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Paleozoic-Mesozoic Sedimentary Complex in the Eastern Mino Terrane, Central Japan and its Jurassic Tectonism

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(With 20 Figures, 10 Tables and 7 Appendix Figures)

Abstract

The Paleozoic-Mesozoic complex in the eastern part of the Mino Terrane, central Japan is subdivided into seven complexes (the Hirayu, Yukawa, Shirahone, Sawando, Shimashima, Misogawa and Kyogatake Complexes from the north to the south) on the basis of lithology. For the sake of comparison, the same complex in the western part of the Mino Terrane is subdivided into five complexes (Complex 1, 2, 3, 4 and 5, from the north to the south). Eastern and western groups of complexes, which are separated by extrusive distribution of the Cretaceous Nohi Rhyolites, can be correlated each others except for Complex 2.

These complexes trend NE-SW or E-W and generally dip northwest or north. The age of genesis of the complexes shows a southward (structurally lower) younging polarity.

The Hirayu and Shirahone Complexes and Complex 1 are the late Middle Jurassic melanges including a large amount of blocks of Permian greenstone, limestone and chert, Triassic and Early Jurassic chert and Jurassic sandstone. The Yukawa Complex is a pile of coarsening-upward chert-clastics sequences, which have been accreted in late Middle Jurassic time. The Sawando Complex and Complex 3 are the pile of chert-clastics sequences which resemble those of the Yukawa Complex. These complexes are considered to have been accreted in early Late Jurassic time. The Shimashima Complex and Complex 4 are the strongly sheared early Late Jurassic melange including blocks of Triassic and Jurassic rocks. The Misogawa and Kyogatake Complexes and Complex 5 are composed mainly of Late Jurassic turbidite. Soft-sediment deformation is widespread in the deposits of these complexes. Complex 2 is the latest Jurassic to possibly Cretaceous melange including blocks of Triassic and Early Jurassic chert and Jurassic clastic rocks. This complex is considered to lie unconformably on Complex 3.

The lithologic and structural features and age of these complexes indicate that they were constructed through a series of accretionary processes. In the late Middle Jurassic time, a seamount chain accompanied by pelagic sediments and clastic trench fills were accreted, and melanges including greenstone-limestones blocks (Hirayu and Shirahone Complexes and Complex 1) and a pile of chert-clastics sequences (Yukawa Complex) were formed.

In latest Middle to early Late Jurassic times, pelagic chert and the overlying trench fill deposits were successively stacked and formed piles of tectonic slices each which is composed of a chert-clastics sequence (Sawando Complex and Complex 3). Thrusting or gliding of the tectonic slices and southeastward-advance of the piles caused a collapse of the accretional complex and precursory olistostromes were developed on the lower slope and trench (Shimashima Complex and Complex 4). These complexes were intensely sheared just after deposition through the overthrusting process of other complexes.

In late Late Jurassic time, abundant detrital sediments were supplied into the trench. The trench fill successively underwent the soft-sediment deformation probably under the high pore-fluid pressure environment (Misogawa and Kyogatake Complexes and Complex 5). In latest

Jurassic or possibly earliest Cretaceous time, sedimentary melanges were widely deposited on the slope of the accretionary complex (Complex 2). Subsequently, Complex 1 has been thrust over Complex 2 in Early Cretaceous time.

Contents

I. Introduction

Geotectonic studies on the areas of recent and past convergent plate boundaries between oceans and continents or arcs have been rapidly accumulated. It is known that accretionary bodies built up in those areas show characteristic styles of geologic structure and deformation.

Geologic studies on the Paleozoic and the Mesozoic sedimentary complexes in Japan have recently been accelerated. In the Southwest Japan, the sedimentation and the development of the geologic structure of complexes, interpreted to be proceeded in past convergent plate boundaries, have been discussed briskly (SAKAI and KANMERA, 1981; MATSUOKA, 1984; TAIRA, 1985, etc.). These studies mainly deal with the Paleozoic and the Mesozoic of the Outer zone of the Southwest Japan which shows apparent gross zonal structure.

Although the Inner zone of the Southwest Japan is also overlain by the same kind of rocks as the Outer zone, they show much less apparent zonal structure. For that reason, it cannot be simply concluded that the Paleozoic and the Mesozoic sedimentary complexes of the Inner zone are the products of the accretion only on the basis of their structures. To clarify the sedimentary and tectonic process of these complexes of the Inner zone is one of the most important geological theme in the Southwest Japan.

Radiolarian biostratigraphic studies of the Mesozoic have been advanced since 1980 in Japan (e.g. YAO *et al.*, 1982; MATSUOKA and YAO, 1986). Results of these studies have made clear that the larger part of the strata which was considered to be the Upper Paleozoic or the Triassic on the basis of fusulinids, conodonts and other fossils are the

Jurassic, and have promoted the discussion on tectonic processes.

Discovery of Jurassic radiolarians from many localities (YAO *et al.*, 1980; MIZUTANI *et al.*, 1981 etc.) in the Mino Terrane (MIZUTANI and HATTORI, 1984) triggered off a re-examination of Jurassic sedimentary and tectonic processes. WAKITA and OKAMURA (1982) and WAKITA (1983, 1984) gave details on Jurrassic olistostromes including Permo-Triassic allochthonous bodies in the Hachiman area of the Mino Terrane. The structural relationship between the Jurassic and the older rocks has been clarified by ADACHI and KOJIMA (1982), KOJIMA (1984) and YAMADA *et al.* (1985) in the eastern Takayama area, by YAMAMOTO (1985) in the Mt. Ibuki area and by OTSUKA (1985) in the Azusa-gawa river area. Also in the northwestern Mino Terrane the Jurassic has been studied utilizing radiolarian biostratigraphy by HATTORI and YOSHIMURA (1982) and otheres. The studies concerning the Paleozoic and the Mesozoic of the Mino Terrane have been recently reviewed by WAKITA (1985), however details of the sedimentary complex in the Mino Terrane and the discussion of the tectonism still remain unresolved.

The Paleozoic and the Mesozoic in the eastern Mino Terrane and neighboring area have been investigated by the author since 1979. In this paper, lithology and deformation features of non-metamorphozed and low-grade metamorphic complexes in the eastern Mino Terrane are described and Jurassic tectonic processes are discussed.

II. Outline of geology

The eastern part of the Mino Terrane, which is 100 kilometers in width, is chiefly underlain by Permian, Triassic and Jurassic sedimentary rocks. This part is conveniently subdivided into three areas, namely the Takayama-Hirayu area, the Azusa-gawa river area and northern Kiso mountains (Fig. 1). Recent noteworthy studies with geologic maps in each area are as follows.

A. Takayama-Hirayu area

The Takayama-Hirayu area is situated on the northernmost part of the Mino Terrane and rocks in this area are in fault contact with the complex of the Hida-gaien tectonic belt. The lithology and fossils in the Hirayu area were described by KAMEI (1952) and those in the Takayama area were by ISOMI and NOZAWA (1957). ADACHI and KOJIMA (1983) and KOJIMA (1984) clarified the lithology and ages of rocks in these areas. It is noteworthy that this area is overlain almost only by Middle Jurassic melange which includes Permian and Triassic blocks.

B. Azusa-gawa River area

An outline of the lithology in the Azusa-gawa River area was preliminarily presented by TANAKA *et al.* (1952) and that of the southernmost part of this area was investigated by KATADA and ISOMI (1964). KANO (1975) first revealed the existence of Triassic cherts on the basis of occurrence of conodonts in this area and proposed stratigraphic classification of the Permian and Triassic rocks.

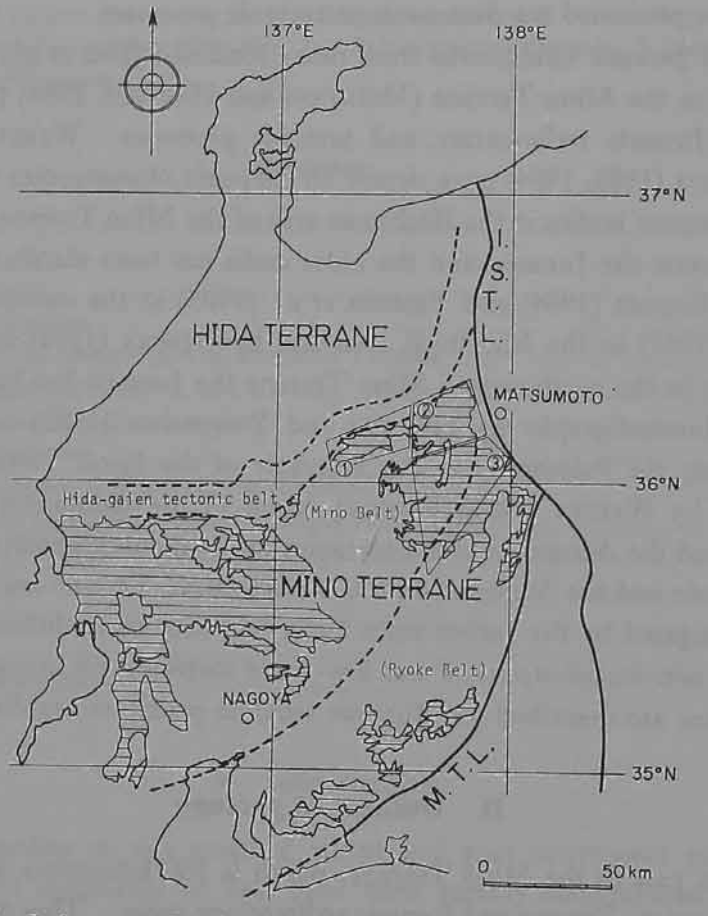

Fig. 1 Index map showing the study area and the distribution of the Paleozoic-Mesozoic sedimentary complex in the Mino Terrane.
①: Takayama-Hirayu area
②: Azusa-gawa River area
③: Northern Kiso Mountains
I.S.T.L.: Itoigawa-Shizuoka Tectonic Line
M.T.L.: Median Tectonic Line

Recently a detailed investigation of the geology (OTSUKA, 1985) has revealed that this area is underlain by the Triassic-Jurassic chert-clastics sequences and that Jurassic olistostromes and that they are distributed in 6 (A-F) zones (Fig. 2).

C. Northern Kiso Mountains

ISOMI and KATADA (1959) and KATADA and ISOMI (1962, 1964) outlined the general geology of these areas. They subdivided sedimentary and low-grade metamorphic rocks into 10 formations which generally strike NE-SW. KATADA *et al.* (1959) found that a part of the Misogawa Formation which overlies the boundary area between so-called the "Mino Belt" and "Ryoke Belt" has been slightly metamorphosed and has clarified that rocks of both "belts" grade into each other. KANO (1975) showed that these areas were underlain by the Mesozoic besides the Permian. MIZUTANI *et al.* (1981) and ADACHI (1982) first pointed out an existence of the Jurassic on the basis of occurrence of Late

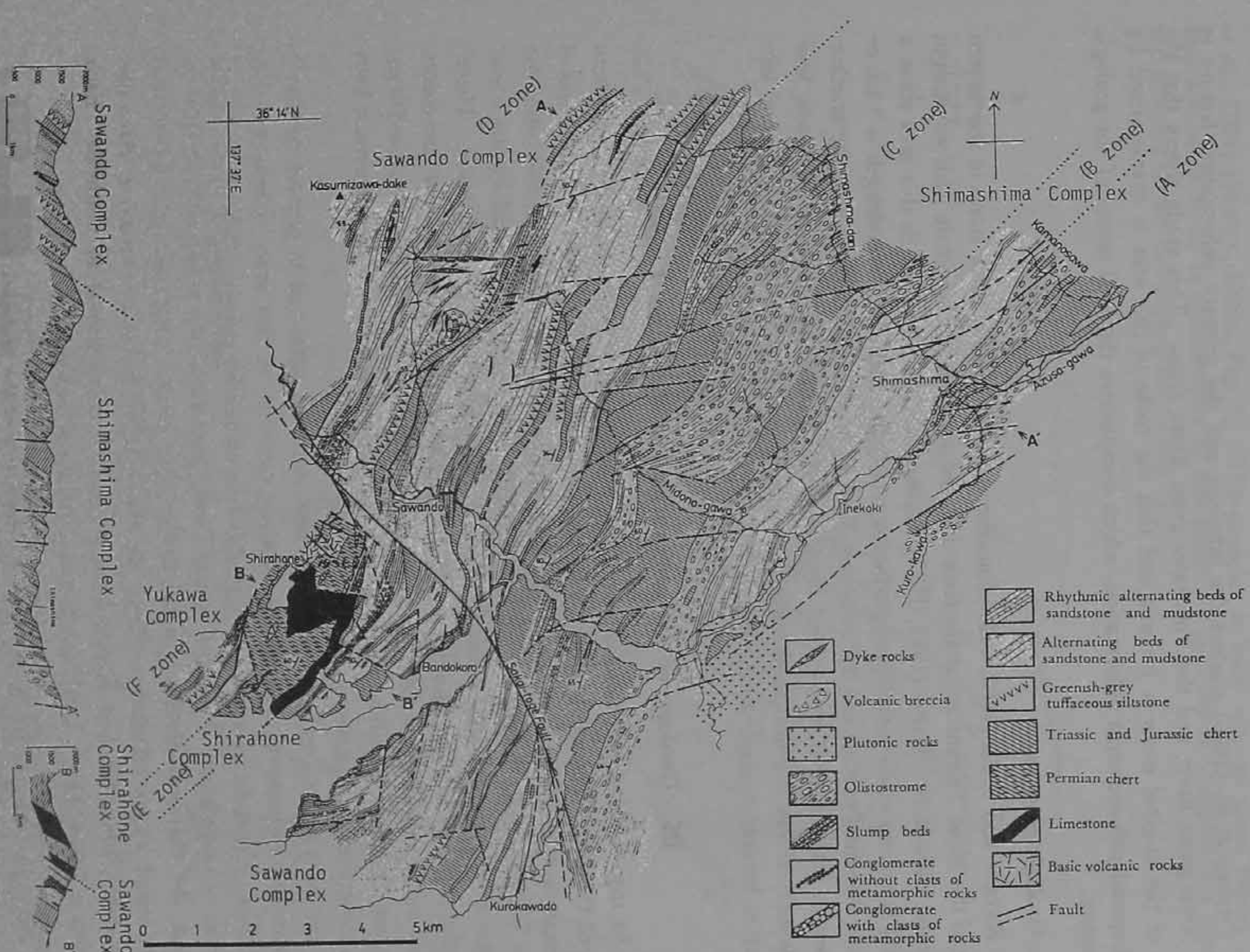

Fig. 2 Lithologic map and profiles of the Azusa-gawa river area (modified from OTSUKA, 1985). A-F zones are areal subdivision by OTSUKA (1985).

Jurassic radiolarians. Recently YANO (1986MS) investigated the geology of the Misogawa River area in detail and reported the occurrence of abundant radiolarians of Late Jurassic age.

OTSUKA *et al.* (1986) studied the lithology and the primary deformation feature in the Narai-gawa River and the Yokokawa-gawa River areas. This study shows that the age of the original rocks is Jurassic and that the rocks of this area is characterized by widespread soft-sediment deformation, which complicates the total aspect of the geologic structure.

D. Geologic structure

KATADA and ISOMI (1962, 1964) considered that extremely thick strata in the eastern part of the Mino Terrane are characterized by the synclinorium structure with wavelength of some kilometers. KANO (1975, 1982) maintained that the strata in this area show a folded structure whose enveloping surface is nearly flat and whose wavelength is 3 km or so and that the Permian and the overlying Triassic and Jurassic are exposed one another. However, OTSUKA *et al.* (1984) and OTSUKA (1985) pointed out that the Mesozoic fundamentally shows the imbricate structure inclining to the north and has a general tendency to become younger to the south.

III. Geology of the eastern part of the Mino Terrane

As mentioned above, information of the lithology and the structure in the eastern part of the Mino Terrane has been accumulated considerably. Cumulative thickness of the strata in this area presumably exceeds 30 km in appearance. However, this estimated value is improbable, because strata are too thick to have been deposited in one basin. Furthermore younger fossils occur from structurally lower units in many cases. Therefore the apparent lithostratigraphic sequences do not always indicate the true succession. Considerable part of the complex is occupied by melanges*. Evidences of soft-sediment deformation occur throughout the area. Even strata not so deformed in appearance have been sometimes tectonically stacked.

For those reasons, primary sequences have not been preserved in general, so that it is impossible to estimate the primary thickness correctly in this area. Under the circumstances, the sedimentary complex in this area cannot be usually subdivided into formations. Consequently the terms "group" and "formation" are not used in this paper. Instead, the Paleozoic-Mesozoic is subdivided into seven complexes each of which is characterized by its lithofacies. They are the Hirayu, Yukawa, Shirahone, Sawando, Shimashima, Misogawa and Kyogatake Complexes from northwest to southeast. Each complex is 5 to 15 km in width and trends northeast-southwest.

* In this paper, the term "melange" is used, irrespective of the processes, for several kinds of mudstone-rich rocks that are broadly characterized by an obscure stratigraphy, stratal disruption or a chaotic, "block-in-matrix" fabric (COWAN, 1985). In the special case of sedimentary process, the melange is expressly called the olistostrome.

The author previously subdivided the eastern part of the Mino Terrane into six (Hirayu, Shirahone, Sawando, Shimashima, Misogawa and Kyogatake) Zones (OTSUKA *et al.*, 1984; OTSUKA, 1986a, Fig. 3). The complex in each zone in those papers corresponds respectively to the complex in this paper. The Yukawa Complex is a part of the complex in the Sawando Zone (Table 1).

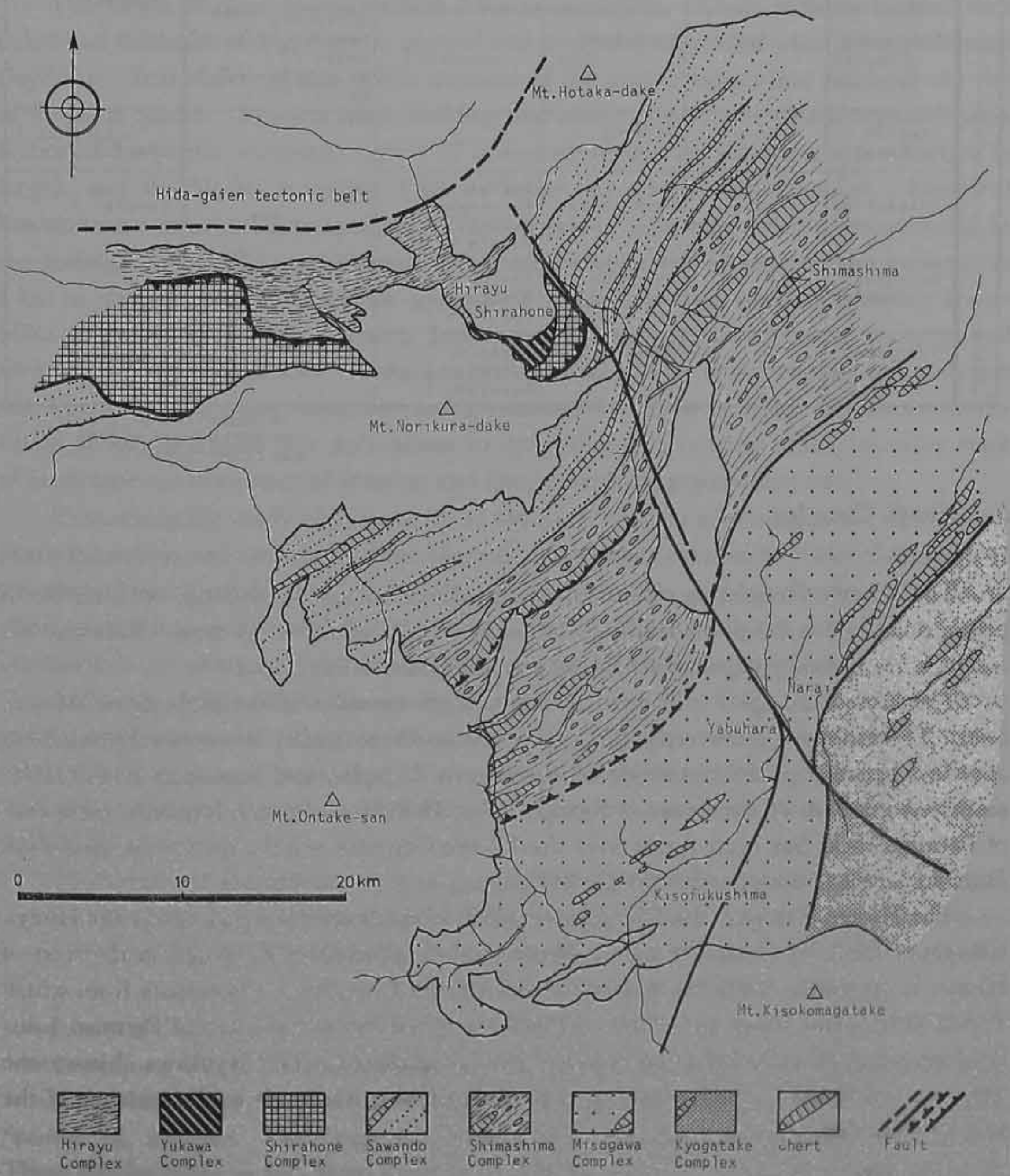

Fig. 3. Grouping of Paleozoic-Mesozoic complex in the eastern part of the Mino Terrane.

Table 1 Correlation of complexes in the Mino Terrane.

	Eastern part					Western part (This paper)
	This paper	Other papers				
		OTSUKA(1985)	OTSUKA(1986)	KATADA and ISOMI(1962, 64)	Others	
→ north	Hirayu Complex	———	Hirayu zone	———	Dayoshi F.* Nyukawa olistostrome**	Complex 1
	Yukawa Complex	F zone	Sawando zone	———	———	
	Shirahone Complex	E zone	Shirahone zone	———	Shirahone F.*** Kohachigagawa F.* Gonbo F.* Higetayama F.* Onishi F.*	
Complexes	Sawando Complex	D zone	Sawando zone	———	Narai F.*** Yabuhara F.*** Misogawa F.***	Complex 2 / Complex 3
	Shimashima Complex	C zone B zone A zone	Shimashima zone	Inekoki F. Kurokawa F. Hata F. Nomata F.		Complex 4
	Misogawa Complex	———	Misogawa zone	Hario F. Misogawa F. Yabuhara F.		Complex 5
south ←	Kyogatake Complex	———	Kyogatake zone	Narai F. Yokokawa F. Kuwazawa F.		

* YAMADA et al. (1985)
** ADACHI and KOJIMA (1983)
*** KANO (1975)

A. Hirayu Complex

1. Outline

The Hirayu Complex is characterized by a large amount of melange with matrix of pelitic rocks and is distributed in the northernmost part of the study area. Rocks in this complex are typically exposed at the eastern Takayama-Hirayu area.

The Hirayu Complex is in fault contact with the complex of the Hida-gaien tectonic belt. The fault plane is steeply dipping to the north in usual. Sheared serpentinite is observed between peblly mudstone of the Hirayu Complex and limestone of the Hida-gaien tectonic belt at the west of Fukuji. The Shirahone Complex mainly composed of Permian rocks has been thrust over the Hirayu Complex and the thrust was named the Dayoshi thrust (ADACHI and KOJIMA, 1983).

The Hirayu Group defined by KAMEI (1952) is involved in the melange of the Hirayu Complex. The Nyukawa Formation (ISOMI and NOZAWA, 1957) exposed in the west of Hirayu is correlative with the melange of the Hirayu Complex. Limestones from which KAMEI (1952) and ISOMI and NOZAWA (1957) reported the occurrences of Permian fusulinid are apparently allochthonous blocks in Jurassic melange. The Nyukawa olistostrome (ADACHI and KOJIMA, 1983; YAMADA *et al.*, 1985) just corresponds to the melange of the Hirayu Complex.

2. Lithology

Melange of the Hirayu Complex is composed of blocks of chert, greenstone, limestone, siliceous siltstone and sandstone and matrix of pelitic rocks. Blocks of chert, greenstone, limestone and siliceous siltstone are considered to be allochthonous on the basis of their mode of occurrence and ages. It is indeterminable whether blocks of sandstone and siliceous siltstone are autochthonous or allochthonous to the matrix. Allochthonous blocks vary in length from a few millimeters to more than 1 km. Blocks smaller than the outcrop scale show subrounded to rounded shapes and, in some cases, coherently and sharply contact with surrounding matrix of pelitic rocks.

The length of chert blocks exceeds 2 km in maximum. Chert is thinly bedded with individual thickness of 2 to 5 cm in general and is often interbedded with thinner siliceous claystone. It is observed that pelitic material of the matrix injects into cracks at the rim of the chert blocks. In some cases, bedding and minor folds of chert have been obliquely truncated by pelitic materials. Most of limestone blocks are less than a few meters in length, and the blocks exceeding 1 km in length are sporadically included. Blocks of limestone are massive in many cases. Various size of greenstone blocks are included in the melange of the Hirayu complex. Maximum size of the greenstone blocks is up to 1 km in length. Almost all of the greenstone is basaltic lava which sometimes shows pillow structure. Blocks of chert, limestone and greenstone are often accompanied with each other. Sandstone blocks are often found out in this melange, but they are not associated with chert, limestone and greenstone blocks as a rule. Sandstone blocks varies in length from a few millimeters to more than the outcrop scale. Smaller scale of sandstone are composed of massive and fine to medium grained arenite.

Concerning the mode of occurrence of blocks, two types are recognized. One shows sharp boundary, and sandstone of the block does not grade into pelitic rocks of the matrix. Another shows remarkably irregular shape and boundary, and sandstone of the block often grades into pelitic rocks of the matrix. In most of the latter case, block-matrix boundary is not sharp and the slip plane cannot be observed in appearance.

Although almost all blocks are represented by the four kinds of rocks mentioned above, small amount of pale greenish siltstone and mudstone are also contained. These siltstone and mudstone blocks vary from a few millimeters to 50 cm in length and show lenticular or irregular shapes. Radiolarian remains are sometimes abundantly contained in these blocks.

The matrix of the melange is dark-grayish siliceous siltstone or mudstone. Lamination and bedding are sometimes remain in the matrix of the melange. Under the microscope, angular clasts of quartz, plagioclase, muscovite and others are observed in the matrix.

3. Fossils and age

Limestone blocks of the melange of the Hirayu Complex often yield fusulinids. Isomi and Nozawa (1957) and Igo (1964, 1965) reported following fusulinids; *Pseudofusulina* cf. *ambigua*, *Neoschwagerina craticulifera*, *Pseudodoliolina ozawai* and others. These species range in ages from Early to Middle Permian.

Chert blocks of this melange yield radiolarians. Kojima (1982, 1984) and Adachi and KOJIMA (1983) reported the occurrence of Permian, Triassic and Early Jurassic radiolarians from chert.

Jurassic radiolarians were reported from pelitic rocks of the melange by KOJIMA (1982, 1984), ADACHI and KOJIMA (1983) and SASHIDA *et al.* (1982). The author recently added the following Jurassic Radiolarians from the mudstone matrix; *Eucyrtidiellum unumaense, Mirifusus* cf. *guadalupensis, Tricolocapsa plicarum, T. fusiformis, Trillus* sp. and others. These radiolarians are representative of the *Unuma echinatus* Assemblage (YAO and MATSUOKA, 1981) which is considered to indicate middle Middle Jurassic in age (YAO, 1982; YOKOTA and SANO, 1986).

Consequently, it is considered that the melange, which includes Permian and Triassic allochthonous blocks, was deposited in Middle Jurassic time or later.

4. Geologic structure

The Hirayu Complex generally strikes E-W and steeply dips north or south. Because sedimentary structures have been considerably destroyed through the deformation, it is difficult to determine the top of the strata and the existence of folds. The geologic structure of the melange should be further studied in detail.

The matrix of the melange of the Hirayu Complex is considerably sheared and it is usually scaly. The foliation is almost parallel to lamination in many cases. The foliation in the matrix is defined by preferred orientation of fine recrystallized micas. However, some micas aligning obliquely to the foliation are observed under the microscope.

A large part of blocks in the melange of the Hirayu Complex underwent deformation and show lenticular forms. The deformation is most conspicuous on the blocks of siliceous siltstone. From this fact, it is suggested that siliceous siltstone was unconsolidated at the stage of the deformation. As some chert and sandstone blocks have been deformed rotated and show rhombic forms in sheared matrix, it is suggested that blocks have been deformed under the simple shear stress.

B. Yukawa Complex

1. Outline

The Yukawa Complex is composed of Jurassic chert, siliceous mudstone, mudstone and sandstone. It is typically exposed in a small area along the Yukawa river, west and southwest of Shirahone. This complex is overlain by Quarternary volcanics and northwestward extension of the complex is unknown. This complex is considered to be structurally situated above the Shirahone Complex. The fault between the two complexes is confirmed in only one outcrop along the Yukawa river.

The Yukawa Complex corresponds to the complex in the F Zone (OTSUKA, 1985). However the F Zone has been included in the Sawando Zone (OTSUKA *et al.*, 1984; OTSUKA, 1986a), the complex of the F Zone is so characteristic that it is discriminated from other complexes.

2. Lithology

The Yukawa Complex is composed of Jurassic chert, siliceous mudstone, mudstone and sandstone (Fig. 2, 4).

Chert is bedded with clayish intercalation and pale green, bluish gray and reddish brown colored. Some cherts are thick and laterally traceable, while others are small blocks of sedimentary melanges. Laterally-continuous chert beds are in fault contact with underlying sandstone and the shear zone of the fault is less than 5 cm thick so far as observed. This kind of chert generally grades upward into siliceous mudstone. Small blocks of chert coherently contact with surrounding siliceous mudstone which is scarcely sheared.

Siliceous mudstone is reddish brown or dark greenish gray and especially shows characteristic reddish brown color just above chert beds almost without exception. This rock is sometimes accompanied by tuffaceous mudstone or siltstone. Siliceous mudstone grades upward into mudstone, which in turn grades upward into mudstone interbedded with sandstone. Thick (1 m+) beds of sandstone include fine and angular clasts of chert and mudstone.

Jurassic rocks in the Yukawa Complex show considerable systematic vertical changes of lithology (Fig. 6). Details of this vertical change will be discussed in Chapter IV.

3. Fossils and age

Radiolarian remains obtained from chert of this complex are shown in Table 2. These radiolarians are characteristic species of the *Parahsuum simplum* Assemblage (YAO, 1982) which indicates Early Jurassic time (YAO, 1982; Hori, 1986).

Siliceous mudstone and mudstone overlying the chert bed yield some radiolarian remains as shown in Table 2. These radiolarians include characteristic species of The *Parahsuum* sp. D Assemblage (YAO *et al.*, 1982), the *Hsuum hisuikyoense* Assemblage (ISOZAKI and MATSUDA, 1985), the *Unuma echinatus* Assemblage (YAO and MATSUOKA 1981) and the *Guexella nudata* Assemblage (MATSUOKA, 1981).

Chert, siliceous mudstone and mudstone are conformable at the localities where the above-mentioned radiolarians are obtained. Among the localities, there are no inconsistency between the radiolarian biostratigraphy and the lithostratigraphy. Consequently it is concluded that the chert-clastics sequence of this complex has been sequentially formed through Early and Middle Jurassic time.

4. Geologic structure

The Yukawa Complex generally trends northeast and dips steeply northwest. The complex which shows the continuous sequence mentioned above is repeatedly exposed by NE-SW strike-slip faults. Small-scale deformation structures of the complex are more inconspicuous than those of other complexes. The asymmetric fold in bedded chert is the most conspicuous feature in this complex.

C. Shirahone Complex

1. Outline

The Shirahone Complex is composed of Permian greenstone and limestone and Permian and Triassic chert with small amount of Jurassic mudstone and sandstone.

Table 2 List of Jurassic radiolarian fossils from the Yukawa Complex. For localities of samples see Appendix 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Canoptum sp.					+																											
Gigi sp.		+																														
Sylingocapsa sp. C		+																														
Parahsuum simplum						+	+												+													
P. sp. A						+	+																									
P. spp.						+	+									+	+		+	+		+										
P. sp. D																																
Acanthocircus hexagonus																																
Parvicingula gigantocornis	+																															
Parahsuum hisuikyoense				+																												
Archicapsa pachyderma			+	+				+	+	+	+	+		+		+	+				+					+						
Zartus spp.	+		+	+								+														+						
Trillus sp.	+							+	+	+						+					+					+						
Tricolocapsa fusiformis												+														+						
Unuma echinatus			+																													
U. spp.			+																					+		+			+		+	+
Tricolocapsa parvipora												+																				
T. plicarum												+	+	+	+			+					+	+				+	+	+		+
T. rusti												+																				
Cyrtcapsa mastoidea								+																								
C.(?) *kisoensis*								+																								
Podobursa sp.																										+						
Stichocapsa tegiminis			+																								+					
S. cf. *convexa*			+	+				+				+		+													+					
Diacanthocapsa normalis				+																												
Eucyrtidiellum unumaense				+				+																								
Tricolocapsa conexa																		+						+				+			+	
T. tetragona													+										+	+	+			+	+		+	+
Williriedellum sp. A group													+																			
L.(?) aff. *nudata*																							+									
Stichocapsa asiatica															+																	

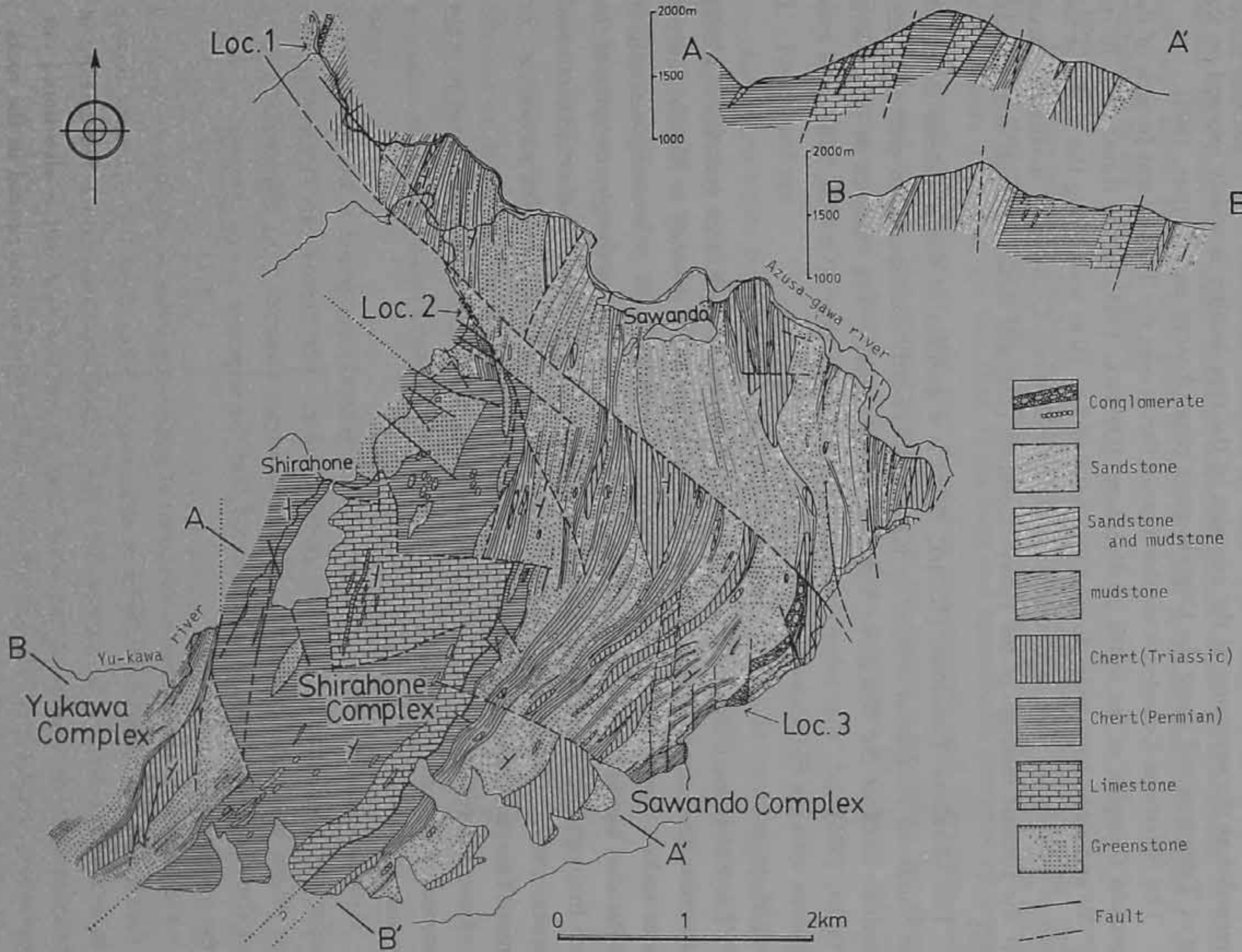

Fig. 4 Lithologic map and profiles of the Shirahone area.

The Shirahone Complex is situated at the northern part of the study area on the south of the Hirayu Complex. The Shirahone Complex is typically exposed at Shirahone. Lithology of the complex of the Shirahone area is shown in Fig. 4. The complex which is regarded as the extension of the complex in the type locality is widely exposed on the east of Takayama and along the Dayoshi-gawa river (ADACHI and KOJIMA, 1983).

The Shirahone Complex is southwestward thrust over the Triassic and Jurassic of the Sawando Complex at the south of Shirahone (OTSUKA, 1985). The thrust dips 30° to 45°NW and rocks have been sheared in a zone of 5 to 10 m wide along the thrust at the south of Shirahone. Western extension of the Shirahone Complex is northward thrust over the Jurassic melange of the Hirayu Complex (Dayoshi thrust, ADACHI and KOJIMA, 1983).

The Shirahone Limestone (KAMEI, 1956) is a member of the Shirahone Complex. The Shirahone Formation defined by KANO (1975) nearly corresponds to greenstone and limestone units of the Shirahone Complex of this paper. The complex in the E zone (OTSUKA, 1985) and "ther other element of the Mino Terrane" (OTSUKA, 1986a) are synonymous with the Shirahone Complex.

2. Lithology

The Shirahone Complex is lithologically characterized by a large quantity of blocks of Permian greenstone, limestone and chert and much lesser quantity of Middle Jurassic clastic rocks. Especially at Shirahone area, this complex looks to be composed only of the Permian blocks. The eastern Takayama area is widely underlain by complex of the same lithology and same age as in the type locality and by Triassic chert (ADACHI and KOJIMA, 1983; YAMADA *et al.*, 1985). The Permian to Jurassic complex exposed in the eastern Takayama area is regarded as the Shirahone Complex in this paper.

Greenstone, limestone and chert of the Shirahone Complex are considered to occur as a medley of various size of blocks.

Greenstone

Greenstones of the Shirahone Complex are generally composed of basalt with lesser amount of hyaloclastite and are dark green in color. The greater part of basalt is massive; pillow basalt and pillow breccia are sometimes observed. At Shirahone, judging from the shape of pillows, it is considered that the sequence is upright and is younger to the northwest.

The basaltic lavas are mainly composed of olivine-augite-basalt which is accompanied by colorless or pale green amphiboles in some cases. They show the subophitic texture or intersertal texture, and sometimes show amygdaloidal texture. Much less amount of microgabbro which consists of the same kind of minerals as basalt is also found out. Greenstones have been chloritized and calcite and sericite are widespread in the rocks.

Basaltic lava grades upward into bedded chert through greenish hyaloclastite and siliceous tuffite at Shirahone. Greenstone includes small limestone bodies generally less than 10 m long.

Chert

Chert is most predominant in the Shirahone Complex. Chert generally shows apparent bedding 2 to 5 cm thick. Clayish layers between Permian chert beds are much thinner than those of Triassic chert of other complexes or are not observable. Chert is dark gray, bluish gray or light gray in color. Chert is sometimes tightly folded with wavelength of less than few meters.

Limestone

Limestone occupies the smaller part of the Shirahone Complex than other rocks. The larger part of the limestone is composed of limestone breccia and other part is massive. Clasts of breccia are less than 10 cm long and sporadically occupied by basaltic lava. Limestone is gray or pale gray biosparite and oosparite and sometimes yields fusulinids and corals. The amount of the matrix of the breccia is much less than that of clasts and the matrix is tuffaceous or limy. Limestone sometimes intercalates thin (less than 2 m) chert beds.

3. Fossils and age

Limestone yields fusulinids, corals and other fossils. Fossils reported by MINATO (1951), TANAKA *et al.* (1952), KAMEI (1956), CHOI and FUJITA (1970) and OTSUKA (1985) are summarized in Table 3. Chert in this complex yields some species of conodonts and radiolarians (Table 4). Fusulinids in limestone are characteristic species and genera of Middle Permian age and conodonts and radiolarians in chert and limestone indicate that these rocks are mainly deposited in Middle Permian time.

In the eastern Takayama area, some cherts contain Early Jurassic radiolarians and siliceous mudstone yield early and late Middle Jurassic radiolarians (ADACHI and KOJIMA, 1983; KOJIMA, 1984). If the rocks in the eastern Takayama area are the true westward extension of the Shirahone Complex, the amount of Middle Jurassic matrix is extremely large.

Fusulinid
Parafusulina japonica
P. kaerimizuensis
P. ambigua
P. nakamigawai
Pseudofusulina kraffti
Yangchienia compressa
Pseudodoliolina ozawai
Schubertella sp.
Chusenella sp.
Minoella nipponica
Neoschwagerina simplex
Misselina sp.
Cancelina cf. *nipponica*
Verveekina cf. *verveeki*
Calcareous algae
Mizzia velevitana
Tetracorallia
Yatsengia aff. *ibukiensis*

Table 3. List of fossils from limestones of the Shirahone Complex.

	1	2	3	4	5
Pseudoalbaillella spp.	+		+		
Follicucullus sp. A	+				
F. scholasticus					+
F. ventricosus		+		+	+

Table 4. List of Permian radiolarian fossils from the Shirahone Complex. For localities of samples see Appendix 2.

4. Geologic structures

The Shirahone Complex generally trends northeast and steeply dips northwest. Most conspicuous deformation structures of the complex in the Shirahone area are asymmetrical fold with wavelength of less than a few meters in bedded chert.

D. Sawando Complex

1. Outline

The Sawando Complex is characterized by repetition of laterally-continuous chert, sandstone and mudstone. This complex is distributed on the southeast of the Shirahone Complex and is typically exposed near Sawando. This complex is in fault contact with the Shirahone Complex and the former is situated structurally under the latter.

The Tokugo-toge Formation (TANAKA *et al.*, 1952) is a member of the Sawando Complex. The Sawando Complex is synonymous with the complex in the D Zone (OTSUKA, 1985). The complex of the Sawando Zone (OTSUKA *et al.*, 1984; OTSUKA, 1986a), excluding the complex north to Shirahone, corresponds to the Sawando Complex, defined in this paper.

2. Lithology

Lithologic details of the Sawando Complex have been described in OTSUKA (1985).

Chert of the Sawando Complex is subdivided into two types on the basis of the mode of occurrence. One is thick (more than 50 m) and laterally-continuous and another forms much smaller blocks.

Chert is thinly (2 to 5 cm), bedded and is gray, grayish blue, grayish green and reddish brown in color. In almost all cases, chert is interbedded by thinner claystone. Bedded siliceous claystone, gray and black in color is sometimes observed below the bed of laterally-continuous chert.

In the uppermost part of chert, individual thin chert bed become sometimes broken into boudins or irregular shaped clasts (chert breccia). The matrix of chert breccia is composed of tuffaceous siltstone. Chert grades upward into greenish-gray taffaceous siltstone.

Greenish-gray tuffaceous siltstone is less than 30 m in thickness and parallel lamination is commonly observed in it. Although this rock is considerably albitized, clasts of intermediate volcanic rocks, plagioclase, quartz, biotite and zircon are observed in it under the microscope. This tuffaceous rock is correlated with "bedded pale green tuffaceous siltstone" by ADACHI (1977).

Greenish-gray tuffaceous siltstone grades upward into black siliceous mudstone which, in turn, is conformably overlain by alternating beds of sandstone and mudstone.

Alternating beds of sandstone and mudstone often exceed more than 300 m in thickness and occupy the largest quantity of the Sawando Complex. These beds of sandstone and mudstone are accompanied by sedimentary melanges and conglomerate. The latter includes metamorphic and granitic boulders. Up-section indicators, such as graded bedding, cross-lamination and sole marks, all indicate that beds are younger to the northwest. Medium to coarse sandstone is feldspathic (potassium feldsper dominant) arenite with micas, garnet, zircon and tourmaline and includes chert, mudstone, siliceous mudstone, granitic rocks, schists and gneisses as lithic fragments.

As mentioned above, systematic vertical change of lithology is apparent (Fig. 6). Details of this point will be discussed in Chapter IV.

Conglomerate

Conglomerates, containing boulders of metamorphic rocks have been found out at three points (Loc. 1, 2 and 3 in Fig. 4). The conglomerate at Loc. 2 has been named the Sawando Conglomerate (TANAKA *et al.*, 1952), and includes sillimanite gneiss (ADACHI, 1976) and some igneous boulders (KANO, 1961).

The conglomerate at Loc. 3 has been named the Bandokoro Conglomerate (OTSUKA, 1981). The Bandokoro Conglomerate is a intraformational conglomerate as well as others and exceeds 50 m thick in maximum. This conglomerate includes a large quantity of gneissose and granitic boulders. Gravels in this conglomerate are rounded or subrounded and ill-sorted and their maximum diameter exceeds 1.5 m. They are composed of chert, sandstone, limestone, marl, ortho-quartzite (sedimentary rocks), granite, granodiorite, sheared granodiorite, diorite, granophyre, quartz porphyry (igneous rocks), garnet biotite gneiss, marble and others (metamorphic rocks) (Fig. 5). Especially, common existence of variously recrystallized and sheared blastomylonitic granodiorite is one of the most characteristic features of this conglomerate. Late Triassic conodonts (*Gondolella polygnathiformis* and *Epigondolella bidentata*) are obtained from cobbles of micritic limestone. Jurassic radiolaria (*Protunuma* sp.) is found out in sandy matrix of the conglomerate.

These conglomerates resemble the Kamiaso Conglomerate (ADACHI, 1971, 1973) in the western part of the Mino Terrane with regards to the age, features of beds intercalating the conglomerate and composition of gravels.

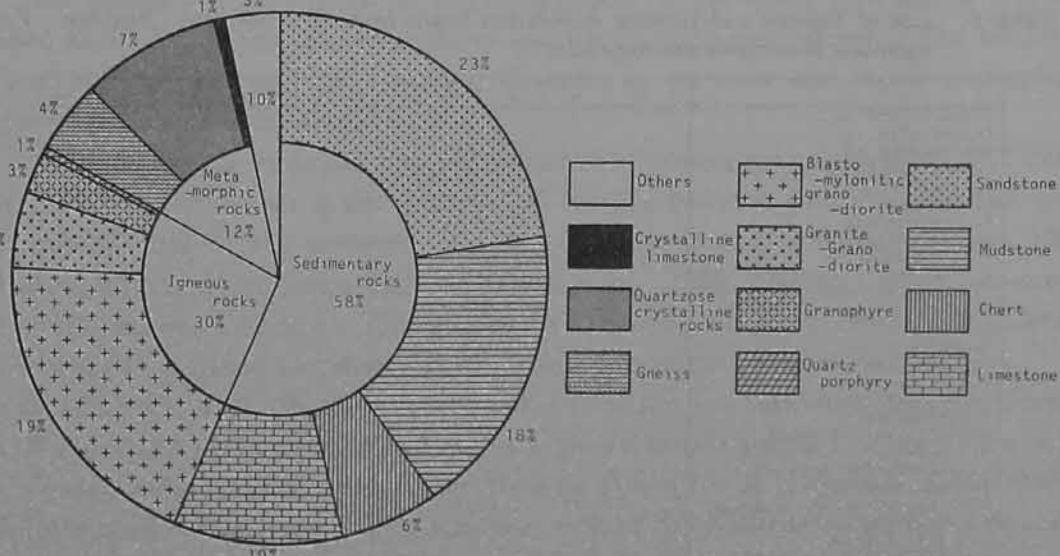

Fig. 5 Composition of gravels of the Bandokoro Conglomerate.

4. Fossils and age

Chert of the Sawando Complex yields Triassic conodonts (Table 5) and Triassic and Early Jurassic radiolarians (Table 6). Some cherts yielding late Early Triassic (Spathian) conodonts occur as blocks in Middle or Upper Jurassic strata.

Siliceous mudstone yields Middle Jurassic radiolarians at many localities (Table 6). These radiolarians are characteristic species of the *Hsuum hisuikyoense* Assemblage (YAO, 1981; ISOZAKI and MATSUDA, 1985), *Unuma echinatus* Assemblage (YAO and MATSUOKA, 1980) and *Guexella nudata* Assemblage (MATSUOKA, 1981).

Mudstone interbedded with sandstone yields late Middle and early Late Jurassic radiolarians which characterizes the *Guexella nudata* Assemblage and the *Gongylothorax sakawaensis—Stichocapsa naradaniensis* Assemblage (MATSUOKA and YAO, 1981, Table 6). Especially the latter assemblage is the youngest in age in the Sawando Complex and the radiolarians characterizing this assemblage have been obtained only from one point.

Thus, ages of the Sawando Complex range from Middle Early Triassic to early Late Jurassic times without age of blocks and the sequences showing systematic vertical changes of lithology, from chert through siliceous mudstone to terrigeneous clastic rocks, were deposited almost continuously throughout these times.

Table 5. List of Triassic conodont fossils from the Sawando Complex. For localities of samples see Appendix 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Gondolella haslachensis			+														+				+				+	+
G. excelsa	+													+							+					
Gladigondolella tethydis			+																							
G. sp.		+																								
Gondolella polygnathiformis					+		+	+	+			+						+								
Epigondolella primitia						+			+				+			+							+			
E. permica																										
E. abneptis						+				+					+											
E. postera																								+		
E. bidentata				+																		+				
Misikella hernsteini											+															
M. posthernsteini											+															

Table 6. List of Triassic and Jurassic radiolarian fossils from the Sawando Complex. For localities of samples see Appendix 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Triassocampe spp.																			+	+
Tripocyclia sp.																			+	+
Staurodorus sp.																			+	+
Palaeosaturnalis cf. *zapfei*															+					
P. heisseli								+							+					
P. elegans															+					
P. triassicus															+					
P. cf. *fissa*																+				
P.(?) *convertus*																+				
P. sp.							+	+							+	+				
Parahsuum simplum									+											
P. spp.									+				+							
Unuma sp.														+						
Tricolocapsa parvipora										+							+			
T. plicarum	+		+							+				+			+			
Cyrtocapsa mastoidea										+										
Podobursa sp.		+	+																	
Stichocapsa tegiminis																		+		
S. convexa										+										
Eucyrtidiellum unumaense		+	+																	
Tricolocapsa conexa					+	+				+	+	+		+		+				
Williriedellum sp. A group			+	+							+	+								
Lithocampe(?) *nudata*				+																
L. aff. *nudata*						+					+									
Eucyrtidiellum ptyctum						+								+						
Stylocapsa catenarum														+						
S.(?) *spiralis*														+						

5. Geologic structure

The Sawando Complex trends northeast and dips 45° to 80° northwest. Triassic and Jurassic sequences showing systematic vertical changes of the lithology are repeatedly exposed. Although the bases of Triassic chert or siliceous claystone are generally bounded by strike-slip thrust faults, siliceous claystone occupying the base of the sequence sometimes coherently contact* with the mudstone at the top of the subjacent sequence without apparent slip planes. Details and significance of this observation will be discussed in the Chapter IX.

Asymmetrical folds which are closed or tight (Fleuty, 1964) are common in bedded chert of the Sawando Complex. The folds indicate intermediate forms between the similar fold and the parallel fold. Tight or open (Fleuty) folds which appear to be originated from soft-sediment deformation are occasionally found out in rhythmically alternating beds of sandstone and mudstone.

Pinch-and-swell structure and boudin structure of sandstone interbedded with mudstone are also found out. These structures are also inferred to be products of the soft-sediment deformation. The layer-oblique cleavage, in some cases, occurs in the siliceous claystone. Because this cleavage limitedly found only in the lowermost part of the sequence, it is considered that the cleavage has genetic relation to the thrust bounding the bottom of the sequence.

Other small-scale deformation structures are not so conspicuous in this complex as in the Hirayu and Shimashima Complexes.

E. Shimashima Complex

1. Outline

The Shimashima Complex is characterized by melanges with chert and sandstone blocks and pelitic rocks of matrix which has undergone remarkable deformation.

This complex is distributed in the central part of the study area and is typically exposed along the Shimashima-dani River and the Nishino-gawa River. The boundary between this complex and the Sawando Complex is not clear and the two complexes appear to grade into each other.

The Ichinosawa Formation and the Shimashima Formation were proposed by Tanaka *et al.* (1952). The former is the melange of the Shimashima Complex and the latter is a stratified unit in the melange. Rocks of the A, B and C Zones (Otsuka, 1985) and those of the Shimashima Zone (Otsuka *et al.*, 1984; Otsuka, 1986) correspond to the Shimashima Complex. The Kurokawa, Inekoki and Hata Formations (Katada and Isomi, 1964) should be referred to the south part of the Shimashima Complex.

It is indeterminate whether thinly bedded turbidite and sandstone (Nomata Formation, Katada and Isomi, 1964) should to be included in this complex or not at this stage. The present author tentatively deals the Nomata Formation as a member of the Shimashima Complex in this paper. The southern limit of the Nomata Formation is bounded

* For application of the term coherent contact, see Kanmera (1982).

by the apparent fault trending northeast and steeply dipping northwest (KATADA and ISOMI, 1964; YANO, 1986MS).

KANO (1975) presented that Permian Narai Formation, Triassic Yabuhara Formation and the Misogawa Formation inferred to be Jurassic are folded to be repeatedly exposed along the Shimashima-dani River. However, existence of the Permian has not been actually confirmed and Triassic chert are nothing but blocks in the melange.

2. Lithology

The Shimashima Complex is composed of large quantity of melange whole of which are remarkably deformed.

Blocks in the melange consist of chert, sandstone, tuffaceous siltstone and siliceous claystone and their sizes range from a few millimeters to more than 1 km in length. Large chert blocks illustrated in the geologic map (Fig. 4) are considered to be aggregates of smaller blocks. Blocks often coherently contact with surrounding pelitic rocks of matrix which are occasionally intruded into cracks in blocks.

Chert occupies the main part of the blocks in volume. Chert is gray, grayish blue and grayish green in color and is thinly bedded intercalating siliceous claystone. Blocks of tuffaceous siltstone are less than 1 m in length and show irregular shapes jumbling with the matrix. The matrix of the melange is considerably siliceous and only small amount of clastic grains of quartz and plagioclase are observed under the microscope. Although sedimentary structures in the matrix are generally inconspicuous, laminae of less than a few millimeters in thickness are occasionally preserved.

Some parts occupied by alternating beds of sandstone and mudstone, in which sedimentary structures have been well preserved, are sporadically found out in this complex. Stratified clastic locks in the B Zone (OTSUKA, 1985) which is extending for distance and in a direction parallel to the general trend, is the most remarkable example. It is considered that each part which is composed of stratified clastic rocks is a giganthic blocks or an assemblage of smaller blocks.

3. Fossils and age

Conodonts have been obtained from chert and siliceous claystone blocks (Table 7). KANO (1975) reported the occurrence of *Epigondolella primitia* from chert blocks. These conodonts indicate ages from the Spathian to the Rhaetian (MOSHER, 1968; SWEET *et al.*, 1971; KOZUR, 1980; KOIKE, 1983).

Siliceous mudstone of the matrix of the melange commonly yields rediolarians. However specimens which are well-preserved enough for specific identification are hardly obtained because of deformation and recrystallization. Through intensive examination, Jurassic radiolarians (Table 8) could be obtained from siliceous mudstone matrix in several localities. Some of these species characterize late Middle and early Late Jurassic radiolarian assemblages (MATSUOKA, 1982, 1983; YAO, *et al.*, 1982).

To sum up, Early to Late Triassic chert and siliceous claystone blocks are included in Late Middle to early Late Jurassic siliceous mudstone and mudstone in this complex. Therefore it is inferred that the melange of the Shimashima Complex has been formed

Table 7. List of Triassic conodont fossils from the Shimashima Complex. For localities of samples see Appendix 4.

	1	2	3	4	5	6	7	8	9
Neospathodus homeri		+							
Gondolella excelsa					+				
Gladigondolella tethydis									+
Gondolella polygnathiformis							+	+	
Epigondolella permica						+			
E. nodosa							+		
E. abneptis							+		
Misikella hernsteini	+			+					
M. sp.			+						

Table 8. List of Jurassic radiolarian fossils from the Shimashima Complex. For localities of samples see Appendixes 4 and 5.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dictyomitra sp. C									+					
Stichocapsa naradaniensis									+	+				
S. robusta								+						
Stylocapsa spiralis								+						
S. lacrimalis								+						
S. hemicostata									+					
S. catenarum								+			+			
Guexella aff. *nudata*										+				
Stylocapsa tecta										+				
Tricolocapsa tetragona	+			+	+	+								
T. aff. *fusiformis*	+			+	+	+								
Guexella nudata			+			+				+				
Hsuum(?) aff. *inexploratum*				+	+									
Tricolocapsa conexa	+		+	+	+	+		+	+	+				
Williriedellum sp. A group		+					+		+			+	+	+
Tricolocapsa plicarum	+	+			+	+	+		+				+	+
T. fusiformis		+					+						+	
Dictyomitrella(?) *kamoensis*				+	+									

in Late Jurassic time or after.

4. Geologic structures

Sedimentary structures are hardly preserved as a result of intense shear and it is difficult to recognize the macroscopic structure only from them. But the trend of predominant cleavage is almost parallel to that of laminae and bedding which are sporadically preserved. Predominant cleavages generally trend northeast and steeply dip northeast or locally southeast.

The melange of the Shimashima Complex is entirely sheared and various deformation structures are commonly observed both in blocks and the matrix.

Some types of folds are observed in the melange. Siliceous mudstone of the matrix is sometimes tightly folded with wavelength of less than 10 cm (Fig. 10-h). The open fold accompanied by axial plane cleavages also occurs in the melange (Fig. 10-i). Tight or open fold with wavelength of 1 to 2 m are found out in alternating beds of sandstone and mudstone (Fig. 10-a). This fold is considered to be formed under unconsolidated condition of sediment because of no evidence of brittle deformation.

Various minor structures are commonly observed in siliceous mudstone matrix, under the microscope or in polished specimens as a result of intense shear. The important minor structures are as follows, 1) rhombic inclusion, 2) irregularly fragmented siltstone, 3) rotation of clasts, 4) layer-oblique cleavage, 5) axial plane cleavage and 6) crenulation cleavage (Fig. 10-j, f, n, k, l, m). Some of deformation structures are apparently asymmetrical and they are inferred to have been deformed under the simple shear stress.

Especially the type-C fold and irregularly fragmented siltstone have been developed through remarkable flow of materials. Ductile deformation or recrystallization of clastic grains concerned with folding or fragmentation are not found out under the microscope. Then these deformation have been formed before consolidation. After all, deformation of the Shimashima Complex is considered to have developed both before and after consolidation of sediments.

F. Misogawa Complex

1. Outline

The Misogawa Complex is characterized by great amount of sandstone, mudstone and melange. Soft-sediment deformation is widespread in this complex and southern part of the complex has undergone the Ryoke metamorphism. The Misogawa Complex is typically exposed along the Miso-gawa River and the Nishino-gawa River. The Misogawa Complex is in fault contact with the Shimashima Complex.

The Hario Formation (KATADA and ISOMI, 1964) is correlated with the melange which occupies the northern part of the Misogawa Complex. The Misogawa Formation (KATADA and ISOMI, 1962) corresponds to the unit of alternating beds of sandstone and mudstone in the Misogawa Zone. YANO (1985) first presented that the Yabuhara Formation (KATADA and ISOMI, 1962) is a sedimentary melange and dealt it as a unit of the Misogawa Formation. The present author agrees with his opinion and regards the Yabuhara Formation and the Hario Formation as sedimentary melanges of the Misogawa Complex.

2. Lithology

The Misogawa Complex is composed of two types of units; one is sandstone-dominant complex and another is sedimentary melange.

Most of coarse to medium sandstone is massive and often includes angular fragment of mudstone. Coarse sandstone is sometimes accompanied by breccia which is composed of chert, mudstone and siliceous mudstone. Mudstone overlying sandstone is commonly thinner than sandstone and shows laminae indicated by aligned flaky muscovite, Carbonized plant fossils and trace fossils, *Helminthoidea* (ISOMI and KATADA, 1959) are sometimes found out in mudstone and fine sandstone.

Melange of this complex are exposed along the Nomata-gawa River and the Naraigawa River in the area east of the Sakai-toge fault (RESEARCH GROUP FOR ACTIVE FAULTS, 1980, Fig. 2) and at the west of Kisofukushima in the area west of the fault. The matrix of the melange is mudstone and does not show apparent sedimentary structures. Although the matrix has been variously sheared, the shearing is not so conspicuous as in the Shimashima Complex. Blocks in the melange are chert, siliceous claystone, sandsonte, limestone and greenstone, and some of them extend over a length of 2 km.

3. Fossils and age

An occurrence of plant fossils has been reported from this complex (GEOLOGICAL SOCIETY OF NAGANO PREFECTURE, 1957), and some geologists have believed that the complex is Mesozoic in age. KOIKE *et al.* (1971), KANO (1975) and YANO (1983, 1985) have obtained Triassic conodonts from chert in this complex.

Limestone blocks yield Permian coral, *Waagenophyllum indicum* at Mt. Utou-yama

	1	2	3	4	5	6	7	8	9	10	11
Pseudodictyomitra primitiva							+			+	
P. sp. D							+		+		
Tricolocapsa sp. A							+	+	+		
Archaeodictyomitra minoensis							+				
Parvicingula mashitaensis										+	
Mirifusus mediodiratatus										+	
M. baileyi											+
Protunuma japonicus										+	+
Stichocapsa sp. A								+			+
Dictyomitra sp. C							+				
Tricolocapsa sp. O									+		
Stichocapsa naradaniensis				+	+	(+)					
S. robusta					+						
Stylocapsa spiralis					+						
S. hemicostata			+								
S. catenarum	(+)										
Eucyrtidiellum ptyctum				+	+				+		+
Cinguloturris carpatica		+	+	+					+		
T. aff. *fusiformis*				+							
Tricolocapsa conexa				+	+	+					
Williriedellum sp. A group				+							
Tricolocapsa plicarum						+			+		

Table 9. List of Jurassic radiolarian fossils from the Misogawa Complex. For localities of samples see Appendix 6.

(KAMEI *et al.*, 1962) and Permian and Late Triassic conodonts along the Narai-gawa River (YANO, 1983, 1985).

Siliceous mudstone and mudstone yield abundant radiolarians which are useful for age-determination. MIZUTANI *et al.* (1981), ADACHI (1982) and YANO (1985, 1986MS) have reported occurrences of Late Jurassic radiolarians (*Mirifusus baileyi* Assemblage, MIZUTANI *et al.*, 1981) from the Miso-gawa River area. Although YANO (1985) also found out early Late Jurassic radiolarians (*Gongylothorax sakawaensis-Stichocapsa naradaniensis* Assemblage) (=G-S Assemblage), he interpreted that they were yielded from exotic blocks. The present author obtained early to late Late Jurassic radiolarians mainly from the area west of the Sakai-toge fault (OTSUKA, 1986b). Representative species of Jurassic radiolarians obtained from the Misogawa Complex are shown in Table 9. Considering wide distribution of occurrences of radiolarians characterizing the G-S Assemblage, early Late Jurassic rocks cannot be concluded as blocks. The early Late Jurassic radiolarians tends to be obtained in the north part of this complex.

These fossil evidences indicate that clastic rocks of the Misogawa Complex deposited during early to late Late Jurassic time.

4. Geologic structure

In the Misogawa Complex, monotonous lithofacies and widespread small-scale deformation structures make it difficult to understand the macroscopic structures. Elaborate checks of change of dip and tops of beds suggest the existence of folds with wavelength of 50 m to some hundreds meters. However beds dipping northwest and indicating north-west-top are predominant all over the study area. It is suggested from this that the northern limbs of the fold are more developed or longer than the southern limbs and that enveloping surface of folds are gently dip northwest as a whole.

Minor folds (Fig. 10-a) are found out in thinly alternating beds of sandstone and mudstone. They are tight or closed (FLEUTY, 1964) folds whose wavelength is 1 m or so and are classified into the similar fold.

Boudinage and pinch-and-swell structures (Fig. 10-c, d) are also found out in thinly alternating beds. Apparent slip planes cannot be observed between sandstone boudins and surrounding pelitic rocks and they sometimes grade into each other under mesoscopic observation. Boudins usually show lenticular and sharply edged (Fig. 10-d) shapes, which indicate the existence of remarkable flowage even in competent layers.

Microfaults (Fig. 10-g) also occur in thinly alternating beds of sandstone and mudstone which are usually accompanied with pinch-and-swell structures. Most of microfaults cut bedding or lamination with high-angle, and their vertical slips are less than 5 cm in usual. Microfaults are not accompanied with mesoscopic shear zones and sandwich thin (less than 30 μm materials under the microscopic observation. These faults are distinct within sandstone layers, but dips and vertical slips of faults become gradually diminished within mudstone layers and finally faults disappear.

Microscopic layer-oblique or layer-parallel cleavages (Fig. 10-k) occur in some melanges. Especially these structures are common in the melange which has been named the Yabuhara Formation (KATADA and ISOMI, 1962).

G. Kyogatake Complex

1. Outline

The Kyogatake Complex is characterized by a large quantity of sandstone and mudstone accompanied with allochtonous blocks of chert, limestone and greenstone. This complex is distributed in the southernmost part of the study area, and rocks are typically exposed along the Narai-gawa River and the Yokokawa-gawa River.

Along the Narai-gawa River, the Kyogatake Complex is in fault contact with the Misogawa Complex.

The Kyogatake Complex has wholly undergone the Ryoke metamorphism. Low-grade metamorphic rocks (the biotite zone and lower) in the northwestern part grade into the high-grade metamorphic rocks (the cordierite zone and higher) toward the south (KATADA *et al.*, 1959; KATADA and ISOMI, 1962, 1964; KATADA, 1965, 1967; ONO, 1969; MORIKIYO, 1984 and others). Because of remarkable metamorphism, it is difficult to determine the exact limit of southeastern extension of this complex.

The Narai Formation, the Yokokawa Formation and the Kuwazawa Formation (KATADA and ISOMI, 1962) are involved in the Kyogatake Complex. The rocks of the Narai Formation, the Yabuhara Formation and the Misogawa Formation whose distributions in the area south of the Narai fault were shown by KANO (1975), are members of the Kyogatake Complex.

2. Lithology

Lithology of the Kyogatake Complex has been described by OTSUKA *et al.* (1986), and in this paper the author gives the outline of the lithology in accordance with their description.

The Kyogatake Complex is composed of a large amount of sandstone and mudstone and is accompanied with a small amount of chert, limestone and greenstone as allochthonous blocks. Alternating beds of sandstone and mudstone are subdivided into two types; the mudstone-dominant type and the sandstone-dominant type.

Beds of the mudstone-dominant type is composed of turbidite. Thickness of one bed is 3 to 7 cm in usual. Sedimentary structures, such as grading and cross lamination, are commonly observed, and the top of usually steeply dipping beds can be determined in many cases. Sedimentary structures of this type of alternating beds have been disrupted into various degrees and some kinds of deformation structures as sandstone breccias and minor folds are common.

Beds of sandstone-dominant type are composed of thicker sandstone beds and thinner mudstone beds, and the total thickness of a set of underlying sandstone and overlying mudstone is 10 to 50 cm. Sandstone and mudstone sometimes occur as individual thick bed. Sandstone blocks which sometimes exceed 1 m in diameters are often contained in mudstone. It is difficult to determine whether this kind of sandstone blocks are allochthonous or products of disruption of neighboring sandstone beds under an unconsolidated condition.

Chert, limestone and greenstone sporadically occur as allochthonous blocks included in mudstone matrix and the complex are considered to be sedimentary melanges. Chert is the most common and the largest among allochthonous blocks, which are more frequently found in the southeastern part (Yokokawa Formation, KATADA and ISOMI, 1962) of this complex. Limestone occurs as small bodies accompanying chert in most cases and are sometimes frequently interbedded with chert. A part of limestone interbedding with chert is replaced by dolomite or silica minerals to various extent. Greenstone also occurs as small blocks, most of which are less than mappable scale, and some of them are accompanied with chert. Greenstones are composed of basaltic massive lava, hyaloclastite, tuff and others. But primary maffic minerals are not preserved and only remains as pseudomorph due to the metamorphism.

3. Fossils and age

OTSUKA *et al.* (1986) have reported the occurrences of conodonts and radiolarians. Limestone yields Late Triassic conodonts from some localities and chert contains conodonts which are inferred to be Triassic types (Table 10). Although radiolarians are commonly contained in siliceous mudstone and mudstone, they are ill-preserved and recrystallized due to the Ryoke metamorphism. From some localities radiolarians of apparently Middle or Late Jurassic types are obtained (Table 10). Faunal composition of these radiolarians show similarities to those of the *Mirifusus baileyi* Assemblage (MIZUTANI *et al.*, 1981). The age of the complex is inferred to be late Late Jurassic in the present stage of the research but details remain unsolved.

4. Geologic structure

Strata of the Kyogatake Complex trend northeast and dip steeply southeast or northwest. Almost all part of the complex are variously disrupted and minor deformation structures are commonly observed. Then it is difficult to recognize the macroscopic structures. For the present, the author infers that the enveloping surface of folds dips southeast as thought by KATADA and ISOMI (1962). KANO (1975, 1982) proposed the

Table 10. List of Triassic conodont and Jurassic radiolarian fossils from the Kyogatake Complex (after OTSUKA *et al.* 1986). For localities of samples see Appendix 7.

	LITHOLOGY	LS	CH	CH	CH	LS	LS	LS	LS	LS	CH	CH	CH	CH	SM	SM	SM	SM
	TAXA / LOCALITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CONODONTS	*Gondolella polygnathiformis*							●										
	G. sp.	●		●				●	●	●	●	●	●	●				
	Epigondolella permica							●										
	E. abneptis	●							●									
	E. primitia					●												
	E. spp.							●		●								
	fragments	●	●	●	●	●	●	●	●	●	●	●	●	●				
RADIOLARIANS	*Tricolocapsa* sp.														(●)	●	●	●
	Eucyrtidiellum sp.																	●
	Solenotryma sp.															(●)		
	Pseudodictyomitra minoensis														(●)			
	Archaeodictyomitra sp.A														●			
	A. spp.															(●)		(●)
	Parvicingula sp.														(●)			
	Mirifusus sp.															●		●

macroscopic folded structure which show almost level enveloping surface of folding. Any evidence of the macroscopic folds as he had proposed was not found out through the survey of OTSUKA *et al.* (1986).

The minor fold, boudinage, pinch-and-swell structure, microfault and sandstone breccia are common and crenulation cleavage, slaty cleavage and schistosity are occasionally found out in the Kyogatake Complex.

Minor folds occur both in the sandstone-dominant type and in the sandstone-dominant type of alternating beds. Folds of the former type (Fig. 10-a) are tight or closed with wavelength of less than 1 m and are close to the similar fold. Folds of the latter type (Fig. 10-b) are open folds with wavelength of more than 1 m. These folds resemble those of the Misogawa Complex.

The boudinage and the pinch-and-swell structure (Fig. 10-c, d) are common in the mudstone-dominant type beds. Boudins usually show thin lens shape, which indicates the existence of remarkable flowage both in competent sandstone and incompetent mudstone. Besides microfaults occur also in the mudstone-dominant type beds.

Sandstone breccia (Fig. 10-e) sporadically occurs within sandstone-dominant alternating beds and they are floated in mudstone. Sandstone clasts in breccia show irregular shapes with length of less than 30 cm in usual. Two types of boundaries between sandstone clasts and surrounding mudstone are mesoscopically recognized; one is sharp contact and the other is obscure and grading into each other as a result of soft-sediment deformation.

The slaty cleavage is found out in the middle to low-grade (biotite zone) metamorphic rocks of this complex. The slaty cleavage occurs apparently oblique to bedding. The crenulation cleavage and the schistosity appear in higher grade part.

IV. Chert-clastics sequence

The rock sequence which shows systematic vertical changes of lithology in the Yukawa and Sawando Complexes (Fig. 6) has been named "the chert-clastics sequence" (OTSUKA 1985) and an idealized columnar section of the sequence is shown in Fig. 7. Bedded grayish siliceous claystone, chert, chert breccia, tuffaceous siltstone, siliceous mudstone and interbedded sandstone and mudstone are accumulated in ascending order almost regularly. The thickness of the sequence is usually some hundreds meters and sometimes exceeds 1.000 m. Distribution of sequences is shown in Fig. 8. Of course, not all sequences show completely regular vertical changes of the lithology and total thickness of the sequences varies to certain extent among sequences.

Fig. 6 shows examples of vertical lithologic changes in individual of sequences. Large part of chert and interbedded sandstone and mudstone are abbreviated in Fig. 6.

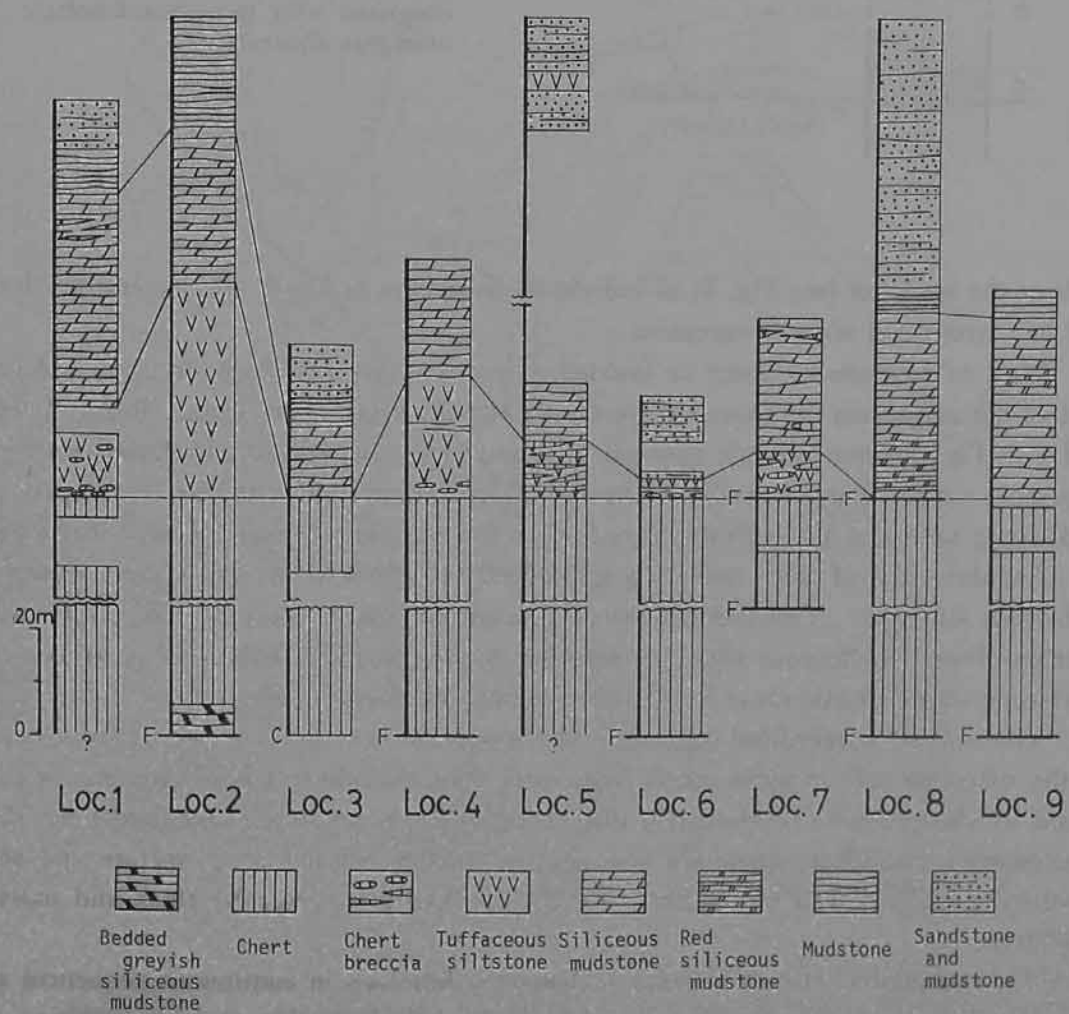

Fig. 6 Examples of stratigraphic columns in the Yukawa and Sawando Complexes. Localities are shown in Fig. 8. Lines connecting adjacent columns show lithological correlation. F: Fault, C: Sharp boundary without fault.

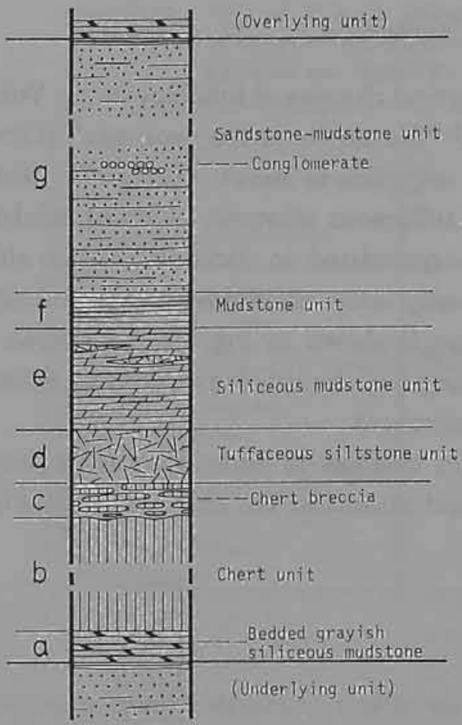

Fig. 7 An idealized chert-clastics sequence (adapted from OTSUKA, 1985). Chert (b) and Sandstone and mudstone (g) actually have much larger thickness compared with the other lithologic units than illustrated.

Beds at the localities (see Fig. 8) of individual sequences in Fig. 6 are dipping northwest and not ovreturned without exception.

Most of bottoms of chert or bedded siliceous claystone which occupies the basal part of the sequences are bounded by faults with apparent shear zone. But at Locs. 3 and 4 in Fig. 8, chert sharply contacts with mudstone and sandstone of the underlying sequences without apparent slip surfaces. These indicate that at least the top of the underlying sequence was unconsolidated when the sequences were stacked.

Angular clasts of chert breccia is sporadically involved in the lower part of greenish tuffaceous siltstone. Tuffaceous siltstone, occasionally with chert breccia, conformably overlies chert. Tuffaceous siltstone, siliceous mudstone and interbedded sandstone and mudstone which overlie chert in this order, gradually change each other.

The unit of interbedded sandstone and mudstone is situated at the uppermost part of the sequence and occupies much larger part than the other units. This unit is composed of characteristic rhythmically alternating beds of sandstone and mudstone, thick and massive sandstone, gneissose and granitic gravels bearing conglomerate and sedimentary melange. The top of the sequence is usually occupied by thick and massive sandstone.

The recognition of this systematic change of lithology in continuous sequences and of the repeatedly piled structure of these sequences is important in considering the tectonosedimentary process of these sequences. This problem will be discussed in Chapter IX.

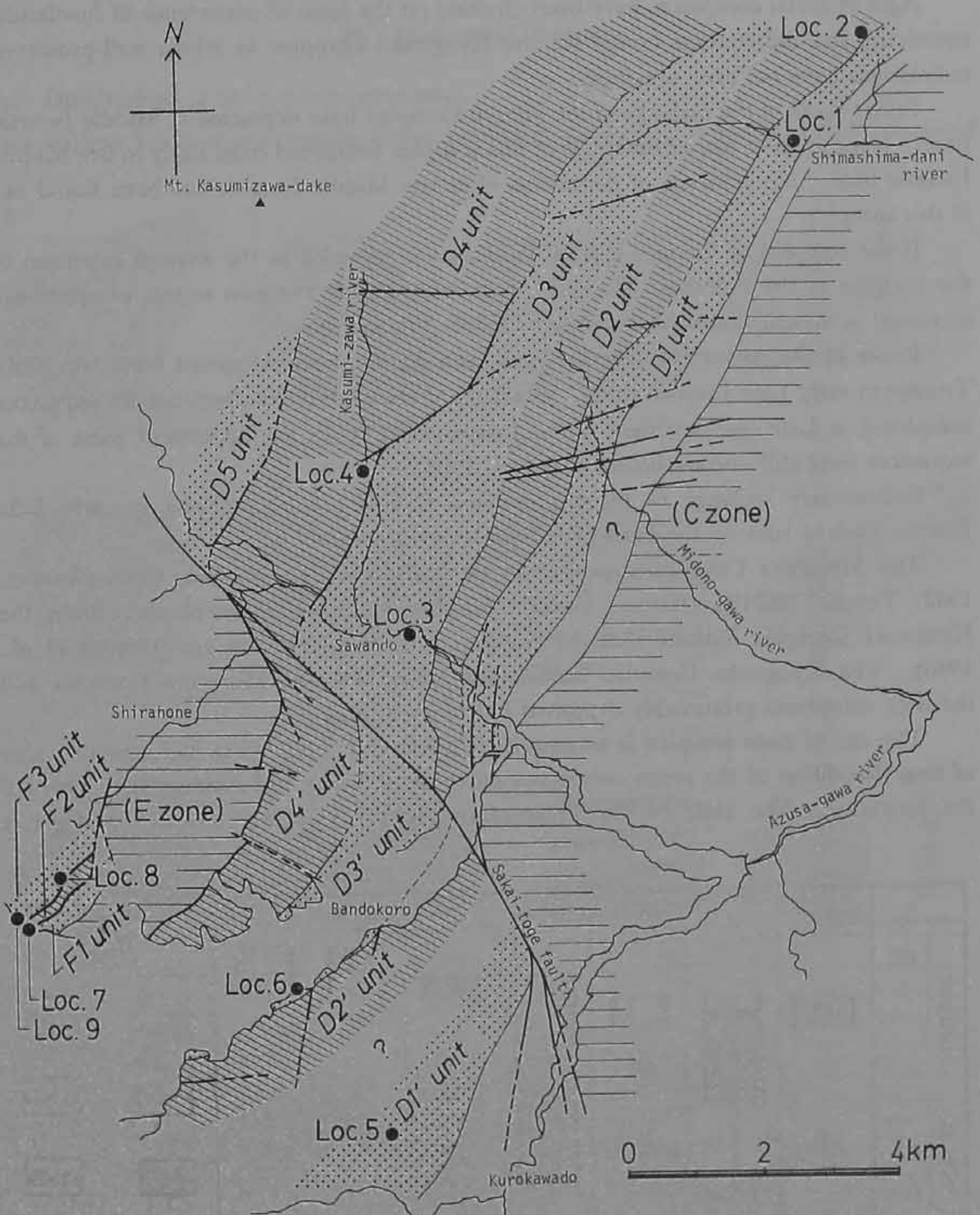

Fig. 8 Tectonic slices of the Yukawa and Sawando Complexes. Locs. 1–9 are localities of columns shown in Fig. 6. An initial letter "D" or "F" of each tectonic slice is given after the name of the zones (D and F zone, OTSUKA 1985).

V. Younging polarity of rock ages

Ages of seven complexes have been clraified on the basis of occurrence of fusulinids, conodonts and radiolarians except for the Kyogatake Complex in which well-preserved radiolarians have not been obtained.

Pelitic rocks of the melange of the Hirayu Complex have deposited in Middle Jurassic time. Deposition of matrix materials of this complex continued from Early to late Middle Jurassic time. No evidence of deposition after late Middle Jurassic has been found out in this complex.

If the complex of the area east of Takayama is regarded as the western extension of the complex of the Shirahone Complex, it is inferred that Permian in this complex was emplaced as allochthonous blocks in late Middle Jurassic time.

Rocks of the Sawando Complex have been continuously deposited from late Early Triassic to early Late Jurassic times. Stacking of the continuous chert-clastics sequences completed in Late (perhaps early Late) Jurassic time when the uppermost parts of the sequences were still unconsolidated (OTSUKA, 1985).

Sedimentary melange of the Shimashima Complex was emplaced in early Late Jurassic time or later on the basis of radiolarian evidences.

The Misogawa Complex deposited in early and late Late Jurassic times (ADACHI, 1982; YANO, 1986MS; OTSUKA, 1986a). Ill-preserved radiolarians obtained from the Kyogatake Complex indicate that the complex is Late Jurassic in age (OTSUKA *et al.*, 1986). The Kyogatake Complex lithologically resembles the Misogawa Complex and the both complexes presumably deposited in the same time.

The age of each complex is summarized in Fig. 9. This figure indicates that ages of final deposition of the seven complexes show the tendency to become younger toward the southeast. The shift of the sedimentary site toward the southeast by stages is

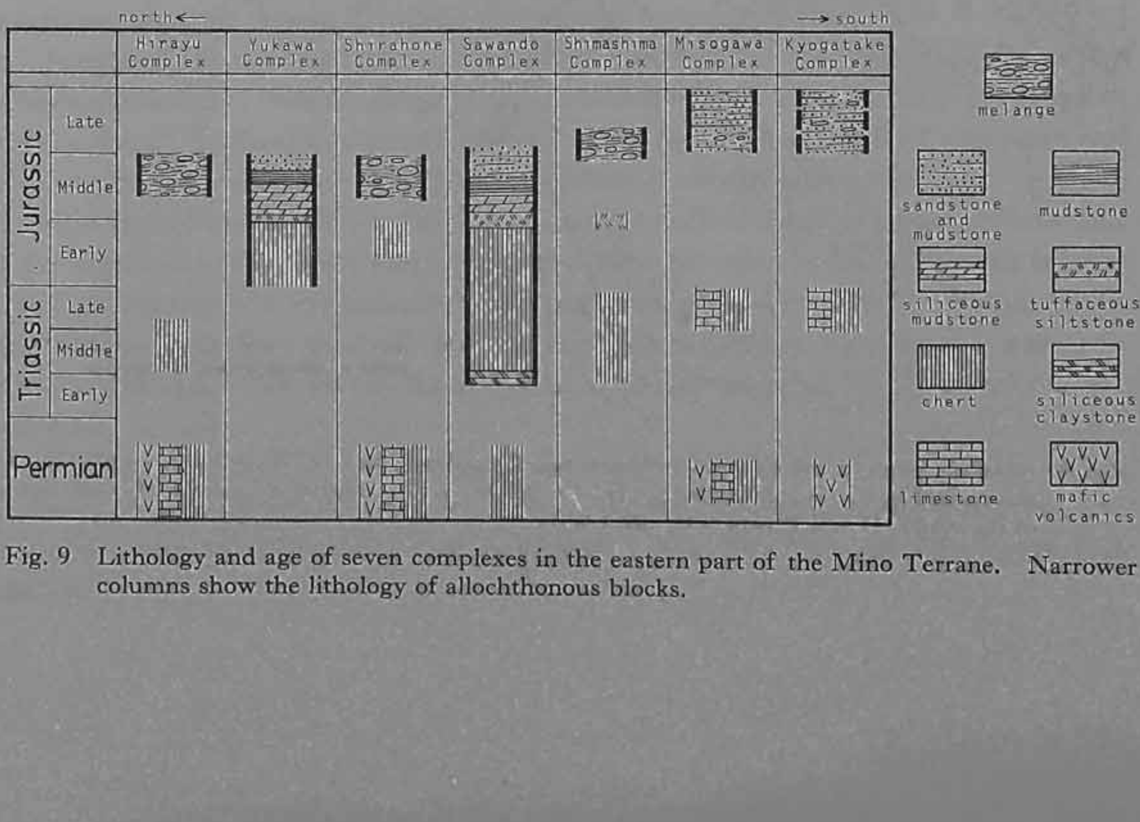

Fig. 9 Lithology and age of seven complexes in the eastern part of the Mino Terrane. Narrower columns show the lithology of allochthonous blocks.

suggested on the basis of this southeastward younging polarity of ages.

VI. Structural features

A. Distribution of deformation structures

Various kinds of deformation structures which are formed in earlier to later stages of

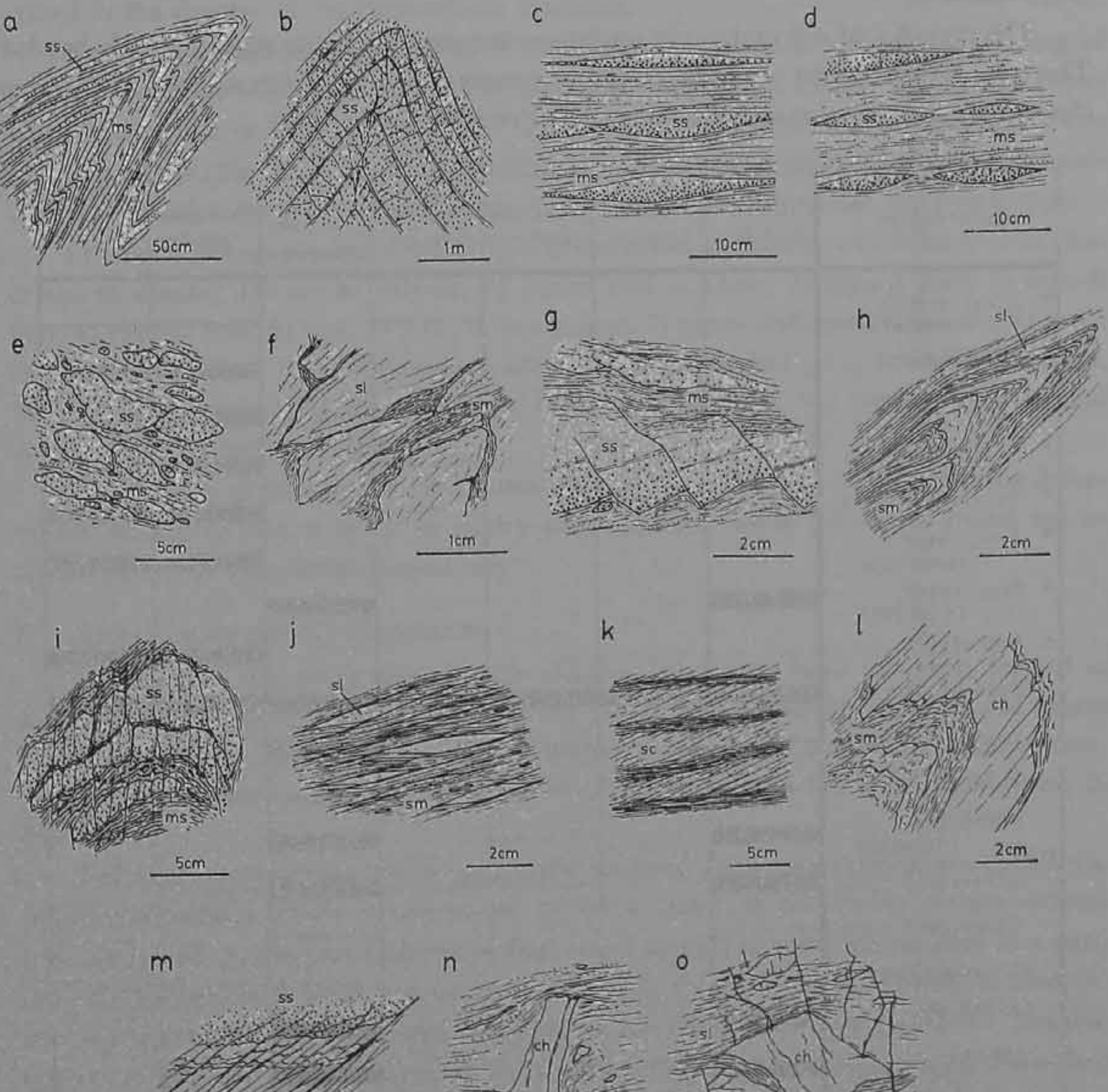

Fig. 10 Schematic sketches of principle deformation structures.
a: Fold (A-type), b: Fold (B-type), c: Boudin, d: Pinch-and-swell structure, e: Brecciation of sandstone, f: Brecciation of siliceous siltstone, g: Microfault, h: Fold (C-type), i: Fold (D-type), j: Rhombic inclusion, k: Cleavage (A-type), l: Cleavage (B-type), m: Cleavage (C-type), n: Rotation of clast, o: Ductile deformation of clasr.

the tectonic process are widespread in the study area. Each complex is characteristic not only in lithology but also in aspect of deformation structures, which were described in Chapter III. In this chapter, the author pays attention to mesoscopic folds, micro-fault, cleavages, boudin, pinch-and-swell structure, tectonic inclusion and other mesoscopic and microscopic structures. Schematic sketches of the principal deformation structures are shown in Fig. 10.

Four types of mesoscopic folds and three types of cleavages found out are explained in the following.

The type-A fold is found out in mudstone-dominant turbidite which is thinly bedded. The type-A fold is tight or closed, angular asymmetrical fold which was described in the chapter of the Misogawa and the Kyogatake Complexes (Fig. 10-a).

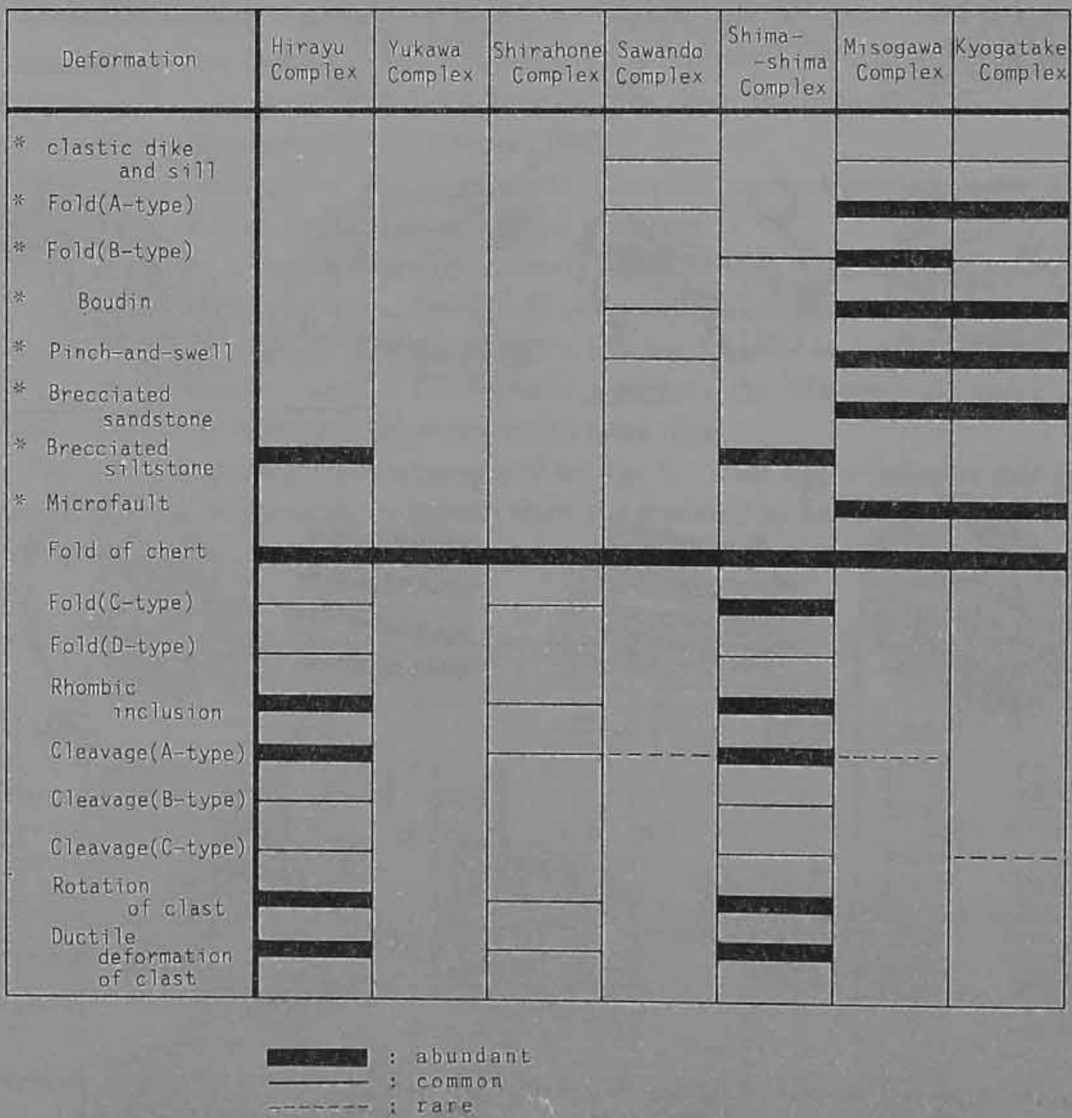

Fig. 11 Distribution of important deformation structures in the eastern part of the Mino Terrane. The deformation structures with the symbol "*" are considered to be formed before consolidation.

The type-B fold is found out in alternating beds of sandstone and mudstone. This fold is open or closed, angular to rounded, asymmetrical fold which was described in the chapter of the Kyogatake Complex. The wavelength and the amplitude of this fold are larger than those of the type-A fold (Fig. 10-b).

The type-C fold (Fig. 10-h) occurs in the pelitic matrix of melange and sometimes shows remarkable passive flow. The type-D fold (Fig. 10-i) occurs in a competent block in melange and is characterized by axial plane cleavages. Both types of folds were described in the chapter of the Shimashima Complex.

The type-A cleavage (Fig. 10-k) is obliquely crossed with laminae or bedding of siliceous claystone and mudstone. The type-B cleavage (Fig. 10-l) is axial plane cleavage which occurs in the Type-D fold. These cleavages are mesoscopic in scale. The type-C cleavage (Fig. 10-m) is the crenulation cleavage, which sometimes occurs in mudstone matrix of melanges. This cleavage can be observed only under the microscope.

Principal mesoscopic and microscopic deformation structures which have been described in chapter III are as follows; 1) minor fold in chert, 2) type-A fold, 3) type-B fold, 4) type-C fold, 5) type-D fold, 6) boudinage, 7) pinch-and-swell structure, 8) brecciation of sandstone, 9) brecciation of siltstone, 10) microfault, 11) rhombic inclusion, 12) type-A cleavage, 13) type-B cleavage, 14) type-C cleavage, 15) rotation of clasts and 16) ductile deformation of clasts.

Distribution of deformation structures are shown in Fig. 11. Although some deformation structures occurs in all or nealry all complexes, some others are found out in certain particular complexes, respectively.

B. States of materials in deformation

Deformation structures dealt in this chapter, of course, have not been formed at one time. Some of them may have occurred under the unconsolidated stage and others after consolidation. Because behaviors of materials depend on confining pressure, temperature, strain rate, and others, it is not always easy to infer the state of materials in deformation.

Deformation structures which apparently occurred after consolidation are as follows. (1) The schistosity which is interpreted to be a result of the Ryoke metamorphism. (2) The type-D folding (at least in the final stage) and (3) minor folds (at least in a part) in thinly bedded chert which are widespread all over the study area. Details of observation and significance of some these folds will be presented in Chapter VIII-A. Besides, type-A, type-B and type-C cleavages occurred on the stage on which consolidation had been considerably progressed.

Sandstone or mudstone dykes and sills were, of course, formed under the unconsolidated condition.

Concerning deformation structures other than cited above, it is not easy to determine the states of materials in which the deformation structures was formed, on the basis of mesoscopic features.

OTSUKA *et al.* (1985, 1986) indicated that type-A and type-B folds, boudinage, pinch-and-swell structure, brecciation of sandstone, microfault, clastic dykes and other deformation structures were widespread in the Kyogatake Complex. MALTMAN (1984) has insisted that intergranular flow without intragranular movement is important for recognition of soft-sediment deformation under the microscope. Under the microscopic observation of the above cited in the Kyogatake Complex, remarkable fractures or deformation of clastic minerals are not observed, and these deformation structures are considered to be formed chiefly through the intergranular flow. Accordingly, OTSUKA *et al.* (1986) concluded that most of these deformation structures was formed in the unconsolidated stage and that soft-sediment deformation occurred all over the Kyogatake Complex.

Brecciation of siltstone and type-C folds seem to have been formed through remarkable flow of materials. The fact that clastic grains such as quartz in siltstone are not deformed suggests a remarkable flow occurred before complete lithification as mentioned in the Chapter III-E.

Concerning formation of rhombic inclusions of siliceous mudstone or siltstone and rotation and ductile deformation of clasts, it is not easy to determine the condition of materials. However, at least, some clasts in these deformation structures are inferred to have been lithified to a certain extent considering that the clasts of same rock species are allochthonous and older than the matrices.

As mentioned above, deformation structures which have been formed before and after lithification coexist in the study area. Of course it is inferred that some of them have occurred under the intermediate conditions between unconsolidation and consolidation. The distribution of deformation structures is not uniform among the complexes (Fig. 11) and this fact is interpret to be the reflection of the difference of tectonic history among seven complexes.

VII. Complexes in the western part of the Mino Terrane

This eastern part is separated from the western part by extensive distribution of Cretaceous Nohi Rhyolites in meridional trend. The Paleozoic-Mesozoic complexes in the western part of the Mino Terrane have been studied by many geologists and an outline of distribution of lithofacies has been clarified to some extent (ISOMI, 1955, 1956; KANUMA, 1958; MIZUTANI, 1964; MIYAMURA, 1967, 1973; MIYAMURA *et al.*, 1981; ADACHI, 1976, 1979; WAKITA, 1985).

FUJIMOTO *et al.* (1962) subdivided the pre-Cretaceous complex in the Mino Terrane into three* lithofacies, which are the Nyukawa facies, Neo facies and Akasaka facies. ADACHI (1976, 1979) classified pre-Cretaceous rocks in this terrane into three lithofacies which he called the greenstone-limestone facies, turbidite-chert facies and shale-chert facies. Various studies of the Mino Terrane have been recently summarized by WAKITA

* FUJIMOTO *et al.* (1962) defined five lithofacies in total. But two of the five lithofacies have since been recognized as members of the Hida-gaien tectonic belt.

(1985), who classified the pre-Cretaceous complex into three lithofacies, namely the greenstone-limestone facies, sandstone-dominant facies and mudstone-dominant (olistostromal) facies.

The author has reexamined the lithology and ages in the south half of the western part of the Mino Terrane. In this chapter, the author proposes a new lithological subdivision of the western part of the Mino Terrane on the basis of new data as well as published data and correlates the complexes of this area with those of the eastern part of the Mino Terrane.

Paleozoic-Mesozoic complexes in the south half of the western part of the Mino Terrane are tentatively subdivided into five major lithologic types, which are described below as Complex 1, 2, 3, 4 and 5* (Fig. 12). Additional complexes have been discriminated in the north half (e.g. KAJITA, 1963; HATTORI, 1982), which are not dealt with here.

A. Description of the complexes

1. Complex 1

Complex in the Mt. Ryozen-san, Mt. Ibuki-yama, Mt. Funafuse and the Gujo-Hachiman areas are composed of greenstone, limestone, chert, shale and others. The lithofacies in these areas is characterized especially by large quantity of greenstone and limestone.

The lithology of this facies has been investigated in some areas; Mt. Ryozen-san area: MIYAMURA (1973), MIYAMURA *et al.* (1976), OKIMURA *et al.* (1986); Mt. Ibuki-yama area: ISOMI (1956), MIYAMURA (1967), YAMAMOTO (1985); NEO area: KAWAI (1964), YAMAMOTO (1985), SANO (1985); Gujo-Hachiman area: KANUMA (1964), WAKITA and OKAMURA (1982), WAKITA (1983, 1984). They show that limestones in this facies are Permian in age which is the oldest member of the Mino Terrane except for some local reports of Carboniferous limestone (ISOMI, 1955; KANUMA, 1958; WAKITA *et al.*, 1981).

A larger part of chert are Triassic and remainder is Permian in age (YAMAMOTO, 1985). WAKITA (1983, 1984) and YAMAMOTO (1985) clarified that greenstone, limestone and chert are allochthonous blocks of the melange. The mudstone matrix yields middle and late Middle Jurassic radiolarians (WAKITA, 1983, 1984; YAMAMOTO, 1985; KURIMOTO, 1986).

Especially KAWAI (1964), ISOMI (1956), MIYAMURA (1967), MIYAMURA *et al.* (1981) and YAMAMOTO (1985) have shown that limestone and associated rocks are thrust over the melange complex which is designated below as Complex 2.

2. Complex 2

Complex 2 is widely exposed in the area south of complex 1 and is bounded from Complex 1 by a northward dipping thrust.

The lithology of Complex 2 has been investigated by ISOMI (1955, 1956), KANUMA (1958), KANO (1975, 1979), MIZUTANI (1981), WAKITA (1983, 1984, 1986), YAMAMOTO

* Some of complexes are possibly subdivided with advance of investigation in future.

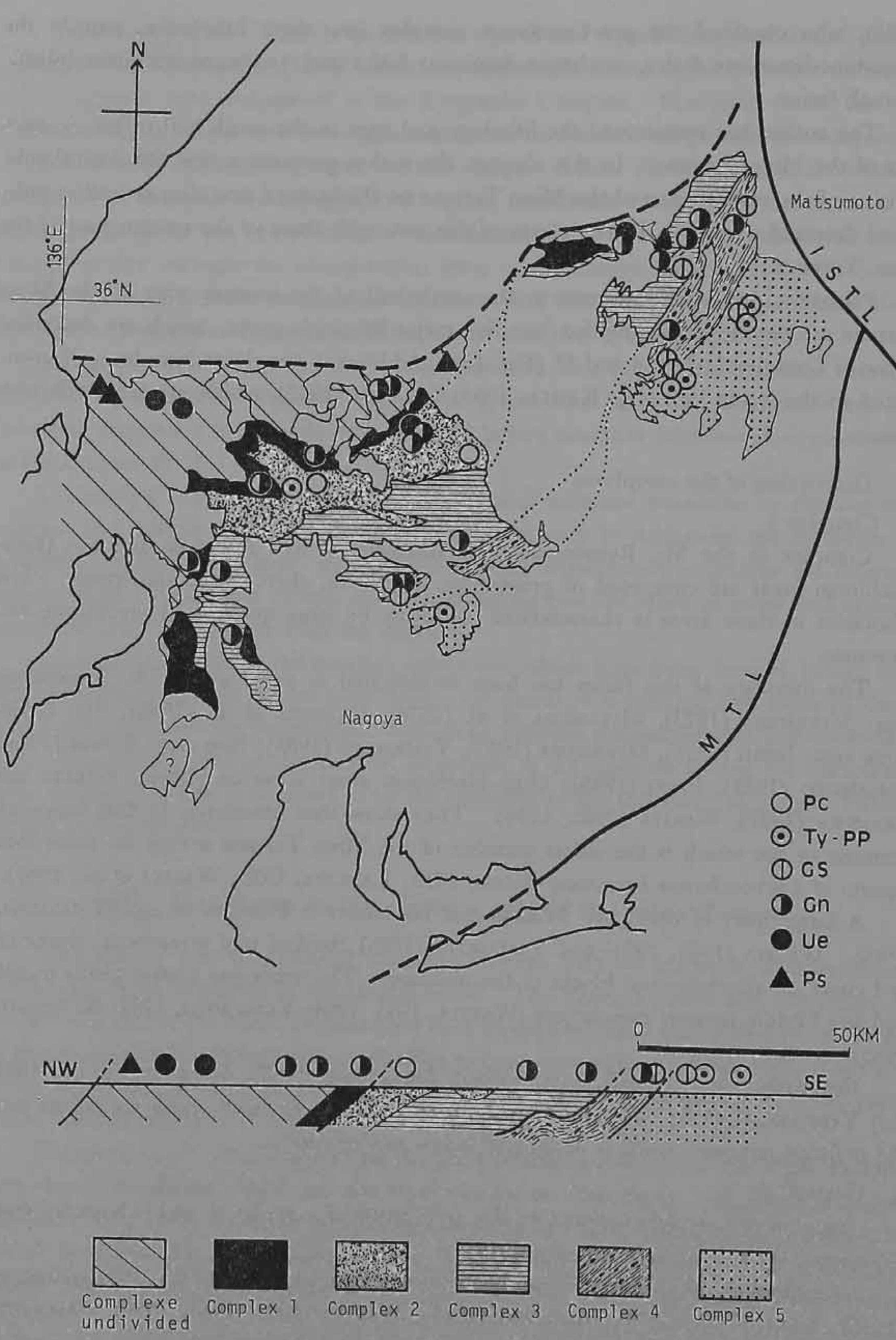
N
136°E
36°N
Matsumoto
I S T L
M T L
Nagoya
Pc
Ty - PP
GS
Gn
Ue
Ps
0
50KM
NW
SE
Complexe undivided
Complex 1
Complex 2
Complex 3
Complex 4
Complex 5

Fig. 12

(1985) and others. Especially, this complex, exposed along the Maze-gawa River, has been lithologically, paleontologically and chronologically investigated well. Complex 2 is a typical melange which is composed of blocks of chert, siliceous claystone and mudstone, sandstone, tuffaceous siltstone and others with pelitic rocks of the matrix.

A large part of blocks is chert, whose length attains a maximum of more than 1 km. Chert is thinly bedded and interbedded with thin tuffaceous claystone. Although chert is often tightly folded, the folds had been formed before blocks were brought into the matrix. Blocks of sandstone and siliceous mudstone are also included in the matrix. On the basis of irregular shapes of sandstone blocks, some of them were inferred to be unconsolidated at the time of their emplacement in pelitic rocks of the matrix.

Many conodonts and radiolarians have been reported from Complex 2 by many geologists. Chert blocks yield Triassic conodonts (KANO, 1979; YAMAMOTO, 1985; WAKITA, 1983, 1984) and Triassic and Early Jurassic radiolarians (WAKITA, 1983; YAMAMOTO, 1985). Pelitic rocks yield Middle and Late Jurassic radiolarians (MIZUTANI *et al.*, 1981; MIZUTANI, 1982; YAMAMOTO, 1983, 1985; WAKITA, 1983, 1986). WAKITA (1986) reported that siliceous mudstone yielding Late Jurassic radiolarians occurs as blocks in mudstone matrix. Recently, WAKITA (1987) pointed out that the radiolarian fauna from this area is of the earliest Cretaceous age. Therefore pelitic rocks of Complex 2 are considered to be deposited from Late Jurassic to earliest Cretaceous time.

Complex 2 is partly sheared considerably and some of the deformation structures such as minor folds and irregular flow of clasts and matrix, have been apparently formed under unconsolidated condition. This complex is considered to have undergone deformation just after deposition.

3. Complex 3

Complex 3 is widely exposed in the area south of Complex 2 and is situated under Complex 2.

Complex 3 is lithologically characterized by repetition of laterally-continuous chert and sandstone. This complex is well represented in the area north of Inuyama and has been lithologically investigated by many geologists (KANUMA, 1958a and b; MIZUTANI, 1964; ADACHI and MIZUTANI, 1971; KONDO and ADACHI, 1975; KANO, 1979; IGO, 1979).

Vertical lithological changes from chert to overlying clastic rocks has been described by KIDO (1982) and ISOZAKI and MATSUDA (1985a). These lithological changes observed in the north of Inuyama are shown in Fig. 13. The lithological changes and thickness

Fig. 12 Complexes in the Mino Terrane and schematic profiles. Occurrences of Jurassic radiolarian assemblages (after summarizing published studies).
Ps: *Parahsuum simplum* or older Assemblage (Early Jurassic)
Ue: *Unuma echinatus* Assemblage (early Middle Jurassic)
Gn: *Guexella nudata* Assemblage (late Middle Jurassic)
G-S: *Gongylothorax sakawaensis-Stichocapsa naradaniensis* Assemblage (early Late Jurassic)
Ty-PP: *Tricolocapsa yaoi* Assemblage and *Pseudodictyomitra primitiva-P.* sp. C Assemblage (late Late Jurassic)
Pc: *Pseudodictyomitra carpatica* Assemblage (latest Jurassic-early Early Cretaceous)

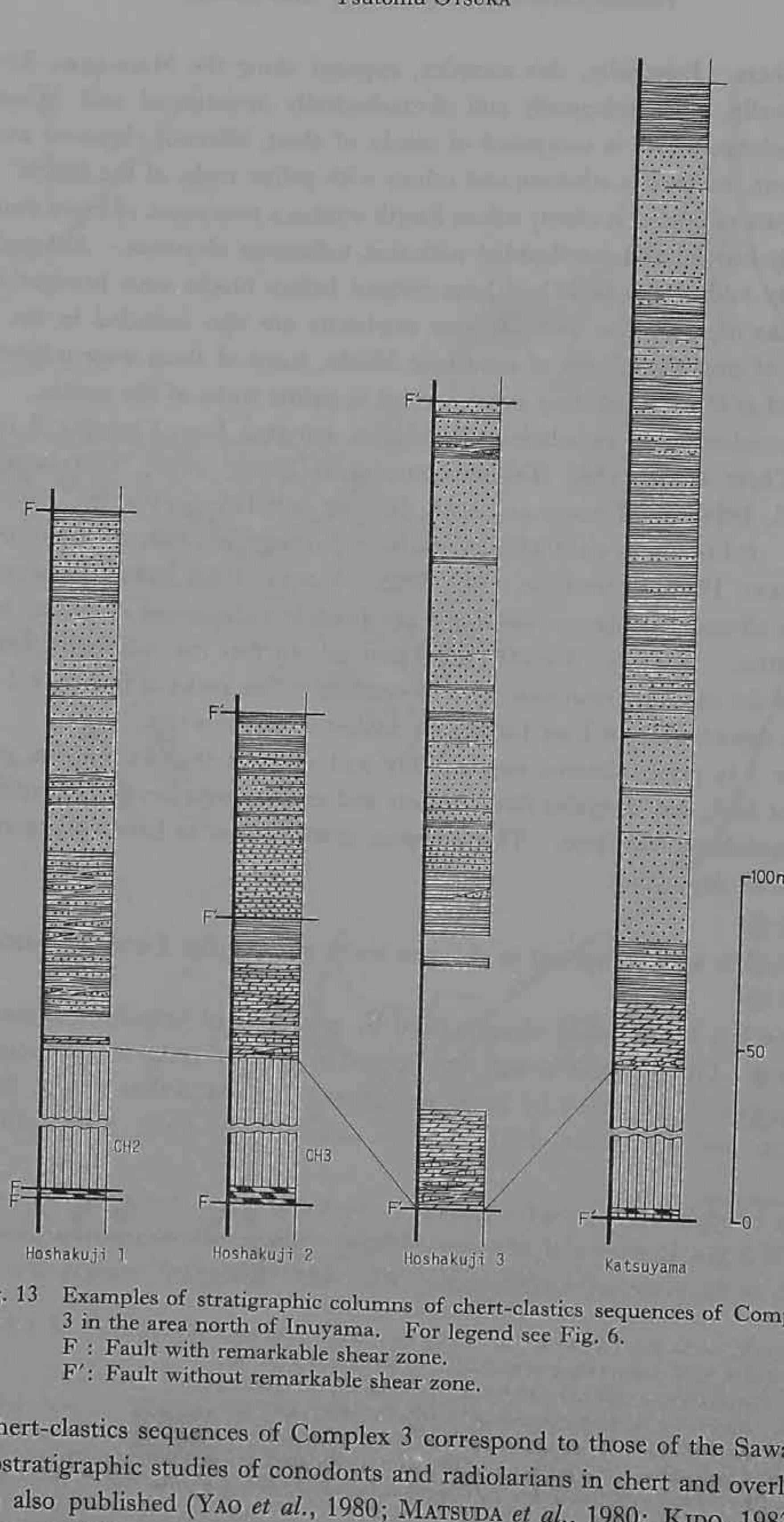

Fig. 13 Examples of stratigraphic columns of chert-clastics sequences of Complex 3 in the area north of Inuyama. For legend see Fig. 6.
F : Fault with remarkable shear zone.
F′: Fault without remarkable shear zone.

of these chert-clastics sequences of Complex 3 correspond to those of the Sawando complex. Biostratigraphic studies of conodonts and radiolarians in chert and overlying rocks have been also published (YAO *et al.*, 1980; MATSUDA *et al.*, 1980; KIDO, 1982; ISOZAKI and MATSUDA, 1985a and b; MATSUOKA, 1986; HORI, 1986). YAO *et al.* (1980) were the first to clarify that Middle Triassic to Early Jurassic chert and conformably overlying Middle Jurassic clastic rocks were exposed repeatedly by strike-slip faults in the north of Inuyama. In many places, Complex 3 is characterized by piles of tectonic slices whose thickness is some hundreds meters or so (IGO, 1979).

Studies of conodonts and radiolarians have revealed that the sequence of each tectonic slice deposited at least through Middle Triassic to late Middle Jurassic times. But depositional age of the sequences may ranges to younger because sandstone-dominant beds occupying the uppermost and largest part of the sequences have not yielded fossils which is useful for age-determination.

4. Complex 4

Complex 4 is exposed on the south of Complex 3, with which it is in fault contact. The relationship between the two complexes is observed at the south of Minokamo. A small fault exists between Early Triassic siliceous claystone of Complex 3 and Late Jurassic melange of Complex 4 (Fig. 14).

Although a part of Complex 4 has been lithologically investigated by ADACHI and MIZUTANI (1971), recent study has not been published except for SAKAMOTO *et al.* (1984) and details of the complex remain unknown.

Complex 4 is a typical melange, which is composed of blocks of chert, sandstone, siliceous claystone and siltstone blocks and matrix of siliceous mudstone and siltstone.

Chert blocks sometimes exceed 1 km in length and are traceable in geologic maps.

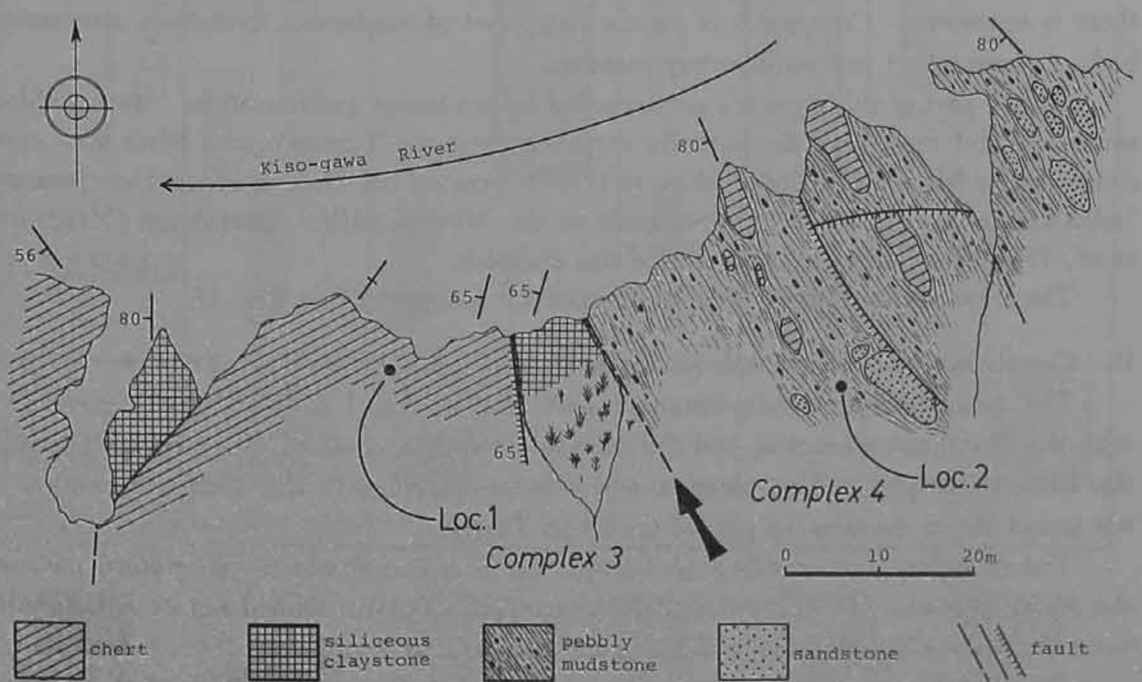

Fig. 14 Boundary part between Complex 3 and 4, south of Minokamo. Location of this point is shown in Fig. 12. An arrow indicates the boundary fault.
Loc. 1: Fossil locality of late Early Triassic conodonts, *Neospathodus homeri* and others.
Loc. 2: Fossil locality of early Late Jurassic radiolarians, *Stylocapsa spiralis* and others.

Chert is thinly bedded and interbedded with siliceous claystone. Blocks of siliceous claystone are composed of interbedded grayish layers and black layers and resembles that of Complex 3.

Most of sandstone occurs as apparent blocks which show sharp outlines. But in some cases, block-like sandstone and block-like interbedded sandstone-mudstone do not show sharp outlines and they grade into surrounding pelitic matrix. This phenomenon indicates that at least some sandstone and interbedded sandstone and mudstone were unconsolidated when the beds were broken into blocks.

Although siliceous mudstone and siltstone of the matrix are black in color in naked eye, they look nearly transparent in thin section. Pelitic rocks of the matrix is intensely and perversively sheared and minor folds, scaly cleavage and other deformation structures are commonly observed. These features are correlated with those of the Shimashima Complex.

Ages of rock,s expecially of the matrix, of Complex 4 have been hardly clarified. Early Late Jurassic radiolarian assemblage (G-S Assemblage) including *Stylocapsa spiralis* and others has been obtained from siliceous mudstone matrix at a point near the boundary fault between Complex 3 and 4 (Loc. 2, Fig. 14). Chert blocks yields fragments of conodonts and most of them are Triassic. Blocks have been also deformed; especially chert and siliceous claystone blocks have been flattened and show lenticular shapes.

5. Complex 5

Complex 5 is exposed in the area south to Complex 4, but the relationship between them is unknown. Complex 5 is mainly composed of sandstone, mudstone, alternating beds of them, chert and sedimentary melange.

A large part of this complex are occupied by sandstone and mudstone. Interbedded sandstone and mudstone are typically exposed along the Tamano-gawa River and were described by MIZUTANI (1964). ADACHI (1982) reported the occurrences of Late Jurassic radiolarian assemblage which corresponds to the *Mirifsus baileyi* Assemblage (MIZUTANI *et al.*, 1981) from siliceous mudstone of this complex.

The lithology and age of five complexes are summarized in Fig. 15.

B. Correlation with the complexes in the eastern part of the Mino Terrane

The greenstone-limestone-dominant part of Complex 1 is lithologically correlated with the Shirahone Complex, and the melange including small blocks is correlated with the Hirayu Complex. The complex which is correlative with the Yukawa Complex is not found out in the western part of the Mino Terrane.

The complex corresponding to Complex 2 is not observed in the eastern part of the Mino Terrane. It is inferred that the complex has been eroded out or structurally covered with the Shirahone, the Yukawa and the Hirayu Complexes.

Complex 3 apparently corresponds to the Sawando Complex. Both of these complexes are characterized by piles of the chert-clastics sequences (Fig. 7).

Complex 4 is lithologically and structurally comparable with the Shimashima Complex. Both complexes are structurally situated under the piles of chert-clastics sequences

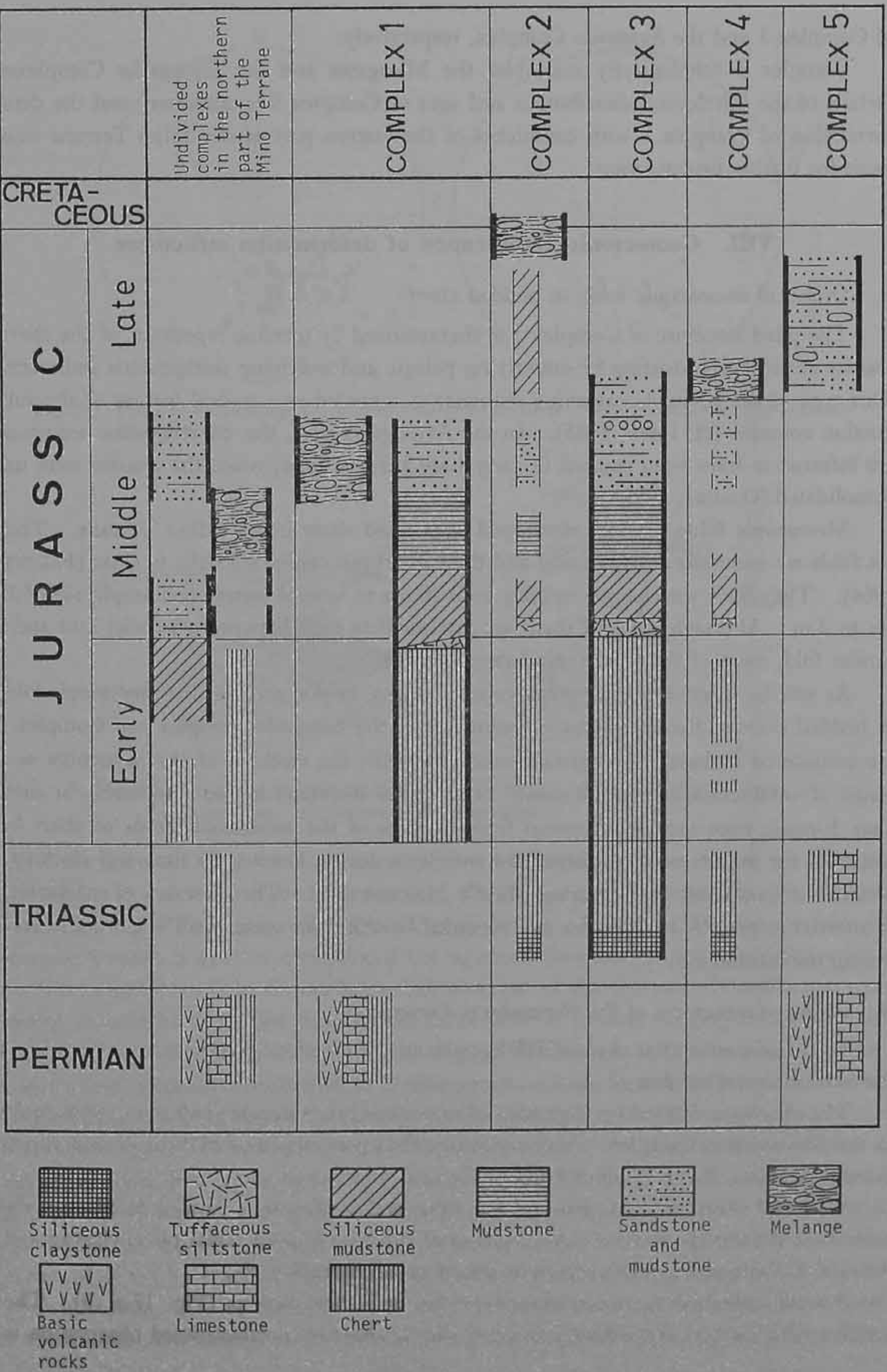

Fig. 15 Lithology and age of the complexes in the Mino Terrane. Narrower columns show the lithology of allochthonous blocks.

of Complex 3 and the Sawando Complex, respectively.

Complex 5 lithologically resembles the Misogawa and the Kyogatake Complexes. Details of the lithological distribution and ages of Complex 5 is unknown, and the detail correlation of Complex 5 with complexes of the eastern part of the Mino Terrane must await for further investigation.

VIII. Geotectonic significance of deformation structures

A. Origin of mesoscopic folds in bedded chert

The piled structure of Complex 3 is characterized by tectonic repetition of the chert-clastics sequences consisting of underlying pelagic and overlying terrigeneous sediments. This type of the upward-coarsening sequence is regarded as a typical feature of the subduction complex (cf. LASH, 1985). In the Azusagawa area, the chert-clastics sequences are inferred to have been stacked in early Late Jurassic time, when the clastics were unconsolidated (OTSUKA, 1985).

Mesoscopic folds are well developed in bedded chert in the Mino Terrane. They are folds are generally asymmetrical and their interlimb angles are tight to close (FLEUTY, 1964). They have wavelength ranging from 20 cm to several meters and amplitude of 10 cm to 2 m. Although some of them are intermediate type between a parallel fold and a similar fold, most of them are typical chevron folds.

As will be discussed in the other paper (OTSUKA, in preparation), the mesoscopic folds in bedded chert of the chert-clastics sequences of the Sawando Complex and Complex 3 are considered to have been formed concerned with the stacking of the sequences as a result of subduction of oceanic crust. The Gross direction of the subduction in early Late Jurassic time can be estimated from analysis of the mesoscopic folds of chert by restoring the macroscopic synforms and antiforms during Cretaceous time and clockwise rotation of Southwest Japan during Middle Miocene time. The direction of subduction is inferred to be NW to W so far as a remarkable strike-slip component is not considered during the subduction.

B. Origin of structures of the Shimashima Complex

As mentioned in the chapter III-E, various deformation structures are observed in the Shimashima Complex.

The cleavages defined by alignment of fine micas are widespread all over pelitic rocks in the Shimashima Complex. Major cleavage (S1) generally dips NW or N and sometimes dips SE or S as a result of folding (Fig. 16).

Flattened clasts of chert, siliceous claystone and sandstone is parallel to S1, and the latter does not cut the former. Axial planes of the type-C folds, axial plane cleavages of the type-D folds and axes of rotation of clasts are all parallel to S1.

Rotation of clasts is observed in outcrops and thin sections (Fig. 17-a, b). The rotation which shows right lateral sense of simple shear on northeastward observation is

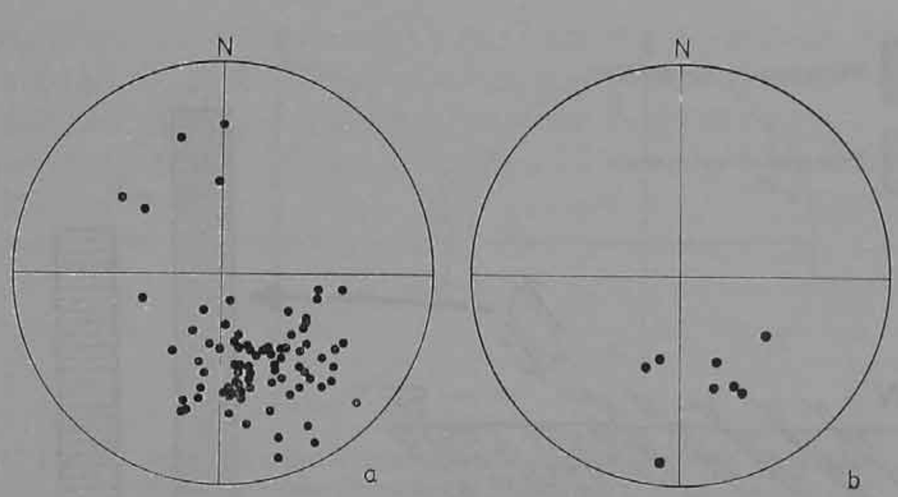

Fig. 16 Poles to S1 cleavage (a) and to axial planes (b) of minor folds in the Shimashima Complex.

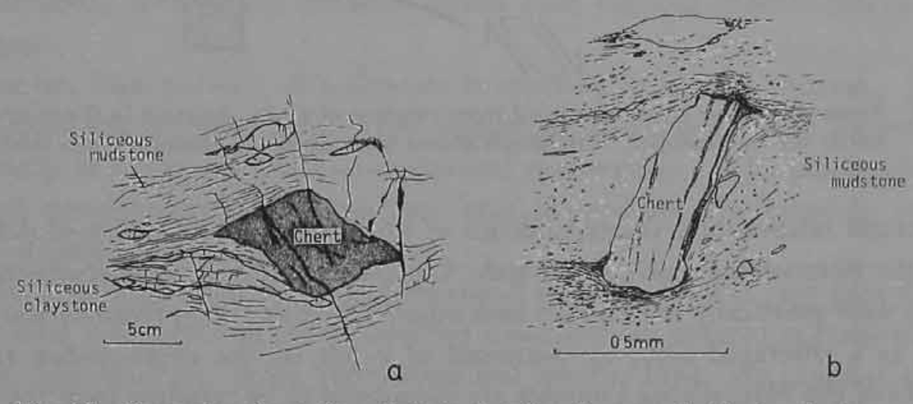

Fig. 17 Examples of rotation of clasts showing the remarkable simple shear.
a: outcrop, b: microscopic observation

called the S-type. The rotation which shows left-lateral sense is called the N-type. The S-type is much more predominant than the N-type both in outcrops and thin sections (Fig. 18). This sense of simple shear is the same as that of mesoscopic folds of Complex 3 which is western extension of the Sawando Complex (OTSUKA, in preparation).

The structures of the Shimashima Complex and of the Sawando Complex are considered to have been formed through the same tectonic process judging from the sense of the simple shear. As mentioned in the chapter III-E, some of deformation, e.g. type-A and type-C folds and fragmentation of siltstone, have been formed before consolidation. All rock species of the blocks in the Shimashima Complex correspond to rocks of the Sawando Complex. Moreover age of each rock species of the Shimashima Complex is correlative with that of the Sawando Complex. The matrix age of the melange of the Shimashima Complex is early Late Jurassic. The youngest age of the chert-clastics sequence of the Sawando Complex is also early Late Jurassic. The pile of chert-clastics sequences of the Sawando Complex is structurally situated on the melange of the Shimashima Complex. The trends of fold axes and vergence of mesoscopic folds in the melange of the Shimashima Complex correspond with those of the Sawando Complex (Fig. 16).

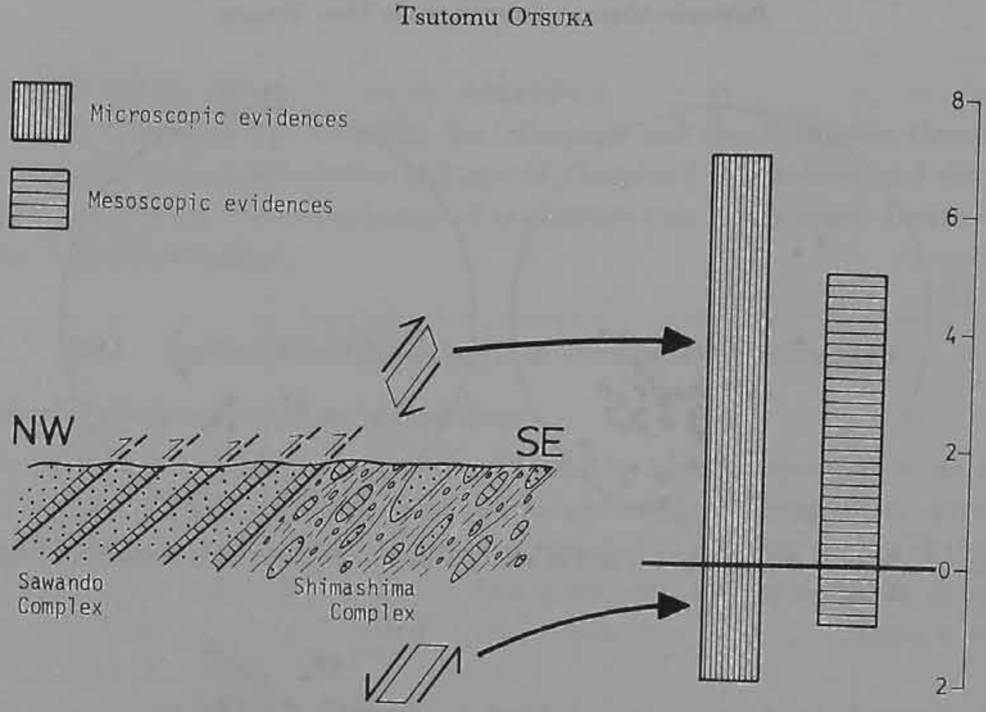

Fig. 18 Senses of simple shear estimated from rotation of clasts observed in the outcrop and under the microscope. The graph shows the number of observation localities.

Structural relationship, correspondence of lithology and orientation of deformation between the Shimashima and the Sawando Complexes, indicate that structures of both complexes were genetically related with each other. OTSUKA (1985) regarded the Sawando Complex as a offscraped complex composed of a pile of the chert-clastics sequences. The blocks of the Shimashima Complex are considered to be supplied from the Sawando Complex. The author infers that the Shimashima Complex was formed as the precursory olistostrome (ELTER and TREVISAN, 1973) which was derived from the collapse of the chert-clastics sequences of the Sawando Complex. The Shimashima Complex might be deformed in the stress field with intense simple shear under the southeastward advance of the Sawando Complex. At least a part of the materials of the Shimashima Complex was unconsolidated in the stage of the deformation.

C. Soft-sediment deformation of the Misogawa and the Kyogatake Complexes

As described in the chapter VI, various deformation structures are widespread in the Misogawa and the Kyogatake Complexes (OTSUKA *et al.*, 1986). Some of them; mesoscopic folds, boudin, brecciation sandstone, microfaults and clastic dykes are inferred to have been formed before consolidation.

These structures are distributed almost all over the Misogawa and the Kyogatake Complexes. They are not restricted within specific horizons or areas. Such a case as that deformed layers are intercalated between undeformed layers has not been observed. Therefore the deformation does not result from the local slumping but probably from the process under the regional stress (OTSUKA *et al.*, 1986). Orientation of axes and axial planes of mesoscopic folds (Fig. 19-a, b) show well concentration. Especially, axes are

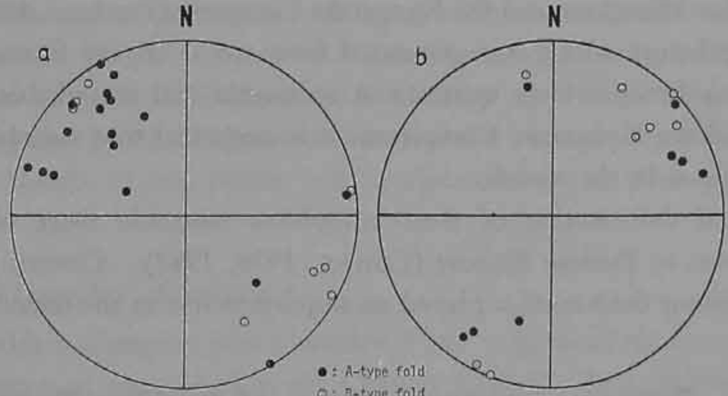

Fig. 19 Axes and poles to axial planes of minor folds in the Kyogatake Complex. (after OTSUKA *et al* , 1986)

parallel to the general trend of the complexes in the Mino Terrane. This indicates that this soft-sediment deformation probably results from regional tectonic process is latest Jurassic time.

Of course, high porosity of sediments is expected in the deformation. Especially the widespread soft-sediment deformation presumably proceeds in rapid accumulation of large quantity of sediments and non-dewatering environment. The places where large quantity of non-dewatered sediments have been trapped are distributed in convergent boundary of plates.

Existence of large quantity of non-dewatered environment and high pore-fluid pressure with mud volcanoes and other disturbed structures are inferred at some subduction zones (e.g. MOORE *et al.*, 1976; WESTBROOK and SMITH, 1982; WILLIAMS *et al.*, 1984). Especially, beneath the Barbados Ridge, abnormal pore-fluid pressure was actually measured (MOORE *et al.*, 1982).

Concerning the deformation of the Misogawa and Kyogatake Complexes, following situation should be noted.

1) The Misogawa and the Kyogatake Complexes are situated on the south of the Sawando and the Shimashima Complexes which are inferred to be formed through subduction and accretion. Moreover the older Shimashima Complex is thrust over the younger Misogawa and Kyogatake Complexes.

2) Trends of folds and strata of the Misogawa and the Kyogatake Complexes are parallel to those of other complexes.

3) Structures in deformation fronts have been described at many areas. Especially MOORE *et al.* (1982), McCARTHY and SCHOLL (1985) and others analyzed seismic data and showed detail profiles of the decollements of the offscraping complex. Comparing with the results of their study, the scale of the complex of the Mino Terrane is comparable with that of the accretionary complex which is defined by decollements.

It has been recently discussed that tectonic deformation structures formed under the high pore-fluid pressure environment cannot been easily distinguished from those of slumping (MALTMAN, 1984; NAKAMURA, 1985). From matters mentioned above, it is suggested that the Misogawa and the Kyogatake Complexes has been deformed under the high pore-fluid pressure which was generated from the overlying Shimashima Complex and others. Considering a large quantity of sediments and remarkable simple shear of the Misogawa and the Kyogatake Complexes, it is suggested that sediments were rapidly supplied and trapped in the trench.

Lithology and deformation of these complexes resemble those of clastics of the Franciscan complex at Piedras Blancas (Cowan, 1978, 1982). Cowan (1982) explained that the soft-sediment deformation played an important roll in the tectonic process.

IX. Tectonosedimentary process of the Mino Terrane

Middle to Late Jurassic tectonosedimentary process is discussed on the basis of results of investigation in the eastern and the western part of the Mino Terrane.

A. Hirayu, Yukawa and Shirahone Complexes—Complex 1

The Hirayu, Yukawa and Shirahone Complexes and Complex 1 are in fault contact with other complexes of the Mino Terrane and structurally situated upon them. The youngest age of the former complexes is Middle Jurassic and that of the latter complexes are Late Jurassic. Therefore the former four complexes are dealt together in this chapter.

These complexes are composed of a large amount of melanges and a small amount of piles of the chert-clastics sequences. Considering the volume and lateral continuity of the greenstone-limestone dominant complex, origin of these complexes is inferred to be related to the accretion of the Permian seamount chain (Mizutani, 1982). It is inferred that Permian, Triassic and Early Jurassic cherts migrated toward the trench where they were overlain by Jurassic siliceous mudstone and turbidite. The large amount of melange is inferred to have been formed during the accretion process. However the process remains to be further studied in detail.

Complex 1 is distinguished from the other complexes on the basis of age and lithology. It is noteworthy that Late Jurassic radiolarians have not been obtained also from the wide-spread complex north of Complex 1 (Nanjo Mountains, Hattori and Yoshimura, 1982; Hattori, 1987 and others). The tectonic process of Complex 1 and a complex north of Complex 1 is considered to represent the stage earlier than the other complexes south of them.

B. Sawando Complex—Complex 3

The Sawando Complex and Complex 3 are composed of piles of the chert-clastics sequences (Chapter IV). The lithological change which shows upward coarsening in each sequence reflects the landward drift of the sea floor from the pelagic environment (Otsuka, 1985). Geomagnetic data of Triassic chert implies that it was deposited in low latitudinal regions (Hattori, 1982 and Shibuya, 1984). A large amount of detrital sediments were deposited overlying pelagic chert as trench-fill deposits. Subduction and stepwise accretion of the chert-clastics sequences took place in late Middle to early Late

Jurassic times following the deposition. In some cases, detrital sediments forming upper part of the sequences were considered to be unconsolidated during offscraping (OTSUKA, 1985). The main compressional direction of that time was NW to W (prior to the opening of the Sea of Japan in middle Miocene time) on the basis of the analysis of mesoscopic folds in chert. Details of this points will be discussed in an other paper (OTSUKA, in preparation).

C. Shimashima Complex—Complex 4

The Shimashima Complex and Complex 4 are considered to be composed of precursory olistostromes as mentioned in the Chapter VIII-B. It is noteworthy that greenstone is not included in these complexes and that all blocks in thees complexes lithologically resemble rocks of the Sawando Complex and Complex 3. These complexes include detrital materials originated from the collapse of the already accreted Sawando Complex. These complex have been deformed probably just after the deposition in early Late Jurassic time. This deformation is interpreted to have proceeded under the southeastward or eastward-advance of piles of the chert-clastics sequences associated with intense simple shear. Judging from the remarkable deformation of clasts of the melange, they are considered to have been brought into structurally deep level.

D. Misogawa and Kyogatake Complexes—Complex 5

The Misogawa and the Kyogatake Complexes and Complex 5 are characterized by a large amount of clastic rocks which underwent widespread soft-sediment deformation. As mentioned in the Chapter VIII-C, the sediments were deposited in the trench and were deformed under the advance of already accreted complexes in Late Jurassic time.

E. Complex 2

Complex 2 is characterized by a large amount of melange. This melange mainly includes blocks of chert, siliceous claystone, siliceous mudstone and sandstone.

Greenstone, Permian chert and limestone are common in Complex 1 which has been thrust over Complex 2. It is important that Complex 2 does not include blocks of these rocks (YAMAMOTO, 1985). This lithological difference between Complex 1 and Complex 2 apparently indicates that the latter cannot be explained as a precursory olistostrome derived from the Complex 1.

The youngest age of Complex 2 is Late Jurassic (MIZUTANI, 1981; YAMAMOTO, 1983, 1985; WAKITA, 1986). YAMAMOTO (1985) and WAKITA (1986) anticipated that Complex 2 ranges to Early Cretaceous in age. The youngest age of Complex 2 is younger than that of Complex 1. Although details of the relationship between Complex 2 and 3 are unknown, Complex 2 obliquely cuts the general trend of Complex 3 in macroscopic view, and the former complex is apparently situated on the latter (KANO, 1979). The boundary is irregularly curved. Complex 3 is underlain by Complex 2 only in the axial part of the Shimonoho synform. From these matters, the writer proposes that Complex 2 had unconformably rest on Complex 3 and that it was subsequently eroded out especially in

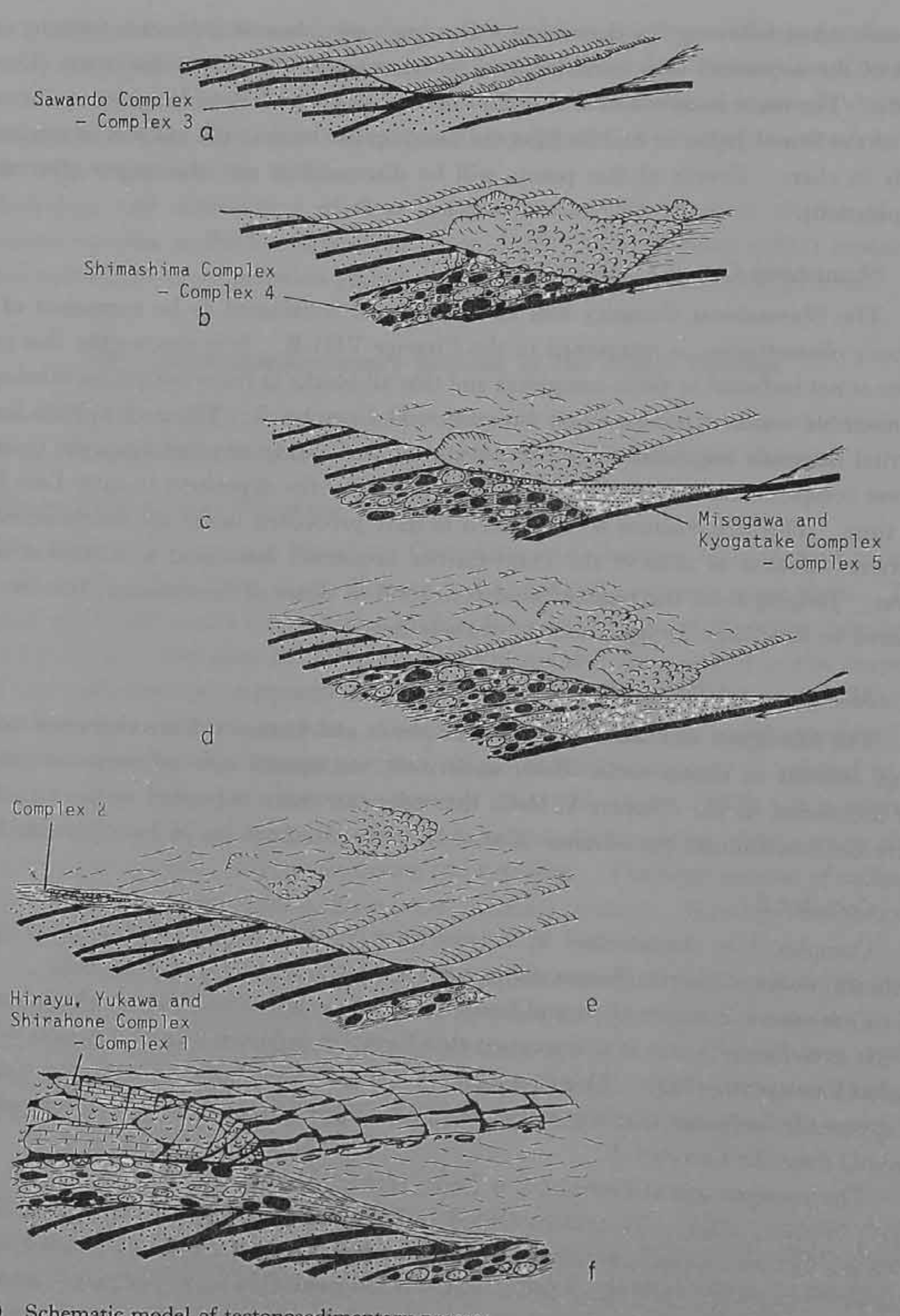

Fig. 20 Schematic model of tectonosedimentary process.
a : Stacking of chert-clastics sequences of the Sawando Complex-Complex 3.
b : Collapse of accretionary complex and forming sedimentary melanges of the Shimashima Complex-Complex 4.
c : Development of trench fills (Misogawa and Kyogatake Complexes-Complex 5).
d : Trenchward advancing of accretionary complex and soft-sediment deformation of the trench fills.
e : Deposition of sedimentary melanges (Complex 2) on Complex 3.
f : Thrusting of Complex 1 over the younger complexes.

the southern area.

Complex 2 mainly includes chert, siliceous claystone, siliceous mudstone and sandstone blocks. Sliceous mudstone blocks yielding Late Jurassic radiolarians are included in mudstone along Maze-gawa River (MIZUTANI, 1981; WAKITA, 1986). Except for this siliceous mudstone, lithology of blocks in Complex 2 resembles lithology of the chert-clastics sequence of Complex 3 and the Sawando Complex.

From structural relationship and resemblance of lithofacies between Complex 2 and Complex 3 and their ages, it is suggested that Complex 3 are unconformably overlain by Complex 3. Materials of Complex 2 are inferred to have been derived from the off-scraped complex (Complex 3—Sawando Complex) in some topographical high.

F. Total view

The Paleozoic-Mesozoic Complexes in the Mino Terrane are considered to be the products of a series of Jurassic—earliest Cretaceous tectonosedimentary process.

Pelagic chert and overlying trench deposits (Complex 3—Sawando Complex) have been accreted and stacked during late Middle to early Late Jurassic times (Fig. 20-a). In early Late Jurassic time, the precursory olistostrome (Complex 4—Shimashima Complex) was supplied from the southeastward advancing accretionary complex and deposited on the slope to the trench. This melange was intensely deformed structurally under the accretionary complex with remarkable simple shear (Fig. 20-b). In the succeeding stage, a large amount of detrital sediments were supplied into the trench (Misogawa and Kyogatake Complexes—Complex 5, Fig. 20-c). The unconsolidated sediments have been deformed probably under the high pore-fluid pressure which was generated by tectonically overlying accretionary complex (Fig. 30-d). On the other hand, siliceous mudstone including Late Jurassic radiolarians was deposited on the slope in this stage. Following these process, olistostromes (Complex 2) including Late Jurassic blocks were finally supplied from the topographical high of the stacked complex and discordantly liked on it in latest Jurassic time or latter (Fig. 20-e).

Complex 1 and the northern complex had already accreted in late Middle Jurassic time. They thrust over the other complexes after the deposition of Complex 2 (Fig. 20-f). This Early Cretacoeus thrusting was completed prior to the formation of macroscopic synforms and antiforms and is regarded as the secondary tectonic process following the accretion of Complex 3 to 5.

The shallow paleomagnetic inclination of the late Late Jurassic rock of Complex 2 was described by HATTORI (1982). If this result is considered, the complexes in the Mino Terrane are regarded to be the products of sedimentation in the low latitudinal area.

X. Summary

(1) The Paleozoic-Mesozoic sedimentary complex in the eastern part of the Mino Terrane is subdivided into seven complexes (Hirayu, Yukawa, Shirahone, Sawando, Shimashima, Misogawa and Kyogatake Complexes) from the north to the south on the basis

of lithology.

(2) The Hirayu Complex is a late Middle Jurassic melange including Permian greenstone, limestone and chert, Triassic and Early Jurassic chert and Jurassic sandstone blocks. The Yukawa Complex is a pile of chert-clastics sequence which is composed, in ascending order, of Early Jurassic chert and Middle Jurassic clastic rocks. The Shirahone Complex is a late Middle Jurassic melange, a large part of which are occupied by blocks of Permian greenstone, limestone and chert. The Sawando Complex is a pile of chert-clastics sequences which is composed, in ascending order, of Triassic to Early Jurassic chert and Middle to early Late Jurassic clastic rocks. The Shimashima Complex is a early Late Jurassic melange including blocks of Triassic and Jurassic rocks. This complexes is strongly sheared. The Misogawa and Kyogatake Complexes are characterized by a large amount of Late Jurassic turbidite and extensive soft-sediment deformation.

(3) These complexes trend NE-SW (eastern part) or E-W (western part) and generally dip northwest or north. The ages of matrices of the melanges and of the top of the sequences in the complexes show the southward (structurally lower) younging polarity.

(4) The complex in the western part of the Mino Terrane is subdivided into five complexes (Complex 1, 2, 3, 4 and 5, from the north to the south). Except for Complex 2, these complexes are correlated with those of the eastern part of the Mino Terrane.

(5) Complex 1 is a late Middle Jurassic melange which is characterized by a large amount of blocks of Permian greenstone, limestone and chert, and is correlated with the Hirayu, Yukawa and Shirahone Complexes. Complex 2 is the latest Jurassic or possibly early Cretaceous melange including Triassic and Early Jurassic chert and Jurassic clastic rocks. This complex is interpreted to lie unconformably on the Complex 3. Complex 3 is a pile of chert-clastics sequences and is a westward extension of the Sawando Complex. Complex 4 is a melange which is correlated with the Shimashima Complex based on the aspects of lithology, deformation and age. Complex 5 is composed mainly of turbidite which shows soft-sediment deformation structures. Complex 5 is interpreted to be the westward extension of the Misogawa and Kyogatake Complexes.

(6) The chert-clastics sequences observed in the Sawando Complex—Complex 3 and the Yukawa Complex show the upward-coarsening lithologic change. This change indicates the drift of depositional site from the pelagic to detrital environment concerning with the plate motion.

(7) On the basis of investigation of lithologic feature, structure and age, these complexes are considered to have been constructed through a series of accretionary processes as follows.

a) In the late Middle Jurassic time, greenstone-limestone composing a seamount chain, pelagic sediments and clastic trench fills were accreted, and melanges accompanied by large greenstone blocks (Hirayu and Shirahone Complexes and Complex 1) and a pile of chert-clastics sequences (Yukawa Complex) were formed.

b) In latest Middle to early Late Jurassic times, the pelagic chert and the overlying trench fill deposits were successively stacked by thrusting or gliding and formed piles of tectonic slices, each of which is composed of a chert-clastics sequence (Sawando Complex and Complex 3).

c) Subsequently, in Late Jurassic time, oceanward advance of the accretionary piles caused a collapse of the accretionary bodies and formed precursory olistostromes on the lower slope and the trench (Shimashima Complex and Complex 4). These complexes were intensely sheared just after deposition through the overthrusting process of other complexes.

d) In late Late Jurassic time, a large amount of detrital sediments were supplied into the trench. The trench fills successively underwent the soft-sediment deformation under the high pore-fluid pressure environment (Misogawa and Kyogatake Complexes and Complex 5).

e) On the accretionary complex (Complex 3), sedimentary melange was supplied from the topographic high. This melange includes blocks of late Late Jurassic siliceous mudstone, and represents the latest sedimentary process in the Mino Terrane. Subsequently Complex 1 was thrust over Complex 2 in Early Cretaceous time.

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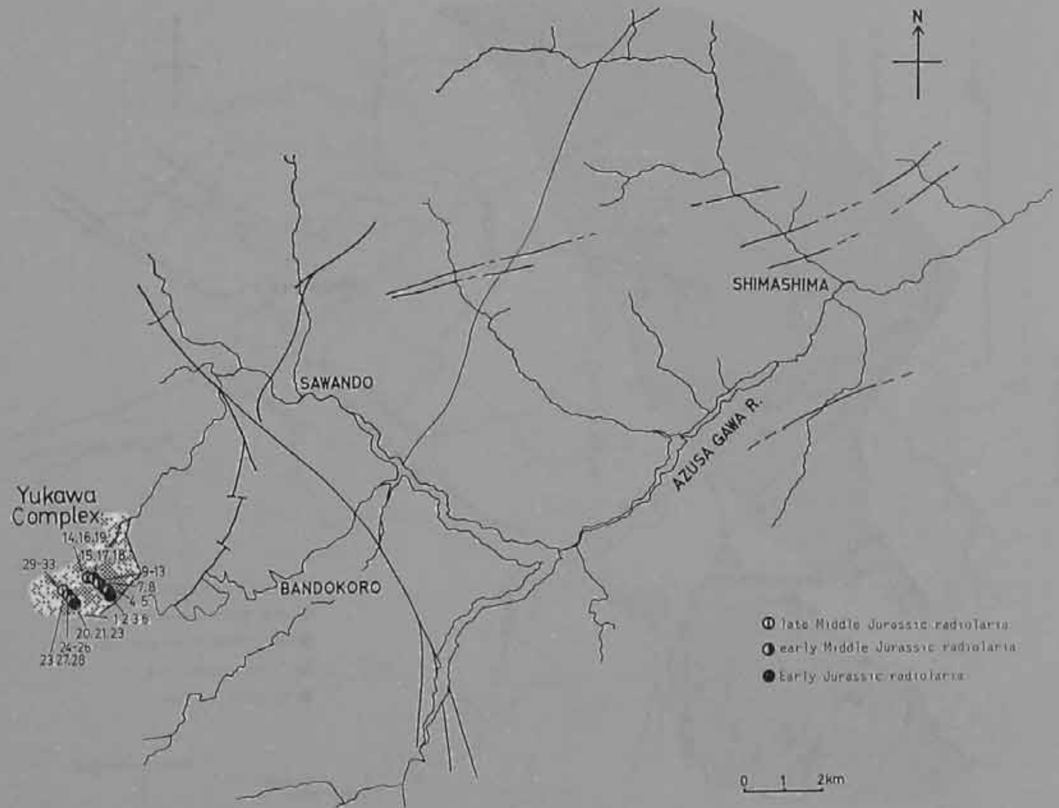
*: in Japanese with English abstract
**: in Japanese



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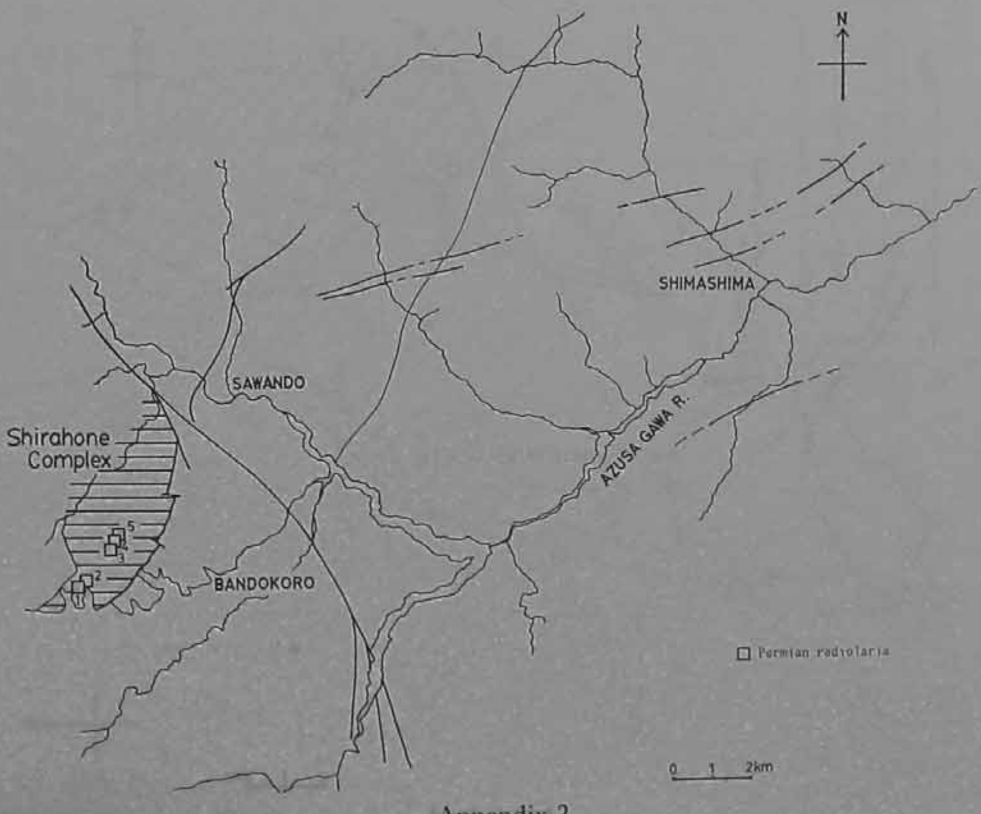

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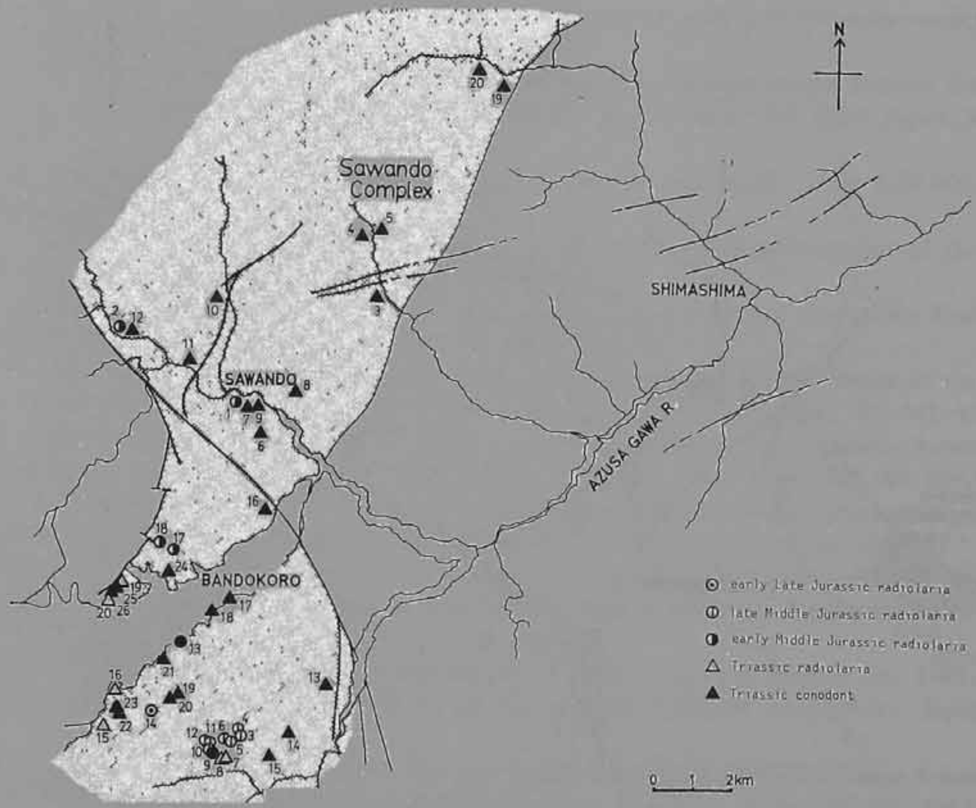

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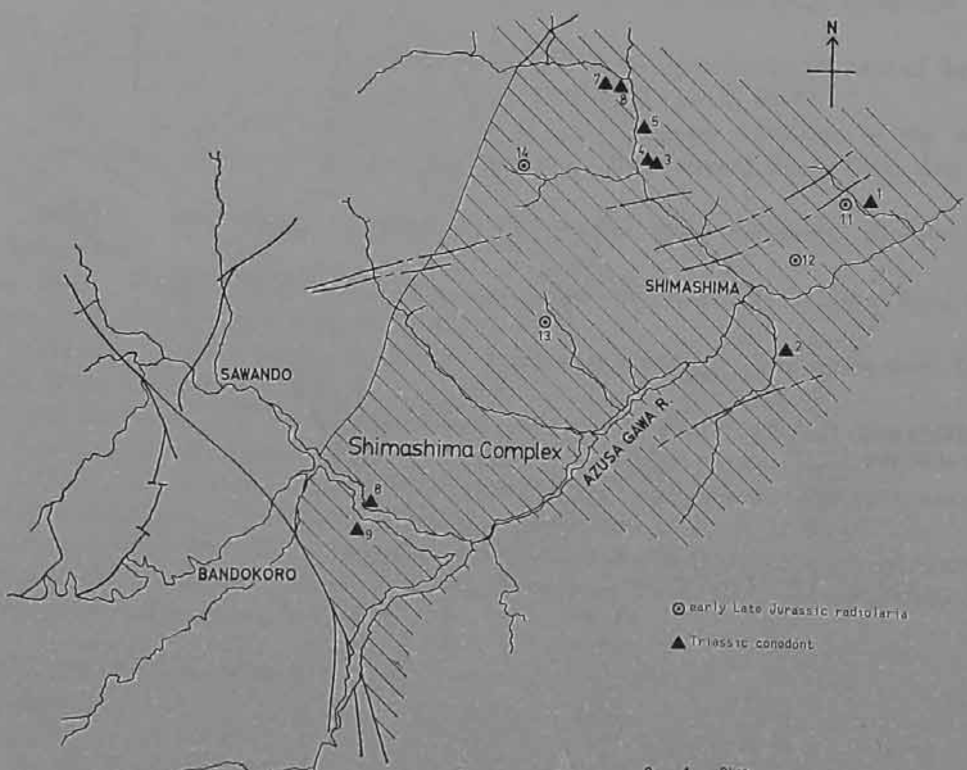

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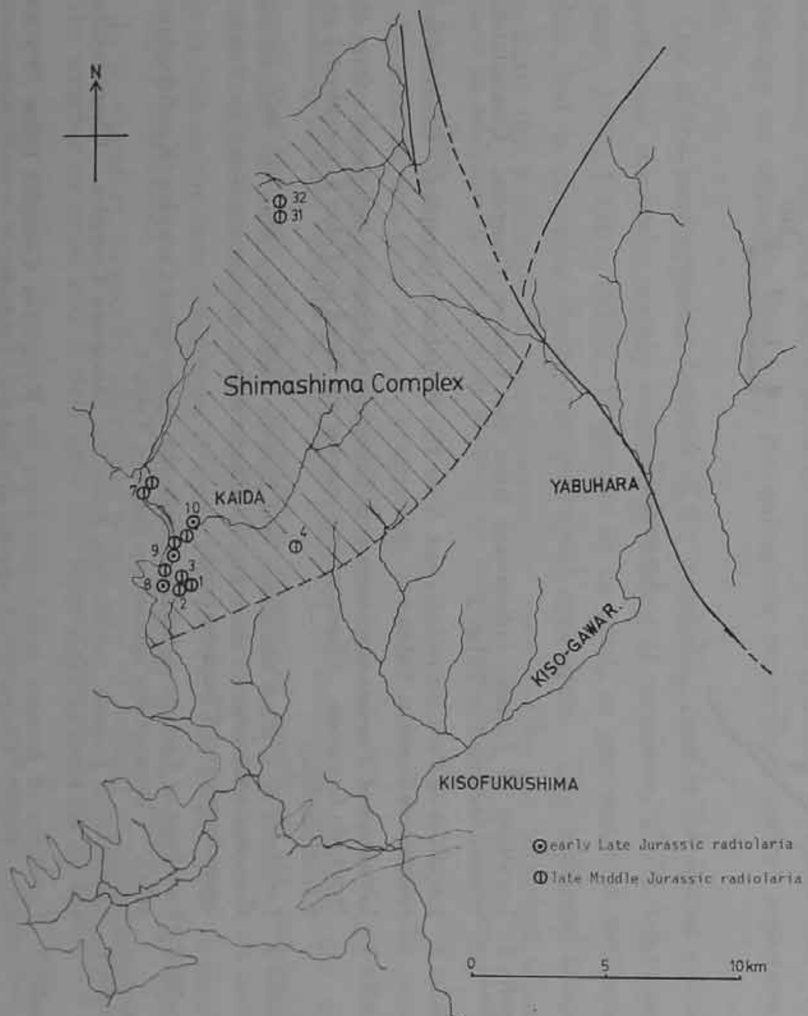

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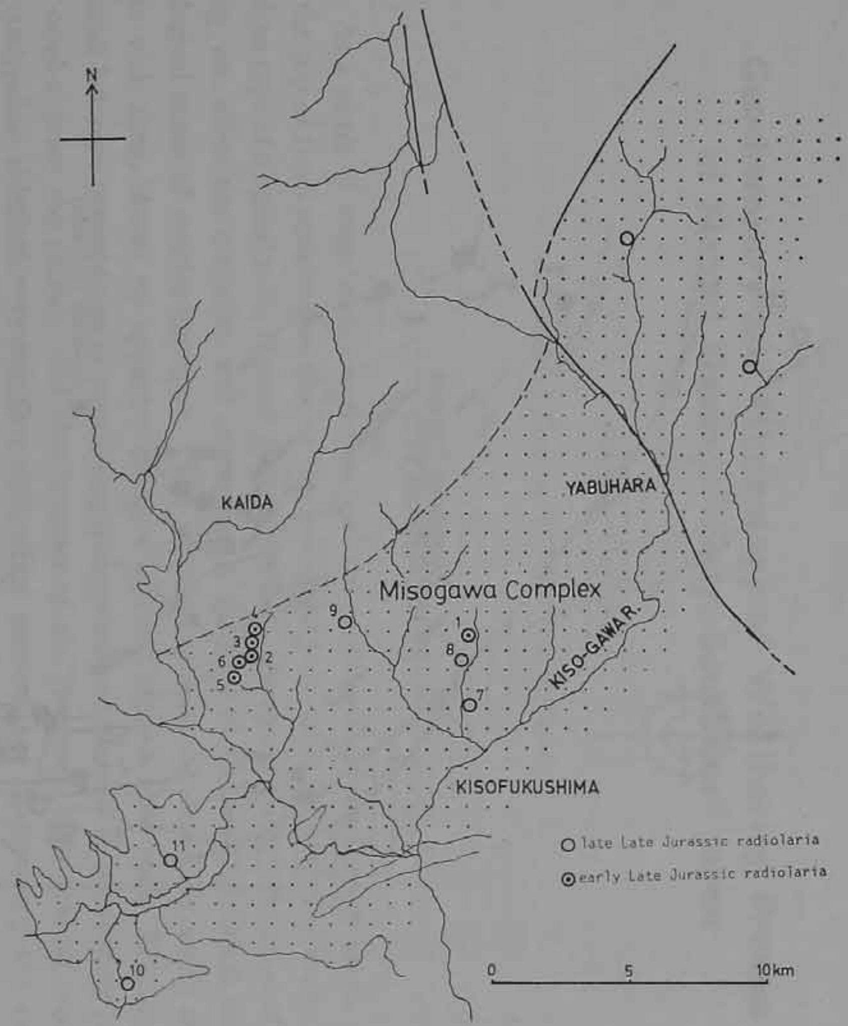

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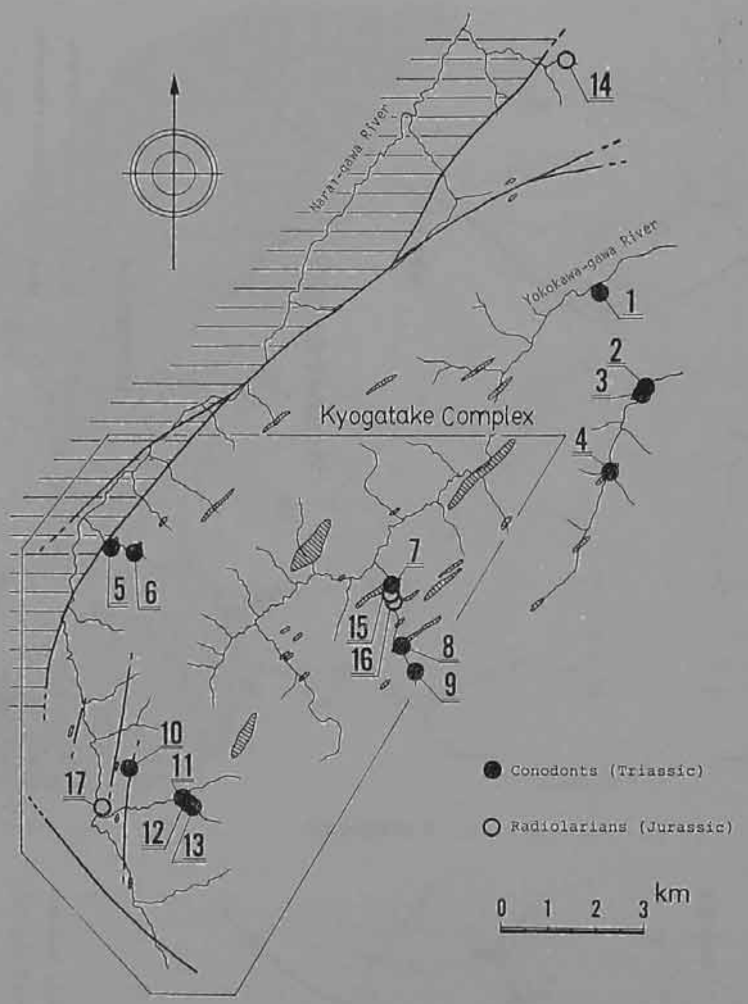

Appendix 7

Appendix 1 Localities of Jurassic radiolarians from the Yukawa Complex. Characteristic species are listed in Table 2.

Appendix 2 Localities of Permian radiolarians from the Shirahone Complex. Characteristic species are listed in Table 4.

Appendix 3 Localities of Triassic conodonts and Triassic and Jurassic radiolarians from the Sawando Complex. Characteristic species are listed in Table 5 (conodonts) and 6 (radiolarians).

Appendix 4 Localities of Triassic conodonts and Jurassic radiolarians from the Shimashima Complex (Azusa-gawa river area). Characteristic species are listed in Table 7 (conodonts) and 8 (radiolarians).

Appendix 5 Localities of Jurassic radiolarians from the Shimashima Complex (Kisofukushima area). Characteristic species are listed in Table 8.

Appendix 6 Localities of Jurassic radiolarians from the Misogawa Complex. Characteristic species are listed in Table 9.

Appendix 7 Localities of Jurassic radiolarians from the Kyogatake Complex (after OTSUKA *et al.*, 1986). Characteristic species are listed in Table 10.