarks: Detailed stratigraphy of the Oi Formation has been examined in the (1) Akaguri-saki area (ISHIGA, 1985b) and Ayabe area (CARIDROIT *et al.*, 1985). According to them, the lower part of this formation consists of siliceous rocks, which grades upward into the clastic rocks of the upper part.

C. Hikami Formation

Distribution of the Hikami Formation in this area is restricted to a narrow zone in the southern part of the area. The formation consists mainly of the greenish grey massive sandstone.

D. Tamba Group

Both Type I and II suites of the Tamba Group are folded and form an antiform with nearly the same wave length of that of the Oi Formation. Its axis also gently plunges to the west. Along and near the axial part of the antiform, the Type I suite is distributed, while the Type II suite is developed in both wings.

D-a. Type II suite of the Tamba Group

Type II suite of the Tamba Group chiefly consists of the grey to greenish grey black sandy mudstone and includes lenticular bodies and blocks of cherts and greenstones. The sandy mudstone is usually deformed and sometimes phyllitic, but quartz veins rarely developed along the foliation. The chert shows reddish brown and grey in color and is often accompanied by greenstone. Late Triassic to Early Jurassic *Canoptum* sp. occurs from the siliceous mudstone of the Type II suite at Locs. 6–8 in Fig. 4 (ISHIGA, 1985a).

D-b. Type I suite of the Tamba Group

Type I suite of the Tamba Group in the area is composed of blackish grey bedded chert, black shale and greenish grey siliceous mudstone in addition to small amount of greenstone. Bedded chert is characteried by the rhythmic alternation of siliceous part with 1–4 cm thickness and mudstone film with less than 5 mm thickness. Siliceous mudstone is compact and partly tuffaceous which includes large amount of radiolarian skeletons (about 15 to 25%). The lithologic character of these rocks are typical of Type I suite of the Tamba Group. These rocks are rather phyllitic and strongly deformed. Bedded chert is usually recrystallized. Greenstone consists of massive basaltic lava which grades upward into tuff and tuffaceous mudstone gradually. This tuff changes laterally into siliceous shale which is so-called Toishi at Loc. B in Fig. 4.

4. Ayabe area

The study area includes the eastern part of Ayabe City covering 5 km longitudinally and 8 km latitudinally (Fig. 6). In this area, the Yakuno complex, the Oi Formation, the Hikami Formation and both Type I and II suites of the Tamba Group are distributed from north to south. They are trending in ENE-WSW and steeply dipping northward. This area includes the southwestern part of the geologic map by CARIDROIT *et al.* (1985).

A. Yakuno complex

The Yakuno complex is mainly composed of gabbro and serpentinite which includes lenticular bodies of black mudstone and grey sandstone. The Yakuno complex strikes NE-SW and dips 20°–30° to the northwest. Black mudstone is usually massive and yields small amount of radiolarians and sponge spicules. Late Middle to early Late Permian *Follicucullus* sp. occurs from black siliceous mudstone at Loc. 4 in Fig. 6.

B. Oi Formation

The Oi Formation in the study area consists of three parts, namely, the very thinly alternating beds of siliceous rock and pelitic rock called the "ribbon rock facies", the thinly alternating beds of sandstone and mudstone (pelitic flysch facies) and olistostrome, in ascending order. The name "ribbon rock facies" is first introduced by CARIDROIT *et al.* (1985), which means a rock characterized by a succession of thin layers of differing composition or appearence (Glossary of Geology, 1972, edited by the American Geological Institute, Washington, D.C.). The former two members are widely distributed and the olistostrome is restricted in distribution. They usually strikes NE-SW and dips 60°–80° to northwest.

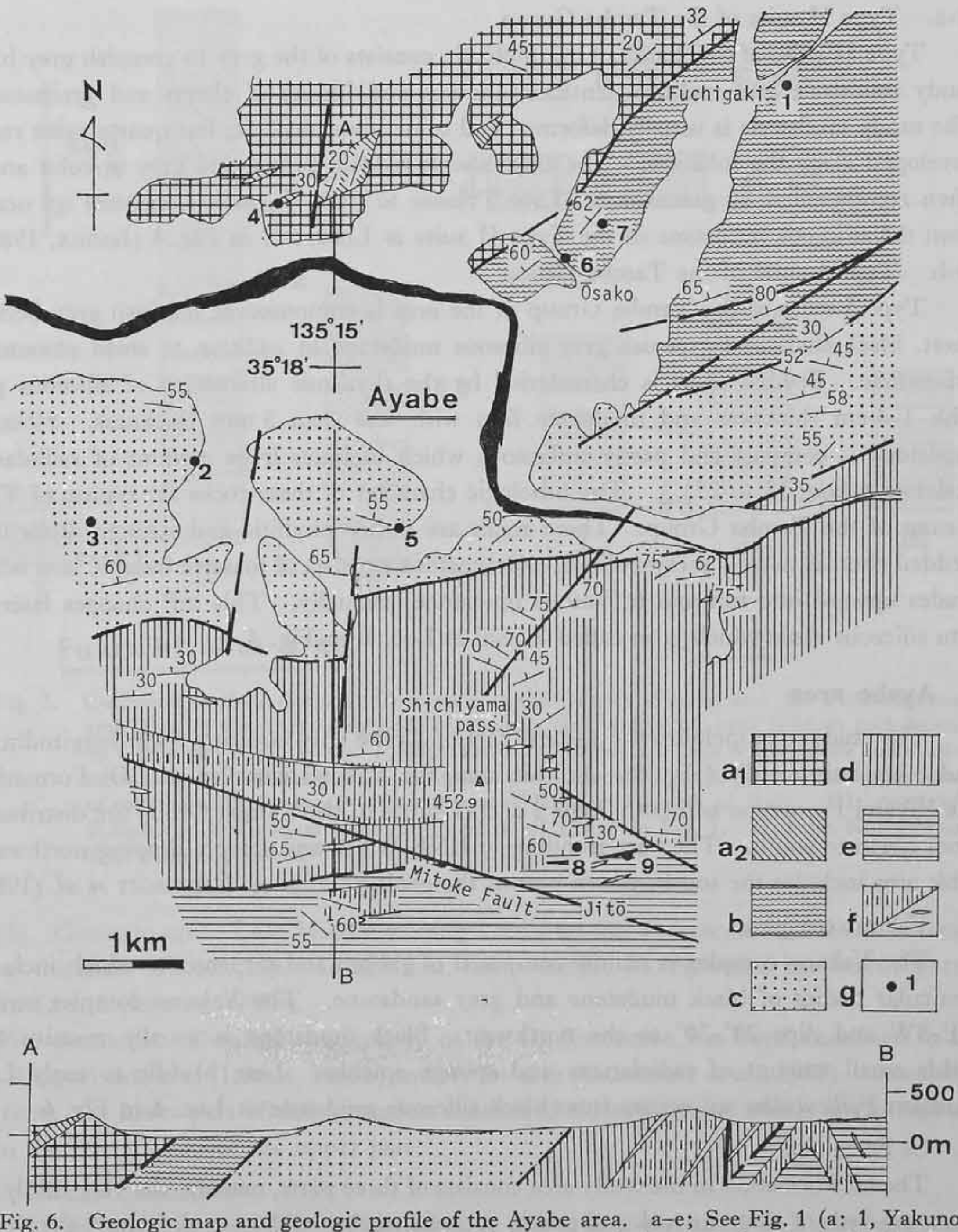

Fig. 6. Geologic map and geologic profile of the Ayabe area. a–e; See Fig. 1 (a: 1, Yakuno complex. 2, black mudstone in the Yakuno complex). f: Left side; bedded chert. Right side; lenticular bodies of greenstone and chert. g, fossil localities and the localities of explanation of geology.

The thinly alternating siliceous rock-pelitic rock of the lower member consists of alternation of siliceous beds (2–4 cm thick) and pelitic films (about a few mm thick). However, detailed observation clarifies that the siliceous beds are composed of thinner siliceous part (about a few mm thick) and pelitic part (less than 1 mm thick). The characteristic lithology of the ribbon rock differs from that of the bedded chert in the Tamba Belt. Well-preserved radiolarians occur from the siliceous part of this rock at Loc. 1 in Fig. 6 (CARIDROIT *et al.*, 1985).

The thinly alternating sandstone and mudstone of the middle member is composed of the alternating beds of greenish grey fine sandstone layer with a few mm thickness or less and greenish grey or black mudstone layer with a few mm thickness. This rock grades upward or laterally into greenish grey siliceous siltstone and mudstone or black phyllitic shale at Loc. 6 in Fig. 6. The alternating beds of sandstone and mudstone are regarded to be lie on the alternating siliceous rock and pelitic rock.

Recently, Late Permian *Neoalbaillella grypus* and *Albaillella levis* were found from the black shale of the alternating sandstone and mudstone at Loc. 7 in Fig. 6 (see Table 1).

C. Hikami Formation

The Hikami Formation in the study area consists of green sandstone with intercalation of greenish grey mudstone and black shale. The sandstone usually grades upward and laterally into mudstone and they sometimes alternate with each other. In this case, the thickness of sandstone layer ranges from 3 to 8 cm thick and that of the mudstone is about 1 cm thick or less, which closely resembles the lithology of the thinly alternating beds of sandstone and mudstone of the middle member of the Oi Formation mentioned above. The greenish gray siliceous mudstone grades upward into greenish grey sandstone within a thickness of about 3 m at Loc. 5.

Concerning the age of this formation, *Follicucullus* (?) sp. occurs from mudstone at Locs. 2, 3 in Fig. 6 (KURIMOTO and KIMURA, 1985; KURIMOTO, 1986).

The Hikami Formation in this area strikes ENE-WSW trend and steeply dips northwest and is tectonically overlain by the Oi Formation.

D. Tamba Group

D-a. Type II suite of the Tamba Group

The Type II suite of the Tamba Group is composed of sandy mudstone which includes lenticular bodies and blocks of sandstone, bedded chert and greenstone. Bedded cherts show red to reddish brown in color and some of which are accompanied by greenstone. The sandy mudstone includes thin beds of siliceous mudstone and tuff both of which yield Early Jurassic *Parahsuum simplum* Assemblage of YAO *et al.* (1982) at Loc. 8. The strata in this area is characterized by Early Jurassic siliceous mudstone which is typically occurring in the Type II suite of the Tamba Group.

D-b. Type I suite of the Tamba Group

The Type I suite of the Tamba Group chiefly composed of grey to greyish black bedded chert and black mudstone and shale. The Type I suite forms antiform with its axis trending E-W and the strata are cut by the Mitoke Fault trending WNW-ESE. The Type I and Type II suites are in fault contact in this area and the fault has sheared zone with about 4 m thickness. The fault plane strikes N70°E and dips 75° to the north, which is nearly parallel to the bedding plane of the Type II siute of the Tamba Group.

The sheared zone is composed of black fault gouge and spouts water from the fault plane at Loc. 9 in Fig. 6.

5. Fukuchiyama area

The examined area occupies the southwestern part of Fukuchiyama City, Kyoto Prefecture and eastern part of Hikami-gun, Hyogo Prefecture, covering 7 km longitudinally and 8 km latitudinally (Fig. 7). The "Meso-Paleozoic strata" in the area consist of the Yakuno complex, the Oi Formation, the Hikami Formation (re-defined here), and Type II suite of the Tamba Group. They are gently dipping northward.

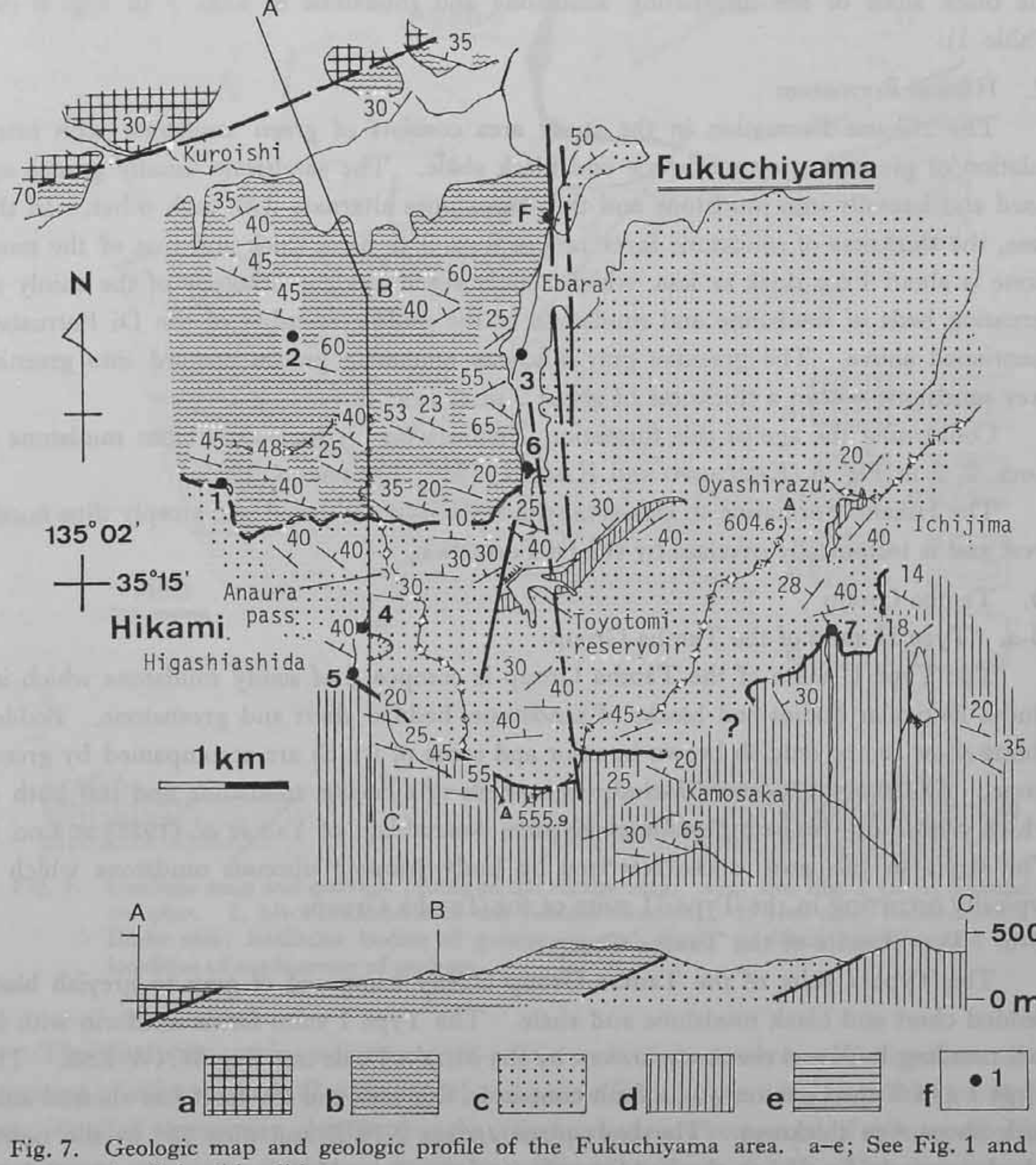

Fig. 7. Geologic map and geologic profile of the Fukuchiyama area. a–e; See Fig. 1 and 4. f, fossil localities.

A. Yakuno complex

The Yakuno complex is distributed in the northern margin of the study area and is composed of mainly gabbro and diabase (NAKAZAWA, 1961).

The Yakuno complex is regarded to be in fault contact with the Oi Formation. The gabbro and diabase of the Yakuno complex is strongly sheared. Although the very point of the contact between them is not exposed, the plane of the shear dips 45° to the north at 1.5 km ENE of Kuroishi (Fig. 7). The foliation of the phyllitic diabasic rock strikes N70°E and dips 48° to the north which is nearly the same with that of the shear plane and the bedding plane of the Oi Formation. Generally, the boundary between the Yakuno complex and the Oi Formation is represented by the linear trend of fault, which is regarded to be steeply dipping northward. The general trend of the Oi Formation is oblique to the direction of this fault as noted below.

B. Oi Formation

The Oi Formation is widely distributed in the middle to north of the study area and is well exposed along the road leading from Ebara to Toyotomi-reservoir.

The Oi Formation in the area strikes N50°W and dips 20°–40° to the north. The apparent total thickness of it is over 1500 m but the beds of the formation is regarded to be repeated tectonically by thrust faults. The distribution of this formation is cut by a fault which is nearly vertical with N-S trend. This fault is here named the Ebara Fault, since it is exposed at Loc. F near Ebara. This fault is accompanied with 3–4 secondary faults trending in N-S and NNE-SSW directions.

The Oi Formation is composed of blackish grey pelitic shale, well bedded siltstone and fine sandstone. In some part, greenish grey siliceous shale and alternating beds of siliceous shale-chert and pelitic rock are included. Black phyllitic shale is often laminated. This rock easily peels off along the planes of the foliation. The laminae consist of alternation of light colored siliceous part and dark grey pelitic part, both of which are composed of chlorite, illite and very fine grains of quartz and feldspar under microscope and by X-ray diffraction analysis.

The thinly alternating beds of siliceous rock and pelitic rock of the formation has the same lithologic character with that of the Ayabe area and grades upward into the greenish grey siliceous shale within 5 m thickness, at Loc. 1 in Fig. 7. In this sequence, the siliceous layer of the alternation diminishes the thickness into 1 mm thick or less and in turn, alternates with the grey shale with nearly equal thickness of about 1 mm or less. Finally, the alternation changes into siliceous shale.

Concerning the age of this formation, Late Permian *Follicucullus bipartitus-Fo. charveti* Assemblage occurs from the siliceous shale near the boundary between the alternated siliceous rock and pelitic rock and the siliceous shale at Locs. 1 and 2. *Follicucullus* (?) sp. was found from the black shale at Loc. 3 by KURIMOTO in KURIMOTO and KIMURA (1985) and KURIMOTO (1986).

The Oi Formation is fault contact with the Hikami Formation in the middle part of the area. The fault plane strikes N55°W, and dips 20°–25° to the north, which is nearly parallel to the bedding plane of the Oi Formation at Loc. 6 in Fig. 7. Beneath the fault plane, the sheared zone of 1 m width is developed and is composed of fault breccia of black phyllite of the Oi Formation and green sandstone of the Hikami Formation. The quartz veins are formed especially in the Oi Formation of the hanging wall of the fault. Some part of the fault breccia is consolidated, while the other is soft and spouting water. It means the fault between the Oi and the Hikami Formation have been moved stepwise at several times. The fault having the same characteristics with this fault are developed within the Oi Formation near the boundary between the Oi and the Hikami Formations. The fault planes between them are mostly parallel to the bedding plane and foliation of the Oi Formation.

C. Hikami Formation (re-defined herein)

(1) Name: This name was first introduced by HIROKAWA *et al.* (1954) in the Tajimatakeda area adjacent to the western part of this area and later by NAKAZAWA (1961) in the present area. As mentioned already, the "Hikami Formation" in their sense includes 2 or 3 formations. Thus, in this paper, the Hikami Formation is re-defined and is applied for the formation represented chiefly by green sandstone. The name Hikami is a county where the stratotype is located.

(2) General concept: The Hikami Formation re-defined is characterized by thick green sandstone, which is strongly sheared and cataclastic.

(3) Stratotype and distribution: The formation is typically exposed along the road near Anaura Pass and the forest road running south of this pass, which are located in Aogaki-cho, Hikami-gun, Hyogo Prefecture near the boundary with Kyoto Prefecture (columnar section I in Fig. 8). It is distributed in the middle part of the examined area and is cut by the Ebara Fault mentioned above.

(4) Description: This formation consists of greenish grey coarse to medium grained sandstone, called collectively the green sandstone, and intercalated black phyllitic shale and greenish grey shale. The total thickness is about 640 m along the stratotype area (columnar section I), while it is regarded to be up to 1000 m thick in the area east of the Ubara Fault (columnar section II).

The green sandstone is usually massive but is partly bedded or graded. The sandstone intercalates a black phyllitic shale of about 2 to 10 m thickness and includes lenticular bodies of black shale as clasts in the stratotype area. All of these leticular bodies are strongly sheared. Black shale at the Toyotomi-reservoir contains small lenses or blocks of sandstone and chert, and laterally changes into homogeneous mudstone without lenses nor blocks.

Petrologic description is done in detail by KUSU and ISHIGA (in prep.) (cf. chapter V) and a brief outline is referred here. Sandstone is usually wacke containing over 30 percent terrigenous muddy matrix and sandgrains are usually poorly sorted and angular. Deeply embayed grains of quartz are abundant and the amount of plagioclase is larger than that of alkali feldspar. Concerning lithic fragments, granitic and acid volcanic rocks are abundantly contained.

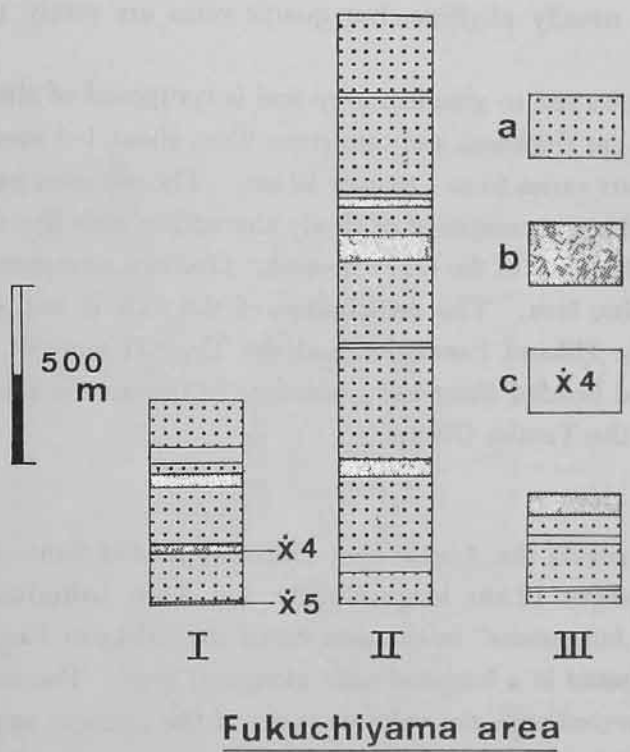

Fig. 8. Columnar section of the Hikami Formation in the Fukuchiyama area (Fig. 7). a, greenish grey sandstone. b, black shale and greenish grey mudstone. c, horizon of the occurrence of radiolarians. I; south of Anaura Pass. II; south of Ebara to Toyotomi-reservoir. III; west of Ichijima.

(5) Geologic age: *Follicucullus* (?) sp. was found from a black shale intercalated within the green sandstone at Loc. 4 and near the Loc. 5 (Fig. 7) by KURIMOTO in KURIMOTO and KIMURA (1985) and KURIMOTO (1986).

(6) Remarks: The Hikami Formation tectonically overlies the Type II suite of the Tamba Group and they are in fault contact at Locs. 5 and 7 in Fig. 7. The fault plane in each locality is gently dipping at about 5° and 10° to the north, respectively. At both localities, the fault is represented by strongly sheared black phyllite with a thickness of several tens of centimeters. The sandstone of the hanging wall is especially cataclastic. The footwall of the fault is composed of greenstone of the Type II suite and is strongly sheared in the width of 1.5 m to 3 m.

D. Tamba Group

In the study area, Type II suite of the Tamba Group is distributed in the southern margin and is well exposed along the forest road leading from Kamosaka to the north. Type II suite is also cut by the Ebara Fault.

Type II suite is mainly composed of sandy mudstone and intercalates a thick bed of sandstone. Bedded chert and greenstone are included as lenticular bodies in various scales. Mudstone is usually phyllitic, but quartz veins are rarely developed along the foliation.

Bedded chert shows red to greenish grey and is composed of alternation of siliceous part with usually 1–4 cm thickness and mudstone films about 1–3 mm thick. The thickness of the siliceous part varies from 1 to over 10 cm. The siliceous part is usually massive and homogeneous and is not composed of thinly alternating beds like that of the alternated siliceous rock and pelitic rock of the Oi Formation. Greenstone commonly consists of tuff, tuff breccia and basaltic lava. The distribution of the rock is well continued along the boundary between the Hikami Formation and the Type II suite of the Tamba Group. The accociation of red bedded chert and greenstone in this area is one of the characters of the Type II suite of the Tamba Group.

6. Aogaki area

The study area covers the Aogaki-cho, Hikami-gun and Santo-cho and Asago-cho, Asago-gun, which ranges 12 km longitudinally and 5 km latitudinally (Fig. 9). The "Mesozoic-Paleozoic formations" in the area called the "Hikami Formation" (Hirokawa *et al.*, 1954) is distributed in a longitudinally elongated area. The strata in the southern part of the area is covered with the volcanic rocks of the younger age, while those in the northern part of it are intruded by granitic rocks.

The "Hikami Formation" by Hirokawa *et al.* (1954) is here integrated into the Oi Formation, the Hikami Formation revised above, the Type II suite and the Type I suite of the Tamba Group. These strata form gentle folding with the axis of E-W trend and are tectonically superposed in this order. The Type I and II suites of the Tamba Group are distributed in the antiform, while the Oi and the Hikami Formations are developed in the synforms.

In the western part of the area, Asago, it is deciphered that the Yakuno complex tectonically overlies the "Hikami Formation", which is equivalent to the Oi Formation in this paper, forming a nappe structure (Hayasaka and Hara, 1980). Through the present examination, it is clarified that in the south of the Asago-yama, adjacent to the northeast of Asago, the Yakuno complex directly overlies the Type II suite of the Tamba Group and both the Oi Formation and the Hikami Formation of the Ultra-Tamba Zone lack in this area.

A. Yakuno complex

The Yakuno complex is distributed in three parts, namely, north of Aogaki, Asago-yama, and west of Asago from eastern to western parts and is composed of gabbro and diabase with a small amount of granitic rocks. Black mudstone is often intercalated and it was called the Chihara Formation (Hirokawa *et al.*, 1954).

B. Oi Formation

This Formation is well exposed along the forest road leading from Ichinose to the northwest. The Oi Formation in this area is chiefly composed of thinly alternating beds of greenish grey fine sandstone and mudstone and subordinately intercalates black shale.

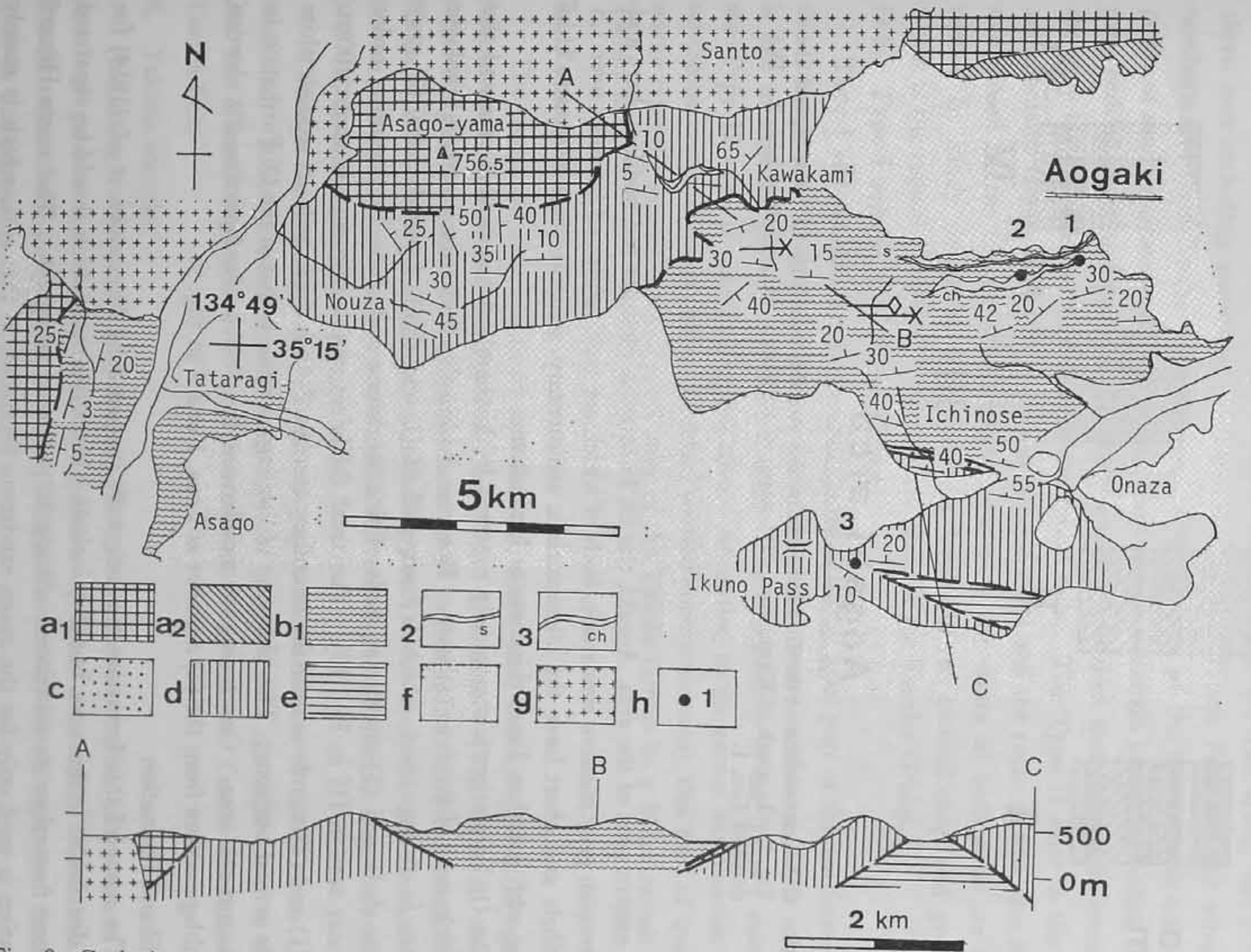

Fig.. 9 Geologic map and geologic profile of the Aogaki area. a–e; See Fig. 1 and 6 (b: 1, mainly alternating beds of black shale and sandstone. 2, massive sandstone. 3, very thin siliceous rock and pelitic rock). f, Late Mesozoic volcanic rocks. g, Late Mesozoic granitic intrusives. h, fossil localities.

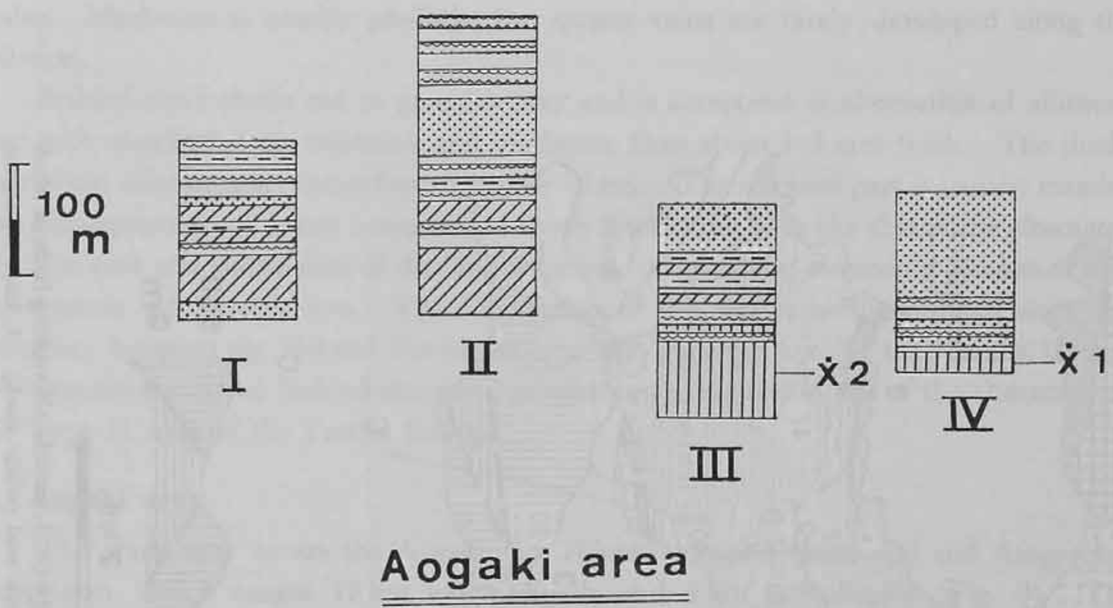

Fig. 10. Columnar section of the Oi Formation in the Aogaki area (Fig. 9). For legend see Fig. 5. I; south of Kawakami. II; north of Ichinose. III; north of Loc. 2. IV; north of Loc. 1.

In the eastern part of the area, Aogaki, the Oi Formation includes red bedded chert and dark greenish grey massive sandstone, both of which are well continued laterally over 1.5 km. Shale and chert have the characteristic sedimentary structure, such as very thin bedding with less than 5 mm thickness or lamination.

The Oi Formation is tectonically repeated by low-angle thrust in this area and the total thickness is difficult to estimate. However, within this formation a certain lithologic sequence is distinguished, which is composed of (1) red thinly bedded chert, (2) grey siliceous shale and (3) alternating beds of fine sandstone and shale, in ascending order (columnar section III in Fig. 10). The total thickness of this sequence is about 100 m. Both (1) and (2) members near the boundary contian 2–4 cm thick beds of reddish white chert in several horizons. This character of lithology is same as that of the Oi Formation in the Akaguri-saki area. Concerning the radiolarians, the *Follicucullus bipartitus-Fo. charveti* Assemblage occurs from the (1) member at Locs. 1 and 2 in Fig. 9.

C. Hikami Formation

The name of this formation was originally proposed by HIROKAWA *et al.* (1954) for strata distributed in this area, but they include 4 kinds of strata which should be separated into four formations as mentioned already in previous paragpaph. The name Hikami Formation is used only for the green sandstone formation in this area, which is mainly composed of greenish grey massive sandstone. It is distributed only in a narrow zone with width of about 80 m at Ichinose and both the northern and the southern boundaries with other formations are represented by faults gently dipping northward. The sandstone of this zone is strongly sheared and cataclastic.

D. Tamba Group

D-a. Type II suite of the Tamba Group

Type II suite of the Tamba Group is distributed in the two areas; one is the southern area including southwest of Onaza and west of Ikuno Pass and the other is the northern area from Nouza to Kawakami. Type II suite of the two areas is mainly composed of sandy mudstone and sandstone, both of which contain lenticular bodies of red to grey bedded chert and greenstone. *Follicucullus scholasticus* morphotype II occurs from the grey bedded chert at Loc. 3 near the Ikuno Pass. The Type II suite in the former area contains larger amount of lenses of bedded chert and the rocks of this area is metamorphosed by the Cretaceous-Paleogene granite. The strata in both areas are characterized by sandy mudstone with lenticular bodies of red bedded chert and greenstone which is the typical lithology of the Type II suite of the Tamba Group.

D-b. Type I suite of the Tamba Group

Type I suite is distributed in a narrow zone of the axial part of the antiform east of the Ikuno Pass. This suite consists of greyish white massive sandstone. The sandstone is fine to medium grained quartzose wacke. The relationship of the Type I suite with the Type II suite is unknown in this area. According to the recent examination of the sandstone composition by Kusu (personal written communication), this kind of quartzose wacke typically occurs in the Type I suite of the Tamba Group in a wider region of the Tamba Belt.

7. Yamasaki area

The examined area is located at Yamasaki, Shiso-gun, western part of Hyogo Prefecture and covers 8 km longitudinally and 7 km latitudinally (Fig. 11). In this area following geologic units are distributed from north to south, according to Hirokawa and Kambe (1963); the Hijima Formation including the Yakuno complex, the Yamasaki Formation and the Mikazuki Formation. The active fault, the Yamasaki Fault, trending in NW-SE direction cuts these strata.

Through the present study, the stratatigraphy and structure of these strata are reexamined. It has been deciphered that they are classified into the equivalent to the Oi and the Hikami Formations of the Ultra-Tamba Zone and the Tamba Group of the Tamba Belt.

A. Yakuno complex

According to Hirokawa and Kambe (1963), the Yakuno complex in the area is composed of gabbro and diabase with intercalation of balck mudstone. Hirokawa and Kambe referred these basic rocks to the Hijima Formation, but is separated from the latter in this paper.

B. Hijima Formation (re-defined herein, equivalent of the Oi Formation)

(1) Name: This name was first introduced by Hipokawa and Kambe (1963). The Hijima Formation in this paper consists mainly of the Late Permian black mudstone and basic rocks, formerly referred to the formation, are assigned to the Yakuno complex.

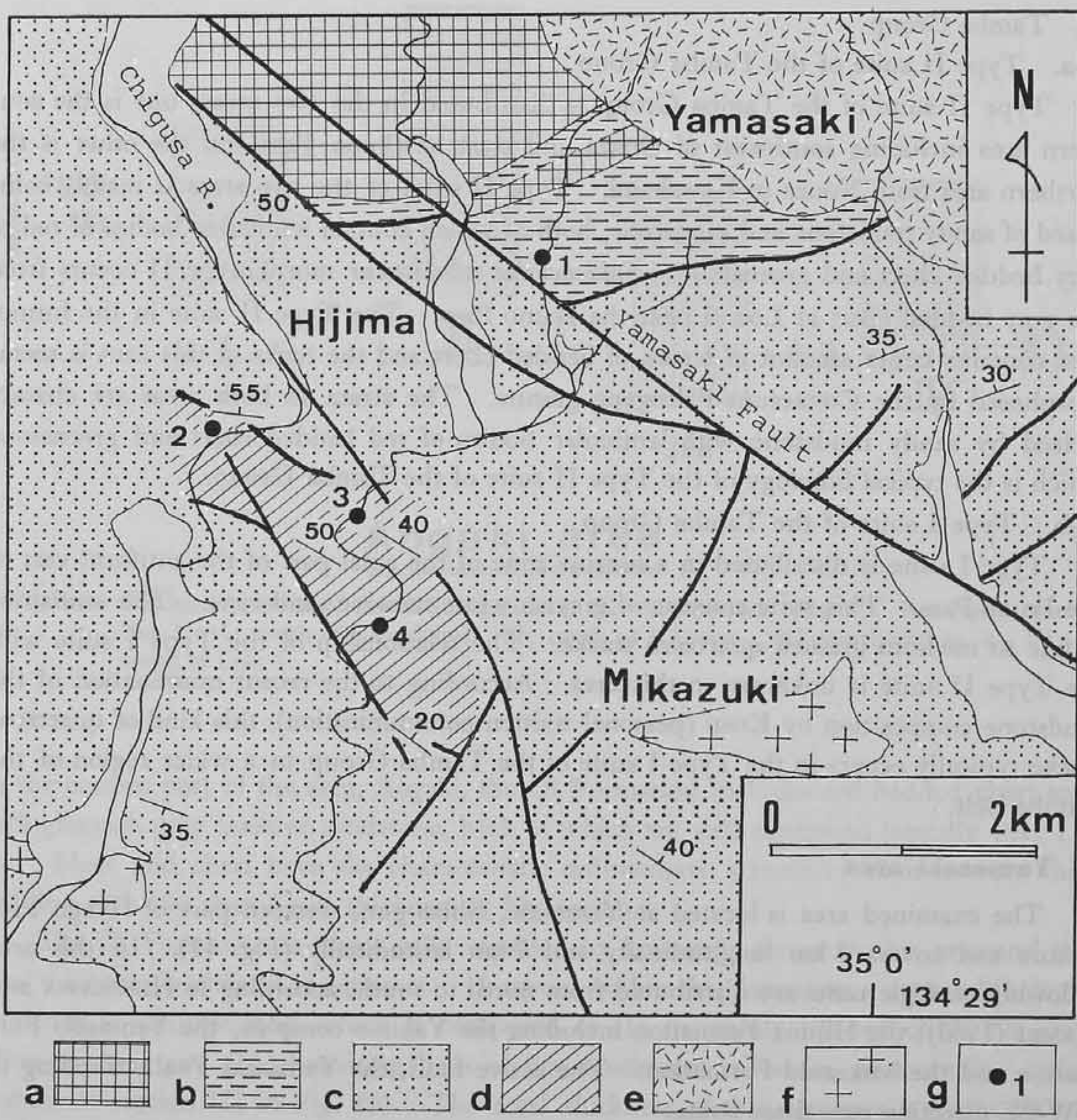

Fig. 11. Geologic map of the Yamasaki area. Compiled from Hirokawa and Kambe (1963) and the unpublished data of the author's. For a–c see in Fig. 1 (b, Hijima Formation, equivalent of the Oi Formation. c, Yamasaki Formation including the Mikazuki Formation, equivalent of the Hikami Formation). d, Type II suite of the Tamba Group. e, Cretaceous-Paleogene volcanic rocks. f, Cretaceous-Paleogene granitic intrusives. g, fossil localities (1–4) and other localities (5–6) cited in the text.

(2) General concept: The Hijima Formation re-defined is characterized by black mudstone.

(3) Stratotype and distribution: The formation is typically exposed along the small river east of Hijima at Loc. 1 in Fig. 11.

(4) Description: The Hijima Formation consists of black mudstone and phyllitic black shale with lenticular bodies of grey sandstone, chert and greenstone including small lenses of limestones. This formation strikes E-W and gently dips northward. The total thickness is estimated at about 800 m near the type area. The Hijima Formation at Loc.

1 is mainly composed of black siltstone and contains greenish grey mudstone and bedded sandstone, which shows the same lithologic character as those of the Oi Formation in the Ayabe area.

(5) Age: Permian fusulinids were reported from the limestones accompanied with greenstones, but the mode of occurrence of these limestones is uncertain at present. The *Follicucullus bipartitus-Fo. charveti* Assemblage, which is characteristic of the Oi Formation of the Ultra-Tamba Zone, was first reported and described from the black mudstone at Loc. 1 (CARIDROIT and DE WEVER, 1984; DE WEVER and CARIDROIT, 1984). Judging from the lithology and the radiolarian assemblage of the Hijima Formation, it is concluded that this formation is equivalent to the Oi Formation of the Ultra-Tamba Zone.

C. Yamasaki Formation (re-defined herein, including the Mikazuki Formation)

The Yamasaki Formation mainly consists of green sandstone and is distributed along south of the Hijima Formation. Accordnig to the author's field survey, the "Mikazuki Formation" forms a gentle folding with its axis trending nearly E-W and is divisible into two parts as follows: One is composed of mainly green sandstone and the other consists of pebbly mudstone. The former is distributed in the synform or both wings of the antiform and has the same lithologic character as the Yamasaki Formation. The latter is developed in the axial part of the antiform and belongs to the Tamba Group as noted below. Since the "Mikazuki Formation" is segregated into the two different formations, the name Mikazuki is not applied in this paper as stratigraphic unit. Under this scheme, re-definition of the Yamasaki Formation is needed.

(1) Name: The Yamasaki Formation was first proposed by HIROKAWA and KAMBE (1963) and as mentioned above, the formation also includes the main part of the "Mikazuki Formation" of HIROKAWA and KAMBE (1963).

(2) General concept: The Yamasaki Formation is characterized by thick green sandstone.

(3) Stratotype and distribution: The formation is typically exposed along the Chigusa River, Yamasaki-cho, Sayo-gun, Hyogo Prefecture. It is distributed in the middle to southern main part of the mapped area (Fig. 11).

(4) Description: This formation consists of greenish grey coarse to medium grained sandstone and intercalated black shale. The total thickness is estimated at about 800 m along the stratotype area. The green sandstone is usually massive but is partly bedded. Sandstone contains black shale of about 1 m thickness. The rocks are not so strongly deformed as in the case of the equivalent Hikami Formation in the Aogaki and other areas.

Sandstone contains about 35% terrigenous clay matrix and sandgrains are usually poorly sorted and angular. The amount of quartz grains is about 25%, while that of feldspar grains is about 30% in average. These grains show wavy extinction. Concerning the lithic fragments, granitic and acid volcanic rocks are abundantly contained which is the same characteristics as those of the Hikami Formation of the Ultra-Tamba Zone.

(5) Correlation: The Yamasaki Formation does not yield age-diagnostic fossil, but, from lithological coincidence, mentioned above, it can be correlated with the Hikami Formation of the Fukuchiyama and the Ayabe areas, where late Middle to early Late Permian *Follicucullus* (?) sp. occurs from the black shale as mentioned already.

(6) Remarks: The Yamasaki Formation strikes E-W and dips gently (15°–30°) to the north in the northern part and is gently folded in the southern part. The geologic relation of the Yamasaki Formation with the Hijima Formation is unknown in this area, while the Yamasaki Formation tectonically overlies the Tamba Group described below, the boundary fault being observed at Locs. 5 and 6 in Fig. 11. The fault strikes N50°W and dips 45° to the northeast, which is nearly parallel to the bedding plane of the Yamasaki Formation. The sandstone of the Yamasaki Formation of the hanging side is strongly cataclastic and is accompanied with many veins of quartz. The pebbly mudstone of the foot wall is also strongly deformed and phyllitic.

D. Tamba Group

The Tamba Group in the area is developed in the narrow part along the axial part of the antiform. The group is characterized by pebbly mudstone mainly consisting of black sandy mudstone with small lenses of sandstone, acidic tuff, chert and greenstone. The rocks are usually phyllitic, especially strongly deformed near the boundary with the Yamasaki Formation as noted above. The mudstone yields the Jurassic (probably Middle Jurassic) radiolarians such as *Tricolocapsa* spp., *Stichocapsa* spp. and unnamed nassellarians at Locs. 2–4 in Fig. 11. The strata is regarded to belong to the Type II suite of the Tamba Group, based on the lithologic character and age.

8. Fukusaki area

The area examined is located at Fukusaki, north of Himeji City, Hyogo Prefecture and covers 6 km longitudinally and 8 km latitudinally (Fig. 12). Accordnig to previous studies, the "Mesozoic-Paleozoic formations" of this area consist of the Kasai Group (Goto *et al.*, 1983) and a Paleozoic formation (Tatsuno Group of the Kamigori Belt of Igi ed., 1971) from north to south. The Kasai Group is divided into the Lower, Middle and Upper Formations. Early to Middle Jurassic radiolarians were reported from the mudstone of the Lower and Middle Formations, which are composed of black mudstone with lenses of chert and greenstone (Goto *et al.*, 1983). These two formations can be correlated with the Tamba Group, probably Type II suite in view of the presence of the Lower to Middle Jurassic clastic rocks. The Upper Formation of the Kasai Group chiefly consists of the greenish grey sandstone and is regarded to be equivalent of the Hikami Formation in this paper. These strata are briefly described below.

A. Black mudstone (Tatsuno Group) of the Kamigori Belt

Black mudstones with small amount of bedded sandstone are distributed in small parts from Toyotomi to Oyanagi, which are covered with Cretaceous to Paleogene volcanic rocks. The strata forms a synform with its axis trending ENE-WSW. The beds of the both wings are gently dipping about 20°–30°. The black mudstones are intruded

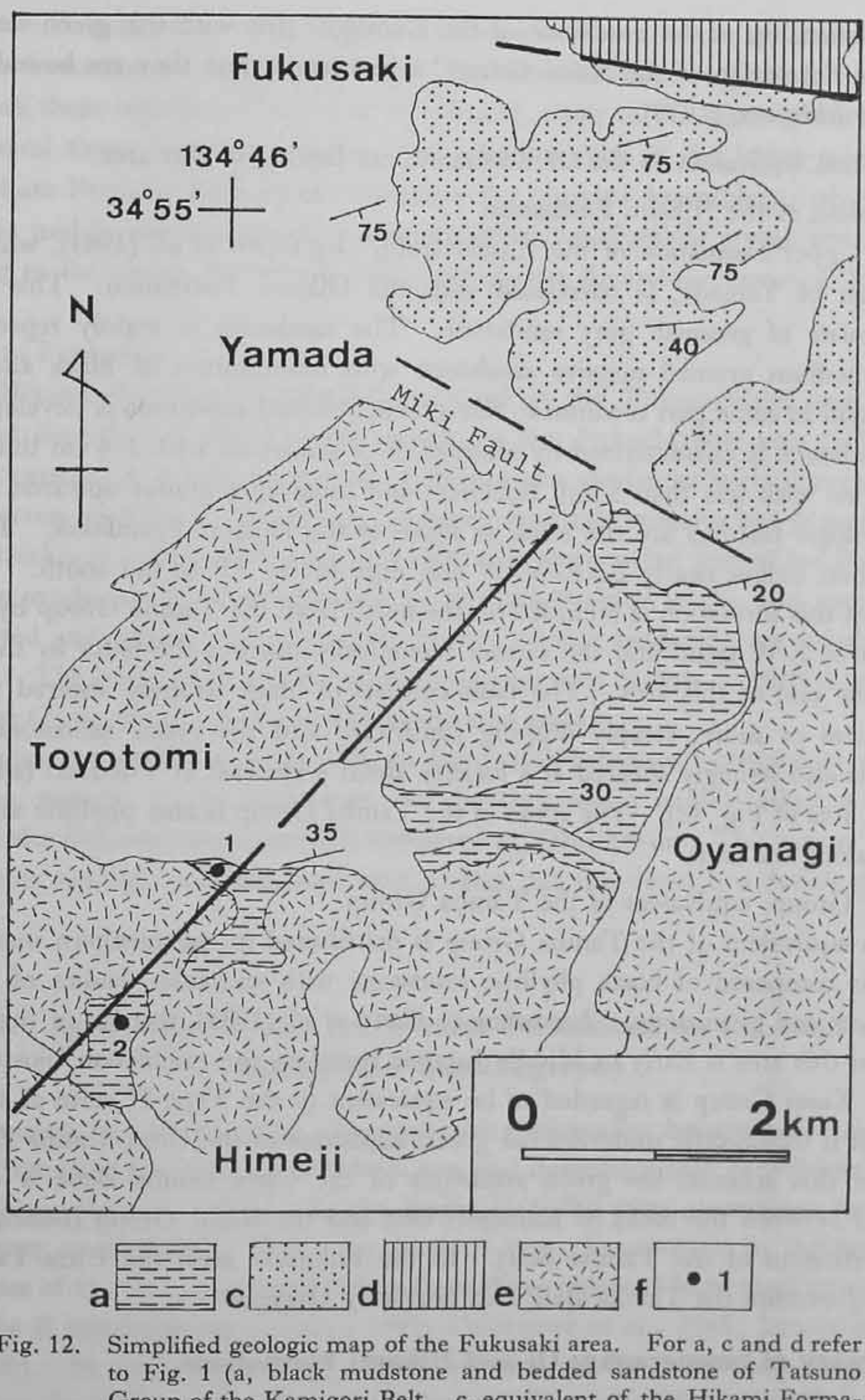

Fig. 12. Simplified geologic map of the Fukusaki area. For a, c and d refer to Fig. 1 (a, black mudstone and bedded sandstone of Tatsuno Group of the Kamigori Belt. c, equivalent of the Hikami Formation. d, Kasai Group revised, equivalent of the Tamba Group). e, Cretaceous-Paleogene volcanic rocks. f, fossil localities.

by clastic dykes of about 1 m thickness, which is composed of tuffaceous rocks trending in N-S and NE-SW.

Concerning the age of the mudstone, late Middle to early Late Permian *Follicucullus scholasticus* morphotype II occurs from the black mudstone at Locs. 1, 2 in Fig. 12. The geologic relationship of the mudstone of the Kamigori Belt with the green sandsotne of the "Upper Formation of the Kasai Group" is uncertain, but they are bounded by the Miki Fault of Hirano (1973).

B. The strata equivalent to the Oi Formation are lacking in this area.

C. Equivalent of the Hikami Formation

The "Upper Formation of the Kasai Group" by Goto *et al.* (1983), which is distributed east of Yamada, is correlated with the Hikami Formation. This formation chiefly consists of greenish grey sandstone. The sandstone is mainly represented by coarse to medium grained massive sandstone with intercalation of black and greenish grey shale and in some part medium to fine grained bedded sandstone is developed. The bedded sandstone is characterized by alternation of sandstone with 1–4 cm thickness and the mudstone with less than 5 mm thickness and sometimes grades upwards into shale. These lithologic features are the same as those of the Hikami Formation. The bed of this formation strikes nearly ENE-WSW and dips 45° to 70° to the south. The green sandstone of this formation is bounded on the north from the Tamba Group by a distinct linear fault of E-W trend and the former tectonically overlies the latter in the area adjacent to the east of this area. The fault consists of black strongly sheared rocks with 5 m thickness or more, steeply dipping southward and the green sandstone near the boundary is also strongly sheared at a locality about 4 km east of Fukusaki (slightly outside of the area of Fig. 12). The rocks of the Tamba Group is also phyllitic and strongly deformed along the fault.

D. Kasai Group, equivalent of the Tamba Group

Strata equivalent of the Tamba Group is distributed in the northern margin of the area. It is composed of black phyllitic mudstone with lenticular bodies of sandstone, bedded chert and greenstone. According to Goto *et al.* (1983), the age of the mudstone in and near this area is Early to Middle Jurassic based on the radiolarian biostratigraphy. Thus, the Kasai Group is regarded to be equivalent to the Type II suite of the Tamba Group and it tectonically underlies the green sandstone of the Ultra-Tamba Zone.

Under this scheme, the green sandstone of the Ultra-Tamba Zone is extensively distributed between the rocks of Kamigori Belt and the Kasai Group (belonging to the western extension of the Tamba Belt). In the Fukusaki area, the Ultra-Tamba Zone tectonically overlies the Tamba Belt with northerly vergence.

9. Summary of Stratigraphy; Oi and Hikami Formations

(1) Oi Formation

The Oi Formation typically exposed in the Oi area, consists of (1) thinly alternating beds of siliceous rock and pelitic rock including ribbon rock facies of Caridroit *et al.* (1985) and/or alternating red siliceous shale and chert, (2) alternating beds of snadstone and mudstone containing pelitic flysch facies of Caridroit *et al.* (1985) and (3) olistostrome, in ascending order. The formation is described in detail in the section on the Oi area (III, 3). Total thickness of this sequence is estimated at about 100 m in the Akaguri-saki and the Aogaki areas. However, these members are often tectonically repeated within this formation so that the apparent thickness becomes larger. In the Akagurisaki area, all these members (1)–(3) are distributed, while in the other areas, they are repeated several times by reverse fault. The siliceous rock of the lower member yields the early Late Permian *Follicucullus bipartitus-Fo. charveti* Assemblage, while the black shale of the middle member contains Late Permian *Neoalbaillella grypus* and others corresponding to the upper part of the *Ne. ornithoformis* Assemblage-zone of Ishiga *et al.* (1982a, b).

(2) Hikami Formation

The Hikami Formation is typically exposed in the Fukuchiyama area. It is redefined and described in detail in the section on the Fukuchiyama area (III, 5). The Hikami Formation is mainly composed of thick green sandstone with intercalated black shale and green mudstone. The green sandstone is usually massive but is partly bedded. The total thickness is estimated to be over 1000 m in the western part of the Fukuchiyama area. The sandstone consists of coarse to medium grained wacke and sandgrains are poorly sorted and angular. Petrographic feature of this sandstone are briefly given in chapter V. The black shale of this sandstone yields late Middle to early Late Permian *Follicucullus* (?) sp. in the Ayabe and Fukuchiyama areas.

The apparent thickness of the Hikami Formation increases westward in the present distribution, namely; in the Shimokato and the Oi areas, it is 100–150 m, while in the Ayabe and the Fukuchiyama areas it is estimeted at 500–1000 m. This means the supply of the clastic materials occured from west to east but the detail is a future problem to be solved.

IV. Age of the Oi and the Hikami Formations on the basis of Radiolarian Biostratigraphy

The author has reported the occurrence of *Follicucullus bipartitus-Fo. charveti* Assemblage from the Oi Formation in the Oi area and described main constituent species of this assemblage (Ishiga, 1985b). In the Ayabe area, the same assemblage was reported by Caridroit *et al.* (1985). This assemblage is very characteristic in the main constituent species of the assemblage and differs from those reported from the Permian bedded chert of the B terrane-group (Ishiga, 1985; Caridroit *et al.*, 1985; Ishiga and Miyamoto, 1986). In this chapter, the author re-examines the constituent species of the *Fo. bipartitus-Fo. charveti* Assemblage and discusses the age of the assemblage.

A. The age of the Oi Formation

Radiolarian species from the Oi Formation in each area are shown in Table 1 of which those from the Akaguri-saki and Oi areas are based on Ishiga (1985b) and those from the Ayabe area is due to Caridroit *et al.* (1985) and Ishiga and Musashino (in prep.). Radiolarians from the Yamasaki area was first described by Caridroit and De Wever (1984) and De Wever and Caridroit (1984).

Table 1. Radiolarians from the Oi and the Hikami Formation of the Ultra-Tamba Zone of Southwest Japan. After ISHIGA (1985), CARIDROIT *et al.* (1985), CARIDROIT and DE WEVER (1984), DE WEVER and CARIDROIT (1984), KURIMOTO and KIMURA (1985), KURIMOTO (1986), ISHIGA and MUSASHINO (in prep.) and other unpublished data of the author's. For detail see text in Chapter III. Abbreviation: Ay; Ayabe. Fu; Fukuchiyama. Ao; Aogaki. Ya; Yamasaki.

	Oi Formation																			Hikami F.			
Localities	Akaguri-şaki Fig. 2						Oi Fig. 4					Ay 6		Fu 7			Ao 9		Ya 11	Ay 6		Fu 7	
Radiolarians	1	2	3	4	5	6	1	2	3	4	5	1	7	1	2	3	1	2	1	2	3	4	5
Neoalbaillella grypus													•										
Albaillella levis													•										
Albaillella triangularis	•	•	•	•	•	•						•		•	•		•	•	•				
Follicucullus scholasticus m. I	•	•	•	•	•	•													•				
Fo. scholasticus m. II	•	•	•	•	•	•	•					•		•	•		•	•	•				
Fo. bipartitus	•	•	•	•	•	•	•					•		•	•		•	•	•				
Fo. charveti	•	•	•	•	•	•						•		•	•		•	•	•				
Fo. sp.								•	•	•	•												
Fo. (?) sp.																•				•	•	•	•
Deflandrella manica												•							•				
D. sp.	•																						
Ishigaum trifustis	•			•								•		•			•		•				
I. sp.	•																						
Pseudotormentus kamigoriensis	•		•		•	•	•					•	•	•	•		•	•	•				
P. sp.																							
Nazarovella gracilis	•	•				•	•					•	•	•	•		•	•	•				
N. sp.																							
Foremanhelena triangula												•							•				
Entactinosphaera sp.	•	•																					
Entactiniidae gen. et sp. indet.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Two radiolarian assemblages are distinguished within the Oi Formation and its equivalence. One is characterized by follicucullids especially, the co-occurrence of *Follicucullus bipartitus* and *Fo. charveti* and the other is by the occurrence of *Neoalbaillella*. The former occurs from the lower member in each area, while the latter occurs from the middle member in the Ayabe area (Table 1).

The former assemblage called the *Follicucullus bipartitus-Fo. charveti* Assemblage (ISHIGA, 1985b) includes *Fo. bipartitus* and *Fo. charveti*. Other important components are *Fo. scholasticus* morphotype I, *Fo. scholasticus* m. II and *Albaillella triangularis*. Concerning the Spumellarians, radiolarians belonging to the family Latentifistulidae and Entactiniidae occur abundantly. The latentifistulids are composed of *Deflandrella manica, Ishigaum trifustis, Pseudotormentus kamigoriensis, Nazarovella gracilis* and *Foremanhelena triangula*. Among these radiolarians, the occurrence of *Fo. scholasticus* m. I is restricted to the *Fo. scholasticus* Assemblage-zone of the bedded chert in the Sasayama area of the Tamba Belt (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1982b). *Albailella tirangularis* firstly occurs in the middle part of the *Fo. scholasticus* A-zone and also ranges to the *Neoalbaillella optima* A-zone (ISHIGA *et al.*, 1982a, b). Considering the co-occurrence of *Fo. scholasticus* m. I and *Albaillella triangularis*, the Oi Formation yielding this assemblage is correlative with the upper part of the *Fo. scholasticus* A-zone of the Tamba Belt (ISHIGA, 1986). On the other side, the occurrence of *Fo. bipartitus* and *Fo. charveti* has not been reported from the bedded chert of the Tamba Belt of the B terrane-group, while the assemblage has been recently found in the *Lepidolina kumaensis* Zone of the Kuma Formation, Kyushu (MIYAMOTO *et al.*, 1985; ISHIGA and MIYAMOTO, 1986). The assemblage occurring from black mudstone of the Kuma Formation has the same specific composition as that of the Oi Formation, including follicucullids and latentifistulids. Judging from the occurrence of the *Fo. bipartitus-Fo. charveti* Assemblage from the Upper Permian Kuma Formation, it is concluded that the thinly alternating beds of siliceous rock and pelitic rock of the Oi Formation includes the lower part of the Upper Permian.

The second assemblage of the Oi Formation consists of *Neoalbaillella grypus, Neoalbaillella* sp., *Albaillella levis, Follicucullus* sp. and undetermined Spumellarians. In the Tamba-Mino Belt, *Neoalbaillella grypus* occurs from the upper part of the *Ne. ornithoformis* Assemblage-zone and the *Albaillella levis* from the upper part of the *Ne. optima* A-zone to the *Ne. ornithoformis* A-zone. Thus, the middle member of the Oi Formation in the Ayabe area is correlative with the upper part of the *Neoalbaillella ornithoformis* A-zone.

Summarizing these evidence from the Oi Formation, the thinly alternating beds of siliceous rock and pelitic rock includes the lower part of the Upper Permian and the alternated sandstone and mudstone contains the Upper Permian of Japan.

B. The age of the Hikami Formation

Concerning the Hikami Formation, less information has been obtained on age determination, for it is mainly composed of coarse clastic rocks. Radiolarians are found from the black shale intercalated in the green sandstone of this formation, but they are ill-preserved and deformed. Until now, *Follicucullus* (?) sp. was reported from the black shale of this formation in the Ayabe and Fukuchiyama areas (KURIMOTO and KIMURA, 1985; KURIMOTO, 1986). Radiolarians of this genus occurs from the bedded chert of late Middle to early Late Permian in the Tamba Belt. Thus, it can be said that the Hikami Formation includes the upper part of the Middle Permian and/or the lower part of the Upper Permian and has the nearly same age with that of the Oi Formation. However, the exact correlation with the Oi Formation based on the radiolarian biostratigraphy is uncertain under present conditions.

V. Sandstone Composition and Provenance of the Hikami Formation

The green sandstone of the Hikami Formation belongs to the coarsest fraction of the clastic rocks composing the Ultra-Tamba Zone. In order to gain data for the nature of the provenance of the Ultra-Tamba Zone, the author has made study on the composition of the green sandstone jointly with T. KUSU. The detailed result will be presented in KUSU and ISHIGA (in prep.). Preliminary results are reported by KUSU *et al.* (1985). In this chapter, only a part of the results is cited so as to provide one of the bases for the discussion in the following chapter.

Samples were collected from four localities, namely, (1) Kataebana in Shimokato, (2) Kuchikanbayashi in northeast of Ayabe, (3) Fukuchiyama and (4) Yamasaki. They are mostly coarse-grained massive sandstone.

The matrix of the sandstone ranges from 30 to 35% and the sandstone belongs to wacke in OKADA's (1968) classification.

Sandstone compositions of the Hikami Formation in the four areas are plotted in Qm-K-P and Q-F-L triangular diagrams (Fig. 13). They shows that the sandstone composition is significantly similar among the four areas. Type of the provenance of this sandstone is discussed in comparison with the comprehensive analysis given by DICKINSON and SUCZEK (1979) and DICKINSON (1984).

The green sandstone of the Hikami Formation is characterized by a large amount of monocrystalline quartz (especially embayed quartz) and plagioclase grains, and less amount of alkali feldspar grains (see Qm-K-P diagram in Fig. 13). In addition, the amount of lithic fragments is smaller than that of the total quartz and feldspar grains (Q-F-L diagram in Fig. 13). As for the Q-F-L diagram, the plotted area coinsides with that of the magmatic arc provenance in Fig. 1 of DICKINSON and SUCZEK (1979) and also in Fig. 2 of DICKINSON (1984), where they distinguished continental block provenance and recycled orogen provenance in addition to the magmatic arc provenance. In detail, the area nearly covers the field of dissected magmatic arc provenance by them. Concerning the Qm-K-P triangular diagram, the plot also falls within area of magmatic arc and coinsides with what DICKINSON called the Circum-Pacific volcano-plutonic suite (DICKINSON, 1984, Fig. 2).

Concerning the composition of the lithic fragments (Fig. 14), acidic tuff, felsitic and

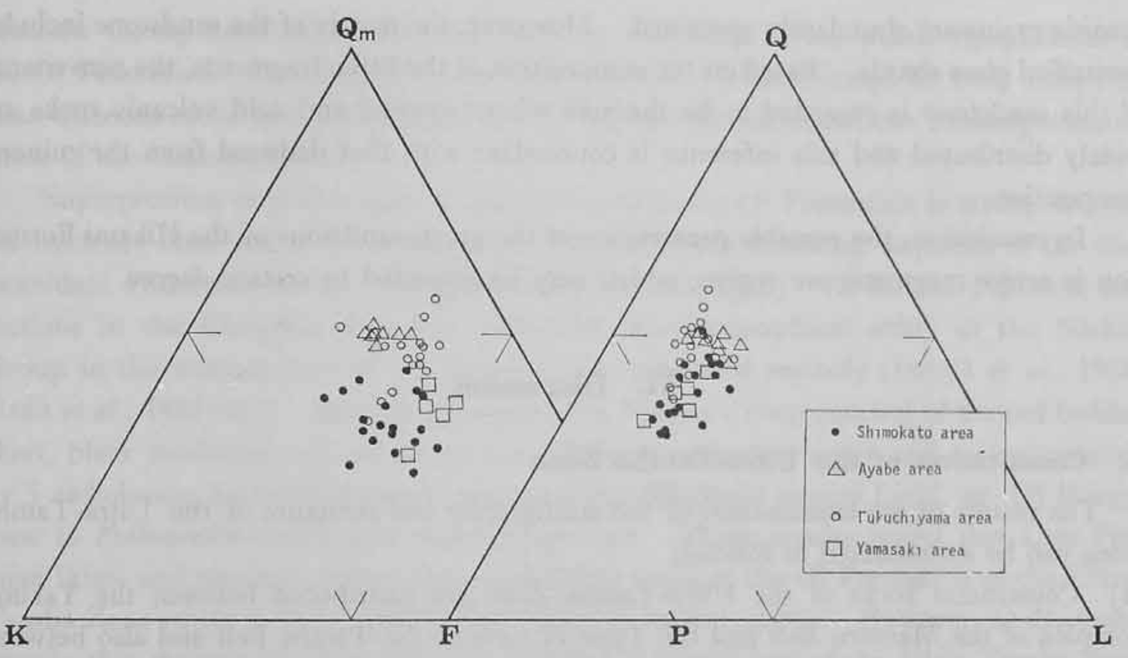

Fig. 13. Qm-K-P and Q-F-L plots of the composition of the green sandstone of the Hikami Formation of the Ultra-Tamba Zone (Modified from KUSU *et al.*, 1985) (Kusu and Ishiga, in prep.). Qm: mono-crystalline quartz grains. Q: total quartz grains. K: total feldspar grains. P: plagioclase grains. L: lithic grains.

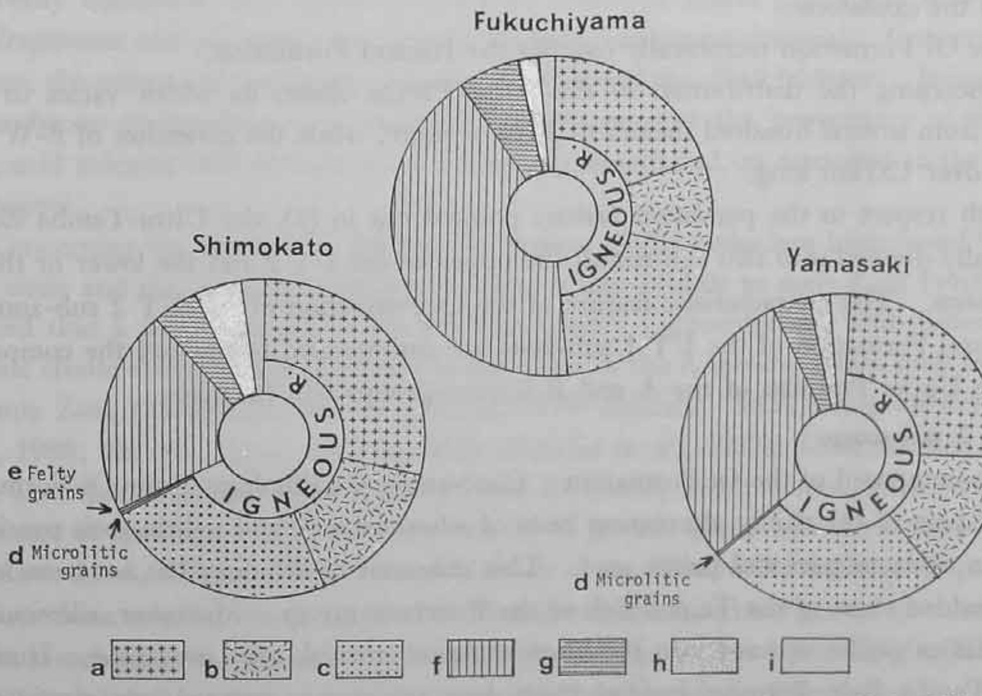

Fig. 14. Composition of the lithic fragments of the green sandstone of the Hikami Formation of the Ultra-Tamba Zone (Kusu and Ishiga, in prep.). Rock types: a, Granitic grains. b, Vitric grains. c, Felsitic grains. d, Microlitic grains. e, Felty grains. f, Polycrystalline grains. g, Metamorphic rock grains. h, Sedimentary rock grains. i, Indetermined rock grains. For detail see text.

granitic grains are abundantly contained. Moreover, the matrix of the sandstone includes devitrified glass shards. Based on the composition of the lithic fragments, the provenance of this sandstone is regarded to be the area where granitic and acid volcanic rocks are widely distributed and this inference is concordant with that deduced from the mineral composition.

In conclusion, the possible provenance of the green sandstone of the Hikami Formation is active magmatic arc region, which may be dissected to certain degree.

VI. Discussion

A. Constitution of the Ultra-Tamba Zone

The results of the examination of the stratigraphy and structure of the Ultra-Tamba Zone can be summarized as follows;

(1) Constituent rocks of the Ultra-Tamba Zone are distributed between the Yakuno complex of the Maizuru Belt and the Type II suite of the Tamba Belt and also between the Tatsuno Formation of the Kamigori Belt and the Kasai Group of the western extension of the Tamba Group. The Ultra-Tamba Zone forms a geotectonic unit distinct from them.

(2) The Ultra-Tamba Zone consists of the Oi Formation mainly composed of early Late Permian pelitic rocks and the Hikami Formation of the nearly same age chiefly composed of the sandstone.

(3) The Oi Formation tectonically overlies the Hikami Formation.

(4) Concerning the distribution of the Ultra-Tamba Zone, its width varies in areas ranging from several hundred meters to 3 km or more, while the extension of E-W trend reaches over 120 km long.

With respect to the persistent feature pointed out in (3), the Ultra-Tamba Zone is tectonically divided into two sub-zones, the upper or the UT 2 and the lower or the UT 1 sub-zones. The characteristic feature of the Oi Formation of the UT 2 sub-zone and the Hikami Formation of the UT 1 sub-zone are summarized below and the comparison with the Upper Permian of the A and B terrane-groups will be made.

1) UT 2 sub-zone

It is composed of the Oi Formation. Concerning the lithology of the Oi Formation, siliceous part of the thinly alternating beds of siliceous rock and pelitic rock consists of very thin siliceous part and pelitic part. This character of lithology has not been known in the bedded chert of the Tamba Belt of the B terrane-group. Moreover, siliceous rock of this facies grades upward into the black shale or greenish grey mudstone. However, in the Tamba Belt, Permian bedded chert does not change upward into clastic rocks. Concerning the Permian strata of the Maizuru Belt of the A terrane-group except for the Yakuno complex, they are characterized by a thick pile of clastic rocks such as Maizuru Group, but do not contain any siliceous rocks like chert (SHIMIZU *et al.*, 1962 etc.). The

Maizuru Group itself shows different lithology from that of the pelitic flysch facies of the Oi Formation. In conclusion, the Oi Formation is characterized by early Late Permian siliceous rocks and clastic rocks and is lithologically different from contemporaneous strata of the Maizuru Belts.

Superposition of pelitic rock on siliceous rock in the Oi Formation is analogous with the tendency observed in the Permian red chert-siliceous mudstone sequence of the Shimomidani Formation of the "Chugoku Belt" (Suzuki, 1982). As for the Paleozoic formations in the Chugoku Belt, the radiolarian biostratigraphical study of the Nishiki Group in the western part of the belt has been advanced recently (Ishiga *et al.*, 1986; Naka *et al.*, 1986 etc.). Accordnig to them, the Nishiki Group consists of the red bedded chert, black mudstone and sandstone formations in ascending order and are represented by 5 radiolarian Assemblage-zones ranging from *Albaillella sinuata* (=*A.* sp. D) Range-zone to *Follicucullus scholasticus* Assemblage-zone. These results reveal that Late Permian litho- and biostratigraphic units resembling those of the Oi Formation of the Ultra-Tamba Zone exists in the Chugoku Belt of the A terrane-group. However, as discussed later in this chapter, the Late Permian radiolarian assemblage of the Ultra-Tamba Zone is different from that of the Chugoku Belt.

2) UT 1 sub-zone

It is composed of the Hikami Formation. The thick green sandstone, which characterizes this formation, consists of coarse to medium grained wacke in the examined areas. As already described, this sandstone contains embayed quartz grains and acid volcanic rock fragments and moreover the matrix contains tuffaceous material. Concerning the feldspar, the amount of plagioclase is larger than that of the alkali feldspar. Judging from the sandstone composition, it is concluded that in or near the provenance of the sandstone, acid volcanic and plutonic rocks are widely distributed, as discussed in the preceding chapter.

Concerning the age of the Hikami Formation, *Follicucullus* has been found from the black shale and the age of the green sandstone is late Middle to early Late Permian. It is noted that a large amount of the Permian (partly Carboniferous) acid—intermediate volcanic clastic materials are contained in the strata of the A terrane-group such as Nagato Tectonic Zone (Murakami and Nishimura, 1979; Isozaki, 1983), Chugoku Belt (Naka *et al.*, 1986; Suzuki, 1982), Maizuru Belt (Suzuki *et al.*, 1982), Unazuki Belt (Hiroi, 1981) and Hida Marginal Belt (Chihara and Komatsu, 1982; Miiko, *et al.*, 1984) and this is one of the major differences between the A terrane-group and the B terrane-group (Ichikawa *et al.*, 1985). The petrological study of the Hikami Formation is important to correlate these volcanic clastic rocks of the Permian in the A terrane-group with each other.

In conclusion, the Oi and the Hikami Formations of the Ultra-Tamba Zone have the different lithology and stratigraphy from the Permian of the Tamba and the Maizuru Belts, while the siliceous rock-clastic rock sequence of the Oi Formation and the acid volcanic clastic rocks of the Hikami Formation resemble those of the Permian of the Chugoku Belt. In view of the last mentioned fact, the Ultra-Tamba Zone is more closely linked with the A terrane-group than the Tamba Belt of the B terrane-group.

B. Significance of Radiolarian Assemblage of the Oi Formation

The Oi Formation of the Ultra-Tamba Zone yields the characteristic radiolarian assemblage mainly composed of *Follicucullus bipartitus-Fo. charveti*. *Fo. scholasticus* morphotype I, *Fo. scholasticus* m. II and *Albaillella triangularis* included in this assemblage are reported also from the bedded chert of the Tamba Belt of the B terrane-group (ISHIGA *et al.,* 1982b etc.), but the occurrence of *Fo. bipartitus* and *Fo. charveti* has not been known in most part of the B terrane-group. Recently Permian radiolarians have been reported from the clastic rocks of the Kurosegawa Tectonic Zone and its northern margin of the B terrane-group [see Fig. 15; (19) ISHIDA; 1985a; (20) ISHIDA, 1985b; (21) SUYARI *et al.,* 1983; (22) MIYAMOTO and TANIMOTO, 1985, 1986; (23) MIYAMOTO *et al.,* 1985 etc.]. Among these occurrences, *Fo. bipartitus-Fo. charveti* Assemblage has been quite recently identified from the Kuma Formation (MIYAMOTO *et al.,* 1985; ISHIGA and MIYAMOTO, 1986) and Yuzuruha Formation (MIYAMOTO and TANIMOTO, 1986). Thus, it can be said that this assemblage occurs characteristically in both the Ultra-Tamba Zone of the A terrane-group and the Kurosegawa Tectonic Zone of the B terrane-group and they belong eventually to the same paleobiogeographic situation in Late Permian time.

As for the fusulinid paleogeography of the Middle Permian, two distinct lineage of the evolutionary trend have been discriminated within the A and the B terrane-groups except for the Kurosegawa Tectonic Zone (ISHII *et al.,* 1985). Although the occurrence of the *Fo. bipartitus-Fo. charveti* Assemblage has not yet been established in the A terrane-group proper, it is expected that this radiolarian assemblage has the same distribution pattern as those of the fusulinids assemblage. In conclusion, the radiolarian assemblage from the thinly alternating beds of siliceous rock and pelitic rock of the Oi Formation of the Ultra-Tamba Zone have the different constituent of radiolarian species from those of the Tamba Belt of the B terrane-group of the same age. The Oi Formation represents a different paleogeographic regime or a different paleobiofacies from that of the Tamba Belt.

C. Geohistory of the Ultra-Tamba Zone of Southwest Japan

Based on the present research on the lithostratigraphy, structure and biofacies of the Oi and the Hikami Formation of the Ultra-Tamba Zone and recent research of adjacent areas by many geologists including the author, main geologic events of the areas in and around the Ultra-Tamba Zone can be summarized as follows (cf. Fig. 16).

(1) Late Carboniferous to Permian

Extensive sedimentation of a successive bedded chert took place in pelagic environments where seamounts or ridges composed of greenstone-limestone were locally developed in the Tamba Belt of the B terrane-group (IMOTO, 1984 etc.). Another Late Paleozoic sedimentary province of greenstone-chert lithology was developed in the Chugoku Belt. The marine clastic sequences of the Maizuru Belt between the two provinces appeared

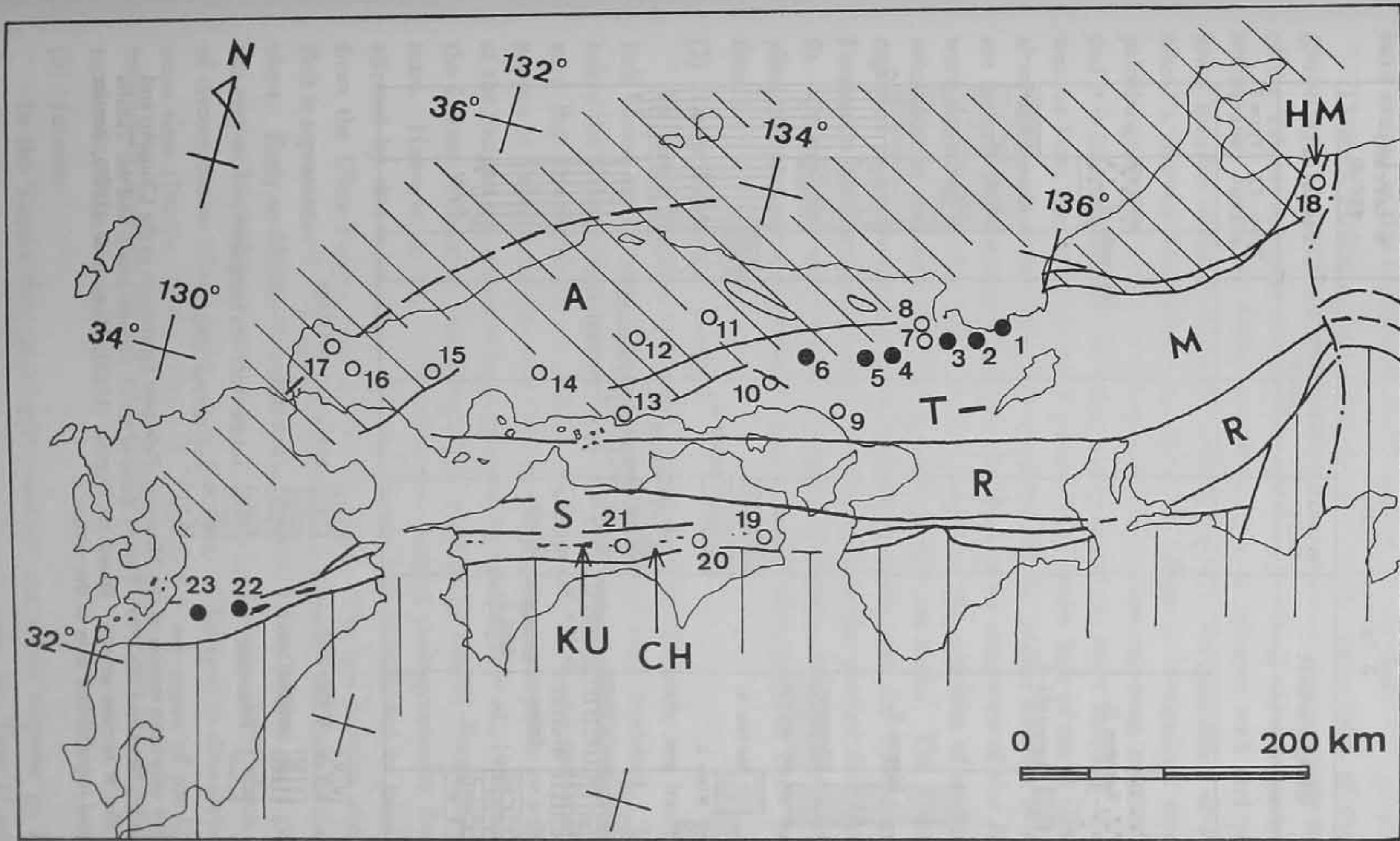

Fig. 15. Occurrence of Permian radiolarians from clastic rocks of Southwest Japan. ●; *Follicucullus bipartitus-Fo. charveti* Assemblage. ○; other radiolarian assemblages. For localities: 1, Akaguri-saki*. 2, Oi*. 3, Ayabe*. 4, Fukuchiyama*. 5, Aogaki.* 6, Yamasaki*. 7, Oeyama area; Ishiga (1984). 8, Shimomidani area; Ishiga and Suzuki (1984). 9, Fukusaki*. 10, Kohzuki area; Goto and Hori (1985). 11, Katsuyama area; Miyake (1985). 12, Taishaku-dai area; Isozaki (1984). 13, Numakuma area; Ishiga and Sato (1985). 14, Northeast of Hiroshima area; Wakita (1985). 15, Nishiki and Muikaichi area; Nishimura and Isozaki (1984), Naka and Ishiga (1985), Naka *et al.* (1986). 16, Akiyoshi area; Sano *et al.* (1983). 17, Dai area; Isozaki (1983). 18, Ohmi area; Tazawa *et al.* (1985), Komatsu *et al.* (1985). 19, East of Tokushima area; Ishida (1985a). 20, Southeast of Tokushima area; Ishida (1985b). 21, Kochi area; Suyari *et al.* (1983). 22, Yuzuruha area; Miyamoto and Tanimoto (1985, 1986). 23, Hikawa area; Miyamoto *et al.* (1985), Ishiga and Miyamoto (1986). Localities with asterisk are described in this paper.

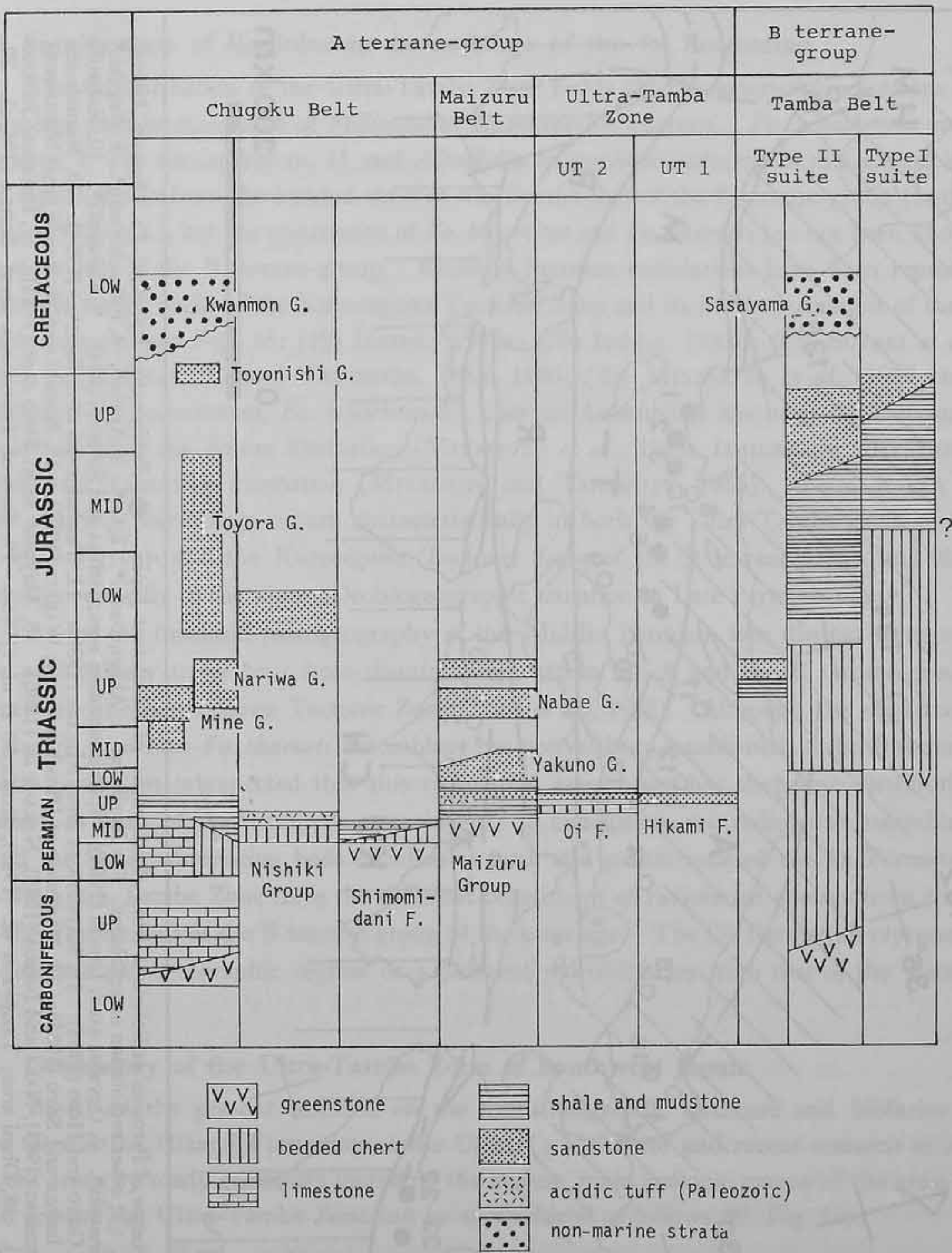

Fig. 16. Simplified columnar section of the Mesozoic-Paleozoic formations in the Chugoku and the Maizuru Belts and the Ultra-Tamba Zone of the A terrane-group and the Tamba Belt of the B terrane-group. Based on SUZUKI (1982), HARA *et al.* (1985), ISHIGA (1983) and unpublished data of the author's.

in late Middle Permian time (SHIMIZU *et al.*, 1962) and the Yakuno ophiolite appears to have arrived at this terrigenous clastic regime by that time.

Through Middle to Late Permian time, coarse clastic rocks of the Maizuru Group (SHIMIZU *et al.*, 1962) was formed above the migrated, comparatively thick oceanic crust of the Yakuno ophiolite (ISHIWATARI, 1985 etc.). Along the southeastern margin of this sedimentary basin, the thinly alternating beds of siliceous rock and pelitic rock of the lower member of the Oi Formation characterized by the occurrence of *Follicucullus bipartitus-Fo. charveti* Assemblage, was formed in pelagic to hemipelagic environments. The paleobiogeography of the Oi Formation is quite different from those of the Tamba Belt and it is inferred that the paleo-oceanic regime of the lower member of the Oi Formation was far from that of the bedded chert of the Tamba Belt of the B terrane-group. The alternating beds of sandstone and mudstone of the middle member of the Oi Formation are formed and contemporaneously the thick green sandstone of the Hikami Formation were deposited in this time. It was caused by the activities of acidic magmatism and volcanism in and near the back ground of this sea basin. The Hikami Formation is regarded to be contemporaneous heterotopic strata with the middle member of the Oi Formation and increases its thickness westward in the present distribution (chapter III, 9). On the other side, the Oi Formation diminishes its thickness westward. This implies that plutonic and volcanic clastic materials were supplied from west to east in this time.

(2) Latest Permian to Triassic

In Latest Permian to Triassic time, the Late Paleozoic sea basin of the Maizuru Belt closed and Triassic shallow marine sediments were deposited. The unconformity below the Triassic strata proves the first tectonic phase affecting the Permian of the Maizuru Belt (NAKAZAWA *et al.*, 1957). In this time, the initial emplacement of ophiolitic nappes of Yakuno complex and the high pressure metamorphism or subsequent uplifting of the Sangun metamorphic rocks proceeded (NISHIMURA *et al.*, 1983 etc.). Furthermore, the Hikami Formation was tectonically overlain by the Oi Formation probably in this time. However, in the Tamba Belt, the bedded chert-greenstone formation were not affected by this tectogenesis and the Tamba Belt is regarded to have been located far from the Ultra-Tamba Zone in Permian time. The late Permian event in the Tamba Belt is represented by the gradational change in lithology and color of the Permian bedded chert. Early to Middle Permian red to reddish brown bedded chert grades upward into the grey or blackish grey chert of late Permian age (ISHIGA, 1983), which means the change of circumstances of the sedimentary site from oxidational to deoxidational in Late Permian time (IMOTO, 1984). The UT 2 and UT 1 sub-zones of the Ultra-Tamba Zone tectonically underlay the Yakuno complex of the Maizuru Belt and became a southernmost unit of the A terrane-group.

(3) Jurassic

In the Tamba Belt, previously extensive sea closed stepwise in Early-Middle and Late Jurassic times. In Early to Middle Jurassic time, the Type II suite of the Tamba

Group was formed, while in Late Jurassic, the Type I suite was completed. The closure of the Tamba-Mino paleo-oceanic basin is caused by the collision between the Hida Belt of the A terrane-group and the Paleo-Ryoke Belt, and a peculiar type of convergent complex was formed (ICHIKAWA, 1981, 1982). Concerning the Tamba Belt, at least two sea basins, which are represented by the Type I and II suites of the Tamba Group, respectively, existed between the Ultra-Tamba Zone and the Paleo-Ryoke Belt, before the closure of each basin. The Type II suite of the Tamba Belt was tectonically overlain by the UT 1 sub-zone of the Ultra-Tamba Zone in Early or Middle Jurassic time. During the time of closure of the previously extensive sea basins, the older tectonic unit of the Type II suite of the Tamba Group was tectonically underlain by the younger tectonic unit of the Type I suite, at probably latest Jurassic time (ISHIGA, 1983). Strata which had been formed between the two sea basins were probably lost during this process.

(4) Cretaceous

Early Cretaceous, sub-continental Sasayama Group unconformably overlies the Type II suite of the Tamba Group in the Sasayama area, Hyogo Prefecture, which means the end of the thrusting movement. The last compressional tectonics of both Ultra-Tamba Zone and Tamba Belt are represented by the upright folding with an East-West trend which occurred simultaneously with the sedimentation of the Sasayama Group (WADATSUMI *et al.*, 1983). The Ultra-Tamba Zone is distributed along the northern margin of the Tamba Belt which forms a huge antiform caused by this upright folding.

VII. Summary

(1) The Ultra-Tamba Zone consists of mainly strongly sheared Late Permian clastic formations and is tectonically divided into the two sub-zones (tectonic units), namely, the lower or UT 1 sub-zone and the upper or UT 2 sub-zone. This zone is distributed not only along the southern margin of the Maizuru Belt but also along the northern margin of the Kamigori Belt, Southwest Japan. Concerning the extension of this zone, its width varies among areas from several hundred meters to over 3 km and the ENE-WSW extension along south of the Maizuru Belt is over 120 km from Obama, Fukui Prefecture to Yamasaki, western part of the Hyogo Prefecture.

(2) The UT 2 sub-zone tectonically overlies the UT 1 sub-zone and forms a nappe structure with a southerly vergence. The UT 2 sub-zone is tectonically overlain by the Yakuno complex (southern sub-belt of the Yakuno complex) of the Maizuru Belt. The UT 1 sub-zone of this zone is in fault contact with the Type II suite of the Tamba Group which is also strongly deformed near the boundary between them.

(3) The UT 2 sub-zone is composed of the Oi Formation which consists of (1) thinly alternating beds of siliceous rock and pelitic rock (including ribbon rock facies), (2) alternating beds of sandstone and mudstone (including pelitic flysch facies) and (3) olistostrome in ascending order. The total thickness of this sequence is estimated at about 100 m. The (1) member of the Oi Formation is quite different from the bedded

chert of the Tamba Belt of the B terrane-group in lithology and radiolarian biofacies, while it resembles siliceous rock-clastic rock sequence in the Chugoku Belt of the A terrane-group. The (1) member yields the early Late Permian *Follicucullus bipartitus-Fo. charveti* Assemblage, while the (2) member is characterized by the occurrence of *Neoalbaillella grypus* and other radiolarians, corresponding to the assemblage of the upper part of the *Neoalbaillella ornithoformis* Assemblage-zone.

(4) The UT 1 sub-zone consists of the Hikami Formatoin which is characterized by the thick green sandstone with intercalated black shale. The total thickness of this formation is estimated to be over 1000 m. The sandstone is usually coarse to medium grained wacke and sandgrains are poorly sorted and angular. Late Middle to early Late Permian *Follicucullus* (?) sp. occurs and the green sandstone is regarded to be contemporaneous heterotopic with the middle member of the Oi Formation.

(5) The geohistory of the Ultra-Tamba Zone is summarized as follows:

i) Late Permian Oi Formation was widely developed not only along southern margin of the Maizuru Belt but alos along northern margin of the Kamigori Belt and successively the Hikami Formation was deposited.

ii) In Triassic time, the Permian paleo-sea basin of the Ultra-Tamba Zone was closed and the UT 2 sub-zone of the Oi Formation tectonically overlay the UT 1 sub-zone of the Hikami Formation. This event nearly corresponds to the tectonic phase represented by the unconformity between the Permian and the Triassic strata of the Maizuru Belt.

iii) The thrust tectonics with a southward vergence started during Jurassic time and the Ultra-Tamba Zone thrust over the Type II suite of the Tamba Group.

iv) In latest Jurassic to earliest Cretaceous time, the Type II suite of the Tamba Group tectonically overlay the Type I suite. The upright folding with an E-W trend occurred simultaneously with the sedimentation of the early Cretaceous Sasayama Group, which resulted in a secondary deformation of the originally low angle pile nappe structure.

(6) Studies of stratigraphy, structure and radiolarian biofacies of the Ultra-Tamba Zone reveals that the Ultra-Tamba Zone underwent a long and stepwise deformation history during Permian-Cretaceous time. This zone is assigned to the A terrane-group and forms a boundary zone between the A and the B terrane-groups of Southwest Japan. It occupies the frontal zone of the A terrane-group and serves as an important key unit in the research of the relationship of these terrane-groups.

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