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Stratigraphy of Lower Cretaceous System in the Jikkoku Pass Area, Western Kanto Mountains, Japan

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Abstract

The Lower Cretaceous sedimentary rocks are widely distributed along the axial part of the Chichibu Belt in the northwestern Kanto Mountains, central Japan. This axial part is traditionally called the Sanchu Graben. The Jikkoku Pass area, northwestern part of the Sanchu Graben is underlain chiefly by the Lower Cretaceous sedimentary rocks. The Sanchu Cretaceous System can be divided into the following five formations; the Shiroi, Ishido, Sanyama Formations, and the newly defined Tozawa and Ohnita Formations in the study area.

The Shiroi Formation is characterized by alternation of conglomerate, sandstone and shale, and yields brackish-water bivalve fossils. The Ishido Formation is composed predominantly of sandstone, and includes coralline limestone blocks, and contains marine bivalve fossils. The Sanyama Formation is subdivided into the lower and upper members. The lower member is composed of medium- to thick-bedded alternation of sandstone and shale, and it yields the marine bivalve fossils sporadically. The upper member is characterized by turbidite facies which is accompanied with conglomerate in its lowermost part and by the rare occurrence of molluscan fossils. The Tozawa and Ohnita Formations show a more monotonous lithology than those of the Shiroi, Ishido and Sanyama Formations. The Tozawa Formation is characterized by calcareous sediments and marine bivalve fossils including rudist. The Ohnita Formation predominates in massive and/or thick-bedded sandstone and contains marine and brackish-water bivalve fossils. The Sanchu Cretaceous System can be classified into two different units, based on their lithology, stratigraphy and bivalve faunas. One unit is the Shiroi, Ishido and Sanyama Formations, and the other is the Tozawa and Ohnita Formations, in ascending order respectively. The former three formations, which are grouped as the Sanchu Group, are close resemblance to that of the Lower Cretaceous Monobegawa Group distributed in the Kurosegawa Belt from Kyushu to Kii Peninsula. The latter two formations correspond to the Lower Cretaceous Pre-Sotoizumi Group overlying the Kurosegawa Belt in Kyushu on the basis of the lithology and bivalve fauna, and they are named the Nanmoku Group.

Key words: stratigraphy, Lower Cretaceous, bivalve fossil, Sanchu Graben, Kurosegawa Belt

Introduction

Lower Cretaceous non-marine to shallow marine sediments are discontinuously and interruptedly distributed in the Chichibu Belt, outer zone of SW Japan. They are considered to record information about palaeoenvironment around the eastern margin of East Asia, which might be under the setting of an active margin during Early Cretaceous (e.g., Maruyama and Seno, 1986; Taira and Tashiro, 1987; Otsuki, 1992; Xu and Shu, 1994; Maruyama *et al.*, 1997). The detailed stratigraphy and paleontological studies of the Lower Cretaceous strata of the Chichibu Belt have been accumulated (e.g., Hayami, 1966; Tamura, 1980; Matsumoto *et al.*, 1982; Ohta, 1981; Tanaka *et al.*, 1984; Sakai and Okada, 1997; Tanaka *et al.*, 1997, 1998). Until 1980's, these studies have mainly done in terms of a chronostratigraphic classification using ammonite and bivalve fossils. After that, Lower Cretaceous strata are focused on one of an important indicator for the reconstruction of the pre-Cretaceous units in the Chichibu Belt.

Tashiro (1985b) firstly paid attention to usefulness of the Cretaceous strata in the reconstruction, and divided the Lower Cretaceous strata of the Chichibu Belt into two units, namely, the Monobegawa and Nankai Groups on the basis of the lithology, bivalve fauna and stratigraphy. He also interpreted that the juxtaposition of two Lower Cretaceous units is probably due to left-lateral displacement along the Kurosegawa Belt which is characterized by lenslike composite masses consisting of Silurian to Devonian sedimentary rocks, granitic and high-grade metamorphic rocks, high-pressure/low-temperature metamorphic rocks and ultramafic rocks (Ichikawa *et al.*, 1956; Yoshikura *et al.*, 1990). The stratigraphy of Lower Cretaceous non-marine to shallow marine starata, from Kyushu, Shikoku to Kii Peninsula, in the Kurosegawa Belt were reexamined by Tashiro and Matsuda (1986), Tanaka (1989), Tanaka *et al.* (1997; 2000b; 2002b). They stressed the occurrence of two Lower Cretaceous units in the Kurose-

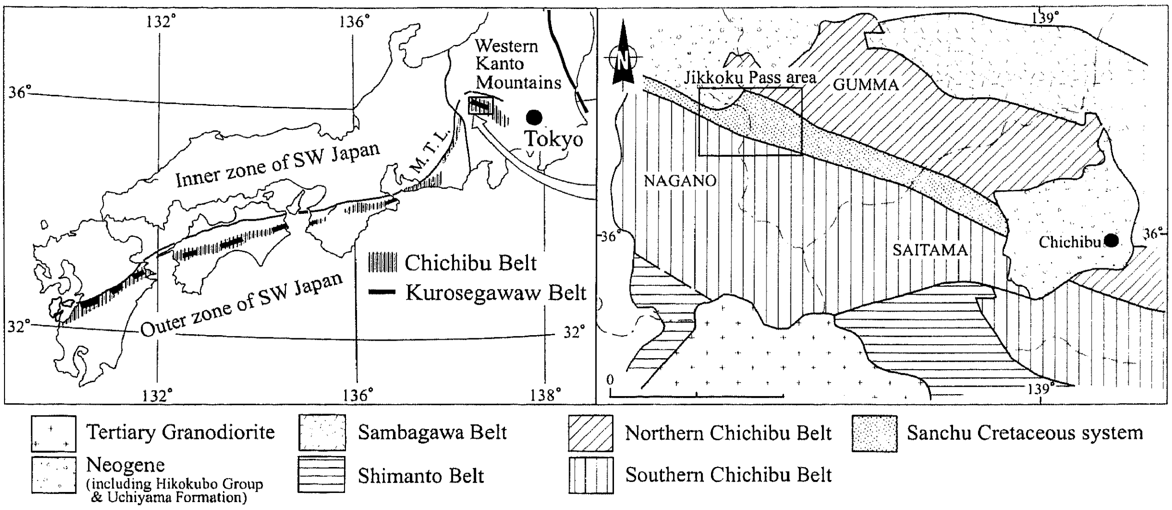

Fig. 1 Geologic outline of the western Kanto Mountains.

gawa Belt. In addition, Ichise *et al.* (2002) indicated the possibility that an equivalent of the Nankai Group or the Pre-Sotoizumi Group (Tashiro and Ikeda, 1987; Tanaka *et al.*, 1999) is distributed in the eastern part of the Sanchu Graben together with the equivalent of the Monobegawa Group.

The so-called Sanchu Graben filled with Cretaceous brackish-water to shallow marine strata is one of the most famous classical fields of the geology and molluscan fossils. I use the terms Sanchu Graben not for a structural basin but for a place name of this belt, and use the term Sanchu Cretaceous System for the Cretaceous strata distributed in the Sanchu Graben. The Jikkoku Pass area in the western part of the Sanchu Graben is located at the borderline between Nagano and Gunma Prefectures, and is a mountainous field including the Nukui River and Kanna River basins (Fig. 1). The lower part of the Sanchu Cretaceous System, namely, the Shiroi and Ishido Formations, are widely distributed with the upper part of the Nukui River in this study area, compared with another part of the Sanchu Graben. Furthermore, these Cretaceous strata are accompanied with lens-shaped serpentinite mass. The purpose is focused to clarify the stratigraphy of the Sanchu Cretaceous System in the Jikkoku Pass area, and to reveal the geologic division of the Sanchu Graben.

Histrical review of Sanchu Cretaceous System

Since the pioneer work of Harada (1890) proposed the Sanchu Graben, stratigraphical and paleontological studies of the Sanchu Cretaceous System have been presented by many authors. Representative recent studies are shown in Fig. 2.

Yabe *et al.* (1926) first studied the Sanchu Cretaceous System, and divided into five groups. They were the Miyakozawa, Ohnosawa, Shiroi, Ishido and Kawarazawa Groups in ascending order. Fujimoto (1958) showed that the Mesozoic strata in the western part of the Sanchu Graben were composed of the Jurassic Naranokidaira Formation, and the Lower Cretaceous Koya and Ishido Formations based on the lithology and contained fossils. On the other hand, Takei (1963) showed that these strata in the eastern part of the Sanchu Graben were composed of the Lower Cretaceous Ishido and Sebayashi Formations and the Upper Cretaceous Sanyama Formation in ascending order. He also divided the Sanchu Graben longitudinally into three fault-bounded subbelts. They are the Northern, Middle and Southern subbelts, and each subbelt has three formations. He concluded that the Cretaceous strata formed a synclinorium as a whole. Okubo and Horiguchi (1969) made a regional mapping covering the quadrangle sheet map of the Mamba area (scale 1:50,000). Matsukawa (1977) interpreted the repetition of formations recognized by Takei (1963) as due to tightly folding in the eastern part of the Sanchu Graben. Also, Matsukawa (1983) made a geological survey over the whole area of the Sanchu Graben. Based on his paleontlogical study, he recognized the non-marine strata Shiroi Formation as a basal part pf the Sachu Cretaceous System, and proposed four-fold division, namely the Shiroi, Ishido, Sebayashi and Sanyama Formations in ascending order. He also made a systematic biostratigraphic study using ammonites. As a result of his study, these formations were assigned to the Lower Cretaceous. Takei (1985) extended his stratigraphic division to the western part, and subdi-

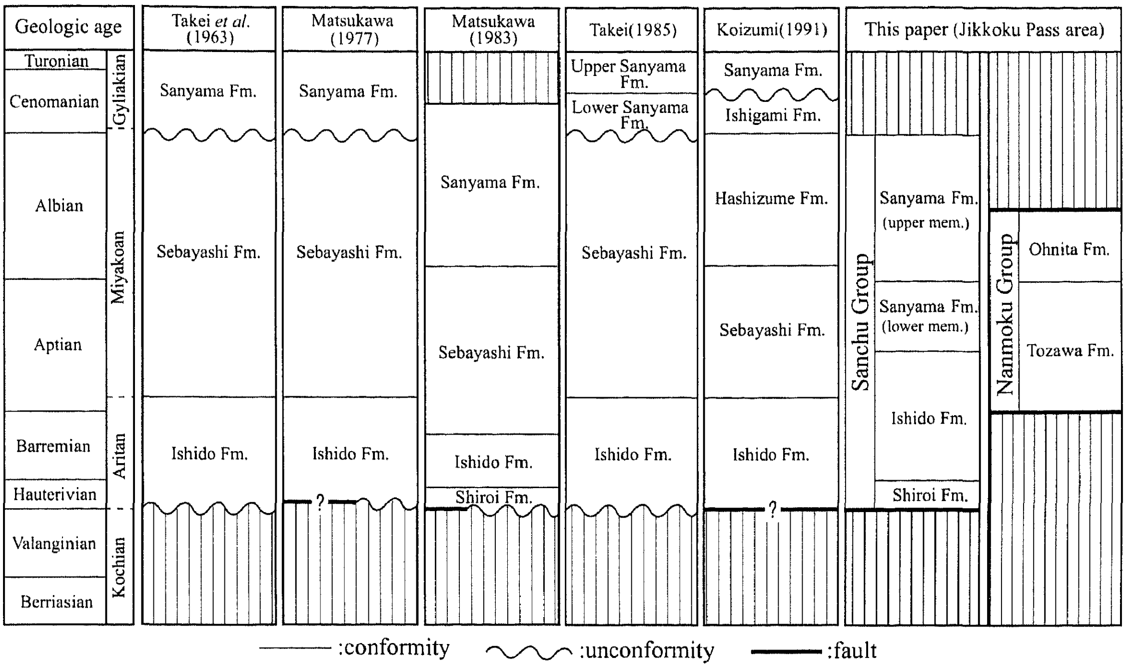

Fig. 2 Comparison of lithostratigraphic divisions of the Sanchu Cretaceous system.

vided the Sanyama Formation into the Lower Sanyama and the Upper Sanyama Formations. In addition, he analyzed petrography of Cretaceous sandstone in the eastern part of the Sanchu Graben. According to his study, sandstone of the Ishido Formation is characterized by lithic wacke, and the others are represented by feldspathic arenite and wacke. Hisada *et al.* (1987) regarded the geologic structure of the Jikkoku Pass area as an extensional duplex caused by a left-slip faulting on the southern boundary fault deduced from the distribution of serpentinite masses after the uppermost Barremian. Koizumi (1991) investigated the Cretaceous strata in the eastern part of the Sanchu Graben from the viewpoint of stratigraphy and structural geology. He proposed a five-fold stratigraphic division, such as the Lower Cretaceous Ishido, Sebayashi and Hashizume Formations, and the Upper Cretaceous Ishigami and Sanyama Formations in ascending order. Hisada and Arai (1993) divided the Cretaceous strata into the newly defined Units 1–3. Moreover, they checked occurrences of detrital chrome spinels in the Sanchu Graben and showed that the source rocks of the Low-Ti and the high-Ti groups originated from the arc to fore-arc upper mantle and the intraplate basalt or E-type MORB, respectively, based on the analysis of their chemistry.

Concerning about fossils contained in these Cretaceous strata, many palaeontological studied have been carried out (Yabe *et al.*, 1926; Tanaka, 1965; Hayami and Ichikawa, 1965; Kase, 1984). Obata *et al.* (1976) described well-preserved ammonite species and discuss the ammonite biostrarigraphy of the Ishido Formation. They concluded that the Ishido Formation is supposed to range from lower Upper Barremian to Upper Hauterivian. Matsukawa (1988) gave description of Barremian ammonites, shows a high similarity to that of the Mediterranean region of the Tethyan realm, from the Ishido Formation. Tashiro (1990) reported bivalve fossils contained in the Sanyama Formation, and correlated with the Aptian to Albian Hibihara Formation of the Monobegawa Group in Shikoku. In addition, Ichise *et al.* (2002c) discovered the occurrence of the different bivalve assemblage at Nakanosawa and Hinatazawa in the eastern part of the Sanchu Graben. They made it clear that this assemblage is different from that previously reported from the Sanchu Graben, and bears a close resemblance to the Albian Tethyan fauna (Tashiro, 1994) which is represented by a bivalve assemblage from the Pre-Sotoizumi Group. The fossil flora was studied by Yokoyama (1895) and Oishi (1940). Kimura and Matsukawa (1979) also studied terrestrial plant fossils from the Sebayashi Formation. Furthermore, a piece of dinosaur vertebra was discovered by Hasegawa *et al.* (1999) from the Sebayashi Formation.

In addition to these megafossils, there are some studies for corals and microfossils (Yabe and Sugiyama, 1935; Eguchi, 1951; Fujimoto, 1958). Sashida *et*

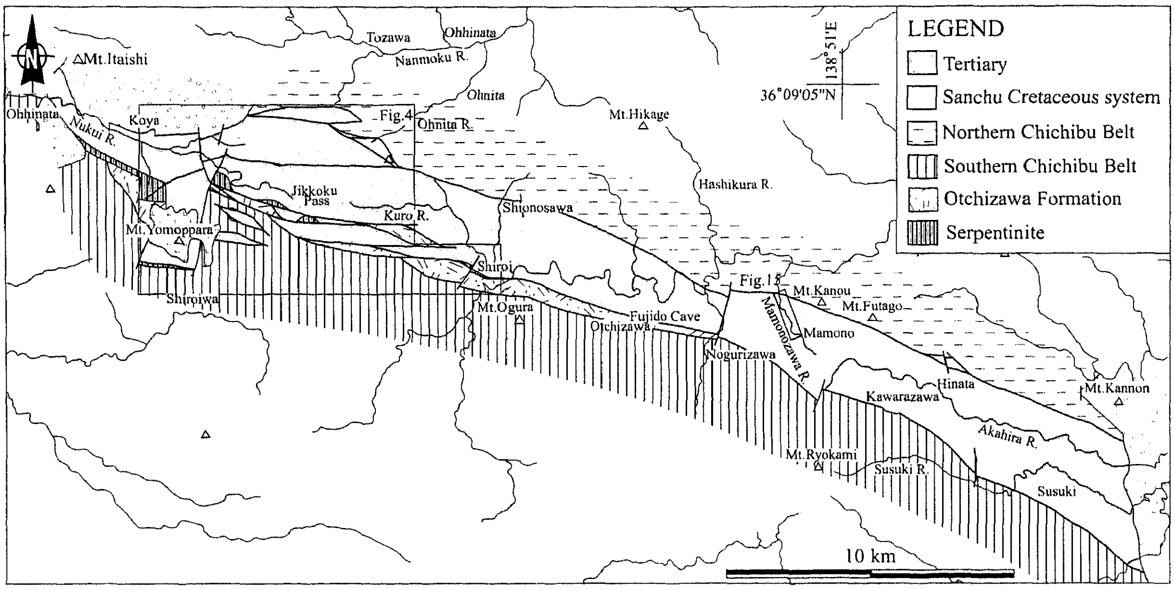

Fig. 3 Simplified geologic map of the northwestern Kanto Mountains.

al. (1992) recovered planktonic and benthic foraminifers with a few radiolarians from this limestone at the Shinzaburozawa Valley, and reported an early Aptian foraminiferal fauna. Subsequently, Yamagiwa *et al.* (1998) described twelve hexacoral species including two new species which were collected from this limestone in the western part of the Sanchu Graben. They mentioned that the age of the hexacoral assemblage indicated Early Cretaceous (probably Barremian to Early Aptian). Moreover, Kamikawa *et al.* (1988) obtained the radiolarians and foraminifers from shale at the northward branch of the Shionosawa Valley. They regarded as the age of this radiolarian assemblage as Albian.

Geologic outline

Three major belts, namely Sambagawa, Chichibu and Shimanto Belts from north to south, constitute the Kanto Mountains (Fig. 1). In the western part of the Kanto Mountains, the Chichibu Belt is occupied by the accretionary complex formed during Jurassic to earliest Cretaceous time subdivided into the Northern Chichibu and Southern Chichibu Belts (Matsuoka *et al.*, 1998). The Sanchu Cretaceous System composed of nonmarine and marine strata are longitudinally distributed and narrowly from Chichibu City, Saitama Prefecture to Saku Town, Nagano Prefecture (Fig. 3). It forms a belt of 2 to 5 km wide and approximately 40 km long extending WNW–ESE, and this belt traditionally has been called the Sanchu Graben (Harada, 1890).

In the Jikkoku Pass area, the Lower Cretaceous strata are in fault contact with beds of the Northern Chichibu Belt on the northern side and with beds of the southern Chichibu Belt, the Otchizawa Formation and serpentinite on the southern side (Fig. 3). The Otchizawa Formation consists mainly of basaltic rocks dating 120±6 Ma (Ishida *et al.*, 1992) and limestone containing Late Carboniferous to Early Permian fusulinaceans (Okubo and Horiguchi, 1969), and subordinate pebbly shale and chert . However, the geologic age of this formation is unsettled. They are unconformably overlain by a basal conglomerate of the Lower Miocene Uchiyama Formation (Watanabe, 1954; Kosaka *et al.*, 1990) in the northwestern part of the study area. In Ishido, serpentinite mass is unconformably overlain by conglomerates of the Quaternary Kagikakezawa Formation (Ishii *et al.*, 1991). Pyroxene andesite is locally exposed at Mt. Yomoppara. Unmappable size rhyolite and andesite dikes are exposed in Miyakozawa and a west valley of Kagikakezawa, respectively.

Description of formations

In this work, I propose two different units of Sanchu Cretaceous System in the Jikkoku Pass area on the basis of stratigraphy and bivalve fauna (Fig. 2). One is the Shiroi, Ishido and Sanyama Formations, and the other is the Tozawa and Ohnita Formations. The former three foamations, are revised in this paper, have been recognized in the Sanchu Graben by Matsukawa (1983), Takei (1985) and others. The latter two formations which are distributed around the boundary with the Sumaizuku Formation (Kamikawa *et al.*, 1997; Matsuoka *et al.*, 1998) of the Northern Chichibu Belt are newly distinguished from the former three forma-

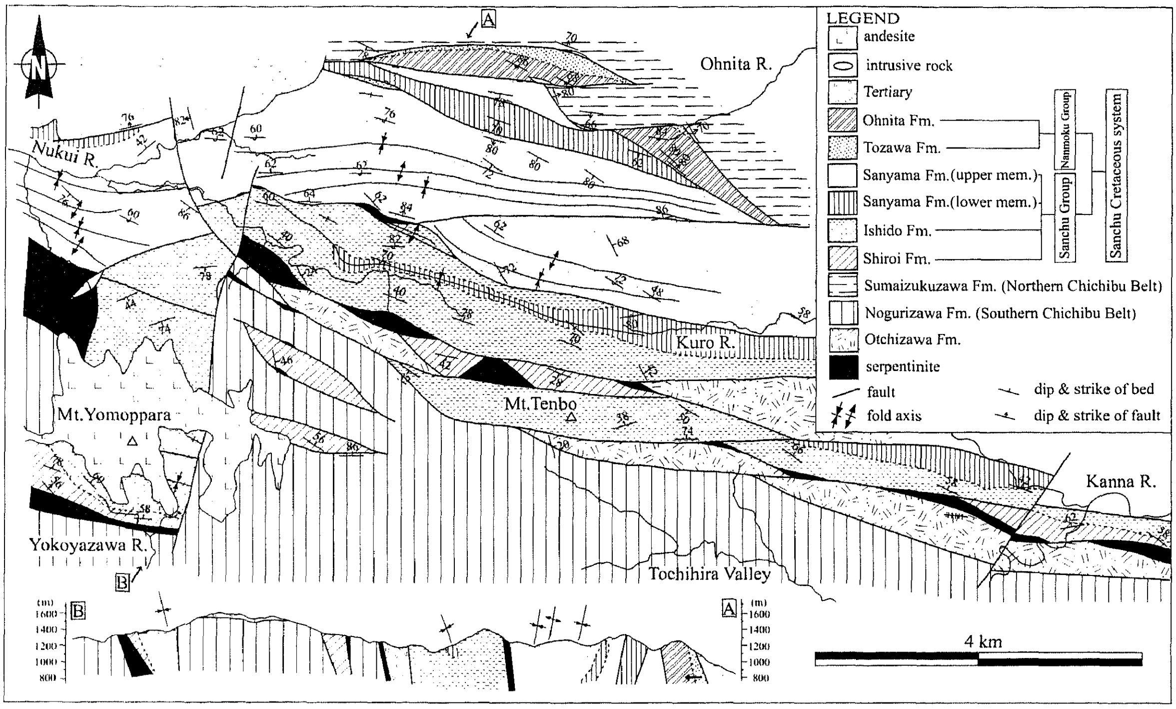

Fig. 4 Geologic map of Jikkoku Pass area.

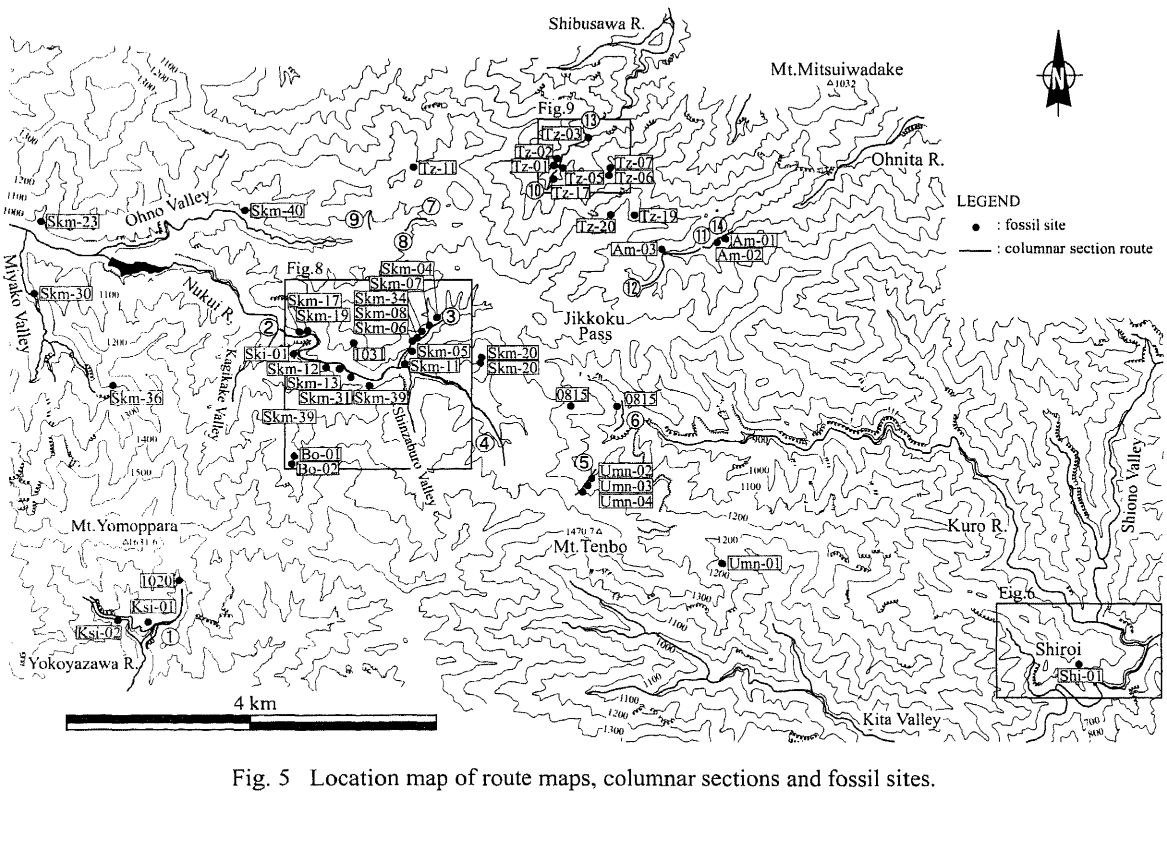

Fig. 5 Location map of route maps, columnar sections and fossil sites.

tions. In addition, I redefine the Sanchu Group (Hisada and Arai, 1993) as a unit comprising the Shiroi, Ishido, Sebayashi and Sanyama Formations, and newly define the Nanmoku Group consisted of the Tozawa and Ohnita Formations in the study area.

Geologic map is shown in Fig. 4. Location of fossil sites and columnar sections route are shown in Fig. 5.

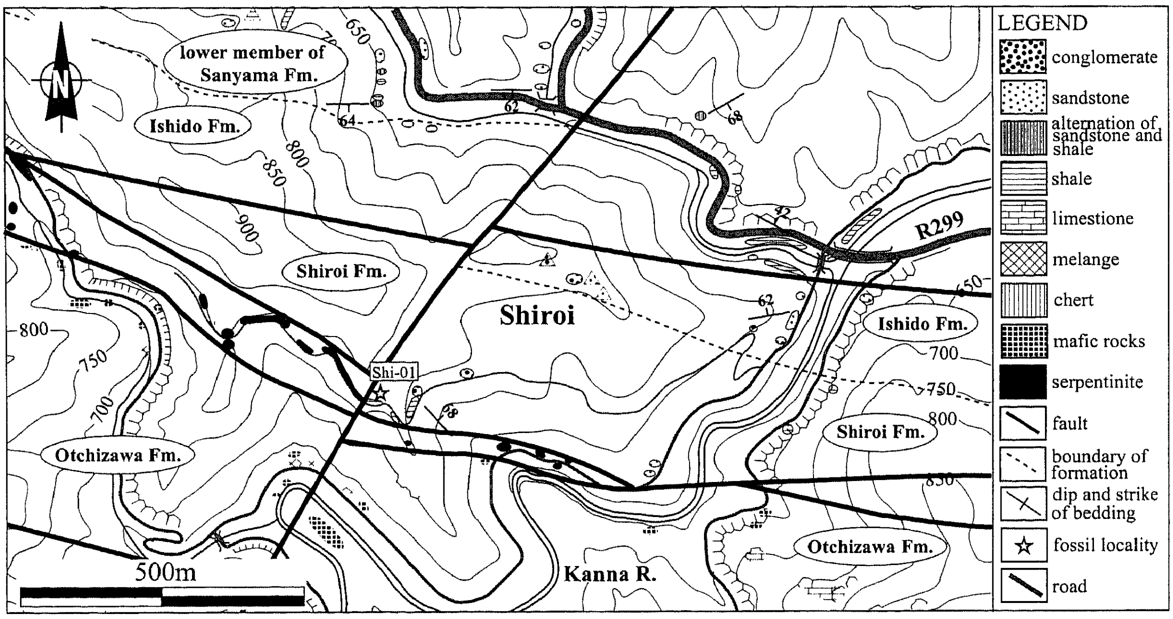

Fig. 6 Route map of Shiroi area.

Sanchu Group

1) Shiroi Formation

Yabe (1955) defined the Shiroi Formation, and Matsukawa (1979) recognized it as a lowermost formation of the Sanchu Cretaceous System which is composed of thick-bedded conglomerate and subordinately sandstone and shale containing numerous brackish-water mollusca and plant fossils.

The Shiroi Formation of the study area occurs discontinuously in seven areas as shown in Fig.4, is in fault contact with the pre-Cretaceous rocks in the study area. Among of them, this formation is typically exposed around the vicinity of Shiroi (Fig. 6) and the upper reaches of the Yokoyazawa River. The distribution of this formation certainly extends to 400 m to northeast of the Fujido Cave which is located to the east of the study area. The total thickness of the Shiroi Formation attains more than 90 m (Fig. 7).

⟨lithofacies⟩

The Shiroi Formation is composed of conglomerate, coarse-grained sandstone to conglomeratic sandstone, thick-bedded sandstone with intercalation of thin-bedded shale and sandy shale (Fig. 7). The lower part of this formation is characterized by alternation of sandy shale and conglomerate. In the Jikkoku Pass area, alternation of sandy shale and conglomerate is about 30 m in thickness, and a lower limit of this formation is undefined owing to fault disturbance. In general, sandy shale is black, and contains molluscan shells densely. Conglomerate is poorly sorted and shows graded-bedding. Clasts are subangular, pebble sized, and mainly sedimentary rocks such as chert and sandstone in sandy matrix. The upper part of this formation consists of conglomerate, conglomeratic sandstone, medium- to coarse-grained sandstone and alternation of thick-bedded sandstone and siltstone in ascending order. Its thickness is about 60 m. It shows an upward-fining sequence (Fig. 7). Conglomerate is usually clast-supported, and clasts of this conglomerate are somewhat subangular and commonly pebble sized. The clasts are mainly chert, and subordinate felsic volcanic rocks. Serpentinite cobbles are also reported at Shiroi (Hisada and Arai, 1986). Sandstone is gray color, thick-bedded medium- to coarse-grained tuffaceous lithic wackes and its each bed is a few meters thick. At some stratigraphic horizons, sandstone is massive. Sandstone occasionally yields molluscan fossils. Alternation of sandstone and siltstone consists of medium- to thick-bedded medium-grained sandstone and thin- to medium-bedded sandy siltstone containing abundant molluscan fossils, whose thickness ranges from several centimeters to a few meters and from several centimeters to several tens of centimeters, respectively. Siltstone is dark gray and contains fragments of plant fossils and molluscan fossils.

⟨fossil and geologic age⟩

I collected molluscan fossils from nine localities of the Shiroi Formaion as shown in Table 1. The Shiroi Formation contains abundant brackish-water bivalves, gastropods and fragments of terrestrial plant fossil. These molluscan fossils are also accompanied with a few genera of marine bivalves which are compara-

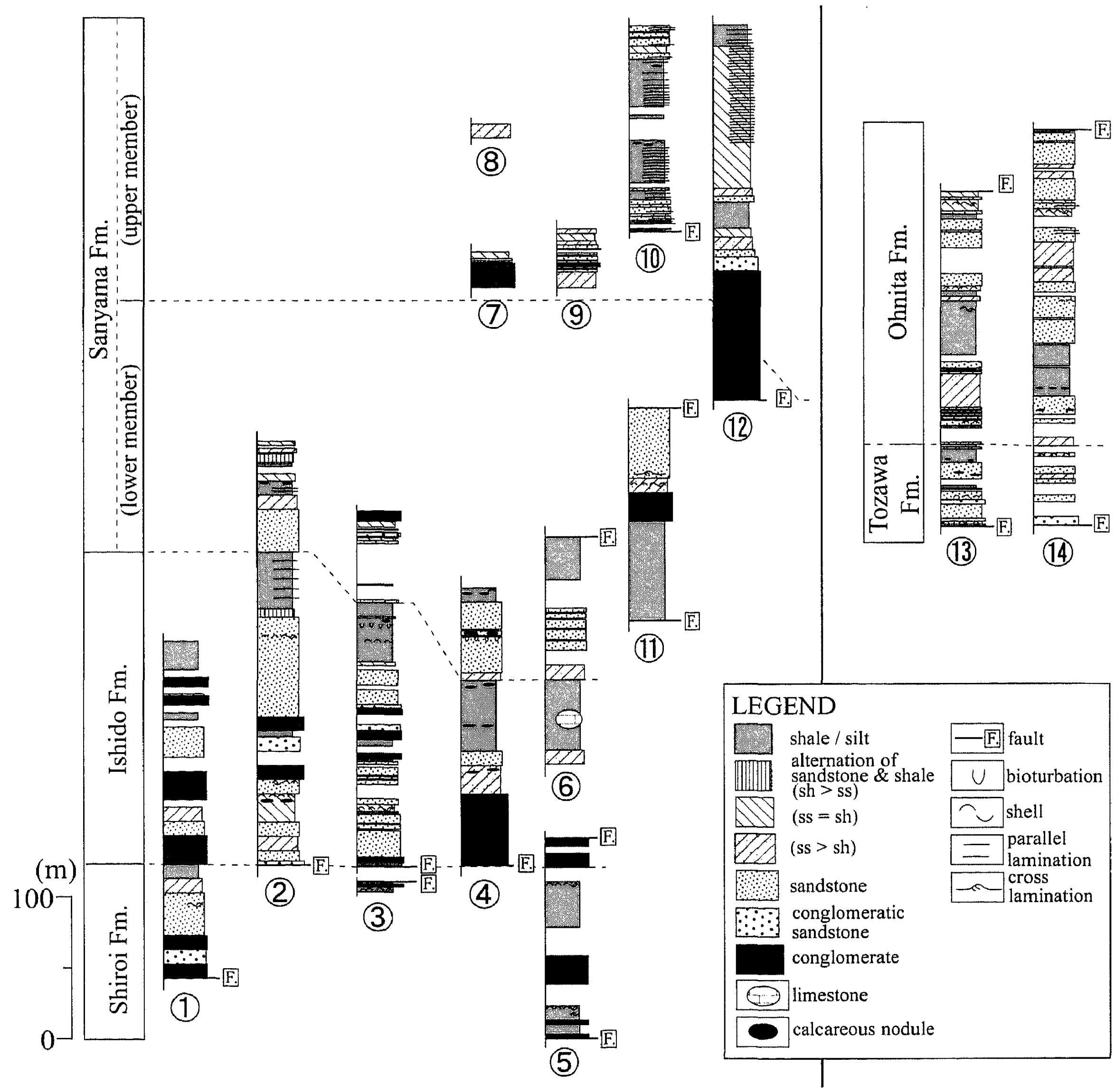

Fig. 7 Columnar sections of the Sanchu Cretaceous system in Jikkoku Pass area.

tively smaller-sized. Shells are densely concentrated and the preservation of fossil mollusks is relatively better. However, the examined shell materials of most specimens were dissolved away, and hydrophilic vinyl polysiloixane impression materials were used for the examination of moulds. Although most bivalve fossils are disarticulated, they are less broken and some articulated valves are included. This fact indicates that most shells of these specimens have not been transported over a long distance from their original habitats.

A geologic age of the Shiroi Formation is indeterminatable precisely, because no index fossil has been obtained from it. As mentioned later, the overlying Ishido Formation can be assigned to the Barremian to early Aptian in age. Therefore, judging from the conformable relationship with the Ishido Formation, a geologic age of the Shiroi Formation may be referable to the Hauterivian.

2) Ishido Foamation

This formation was primarily defined as the Ishido Group by Yabe *et al.* (1926). Later, Takei (1963) recognized a distribution of the Ishido Formation in the eastern part of the Sanchu Graben. He defined the sequence which is composed of basal conglomerate and overlying sandy shale as the Ishido Formation.

In the Jikkoku Pass area, the Ishido Formation typically crops out at the riverbeds and excavations in the south of Mt. Yomoppara, the upper reaches of the Miyakosawa Valley, tributary of the upper reaches

Table 1. List of molluscan fossils from the Shiroi Formation.

	Locality (lithology)	Ksi-01 (s. sh)	Ksi-02 (s. sh)	Bo-01 (s. sh)	Bo-02 (s. sh)	Skm-07 (silt)	Umm-02 (s. sh)	Umm-03 (sh)	Umm-04 (sh)	Shi-01 (sh)
Marine bivalve	*Arca shinanoensis* Yabe and Nagao		○			○				○
	Amygdalum aff. *ishidoense* (Yabe and Nagao)									○
	Leptosolen ? sp.			○		○				○
Brackish-water bivalve	*Placunopsis pseudotruncata* (Yabe and Nagao)	○	○	○		○		○		○
	Protocardia ibukii Nakazawa and Murata	○	○							○
	P. cf. *ibukii* Nakazawa and Murata		○			○	○			
	P. sp.			○						
	Crassostrea ryosekiensis (Kobayashi and Suzuki)					○				
	Costocyrena otsukai otsukai (Yabe and Nagao)	○	○	○	○	○	○		○	○
	C. cf. *otsukai otsukai* (Yabe and Nagao)		○			○	○		○	
	C. sp.							○	○	
	Isodomella shiroiensis (Yabe and Nagao)		○			○				○
	I. cf. *shiroiensis* (Yabe and Nagao)	○				○				
	Hayamina naumanni (Neumayr)			○						○
	H. cf. *naumanni* (Neumayr)				○					
	H. sp.							○		
	Tetoria sanchuensis (Yabe and Nagao)	○		○	○	○				○
	T. cf. *sanchuensis* (Yabe and Nagao)		○			○				
	Ostreidae *gen.* & sp. indet.	○		○			○	○	○	○
Gastropoda	*Cacciope* sp.						○			
	Brunonia ? sp.						○			

s. sh; sandy shale sh; shale

of the Nukui River and around Mt. Tenbo (Fig. 4). A route map around the upper reaches of the Nukui River is shown in Fig. 8. Though I could not observe any outcrop of contact between the Shiroi and Ishido Formations, the Ishido Formation of the study area rests on sandy siltstone of the Shiroi Formation yielding numerous brackish-water mulluscan fossils. It suggests that the Ishido Formation conformably overlies the Shiroi Formation. The Ishido Formation attains more than 200 m (Fig. 7).

〈lithofacies〉

This formation is characterized by predominance of fine- to medium-grained lithic wackes sandstone, and by occurrence of limestone blocks and prolific calcareous concretions in siltstone of the uppermost part (Fig. 7). The lower part of this formation is composed mainly of conglomerate, medium-grained sandstone and alternation of sandstone and siltstone. On the other hand, the upper part of this formation begins with conglomerate intercalated with siltstone and sandstone. They are followed by massive fine- to medium-grained sandstone, and then by siltstone. Conglomerate of the lowermost part is about 40 m thick, clast-supported and poorly sorted. This conglomerate laterally changes to granule conglomerate and/or coarse-grained sandstone as shown in Fig. 7. Clasts are granule to pebble sized and somewhat subangular to subrounded. Their lithofacies are chert, sandstone, micritic limestone, shale and others. The other conglomerates at the upper part are commonly clast-supported and moderately sorted. Clasts are usually pebble sized and subrounded. Their lithofacies are chert and subordinate sandstone. Fine- to medium-grained sandstone is gray, and usually massive and very thick- bedded. In the lower part of this formation, the sandstone intercalates conglomeratic sandstone containing fragments of marine bivalve fossils. Fine- to medium-grained sandstone is rarely calcareous in the upper part of this formation and contains trace fossils. Very thick-bedded sandstone intercalates thin-bedded shale, which yields abundant marine molluscan fossils. Alternation of sandstone and shale is medium- to thick-bedded, and laterally changes to siltstone containing calcareous concretions and marine molluscan fossils. Siltstone and shale are dark gray, occasionally bioturbated, and trails and burrows are observed as well. Parallel lamination is present in thin- to medium-bedded siltstone. Siltstone of the uppermost part contains limestone and numerous calcareous concretions. Limestone usually occurs as blocks from a few meters to several tens of meters in thickness. These limestone blocks yield reef-forming fossils such as corals, stromatoporoid and algae, and are mainly ooid grainstone, skeletal grainstone and calcarenite. Calcareous concretions are flattened, and spherical and ellipsoidal or irregularly shaped. They are several centimeters to a few tens of centimeters in diameter.

〈fossil and geologic age〉

I collected ammonites, marine bivalve fossils, gastropods and echinoids from sixteen localities, and corals and sponges from three localities in the study area. These localities are shown in Fig. 5, and fossil lists are

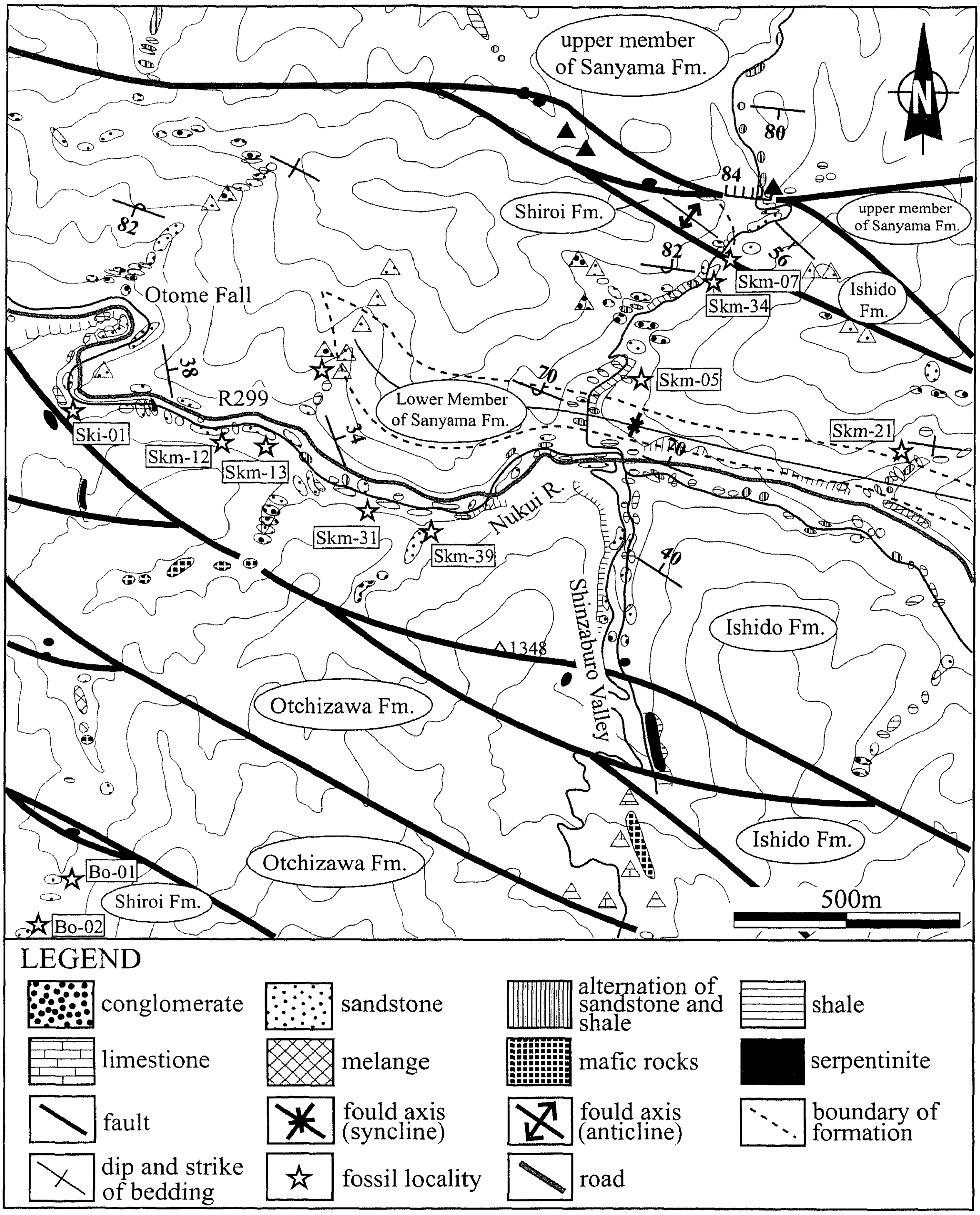

Fig. 8 Route map of Ishido area.

shown in Table 2. Fine- to medium-grained sandstone yields bivalve fossils abundantly, and siltstone occurss sporadically. Most bivalve shells, more or less broken, from sandstone are disarticulated, though siltstone yields several conjoined valves. The preservation of fossil mollusks is relatively better, though examined shell materials of most specimens are partly dissolved away.

A few reliable index fossils, namely, *Karsteniceras obatai* Matsukawa and *Leptoceratoides* sp. are obtained from the lower part, and *Ancyloceras* sp. obtained from the upper part, respectively. *Karsteniceras*

Table 2. List of fossils from the Ishido Formaiton.

	Locality (lithology)	Skm-04 (s.sh)	Skm-05 (sh)	Skm-06 (f.ss)	Skm-08 (m.ss)	Skm-11 (silt)	Skm-12 (f.ss)	Skm-13 (f-m.ss)	Skm-17 (m.ss)	Skm-19 (f.ss)	Skm-20 (s.sh)	Skm-21 (f-m.ss)	Skm-31 (s.sh)	Skm-34 (f.ss)	Skm-36 (silt)	Skm-39 (f.ss)	Ski-01 (silt)	815(limestone)	1020(limestone)	1031(limestone)
Ammonite	*Ancyloceras* sp.															○				
	Karsteniceras obatai Matsukawa													○			○			
	Leptoceratoides sp.																○			
	Valdedorsella sp. or *Barremites* sp.													○						
Marine bivalve	*Nuculopsis* (*Palaeonucula*) *ishidoensis* (Yabe and Nagao)	○												○			○			
	Portlandia (*Portlandia*?) *sanchuensis* (Yabe and Nagao)		○											○			○			
	Portlandia sp.					○														
	Nanonavis yokoyamai (Yabe and Nagao)														○		○			
	N. sp.		○										○				○			
	Pinna sp.																○			
	Gervillaria cf. *haradae* (Yokoyama)						○	○				○								
	Gervillia (*Gervillia*) *forbesiana* d'Orbigny																○			
	Chlamys cf. *robinaldina* (d'Orbigny)													○						
	Plicatula aff. *monobensis* Tashiro and Kozai														○					
	Placunopsis aff. *pseudotruncata* (Yabe and Nagao)										○									
	Nipponitrigonia cf. *plicata* Kobayashi and Nakano							○												
	N. sp.							○	○											
	Pterotrigonia (*Pterotrigonia*) cf. *kesadoensis* Tashiro							○				○			○		○			
	Pterotrigonia sp.		○		○					○				○	○		○			
	Myrtea (?) aff. *monobeana* Tashiro and Kozai																○			
	Astarte (*Astarte*) *subsenecta* Yabe and Nagao			○										○			○			
	Astarte (*Nicaniella*) *costata* Yabe and Nagao			○													○			
	A. sp.								○					○			○			
	Yabea shinanoensis (Yabe and Nagao)			○									○				○			
	Y. cf. *shinanoensis* (Yabe and Nagao)											○		○			○			
	Plectomya cf. *aritagawana* Hayami																○			
	Periplomya sp.						○										○			
	Periploma (*Periploma*) sp.																○			
Gastro-poda	Gastropoda gen. & sp. indet.		○	○									○				○			
Hexacoral	*Eohydnophora* cf. *sanchuensis* Yamagiwa, Hisada and Tamura																	○		
	Eugyra cotteaui Fromentel																	○		
	Eugyra or *Eohydnophora* sp. indet.																		○	
	Palaeopsammia cf. *zljebinensis* Turnsek and Mihajlovic																	○		
	Thamnasteria cotteaui Fromentel																	○		
	Isastrea sp. C																	○		
	Dimorphastraea or *Meandraraea* sp. indet.																	○		
Sponge	*Spongimorpha asiatica* Yabe and Sugiyama																	○		○

f.ss; fine-grained sandstone, m.ss; medium-grained sandstone, sh; shale, silt; siltstone, s.sh; sandy shale *obatai* Matsukawa occurs from the Kimigahama Formation of the Choshi Group which can be assigned to the Lower Barremian (Matsukawa and Eto, 1987). The other genera, *Leptoceratoides* sp. and *Ancyloceras* sp. are also known from the Barremian of the Tethys, Boreal and circum-Pasific provinces. Thus, these ammnonites species and genera indicate to the Barremian. In addition, a hexasoral assemblage collected from limestone blocks of the uppermost part is similar to the Barremian to early Aptian assemblage reported by Yamagiwa *et al.* (1998).

Taking the age of hexacorals and these microfossils into account, the uppermost part of the Ishido Formation can be regarded as an early Aptian age. Therefore, based on these lines of fossil evidence, the geologic age of the Ishido Formation can be regarded as the Barremian to early Aptian in the study area.

3) Sanyama Formation

The formation first named by Takei (1963) is composed mainly of shale accompanied with the basal conglomerate, and shows two cyclic sedimentations. The Sanyama Formation is widely distributed in the northern part of the Jikkoku Pass area as shown in Fig. 4. This formation typically crops out along the upper reaches of the Ohnita River, the Miyakozawa Valley, the logging road around the upper reaches of the Ohnozawa Valley and the Route 299 around the upper reaches of the Kuro River. The Sanyama Formation conformably overlies the Ishido Formation, and this is unconformably overlain by the Uchiyama Formation in the northwestern part. The estimated thickness of the Sanyama Formation exceeds 480 m (Fig. 7).

In the study area, the Sanyama Formation is subdivided into the lower and upper members. The lower member is characterized by thick-bedded alternation of sandstone and shale, and the upper member is characterized by conglomerate and thin-bedded fine-grained sandstone and shale (Fig. 7).

〈lithofacies of lower member〉

The lower member consists mainly of feldspathic arenite sandstone, alternation of sandstone and shale with intercalation of conglomerate and shale (Fig. 7). Its estimated thickness attains more than 200 meters. Thick-bedded medium-grained sandstone rests conformably on shale in the uppermost part of the Ishido Formation. Alternation of sandstone and shale is composed of medium- to thick-bedded fine- to medium-grained sandstone, and thin- to medium-bedded siltstone with several interbeds of conglomerate. Conglomerate is usually sandy matrix-supported, and moderately sorted. This conglomerate is commonly medium- to thick-bedded, and often shows graded-bedding. Its clasts are granule to pebble sized, subrounded, and are composed mainly of chert and sandstone. Siltstone is generally thin-bedded, rarely intercalated with thin-bedded fine-grained sandstone. Parallel lamination is common in siltstone. The uppermost part of the lower member consists of very thick-bedded fine-grained sandstone and muddy sandstone including marine molluscan fossils. Low-angled cross lamination is rarely developed in this sandstone.

〈lithology of upper member〉

The upper member conformably covers the lower member with an abrupt change of lithofacies. It begins with conglomerate containing fragments of molluscan fossils. It is followed by thin- to thick-bedded alternation of sandstone and shale, and then thin- to medium-bedded shale intercalated with thin-bedded sandstone (Fig. 7). The total thickness of the upper member is estimated to be more than 280 meters.

Conglomerate is remarkably thick, and laterally changes to granule to pebble conglomerate or medium- to thin-bedded alternation of granule conglomerate and coarse- to mediun-grained sandstone accompanied with thin-bedded shale as shown in Fig. 7. This conglomerate attains about 90 m in thickness. Conglomerate is commonly clasts-supported, poorly sorted, and massive and/or planar stratified, though its upper part is sandy matrix-supported. Its clasts are almost pebble to cobble sized and subrounded to rounded. They are granite, andesite, shale, chert, sandstone, limestone, acidic tuff and others. Particularly, granitic clasts are commonly cobble sized, and occasionally more than one meter in diameter. Alternation of sandstone and shale consists of medium- to thick-bedded fine- to coarse-grained sandstone, and medium- to thin-bedded siltstone. This alternation except for the lower part, has the characteristics of a distal turbidite. Sandstone of the lower part is thick-bedded and medium- to coarse-grained. The other intercalated sandstone is commonly thin- to medium-bedded and fine-grained, and is frequently parallel-laminated. The linguloid type ripple, flute mark and groove cast are occasionally observed in the intercalated sandstone. Siltstones are usually dark gray and/or black, and are wavy or parallel-laminated. Convolute lamination is rarely developed in shale. Siltstones also contain calcareous concretions, several centimeters to rarely a few tens of centimeters. Also, siltstone is rarely accompanied with calcareous parts. Shale of the uppermost part is medium- to thick-bedded, rarely parallel-laminated and bioturbated.

〈fossil and geologic age〉

The Sanyama Formation rarely yields molluscan

Table 3. List of molluscan fossils from the Sanyama Formation.

	Locality (Lithology)	Skm-23 (md. ss)	Skm-30 (cgl. ss)	Skm-40 (m. ss)	Am-03 (sh)	Tz-17 (sh)
Marine bivalve	*Nuculopsis* (*Palaeonucula*) cf. *ishidoensis* (Yabe and Nagao)					○
	Gervillia (*Gervillia*) *forbesiana* d'Orbigny	○				
	Nipponitrigonia kikuchiana (Yokoyama)		○			
	Pterotrigonia sp.		○			
	Eriphyra cf. *monobeana* Tashiro and Kozai				○	
	Aphrodina sp.	○				
	Panopea sp.	○		○		
	Ostrea gen. & sp. indet.	○			○	

m. ss; medium-grained sandstone, md. ss; muddy sandstone, sh; shale

fossils in the study area. As shown in Fig. 5, I collected marine bivalve fossils from two localities of the lower member, and from three localities of the upper member. Seven species were discriminated from these localities and a fossil list is shown in Table 3. These bivalve fossils were obtained from muddy sandstone and medium-grained sandstone of the lower member at Skm-23 and Am-03. Shells are disarticulated and densely concentrated. Their preservation is poor, though several specimens remain shell materials. In addition, bivalve fossils were obtained from conglomeratic sandstone, medium-grained sandstone, and shale of the upper member at Skm-30, Skm-40, and Tz-17, respectively. Shells collected from Skm-30 and Skm-40 are lenticularly concentrated, disarticulated and less broken. Their preservation is relatively better.

No reliable index fossil has been obtained from the Sanyama Formation in the study area. Taking account into the conformable relationship with the Ishido Formation and previous work such as Kamikawa *et al.* (1988) reporting the Albian radiolarian assemblage from shale corresponding to the uppermost part of the Sanyama Formation of the study area, this formation is inferred to be late Aptian to Albian in age in the study area.

Nanmoku Group

1) Tozawa Formation

The Tozawa Formation is newly proposed herein for calcareous conglomerate and/or conglomeratic sandstone and medium- to coarse-grained sandstone, and subordinate alternation of sandstone and shale. This name is derived from a place name, Tozawa, Nanmoku Village, Kanra County, Gunma Prefecture. Tozawa is located along the Nanmoku River, approximately 6 km to north-northeast of the Jikkoku Pass.

A type section of the Tozawa Formation is selected; exposures of a logging road along an unnamed river which meets the Shibusawa River (Fig. 5). The route map is shown in Fig. 9. As shown in Fig. 4, the distributional area of the Tozawa Formation is narrowly limited along the northern boundary in the study area. It occurs not only at the type locality but also in the upper reaches of the Ohnita River, and also crops out in the remarkably limited area along the boundary fault with the Sanyama Formation.

The Tozawa Formation is in fault contact with the pre-Cretaceous rocks of the Sumaizukuzawa Formation (Kamikawa *et al.*, 1997; Matsuoka *et al.*, 1998) of the Northern Chichibu Belt. The contact surface between the Tozawa and the Sumaizuku Formations can not be observed because of lack of the outcrop (Fig. 9). The total thickness of the Tozawa Formation attains more than approximately 60 meters in the type section (Fig. 7).

⟨lithofacies⟩

The Tozawa Formation is composed mainly of conglomerate, sandstone and medium- to thick-bedded alternation of sandstone and shale (Fig. 7). Sandstone characteristically includes calcareous concretions, several centimeters long. Also, this formation is characterized by the occurrence of calcareous sandstone.

Each bed of conglomerate is 1 m to 4 m thick. It is sandy matrix-supported, poorly sorted and contains molluscan fossils. Clasts are granule and subordinate pebble sized, and subrounded to subangular. They are mainly chert, limestone and others. In addition, limestone clasts are occasionally dissolved away, and their cavities can be observed in conglomerate and conglomeratic sandstone.

Sandstone is commonly fine- to coarse-grained, and its grain size varies remarkably at each stratigraphic horizon. Sandstone is usually light to dark gray and massive or thick-bedded. In the lower part of this formation, sandstone becomes calcareous. It also sporadically changes to medium-bedded conglomeratic one and includes granule to pebble-sized chert clasts.

Alternation of sandstone and shale is composed of thick-bedded fine to coarse-grained sandstone and thin-bedded siltstone. Each sandstone bed usually shows grading-bedded, and parallel lamination and patches of shale are rarely observed in fine- to medium-grained sandstone.

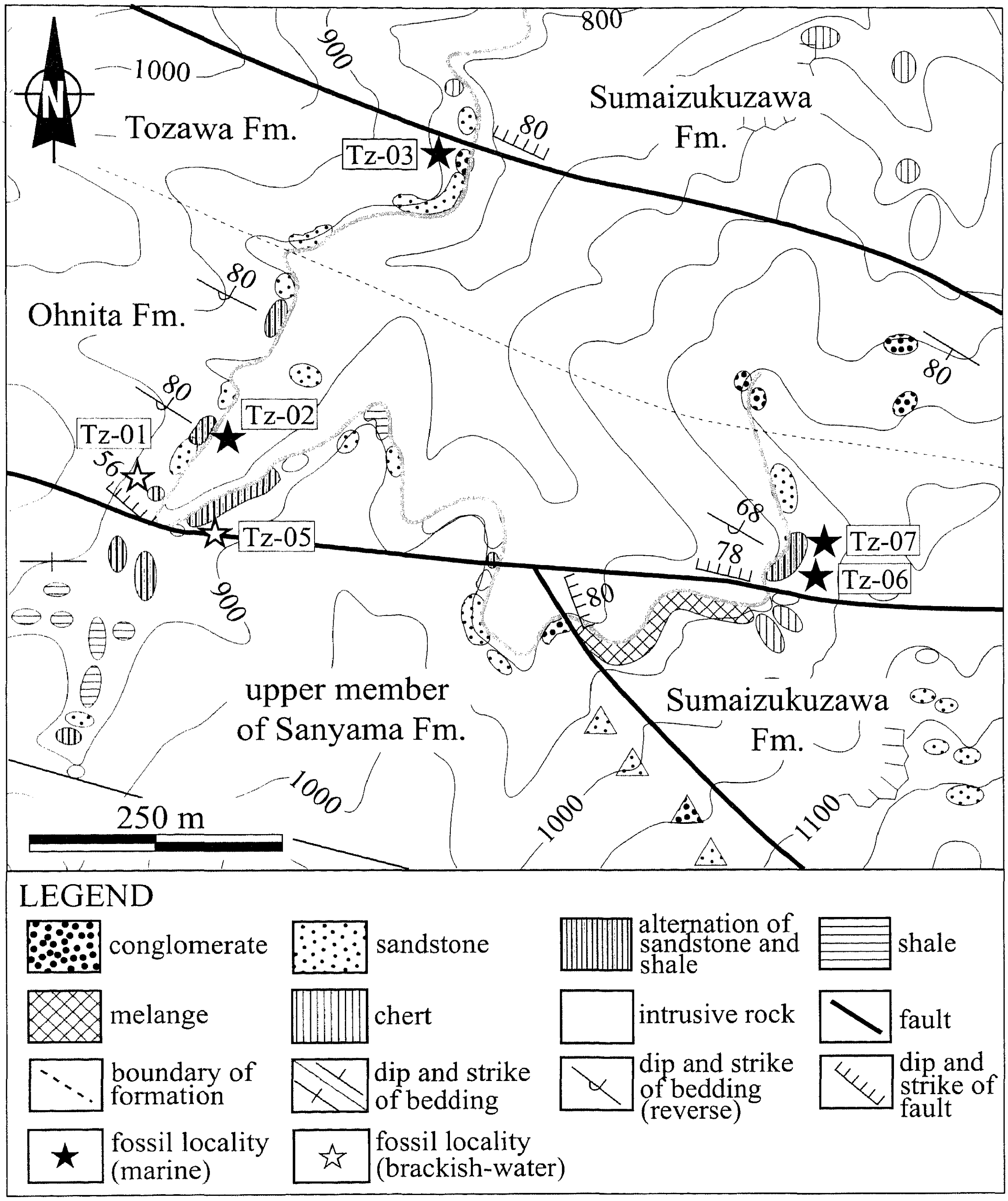

Fig. 9 Route map of the type locality of the Tozawa and Ohnita Formations.

〈**fossil and geologic age**〉

The Tozawa Formation yields marine molluscan fossils such as ammonites, bivalves, gastropods and echinoids (Table 4). Bivalve fossils were obtained from granule conglomerate at locality Tz-03 and coarse-grained sandstone at locality Tz-20, respectively (Fig. 5). Shells are disarticulated, occasionally broken, and their preservation is poor. The discriminated bivalve fossils are *Globocardium sphaeroideum*, *Rastellum* (*Arctostrea*) *carinatum*, "*Pachytraga*" *japonica* and so on (Table 4).

Ammonite, *Paracrioceras* cf. *asiaticum* (Matsumoto) was obtained from a medium-grained sandstone float around locality Tz-03. This specimen is a part of the chamber and its preservation is relatively poor. I have obtained no reliable index fossils except for

Table 4. List of molluscan fossils from the Tozawa Formation.

		Locality (lithology)	Tz-03 (g.cgl)	Tz-03 (f.ss)	Tz-20 (m.ss)
Ammonoite	*Paracrioceras* cf. *asiaticum* (Matsumoto)			☆	
Marine bivalve	*Neithea* sp.		○		○
	Globocardium spaeroideum (Forbes)		○		
	Rastellum (*Arctostrea*) cf. *carinatum* (Lamarck)		○		
	"*Pachytraga japonica*" Okubo and Matsushima		○		○
Gastropoda	Gastropoda gen. & sp. indet.		○		

g.cgl; granule conglomerate, m.ss; medium-grained sandstone, f.ss; fine-grained sandstone, ☆ ; float

Paracrioceras cf. *asiaticum* from the Tozawa Formation. According to Matsukawa and Obata (1993), *Paracrioceras asiaticum* (Matsumoto) occurs from the upper Arida, upper Hanoura and lower Idaira Formations in southwest Japan, and suggests early Barremian in age. Hisada *et al.* (1992) also reported ammonites, *Paracrioceras* aff. *elegans* (Koenen), *Shasticrioceras nipponicum* Matsumoto and *Shasticrioceras* (?) sp. from thin-bedded shale of the Tozawa Formation, which are regarded as the Barremian species (Matsukawa and Obata, 1993). As these ammonite specimens are small population and poor preservation, further fossil evidence is required to determine the age of its ammonite assemblage.

Concerning the bivalves, the assemblage of the Tozawa Formaion is similar to that of the Aptian Kesado and Osaka Formations of the Pre-Sotoizumi Group. *Globocardium sphaeroidea* (Forbes) obtained at locality Tz-03 was described from the following Aptian and Albian formations. The Aptian formations are the Hiraiga Formation of the Miyako Group (Hayami, 1965), the Osaka (Tanaka, 1989) and Kesado (Tashiro and Ikeda, 1987; Tanaka *et al.*, 1998) Formations of the Pre-Sotoizumi Group, and the Albian formation is the Takahata Formation of the Pre-Sotoizumi Group (Tashiro and Tanaka, 1992). This species is also known from the Aptian of England, France, the upper Neocomian to Aptian of Crimea and Caucasus, and the Albian of Belgium (Hayami, 1965). Thus, its occurrences have been known almost in Aptian age. In addition, *Pachytraga japonica* reported from the Akaishi area of central Japan (Okubo and Matsushima, 1959) and the Aptian Osaka Formation of the Pre-Sotoizumi Group (Tanaka, 1989).

Judging from these lines of fossil evidence, the Tozawa Formation is roughly correlative with the Barremian (?) to Aptian, probably Aptian.

2) Ohnita Formation

The Ohnita Formation is newly defined for massive, fine- to medium-grained sandstone and alternation of thick-bedded sandstone and thin-bedded siltstone in the study area. This formation name is derived from a river name, Ohnita River, Manmoku Village, Kanra County, Gunma Prefecture, which is a branch river of the Nanmoku River.

A type section of the Ohnita Formation is proposed for exposures of a logging road along an unnamed river which meets the Shibusawa River. The route map of the type section is shown in Fig. 9. The Ohnita Formation is discontinuously and narrowly distributed in the limited area, which is situated in the northernmost part of the study area as shown in Fig. 4. It occurs around the upper reaches of the Ohnita River as well.

The Ohnita Formation is inferred to overlie conformably the Tozawa Formation, though there is no exposure between them. Its upper part is generally bounded by faults. The thickness of the Ohnita Formation is more than 230 meters in the type locality (Fig. 7).

〈lithofacies〉

The Ohnita Formation is characterized by predominance of massive and/or thick-bedded sandstone. This formation is composed of the massive and/or thick-bedded sandstone which occasionally intercalates thin-bedded siltstone, and alternation of medium- to thick-bedded sandstone and thin- to medium-bedded shale (Fig. 7).

Massive and/or thick-bedded sandstone are usually fine-grained and gray to dark gray. The thickness of each bed ranges from one meter to several meters. This sandstone occasionally amalgamated, and the sedimentary structure such as graded bed and parallel lamination are rarely detected. In the middle part of the Ohnita Formation, fine-grained sandstone contains lenticular shape beds of condensed marine bivalve fossils.

Alternation of medium- to thick-bedded sandstone and thin- to medium-bedded shale is usually intercalated with massive and/or thick-bedded sandstone in the middle and upper parts. Medium- to thick-bedded sandstone is very fine- to fine-grained and occasionally muddy. The fine-grained sandstone is parallel laminated in some places. The fine-grained and muddy sandstones of the middle and upper parts yield marine molluscan fossils and brackish-water bivalve fossils, respectively (Fig. 7). Thin- to medium-bedded shale is gray and black. The thickness of each bed ranges from 5 cm to 30 cm.

〈fossil and geologic age〉

The Ohnita Formation yields abundant marine and brackish-water bivalve fossils, and subordinate gastropods and echinoids. I collected these fossils from four localities in the middle part, and from four localities in the upper part. These localities are shown in Fig. 5 and the fossil list is shown in Table 5.

Marine bivalve fossils were obtained from fine-grained sandstone in the middle part at localities Tz-02, 06 and 07, and Am-01 (Fig. 5). Shells are densely concentrated, disarticulated. However, their preservation is relatively better. The discriminated bivalve fossils are *Pterotrigonia hokkaidoana*, *Rastellum* (*Arctostrea*) *carinatum*, *Astarte* (*Astarte*) *yatsushiroensis* and others (Table 7). Brackish-water bivalve fossils were obtained from muddy sandstone of the upper part at localities Tz-01 and 05 and from fine- to medium-grained sandstone of the upper one at localities Tz-11 and Am-02 (Fig. 5). Shells are concentrated and disarticulated, and their preservation is relatively poor. The brackish-water bivalve species obtained from these localities are *Costcyrena matsumotoi*, *Tetoria yatsushiroensis* and others (Table 5).

No reliable index fossil has been obtained from the Ohnita Formation in the study area. However, the marine and brackish-water bivalve assemblages of the Ohnita Formation are quite similar to those of the Yatsushiro Formation of the Pre-Sotoizumi Group containing such as *Pterotrigonia hokkaidoana*, *Astarte* (*Astarte*) *yatsushiroensis*, *Neithea matsumotoi*, *Costocyrena matsumotoi* and *Tetoria yatsushiroensis* (Tanaka *et al.*, 1998). The Yatsushiro Formation is correlative with the lower Albian on the basis of the occurrence of ammonoid, *Uhligella* sp. (Tanaka *et al.*, 1998). In particular, *Costocyrena matsumotoi* and *Tetoria yatsushiroensis* obtained at localities Tz-01, 05 and 11 and Am-02, have been reported only from the Yatsushiro Formation (Hayami, 1965; Ohta, 1981). In addition to the occurrence of these species from the Yatsushiro Formation, *Pterotrigonia hokkaidoana* collected at locality Tz-02 has been known from the Miyako Group (Yehara, 1915). *Astarte* (*Astarte*) *yatsushiroensis* obtained at locality Tz-02 has been reported from the Takahata Formation of the Pre-Sotoizumi Group (Tashiro and Tanaka, 1992). The Miyako Group is correlative with the Aptian to Albian (e.g., Hanai *et al.*, 1968), and the Takahata Formation corresponds to the upper Albian (Tanaka *et al.*, 1997). Therefore, the bivalve assemblage of the Ohnita Formation is assignable to Albian, probably early Albian. Its geologic age can be regarded tentatively as the early Albian in the study area.

Table 5. List of molluscan fossils from the Ohnita Formation.

	Locality (Lithology)	Tz-02 (s.sh)	Tz-06 (f.ss)	Tz-07 (f.ss)	Am-01 (f.ss)	Tz-01 (s.sh)	Tz-05 (s.sh)	Tz-11 (s.sh)	Am-02 (m.ss)
Marine bivalve	*Gervillaria* sp.				○				
	Amphidonta (*Amphidonta*) cf. *subhaliotoidea* (Nagao)								○
	Rastellum (*Arctostrea*) cf. *carinatum* (Lamarck)			○	○				
	Pterotrigonia (*Pterotrigonia*) *hokkaidoana* (Yehara)	○							
	P. (*P.*) cf. *kesadoensis* Tashiro	○		○					
	P. sp.	○							
	Astarte (*Astarte*) *yatsushiroensis* Tashiro	○							
	A. sp.	○		○					
	Protocardia sp.								○
	Panopea (*Myopsis*) sp.								○
Brackish-water bivalve	*Costocyrena matsumotoi* Hayami					○	○	○	○
	Tetoria yatsushiroensis Ohta					○			○
	T. cf. *yatsushiroensis* Ohta							○	○
	Ostreidae gen. & sp. indet.		○			○	○	○	○

s.sh; sandy shale, f.ss; fine-grained sandstone, m.ss; medium-grained sandstone

Geologic structure

The Sanchu Cretaceous System is bounded on both northern and southern margins by vertical or steeply northward-dipping longitudinal faults in the Jikkoku Pass area (Fig. 4). In the northern margin, the Sanchu Cretaceous System is in fault contact with the Sumaizuku Formation of the Northern Chichibu Belt. Andesite dikes are exposed along these faults. In the southern margin, it is bounded to serpentinite masses, the Otchizawa Formation (Okubo and Horiguchi, 1969; Hisada *et al.*, 1987) and the Hamadaira Group (Hisada and Kishida, 1986) of the Southern Chichibu Belt. In addition, the Sanchu Cretaceous System and the Otchizawa Formation are sliced by approximately E-W to ENE-WSW trending faults (Fig. 4), and these faults are generally regarded as normal faults. Then, these longitudinal faults are occasionally accompanied with serpentinites in the southern part of the study area, especially along the southern margins of the Sanchu Cretaceous System. The contact surface between serpentinite and the Sanchu Cretaceous System could not be observed except for one locality. The fault contact between serpentinite and the Sanchu Cretaceous System is well exposed at a path along unnamed valley which is located to the north to the Shinzaburozawa Valley. The fault is associated with fault breccia and fault gouge. The fault plane trends N84°W and dips 84 °N, and slickenlines are observable on its surface. To the contrary, no serpentinite crops out in the northern part of the Sanchu Graben. In addition to these longitudinal faults, some faults trending NNE–SSW or NNW –SSE are developed on the western side of the Kagikakezawa Valley.

The Sanchu Cretaceous System in this area commonly strike N60°W to E–W and dip 60°–80°N or 60°–80°S, as shown in Fig. 4. The Shiroi, Ishido and Sanyama Formations essentially form a closed synclinorium (Fig. 4). The fold axes trend generally WNW–ESE, which is roughly parallel to the longitudinal faults in the Jikkoku Pass area. The axes plunge moderately low-angled to WNW judging from the distribution of strata. The axial surface steeply inclines to the north or south. Moreover, many minor closed folds are developed in the Sanyama Formation. On the other hand, the Tozawa and Ohnita Formations steeply incline to the north and are overturned. Stratigraphical tops of these two formations face southward.

A relationship between the Sanchu and Nanmoku Groups, that is, the Shiroi – Ishido – Sanyama Formations and the Tozawa and Ohnita Formations, is also in fault contact, and the fault steeply digs northward. The fault trends E–W with a 6 m wide shear zone at the river bed outcrop in the upper reaches of the Shibusawa River, 4 km southwest of Tozawa, while it trends NE–SW at an outcrop along the Ohnita River, approximately 4 km to southwest of Ohnita.

Correlation with Lower Cretaceous in the Chichibu Belt

Lower Cretaceous strata are discontinuously distributed in the Chichibu Belt. They are roughly divided into three contemporaneous but heterogeneous groups, judging from their lithofacies, stratigraphy, bivalve fauna and geographic distribution. They are, namely, the Monobegawa, Nanaki and pre-Sotoizumi Groups (e.g., Tashiro, 1985a; Tashiro & Ikeda, 1987; Tanaka *et al.*, 1998). Though these groups are characterized by repeated sequence of brackish-water and marine strata, the lithofacies and bivalve fauna of the Monobegawa Group is different from those of the Nankai and pre-Sotoizumi Groups. The Nankai Group shows a close resemblance to the pre-Sotoizumi Group with regard to the stratigraphy, lithofacies and bivalve fauna except for those in Albian. Moreover, the Monobegawa Group occurs in the Northern Chichibu Belt or on the northern side of the Kurosegawa Belt, and the Nankai Group is distributed sporadically in the Southern Chichibu Belt or on the southern side of the Kurosegawa Belt (Tashiro, 1985b). The pre-Sotoizumi Group occurs in the Kurosegawa Belt of Kyushu. They are summarized as follows (Fig. 10).

Sanchu Group

The Shiroi Formation is characterized by the occurrence of a brackish-water bivalve fauna such as *Costocyrena otsukai otsukai*, *Hayamina naumanni*, *Tetoria sanchuensis*, *Isodomella shiroiensis* and *Protocardia ibukii*. It also contains a few marine species such as *Arca shinanoensis*, *Placunopsis pseudotruncata* and others. This bivalve fauna is similar to the brackish-water fauna from the Ryoseki Formation of the Monobegawa Group in Kochi, though the former reflects somewhat closer to a marine environment than the latter. This fauna is also similar to those of the Idaira (Tanaka *et al.*, 2000a), Yuasa (Tanaka *et al.*, 2002b), Tatsukawa (Nakai, 1968) and Togawa (Tanaka *et al.*, 1997) Formations of the Monobegawa Group. Concerning lithology, the lower parts of the Ryoseki Formation and its equivalent are generally characterized by reddish to purplish sediments and the repetition of upward-fining minor sedimentary cycles. The Shiroi Formation shows the repetition of upward-fining minor sedimentary cycles at least two times, though these reddish sediments are barren in it. Judging from the occurrence of the bivalve fauna, the Shiroi Formation is compared with the Ryoseki Formation of the Monobegawa Group and its equivalent (Fig. 11).

The Ishido Formation yields a relatively shallow marine bivalve fauna. The representative species are *Nuculopsis* (*Palaeonucula*) *ishidoensis*, *Portlandia* (*Portlandia*?) *sanchuensis*, *Nanonavis yokoyamai*, *Gervillia forbeshiana*, *Astarte* (*Astarte*) cf. *subsenecta*, *Astarte* (*Nicaniella*) *costata*, *Yabea shinanoensis* and others. These species are well known from the Monobe Formation of the Monobegawa Group and its equivalents. It also contains a few elements of the Nankai and Pre-Sotoizumi Groups. This bivalve fauna may a transitional fauna between a fauna from the Monobegawa Group and that of the Nankai and Pre-Sotoizumi Groups obtained from the Lower Cretaceous beds of the Konomori area belonging to the Kurosegawa Belt (Kondo *et al.*, 1999). The Ishido Formation except for its uppermost part is characterized by sandstone pre-

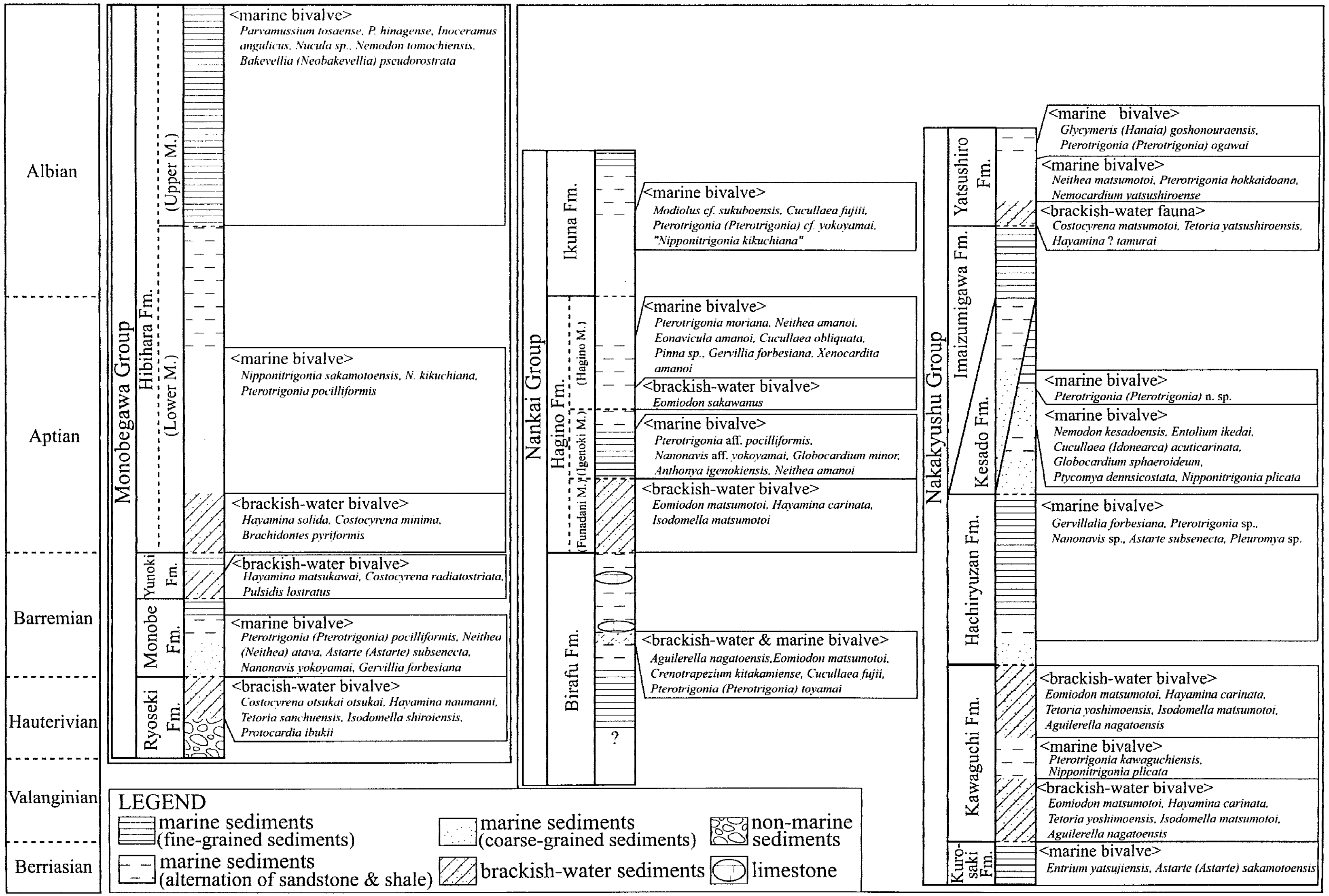

Fig. 10 Classification of Early Cretaceous formations in Shikoku and Kyushu. This figure compiled after Tashiro (1985a, 1985b), Tanaka *et al.*, (1998), Tanaka *et al.*, (2002a) and Kawano *et al.*, (2002).

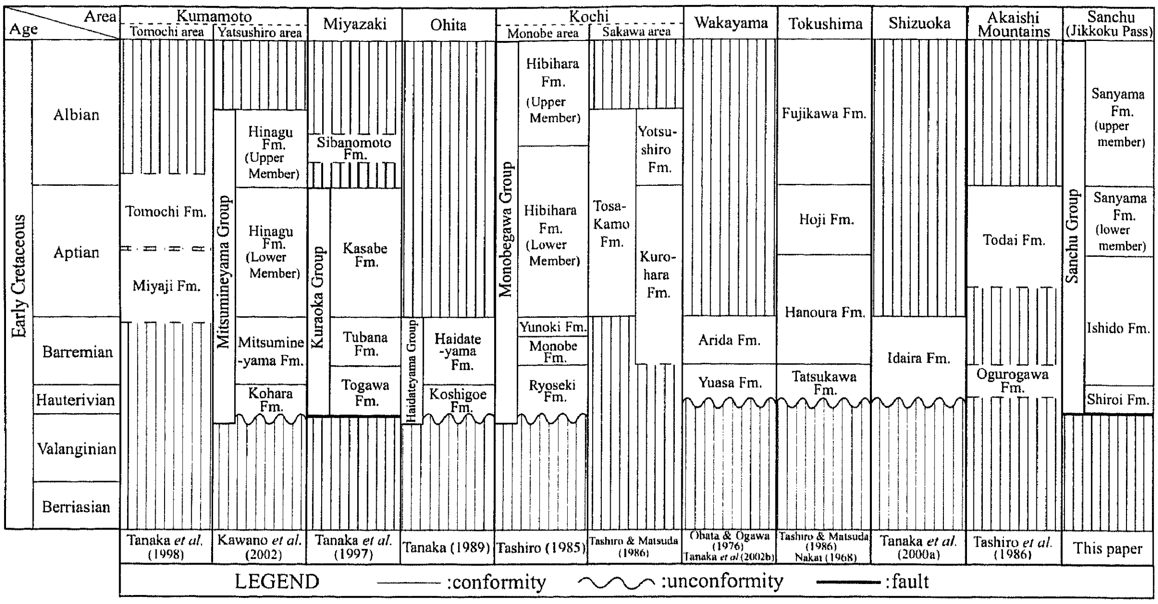

Fig. 11 Correlation of the Monobegawa Group and its equivalents in the Chichibu Belt of SW Japan.

dominant facies. The Monobe Formation is also characterized by similar facies (Tashiro, 1993).

The Sanyama Formation is divided into the lower and upper members which are assigned to the Aptian and Albian, respectively. The lower member is characterized by medium to thick-bedded alternation of sandstone and shale, and yields marine bivalve fossils which are also known from the Monobegawa Group. Taking account into its lithofacies, geologic age and bivalve fauna, the lower member is compared with the lower member of the Hibihara Formation of the Monobegawa Group (Tashiro, 1993), probably its upper part. The upper member is characterized by the turbidite facies which is accompanied with conglomerate in its lowermost part, and by the rare occurrence of molluscan fossils. The conglomerate contains characteristically abundant granite cobbles. Based on the lithofacies, the upper member is correlatable to the upper member of the Hibihara Formation (Tashiro, 1993), the Tosakamo (Tashiro and Matsuda, 1986), Tomochi (Kawano *et al.*, 2002) and Hinagu (Tanaka *et al.*, 1998) Formations (Fig. 11).

Nanmoku Group

The Tozawa Formation is characterized by calcareous sandstone yielding a marine bivalve fauna containing of *Rustellum* (*Arctostrea*) cf. *carinatum*, *Globocardium sphaeroideum* and "*Pachytraga*" *japonica*. This marine fauna is compared with a fauna of the Kesado Formation of the Pre-Sotoizumi Group in Kumamoto Prefecture. The Kesado Formation is also characterized by calcareous sediments (Tanaka *et al.*, 1998). In addition, the Tozawa Formation is much similar to the Osaka Formation of the Pre-Sotoizumi Group in Ohita Prefecture (Tanaka *et al.*, 1996) with regard to the lithofacies, and occurrence of rudists and *Globocardium sphaeroideum*. Thus, the Tozawa Formation is correlatable to the Kesado and Osaka Formations of the Pre-Sotoizumi Group (Fig. 12).

The Ohnita Formation yields marine bivalves such as *Pterotrigonia* (*Pterotrigonia*) *hokkaidoana* and *Astarte* (*Astarte*) *yatsushiroensis* and brackish-water bivalve fauna represented by *Costocyrena matsumotoi* and *Tetoria yatsushiroensis*, and is assigned to the lower Albian. These bivalve faunas correspond to marine and brackish-water faunas from the Yatsushiro Formation of the Pre-Sotoizumi Group in Kumamoto Prefecture. The Yatshshiro Formation can be regarded as the lower Albian on the basis of the occurrence of *Uhligella* sp. (Tanaka *et al.*, 1998). The Yatsushiro type marine fauna has been reported from the Mamonozawa Formation in the eastern part of the Sanchu Graben (Takahashi *et al.*, 2000; Ichise *et al.*, 2002). In addition to the marine fauna, this brackish-water fauna was discovered from the Hinatazawa Formation in the eastern part of the Sanchu Graben (Takahashi *et al.*, 2000; Ichise *et al.*, 2002). Thus, the Ohnita Formation is compared with the Yatsushiro Formation and the strata distributed in Mamonozawa or Hinatazawa in the Sanchu Graben (Fig. 12).

As mentioned above, the Sanchu Group in the study area is correlated with the Monobegawa Group, and

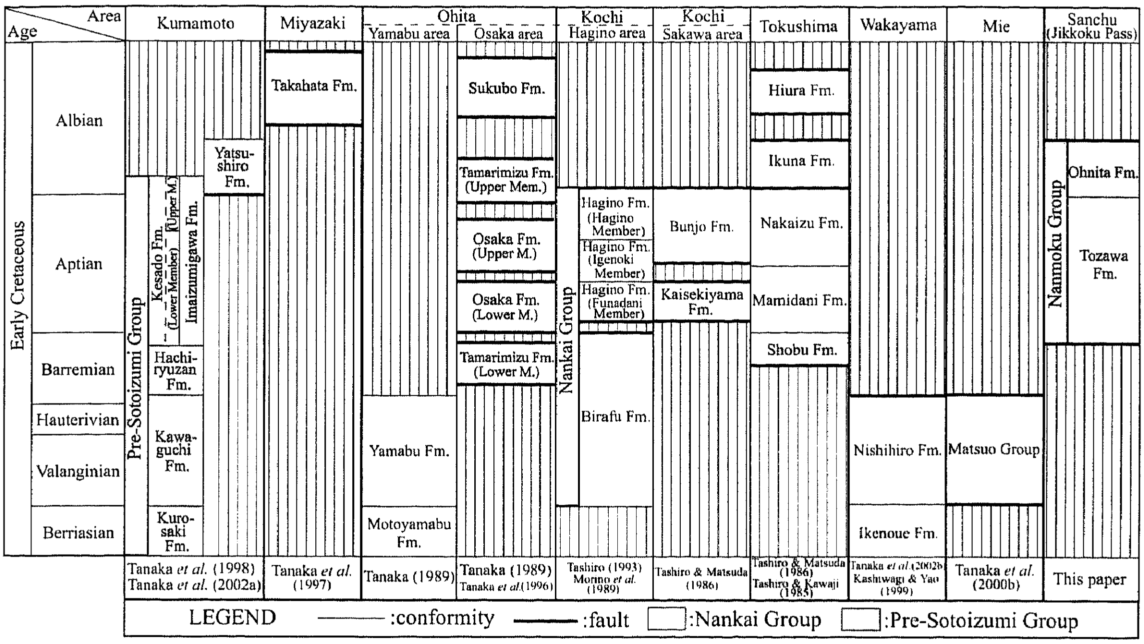

Fig. 12 Correlation of Nankai and Pre-Sotoizumi Groups and their equivalents in Chichibu Belt of SW Japan.

the Nanmoku Group corresponds to the Pre-Sotoizumi Group in Kyushu with regard to their lithofacies, stratigraphy, molluscan fossils.

Belonging problem of Sanchu Cretaceous System

The Chichibu Belt was divided into the Northern, Middle and Southern Chichibu Belts from north to south, typically in Shikoku (e.g., Yamashita *et al.*, 1954). Then, Ichikawa *et al.* (1956) gave the name Kurosegawa Tectonic Zone for the pre-Carboniferous rocks of the Middle Belt. The Middle Belt has been called the Kurosegawa Belt alternatively. While the Northern and Southern Chichibu Belts are represented by Jurassic accretionary complexes, the Kurosegawa Belt is characterized by lensoid composite masses consisting of Silurian to Devonian sedimentary rocks, granitic and high-grade metamorphic rocks, high-pressure/low-temperature metamorphic rocks and ultramafic rocks (Ichikawa *et al.*, 1956; Yoshikura *et al.*, 1990). This division was also applied to the Kanto Mountains. However, the division of the Kanto Mountains was based on somewhat different criteria from those of Shikoku because the diagnostic elements of the Kurosegawa Belt are absent except for locally exposed serpentinites and metamorphic rocks (e.g., Yokoyama, 1987; Saka *et al.*, 1989; Hisada and Arai, 1993; Fujita *et al.*, 2001). Instead of diagnostic elements of the Kurosegawa Belt, the Sanchu Cretaceous System is widely distributed along the axial part of the Chichibu Belt in the western Kanto Mountains. Therefore, the Sanchu Graben is traditionally regarded as the Middle Belt (e.g., Okubo and Horiguchi, 1969; The conveners of the Annual Meeting at Saitama, 1995). Recently, Yamakita (1998) discussed a tectonic division between the Northern Chichibu and the Kurosegawa Belts. He suggested that the Monobegawa Group should be assigned not to the Kurosegawa Belt, but to the Northern Chichibu Belt. In addition, Matsuoka *et al.* (1998) proposed a revised unit division applicable for the entire Chichibu Belt. Then, they assigned the Sanchu Cretaceous System to the Northern Chichibu Belt, as it has been regarded as an equivalent of the Monobegawa Group (Matsukawa, 1983; Tashiro, 1990 and others).

Juxtaposition of two different units of Sanchu Cretaceous System

The Sanchu Group in the Jikkoku Pass area is comparable with the Monobegawa Group. The Nanmoku Group is newly distinguished from the Sanchu Group in the Jikkoku Pass area, and compared with the pre-Sotoizumi Group. As to juxtaposition of the contemporaneous but heterogeneous Sanchu and Nanmoku Groups, the Monobegawa and pre-Sotoizumi Groups is also known to Kurosegawa Belt in Kyushu (Tanaka, 1989; Tanaka *et al.*, 1997; Tanaka *et al.*, 1998). The Pre-Sotoizumi Group is widely distributed in the Kurosegawa Belt of Kyushu (Tashiro and Ikeda, 1987; Tanaka *et al.*, 1998). In addition, the Monobegawa Group is distributed also on the southern side of diagnostic elements of the Kurosegawa Belt in the

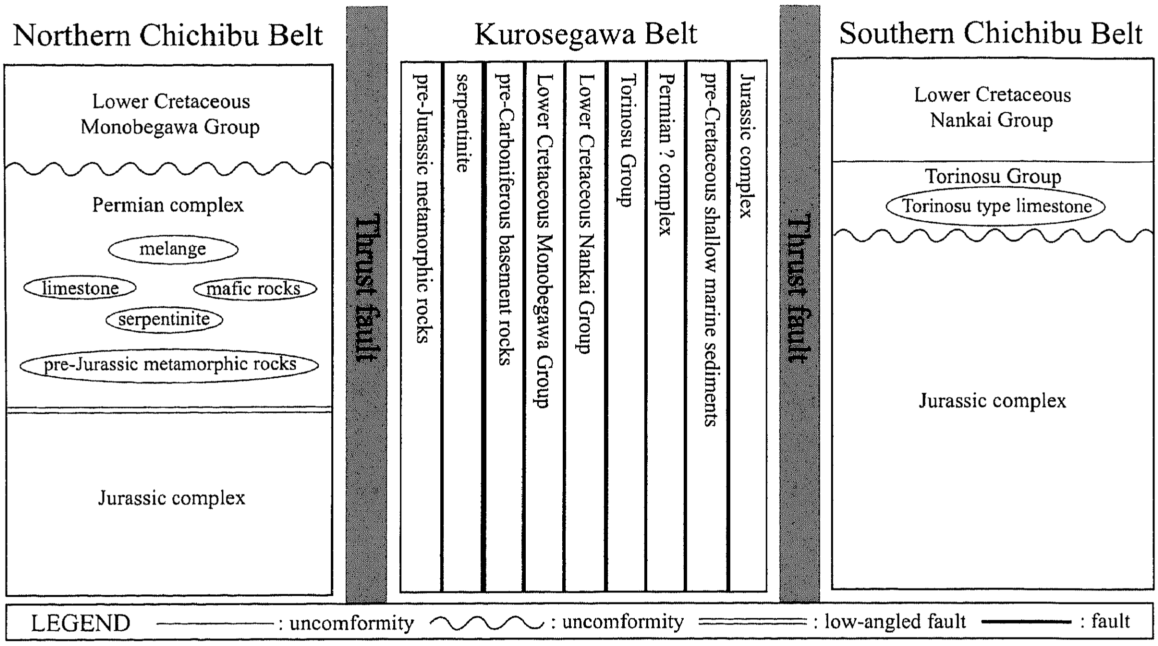

Fig. 13 Typical components of Northern, Kurosegawa and Southern Chichibu Belts in Shikoku. This figure modified from Yamakita (1998) and Matsuoka *et al.* (1998).

Sakawa area of Shikoku (Tashiro and Matsuda, 1986; Yamakita, 1998). Thus the Monobegawa Group occurs not only in the Northern Chichibu Belt, but also in the Kurosegawa Belt. Therefore, both of the Monobegawa and Nankai Group are commonly developed in the Kurosegawa Belt (Fig. 13).

Lenzoid body of Sanchu Cretaceous System

The Sanchu Cretaceous System in the Jikkoku Pass area is sliced by several longitudinal high-angled faults as a whole. In particular, this feature is notable in the southernmost part of the Sanchu Graben, and the Otchizawa Formation and serpentinites are also sliced as well as the Sanchu Cretaceous System.

The stratigraphy of Sanchu Group in the study area (Fig. 14) is different from that of the Mamonozawa area situated in the eastern part of the Sanchu Graben, which is a stratotype of the Ishido Formation. The Mamonozawa area is underlain by the Ishido, Sebayashi and Sanyama Formations in ascending order (Fig. 15). The Sebayashi Formation characterized by alternation of shale and sandstone and non-marine fossils is not distributed in the study area. Compared with stratigraphy, the Sebayashi Formation in the Mamonozawa area may correspond to a lower part of the lower member of the Sanyama Formaion in the Jikkoku Pass area. In addition, the Nanmoku Group is comparable with the Hinatazawa Formation proposed by the Takahashi *et al.* (2000) and Tanaka *et al.* (2002c) in the eastern part of the Sanchu Graben. These evidences suggest that the Sanchu Graben is occupied by sliced bodies during all area of the Sanchu Graben, which are similar to the geologic structure of the Kurosegawa Belt. Concerning ultramafic rocks, Yokoyama (1987) indicated that ultramafic rocks of the Jikkoku Pass area have the same textual and chemical characteristics as those of the typical Kurosegawa Belt in Shikoku. Hisada and Arai (1993) suggested that low-Ti group detrital chrome spinels within sandstone of the Sanchu Cretaceous were supplied from ultramafic rocks similar to serpentinite distributed in the Sanchu Graben. Judging from these lines of evidence, the Sanchu Cretaceous System and serpentinite, should be assigned not to the Northern Chichibu Belt, but to the Kurosegawa Belt.

Conclusion

In the present study, I obtained new lines of evidence for stratigraphic division. The Sanchu Cretaceous System in the Jikkoku Pass area is composed of the Shiroi, Ishido, Sanyama, Tozawa and Ohnita Formations, the last two formations are newly distinguished. The Sebayashi Formation distributed in the eastern part of the Sanchu Graben could not be observed in this area. In the study area, an upper part of the Ishido Formation and the lower member of the Sanyama Formation are regarded as a contemporaneous heterotopic facies of the Sebayashi Formation, which occurs in the eastern

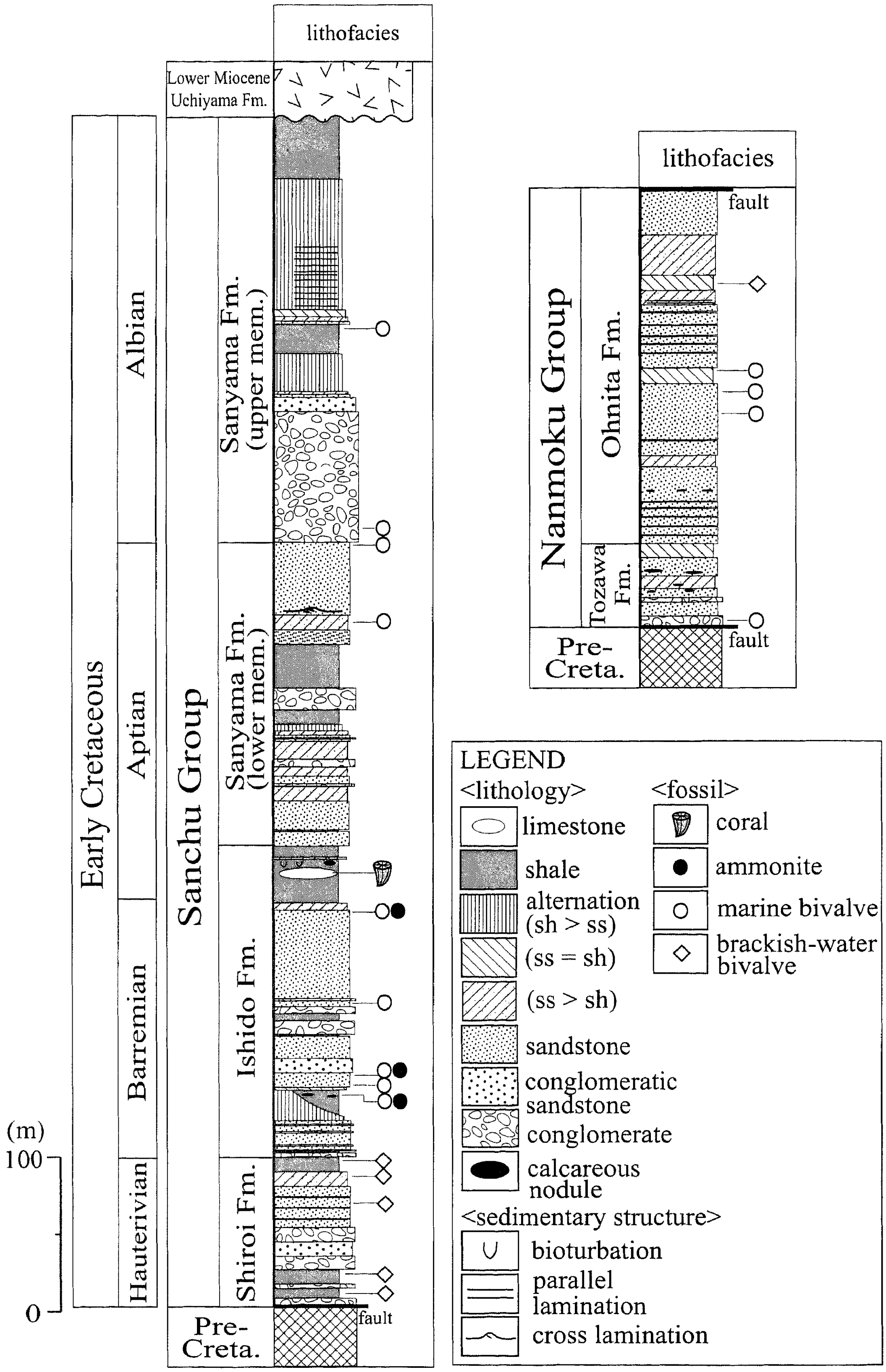

Fig. 14 Modified Columner Sections in the Jikkoku Pass area.

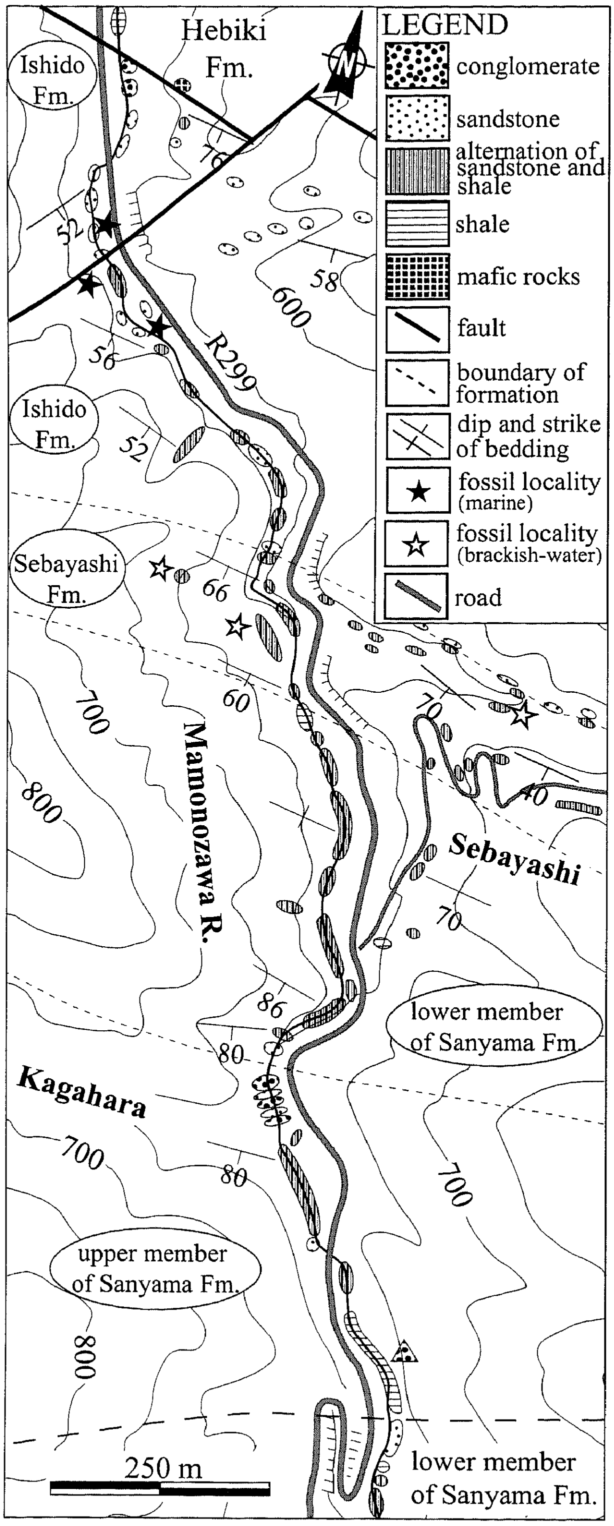

Fig. 15 Route map of the Mamonozawa River area.

area of the Sanchu Graben.

These five formations are grouped into the Sanchu and Nanmoku Groups; the former group is composed of the Shiroi, Ishido and Sanyama Formations, and the latter one is composed of the Tozawa and Ohnita Formations. Sedimentary environment of the Sanchu Group changes from brackish-water, shallow-marine to marine, while the Nanmoku Group shows shallow-marine to brackish-water facies in ascending order. In addition, the Sanchu Group is correlated with the Monobegawa Group in Shikoku and Kyushu, and the Nanmoku Group corresponds to the Pre-Sotoizumi Group in Kyushu, based on lithofacies, stratigraphy and fossil data.

The present juxtaposition of the two different units in Jikkoku Pass area indicates that the Sanchu Cretaceous System is assigned to the Kurosegawa Belt. This is concordant with the geologic structures showing that the Sanchu Cretaceous System is sliced by several longitudinal faults and the southern part of the study area is characterized by lensoid composite masses consisting of sedimentary rocks of the Shiroi or Ishido Formations, basaltic rocks, limestone, pebbly shale and chert of the Otchizawa Formation and serpentinite.

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References

Eguchi, M., 1951: Mesozoic hexacorals from Japan. *Science Report of Tohoku University, 2nd Series*, vol. 24, p. 1–96.

Fujimoto, H., 1958: *Geology of Minamisaku-gun, Nagano prefecture*. Minamisaku – Kyoikukai, Ueda, 314 pp. (*in Japanese*)

Fujita, K., Shimamura, T., Takagi, H. and Saka, Y., 2001: "Naguri Fault", the Kurosegawa Terrane in the Kanto Mountains. *The 108th Annual Meeting of the Geological Society of Japan*, p. 268. (*in Japanese with English abstract*)

Hanai, T., Obata, I. and Hayami, I., 1968: Notes on the Cretaceous Miyako Group. *Bulletin of National Science Museum, Series C* (*Geology*), no. 1, p. 20–28, pls. 1–4. (*in Japanese*)

Harada, T., 1890: *Die japonischen Inseln, eine topographisch geologische Übersicht*. Paul Parey, Berlin, 126 pp.

Hasegawa, Y., Manabe, M., Kase, T., Nakajima S. and Takakuwa Y., 1999: An Ornithomimid Vertebra from the Early Cretaceous Sebayashi Formation, Sanchu Terrane, Gunma Prefectrure, Japan. *Bulletin of Gunma Museum of Natural History*, vol. 3, 1–6.

Hayami, I., 1965: Lower Cretaceous marine pelecypods of Japan, Part 1. *Memoirs of the Faculty of Science, Kyushu University Series D, Geology*, vol. 15, no. 2, p. 221–349.

Hayami, I., 1966: Lower Cretaceous marine pelecypods of Japan, Part3. *Memoirs of the Faculty of Science, Kyushu University Series D, Geology*, vol. 17, no. 3, p. 151–249.

Hayami, I. and Ichikawa, T., 1965: Occurrence pf *Nippononaia ryosekiana* from the Sanchu area, Japan. *Transactions and proceedings of the Palaeontological Society of Japan*, New Series, no. 60, p. 145–155.

Hisada, K. and Arai, S., 1986: Mode of occurrence of serpentinite and Cretaceous serpentinite-bearing conglomerate in the Kanto Mountains, central Japan. *Journal of the Geological Society of Japan*, vol. 92, no. 5, p. 391–394. (*in Japanese with English abstract*)

Hisada, K. and Arai, S., 1993: Detrital chrome spinels in the Cretaceous Sanchu sandstone, central Japan: indicator of serpentinite protrusion into a fore-arc region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 105, p. 95–109.

Hisada, K., Arai, S. and Miyata, T., 1987: Distribution of serpentinite bodies and its tectonic significance in the southern marginal part of the Sanchu Graben, Kanto Mountains, central Japan. *Memoir, Osaka Kyoiku University, Series ?*, vol. 36, no. 2, p. 129–134. (*in Japanese*)

Hisada, K., Igo, H. and Arai, S., 1992: Mesozoic melanges and associated rocks in the Kanto Mountains. *29th IGCP field trip guide book*, p. 115–141.

Hisada, K. and Kishida, Y., 1986: The Hamadaira Group in the western Kanto Mountains, central Japan – the developmental processes of the Juassic – Lower Cretaceous accretionary prism –. *Journal of the Geological Society of Japan*, vol. 92, no. 8, p. 569–590. (*in Japanese*)

Ichikawa, K., Ishii, K., Nakagawa, C., Suyari, K. and Yamashita, N., 1956: Die Kurosegawa-Zone. *Journal of the Geological Society of Japan*, vol. 62, no. 725, p. 82–103. (*in Japanese with German abstract*)

Ichise, M., Tanaka, H., Takahashi, T., Miyamoto, T. and Kawaji, Y., 2002: Discovery of the Tethyan fauna from the Lower Cretaceous in the eastern part of the Sanchu Graben, Kanto Mountains, and its significance. *Journal of the Geological Society of Japan*, vol. 108, no. 10, p. 663–670. (*in Japanese with English abstract*)

Ishida, T., Arai, S., Ishiwatari, A., Hisada, K. and Matsuzawa, M., 1992: Greenstones from the south marginal part of the Cretaceous Sanchu belt in the Kanto Mountains, central Japan. *Journal of Mineralogy, Petrology and Economic Geology*, vol. 87, p. 174–186. (*in Japanese*)

Ishii, A., Ito, T. and Takahashi, O., 1991: Kagikakezawa Formation, Quaternary Conglomerates, retained in the Kagikake-zawa, Saku-machi, Nagano Prefecture, Central Japan. *Bulletin of Tokyo Gakugei University, Section* 4, vol. 43, p. 89–99. (*in Japanese*)

Isozaki, Y. and Itaya, T., 1991: Pre-Jurassic klippe in northern Chichibu Belt in west-central Shikoku, Southwest Japan –Kurosegawa Terrane as a tectonic outlier of the pre-Jurassic rocks of the Inner Zone. *Journal of the Geological Society of Japan*, vol. 97, no. 6, p. 431–450. (*in Japanese*)

Kamikawa, Y., Hisada, K., Sashida, K. and Igo, H., 1997: Geology of the Nanmoku area in the Chichibu Terrane, the northwestern part of the Kanto Mountains, central Japan. *Science Report of the Institute of Geoscience, University of Tsukuba, Section B*, vol. 18, p. 19–38.

Kamikawa, Y., Kishida, Y., Kaiho, K. and Hisada, K., 1988: Radiolarians obtained from the Cretaceous formations of the Sanchu graben in the Kanto mountains, central Japan. *Journal of the Geologi-*

cal Society of Japan, vol. 94, no. 11, p. 903–905. (*in Japanese with English abstract*)

Kase, T., 1984: Early Cretaceous Marine and Brackish-water Gastropoda from Japan. *National Science Museum, Tokyo*, 179 pp.

Kashiwagi, K. and Yao, A., 1999: Upper Jurassic to Lower Cretaceous Ikenoue Formation around the Kurosegawa Terrane in the western Kii Peninsula, Southwest Japan. *Journal of the Geological Society of Japan*, vol. 105, no. 8, p. 523–534. (*in Japanese with English abstract*)

Kawano, T., Tanaka, H., Takahashi, T., Toshimitsu, S. and Mori, D., 2002: Stratigraphy and Structure of the Lower Cretaceous Tomochi Formation in the Chichibu Terrane, Kumamoto Prefecture. *Bulletin of Goshoura Cretaceous Museum*, no. 3, P. 11–22.

Kimura, T. and Matsukawa, M., 1979: Mesozoic plants from the Kwanto Mountainland, Gunma Prefecture, in the Outer Zone of Japan. *Bulletin of National Science Museum, Series C (Geology)*, vol. 5, no. 3, p. 89–112.

Koizumi, K., 1991: Stratigraphy and geologic structure of the Cretaceous System in the eastern half of the Sanchu Graben, Kanto Mountains, central Japan. *Journal of the Geological Society of Japan*, vol. 97, no. 10, p. 799–815. (*in Japanese*)

Kondo, Y., Kono, Y., Kikuchi, N. and Tashiro, M., 1999. A transitional fauna between Monobegawa and Nankai faunas from the Lower Cretaceous of Konomori, Kochi. *The 106th Annual Meeting of the Geological Society of Japan*, p. 208. (*in Japanese with English abstract*)

Kosaka, T., Kubota, M., Otsuka, S. and Bizen, N., 1990: Discovery of Early Miocene planktonic foraminifers from the Uchiyama Formation in the northwestern part of the Kanto Mountains, central Japan. *Earth Science*, vol. 44, p. 154–158. (*in Japanese*)

Maruyama, S., Isozaki, Y., Kimura, G. and Terabayashi, Y., 1997: Paleogeographic maps of the Japanese Islands: Plate tectonic synthesis from 750 Ma to the present. *The Island Arc*, no. 6, p. 121–142.

Maruyama, S. and Seno, T., 1986: Orogeny and relative plate motion: example of the Japanese islands. *Tectonophysics*, vol. 127, p. 305–329.

Matsukawa, M., 1977: Cretaceous System in the eastern part of the Sanchu "Graben", Kanto, Japan. *Journal of the Geological Society of Japan*, vol. 83, no. 2, p. 115–126. (*in Japanese*)

Matsukawa, M., 1979: Some problems on the Cretaceous Shiroi Formation of the Sanchu "Graben", Kwanto Mountainous, Japan. *Journal of the Geological Society of Japan*, vol. 85, no. 1, p. 1–9. (*in Japanese*)

Matsukawa, M., 1983: Stratigraphy and sedimentary environments of the Sanchu Cretaceous, Japan. *Memoirs of the Ehime University, Natural Science, Series D (Earth Science)*, vol. 9, no. 4, p. 1–50.

Matsukawa, M., 1988: Barremian ammonites from the Ishido Formation, Japan – supplements and faunal analysis –. *Transactions and proceedings of the Palaeontological Society of Japan*, New Series, no. 149, p. 396–416.

Matsukawa, M. and Eto, F., 1987: Stratigraphy and sedimentary environment of the Lower Cretaceous System in the Katsuuragawa Basin, Southwest Japan. *Journal of the Geological Society of Japan*, vol. 93, no. 7, p. 491–511. (*in Japanese*)

Matsukawa, M. and Obata, I., 1993: The ammonites Crioceratites (Paracrioceras) and Shasticrioceras from Barremian of southwest Japan. Palaeontology, London, vol. 36, part 2, p. 249–266, pls. 3.

Matsumoto, T., Obata, I., Tashiro, M., Ohta, Y., Tamura, M., Matsukawa, M. and Tanaka, H., 1982: Correlation of marine and non-marine formations in the Cretaceous of Japan. *Fossils*, no. 31, p. 1–26.*

Matsuoka, A., Yamakita, S., Sakakibara, M. and Hisada, K., 1998: Unit division for the Chichibu Composite Belt from a view point of accretionary tectonics and geology of western Shikoku, Japan. *Journal of the Geological Society of Japan*, vol. 104, no. 9, p. 634–653. (*in Japanese*)

Morino, Y., Kozai, T., Wada, T. and Tashiro, M., 1989: On the Lower Cretaceous Birafu Formation including the Torinosu type limestone in the Monobe area, Kochi Prefecture. *Research Reports of Kochi University*, vol. 38, *Natural Science*, p. 73–83. (*in Japanese*)

Nakai, I., 1968: Cretaceous Stratigraphy of the Katsuuragawa Valley of Tokushima Prefecture, Shikoku – Especially on the Correlation with the European Standard Based on Ammonites –. *Journal of the Geological Society of Japan*, vol. 74, no. 5, p. 279–293. (*in Japanese*)

Obata, I. and Ogawa, Y., 1976: Ammonites Biostratigraphy of the Cretaceous Arida Formation, Wakayama Prefecture. *Bulletin of National Science Museum, Series C (Geology)*, vol. 2, no. 3, p. 95–110, pls. 1–4. (*in Japanese with English abstract*)

Obata, I., Matsukawa, M., Tsuda, H., Futakami, M. and Ogawa, Y., 1976: Geological Age of the Cretaceous Ishido Formation, Japan. *Bulletin of National Science Museum, Series C (Geology)*, vol. 2, no. 3, p. 122–138. (*in Japanese*)

Ohta, Y., 1981: Some Lower Cretaceous Corbiculidae and Neomiodontidae (Bivalvia) from Japan. *Bulletin of Fukuoka University of Education*, vol. 31, no. 3, p. 103–134.

Oishi, S., 1940: The Mesozoic floras of Japan. *Journal of the Faculty of Science, Hokkaido Imperial University*, vol. 5, nos. 2–4, p. 123–480, pls. 1–48.

Okubo, M. and Horiguchi, M., 1969: Geology of the Manba district. *Geological Survey of Japan, Quadrangle series*, Tokyo, 26, p. 1–66.

Okubo, M. and Matsushita, N., 1959: On a new species of Pachyodonta from the Akaishi Mountains, Central Japan. *Earth Science*, no. 42, p. 1–4. (*in Japanese*)

Otsuki, K., 1992: Oblique subduction, collision of microcontinents and subduction of oceanic ridge: Their implications on the Cretaceous tectonics of Japan. *The Island Arc*, vol. 1, p. 51–63.

Saito, Y., 1964: A Rudistid from the Cretaceous deposits of Ryoseki, Kochi Prefecture, Japan. *Transactions and proceedings of the Palaeontological Society of Japan*, New Series, no. 56, p. 317–321, pl. 47.

Saka, Y., Taira, A. and Ogasawara, Y., 1989: Naguri Fault in the Chichibu terrain of the Kanto Mountains, central Japan – possible eastern termination of the Kurosegawa Tectonic Zone –. *Journal of the Geological Society of Japan*, vol. 95, no. 4, p. 339–342. (*in Japanese with English abstract*)

Sakai, T. and Okada, H., 1997: Sedimentation and Tectonics of the Cretaceous Sedimentary Basins of the Axial and Kurosegawa Tectonic Zones in Kyushu, SW Japan. *The Memoirs of the Geological Society of Japan*, no. 48, p. 7–28.

Sashida, K., Igo, H., Adachi, S. and Ito, S., 1992: Foraminifers from the "Torinosu limestone" embedded in the Ishido Formation of the Sanchu Cretaceous System, Kanto Mountains, central Japan. *Centenary of Japanese Micropaleontology*, K. Ishizaki and T. Saito eds., p. 273–280.

Taira, A. and Tashiro, M., 1987: *Late Paleozoic and Mesozoic accretion tectonics in Japan and east Asia.* In: A. Taira and M. Tashiro (Editors), Historical Biography and Plate Tectonic Evolution of Japan and Eastern Asia. Terrapub, Tokyo, p. 1–43.

Takahashi, T., Tanaka, H., Miyamoto, T., Kawaji, Y. and Ichise, M., 2000: Cretaceous strata in the eastern part of the Sanchu Graben. *The 107th Annual Meeting of the Geological Society of Japan*, p. 65. (*in Japanese with English abstract*)

Takei, K., 1963: Stratigraphy and geological structure of the Cretaceous System in the eastern part of the Sanchu graben, Kwanto mountainland. *Journal of the Geological Society of Japan*, vol. 60, no. 810, p. 130–146. (*in Japanese*)

Takei, K., 1985: Development of the Cretaceous sedimentary basin of the Sanchu Graben, Kanto Mountains, *Japan. Journal of Geosciences, Osaka City University*, vol. 28, p. 1–44.

Tamura, M., 1980: A Summary of the Cretaceous Bivalves of Fresh and Brackish Waters 59–74, in Japan. *Journal of the Geological Society of Korea*, vol. 16, no. 4, p. 223–238.

Tanaka, H. and Saka, Y., 1993: Block rotation by basement strake-slip faulting in the Sanchu graben, central Japan. *Journal of Structural Geology*, vol. 15, no. 8, p. 1021–1032.

Tanaka, H., 1989: Mesozoic Formations and their Molluscan Faunas in the Haidateyama Area, Oita Prefecture, Southwest Japan. *Journal of Science of the Hiroshima Univeisity, Series C*, vol. 9, p. 1–43.

Tanaka, H., Kozai, T. and Tashiro, M., 1984: Lower Cretaceous stratigraphy in the Monobe Area, Shikoku. *Research Reports of Kochi University*, Vol. 32, *Natural Science*, p. 1–9. (*in Japanese*)

Tanaka, H., Miyamoto, T., Tashiro, M. and Takahashi, T., 1996: Bivalve Fauna from the Pre-Sotoizumi Group developed to the North of Mt. Haidate, Oita Prefecture, Kyushu. *The Memoirs of the Faculty of Education, Kumamoto University*, no. 45, *Natural Science*, p. 11–52.

Tanaka, H., Sakamoto, D., Takahashi, T. and Kashiwagi, K., 2002a: Lower Cretaceous Imaizumigawa Formation (new name) of the Yatsushiro Mountains, Kumamoto Prefecture. *Bulletin of Goshoura Cretaceous Museum*, no. 3, p. 1–10.

Tanaka, H., Takahashi, T., Ichise, M., Kashiwagi, K., and Kawano, T., 2002b: Cretaceous Formations and their Bivalve Faunas in Yuasa Area, Wakayama Prefecture. *Proceedings of the Nishinihon Branch Geological Society of Japan*, p. 18. (*in Japanese with English abstract*)

Tanaka, H., Takahashi, T., Ichise, M., Miyamoto, T. and Komatsu, T., 2000b: Molluscan *Fossils* from the Lower Cretaceous Matsuo Group in the Toba Area, Mie Prefecture, Southwest Japan. *The Memoirs of the Faculty of Education, Kumamoto University*, no. 49, *Natural Science*, p. 57–72. (*in Japanese*)

Tanaka, H., Ichise, M., Takahashi, T., Miyamoto, T. and Komatsu, T., 2006a: Stratigraphy and bivalve fauna of the Lower Cretaceous Idaira Formation in the western part of Shizuoka Prefecture. *The*

Memoirs of Faculty of Education, Kumamoto University, no. 49, *Natural Science*, p. 73–86. (in Japanese with English abstruct)

Tanaka, H., Takahashi, T., Miyamoto, T., Toshimitsu, S., Ichise, M., Kuwazuru, J. and Ando, S., 1998: Cretaceous Formations and their Bivalve Faunas in the Eastern Area of the Yatsushiro Mountains, Kumamoto Prefecture, Southwest Japan. *The Memoirs of the Faculty of Education, Kumamoto University*, no. 47, *Natural Science*, p. 11–40. (*in Japanese with English abstract*)

Tanaka, H., Takahashi, T., Sakamoto, D., Ichise, M. and Katozumi, M., 2002c: Cretaceous Formations and their Bivalve Faunas in the Eastern Area of the Sanchu Graben, Kanto Mountains. *The 109th Annual Meeting of the Geological Society of Japan*, p. 61.

Tanaka, H., Takahashi, T., Sogabe, A., Miyamoto, T. and Tashiro, M., 1997: Mesozoic Formations and their Bivalve Faunas in the Gokase Area, Miyazaki Prefecture, Southwest Japan. *The Memoirs of the Faculty of Education, Kumamoto University*, no. 46, *Natural Science*, p. 9–44. (*in Japanese*)

Tanaka, K., 1965: Cretaceous echinoids from the Sanchu Graben, central Japan. *Transactions and proceedings of the Palaeontological Society of Japan*, New Series, no. 59, p. 126–142.

Tashiro, M., 1985a: The bivalve faunas and their biostratigraphy of the Cretaceous in Japan. *The Memoirs of the Geological Society of Japan*, no. 26, p. 43–75. (*in Japanese*)

Tashiro, M., 1985b: The Cretaceous System of the Chichibu Belt in Shikoku – On the Early Cretaceous lateral fault in the Chichibu Belt –. *Fossils*, no. 38, p. 23–25. (*in Japanese*)

Tashiro, M., 1990: Bivalve fossils from the Sanyama Formation in Sanchu, Kwanto Mountains. *Research Reports of Kochi University*, vol. 39, *Natural Science*, p. 29–37. (*in Japanese*)

Tashiro, M., 1993: Bivalve faunas from Cretaceous of Japan Part1:On the bivalve faunas from the Chichibu and "Ryouke" Belts in Southwest Japan. *Research Reports of Kochi University*, vol. 42, *Natural Science*, p. 105–155. (*in Japanese*)

Tashiro, M., 1994: Cretaceous tectonic evolution of southwest Japan from the bivalve faunal viewpoints. *Research Reports of Kochi University*, vol. 43, *Natural Science*, p. 43–54. (*in Japanese*)

Tashiro, M. and Ikeda, M., 1987: Cretaceous System of the Yatsushiro Mountains. *Research Reports of Kochi University*, vol. 36, *Natural Science*, p. 71–91. (*in Japanese*)

Tashiro, M. and Kawaji, Y., 1985: On the Ikuna Formation (new name) of the Katsuura Area, Tokushima Prefecture, Japan. *Research Reports of Kochi University*, vol. 34, *Natural Science*, p. 55–60. (*in Japanese with English abstract*)

Tashiro, M. and Matsuda, T., 1986: Lower Cretaceous bivalves from the Sakawa Area, Shikoku. *Transactions and proceedings of the Palaeontological Society of Japan*, New Series, no. 142, p. 366–392.

Tashiro, M. and Tanaka, H., 1992: Bivalve *Fossils* from the Takahara Formation of Central Kyushu, Japan. *Research Reports of Kochi University*, vol. 41, *Natural Science*, p. 139–156, pls. 3.

Tashiro, M., Yanagisawa, H. and Kitamura, T., 1986: Discovery of the Ryoseki fauna from Todai area, Akaishi Mountains. *Journal of the Geological Society of Japan*, vol. 92, no. 10, p. 757–759. (*in Japanese*)

The conveners of the Paleo-Mesozoic Symposium of the Annual Meeting at Saitama, 1995: The results of resent researches on the Paleo-Mesozoic of the Kanto Mountains, central Japan. *Earth Science*, vol. 49, p. 271–291. (*in Japanese*)

Watanabe, K., 1954: On the Uchiyama fault-Historical geology of the Tertiary strata in the northwestern part of the Kanto mountains. *Studies from Geology and Mineral Institute, Tokyo University of Education*, vol. 3, p. 105–115. (*in Japanese*)

Xu, J. W., and Shu, G., 1994: Tectonic models of the Tan-Lu Fault Zone, Eastern China. *International Geology Review*, vol. 36, p. 771–784.

Yabe, H. and Eguchi, M., 1936: *Eohydnophora*, a new genus of Cretaceous. *Proceeding of Imperial Academy of Japan*, vo. 12, p. 141–143.

Yabe, H., Nagao, T. and Shimizu, S., 1926: Cretaceous mollusca from the Sanchu-Graben in the Kwanto Mountainland, Japan. *Science Reptort* of the *Tohoku Imperial University. 2nd series* (*Geology*), vol. 9, p. 33–76.

Yabe, H. and Sugiyama, T., 1935: Jurassic Stromatoporoids from Japan. *Science Reptort* of the *Tohoku Imperial University. 2nd series* (*Geology*), vol. 14.

Yabe, Y., 1955: *Geology of the vicinity of Ueno-mura, Tano-gun, Gumma Prefecture.* 8 pp, Guide book of the geological excursions. (*in Japanese with English abstract*)

Yamagiwa, N., Hisada, K. and Tamura, M., 1998: Early Cretaceous Hexacorals from the Western Part of the Sanchu Area, Kanto Mountains. *Bulletin of National Science of Museum, Series C* (*Geology*), vol. 24, no. 1–2, p. 51–66.

Yamakita, S., 1998: What belongs to the Northern Chichibu Belt? – tectonic division between the Northern Chichibu Belt and the Kurosegawa Belt –. *Journal of the Geological Society of Japan*, vol. 104, no. 9, p. 623–633. (*in Japanese*)

Yamashita, N., Tanaka, K., Yamagiwa, N., Yoshida, S., Nakagawa, A., Suyari, K., Ishii, K., Katto, J. and Ichikawa, K., 1954: Mesozoic of the Outer Zone in Shikoku. *Journal of the Geological Society of Japan*, vol. 60, no. 9, p. 706. (*in Japanese*)

Yehara, S., 1915: The Cretaceous trigoniae from Miyako and Hokkaido. *Science Report of the Tohoku Imperial University*, Ser. 2, vol. 2, p. 35–44.

Yokoyama, K., 1987: Ultramafic rocks in the Kurosegawa tectonic zone, Southwest Japan. *Journal of Mineralogy, Petrology and Economic Geology*, vol. 82, p. 319–335. (*in Japanese*)

Yokoyama, M., 1895: Mesozoic Plants from Kozuke, Kii, Awa and Toza. *Journal of the College of Science, Imperial University of Tokyo*, vol. 7, no. 3, p. 201–231.

Yoshikura, S., Hada, S. and Isozawa, Y., 1990: Kurosegawa Terrane. in: K. Ichikawa *et al.* (Editors), *Pre-Cretaceous Terranes of Japan*. Osaka, pp. 185–201.