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Permian Maizuru Group and Yakuno Ophiolitic Rocks in the Northeastern Part of Yanahara Area in Okayama Prefecture, Southwest Japan

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A Permian convergent margin rock suite is discussed on the basis of the results of precise mapping at the junction area of the Maizuru and the Kozuki-Tatsuno Belts. Middle to Late Permian radiolarians have been discovered from both the Kozuki unit (argillite-meta volcanics-bedded chert) and the Maizuru Group (predominantly mudstones). The newly proposed Tonoshiki Formation is composed of sedimentary breccias interpreted as being derived mostly from the Yakuno Ophiolitic rocks. Lower Permian radiolarians have been discovered from mudstone intercalated in the Tonoshiki breccias. The formation is regarded to have been deposited on the ophiolite. The Yakuno Ophiolitic rocks together with the Tonoshiki Formation may have constituted a volcanic arc system, separating the Maizuru and Kozuki basins in Middle Permian time. The Tonoshiki Formation can be compared with the Upper Permian Upukerora Formation of the Maitai Group from the South Island of New Zealand, which was derived predominantly from the underlying Dun Mountain Ophiolite.

1. Introduction

Recent work has subdivided rocks of Southwest Japan on the basis of terrane analysis. These studies have culminated in the volume "Pre-Cretaceous Terranes of Japan" edited by K. ICHIKAWA, S. MIZUTANI and I. HARA (1987), in which ICHIKAWA emphasises the division into an A terrane group (pre-Jurassic accreted terranes) and a B terrane group (Jurassic to Cretaceous accreted terranes).

Within the A terrane group, a Permian-Triassic "composite terrane" is recognised extensively in Southwest Japan. Three main constituent terranes–Akiyoshi-Nishiki, Maizuru and Ultra-Tamba are recognised. Rocks of the latter two comprise the study area described here, cropping out between the Sangun metamorphic terrane to the north and the Tamba Jurassic olistostromal terrane to the south. Maizuru rocks have been

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described for more than three decades (MATSUSHITA, 1950; NAKAZAWA, 1958; SHIMIZU, 1962; SHIMIZU *et al.*, 1962). Ultra-Tamba rocks have only recently been distinguished from Maizuru and Tamba strata (CARIDROIT *et al.*, 1985; ISHIGA, 1986).

The Maizuru terrane, named for its characteristic lithostratigraphic unit, the Maizuru Group, extends as an elongate NE–SW trending structural belt (the Maizuru belt) from near Maizuru City at the boundary between Kyoto and Fukui Prefectures southwest to the Okayama region (Fig. 1). Extensions to the northeast as far as North Fossa Magna (KOMATSU *et al.*, 1985) and to the southwest to near Hiroshima are provisionally recognised (WATANABE *et al.*, 1987; ISHIGA, 1987), suggesting an overall length in excess of 700 km. In addition, rocks of the Maizuru terrane are also recognised in a southeasterly trending structural zone, the Kamigori belt, which splits off the main Maizuru belt near Tsuyama (Figs. 1 and 2).

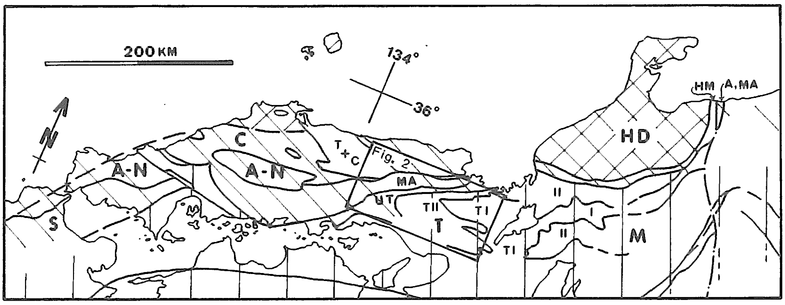

Fig. 1. Index map showing the tectonic division of Pre-Cretaceous terranes of Southwest Japan (after ICHIKAWA, 1987).
HD; Hida terrane. HM; Hida marginal (Hida-gaien) terrane. A-N; Akiyoshi-Nishiki terrane. MA; Maizuru terrane. UT; Ultra-Tamba terrane. S; Suou terrane. C; Chizu terrane. T; Tamba terrane (T II; Upper Tamba nappe, T I; Lower Tamba nappe). M; Mino terrane.

Lithological components of the Maizuru terrane include (1) Maizuru Group–middle to upper Permian mudstones and tuffs with turbidite sandstones in the upper part and possible volcanic rocks near the base, (2) locally developed Triassic shelf sediments which unconformably overlie the Maizuru Group, and (3) Yakuno Igneous Complex, a disrupted suite of mafic and felsic intrusives, widely described as ophiolitic, and believed to form the Maizuru Group basement.

The Ultra-Tamba terrane, named by WATANABE *et al.* (1987) for rocks described as Ultra-Tamba zone by CARIDROIT *et al.* (1985) and ISHIGA (1986) comprises three intimately associated but structurally and lithologically distinctive Permian sedimentary and volcanic units (Hikami and Oi Formations; Kozuki unit) which are grouped together on the basis of similar radiolarian faunas, age and tectonic position. Ultra-Tamba rocks lie in thrust contact upon the Mesozoic Tamba terrane and are in turn overthrust by rocks of the Maizuru terrane. They have been described as forming the frontal zone

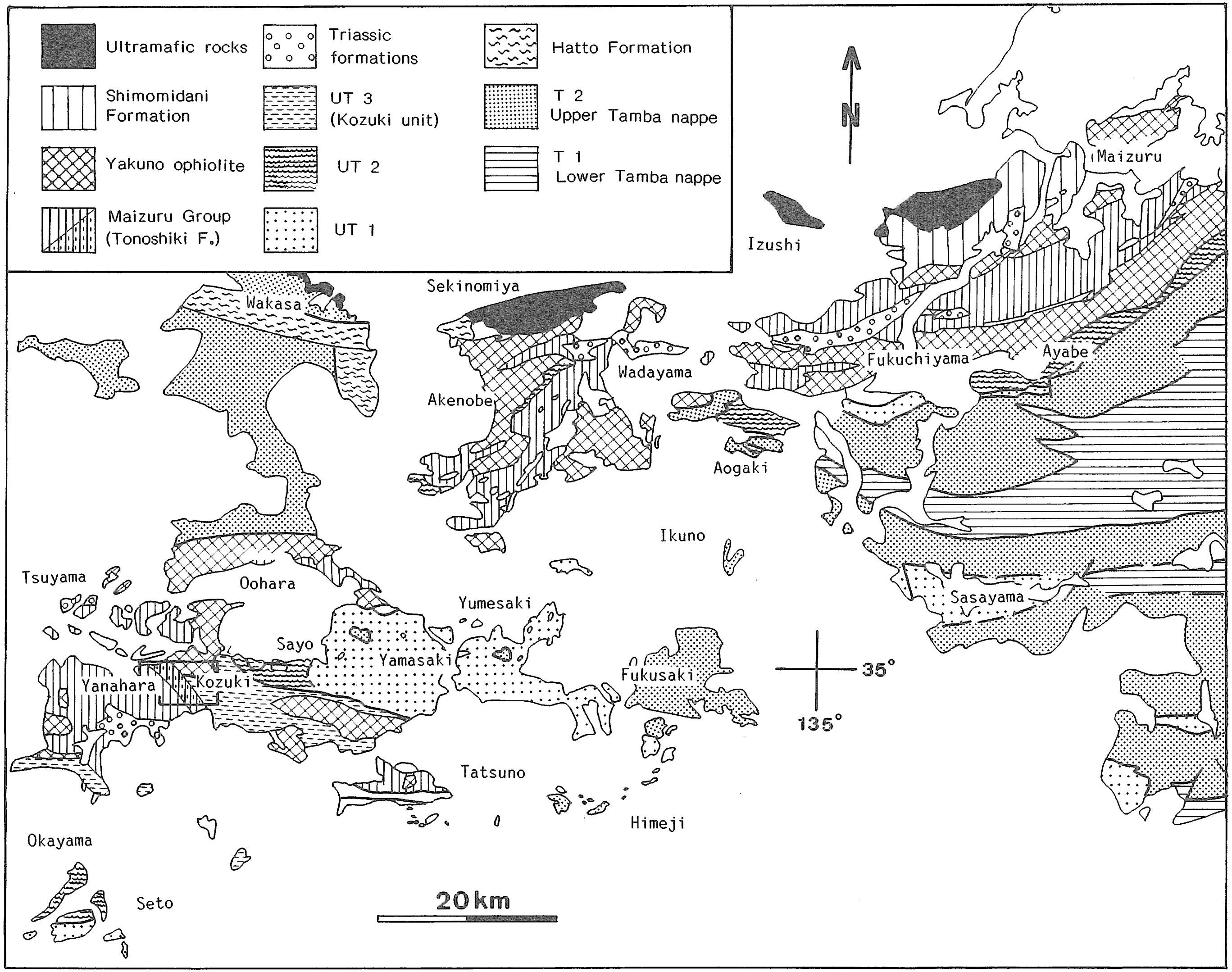

Fig. 2. Compiled geologic map of the Maizuru terrane and adjacent areas showing location of study area (Ishiga 1987, partly modified)

of the A terrane group (ISHIGA, 1986). The Ultra-Tamba terrane forms a narrow belt along the southern side of, and as fault slices within, the Maizuru terrane, extending approximately 100 km from Obama southwest to near Akenobe. Farther southwest, in the Sayo-Kozuki region (Fig. 2), Ultra-Tamba rocks comprise a substantial component of the southeast trending Kamigori belt.

The study area described here is located at the junction between the northeast trending Maizuru belt and the southeast trending Kamigori belt, in an area where Maizuru Group, Yakuno Igneous Complex, and Kozuki unit are all exposed (Fig. 2; IGI and WADATSUMI, 1980; IGI, 1981). The Lower to Middle Triassic Fukumoto Group (NAKAZAWA *et al.,* 1954) unconformably overlies Maizuru Group rocks west of the area mapped. Understanding the sedimentary and structural evolution of this region is essential for reconstructing the late Paleozoic arc-trench system.

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2. A BRIEF REVIEW OF THE MAIZURU TERRANE, ULTRA-TAMBA TERRANE AND YAKUNO OPHIOLITIC ROCKS

Rocks of the Maizuru terrane (WATANABE *et al.*, 1987) broadly correspond to rocks mapped as the Maizuru Zone by MATSUSHITA (1953) in the Maizuru area, at the boundary between Kyoto and Fukui Prefectures. He distinguished the Maizuru Zone from similar rocks in the neighbouring Chugoku Zone to the NW and from the Tamba Zone to the SE by the additional presence of Yakuno basic intrusive rocks and Triassic sediments. Although basic intrusive rocks have since been described from the Chugoku Zone and Triassic sediments have been discovered in both the Chugoku and Tamba Zones, the existence of the Maizuru terrane is still recognized. This is largely due to advances in radiolarian biostratigraphy. The Maizuru Zone has been divided into three components on the basis of work by NAKAZAWA (1958), KANO *et al.* (1959); SHIMIZU *et al.* (1962) and SHIMIZU (1962).

1) Middle to Upper Permian Maizuru Group consisting mainly of mudstones and acid tuff with possible metavolcanics at the base and becoming sandy toward the top.

2) Lower to Middle Triassic shelf sediments assigned to the Yakuno, Shidaka, Fuku-

moto and Miharaiyama groups which consist of shallow facies sandstone, shale and conglomerate; Upper Triassic shelf sediments, namely the Nabae and other correlated formations.

3) Yakuno Complex consisting of basic and acidic intrusive rocks interpreted as basement rocks tectonically underlying the Maizuru Group.

Rocks assigned to the Maizuru Belt crop out in a generally NE–SW trending zone in the Inner Side of SW Japan. An exception to this pattern occurs near Kamigori, Hyogo Prefecture, where Maizuru strata extend in a SE trending branch of the main belt. This is the Kamigori belt (Hyogo-ken, 1961; IGI and WADATSUMI, 1980). IGI and GOTO (1981) redefined this belt as the Kozuki-Tatsuno belt, reflecting the interpretation that the belt comprises the Carboniferous Kozuki Formation and the Permian Tatsuno Group, the latter correpsonding to the Maizuru Group proper.

The Ultra-Tamba belt (terrane) was proposed by CARIDROIT *et al.* (1985), and has been examined in detail by ISHIGA (1986, 1987). Recently, a new unit called UT 3 (Kozuki unit of this paper) has been recognized in the Kozuki area of the Kamigori Belt. The Kozuki unit contains a radiolarian fossil assemblage which characterizes the Ultra-Tamba terrane (PILLAI and ISHIGA, 1987; ISHIGA, 1987).

Yakuno ophiolitic rocks have long been studied by many workers (IGI, 1959, 1973; NAKAZAWA, 1961; KANO *et al.*, 1961; HIRANO, 1969; AGATA, 1974; KUROKAWA, 1984; ISHIWATARI, 1985, 1986, etc). NAKAZAWA (1961) and KANO *et al.* (1961) proposed that these rocks were older than and perhaps the basement of the Maizuru Group. The irregular nature of their occurrence has led to the proposal that the Yakuno should be called a dismembered ophiolite (KOIDE, 1986; ISHIWATARI, 1986). In fact, the Yakuno is not a true ophiolite regardless of tectonic disruption since sheeted dyke complex are not yet recognized, volcanic rocks are very rare throughout and both volcanic and ultramafic rocks are very rare in the Kamigori belt.

Yakuno ophiolitic rocks in the Maizuru City area were derived from unusually thick oceanic crust (ISHIWATARI, 1985), while in the east of the Yanahara area, they are interpreted as being formed in an island-arc environment (ISHIWATARI, 1986). The age of the Yakuno Ophiolite is not well understood, however, a metamorphic K-Ar age for amphibole of 228–278Ma (SHIBATA *et al* ., 1977) and Rb-Sr age of 285Ma (KOIDE *et al.*, 1987) were reported. The Yakuno Ophiolite was emplaced at the latest during the deposition of the Maizuru Group. KANO *et al.* (1959) recorded amphibolite boulders in the uppermost conglomerate beds of the Maizuru Group in the Maizuru area. Later in this paper we present further evidence for determination of the upper limit of this event.

3. GEOLOGY OF THE STUDY AREA AND ITS ENVIRONS

3.1 Maizuru Group

Permian rocks predominantly composed of black shales with acid tuff and sandstone beds were mapped in the Yanahara area (Fig. 2) and named Dodo, Kose, Yanahara and

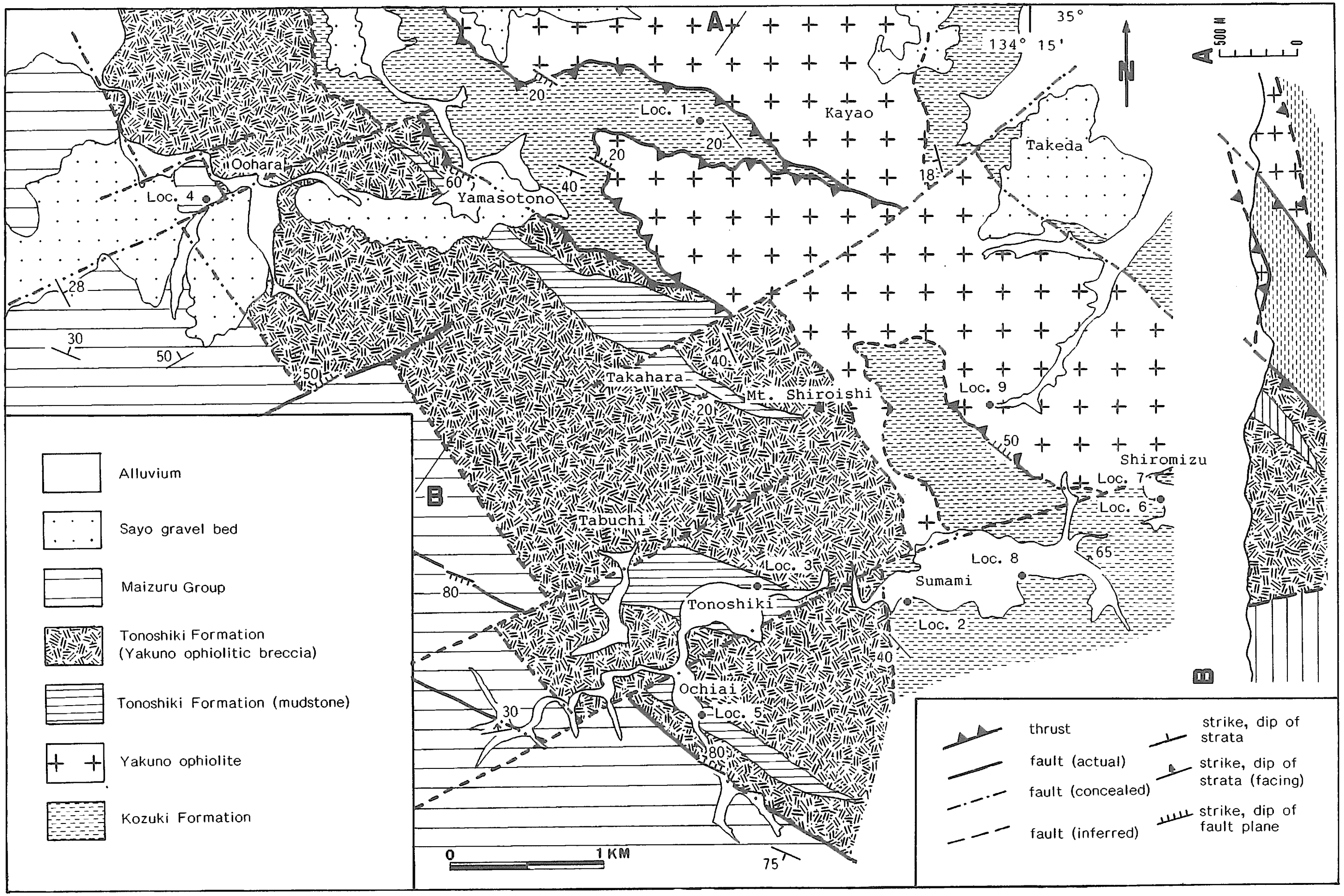

Fig. 3. Geologic map and geologic profile of the surveyed area (N.B., KOZUKI Formation refers to KOZUKI unit as used in the text.)

Nigaki Groups by MITSUNO and OMORI (1965). It was generally considered that these groups formed a stratigraphic succession. Elsewhere in the Maizuru Belt the base of the Maizuru Group consists of lower Permian basic volcanics, however these are absent from the Maizuru Group in the Yanahara area and the base of the group is considered to be faulted.

The Nigaki Group, which is composed of metamorphosed basic volcanics and highly sheared shale, was included in the Maizuru Group of this area by MITSUNO and OMORI (1965). This group may correspond lithologically to the Kozuki rocks of the Kamigori belt, but as yet, no radiolarian fossils have been discovered to test this idea.

Middle Permian radiolarian assemblages from *Pseudoalbaillella longtanensis?* to *Follicucullus scholasticus* Assemblages have been extracted from the Dodo, Kose and Yanahara groups, and the three are now considered to be correlative (NISHIMURA, 1987; NISHIMURA and ISHIGA, 1987). Since they are also lithologically similar, continued usage of these three groups is no longer necessary.

The Maizuru Group sedimentary rocks of the Yanahara area strike in a generally NW–SE direction subparallel to the trend of the Kamigori Belt. Although not as highly deformed as the Kozuki unit, the Maizuru Group appears to lack a consistent younging direction, and is complicated by folding and faulting (NISHIMURA and TOKUOKA, 1986).

In this study area the predominant Maizuru lithology is mudstone which is associated with fine- to medium-grained sandstones and interbedded sandstone and mudstone (Fig. 3; Plate 1, Figs. 2 and 4). Middle Permian radiolarians from the *Pseudoalbaillella* sp. C. and *Follicucullus scholasticus* Assemblage Zones have been discovered from an area adjacent to the present study area (NISHIMURA and TOKUOKA, 1986; NISHIMURA and ISHIGA, 1987). *Follicucullus monacanthus* and *P.* sp. were discovered from mudstone at Loc. 4 in Fig. 3. The age of the Maizuru Group in the present area is inferred to be Middle to Late Permian.

3.2 Kozuki Unit

The Kozuki Formation was originally proposed by GOTO (1965) for rocks of the Kozuki area (Fig. 2). He considered the Kozuki Formation to belong to the Maizuru Belt in the "Maizuru extension" (that is, the Kamigori belt). However, the occurrence of bedded chert which is absent from the Maizuru Group caused other workers to reject this correlation. Detailed stratigraphic work by GOTO (1987MS) led him to propose a new Kozuki Group composed of three formations, however, as the stratigraphic details have not yet been published and our mapping reveals structural complications, we prefer the general term Kozuki unit in the meantime (see also PILLAI and ISHIGA, 1987). Recently radiolarian fossils have enabled correlation of the Kozuki unit with the Ultra-Tamba terrane (PILLAI and ISHIGA, 1987; ISHIGA, 1987).

The Kozuki unit is distributed in the northeastern half of the study area. It is characterized by black argillite and shaley phyllitic beds along with subordinate pebbly-sandy diamictite, acidic tuff, chert, metamorphosed pillow-basalt and basaltic hyaloclastite. Volumetrically, hyaloclastite predominates over metamorphosed pillow basalt. At many localities hyaloclastite is intercalated with argillaceous sediments indicating contemporaneous volcanism with pelitic sedimentation. For example, along the roadside from Takahara to Kayao (Loc. 1 in Fig. 3), basic volcanic rocks, predominantly hyaloclastite, are interbedded with argillite and rare pillow lavas. Pillow lavas can also be observed at Locs. 6 and 7 in Fig. 3 (Plate 2, Figs. 1 and 2). At some localities hyaloclastite is composed of only one type of basaltic rock fragments enclosed within a recrystallized basaltic glass matrix. At other localities fragments in the hyaloclastite exhibit a wide variety of basaltic textures (plate 3, Fig. 3).

Diamictites contain granule to pebble sized clasts of acidic to basic volcanics, sandstone, tuff and argillite dispersed in a argillaceous matrix. Some clasts exhibit detrital rounding, whereas others such as muddy sandstone, argillite and tuff are very angular and probably locally derived. All clasts are now flattened subparallel to the well developed foliation direction (Plate 3, Fig. 2). Diamictites are interbedded with argillite and silicic tuff, for example at Loc. 8 in Fig. 3 along the riverside west of Sunami, argillites are interbedded with diamictites (Plate 2, Fig. 4).

Late Carboniferous fusulinids and corals occur in limestone lenses intercalated with metavolcanics further to the east in the Hieda area (GOTO, 1965; IGI and WADATSUMI, 1980). Because of these fossils, the Kozuki unit was originally assigned an entirely Carboniferous age. However, more recently lower to middle Permian radiolarians have been discovered from argilliceous and siliceous rocks (GOTO and HORI, 1985; OHOKA, 1984MS), late Middle to early Late Permian *Follicucullus scholasticus* morphotype I was reported by GOTO, 1987 (MS) and early Late Permian *Follicucullus bipartitus-F. charveti* Assemblage was found in tuffaceous and argillitic rocks (PILLAI and ISHIGA, 1987).

Ubiquitous shearing is a characteristic of the Kozuki unit and it unclear whether the rocks represent a true stratigraphic sequence. The Kozuki unit strikes predominantly in an east-west direction, dip is usually moderate to steep. In the Ishido area, on the eastern extreme of the mapped area, the Kozuki unit youngs to southeast but strata at other localities young in the opposite direction. The variation in younging direction, the ubiquitous shearing, and frequent occurrence of faults suggests structural complications and these rocks may, at least in part, represent a broken formation.

High-angle fault contacts separate the Kozuki from the Yakuno ophiolitic rocks in several places. From a regional tectonic viewpoint (CARIDROIT *et al.,* 1985; ISHIGA, 1987), it is likely that the Kozuki is previously overlain by the Yakuno with a low-angled thrust contact.

3.3 Yakuno Ophiolitic Complex

In the Yanahara area rocks mapped as meta-granite, meta-quartzdiorite, meta-felsite, meta-diabase and meta-gabbro by Mitsuno and Omori (1965) occur in the zone between the Kozuki unit and the Maizuru Group. They proposed that the Yakuno intruded the Maizuru Group in Triassic time. It is now generally believed that these rocks constitute part of the dismembered Yakuno Ophiolitic Complex. However pillow lavas and ultramafic rocks are absent from the Yakuno rocks in the Yanahara area, and the term "ophiolitic" can be used only in a regional sense.

Yakuno rocks also occur further east in the Kozuki area as large blocks trending WNW–ESE parallel to the trend of the Kamigori Belt and within the Kozuki unit (Igi and Wadatsumi, 1980, Fig. 2).

In the study area, the Yakuno ophiolitic rocks are well exposed and are composed mostly of metamorphosed gabbroic rocks (Plate 2, Fig. 5). These are medium- to coarse-grained, and massive. Plagiogranite is also common. Small quantities of anorthosite and other rocks are also found associated with the meta-gabbro and plagiogranite. Serpentinite occurs along the faulted boundary with the Kozuki unit at several localities.

3.4 Tonoshiki Formation (*newly proposed*)

The Tonoshiki Formation is distributed in a NW–SE trending direction in the central part of the study area. The area occupied by the newly proposed unit, the Tonoshiki Formation, was previously mapped as meta-granite by Mitsuno and Omori (1965). The Tonoshiki Formation is well exposed along the road from Ochiai to Takahara and crops out extensively to the east of the small village of Tonoshiki from which the name is derived (Figs. 4, 5). The Tonoshiki Formation is composed almost entirely of sedimentary breccias containing predominant clasts similiar in lithology to rocks of the Yakuno Ophiolite. At first inspection, hand specimens of the breccia look superficially like a kind of brecciated or cataclastic igneous rock, however, careful examination reveals its sedimentary nature.

The Tonoshiki Formation is mostly composed of breccias, attaining a thickness of more than several hundred metres. Several mudstones layers are intercalated with the breccias, from which Lower Permian radiolarians have been discovered (Plate 1, Fig. 3). It is in fault contact with the Kozuki unit to the north and east, and with the Maizuru Group to the southwest. The contact between the Tonoshiki Formation and the Yakuno ophiolitic rocks is also inferred to be faulted.

Massive breccias are common in the formation (Plate 1, Fig. 1), however parallel lamination or parallel alignment of clasts can also be observed in several places. Clasts are sometimes subangular or rarely subrounded (Fig. 6; Plate 3, Fig. 1). These are mostly composed of amphibolite or meta-gabbro, and subordinately of plagiogranite and

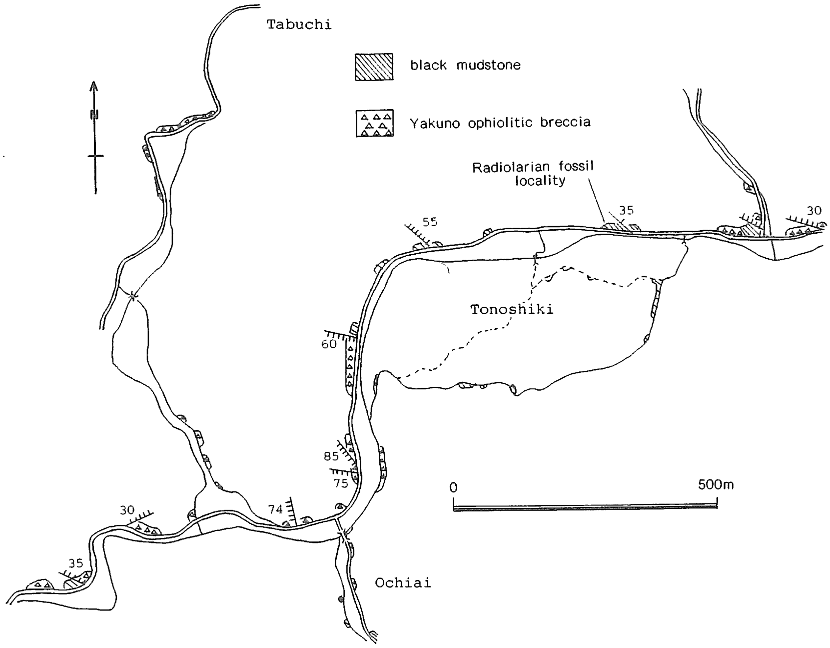

Fig. 4. Route map of the Tonoshiki Formation along the road from Ochiai to Tabushi showing the radiolarian fossil locality.

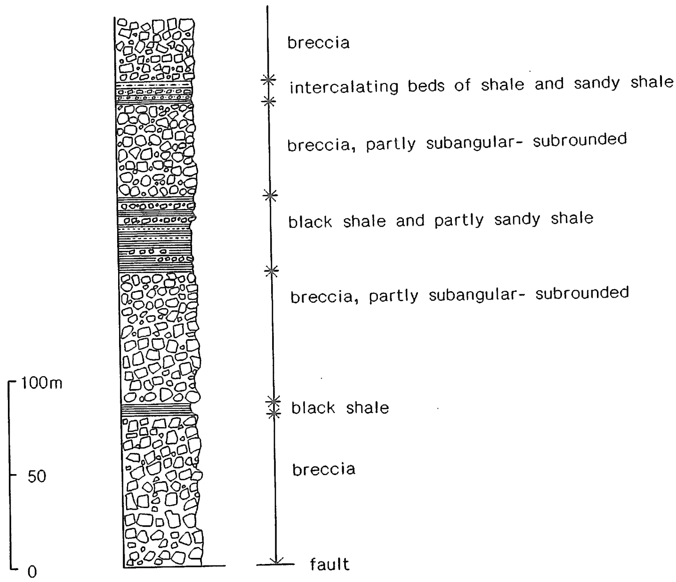

Fig. 5. Columnar section of the sequence of the intercalated terrigenous sediments in the Tonoshiki sedimentary breccia at Takahara.

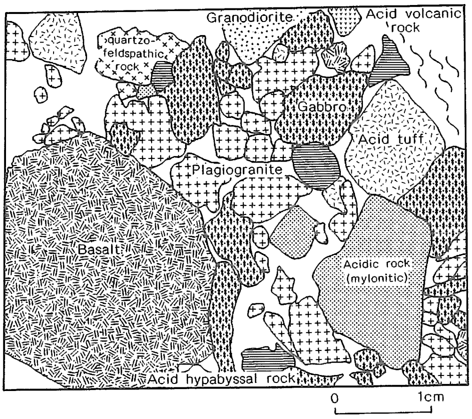

Fig. 6. Sketch of a thin section of Yakuno sedimentary breccia (compare with Plate 3, Fig. 1).

Table 1. Chemical composition of representative clasts in the Tonoshiki breccia (H_2O-free). Analysis of trace elements is based on ICHIKAWA, H. *et al.* (1987).

	No. 1 AMP-1	No. 2 AMP-2	No. 3 BASALT	No. 4 ACIDIC-1
SiO_2	49.11wt %	54.39	47.40	73.20
TiO_2	0.96	1.17	0.98	0.11
Al_2O_3	14.11	14.10	18.39	12.78
Fe_2O_3	15.33	10.67	16.72	3.06
MnO	0.30	0.17	0.32	0.05
MgO	9.27	8.03	10.19	.05
CaO	8.31	7.80	2.06	9.12
Na_2O	2.25	3.15	3.20	1.68
K_2O	0.20	0.41	0.60	tr.
P_2O_5	0.08	0.08	0.08	0.04
Total	99.92	99.97	99.94	100.09
Zr	38ppm	60	41	71
Y	26	22	21	20
Sr	140	178	88	245
Rb	9	22	19	12
Zn	118	64	115	4
Cu	76	88	64	116
Ni	44	63	136	—
Cr	50	242	335	17
V	334	229	280	61
Ba	257	332	394	19

acidic volcanic rocks. Siliceous rock of unknown origin and mudstone clasts also occur in the conglomerates. Four clasts—amphibolite, metabasalt and acidic rock—were analysed by XRF for major and trace elements (Table 1). Amphibolites are non-alkaline, while the metabasalt is very weakly alkaline. Acidic rock containing quartz crystals and mylonitized brownish glassy materials shows high CaO and extremely low K_2O contents, presumably reflecting secondary chemical alteration. Figs. 7 and 8

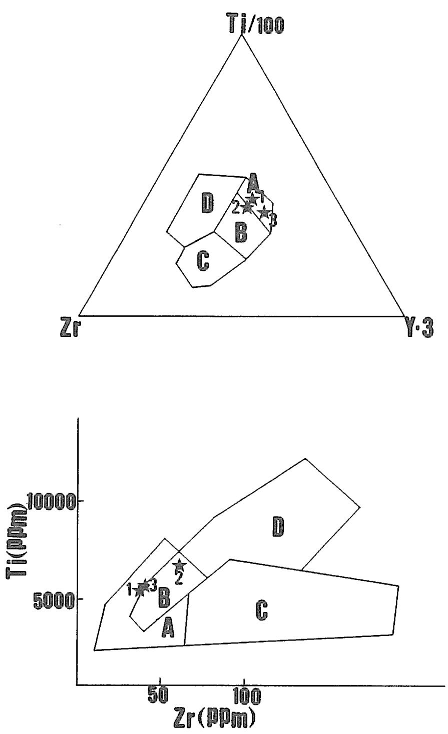

Fig. 7. Diagrams showing trace elements data of the breccia clasts in the Tonoshiki Formation. Sample numbers correspond to those in Table 1.

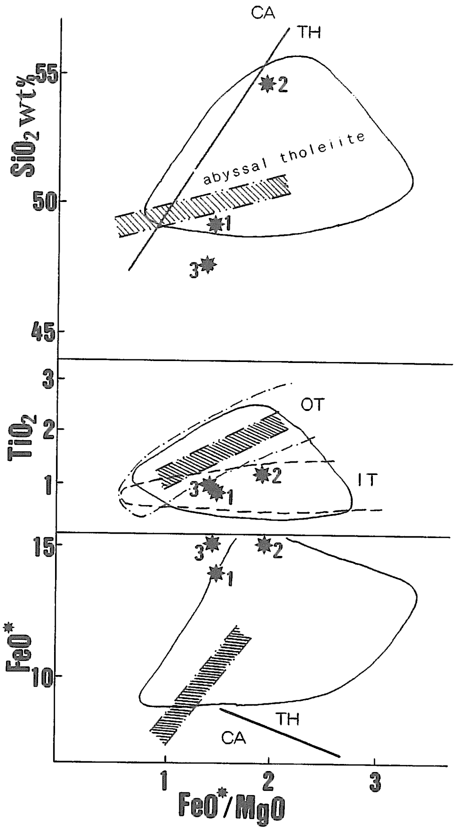

Fig. 8. MIYASHIRO's (1975) diagram showing chemical composition of the breccia in the Tonoshiki Formation. Enclosed area: Ibara ophiolite (KOIDE, 1987), OT, IT: classification by SHUTO *et al.*, 1985 (modified)

reveal that amphibolite and metabasalt are equivalent to island-arc tholeiite or abyssal tholeiite, though we tentatively assume very weak influence of spilitization for metabasalt as the basalt is composed mainly of albitized plagioclase and chlorite. A plot to $MnO-TiO_2-P_2O_5$ diagram and Cr–Y diagram show that they are of island-arc affinity rather than abyssal tholeiite due to high MnO and low TiO_2 and Y. V and Sr elements are high as island-arc tholeiite. It seems likely that the ophiolitic clasts which dominate these conglomerates were derived from the nearby island-arc crust (possibly thin), presumablly a part of the Yakuno ophiolitic rocks. Clasts range from pebble to boulder size and beds are generally poorly sorted suggesting deposition from a debris flow or other such mass transport mechanism.

4. Radiolarian Fossils

Radiolarian fossils have been discovered from mudstones in the Tonoshiki Formation exposed in the road-side near Tonoshiki (Loc. 3 in Fig. 3, Fig. 4 and Plate 1, Fig. 3). Continuous outcrop between this mudstone and the breccia beds cannot be found, however a conformable relationship between them is inferred. *Pseudoalbaillella* sp. cf. *P. sakmarensis* (KOZUR) (Plate 1, Fig. 8), one of the characteristic species of the Sakmarian; and *Pseudoalbaillella* sp. (Plate 1, Fig. 9) are identified among the radiolarian species. From this we conclude that the Tonoshiki Formation is, at least in part, Early Permian in age.

Follicucullus monacanthus and *P.* sp. were discovered from the Maizuru Group at Loc. 4 in Fig. 3 (Plate 1, Figs. 5, 6 and 7).

5. Discussion

NAKAZAWA (1961) and KANO *et al.* (1961) proposed that sediments of the Maizuru Group rest depositionally on the Yakuno Complex. The basic metavolcanics at the base of the Maizuru Group in the Ibara area are assigned to comprise the volcanic part of the Yakuno Ophiolite (KOIDE, 1986). Thus, it was suggested that subsequent tectonism has structurally dismembered the Yakuno Ophiolite from the presumed overlying volcanics and sediments of the basal Maizuru Belt (KUROKAWA, 1984; ISHIWATARI, 1986). In addition, ophiolitic debris is contained in the Upper Maizuru Group sediments (KANO *et al.*, 1961), implying a proximal relationship between these units from at least Late Permian time onwards.

The amphibolitic (or meta-gabbroic) and plagiogranitic fragments comprising the major clast types of the Tonoshiki Formation are most likely derived from the nearby Yakuno igneous rocks. Whole rock and trace element analyses of clasts are consistent with this interpretation (Figs. 7, 8). It is inferred that originally the Tonoshiki Formation had been deposited upon the Yakuno rocks. Lower Permian radiolarian fossils discovered from the Tonoshiki Formation require the genesis of the Yakuno Ophiolitic rocks to be even older, and thus provides an upper limit on the age of the Yakuno Ophiolitic rocks.

The Tonoshiki breccia contains acid volcanic and pyroclastic clasts, lithologies that do not occur in the Yakuno rocks. Either such lithologies have been subsequently eroded off Yakuno rocks or an additional detrital source such as an evolved volcanic arc is required. The poorly sorted, massive nature of the Tonoshiki breccias suggests deposition from debris flows. If so, this would require ophiolitic and volcanic detritus to be supplied to the basin from the same sediment transport direction. This implies that regardless of the site of origin of the Yakuno, it was part of a volcanic arc and was partly exposed as a structural high during the deposition of the Tonoshiki Formation. It is possible to interpret the Tonoshiki Formation as forming the base of the Maizuru Group, resting depositionally on the Yakuno Ophiolitic rocks. This would imply that Yakuno, Tonoshiki and Maizuru units together comprise one single terrane, Maizuru terrane, with a continuous history since the Permian.

The nature of occurrence of the Tonoshiki Formation a poorly sorted breccia derived predominantly from ophiolitic rocks, is very similiar to the Permian Upukerora Formation located at the base of the Maitai Group from the South Island of New Zealand (LANDIS, 1974; COOMBS *et al.*, 1976; LANDIS, 1980). The Upukerora Formation attains a thickness of 600 m and rests unconformably on volcanic rocks of the Lower Permian Dun Mountain ophiolite belt (PILLAI, 1981). The Upukerora is characterised by polymict breccias predominated by basic intrusive and volcanic clasts interpreted as being derived from the underlying ophiolite, however, some exotic arc-derived volcanic detritus is also present. The breccia beds are interpreted as talus cones and debris flow sheets derived from submarine scarps developed in oceanic crust adjacent to a volcanic arc (PILLAI, manuscript). Thus sedimentary units such as the Tonoshiki and the Upukerora Formations which directly overlie these ophiolites provide valuable information on the history of the ophiolitic rocks, from their origin to their subsequent incorporation into a convergent margin.

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* in Japanese with English abstract
** in Japanese
*** in French with English abstract

Explanation of Plates

Plate 1

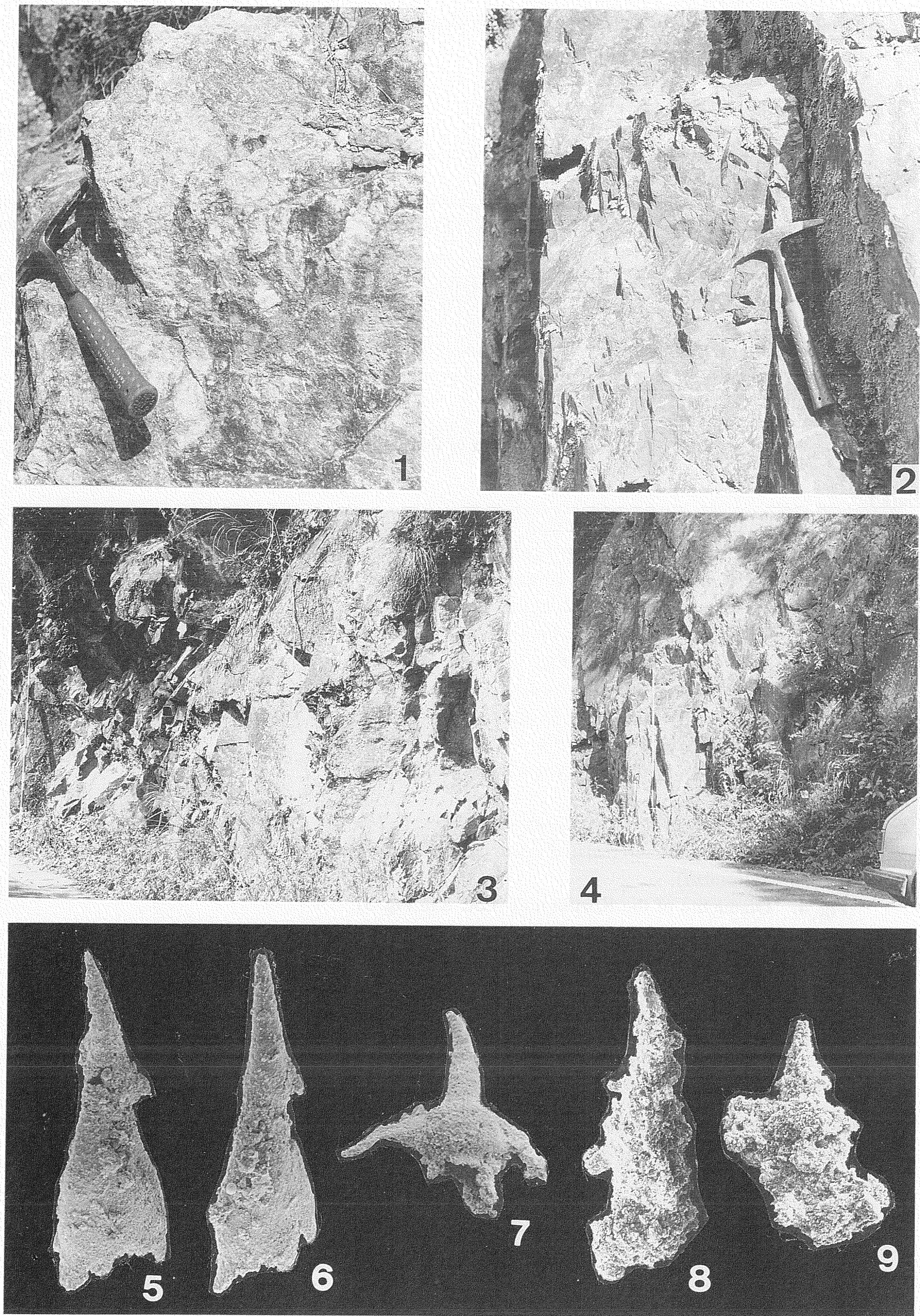
Fig. 1. Yakuno ophiolitic breccia of the Tonoshiki Formation.
Fig. 2. Close up of Plate 1, Fig. 4 (black mudstone of the Maizuru Group).
Fig. 3. Black mudstone of the Tonoshiki Formation at radiolarian fossil locality in Tonoshiki.
Fig. 4. Massive black mudstone of the Maizuru Group.
Figs. 5, 6. *Follicucullus monacanthus* Ishiga and Imoto from black mudstone of the Maizuru Group at Loc. 4 in Fig. 4.
Fig. 7. *Pseudoalbaillella* sp. from same locality as Figs. 5 and 6.
Fig. 8. *Pseudoalbaillella* sp. cf. *P. sakmarensis* (Kozur) from black mudstone of the Tonoshiki Formation at Loc. 3 in Fig. 4, Plate 1, Fig. 3.
Fig. 9. *Pseudoalbaillella* sp. from same Loacality as Fig. 8.

Plate 2

Figs. 1, 2. Pillow lava of the Kozuki unit (Locs. 6, 7 in Fig. 3).
Fig. 3. Black argilite intercalated in the basic hyaloclastite of the Kozuki unit (1 km northeast of Shiromizu).
Fig. 4. Diamictite of the Kozuki unit (Loc. 8 in Fig. 3).
Fig. 5. Layered gabbro of the Yakuno ophiolite (Loc. 9 in Fig. 3).

Plate 3

Fig. 1. Yakuno ophiolitic breccia of the Tonoshiki Formation collected at Oohara in Fig. 4.
Fig. 2. Diamictite of the Kozuki unit at Loc. 8 in Fig. 4.
Fig. 3. Hyaloclastite of the Kozuki unit.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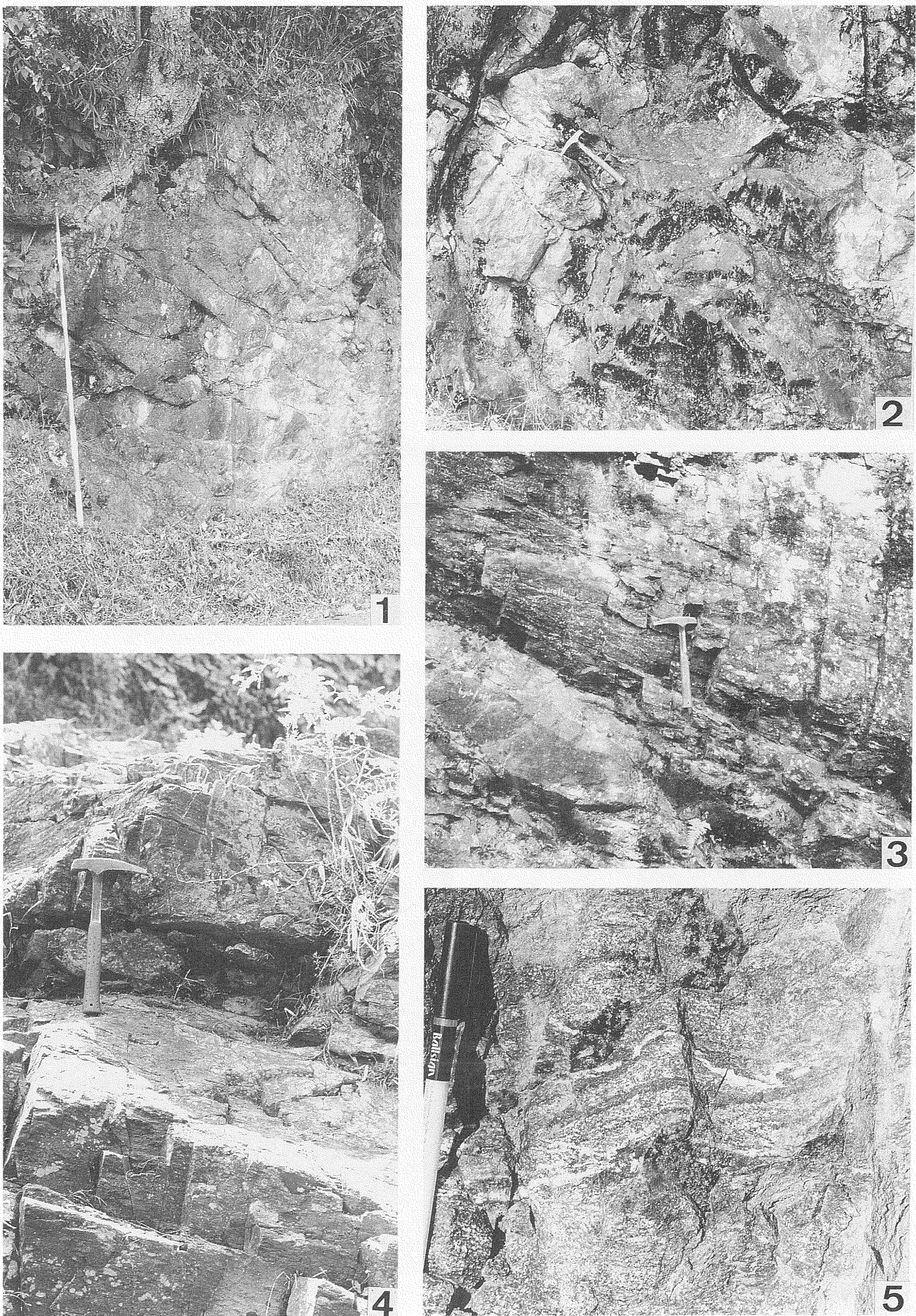
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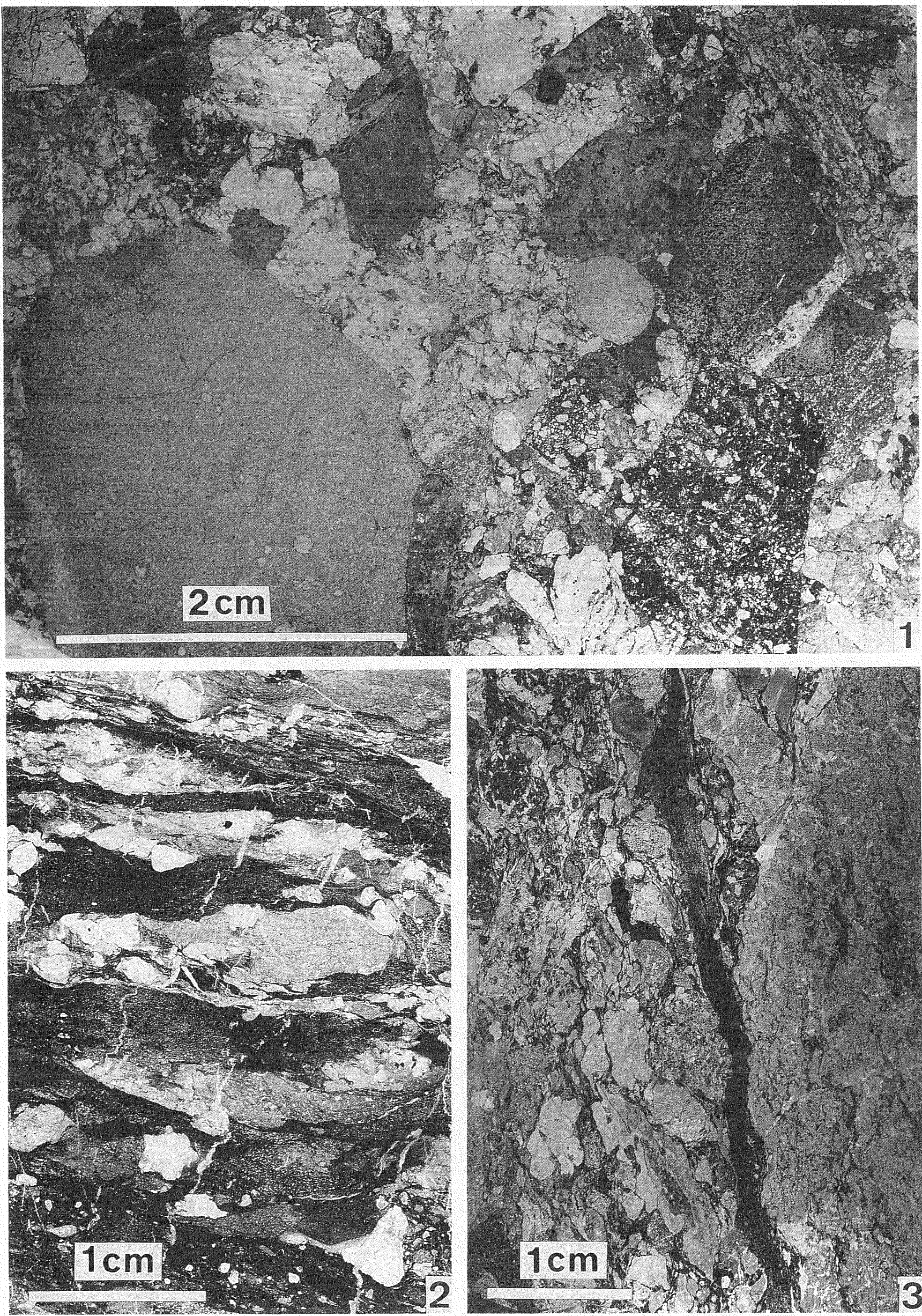
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