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Redefinition of the Permian strata in the Hida-gaien Tectonic Zone, Fukuji area, Gifu Prefecture, Central Japan

Kazuhiro TSUKADA[1] and Yasushi TAKAHASHI[2]

[1] *The Nagoya University Museum, Nagoya 464-8601, Japan*
[2] *Yamanashi Institute of Gemmology and Jewellery Arts, Kofu 400-0808, Japan*
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ABSTRACT

This paper presents the results of the detailed re-examination of lithology, stratigraphy, and structure of the Permian strata in the Fukuji area of the Hida-gaien Tectonic Zone (HTZ), which is the eastern extension of the boundary between the North and the South China Blocks.

The strata which have been referred to the Permian are divided into the following three Formations in ascending order; 1) the Lower to Middle Permian Mizuyagadani Formation (redefined), 2) the Middle Permian Sorayama Formation (redefined), and 3) the age-unknown Kashiate Formation (newly named).

The Mizuyagadani Formation, composed mainly of felsic tuff, clastic rocks, and tuffaceous clastic rocks, is subdivided into the Lowermost, Lower, Middle, and Upper Members. Although this formation is in fault contact with the Carboniferous Ichinotani Formation, it is inferred that the former primarily overlies the later based on the field evidence.

The Sorayama Formation, composed mainly of mafic to intermediate tuff breccia and tuffaceous clastic rocks, is subdivided into Member A to D in ascending order. This formation conformably overlies the Mizuyagadani Formation.

The Kashiate Formation, composed mainly of mafic igneous rocks and breccia including clasts largely of basalt to gabbro, is thrust over the Sorayama Formation.

Although the three conglomerates exposed in the upper stream of the Ichinotani and Mizuyagadani Valleys and Osobudani Valley were dealt with as the basal conglomerate of the Sorayama Formation previously, these conglomerates are considered to be on the different lithostratigraphical units of the Mizuyagadani Formation and "undivided strata."

INTRODUCTION

The Fukuji area in the Hida-gaien Tectonic Zone (HTZ*) (Fig. 1) is one of the most important area on the Paleozoic stratigraphy in Japan, because the Upper Paleozoic successions are well-preserved, and rocks of the eastern extension of the boundary between the North and the South China Blocks are exposed.

The HTZ has been defined as the complex zone between the Hida Belt and the Mino Belt by Kamei (1955a); described major facies are Paleozoic-Mesozoic shelf facies

* "Hida-gaien (Kozo) Tai" is almost the same as the "outer margin of the Hida belt" in English. In this paper, however, "Hida-gaien Tectonic Zone (HTZ)" is used by the definition of Tsukada et al. (1999).

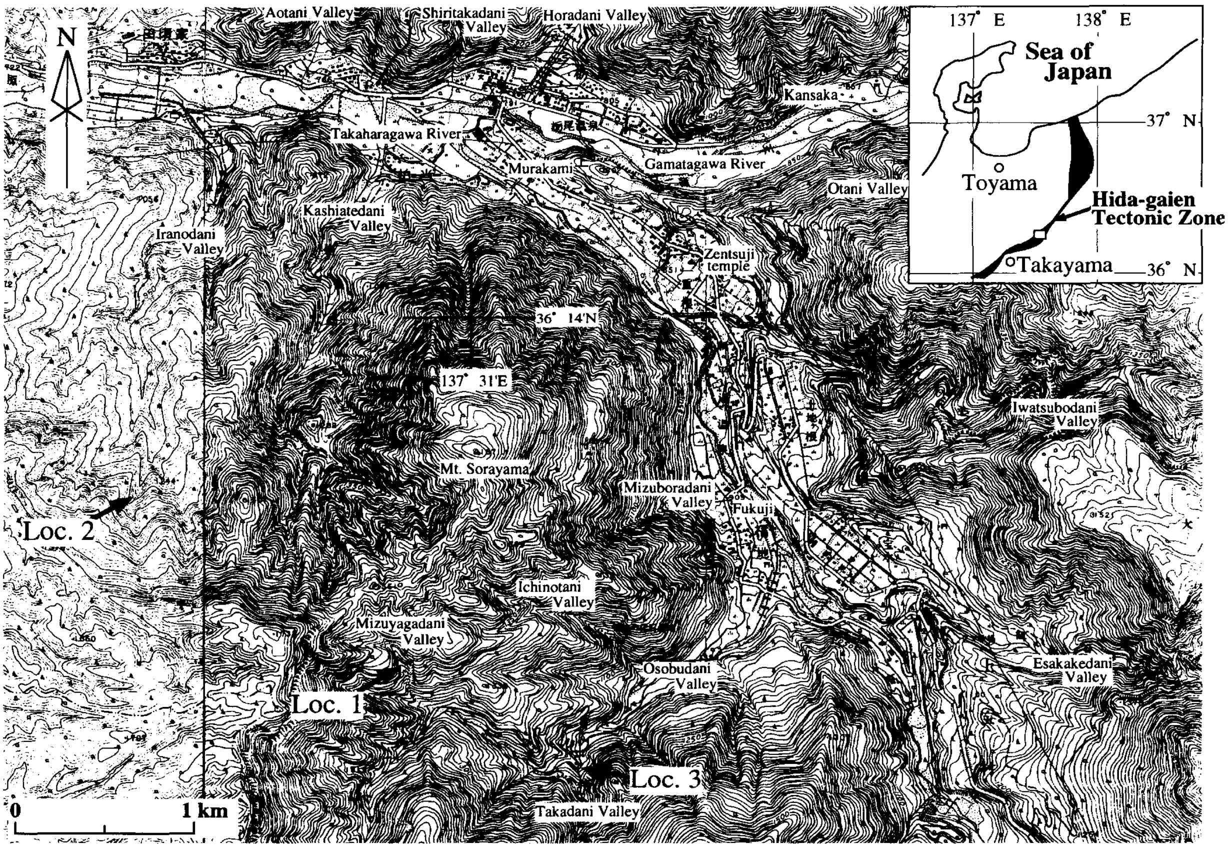


Fig. 1 Index map of the studied area. The topographical map is part of 1 : 25,000 scale map sheets "Yakedake" and "Hatahoko" published by the Geographical Survey Institute of Japan. Locs. 1, 2, and 3 show the locality of Figs. 4, 7, and 15, respectively.

rocks (e.g. Fukuji, northeastern Takayama, Naradani, and Kuzuryu areas), Paleozoic accretionary complex (Ohmi area), serpentinite melange (e.g. Shiroumadake area), and low to high pressure type metamorphic rocks (e.g. Unazuki, Naradani, and Kuzuryu areas). These constituents are mainly in fault contacts with one another and intensely tectonically sheared in several places. The tectonic history of the HTZ, however, has not been revealed precisely. In the recent work, the Paleozoic shelf facies rocks of HTZ were divided into the "Fukuji type" and the "Northeastern Takayama type" strata based on the lithostratigraphy (Otho and Tsukada, 1996; Tsukada, 1999). The fossils found from the "Fukuji type" and the "Northeastern Takayama type" strata are similar to that of the fauna reported from the South and the North China Blocks, respectively (e.g. Tazawa, 1989; Tsukada, 1999; Tsukada et al. 1999).

Although many geologists and paleontologists have studied the Paleozoic strata in this area (e.g. Adachi, 1985; Adachi and Igo, 1980; Fujimoto et al., 1962; Furutani, 1990; Hamada, 1959a, b; Harayama, 1990; Igo, 1956a, b, c, d, 1957a, b, 1959, 1960, 1978, 1990; Igo and Adachi, 1981a, b; Igo et al., 1975, 1980; Kamei, 1952, 1955b, 1961, 1962; Kamei and Igo, 1955; Kato, 1959; Kobayashi and Igo, 1956; Koizumi and Kakegawa, 1970; Kozu, 1911; Kuwano, 1986, 1987; Niikawa, 1980; Niko et al., 1978; Ohno, 1977; Okazaki, 1974; Research Group for the Paleozoic of Fukuji, 1973; Tsukada et al., 1999; Umeda and Ezaki, 1997), stratigraphy and structure of the Permian strata of the area remain unanswered as mentioned by Igo and Adachi (1981a), Umeda and Ezaki (1997), Tsukada et al. (1999), and others.

In order to understand the Pre-Cretaceous history and geological framework of East Asia, the stratigraphy and structure of the Permian strata of the Fukuji area have been re-examined. In the present study, the lithology, stratigraphy, and geological structure of the Mizuyagadani Formation and the Sorayama Formation are focused, and the results of re-examination of the Permian strata of the Fukuji area are discussed.

DESCRIPTION OF GEOLOGY

Geological framework

The strata which have been referred to the Permian are divided into the following three formations in ascending order; 1) the Lower to Middle Permian Mizuyagadani Formation, which is in fault contact with the Ichinotani Formation, is composed mainly of tuffaceous clastic rocks and clastic rocks, 2) the Middle Permian Sorayama Formation, which conformably overlies the Mizuyagadani Formation, is composed mostly of intermediate to mafic pyroclastic rock and tuffaceous clastic rocks, and 3) the age-unknown Kashiate Formation, which is thrust over the Sorayama Formation, is composed mainly of mafic volcano-plutonic rocks and breccia containing abundant volcano-plutonic rock clasts (Fig. 2).

The Paleozoic strata are folded with the axis that plunges steeply southeast, and are cut by three younger north-south subvertical oblique-slip faults (Fig. 2).

All the formations are intruded by many small dikes of felsic to intermediate rocks, and are overlain by Tertiary to Quaternary volcaniclastic rocks.

Mizuyagadani Formation

Definition : The Permian clastic rocks exposed on the south hillside of Mt. Sorayama are regard as the Mizuyagadani Formation in this study (Fig. 2).

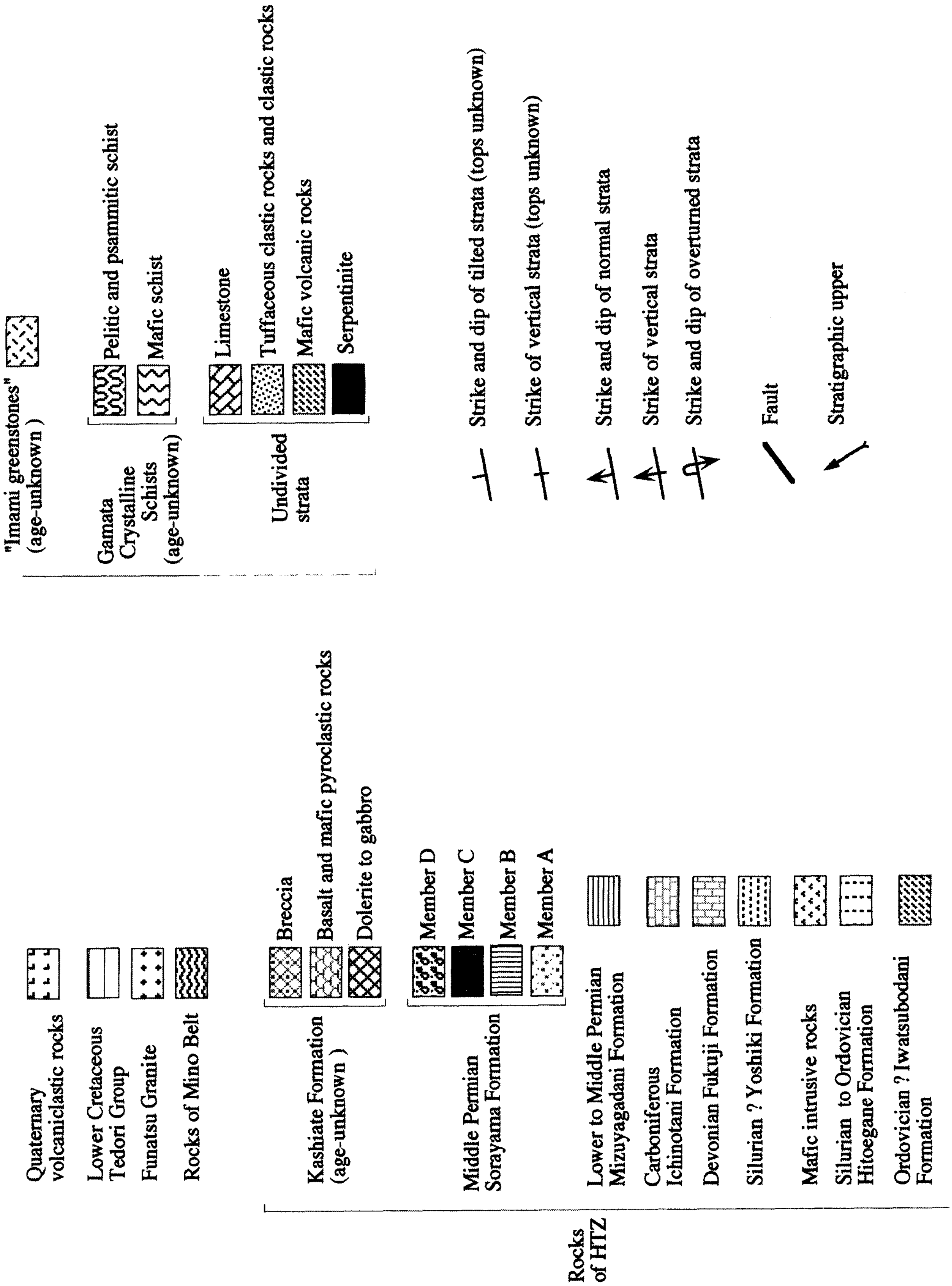
Type locality : Type section is exposed in the Mizuyagadani Valley (further upstream at an elevation of 1,330 m) (Figs. 1, 2). Reference sections are exposed in the area of upper stream of the Ichinotani Valley (elevation 1,310 to 1,400 m) and the Iranodani Valley (further upstream at an elevation of 1,280 m) (Figs. 1, 2).

Distribution : This formation is exposed in the Mizuyagadani Valley, and the upper area of the Ichinotani, the Iranodani, and the Kashiatedani Valleys (Fig. 2).

Thickness : About 300 m.

Stratigraphy and structure : This formation can be subdivided into the Lowermost, Lower, Middle, and Upper Members (Fig. 3). These members form conformable succession and consist mainly of calcareous clastic rocks and fossiliferous mudstone, alternating beds of felsic tuff and tuffaceous sandstone, sandstone and mudstone, and well-bedded felsic tuff and tuffaceous sandstone, respectively in ascending order (Fig. 3). Characteristic conglomerates are intercalated in the Middle and Upper Members. The latter is called the Ichinotani Conglomerate by Kamei (1952). Mafic tuff is intercalated in the middle part of the Upper Member in the Iranodani Valley.

This formation is east-trending and north-dipping homocline, and is in northeast-


Quaternary volcaniclastic rocks
Lower Cretaceous Tedori Group
Funatsu Granite
Rocks of Mino Belt
Rocks of HTZ
Kashiate Formation (age-unknown)
Breccia
Basalt and mafic pyroclastic rocks
Dolerite to gabbro
Middle Permian Sorayama Formation
Member D
Member C
Member B
Member A
Lower to Middle Permian Mizuyagadani Formation
Carboniferous Ichinotani Formation
Devonian Fukuji Formation
Silurian ? Yoshiki Formation
Mafic intrusive rocks
Silurian to Ordovician Hitoegane Formation
Ordovician ? Iwatsubodani Formation
"Imami greenstones" (age-unknown)
Gamata Crystalline Schists (age-unknown)
Pelitic and psammitic schist
Mafic schist
Undivided strata
Limestone
Tuffaceous clastic rocks and clastic rocks
Mafic volcanic rocks
Serpentinite
Strike and dip of tilted strata (tops unknown)
Strike of vertical strata (tops unknown)
Strike and dip of normal strata
Strike of vertical strata
Strike and dip of overturned strata
Fault
Stratigraphic upper

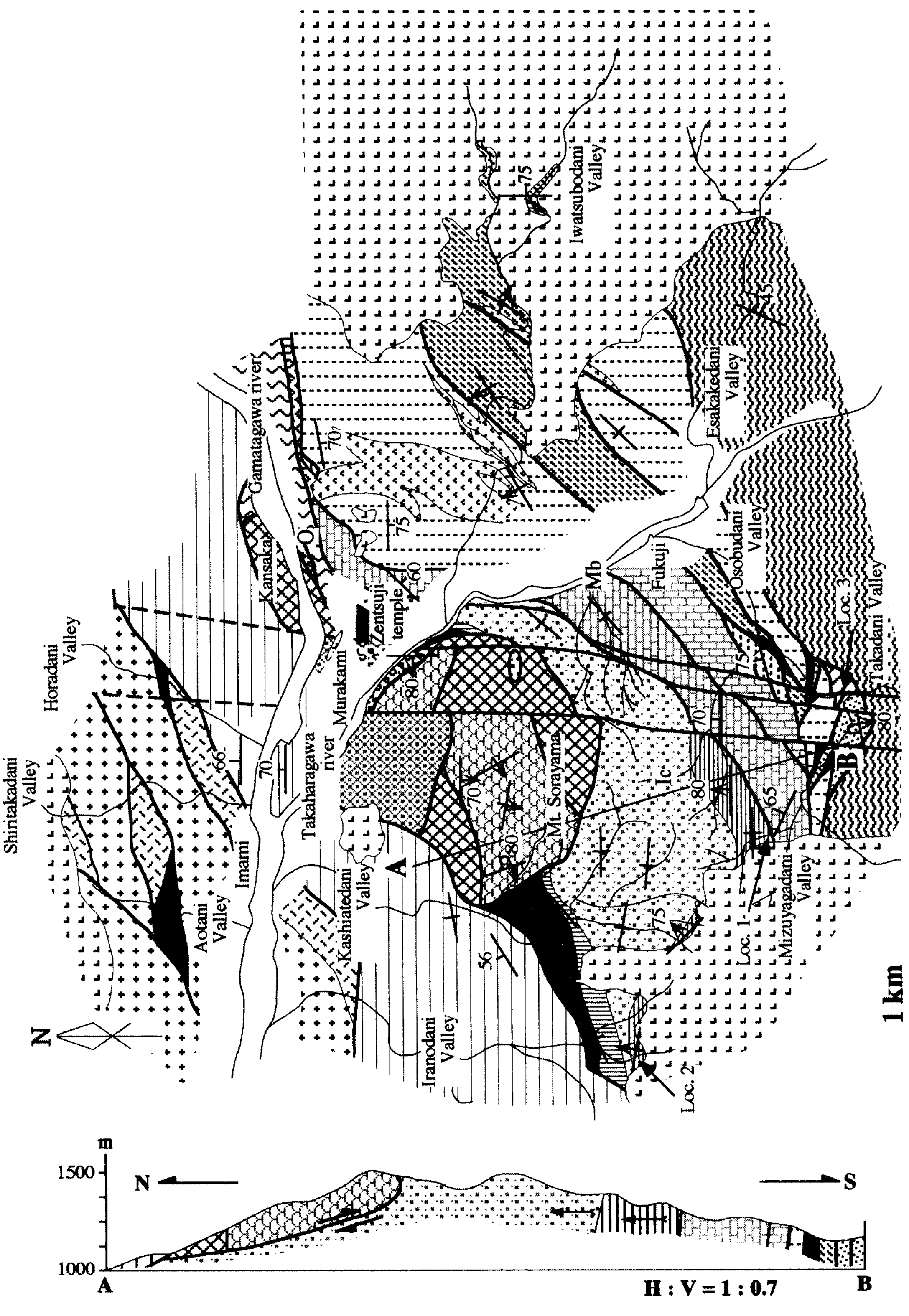


Fig. 2 Geological map and geological cross section of the Fukuji area, Gifu Prefecture, Central Japan. Mb: Mizuboradani Valley, Ic: Ichinotani Valley, O: Otani Valley.

southwest fault contact with the underlying Ichinotani Formation. The western part of this formation is limited by younger north-south vertical oblique-slip fault (Fig. 2).

Occurrence and lithology :

Lowermost Member : This member consists of tuffaceous calcareous sandstone, calcareous sandstone, calcareous breccia, and fossiliferous mudstone (Figs. 3, 4, 5). These calcareous clastic rocks are well-bedded and porous.

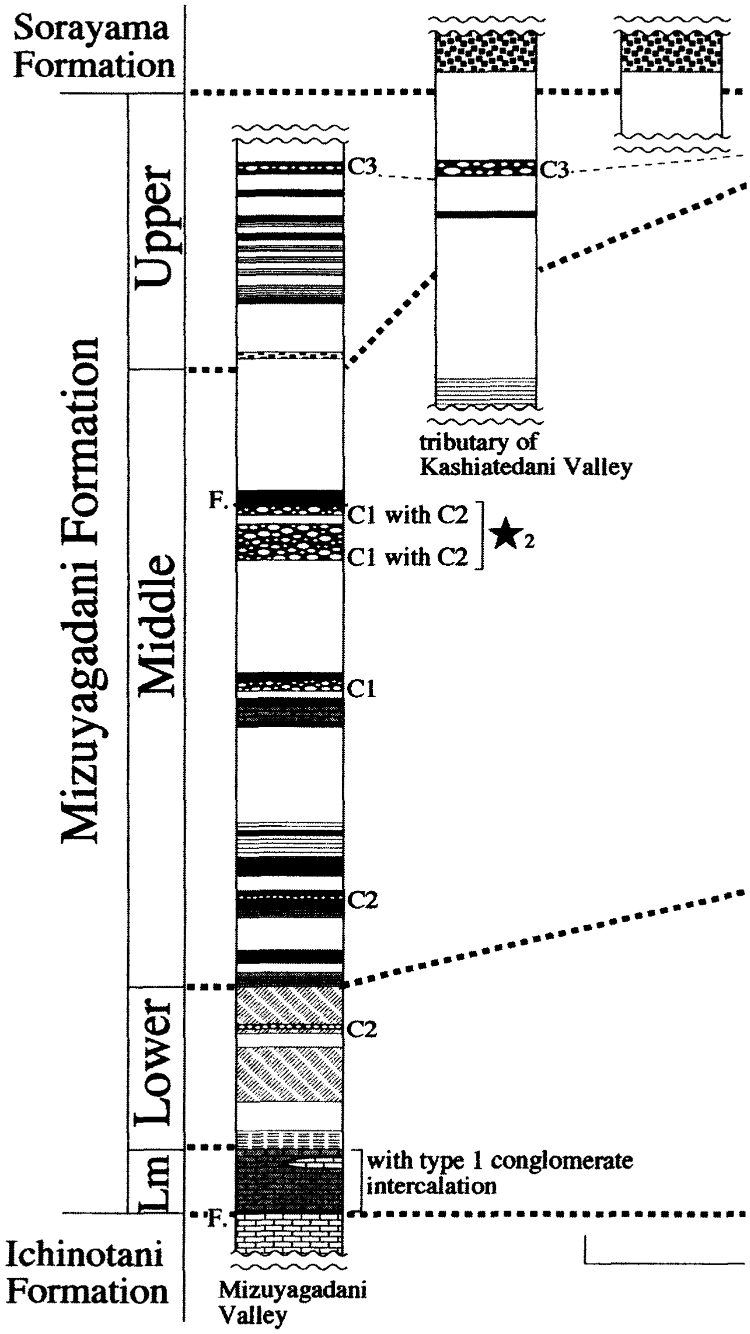
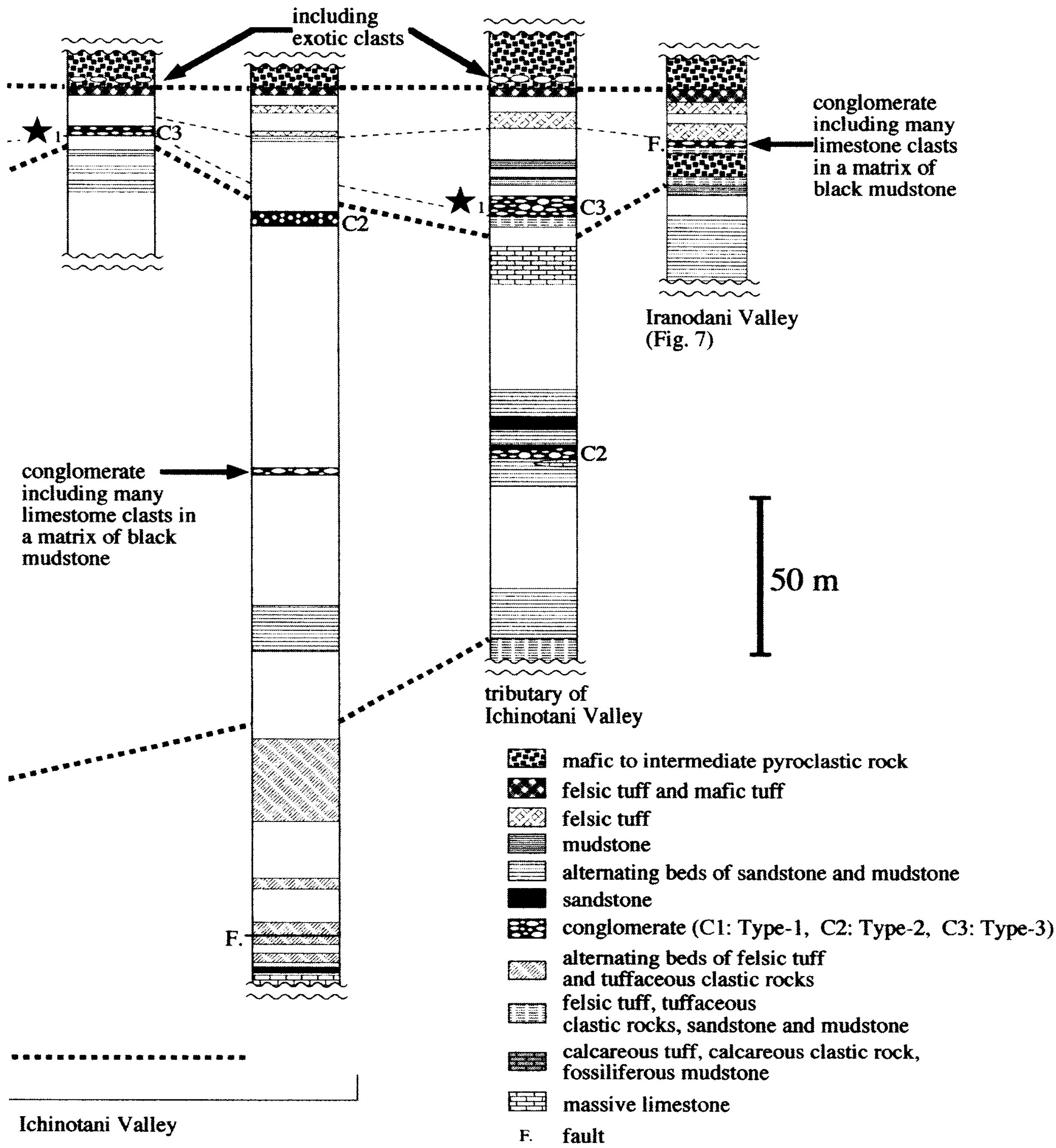


Fig. 3 Columnar sections of the Mizuyagadani Formation along the Mizuyagadani, the Kashiatedani, the Ichinotani, and the Iranodani Valleys.
Lm: the Lowermost Member, ★1: Ichinotani conglomerate, ★2: Mizuyagadani conglomerate.

The tuffaceous calcareous sandstone includes abundant felsic volcanic rock fragments, plagioclase, quartz, calcite, and a minor amount of limestone clasts and fossil fragments.

Coarse-grained calcareous sandstone and breccia include abundant angular limestone clasts, fossil fragments, felsic to intermediate volcanic rock fragments, plagioclase, quartz, and calcite in a matrix of fine-grained calcite cement (Fig. 6-1a).



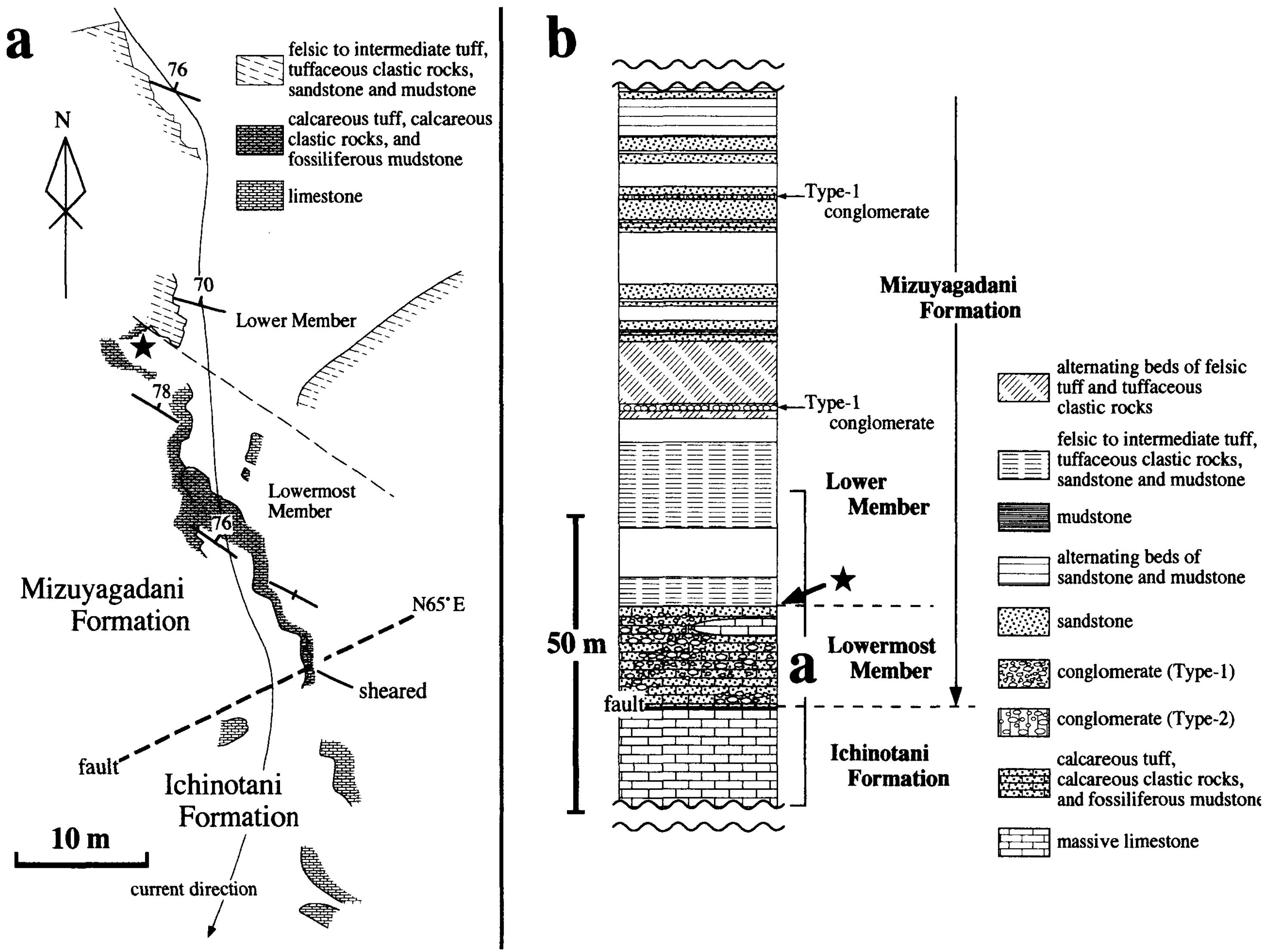


Fig. 4 Route map (a) and columnar section (b) along the lower stream of the Mizuyagadani Valley (Loc. 1 of Figs. 1 and 2) showing the lithology and stratigraphy of the lower part of the Mizuyagadani Formation. Black star shows locality of Fig. 5.

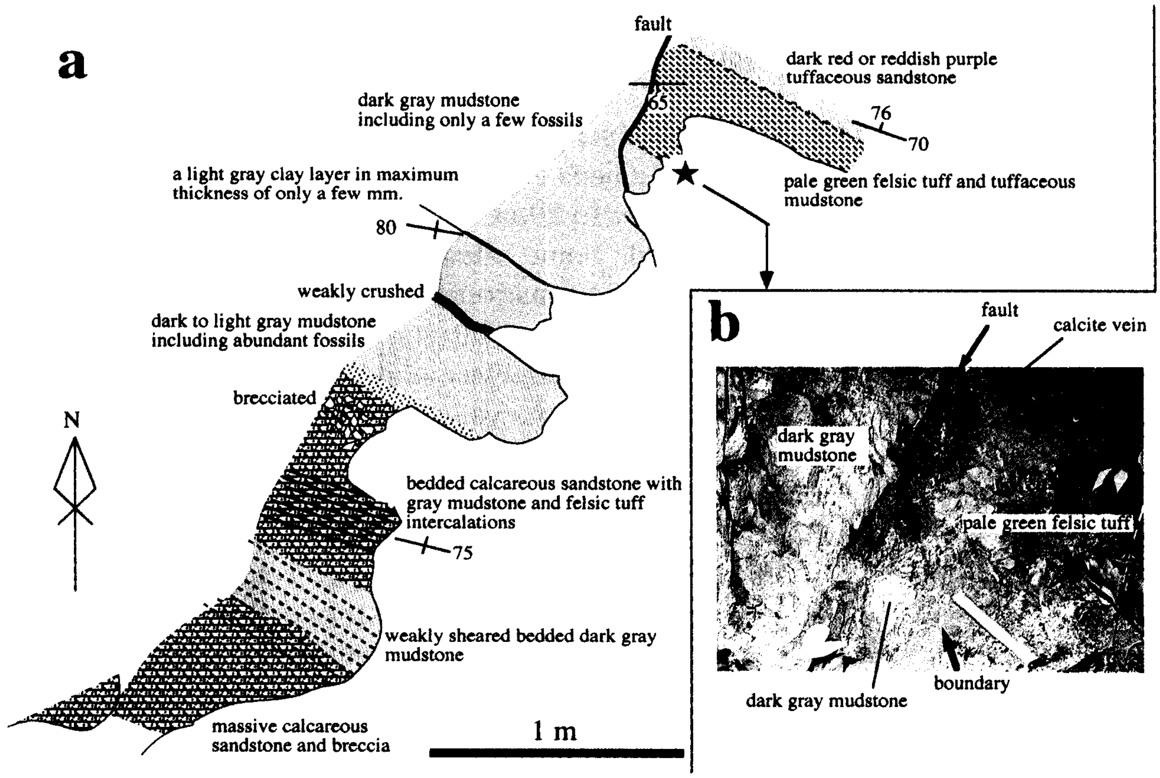


Fig. 5 (a) Route map around the boundary between the Lowermost and the Lower Members of the Mizuyagadani Formation. Bedding planes of both Members are parallel to subparallel. Black star shows the locality of (b). The Lowermost Member of the Mizuyagadani Formation is made up of calcareous clastic rocks and fossiliferous mudstone in ascending order. (b) Photograph of the boundary between the Lowermost Member and the Lower Member. Pale green felsic tuff of the Lower Member overlies the fossiliferous dark gray mudstone of Lowermost Member.

In several places, coarse-grained calcareous sandstone and breccia are composed mostly of fossil fragments such as crinoid stems, bryozoans, and others, and fine-grained calcite cements (Fig. 6-1b).

Fossiliferous massive mudstone which overlies calcareous clastic rocks intercalates calcareous sandstone and felsic tuff, and includes abundant fossil fragments in the lower part but only a few fossil fragments in the upper part (Fig. 5).

Lower Member : This member is characterized by tuffaceous rocks, and consists of alternating beds of felsic tuff and tuffaceous clastic rocks, and tuffaceous clastic rocks (Fig. 3). The alternating beds exhibit graded bedding indicating northward facing, and each bed is from a few to 10 cm thick. Laminated felsic tuff layers (a few to tens of millimeters thick) are commonly intercalated in the alternating beds. The layers of conglomerate which are less than several tens centimeters thick are intercalated in the alternating beds (Fig. 6-2b).

Felsic tuff consists mainly of felsic volcanic rock fragments, fine-grained plagioclase and quartz, and opaque minerals. Some very fine-grained felsic tuff includes radiolarian fossils (Niko et al., 1987; Umeda and Ezaki, 1997).

Tuffaceous sandstone consists mainly of intermediate to felsic volcanic rock fragments, plagioclase, quartz, opaque minerals, and secondary minerals such as chlorite and calcite.

Middle Member : Alternating beds of sandstone and mudstone are major facies of this member (Fig. 6-2a). The alternating beds exhibit graded bedding indicating northward facing, and each bed is from a few to 20 cm thick. Synsedimentary deformed structure such as slump fold is observed. Some calcareous clastic rock layers, similar to that of the Lowermost Member of the formation, are intercalated in some levels. Sandstone is gray lithic wacke, and includes many intermediate to felsic volcanic rock, sandstone, and mudstone fragments, and plagioclase and quartz (Fig. 6-1c). Roundness of these fragments and grains is low. Some volcanic rock fragments have microspherulitic, hyalopilitic and vitroclastic textures. Mudstone includes abundant pyrite as secondary mineral, rarely though.

A thick layer of poorly-sorted conglomerate, which includes boulder-sized clasts rarely, lies on the middle part of this member. The conglomerate, called "Mizuyagadani Conglomerate" in the present paper, is particularly well-exposed in the Mizuyagadani Valley. The conglomerate includes felsic to mafic volcanic rocks, sandstone, mudstone, and limestone clasts in a matrix of calcareous or argillaceous sandstone. The roundness of these clasts is high. The conglomerate is associated with calcareous sandstone rarely.

A massive limestone block crops out in the area of upper stream of the Ichinotani Valley, which might be derived from the other formations.

Upper Member : This member is well exposed in the area of upper stream of the Iranodani Valley (Fig. 7). It is made up of the following lithostratigraphy in ascending order; 1) tuffaceous sandstone with an intermediate to mafic tuff intercalation, 2) alternating beds of felsic tuff and tuffaceous clastic rocks, and 3) bedded mafic tuff. The alternating beds and bedded mafic tuff show graded beddings indicating northward facing, and the thickest one being 20 cm thick. The uppermost part of the Mizuyagadani Formation graded upward into mafic pyroclastic rock of the lowermost part of the Sorayama Formation.

Tuffaceous sandstone includes mafic volcanic rock fragments including red opaque minerals, intermediate to felsic volcanic rock fragments, plagioclase, quartz, opaque minerals and secondary minerals such as chlorite and calcite. Felsic tuff includes many of cryptomicrocrystalline plagioclase and quartz, and an accessory amount of felsic to mafic volcanic rock fragments, biotite, and opaque minerals. Felsic tuff includes many red mafic volcanic rock fragments and red opaque minerals in some places. Intermediate to mafic tuff includes altered intermediate to mafic volcanic rock fragments, plagioclase, clinopyroxene, hornblende, opaque minerals, and secondary minerals such as chlorite and calcite. Bedded mafic tuff includes mafic volcanic rock fragments, plagioclase grains, red opaque mineral, and an accessory amount of arkose sandstone and felsic volcanic rock fragments. Mafic volcanic rock fragments include abundant red opaque minerals.

The Ichinotani Conglomerate is intercalated in the middle part of this member. The conglomerate includes clasts of limestone, felsic porphyritic rock, felsic to mafic vol-

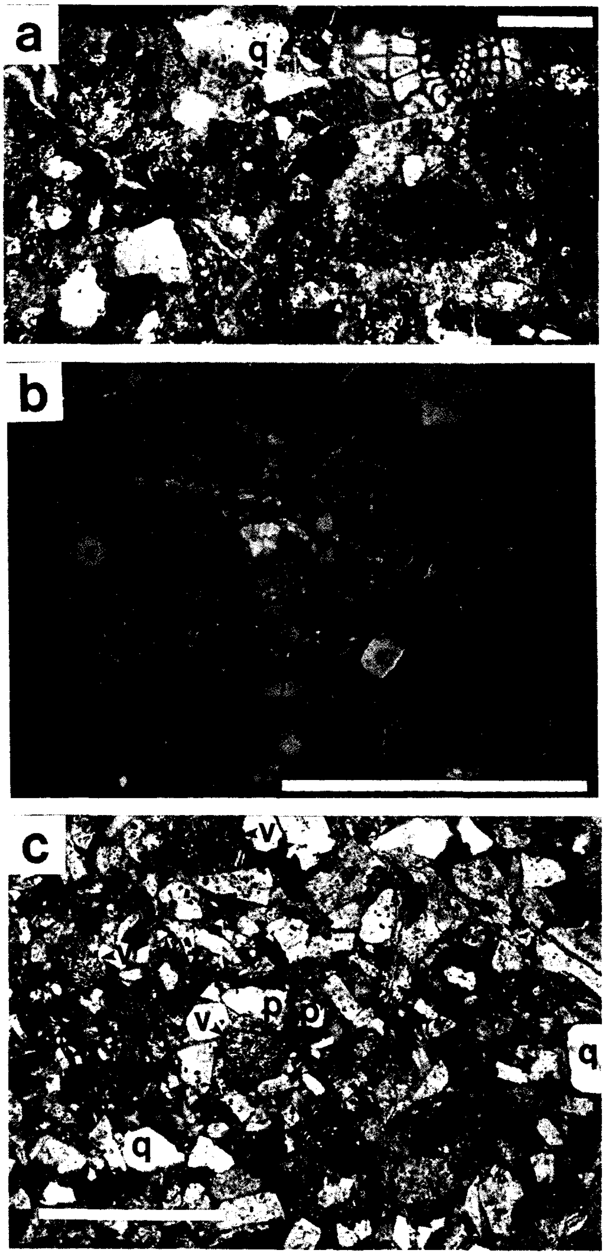


Fig. 6-1 Thin section photomicrographs of the Mizuyagadani Formation. (a) Thin section photomicrograph of calcareous sandstone of the Lowermost Member including some volcanic fragments and a fusulinacean fossil in a matrix of microcrystalline calcite. Scale bar denotes 1 mm. (crossed polars) (b) Photograph showing the polished surface of calcareous breccia (Type-1 conglomerate) of the Lowermost Member containing abundant fossil fragments in a matrix of calcareous sandstone. Scale bar denotes 1 cm. (c) Thin section photomicrograph of gray lithic sandstone of the Middle Member including many felsic to intermediate volcanic fragments. Scale bar denotes 1 mm. (plane polarized light)
q: quartz, p: plagioclase, v: volcanic fragment.

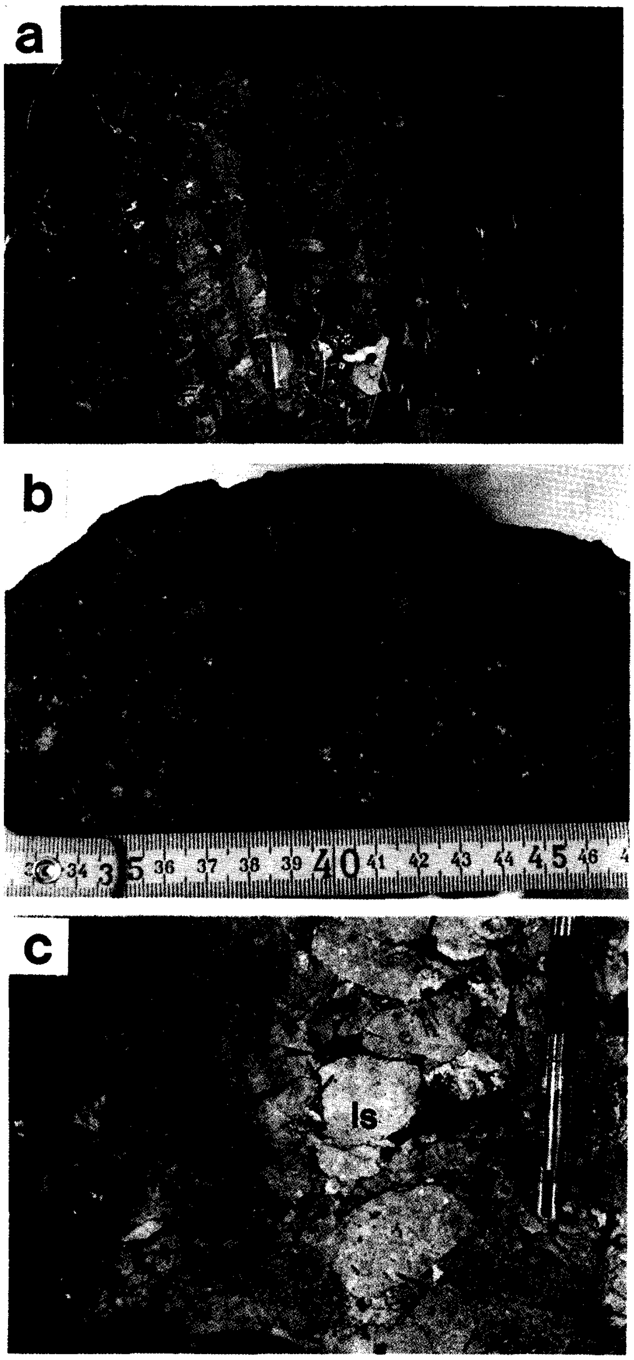


Fig. 6-2 Photographs showing the occurrence of rocks of the Mizuyagadani Formation. (a) Photograph showing the occurrence of alternating beds of gray tuffaceous sandstone and black tuffaceous mudstone of the Middle Member. (b) Photograph showing the natural surface of intercalated conglomerate (Type-2 conglomerate) in the Middle Member including clasts of felsic volcanic rocks, intermediate to mafic volcanic rocks, sandstone, mudstone and minor amount of limestone in a matrix of argillaceous sandstone. (c) Photograph showing the natural surface of the Ichinotani Conglomerate (Type-3 conglomerate) containing abundant limestone clasts in a matrix of mafic tuffaceous sandstone. The limestone clasts show irregular shape.
fv: felsic volcanic rock, mv: mafic volcanic rock, s: sandstone, m: mudstone, ls: limestone, mt: matrix.

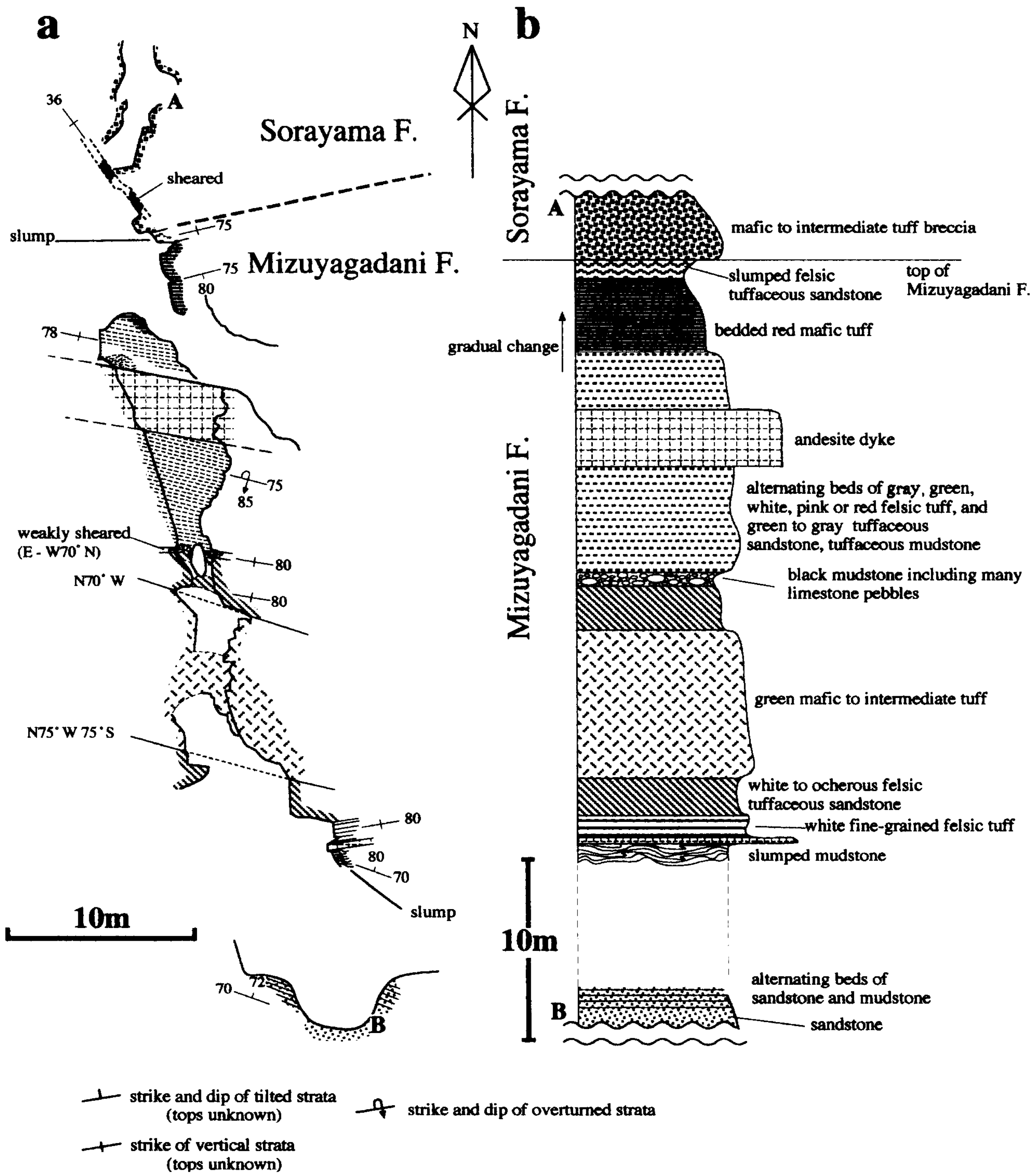


Fig. 7 Route map (a) and columnar section (b) of the Upper Member of the Mizuyagadani Formation along the upper stream of the Iranodani Valley (Loc. 2 of Figs. 1 and 2).

canic rocks, sandstone, and mudstone in a matrix of intermediate to mafic tuffaceous sandstone (6-2c). The conglomerate is not exposed in the area of upper stream of the Iranodani Valley.

Conglomerates : On the basis of the lithological properties of matrix, conglomerates in this formation can be classified into three; Type-1 conglomerate (Fig. 6-1b) having matrix of calcareous sandstone, Type-2 conglomerate (Fig. 6-2b) having matrix of argillaceous sandstone, and Type-3 conglomerate (Fig. 6-2c) having matrix of intermediate to mafic tuffaceous sandstone.

Calcareous breccia in the Lowermost Member, thin conglomerate intercalation in the Lower Member, and the Ichinotani Conglomerate in the Upper Member correspond to Types-1, 2, and 3, respectively (Fig. 3). The Mizuyagadani Conglomerate is the mixture of Type-1 and Type-2 conglomerate.

Type -1 conglomerate is well-exposed in the area of middle and upper stream of the Mizuyagadani Valley (Fig. 3). This conglomerate is matrix-supported, and includes abundant angular limestone clasts and fossil fragments, and a minor amount of subrounded to angular clasts of felsic to intermediate volcanic rocks, sandstone, and mudstone (Figs. 6-1b, 8). Generally clast of this conglomerate is granule to pebble, rarely cobble to boulder in size. Type-2 conglomerate is matrix-supported, and includes abundant clasts of felsic to mafic volcanic rocks, sandstone, mudstone, and a minor amount of limestone (Figs. 6-2b, 8). The roundness of these clasts is high. Generally clast of this conglomerate is granule to pebble, rarely cobble to boulder in size. Type-2 conglomerate layers are less than several tens centimeter thick in general. Type-3 conglomerate is matrix-supported, and includes clasts of limestone, felsic porphyritic rock, felsic to mafic volcanic rocks, sandstone, and mudstone (Fig. 8). Though the limestone clasts are irregular-shaped pebble to cobble in size, the other clasts are well-rounded granule to pebble. A part of this conglomerate is clast-supported, and includes only pebble- to cobble-sized limestone clasts (Fig. 6-2c).

Fossils and age : Igo (1956a; 1959), Kamei (1957), Niikawa (1980), Okimura et al. (1984), and Niko et al. (1987) reported the Upper Carboniferous to Lower Permian fusulinaceans (e.g. *Quasifusulina longissima, Q. pseudoelongata, Triticites elongatus, T. saurini, Pseudofusulina vulgaris*), brachiopods (*Squamularia asiatica, Spiriferella* cf. *salteri*), cephalopods (*michelinoceratine nautiloids*), smaller foraminifers (*Agathammina* spp., *Calcitornella* spp., *Flectospira* sp., *Giralianella*? sp., *Hemigordius schlumbergi, Meandrospira australae, M. meandrina, Nodosaria irwinensis, Trepeilopsis australiensis*), corals (e.g. *Sochkineophyllum japonicum, S. japonicum pauciseptatum, Plerophyllum hidense, Huangia mizuyagadaniensis*), and radiolarians (*Pseudoalbaillella lomentaria, Ps. longicornis, Ps. sakmarensis*) from the calcareous clastic rocks, felsic tuff, sandstone, and clast of limestone of the formation, and the formation was assigned to the Asselian or Sakmarian Stage. However, Umeda and Ezaki (1997) reported the Middle Permian radiolarians (*Pseudoalbaillella longicornis, Follicucullus monacanthus* etc.), from the felsic tuff of the Lower Member, and concluded the formation to be the late Middle Permian strata. They mentioned that the Carboniferous and Lower Permian fossils from the formation except for the lowermost part may be reworked fossils. Recently, some fossils indicating Kazanian stage of Middle Permian (*Parafusulina kaerimizensis* and *Dolorthoceras nakazawai*) were reported from a limestone float supposedly derived from this formation by Niko and Nishida (2000).

The Lower Permian fusulinaceans from the Lowermost Member show the contemporaneous or penecontemporaneous occurrence (Igo, 1959). Therefore, it is considered that this formation is assigned to the Lower to Middle Permian.

type of conglomerate		Type-1	Type-2	Type-3
matrix		calcareous sandstone	argillaceous sandstone	intermediate to mafic tuffaceous sandstone
clast composition	abundant	limestone and fossil fragments	felsic to mafic volcanic rocks	limestone, felsic porphyritic rock, felsic volcanic rocks, sandstone, and mudstone
	common	sandstone and mudstone	sandstone and mudstone	
	rare	felsic to intermediate volcanic rocks	limestone	intermediate to mafic volcanic rocks
clast size		granule to pebble	granule to pebble	limestone clasts are irregular-shaped pebbles to cobbles in general
roundness		angular to subangular	subrounded to rounded	other clasts are subangular to well-rounded granules to pebbles
remarks		matrix-supported conglomerate	matrix-supported conglomerate maximum thickness is less than several tens centimeters	commonly matrix-supported and includes some kind of granules and pebbles rarely clast-supported and includes only limestone pebbles and cobbles

Fig. 8 Classification of conglomerates of the Mizuyagdani Formation.

Sorayama Formation (redefined)

Definition : The Middle Permian strata which are composed mainly of intermediate to mafic pyroclastic rocks and tuffaceous sandstone of the Fukuji area are defined as the Sorayama Formation.

Type locality : Type section is exposed in the area of upper stream of the Kashiatedani Valley (further upstream at an elevation of 1,100 m). Reference sections are exposed in the area of upper stream of the Ichinotani Valley (further upstream at an elevation of 1,400 m) and the Iranodani Valley (elevation 1,150 to 1,280 m). The boundary stratotype section between the Mizuyagadani Formation and the Sorayama Formation is exposed in the area of upper stream of the Iranodani Valley (elevation 1,280 m).

Distribution : This formation is exposed in the area of upper stream of the Ichinotani, Kashiatedani, Iranodani, and Mizuboradani Valleys, on the left bank of the Takaharagawa River, on the east hillside of Mt. Sorayama, on the hillside of southeast of Murakami hamlet, and the lower area of tributary of the Gamatagawa River (called "Otani" Valley) south of Kansaka hamlet. (Fig. 2).

Thickness : 300 to 1000 m.

Stratigraphy and structure : This formation conformably overlies the Mizuyagadani Formation (Figs. 7, 9). The boundary plane trends east and dips vertically to subvertically. The top of the formation is limited by the west-northwest trending and gently north dipping reverse fault as will be mentioned later (Fig. 2).

This formation is subdivided into Members A to D in ascending order. The Members A, B, and C are conformable succession, and consist mainly of intermediate to mafic tuff breccia, alternating beds of mafic to felsic tuff and tuffaceous clastic rocks, and intermediate to mafic tuffaceous sandstone, respectively (Fig. 9). Member D is composed mainly of mafic lava and tuff breccia. The stratigraphical relationship between Member C and Member D is uncertain because the boundary is not exposed.

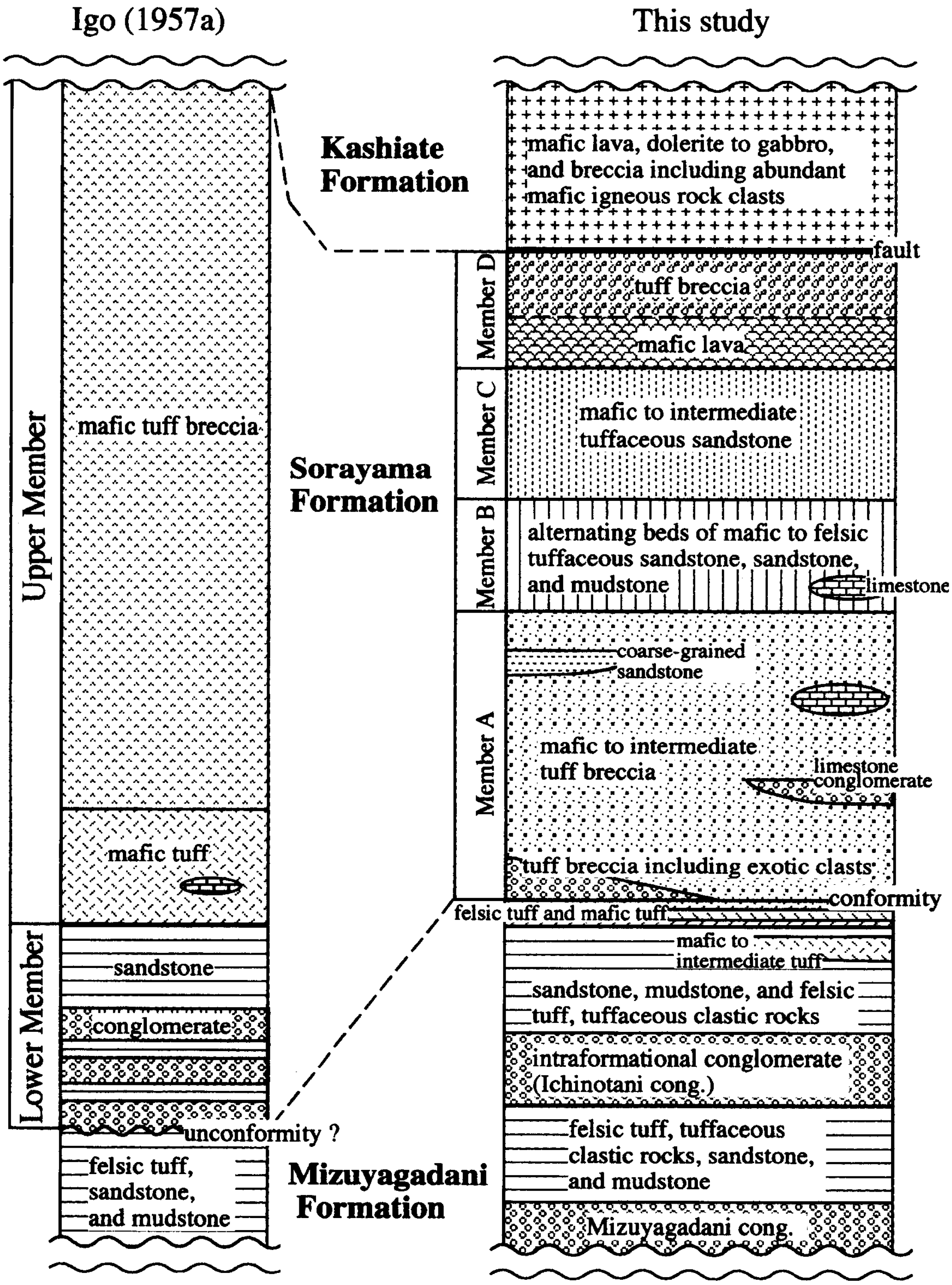


Fig. 9 Schematic columnar section of the upper part of the Mizuyagadani Formation, and the Sorayama and the Kashiate Formations (the present study and Igo, 1957a).

This formation trends east and steeply dips north or south on the south hillside of Mt. Sorayama; on the other hand, it trends north-northeast and dips westward on the west hillside of Mt. Sorayama (Fig. 2).

Occurrence and lithology :

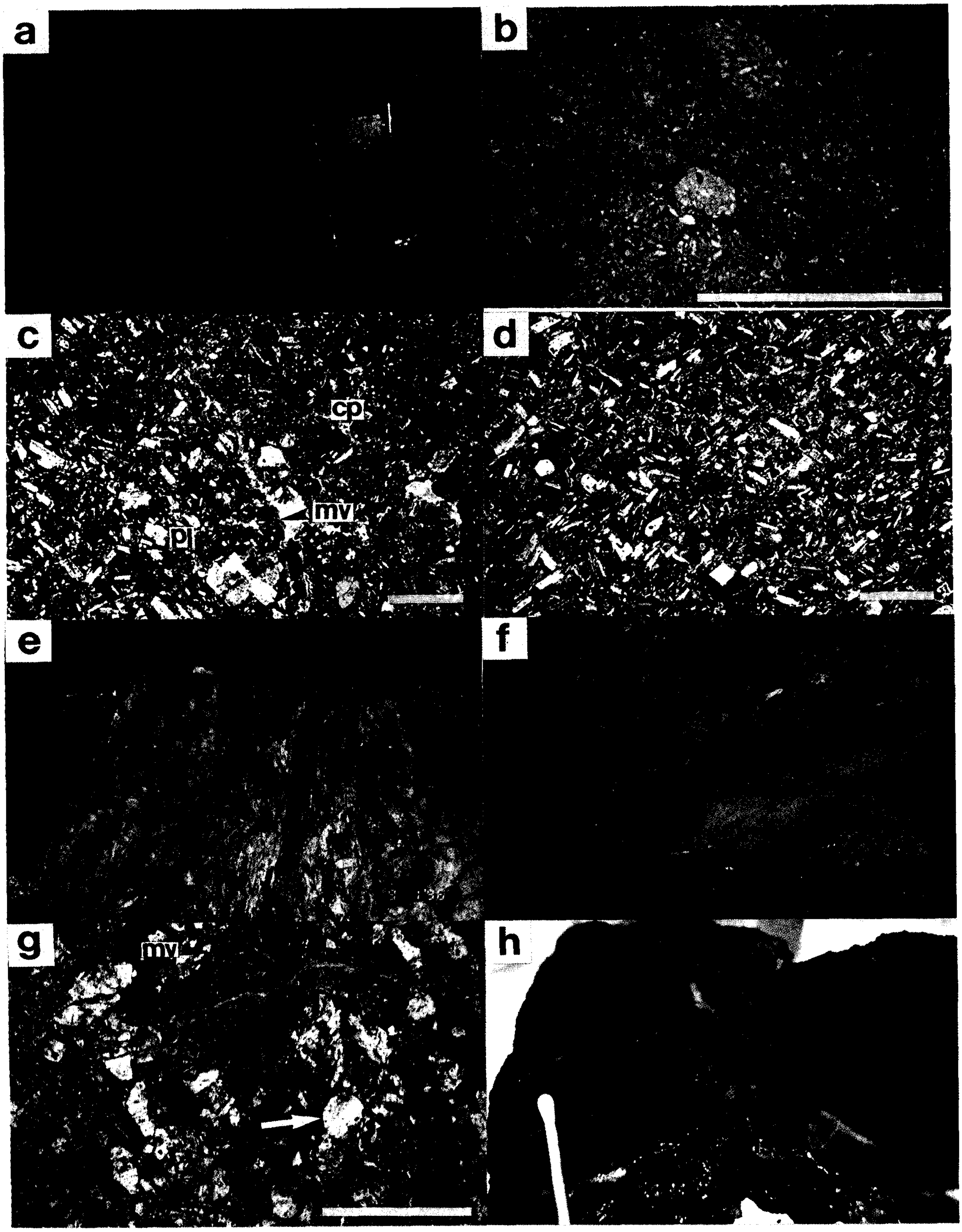
Member A : This member is composed mostly of intermediate to mafic tuff breccia (Fig. 10a). The lowermost part of the member includes intermediate to mafic volcanic rocks, limestone, felsic volcanic rocks, sandstone, and mudstone granules to cobbles. In comparison with the intermediate to mafic volcanic rock clasts, exotic clasts, such as limestone, felsic volcanic rocks, sandstone, and mudstone, are commonly well-rounded.

The volcanic rock clasts in this member are generally granule to cobble in size, and rarely boulder. The volcanic rock clasts show porphyritic texture and intersertal texture (Figs. 10b, c, d). In the intermediate to mafic volcanic rock clasts showing porphyritic texture, strongly zoned phenocrysts of plagioclase and granular clinopyroxene are embedded in a groundmass which is made up mostly of fine-grained opaque minerals, plagioclase laths, and secondary minerals such as chlorite and calcite (Fig. 10b, c). Strongly zoned phenocrysts of clinopyroxene and opaque minerals are rarely observed. Altered mafic minerals are commonly rimmed with fine-grained opaque minerals along its surface and zonal structure. Owing to alteration, the plagioclase laths is commonly turbid in the interior, and strongly saussuritized. The intermediate to mafic volcanic rock clasts showing intersertal texture contain plagioclase with intersertal clinopyroxene, opaque minerals, and accessory chlorite and calcite (Fig. 10d). Chlorite and calcite are seen as alteration products.

Matrix of the tuff breccia is made up of intermediate to mafic tuff including large amounts of intermediate to mafic volcanic rock fragments, plagioclase, clinopyroxene, epidote, chlorite, calcite, quartz, and fine-grained opaque minerals (Fig. 10c). Some mafic volcanic rock fragments are coated by thin layer of fine-grained opaque minerals. The matrix includes abundant red opaque minerals.

Rarely, laminated felsic tuff layers (about a few centimeters thick) and poorly stratified coarse-grained tuffaceous sandstone and granule to pebble conglomerate including many dolerite clasts are intercalated in the tuff breccia. The middle part of this member intercalates limestone conglomerate. The limestone clasts include fusulinaceans, corals, bryozoans, and other fossils, and the matrix also includes fusulinaceans and corals. Most of limestone clasts in this conglomerate are Folk's (1959) micrite, biomicrite, oomicrite and biosparite. Clast-supported cobble conglomerate of the lower part of the conglomerate grades upward into the matrix-supported granule to pebble conglomerate of the upper part. Thin tuffaceous sandstone beds are rarely intercalated in the upper part of this Member. The member becomes thicker to the west, and grades upward into Member B.

Member B : This member consists of alternating beds of predominantly felsic tuff, tuffaceous sandstone, and tuffaceous mudstone, and a subordinate amount of intermediate to mafic tuff (Fig. 10e). The alternating beds exhibit graded bedding indicating northward facing, and each bed is from a few to 10 cm thick. The member includes limestone clasts and blocks including fossils. Tuffaceous sandstone is composed mainly of felsic to mafic volcanic rock fragments, plagioclase, quartz, opaque mineral, and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secondary minerals such as chlorite and calcite. Rocks of the member, except for the rocks in the Iranodani Valley, are sheared and highly altered by weathering.

Member C : This member is composed mostly of massive intermediate to mafic tuffaceous sandstone (Fig. 10f). Characteristically, lenticular felsic tuffaceous mudstones are intercalated in the member in some places. Laminated felsic tuff layers (only a few centimeters thick) are rarely intercalated in the middle part of the member. A large crystalline limestone block is exposed on the left bank of the middle area of the Kashiatedani Valley (elevation at 1,150 m). The tuffaceous sandstone is composed mainly of altered mafic to felsic volcanic rock fragments, turbid grains of plagioclase, opaque minerals, and secondary minerals such as chlorite and calcite (Fig. 10g). Allochthonous well-rounded quartz is also found less abundantly.

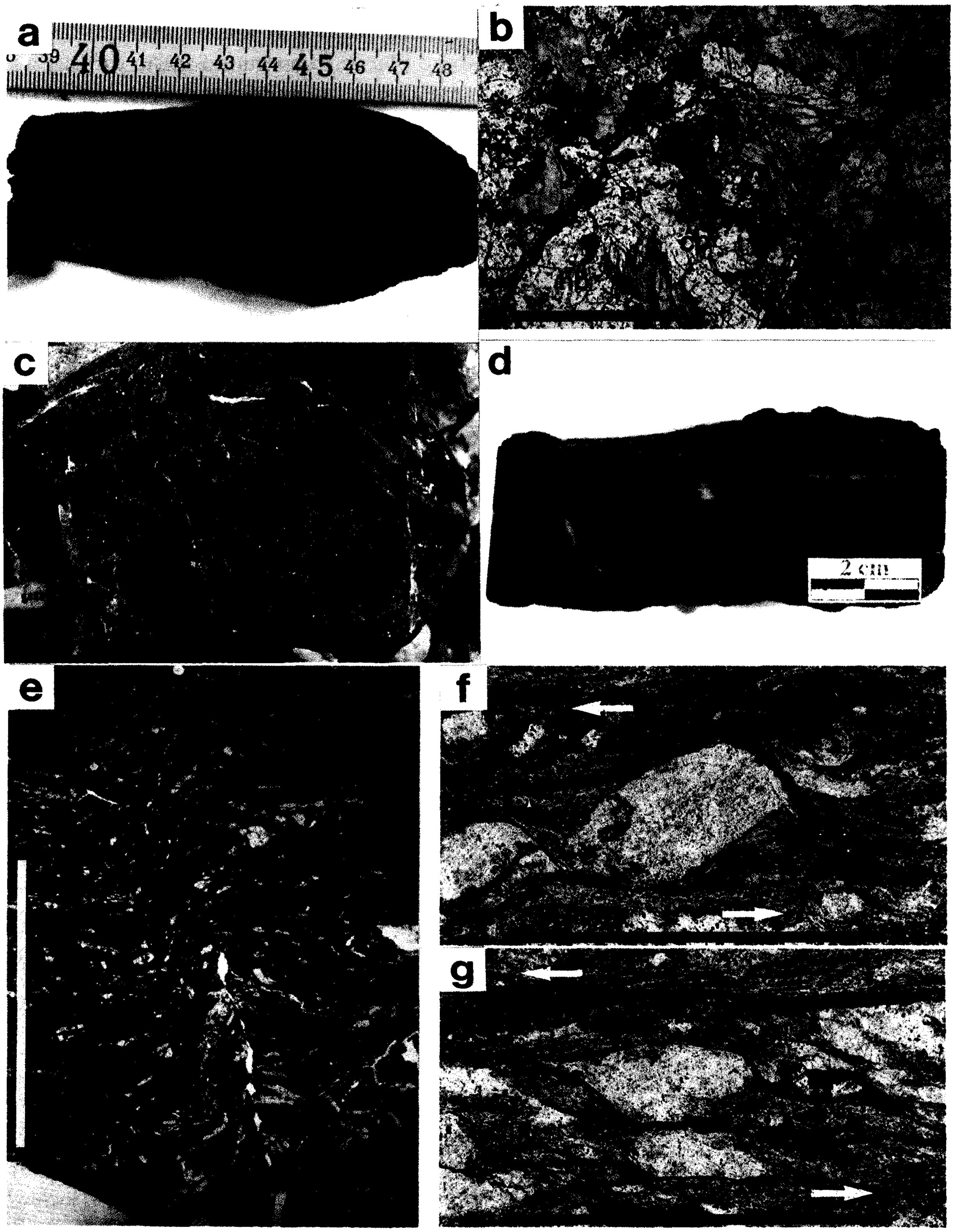
Member D : This member is exposed in a limited area along the Takaharagawa and Gamatagawa Rivers (Fig. 2).

The lower part of this member is made up of mafic pillow lava indicating westward facing. Chilled margins, radial joints, and spherical-ellipsoidal and pipe vesicles are observed.

The upper part of this member is made up of mafic tuff breccia including many mafic volcanic rock clasts. A part of tuff breccia in Members A and D is closely similar to each other in lithofacies. The clasts are granule to boulder in size. The matrix is made up of mafic tuff, and partly includes abundant red opaque minerals. The tuff breccia is weakly sheared, and foliation is formed rarely.

A part of the tuff breccia including abundant exotic clasts such as limestone, sand-

Fig. 10 Photographs showing the lithology and occurrence of the Sorayama Formation. (a) Photograph showing the occurrence of mafic tuff breccia of Member A containing many mafic volcanic rocks in a matrix of mafic tuff. (b and c) Thin section photomicrographs of mafic tuff breccia of Member A containing many mafic volcanic rock clasts showing porphyritic texture. Matrix is made up chiefly of small mafic volcanic rock fragments, plagioclase laths, and abundant red opaque minerals. In the mafic volcanic rock clast, phenocrysts of strongly zoned plagioclase grains and granular clinopyroxene are embedded in a groundmass made up mostly of much finer red and black opaque minerals and plagioclase laths. Scale bars of (b) and (c) denote 1 cm and 1 mm, respectively. (b: plane polarized light, c: crossed polars) (d) Thin section photomicrograph of a clast of mafic volcanic rock showing intersertal texture of Member A made up mostly of plagioclase laths, and accompanied by granular clinopyroxene and opaque minerals. Scale bar denotes 1 mm. (crossed polars) (e) Photograph showing the occurrence of alternating beds of felsic tuff, mafic to intermediate tuff, tuffaceous sandstone and tuffaceous mudstone of Member B. The rocks are sheared and altered by weathering. (f) Photograph showing the occurrence of massive mafic to intermediate tuffaceous sandstone of Member C. Black arrow shows lenticular felsic tuffaceous mudstone intercalation. (g) Thin section photomicrograph of mafic to intermediate tuffaceous sandstone of Member C. The rock is greatly altered by weathering, and most of volcanic fragments has been completely altered. White arrow shows allochthonous well-rounded quartz grain. Scale bar denotes 1 mm. (crossed polars) (h) Photograph showing the polished surface of mafic tuff breccia of Member D including many exotic clasts. The red mafic volcanic fragments commonly show irregular shape.
mv: mafic volcanic rock, fv: felsic volcanic rock, ls: limestone, s: sandstone, pl: plagioclase, cp: clinopyroxene.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stone, mudstone, felsic tuff, schist, and granitoid was once named as the "Murakami Conglomerate" by Kamei (1949) and Minato (1949a) (Fig. 10h). The limestone and mafic volcanic rock clasts show irregular shape.

Mafic tuff breccia and breccia cropping out along the lower area of the Otani Valley are closely similar to the "Murakami Conglomerate" in clast composition and matrix lithology (Figs. 1, 2). The tuff breccia and breccia cropping out in the Otani Valley might be an eastern extension of the upper part of Member D.

Fossils and age : Tuff breccia of Member A includes limestone clasts which yield some Devonian corals (*Favosites* cf. *asper*, *Heliolites barrandei*) and Carboniferous fusulinaceans (*Quasifusulina* aff. *longissima*, *Triticites exsculptus*, *T. hidensis*, *T. hataii*, *T. henbesti*, *T.* sp., *Carbonoschwagerina morikawai*) (Igo, 1957b). The limestone conglomerate intercalation of Member A includes abundant Devonian to Carboniferous fossils (*Favosites* sp., *Ozawainella* sp., *Pseudostaffella sphaeroidea*, *Profusulinella* sp., *Fusulinella fukujiensis*, *Beedeina ichinotaniensis*, *Quasifusulina longissima*, *Triticites* sp., *Carbonoschwagerina morikawai*, *Pseudofusulina* sp., *Eoschubertella lata*, *Schubertella* sp., *Bradyina* sp.) in the limestone clasts, and Middle Permian fusulinaceans (*Nankinella* sp., *Parafusulina* aff. *gigantea*, *Parafusulina* sp., *Russiella pulchra*) in the matrix (Tsukada et al., 1999). Member B includes limestone clasts and blocks which yield some Devonian corals (e.g. Favositids, Heliolitids). Limestone clasts of Member D yield Devonian to Carboniferous fossils (*Favosites* sp., *Heliolites* cf. *barrandei*, *Amphipora cylindrica*, *Clathrodictyon onukii*, *Clathrodictyon* sp., *Clavidictyon* sp., *Fusulinella* sp., *Bradyina nautiliformis*., *Climacammina* sp.) (Kamei, 1952; Igo, 1957b).

This formation is considered to be Middle Permian in age because of contemporaneous or penecontemporaneous occurrence of fusulinaceans from the matrix of the limestone conglomerate of Member A (Tsukada et al., 1999).

◄

Fig. 11 Photographs showing the lithology and occurrence of the Kashiate Formation. (a) Photograph showing the polished surface of gabbro of the Kashiate Formation. (b) Thin section photomicrograph of gabbro of the Kashiate Formation composed mainly of plagioclase and hornblende. Small granular clinopyroxene and opaque mineral occupy interspaces. Scale bar denotes 1 mm. (plane polarized light) (c) Photograph showing the occurrence of breccia of the Kashiate Formation including clasts of melanocratic dolerite to gabbro in a matrix of mafic volcaniclastic rock. (d) Photograph showing the polished surface of the rock near the boundary between the Kashiate Formation and the Sorayama Formation. This plane shows vertical to foliation and parallel to lineation. The rock was intensely sheared, and phyllite-like planar structure was formed. (e-g) Thin section photomicrographs of the "phyllite" near the boundary between the Kashiate Formation and the Sorayama Formation show the asymmetric deformation structures indicating the sense of shear. All deformation structures in these photomicrographs indicate the top to the south shear sense. White arrows show the shearing direction. Scale bars denote 1 mm. (e) Photomicrograph showing reverse kink band. (plane polarized light) (f) Photomicrograph showing the δ structure. (plane polarized light) (g) Photomicrograph showing the σ structure. (plane polarized light)
gb: gabbro, pl: plagioclase, hb: hornblende, cp: clinopyroxene.

Kashiate Formation (newly named)

Definition : The mafic lava, dolerite to gabbro, and breccia including mafic to ultramafic rocks and limestone clasts in a matrix of mafic volcaniclastic rocks in the Fukuji area are newly designated as the Kashiate Formation (Fig. 2). Although this formation was dealt with as a part of the Sorayama Formation by Kamei (1952), Igo (1956a), Niikawa (1980), and Harayama (1990) (Fig. 9), these rocks should be distinguished from the Sorayama Formation on the basis of the following two reasons; 1) lithofacies is clearly different in these two formations, 2) a remarkable shear zone is observed around the boundary between them.

Type locality : Type section is exposed in the gorge which meets the Kashiatedani Valley at an elevation of 995 m.

Distribution : This formation is exposed on the north hillside of Mt. Sorayama and along the Gamatagawa River around the Kansaka hamlet (Fig. 2).

Stratigraphy and structure : This formation is composed of mafic igneous rock and breccia including abundant mafic igneous rock clasts (Fig. 2). Though the mafic igneous rock and breccia are in east-trending fault contact with each other, the former is likely to underlie the latter primarily because the breccia includes abundant mafic igneous rock clasts.

This formation is thrust over the Sorayama Formation and the Gamata Crystalline Schists (GCS) (Fig. 2). The boundary plane between the Kashiate and the Sorayama Formations trends west to northwest and gently dips north on the north hillside of Mt. Sorayama, and steeply dips south at the summit of Mt. Sorayama (Fig. 2). The fault plane between this formation and the GCS trends northeast and gently dips north. Horizontal to subhorizontal joints and weakly sheared rocks are observed near the boundary with the GCS. The shear planes trend west to northwest and gently dip south.

Occurrence and lithology : This formation consists of mafic lava, dolerite to gabbro, and breccia including abundant mafic rock clasts in a matrix of mafic volcaniclastic rock (Fig. 2). The occurrence and lithology of each rock are described as follow.

Mafic lava : Mafic lava has the largest exposure on the hillside of east of the Kashiatedani Valley. The lava shows pillow structure which has chilled margins, radial joints, and spherical-ellipsoidal and pipe vesicles. The lava trend north to west and steeply dip west to south. The lava contains many plagioclase grains with intersertal clinopyroxene, opaque minerals, and others. The lava is highly altered, and groundmass is commonly changed chiefly into the alteration products such as chlorite, calcite, and others.

Dolerite to gabbro : Dolerite to gabbro is most common in this formation. The gabbro is augite-hornblende gabbro, and consists of large euhedral to subhedral grains of plagioclase and hornblende with subordinate amounts of intersertal clinopyroxene, orthopyroxene, opaque minerals, and others (Figs. 11a, b). These rocks rarely include grains of quartz showing wavy extinction. Most of hornblende show pleochroism from pale green to dark green, and only a few of hornblende show pleochroism from pale brown to brown and clear to pale blue-green (Fig. 11b). Some hornblende are rimmed by clinopyroxene. Pyroxene is commonly uralitized and changed to fibrous hornblende and actinolite. The gabbro partly shows cumulus textures. Anhedral chlorite derived from some mafic minerals occupies a little irregular interspace of abundant unzoned euhedral plagioclase. Euhedral to subhedral grains of plagioclase and larger anhedral grains of hornblende and chlorite derived from hornblende show poikilitic texture. A part of the plagioclase is strongly saussuritized. The dolerite consists of large subhedral to anhedral grains of plagioclase, rounded granules of clinopyroxene, euhedral to subhedral actinolite changed from hornblende, opaque minerals, and others with intergranular texture. The common alteration product is calcite.

These rocks are weakly metamorphosed in general. Actinolite, tremolite, epidote, and chlorite with decussate texture are produced, and hornblende is changed chiefly into actinolite and chlorite. Twin and cleavage of primary minerals are cut by acicular or slender prismatic minerals which were produced by metamorphism.

Breccia : Breccia includes abundant basalt and dolerite to gabbro clasts, and a minor amount of mafic pyroclastic rock, crystalline limestone, and ultramafic rock clasts (Fig. 11c). The clasts are commonly granule to cobble, and rarely boulder in size. Roundness of clasts is low. The breccia is matrix-supported and unsorted. Ultramafic rock is only found in the left bank of the Gamatagawa River as small rock bodies. The ultramafic rock is altered into serpentinite. Crystalline limestone clasts are rarely found in the north hillside of Mt. Sorayama and the left bank of the Gamatagawa River. The limestone clasts have a maximum size of 10 cm, and show irregular shape. They are barren a fossils, and rarely include mafic volcanic rock fragments.

The matrix is composed of coarse-grained mafic volcaniclastic rock which includes many mafic volcano-plutonic rock fragments, mineral grains of plagioclase, clinopyroxene, opaque minerals commonly, and of tuffaceous mudstone rarely.

Rocks around the boundary with other strata : Along the boundary between the Kashiate and the Sorayama Formations on the hillside and summit of Mt. Sorayama, they are intensely deformed and phyllite-like planar structure is formed (Fig. 11d). The deformed rocks show various asymmetric deformation structures indicating the sense of shear. The asymmetric structures show the reverse-fault sense on the north hillside of Mt. Sorayama (Figs. 11e, f, g).

This formation is in fault contact with spotted green schist of the GCS in the left bank of the Gamatagawa River (Fig. 2). Around the boundary between them, both are intensely crushed, and gouge is formed. The crush zone is several tens of centimeter thick.

Fossils and age : No fossils have been found from this formation. Igo (1956a), Minato (1949b), and Kamei (1952), however, reported *Fusulinella bocki*, *F.* sp., *Texturalia* cf. *gibbosa*, Dibinophylloid, and Camophylloid from the limestone exposed in the Kansaka hamlet. If this limestone is a clast of the breccia of this formation, the age of the formation is younger than Carboniferous.

DISCUSSION

In this section, the results of re-examination of the Permian strata in the Fukuji area are discussed.

1. Mizuyagadani Formation

1-1. Redefinition of the Mizuyagadani Formation

Igo (1956a) and Niikawa (1980) described the detailed lithostratigraphy and fusulinaceans biostratigraphy of the "Mizuyagadani Formation" exposed on the south hillside of Mt. Sorayama (M1 in Fig. 12) and around the junction of the Osobu and Takadani Valleys (M2 in Fig. 12). Niikawa (1980) subdivided the Mizuyagadani Formation into P1 to P4 Members on the basis of lithofacies and fusulinacean zones in ascending order (Figs. 12, 13, 14). The limestone of M1 (lower part of P1 Member) was separated from the Mizuyagadani Formation and was included as the uppermost member of the Ichinotani Formation by Adachi (1985) (Fig. 14). The age of limestones of M1 and M2 (lower part of P1 Member and P3 Member) was redefined as Late Carboniferous by Watanabe (1991) (Fig. 14). Umeda and Ezaki (1997) defined the clastic rocks of M1 and M2 (P2 Member and P4 Member) as the Mizuyagadani Formation, and dealt with as the upper part of P1 Member as "undivided strata" (Fig. 14).

In the present study, the Lower to Middle Permian clastic rock of M1 can be redefined as the Mizuyagadani Formation because of the following two reasons; 1)

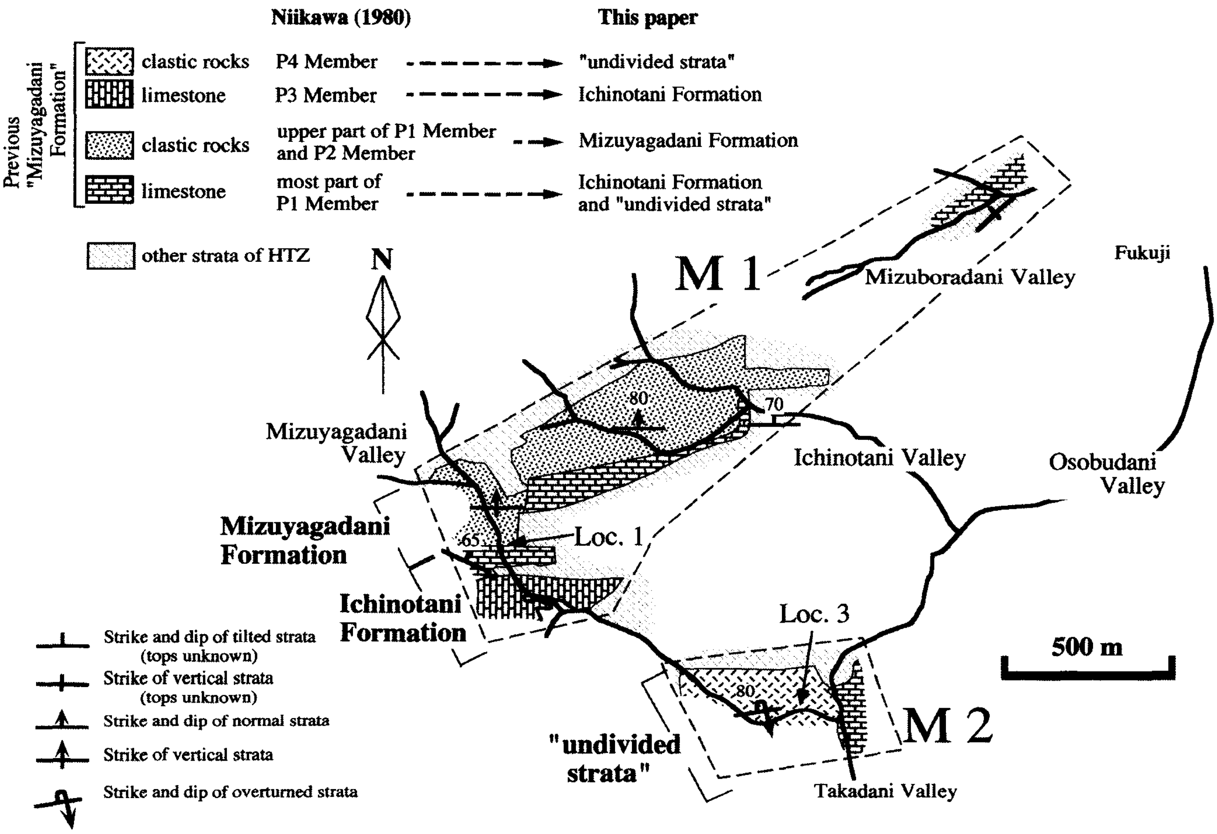


Fig. 12 Simplified geological map of the Mizuyagadani Formation of Niikawa (1980) showing the area of redefined Mizuyagadani Formation in this paper. Though some previous studies dealt with limestone and clastic rocks of M1 and M2 as the Mizuyagadani Formation, clastic rocks of M1 can be defined as the Mizuyagadani Formation in this paper. Geological map is modified from Niikawa (1980). Locs. 1 and 3 show the locality of Figs. 4, and 15, respectively.

stratigraphical relationship between the strata of M1 and M2 is not clear, 2) age of clastic rock of M2 is unknown. The Mizuyagadani Formation of this study corresponds to the Niikawa's (1980) upper part of P1 Member and P2 Member (Figs. 12, 13, 14).

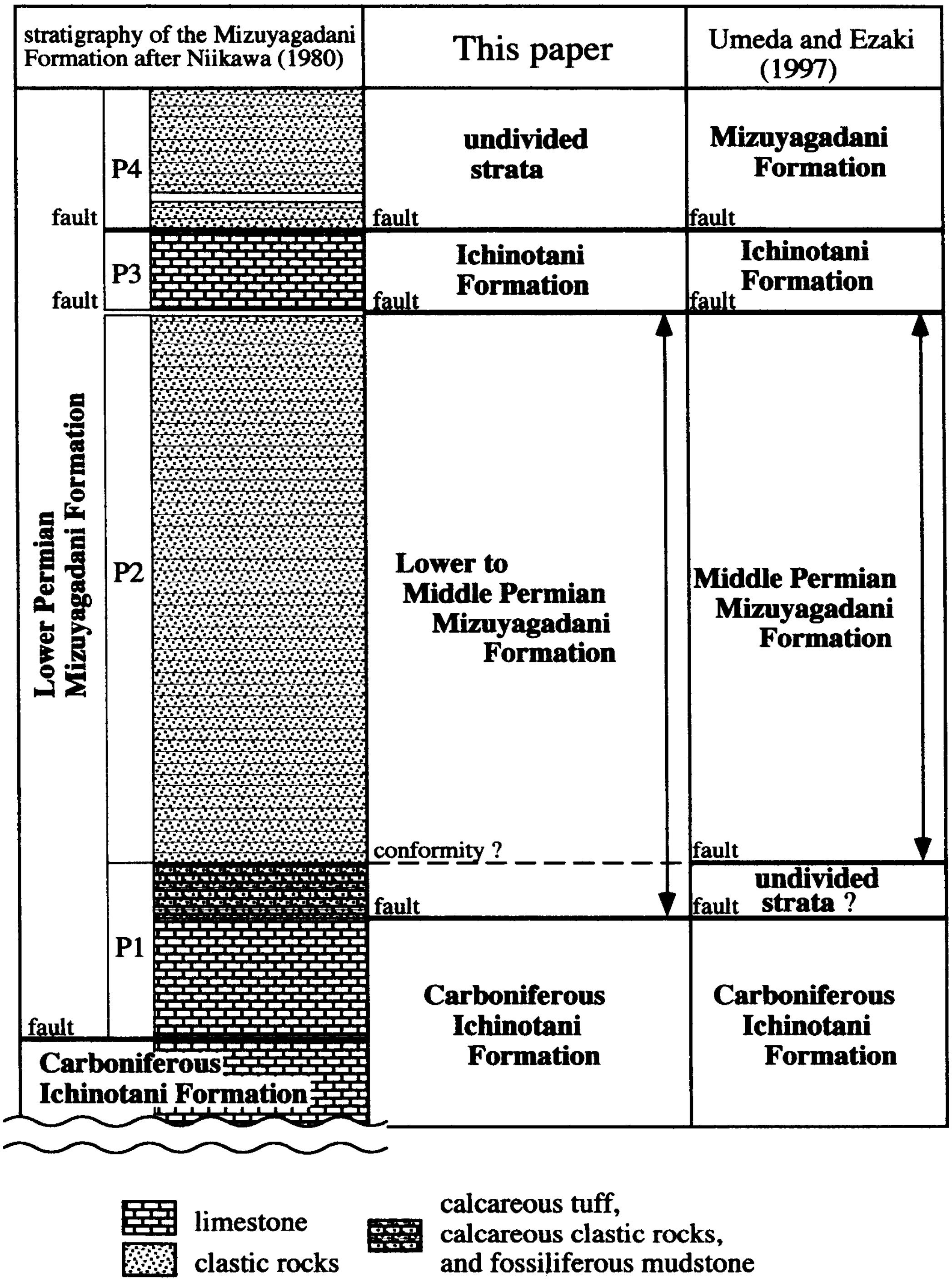
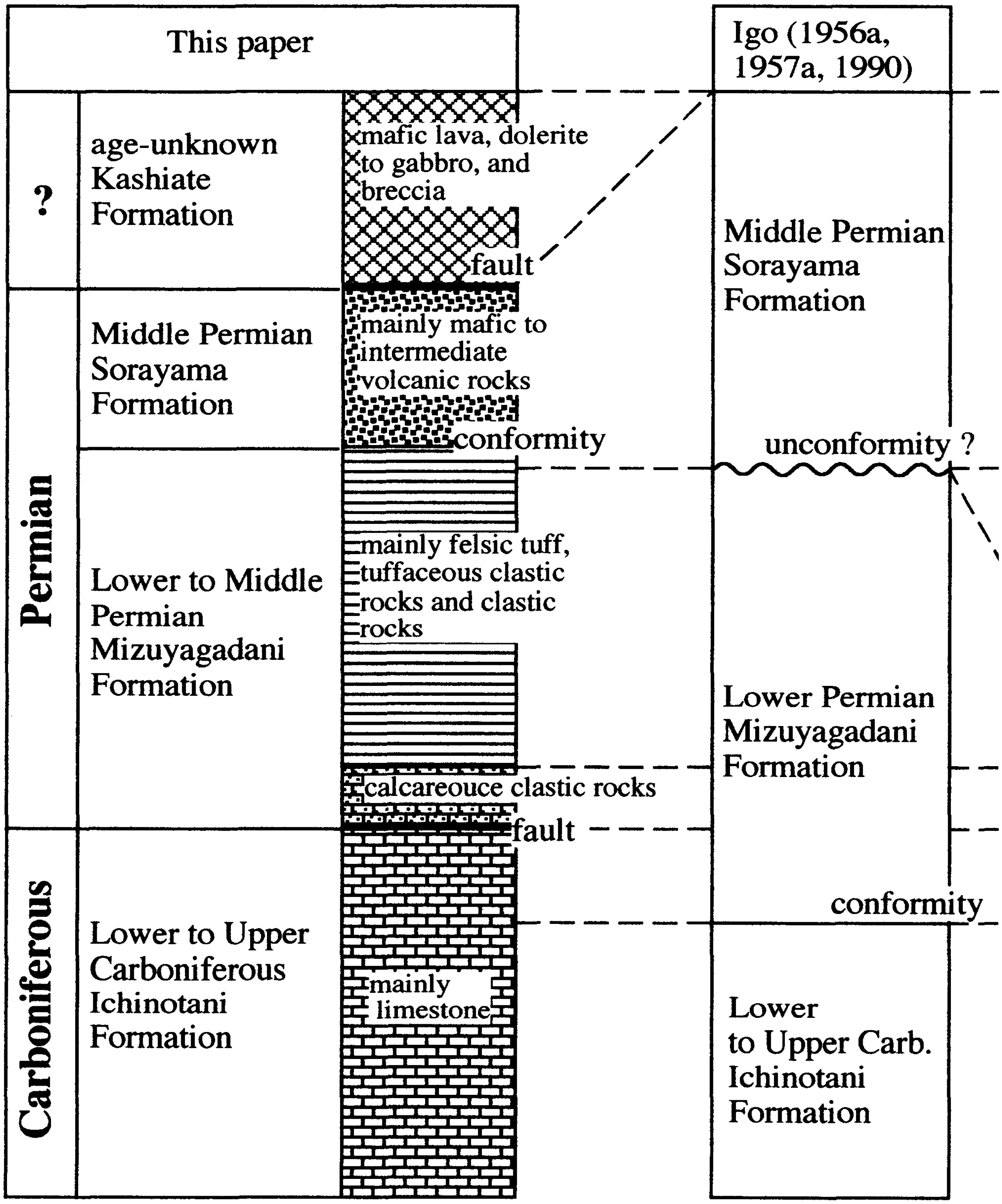


Fig. 13 Newly proposed definition of the Mizuyagadani Formation, compared with the definitions by Niikawa (1980), Umeda and Ezaki (1997). Columnar section is modified from the Niikawa (1980).


This paper
Igo (1956a, 1957a, 1990)
?
age-unknown Kashiate Formation
mafic lava, dolerite to gabbro, and breccia
fault
Permian
Middle Permian Sorayama Formation
mainly mafic to intermediate volcanic rocks
conformity
Lower to Middle Permian Mizuyagadani Formation
mainly felsic tuff, tuffaceous clastic rocks and clastic rocks
calcareouce clastic rocks
fault
Carboniferous
Lower to Upper Carboniferous Ichinotani Formation
mainly limestone
Middle Permian Sorayama Formation
unconformity ?
Lower Permian Mizuyagadani Formation
conformity
Lower to Upper Carb. Ichinotani Formation

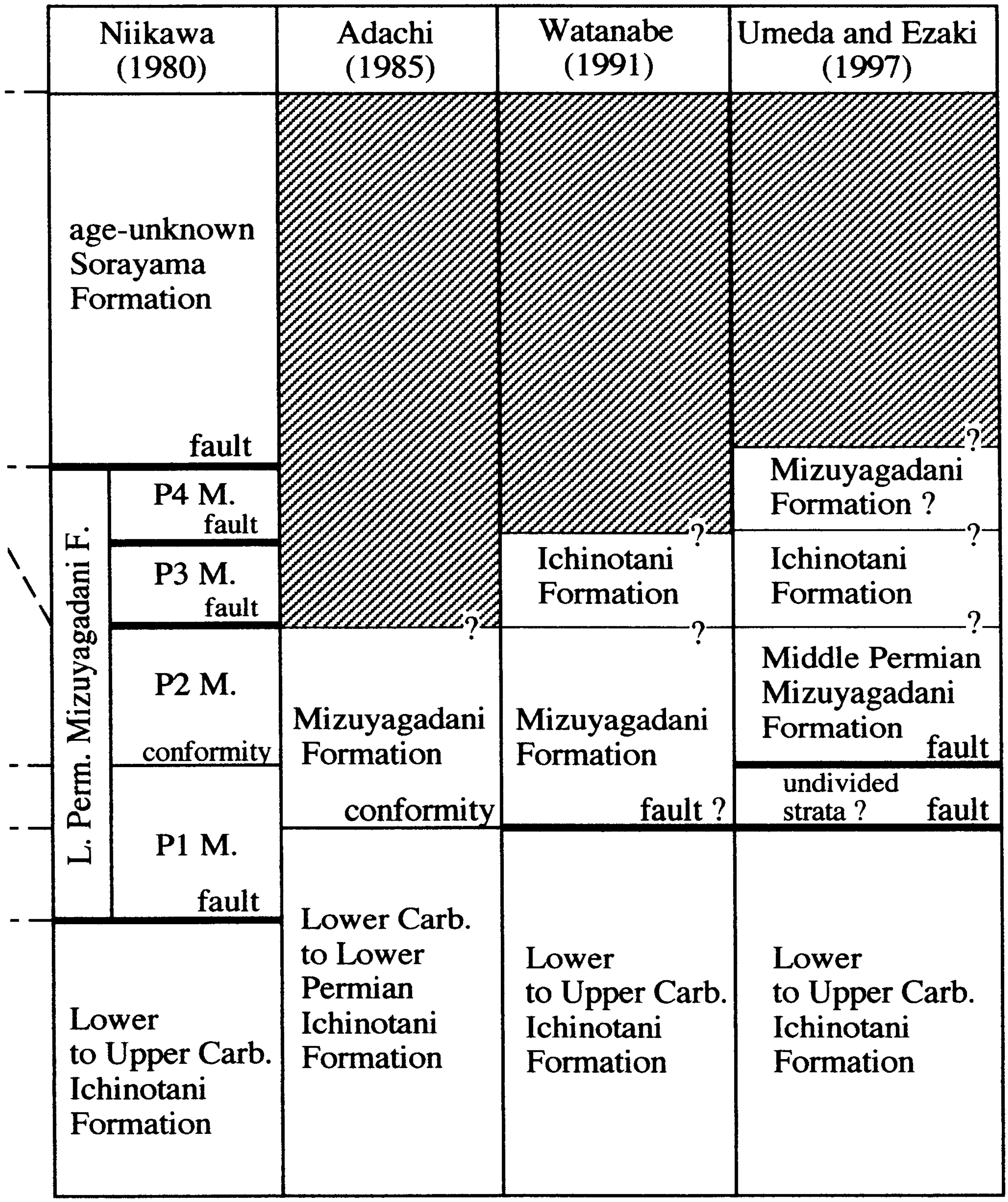


Fig. 14 Newly proposed definition of the Permian strata in the Fukuji area, compared with the definitions by Igo (1956a, 1957a, 1990), Niikawa (1980), Adachi (1985), Watanabe (1990), and Umeda and Ezaki (1997).
F. : Formation, M. : Member, L. : Lower, Carb. : Carboniferous.

Along the Osobudani Valley, a number of east-trending crash zone and phyllite-like shear zone are observed. This suggests that the boundary between the HTZ and the Mino Belt is in the Osobudani Valley, and the strata of M2 may not be in the HTZ. Whether the strata of M2 are in the HTZ or not is not discussed here, and they are dealt with as "undivided strata" in this paper.

1-2. The lowermost part of the Mizuyagadani Formation

In the present study, the calcareous clastic rocks and fossiliferous mudstone in the area of lower stream of the Mizuyagadani Valley are defined as the Lowermost Member of the Mizuyagadani Formation (Figs. 4, 5, 14). The reasons are as follows; 1) the Permian felsic tuff of the Mizuyagadani Formation conformably overlies the fossiliferous mudstone, 2) The Mizuyagadani Formation is defined as the clastic rocks of M1 in the study.

Igo (1959) reported the Lower Permian corals (*Sochkineophyllum japonicum*, *S. japonicum pauciseptatum*) and fusulinaceans (*Pseudofusulina vulgaris* and others) from calcareous tuff of the Lowermost Member. The occurrence shows that these fusulinaceans may be contemporaneous or penecontemporaneous (Igo, 1959). Umeda and Ezaki (1997) reported Middle Permian radiolarians (*Pseudoalbaillella longicornis*, *Follicucullus monacanthus*, and others) from felsic tuff just above the base of the Lower Member. The radiolaria-bearing felsic tuff overlies the calcareous clastic rocks including the above Lower Permian corals and fusulinaceans. Bedding planes of both Members are almost parallel to subparallel, and there is no evidence of unconformity such as erosion and basal conglomerate. These facts suggest that above-said two members were settled conformably (Figs. 4, 5).

However, the age of *Pseudofusulina vulgaris* zone and that of *Follicucullus monacanthus* zone are correlated to Artinskian and lower Midian stages, respectively (Rotai, 1979; Watanabe, 1991; Ezaki and Kuwahara, 1994; Kotlyar, 1994), suggesting that there is a large hiatus between both members from the viewpoint of fossils.

Tsukada et al. (1999) mentioned that the correlation between the Middle Permian radiolarian and fusulinacean zonations may be uncertain. In this paper, we infer that the Lowermost Member is conformably overlain by the Lower Member on the basis of the field evidence.

1-3. Stratigraphical relationship between the Mizuyagadani Formation and the Ichinotani Formation

The following two lines of evidence suggest that the Mizuyagadani Formation primarily overlies the Ichinotani Formation; 1) Type-1 conglomerate observed in several levels of the Mizuyagadani Formation includes angular to subangular Carboniferous limestone clasts which were derived from the Ichinotani Formation (Kamei, 1952; Igo, 1956a; Niikawa, 1980), 2) the lowermost part of the Mizuyagadani Formation with thick calcareous strata (about 15 m thick) includes abundant angular limestone clasts and fossil fragments which are similar to those of the Ichinotani Formation.

2. Sorayama and Kashiate Formations

2-1. Redefinition of the Sorayama and Kashiate Formations

Previously, it was believed that the Kashiate Formation is included in the "Sorayama Formation" (e.g. Igo, 1956a). In the present study, the Middle Permian strata which are composed mainly of intermediate to mafic pyroclastic rocks are redefined as the Sorayama Formation, and the age-unknown mafic lava, gabbro, and breccia including abundant mafic igneous rock clasts are excluded from the previous “Sorayama Formation,” and newly named as the Kashiate Formation (Figs. 2, 9, 14). The Kashiate Formation is thrust over the Sorayama Formation with a remarkable shear zone (Figs. 11d, e, f, g).

2-2. Stratigraphy of the Sorayama Formation

The Sorayama Formation was subdivided into the Lower and Upper Members on the basis of lithology by Igo (1956a) (Fig. 9). Here, the Lower Member of Igo (1956a) is included into the Mizuyagadani Formation, and the Upper Member is dealt with the Sorayama Formation. The redefined Sorayama Formation is subdivided into the Members from A to D by lithology in ascending order (Fig. 9).

3. Stratigraphical Level of Three Conglomerates (the Ichinotani, Mizuyagadani, and Osobudani Conglomerates)

It has been considered that the Ichinotani Conglomerate (★1 of Fig. 3), the Mizuyagadani Conglomerate (★2 of Fig. 3), and the conglomerate of M2 (★3 of Fig. 15, Fig. 16) are on the same stratigraphical level as the basal conglomerate of the Sorayama Formation by Igo (1956a, b, c, d). The conglomerate of M2 was named the Osobudani Conglomerate, and this was used for a general term of the three conglomerates (Igo, 1956a, b, c, d). On the other hand, Niikawa (1980) considered that these three conglomerates are not one and the same stratigraphic unit and not the basal conglomerate of the Sorayama Formation.

The following two points are discussed further; 1) the stratigraphical level of three conglomerates, and 2) the base of the Sorayama Formation.

3-1. The Stratigraphical Level of Three Conglomerates

It is inferred that above three conglomerates are on the different stratigraphical levels. The reasons are as follows; 1) As already mentioned, the Ichinotani Conglomerate belongs to Type-3 conglomerate, whereas, the Mizuyagadani Conglomerate is mixture of Type-1 and Type-2 conglomerates. The Osobudani Conglomerate includes clasts of felsic to intermediate volcanic rock, sandstone, mudstone, limestone, and granitoid granules to boulders, in a matrix of coarse-grained sandstone. Granitoid clasts are commonly observed in the Osobudani Conglomerate (Fig. 16b); in contrast, no granitoid clasts are observed in the Ichinotani and Mizuyagadani Conglomerates. These three conglomerates have quite different clast composition and matrix lithology. 2) The Ichinotani Conglomerate is exposed on the upper level than that of the Mizuyagadani Conglomerate in the upper stream of the Mizuyagadani Valley (Fig. 3).

3-2. The base of the Sorayama Formation

The base of the Sorayama Formation can be defined as the base of the intermediate to mafic pyroclastic rock (the base of Member A of the Sorayama Formation), and we consider that three conglomerates mentioned above are not the basal conglomerates of the Sorayama Formation. The reasons are as follows; 1) field evidence suggests that the alternating beds of sandstone and mudstone, mudstone, and felsic tuff which should be included in the Mizuyagadani Formation crop out on the upper levels than the Ichinotani Conglomerate and the Mizuyagadani Conglomerate (Fig. 3), 2) interme-

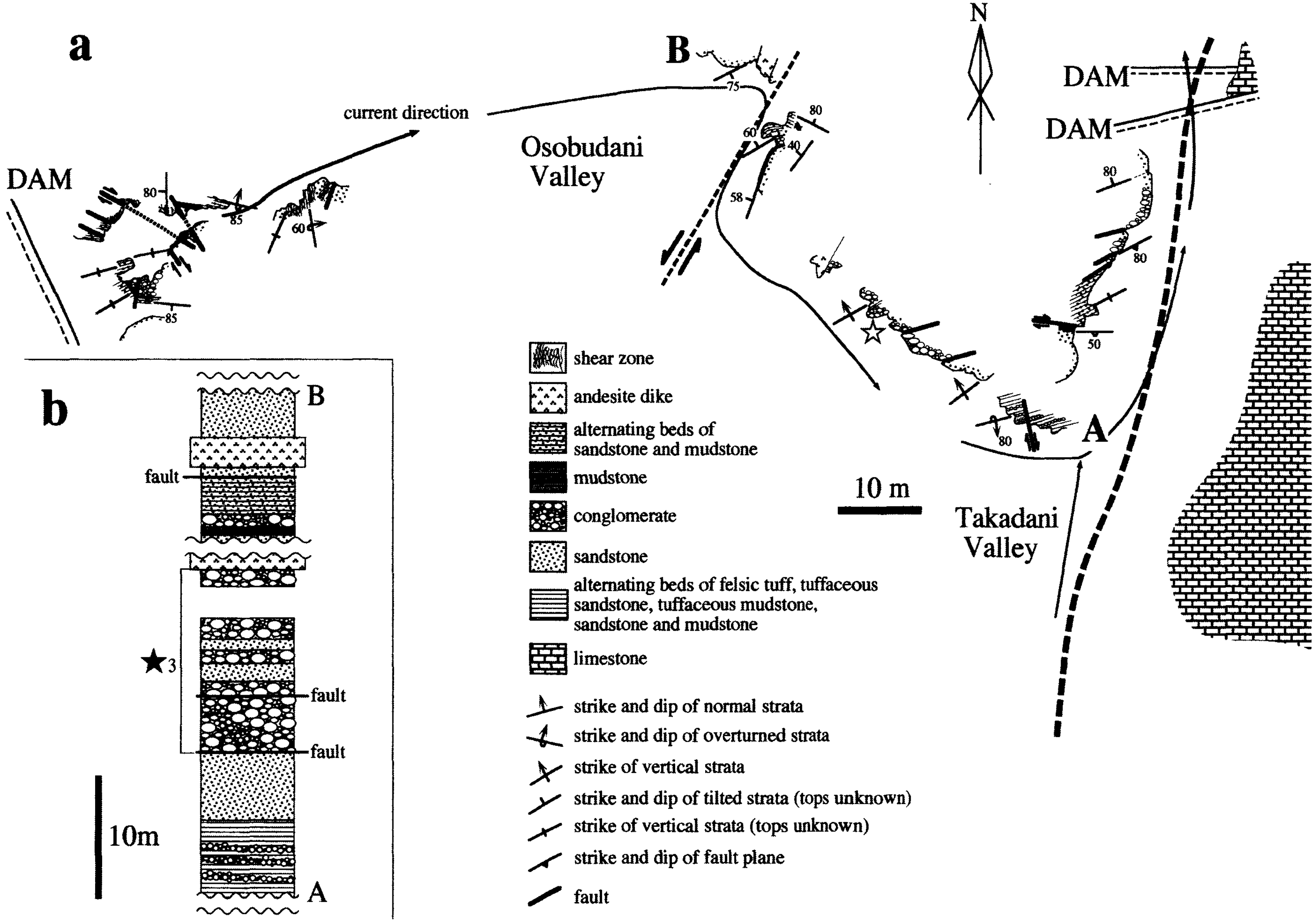


Fig. 15 Route map (a) and columnar section (b) along the Osobudani Valley (Loc. 3 of Figs. 1 and 2). The columnar section shows lithostratigraphy from A to B of the route map. Star in the route map shows locality of Fig. 16.

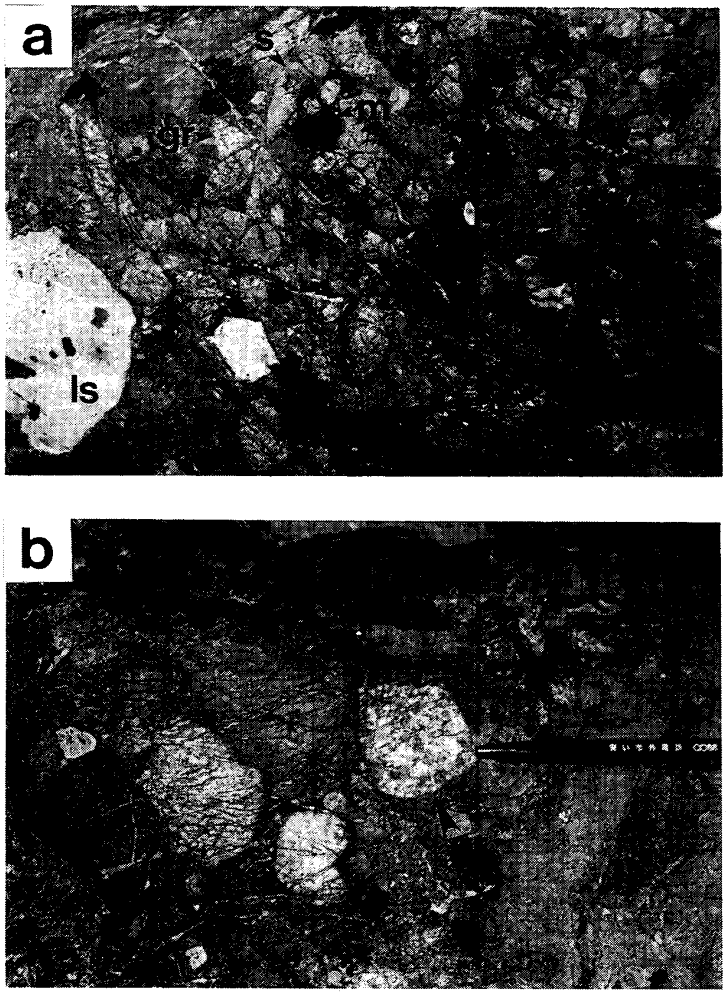


Fig. 16 Photographs showing the occurrence of the Osobudani Conglomerate. (a) The Osobudani Conglomerate includes well-rounded clasts of felsic to intermediate volcanic rock, sandstone, mudstone, limestone, and granitoid in a matrix of coarse sandstone. The clasts are granule to boulder in size. (b) Photograph showing the granitoid clasts in the Osobudani Conglomerate. The Osobudani Conglomerate includes granitoid clasts commonly.
ls: limestone, fv: felsic volcanic rock, s: sandstone, m: mudstone, gr: granitoid.

diate to mafic volcanic rock clasts are rare in the Ichinotani and the Mizuyagadani Conglomerates. The Mizuyagadani Conglomerate is quite different from Member A of the Sorayama Formation in clast composition and lithofacies of matrix, 3) The abrupt changes in lithology, sedimentary environment and volcanic activity are not recognized in the bottom of the Ichinotani and of the Mizuyagadani Conglomerates, but in the bottom of the intermediate to mafic pyroclastic rock (Member A of the Sorayama Formation), 4) The stratigraphical relationship between the strata of M2 and the Sorayama Formation is not clear. The Osobudani Conglomerate is quite different from Member A of the Sorayama Formation in clast composition and lithofacies of the matrix. Furthermore, this conglomerate is overlain by alternating beds of sandstone and mudstone (Fig. 15).

These lines of evidence show that these three conglomerates are not the basal conglomerate of the Sorayama Formation.

SUMMARY

We redefined the previous "Permian Formations" as follows: 1) the Lower to Middle Permian Mizuyagadani Formation which is in fault contact with Carboniferous Ichinotani Formation is composed mainly of clastic rocks, and is subdivided into four Members based on its lithology, 2) the Middle Permian Sorayama Formation which conformably overlies the Mizuyagadani Formation is composed mainly of intermediate to mafic pyroclastic rocks, and is subdivided into four Members based on its lithology, 3) the age-unknown Kashiate Formation which is thrust over the Sorayama Formation is composed mainly of mafic volcano-plutonic rocks and breccia containing abundant volcano-plutonic rock clasts.

Although the three conglomerates (the Ichinotani, Mizuyagadani, and Osobudani Conglomerates) were dealt with as the basal conglomerate of the Sorayama Formation previously, these conglomerates are on the different stratigraphical levels as the intraformational conglomerate of the Mizuyagadani Formation and "undivided strata."

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河川名および地名など

Gamatagawa .... 蒲田川	Takaharagawa .... 高原川
Aotani .... 青谷	Esakakedani .... 餌掛谷
Horatani .... 洞谷	Ichinotani .... 一ノ谷
Iranodani .... イラノ谷	Iwatsubodani .... 岩坪谷
Kashiatedani .... 柏当谷	Mizuboradani .... 水洞谷
Mizuyagadani .... 水屋鶩ヶ谷	Osobudani .... オソブ谷
Otani .... 大谷	Shiritakadani .... 尻高谷
Sorayama .... 空山	Takadani .... 高谷
Fukiji .... 福地	Kansaka .... 神坂
Murakami .... 村上	Zuntsuji .... 禅通寺