AMMONOID BIOSTRATIGRAPHY OF THE MIDDLE PERMIAN IN THE SOUTH KITAKAMI BELT, JAPAN, AND CORRELATION WITH THE REFERENCE SECTIONS IN THE TETHYAN REGION AND NORTH AMERICA

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Based on the stratigraphic distribution of ammonoids and fusulinids the Middle Permian sequence in the South Kitakami is correlated with those of South China, Southern Primorye and American Midcontinent. *Colania kotsuboensis* (*Neoschwagerina margaritae*) Zone and *Lepidolina multiseptata* Zone of Japan, both of which contain Capitanian ammonoids *Timorites* and *Cibolites*, may be correlatable with the lower Capitanian (*Polydiexodina*-bearing horizon) and upper Capitanian (*Yabeina*-bearing horizon), respectively.

AMMONOIDS frequently occur in shallow marine Permian strata and provide a powerful tool for stratigraphic correlation. Fusulinids are another tool and are often more useful than ammonoids, because they are very abundant in calcareous strata and often more diverse than ammonoids. Fusulinids, however, sometimes show not only latitudinal but also longitudinal faunal differences (Ozawa 1987; Ross 1995) and have presented problems concerning precise faunal correlation between the various provinces (Ross 1995). For example, Middle Permian fusulinids in the Tethyan province and those of American Midcontinent have separate zonations, although they were both in the equatorial belt during Permian time. On the other hand the longitudinal faunal differences of Permian ammonoids are not so marked and can compensate for this deficiency.

In this paper I examine the stratigraphic distribution of ammonoids and fusulinids of the Middle Permian sequences in the South Kitakami Belt, Japan, and attempt to correlate the Middle Permian fusulinid-bearing formations in the South Kitakami with those of American Midcontinent, South China and Southern Primorye based mainly on the ammonoid fauna.

MIDDLE PERMIAN AMMONOID- AND FUSULINID-BEARING FORMATIONS IN THE SOUTH KITAKAMI BELT

Permian strata are widely distributed in the South Kitakami Belt, especially in the southern part of the Kitakami Massif, Northeast Japan (Fig. 1). They are composed of shallow marine sediments, such as conglomerate, sandstone, shale and limestone. The Permian of this region is stratigraphically divided in ascending order into the Sakamotozawan, Kanokuran and Toyoman Series. The Middle Permian Kanokuran Series comprises lower Kattisawan Stage and upper Iwaizakian Stage. In the type area, the Kattisawan Stage consists mainly of calcareous sandstone and the Iwaizakian Stage of limestone. The lithofacies, however, change laterally in the belt and shales are rather dominant in many districts. The calcareous facies of the Kanokuran Series yield many fossils such as fusulinids, crinoids, corals, bryozoas, brachiopods and molluscs. The Middle Permian formations in the following three districts (see Fig. 1) yield rich fusulinid fauna in association with ammonoids.

Setamai district

This district is in the central part of the South Kitakami Belt. Along and around the Kanokurasawa River, west of Setamai, the type locality of the Kanokuran Series, the Permian sequence is divided in ascending order into the Sakamotozawa, Kanokura and Kowaragi Formations. The Sakamotozawa Formation is composed mainly of sandstone and shale in the lower part and limestone in the middle-upper part, but limestone of the uppermost part sometimes changes laterally to sandstone. The lower part of the Kanokura Formation (Kattisawan Stage), which conformably overlies the Sakamotozawa Formation, consists of conglomeratic sandstone, calcareous sandstone and shale with subordinate amounts of intercalated

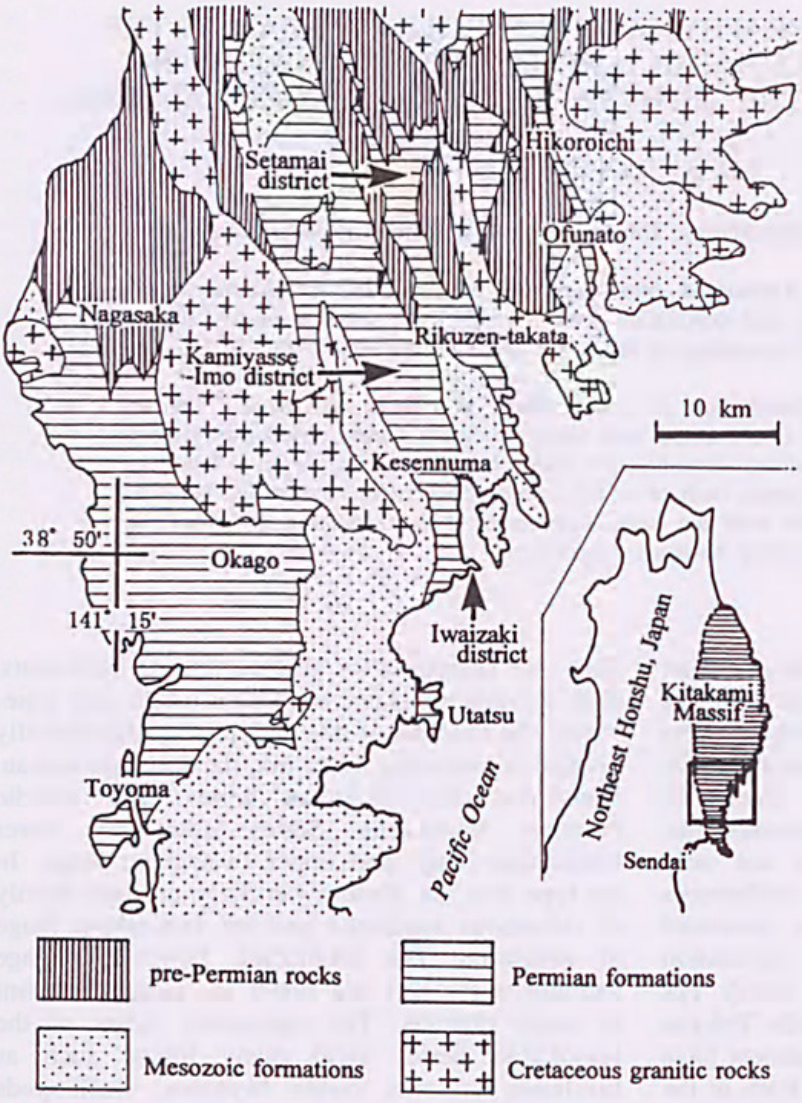
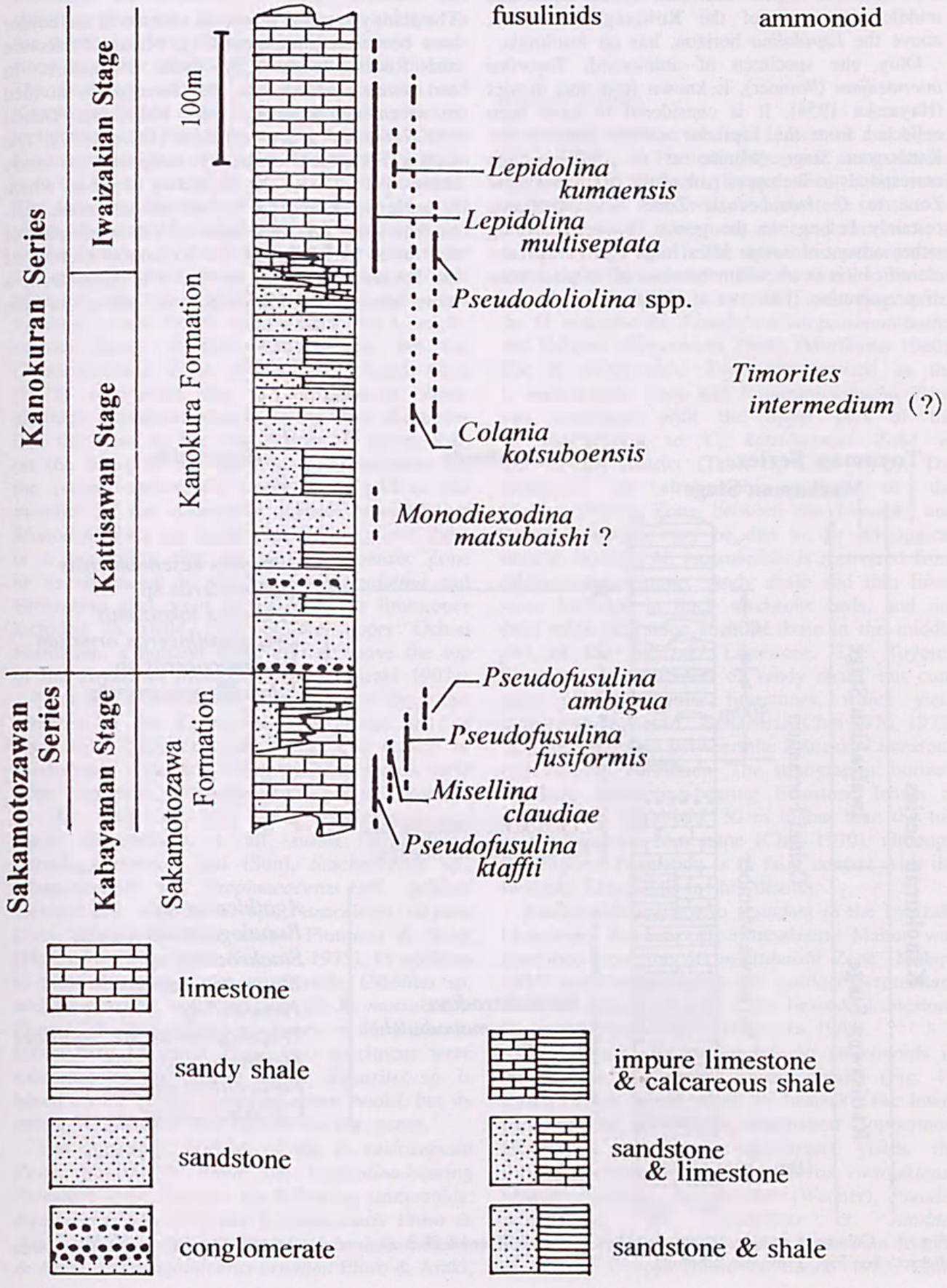


Fig. 1. Index map of the study area, the South Kitakami Belt, Japan.

limestone (Fig. 2). The upper part of the formation (Iwaizakian Stage) is made up largely of limestone. The uppermost part of the limestone contains calcareous shale, which grades laterally into shale of the lower part of the Kowaragi Formation. The Kowaragi Formation is dominated by massive sandy shale, but contains intraformational conglomerate in its lower part. The Sakamotozawa and Kanokura Formations yield rather rich fusulinid faunas except for the lowermost parts of both. Fusulinid biostratigraphy of the Sakamotozawan and Kanokuran Series was studied by Choi (1973). The uppermost fusulinid zone in the Sakamotozawan Series (Kabayaman Stage) is the *Pseudofusulina fusiformis* Zone, which is characterised by the common occurrence of *P. ambigua* (Deprat), *P. fusiformis* (Shellwien & Dyhrenfurth) in association with *Misellina claudiae* (Deprat). The Kattisawan Stage of the Kanokuran Series includes two fusulinid zones, namely the *Monodiexodina matsubaishi* Zone and overlying *Colania kotsuboensis* Zone, and the Iwaizakian Stage has the *Lepidolina multiseptata* Zone. *M. matsubaishi* Zone is characterised by abundant occurrence of *M. matsubaishi* (Fujimoto) and yields *Cancellina* sp. in its lower part. *C. kotsuboensis* Zone contains *C. kotsuboensis* Choi and *Pseudodoliolina* spp. *L. multiseptata* Zone is defined by the occurrence of *Lepidolina* spp., such as *L. multiseptata* (Deprat), *L. kumaensis* Kanmera and *L. minatoi* Choi, but

Fig. 2. Generalised columnar section, major fusulinid ranges and ammonoid datum of the Middle Permian in the Setamai district. Column (modified) and fusulinid data are taken from Choi (1973).


fusulinids
ammonoid
Kanokuran Series
Iwaizakian Stage
Kattisawan Stage
Kanokura Formation
100m
Lepidolina kumaensis
Lepidolina multiseptata
Pseudodoliolina spp.
Timorites intermedium (?)
Colania kotsuboensis
Monodiexodina matsubaishi ?
Sakamotozawan Series
Kabayaman Stage
Sakamotozawa Formation
Pseudofusulina ambigua
Pseudofusulina fusiformis
Misellina claudiae
Pseudofusulina ktaffti
limestone
sandy shale
sandstone
conglomerate
impure limestone & calcareous shale
sandstone & limestone
sandstone & shale

the first appearance horizons of the last two species are somewhat higher than that of the first. The middle-upper part of the Kowaragi Formation, above the *Lepidolina* horizon, has no fusulinids.

Only one specimen of ammonoid, *Timorites intermedium* (Wanner), is known from this district (Hayasaka 1954). It is considered to have been collected from the *Leptodus nobilis* Zone of the Kattisawan Stage (Minato et al. 1978), which corresponds to the upper part of the *M. matsubaishi* Zone to *C. kutsuboensis* Zone. This specimen certainly belongs to the genus *Timorites*, having rather advanced suture lines, although its specific identification is uncertain because of its poor state of preservation (Ehiro et al. 1986).

Kamiyasse-Imo district

The Kamiyasse-Imo district is situated in the border area between Kesennuma City, Miyagi Prefecture and Rikuzen-takata City, Iwate Prefecture. In and around this district, the Permian is divided in ascending order into the Nakadaira, Ochiai and Nabekoshiyama Formations (Ehiro 1977). The Ochiai Formation is mainly composed of sandy shales, but includes the Toyazawa Member, which is made up largely of calcareous sandstone, calcareous shale and limestone, in the upper part of the lower horizon (Fig. 3). Columnar section of the Toyazawa Member in Fig. 3 is taken from a route along the Minaminosawa valley in the

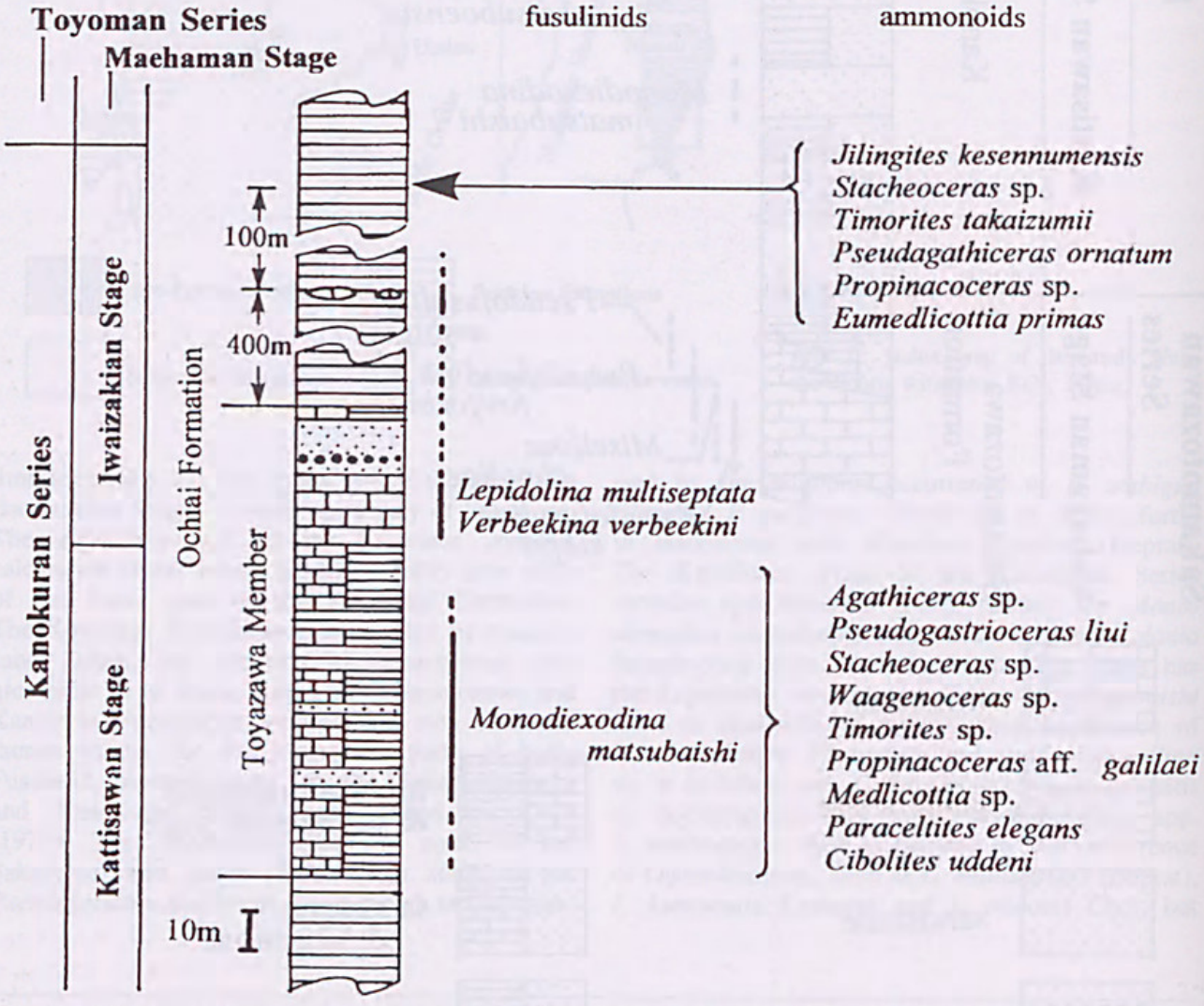


Fig. 3. Columnar section, major fusulinid ranges and ammonoid data of the Middle Permian in the Kamiyasse district. See Fig. 2 for the lithology.

Kamiyasse district. Calcareous shale and impure limestone are dominant in Minaminosawa and vicinity. However, lateral lithofacies change in the member is very common and calcareous sandstone is rather abundant throughout this district. The boundary between the Sakamotozawan and Kanokuran Series may be situated at some horizon in the shales of the lower part of the lower Ochiai Formation, and that of the Kanokuran and Toyoman is in the lower part of the upper Ochiai Formation. The lower-middle part of the Toyazawa Member yields abundant *M. matsubaishi* and uppermost part of the member is characterised by the occurrence of *Lepidolina multiseptata* and *Verbeekina verbeeki* (Geinitz). Tazawa (1975) established only two fusulinid zones, the *M. matsubaishi* and *L. multiseptata* Zones in this member, and not the *C. kutsuboensis* Zone. On the other hand, Choi (1973) recognised the *C. kutsuboensis* Zone, although *Pseudodoliolina elongata* Choi characterises the zone, in the Imo district. It seems that, on the basis of the preliminary examination by the present author, the lower upper part of the member in the Kamiyasse district have neither *Monodiexodina* nor *Lepidolina* (Fig. 3), and there is a possibility that the *C. kotsuboensis* Zone or its equivalent is also present. *Lepidolina* and *Verbeekina* also occur in the lenticular limestones included in shale beds of the upper Ochiai Formation, a horizon about 400 m above the top of the Toyazawa Member (Ehiro & Araki 1997).

From the *M. matsubaishi* Zone of the Toyazawa Member in the Kamiyasse-Imo district and its equivalent strata exposed around the streets of Kesennuma City, the following ammonoids have been reported, although their precise horizon in the zone are not clear: *Agathiceras* cf. *suessi* Gemmellaro, *A.* aff. *suessi* Gemmellaro, *Pseudogastrioceras liui* (Sun), *Stacheoceras* sp., *Waagenoceras* sp., *Propinacoceras* aff. *galilaei* Gemmellaro, *Medlicottia* sp., *Paraceltites elegans* Girty, *P.* sp., *Cibolites uddeni* Plummer & Scott (Hayasaka 1940, 1963; Koizumi 1975). In addition to these specimens, two ammonoids, *Cibolites* sp. and *Timorites* sp. collected from the *M. matsubaishi* Zone in the Imo district are stored in the Rikuzentakata City Museum. These two specimens were examined by the present author. *Timorites* sp. is based on the poorly preserved inner mould, but its suture is traceable and typical for the genus.

The uppermost horizon of the *L. multiseptata* Zone, 80–100 m above the *Lepidolina*-bearing limestone lense, contains the following ammonoids: *Agathiceras* sp., *Jilingites kesennumensis* Ehiro & Araki, *Stacheoceras* sp., *Timorites takaizumii* Ehiro & Araki, *Pseudagathiceras ornatum* Ehiro & Araki, *Propinacoceras* sp., *Eumedlicottia primas* (Waagen) (Ehiro & Araki 1997). *Timorites* is abundant in the fauna.

Iwaizaki district

The Middle Permian Iwaizaki Limestone and Upper Permian Toyoma Formation crop out along the sea coast of Cape Iwaizaki, located about 8 km south of Kesennuma. The Iwaizaki Limestone consists of sandstone in its lowermost part and limestone in its main part (Fig. 4). The uppermost part contains some shale intercalations. The Iwaizaki Limestone has three fusulinid zones: in ascending order the *M. matsubaishi*, *Pseudofusulina paramotohashii* and *Yabeina shiraiwensis* Zones (Morikawa 1960). The *Y. shiraiwensis* Zone was revised as the *L. multiseptata* Zone and *P. paramotohashii* Zone was correlated with the upper part of the *M. matsubaishi* to *C. kotsuboensis* Zone in the Setamai district (Table 1; Choi 1973). The difference of stratigraphic ranges of the *M. matsubaishi* Zone between the Iwaizaki and Setamai districts may be due to the lithological control, because *M. matsubaishi* is recovered from calcareous sandstone, sandy shale and thin limestone included in thick sandstone beds, and not from thick limestone such as those in the middle part of the Iwaizaki Limestone. The Toyoma Formation is composed of sandy shale, but contains small lenticular limestones, which yield *L. multiseptata* and *L. kumaensis* (Choi 1970, 1973) near the boundary between the Iwaizaki Limestone and Toyoma Formation. The stratigraphic horizon of these *Lepidolina*-bearing limestone lenses is estimated to be about 130 m higher than the top of the Iwaizaki Limestone (Choi 1970), although the Toyoma Formation is in fault contact with the Iwaizaki Limestone in this district.

Ammonoids are not so abundant in the Iwaizaki Limestone. *Stacheoceras iwaizakiense* Mabuti was described from the *M. matsubaishi* Zone (Mabuti 1935) and *Propinacoceras* aff. *galilaei* Gemmellaro from the uppermost part of the Iwaizaki Limestone (*L. multiseptata* Zone) (Hayasaka 1963).

The Toyoma Formation has no ammonoids in this district, but in the Utatsu district (Fig. 1), about 10 km to the south of Iwaizaki, the lower part of the Suenosaki Formation (uppermost Kanokuran to Middle Toyoman) yields the following ammonoids: *Stacheoceras iwaizakiense* Mabuti, *Timorites intermedium* (Wanner), *Pseudogastrioceras* sp., *Araxoceras* cf. *rotoides* Ruzhentsev, *A.* sp., *Vescotoceras japonicum* (Bando & Ehiro), *V.* spp. (Ehiro & Bando 1985; Ehiro

et al. 1986). This fossil horizon is situated about 100 m above the *Lepidolina*-bearing calcareous sandstone and contains some pelecypods, which characterise the Lower Toyoman. Therefore, it may correspond to the basal part of the Toyoman Series. In addition, *Xenodiscus* cf. *carbonarius* Waagen was reported from nearly the same horizon in the Okago district, about 15 km northwest of Utatsu (Ehiro & Bando 1985). These ammonoids provide a basis for correlating the Lower Toyoman Series with the Upper Permian Wuchiapingian or Dzhulfian.

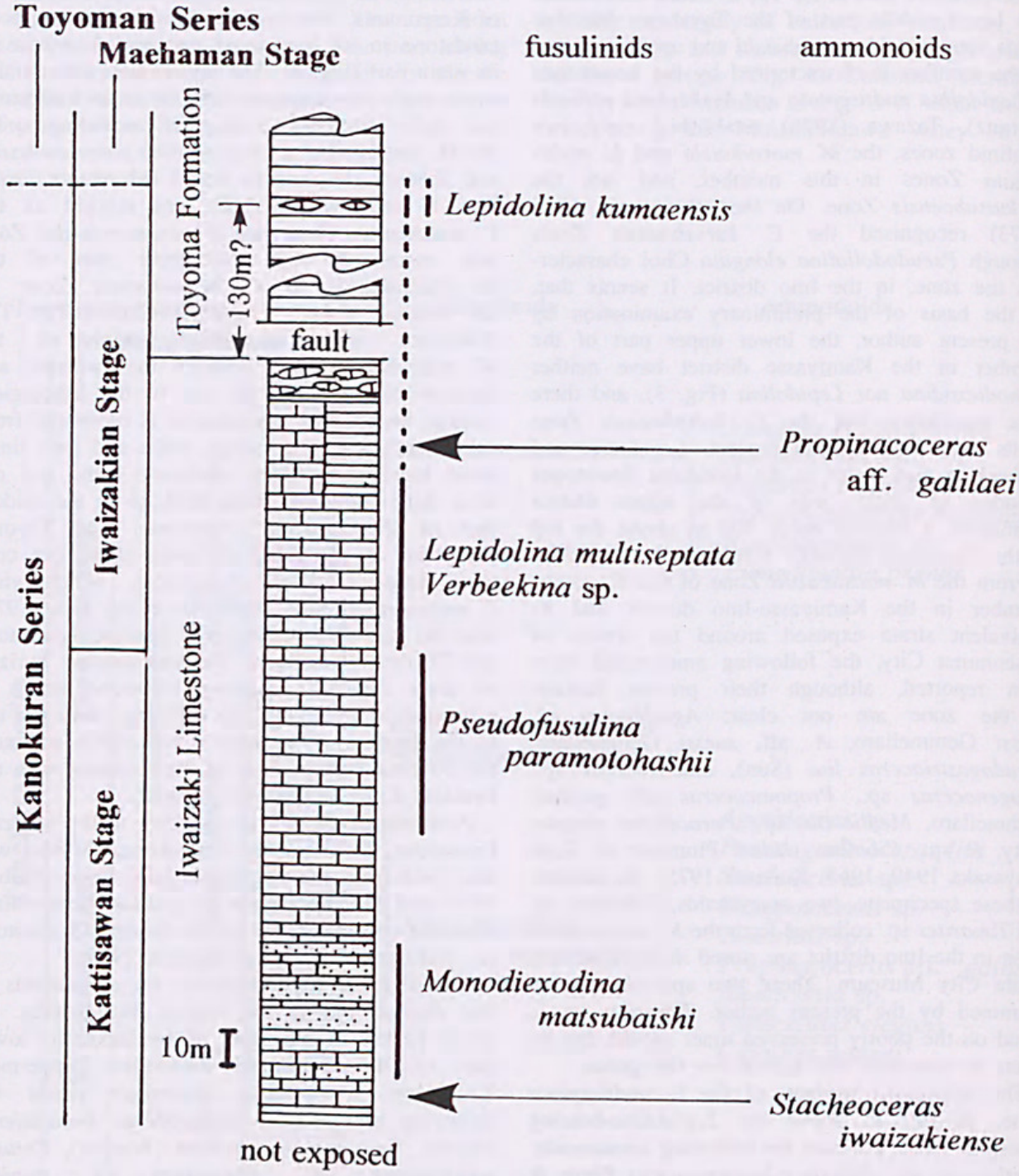


Fig. 4. Columnar section, major fusulinid ranges and ammonoid occurrences of the Middle Permian in the Iwaizaki district. Column (simplified) and fusulinid data from Morikawa (1960). See Fig. 2 for the lithology.

AMMONOID BIOSTRATIGRAPHY AND CORRELATION

Of the abovementioned ammonoids known from the Middle Permian Kanokuran Series in the South Kitakami Belt, the genera *Timorites* and *Cibolites* are particularly important for stratigraphic correlation. *Timorites* is an index fossil of the Capitanian Stage in North America (Glenister et al. 1992; Jin et al. 1994a). In the Tethyan districts, species of *Timorites* also occur in the Capitanian formations, but also in the Wuchiapingian ones (Ehiro et al. 1986; Zhou et al. 1989). In Texas and Coahuila, most specimens of *Cibolites* have been collected from the Capitanian strata, except for ones probably from the Wordian formation in the Glass Mountain (Spinosa et al. 1975). *Paraceltites* ranges from the Roadian to Capitanian Stage and *Waagenoceras* from the Wordian to Capitanian. Ranges of the other genera are rather long or not clearly known. Therefore, based on the ammonoids, the *C. kotsuboensis* to *L. multiseptata* Zone and probably the upper part of the *M. matsubaishi* Zone, which are characterised by the occurrence of *Timorites* and *Cibolites*, are considered to be correlatable with the Capitanian, and the lower-middle part of the *M. matsubaishi* Zone with the Roadian (?) to Wordian (Table 2).

The fusulinid zones, the *M. matsubaishi*, *C. kotsuboensis* and *L. multiseptata* Zones are correlated, respectively, with the *Neoschwagerina simplex–N. craticulifera*, *N. margaritae* and *Lepidolina toriyamai–L. shiraiwensis* (*Lepidolina–Yabeina*) Zones of Southwest Japan (Table 1; Choi 1973). Jin et al. (1994b) correlated the *Polydiexodina* Zone of the Capitanian with the *N. margaritae* Zone in the Tethyan province. On the other hand, Ross (1995) and Davydov (1996) correlated the Capitanian, which yields *Polydiexodina*, *Yabeina*, etc., with the 'Midian' (*Yabeina–Lepidolina* Zone) in the Tethyan province. Ammonoid and fusulinid data of the Middle Permian in the South Kitakami support the former's opinion and, moreover, there is a possibility that a part of the *Polydiexodina* Zone is correlatable with that of the *Neoschwagerina simplex–N. craticulifera* Zone, because the Capitanian ammonoid *Timorites* is recovered with *M. matsubaishi*.

According to Ross (1995) the stratigraphic range

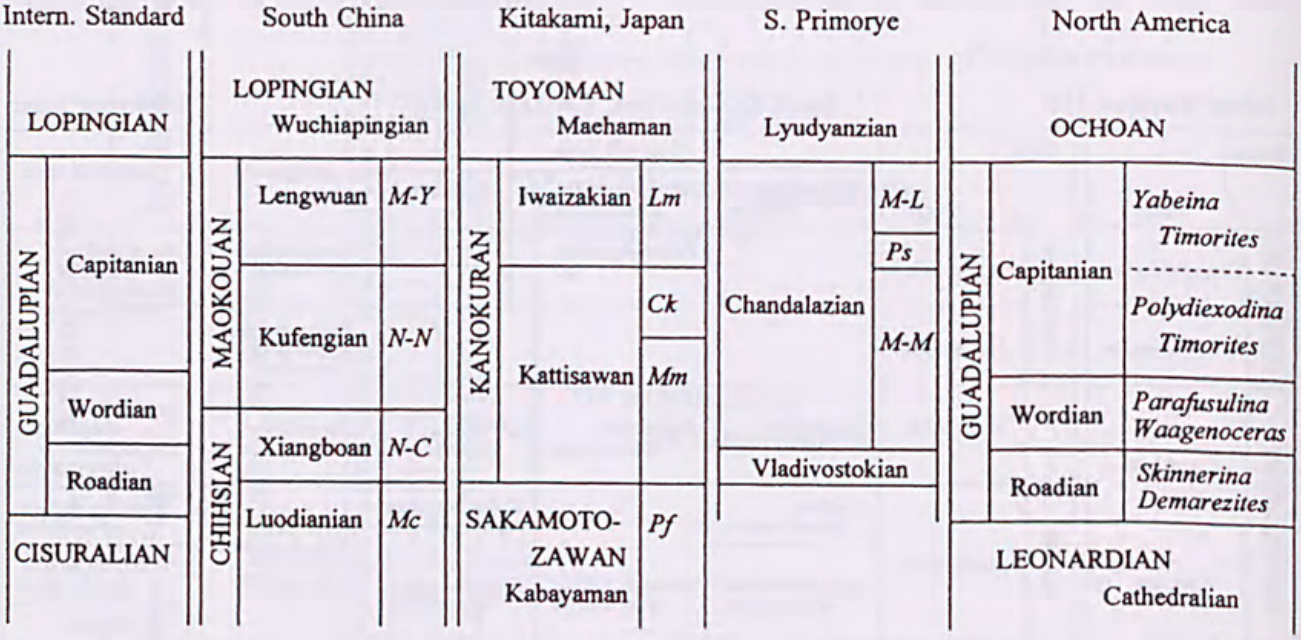
Intern. Standard		South Kitakami Belt, Northeast Japan						Southwest Japan
Series	Stage	Series	Stage	fusulinid zone: Hikoroichi-Setamai	fusulinid zone: Kamiyasse-Kesennuma	fusulinid zone: Iwaizaki	ammonoid	fusulinid zone
LOPINGIAN	Changhsingian	TOYOMAN	Nabekoshian		*Palaeofusulina* sp.		*Paratirolites* ? *Cyclolobus*	*Nankinella-Staffera Reichelina-Paleofusulina*
	Wuchiapingian		Maehaman				*Eusanyangites Araxoceras Timorites*	
GUADALUPIAN	Capitanian	KANOKURAN	Iwaizakian	*Lepidolina multiseptata*	*Lepidolina multiseptata*	*Lepidolina multiseptata*	*Timorites*	*Lepidolina toriyamai - Lepidolina shiraiwensis*
			Kattisawan	*Colania kotsuboensis*	?	*Pseudofusulina paramotohashii*	*Timorites Waagenoceras Cibolites Paraceltites*	*Neoschwagerina margaritae*
	Wordian			*Monodiexodina matsubaishi*	*Monodiexodina matsubaishi*	*Monodiexodina matsubaishi*		*Neoschwagerina craticulifera*
	Roadian							*N. simplex*
CISURALIAN	Kungurian	SAKAMOTO ZAWAN	Kabayaman	*Pseudofusulina fusiformis*			*Artinskia Agathiceras*	*Pseudofuslina kraffti*
	Artinskian			*Chalaroschw. vulgaris*				*Chalaroschw. vulgaris*
	Sakmarian		Kawaguchian	*Robustoschw. schellwieni*				*Pseudoschw. subsphaerica*
	Asselian							*Triticites simplex*

Table 1. Correlation chart of the Permian fusulinid zones in the Hikoroichi-Setamai, Kamiyasse-Imo and Iwaizaki districts in the South Kitakami Belt, and that of Southwest Japan. Ammonoid occurrences in the South Kitakami are also shown. International standard chronostratigraphic scale is taken from Jin et al. (1997).

of the genus *Monodiexodina* is from his *Misellina* Zone to the middle part of the *Cancellina* Zone. However, as stated above, *M. matsubaishi* co-occurs with *Timorites* and *Cibolites* in Japan, and the range of the genus *M. matsubaishi* must extend at least into the *Neoschwagerina* Zone (s.l.), possibly into the lower part of the *N. margaritae* Zone.

In South China the Middle Permian is represented by the Maokouan Series, which comprises the lower Kufengian Stage and the upper Lengwuan Stage (Jin et al. 1994a). It includes four fusulinid zones (Sheng & Jin 1994): in ascending order the *Neoschwagerina craticulifera* and *N. margaritae* Zones in the Kufengian Stage, and *Yabeina gubleri* and *Metadoliolina multivoluta* Zones in the Lengwuan Stage. Based on the fusulinids, the middle to upper part of the Kattisawan Stage (*M. matsubaishi* and *C. kotsuboensis* Zones) and Iwaizakian Stage (*L. multiseptata* Zone) are roughly correlated with the Kufengian and Lengwuan Stages, respectively (Table 2).

Species of the genus *Waagenoceras*, which is an index fossil of the Wordian, have been reported from the Wenbishan Formation of Fujian Province (*W. longyannense* Zhao & Zheng) and from the Dangchong Formation of Hunan Province (*Waagenoceras* sp.) (Zhao 1980) in South China. These formations are Kufengian in age. *Timorites yunnanensis* Liang from Yunnan is the only one belonging to the genus known from South China. It was collected from the Maokouan Formation, but its precise stratigraphic position in the Maokouan is unknown. Zhao & Zheng (1977) reported the occurrence of *Cibolites curvoplicatus* Zhao & Zheng and *C. dongwuliensis* Zhao & Zheng with *Paraceltites altudensis* (Bose) from the Shimentang Member of the Lixian Formation in West Zhejiang. The Shimentang Member is correlated with the lower part of the Lengwuan Stage by Sheng & Jin (1994). *Cibolites parvus* Zhou, associated with *Paraceltites altudensis* (Bose), *P. hoeferi* (Gemmellaro), *Cibolites curvoplicatus* Zhao & Zheng, *Roadoceras* spp. and *Doulingoceras* spp., has also been described from the upper Maokouan *Roadoceras–Doulingoceras* Zone in Hunan (Zhou 1987), although the zone is



M-Y: *Metadoliolina multivoluta - Yabeina gubleri*
N-N: *Neoschwagerina margaritae - Neoschwagerina craticulifera*
N-C: *Neoschwagerina simplex - Cancellina neoschwagerinoides*
Mc: *Misellina claudiae*
Lm: *Lepidolina multiseptata*
Ck: *Colania kotsuboensis*
Mm: *Monodiexodina matsubaishi*
Pf: *Pseudofusulina fusiformis*
M-L: *Metadoliolina lepida - Lepidolina kumaensis*
Ps: *Parafusulina stricta*
M-M: *Monodiexodina satchanica - Metadoliolina dutkevitchi*

Table 2. Correlation chart of some Middle Permian sequences in the Eastern Tethys and American Midcontinent based on ammonoids and fusulinids.

included by Jin et al. (1994a, 1994b) in the lowermost part of the Upper Permian Wuchiapingian Stage. The stratigraphic horizon of *Cibolites costatus* (Hayasaka) (originally described as *Paracibolites* by Hayasaka 1947) from Zhejiang is, according to Chao (1965), the lower part of the Maokouan Series (*Waagenoceras* Zone). These ammonoid data support generally the above-mentioned fusulinid-based correlation between South China and South Kitakami, but at present the precise correlation based on the ammonoids is difficult, because we have few ammonoid data for the Maokouan, especially for the upper Kufengian, and precise stratigraphic data for the ammonoids are lacking.

The Midian Chandalaz Formation of the Southern Primorye district in the Russian Far East is divided into three fusulinid zones (Kotlyar et al. 1989): in ascending order the *Monodiexodina sutchanica–Metadoliolina dutkevitchi*, *Parafusulina stricta* and *Metadoliolina lepida–Lepidolina kumaensis* Zones. It is, as a whole, correlatable with the Kanokuran Series. *P. stricta* Zone yields *Lepidolina multiseptata* and *L. kumaensis* (Zakharov et al. 1992). Therefore, it is considered that the *M. sutchanica–M. dutkevitchi* Zone is correlatable with the *M. matsubaishi* and *C. kotsuboensis* Zones, and *P. stricta* and *M. lepida–L. kumaensis* Zones with *L. multiseptata* Zone (Table 2). The occurrence of *Timorites markevichi* Zakharov from the *P. stricta* Zone (Kotlyar et al. 1989) supports this correlation and provides the ammonoid based correlation between the Southern Primorye and South Kitakami. The Nakhodka Reef distributed in the Nakhodka district yields ammonoids *Eumedlicottia nikitinae* Zakharov, *Neogeoceras thaumastum* Ruzhentsev in its lower part, *Stacheoceras orientale* Zakharov in the middle and *Xenodiscus subcarbonarius* Zakharov & Pavlov in the uppermost (Zakharov et al. 1992). The lower part of the Lyudyanza Formation, which overlies the Nakhodka Reef, contains the Late Permian ammonoid *Cyclolobus kiselevae* Zakharov. The Nakhodka Reef is included in the Chandalaz Formation and correlated with the Middle Permian Midian (Zakharov 1992), but it is likely that the upper part of the Nakhodka Reef is correlatable with the Upper Permian Wuchiapingian (Dzhulfian) and Maehaman Stage of the Toyoman based on the occurrence of *Xenodiscus*.

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