

# STRATIGRAPHY AND GEOLOGICAL AGE OF THE TAGA GROUP IN THE JOBAN COAL-FIELD OF FUKUSHIMA AND IBARAKI PREFECTURES

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## Abstract

Recently, an unconformity was recognized within the so-called Taga Group distributed widely in the Joban coal-field (Sugai and Matsui, 1957). The purpose of the present study is to make the stratigraphic correlation of the so-called Taga Group distributed in the separated sedimentary basins and to discuss the age of the Group.

The results of the present study can be summarized as follows; (1) The so-called Taga Group should be subdivided into two formations (Table 2), each separated by an unconformity. (2) The geological age of the strata below the unconformity are Late Miocene and that above the unconformity Early Pliocene. Hence, the unconformity between the formations marks the Miocene-Pliocene boundary in the Joban coal-field.

## Introduction

The writers take great pleasure in dedicating this article to Dr. Kotora Hatai, Professor Emeritus of the Tohoku University in commemoration of his retirement from the Tohoku University.

The so-called Taga Group (Sugai and Matsui, 1957) is widely distributed in the Joban coal-field, extending from the southeastern part of Fukushima Prefecture southwards to the northeastern part of Ibaraki Prefecture (Fig. 1). The majority of the studies for the stratigraphic classification and geological age of the so-called Taga Group have been left in manuscript form, and the published articles show that the stratigraphic classification and formation names proposed for the group differ with the sedimentary basins and no unification had been proposed to date. And, the Taga Group had been considered to range in age from Miocene to Pliocene.

It had been the general thought that no unconformity existed within the Taga group. However, recently, Mitsui and Ouchi investigation of the so-called Taga Group distributed in the Izumi-Ueda district (Mitsui and Ouchi, 1972), and Mitsui's study of the group in the Yotsukura Area (Mitsui, 1973), revealed the presence of an unconformity in the group and pointed that it marks the Miocene-Pliocene boundary in the Joban coal-field. Subsequently an unconformity within the Taga Group was described in the Hirakata-Otsu Area by Endo (1971 MS) and also in the Isohara and Takahagi areas by Hasegawa (1971 MS).

The purpose of the present study is to correlate the so-called Taga Group distributed in the separated sedimentary basins, and to discuss the age of the Group.

To clarify these problems is important to determine the age of the fold and fault structures developed in the formations in the Joban coal-field.

### Acknowledgements

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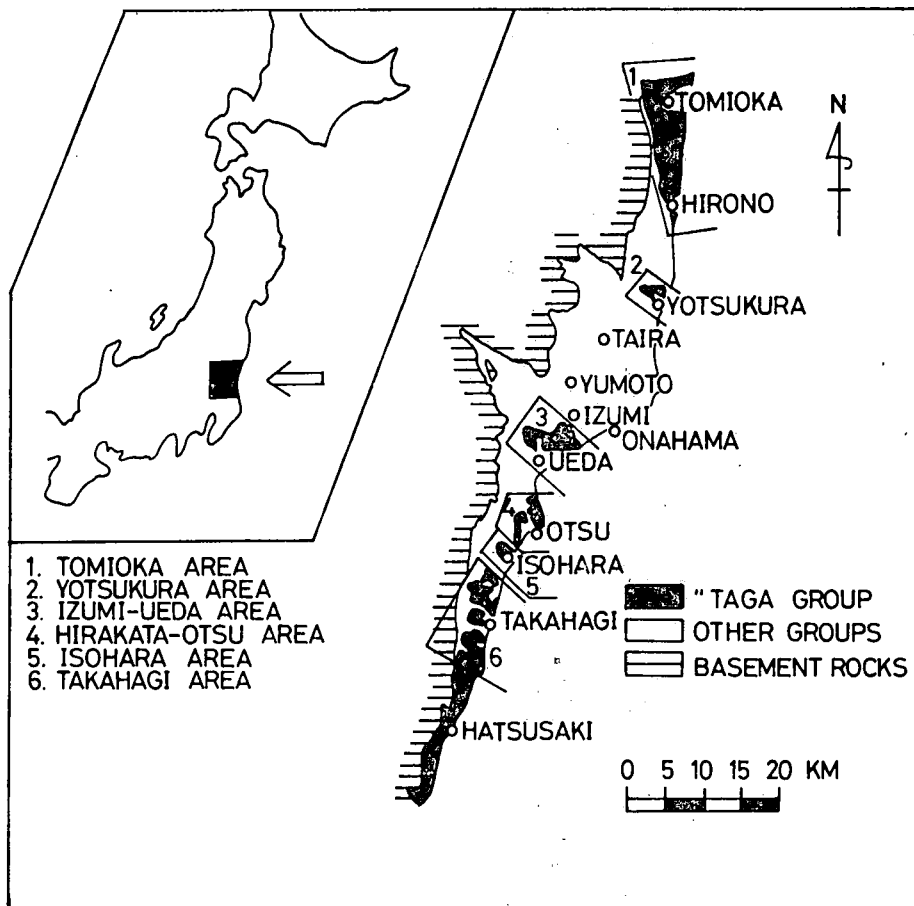


Fig. 1. Index map of the area investigated.

## Stratigraphy

As pointed out by Mitsui and Ouchi (1972), the "Taga Group" in this paper can be correlated with the Taga Group of Sugai and Matsui (1953, 1957).

Previously it had been considered that no unconformity exists in the Taga Group, but, the new outcrops revealed that an unconformity exists in the Taga Group distributed in the Futaba (Mitsui, 1971), Yotsukura (Mitsui, 1973), Izumi-Ueda (Ouchi, 1972 MS; Mitsui and Ouchi, 1972), Hirakata-Otsu (Endo, 1971 MS), Isohara (Hasegawa, 1971 MS) and Takahagi areas (Hasegawa, 1971 MS). These areas are separated tectonically from one another. From paleontological and stratigraphical evidences, the Taga Group in the Joban coal-field extends from Miocene to Pliocene in geological age, and for this reason the writers refrain from using the name of Taga Group to avoid confusion. And, in this paper, the authors propose to use new formation names for the strata immediately below and above the unconformity, in each of the areas studied.

The descriptions of the stratigraphy and geological structures of the respective areas are given in the order of Tomioka Area, Yotsukura Area, Izumi-Ueda Area, Hirakata-Otsu Area, Isohara Area and Takahagi Area. Since the present work is concentrated on the stratigraphic correlation of the so-called Taga Group of the areas mentioned, details concerning the formations superposed by the Taga Group are omitted.

### I. Tomioka Area

In the Tomioka Area (east of the Futaba thrust, Sugai and Matsui (1957)), the so-called Taga Group is subdivided into the Hirono and Tomioka formations by Sugai and Matsui (1957), and their stratigraphic relationship was stated to be a conformity. Kamada (1962) used the name of Futaba-Tomioka Formation for the Group. But, because of the existence of an unconformity, for the so-called Taga Group distributed in this area, Mitsui (1971) proposed the names of Sekinoue and Yamadahama formations for the strata respectively above and below the unconformity, as used in this paper (Fig. 2).

#### I-A. Sekinoue Formation

This Formation nearly corresponds to the Hirono Formation of Sugai and Matsui (1957), and to the lower part of the Futaba-Tomioka Formation of Kamada (1962). The type locality is Sekinoue, Hirono-cho, Futaba-gun, Fukushima Prefecture.

The Formation shows strike of N-S to NNW-SSE and dips of 5° to 10°E and is in fault contact with the Yunagaya Group in the Tomioka Area, but rests on the Yunagaya Group with unconformity in the vicinities of Sekinoue and Nanamagari (Fig. 3).

The Sekinoue, mainly of dark olive, micaceous and pumiceous muddy sandstone and sandy mudstone, intercalated with thin layers medium to coarse grained sandstone, yielded fossil molluscs, foraminifers, *Makiyama* (= *Sagarites*) and distoms (Fig. 4).

#### I-B. Yamadahama Formation

The Yamadahama Formation nearly corresponds to the Tomioka Formation of Sugai and Matsui (1957) and almost with the upper part of the Futaba-Tomioka Formation of the Kamada (1962). It strikes NNW-SSE and dips at about 10°E and lies with unconformity upon the Sekinoue Formation.

AGE	FORMATION	COLUMN	TH	ROCK FACIES
PLIOCENE	YAMADAHAMA FORMATION	[Symbol: horizontal dashes]	41 m	massive mudstone with sandstone thin layers
		[Symbol: dots]		fine to coarse grained sandstone
MIOCENE	SEKINOUE FORMATION	[Symbol: horizontal dashes]	164 m	massive or roughly stratified, muddy sandstone and sandy mudstone with sandstone (med. to c.) thin layers

Fig. 2. Composite columnar sections of the Tomioka Area, Futaba-gun, Fukushima Prefecture.

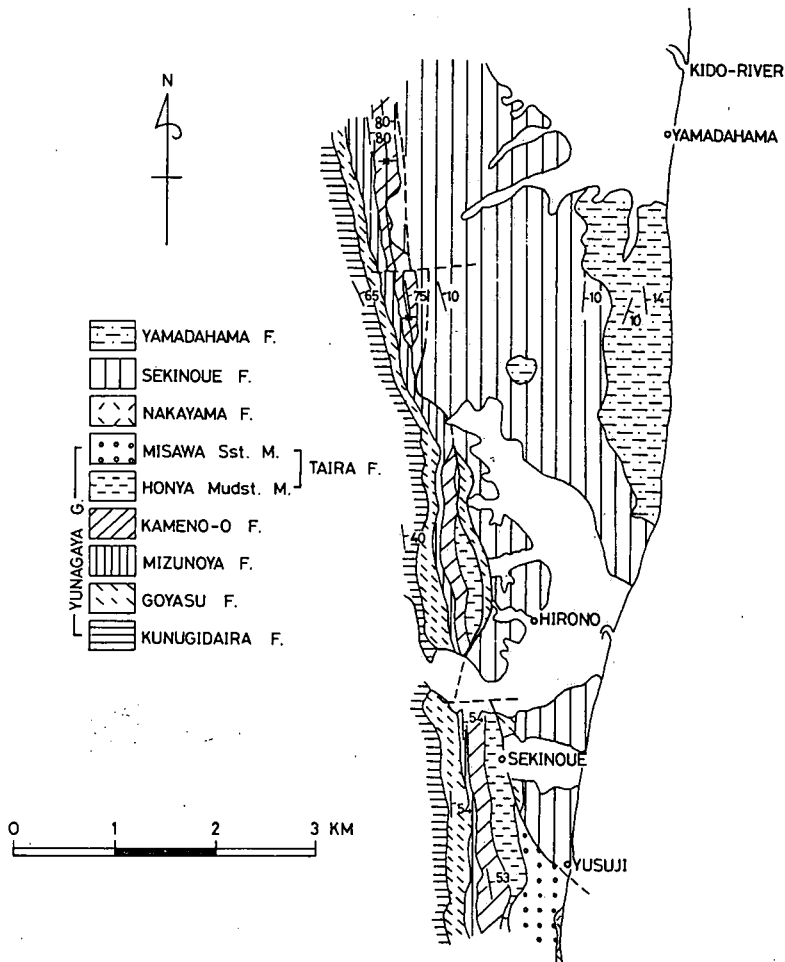


Fig. 3. Geological map of the Tomioka Area, Futaba-gun, Fukushima Prefecture.

The basal conglomerate (1-5 m thick) is composed predominately of cobble to boulder size muddy rocks derived from the Sekinoue Formation. The lower part of the Formation consists mainly of fine to coarse grained tuffaceous sandstone intercalated with thin layers of coarse grained arkose sandstone and coarse grained sandstone with abundant molluscan fossils in the lower part. The upper part comprises dark olive, micaceous, massive mudstone intercalated with thin layers of sandstone with pumice and carbonaceous fragments and yields distoms (Fig. 4).

**II. Yotsukura Area**

As pointed out by Mitsui (1973), the so-called Taga Group in the Yotsukura area, Iwaki City, Fukushima Prefecture, is subdivided into the Yotsukura and Toda formations. The Toda Formation lies on the Yotsukura Formation with unconformity (Fig. 5). The geological map of the Area is shown in Fig. 6.

**II-A. Yotsukura Formation**

The Yotsukura Formation (Mitsui, 1973) lies with angular unconformity upon the Shiramizu and Yunagaya groups, and is superposed with unconformity by the Toda Formation. The strikes of the formation are varied, but the dips are generally 10° to

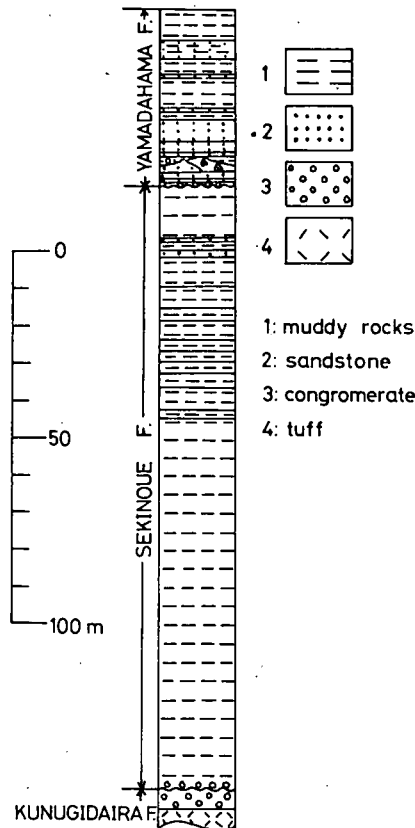


Fig. 4. Columnar section of the Sekinoue and Yamadahama formations in the Tomioka Area.

AGE	FORMATION	COLUMN	TH.	ROCK FACIES
PLIOCENE	TODA FORMATION	[Symbol: horizontal lines]	20 m	sandy mudstone and muddy sandstone
		[Symbol: dots]		medium to coarse grained sandstone mudstone including shale cob. or boul.
MIOCENE	YOTSUKURA FORMATION	[Symbol: dots]	150 m	medium to coarse grained sandstone
		[Symbol: horizontal lines]		sandy mudstone and muddy sandstone
		[Symbol: dots]		peb. to cob. size conglomerate
		[Symbol: horizontal lines]		med. to c. grained sandstone
		[Symbol: dots]		fine to med. grained sandstone

[Symbol: horizontal lines] muddy rocks    [Symbol: dots] sandstone    [Symbol: dots in squares] conglomerate

Fig. 5. Generalized stratigraphic sequence of the Yotsukura Area, Iwaki City, Fukushima Prefecture.

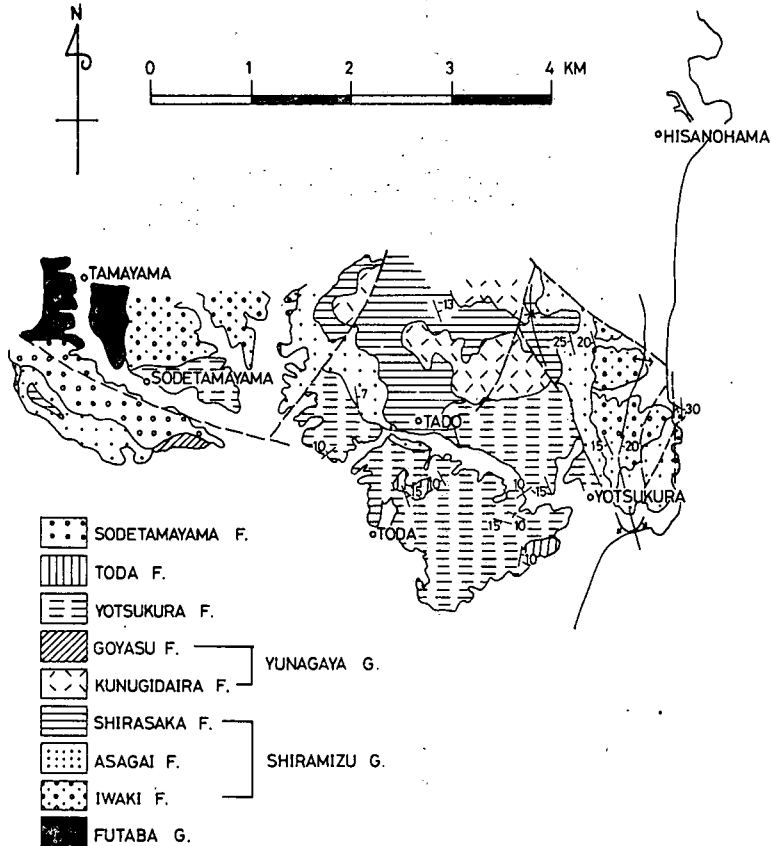


Fig. 6. Geological map of Yotsukura Area, Iwaki City, Fukushima Prefecture.

15°. The strata of the Yotsukura are gently undulated and differ distinctly from the structure of the Shiramizu and Yunagaya groups. It forms a sedimentary basin (Fig. 6).

The Yotsukura Formation, about 150 meters in thickness, consists mainly of dark olive, massive muddy sandstone and sandy mudstone. Intercalated in the middle part are layers of medium to coarse grained sandstone (max. 2-3 m), granule to pebble size conglomerate with sandstone layers (max. 2-3 m) and soft pebble conglomerate (max. 50cm). In the upper part of the formation there are layers of stratified and laminated, medium to coarse grained sandstone amounting to 2 to 10 meters in thickness (Fig. 7). The muddy rocks are diatomaceous and contain carbonaceous fragments, pumice, mica and *Makiyama* (= *Sagarites*). Mollusca, foraminifera, diatoms and radiolarians have been reported from this formation (Sugai and Matsui, 1957; Iwao and Matsui, 1961).

### II-B. Toda Formation

The Toda Formation, which was proposed for the strata above the unconformity by Mitsui (1973), rests on the Yotsukura Formation with angular unconformity and distributed in a small area in the northeast of the Sumitomo Cement Yotsukura Plant and of Toda (Fig. 6).

The Toda Formation is composed mainly of roughly stratified sandy mudstone and

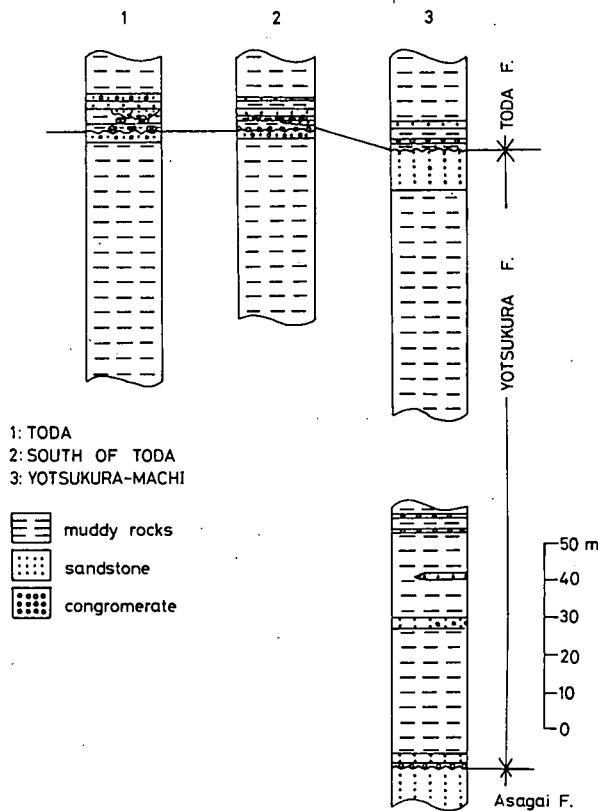


Fig. 7. Columnar sections sections on the Yotsukura and Toda formations in the Yotsukura Area, Iwaki City, Fukushima Prefecture.

muddy sandstone with carbonaceous fragments, pumice, mica, mollusca and diatoms, and is intercalated with layers of conglomeratic (pebble size) sandstone, fine to coarse grained sandstone and soft pebble conglomerate (Fig. 5 and Fig. 7).

AGE	FORMATION	COLUMN	TH	ROCK FACIES
PLIOCENE	NAGISA FORMATION		36	stratified sandy mudstone and muddy sandstone medium to coarse grained sandstone and pebble size conglomerate
			m	
MIOCENE	KUROSUNO FORMATION		50	pumice tuff massive sandy mudstone and muddy sandstone
	70			
	YOKOYAMA SANDSTONE MEMBER			fine to medium grained sandstone conglomerate-bearing coarse grained sandstone

Fig. 8. Generalized stratigraphic sequence of the Izumi-Ueda Area, Iwaki City, Fukushima Prefecture.

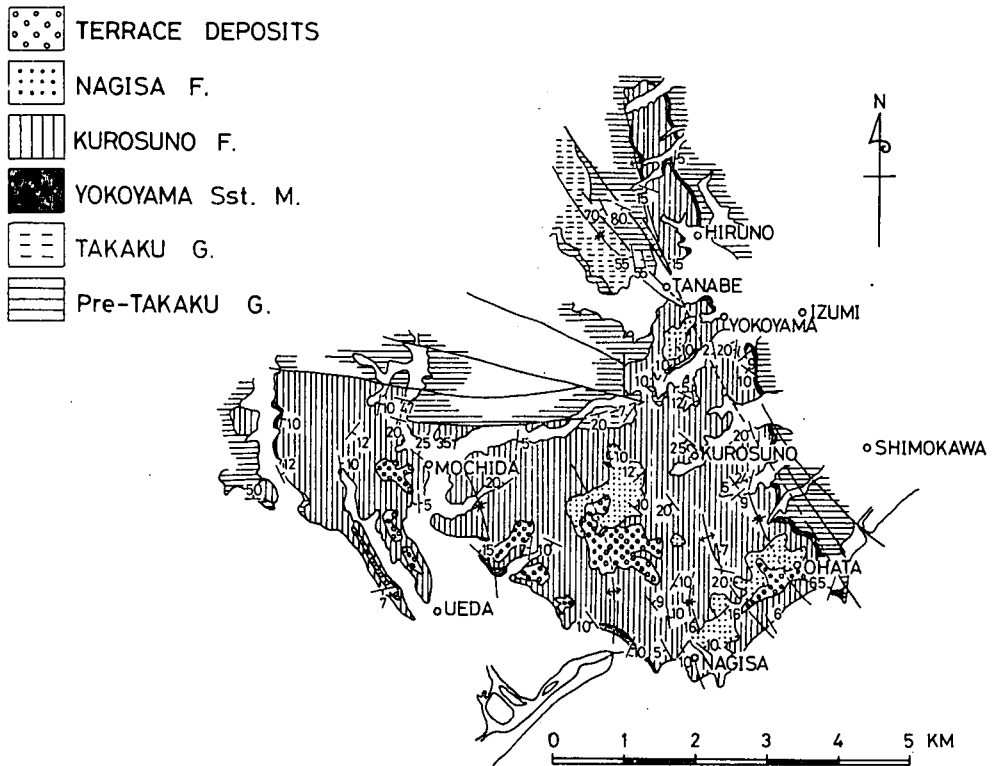


Fig. 9. Geological map of the Izumi-Ueda Area, Iwaki City, Fukushima Prefecture.



### III. Izumi-Ueda Area

The so-called Taga Group in the surveyed area of Izumi-Ueda, is distributed in the vicinities of Hiruno, Izumi-cho, and Shimo-Yamada, Yamada-cho, and in the area enclosed by the Izumi-Ueda line and the Pacific coast.

According to Mitsui and Ouchi (1972), the names of Kurosuno and Nagisa formations are proposed for the strata below and above the unconformity, respectively.

#### III-A. Kurosuno Formation

The Kurosuno Formation covers the Yunagaya Group, the Nakayama Formation and the Takaku Group with angular unconformity, and is superposed with unconformity by the Nagisa Formation. The Yokoyama Sandstone Member occupies the lower part of the formation (Fig. 8). The formation has strikes of N30°E to N30°W and dips 5° to 20°E or W. The Kurosuno is gently folded and differs from the structure of the Nakayama Formation and the Yunagaya and Takaku groups. In the environs of Hiruno, Izumi-cho, the Kurosuno Formation, forming a trough, lies with clino-unconformity

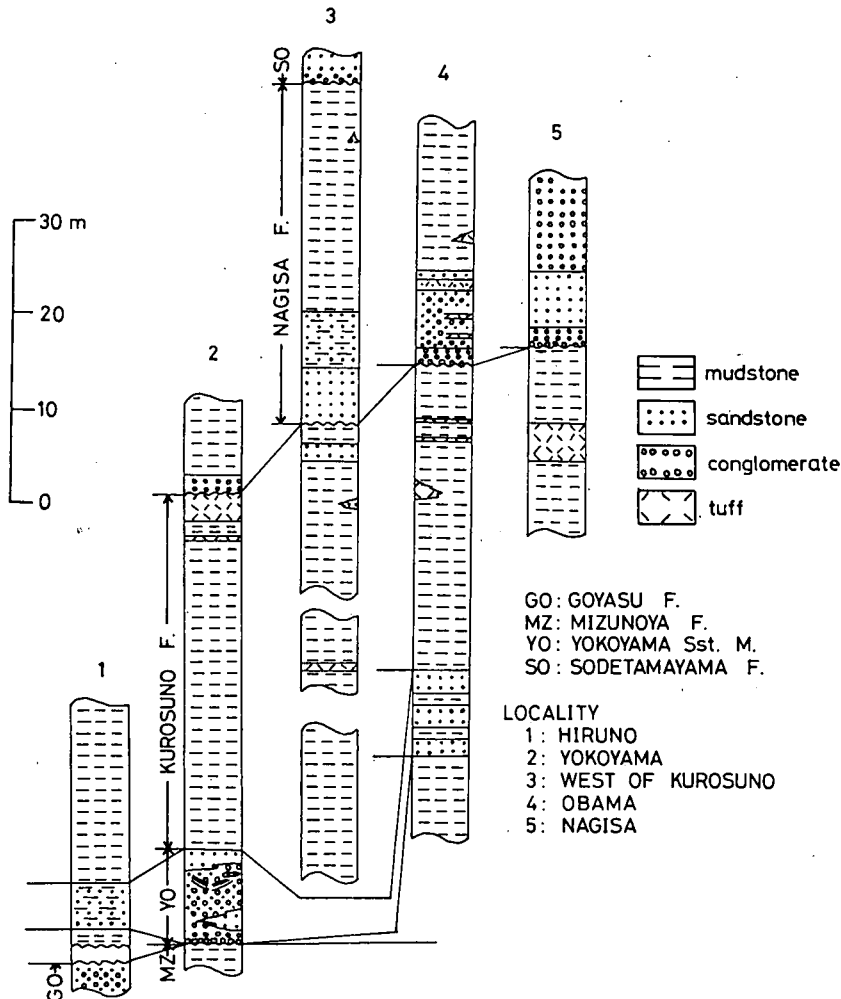


Fig. 10. Columnar sections of the Izumi-Ueda Area, Iwaki City, Fukushima Prefecture.

upon the Yunagaya Group and erosion has cut deeply to the core of the Hiruno Anticline (Ishiguri, 1968 MS; Mitsui, 1971) before deposition of the Kurosuno (Fig. 9).

The Kurosuno Formation consists mainly of dark olive or gray massive muddy sandstone and sandy mudstone. Intercalated are thin layers (5-20 cm) of pebble conglomerate (soft rock), fine to coarse grained tuffaceous sandstone and pumiceous sandstone. The muddy rocks are diatomaceous and contain carbonaceous fragments, pumice, mica, *Makiyama* (= *Sagarites*). Molluscs, foraminifers and diatoms also occurred from this formation. In the upper part of the formation there are layers of rhyolitic tuff or pumiceous sandstone (Fig. 10). The tuffaceous rocks form lenses of 5 meters in maximum thickness, but the thickness changes in lateral direction.

### III-A-1. Yokoyama Sandstone Member

The Yokoyama Sandstone Member, about 20 meters in thickness, occupies the lower part of the Kurosuno Formation. It is distributed in the environs of Shimo-Yamada, Yamada-cho, Higashida, Iwama, both of Ueda-cho, Ohata, Yokoyama and Hiruno, all in Izumi-cho. At the localities of Yokoyama, Ohata, Shimo-Yamada, south of Kurosuno the Member lies with angular unconformity on the Nakayama Formation and Yunagaya Group (Fig. 9).

The lower part of the Yokoyama Sandstone Member comprises pebble size conglomerate (soft rocks)-bearing coarse grained sandstone with cross-lamina. The upper part of the Member consists of roughly stratified medium to fine grained sandstone (Figs. 8, 10).

### III-B. Nagisa Formation

The Nagisa Formation rests with angular unconformity upon the Kurosuno Formation and is distributed in a small area in the vicinities of Yokoyama, south of Kurosuno, Ohata, Minami-Tomioka, all of Izumi-cho, and Nagisa and Kanayama, both in Ueda-cho. (Fig. 9).

The lower part of the Nagisa Formation is composed mainly of pebble size conglomerate (soft rock) and medium to coarse grained sandstone, and the upper part of roughly stratified sandy mudstone and muddy sandstone with carbonaceous fragments, pumice, mica, mollusca and diatoms.

## IV. Hirakata-Otsu Area

The Hirakata-Otsu Area is the area between Nakoso-cho, Iwaki City Fukushima Prefecture, and Futatsushima, Isohara-cho, Kita-Ibaraki City, Ibaraki Prefecture.

The so-called Taga Group in this area is subdivided into the Futatsushima, Kokozura and Otsu formations, and the stratigraphic relationship between the Futatsushima and Kokozura is a conformity and the Kokozura Formation is superposed with unconformity by the Otsu Formation (Fig. 11).

### IV-A. Futatsushima Formation

The Futatsushima Formation was proposed by Eguchi and Shoji (1953) for the sandstone developed remarkably in the lowest of the Taga Group distributed in this

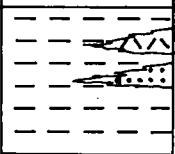
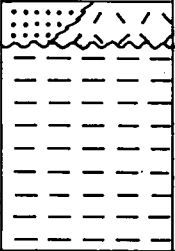
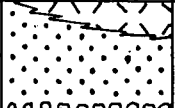

AGE	FORMATION	COLUMN	TH	ROCK FACIES
PLIOCENE	OTSU FORMATION		70 m	pumice tuff pumiceous sandstone massive sandy mudstone and muddy sandstone med. to c. sandstone, pumice tuff
				
MIOCENE	KOKOZURA FORMATION		100 m	massive sandy mudstone and muddy sandstone
	FUTATSUSHIMA FORMATION		60 m	pumice tuff fine to coarse grained arkose and tuffaceous sandstone

Fig. 11. Generalized stratigraphic sequence of the Hirakata-Otsu Area, Ibaraki and Fukushima Prefectures.

area. The type locality is the vicinity of Futatsushima, Isohara-cho, Kita-Ibaraki City, Ibaraki Prefecture.

This formation, about 50 to 60 meters in thickness, is distributed in the environs of Nakosono-seki, Awano and Otsu-machi, and between Sekimoto and Futatsushima (Fig. 12). The formation lies with angular unconformity upon the Nakayama Formation and Yunagaya Group (mainly upon the Kameno-o Formation). The basal conglomerate is of cobble to boulder size and consists of chert, slate, sandstone and muddy rocks, the latter two being derived from Tertiary formations.

The Futatsushima Formation is composed mainly of fine to coarse grained arkose and tuffaceous sandstone intercalated with layers of mudstone, arkose sandstone, pumiceous sandstone, pumice tuff and granule to pebble size conglomerate (soft rocks). The mudstone is dark gray and contains pumice, carbonaceous fragments, abundant remains of *Makiyama* (= *Sagarites*), and mollusca. This formation grades upwards into the next younger Kokozura Formation.

#### IV-B. Kokozura Formation

The Kokozura Formation redefined in this paper consists of the strata excluding the Futatsushima and Otsu formations and also the "Kokozura Formation" of Hanzawa (1954, 1957) and Kamada (1962). Namely, the name is restricted for the strata, composed mainly of muddy rocks, underlying the unconformity. The thickness of the Formation is about 100 meters.

The redefined Kokozura Formation overlies the Futatsushima Formation with conformity and is overlain by the Otsu Formation with angular unconformity.

The Kokozura Formation is composed mainly of dark gray to dark olive, massive sandy mudstone and muddy sandstone intercalated with thin layers (5-20 cm) of pebble size conglomerate (soft rock), fine to coarse grained sandstone and pumiceous

sandstone. The muddy rocks are diatomaceous and contain carbonaceous fragments, pumice, mica and *Makiyama* (= *Sagarites*). Molluscs, foraminifers and diatoms occurred from this Formation.

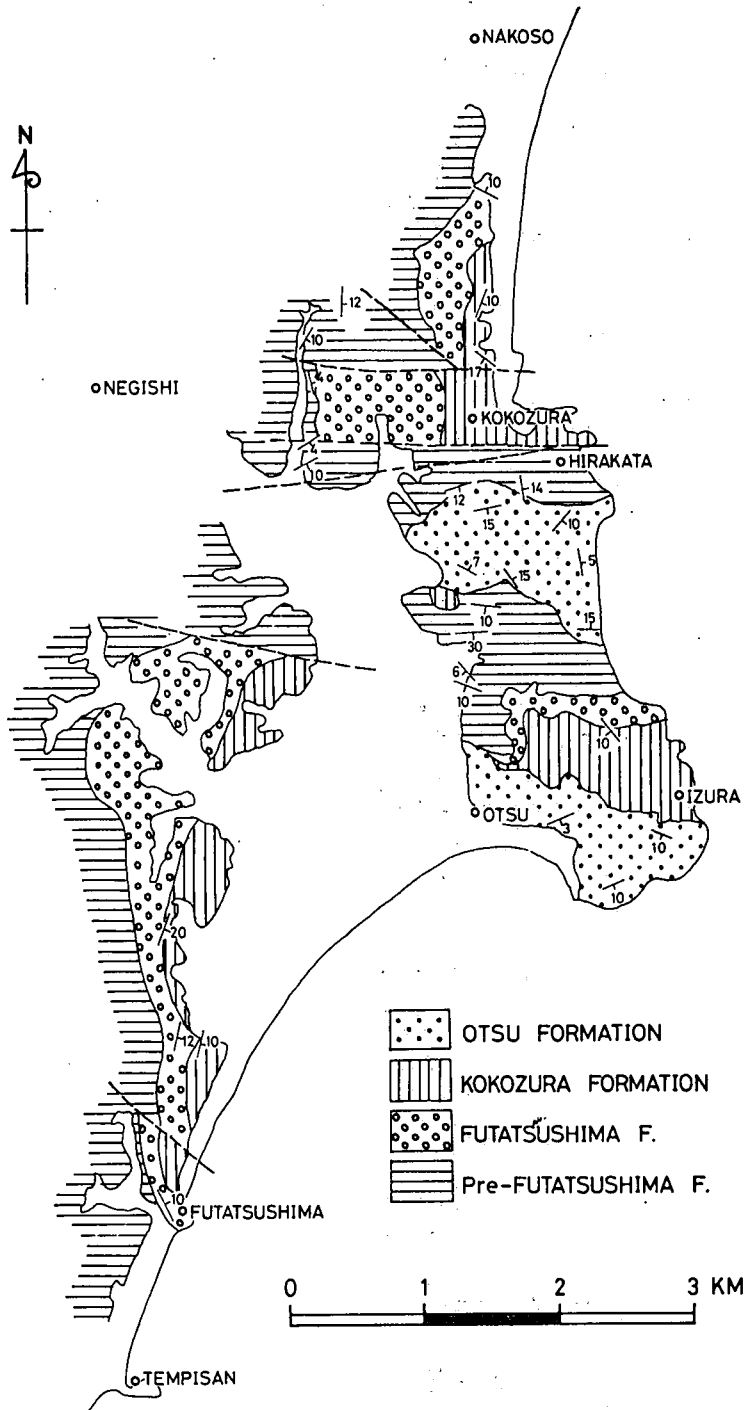


Fig. 12. Geological map of the Hirakata-Otsu Area.

#### IV-C. Otsu Formation

The Otsu Formation, first used by Endo (1971 MS), is newly proposed by the writers for the strata above the unconformity in the Hirakata-Otsu Area. The type locality is the vicinity of Otsu-machi, Kita-Ibaraki City, Ibaraki Prefecture.

The Otsu Formation, about 70 meters in thickness, is distributed in the environs of Kunosaki and Otsu-machi (Fig. 12).

The unconformity between the Kokozura and Otsu formations can be observed at the following localities, namely; (1) East of the Otsu-ko Station of the National Railways, where medium to coarse grained, laminated pumiceous sandstone of the Otsu Formation abuts with unconformity upon the sandy mudstone of the Kokozura Formation. At this locality, the strike and dips of the Kokozura Formation are N60°W and of 10°S respectively, and those of the Otsu Formation are N75°W and of 5°N. (2) The outcrops of Izura show that the sandy mudstone of the Kokozura Formation is abutted by medium to very coarse grained, laminated pumiceous sandstone with unconformity. At this locality the strata of the Otsu Formation are nearly horizontal.

The lower part of the Otsu Formation consists mainly of laminated, medium to coarse grained pumiceous sandstone and quartzose sandstone, pumice tuff and an alternation of sandstone and mudstone, and covers the Kokozura Formation and Yunagaya Group with angular unconformity. In the upper, there is coarse to very coarse pumice tuff, about 2 to 10 meters in thickness and which forms the key bed of the Otsu Formation in this area.

Dark gray to dark olive, massive sandy mudstone and muddy sandstone in the upper part of this formation are intercalated with granule to pebble size conglomerate (soft rocks), pumiceous sandstone and pumice tuff, with carbonaceous fragments, pumice, mica and *Makiyama* (=Sagarites).

#### V. Isohara Area

This area is the environs of Isohara-machi, Kita-Ibaraki City, Ibaraki Prefecture, and is situated south of the Komaki Fault which can be traced from Tempisan to the northeast of Komaki. The so-called Taga Group in the Isohara area is subdivided into the Isohara Formation and the Tempisan Formation, and the latter covers the former with angular unconformity (Fig. 13).


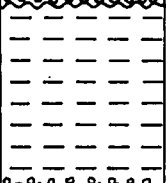
AGE	FORMATION	COLUMN	TH	ROCK FACIES
PLIOCENE	TEMPISAN FORMATION		60 m	medium to coarse grained, granule size conglomerate-bearing arkose to quartzose sandstone
MIOCENE	ISOHARA FORMATION		80 m	pumice tuff massive or roughly stratified, sandy mudstone and muddy sandstone

Fig. 13. Generalized stratigraphic sequence of the Isohara Area, Kita-Ibaraki City, Ibaraki Prefecture.

### V-A. Isohara Formation

The Isohara Formation is superjacent to the Yunagaya and Shiramizu groups with unconformity and superjacent to the Tempisan Formation with unconformity. The thickness of the formation is about 70 to 80 meters. The strike of the formation varies, but the dips are generally  $10^{\circ}$  to  $15^{\circ}$  (Fig. 14).

The Isohara Formation is composed mainly of massive or roughly stratified sandy mudstone and muddy sandstone. Intercalated are thin layers of pumice tuff and pumiceous sandstone. The muddy rocks are diatomaceous and contain carbonaceous fragments, pumice, mica, *Makiyama* (= *Sagarites*); Mollusca, foraminifera and diatoms occurred from the sandy mudstone and muddy sandstone.

### V-B. Tempisan Formation

The Tempisan Formation is distributed widely in the area between Tempisan (type locality of this formation) and Usuba, with nearly horizontal dips.

This formation is composed mainly of granule size conglomerate-bearing laminated, medium to coarse grained arkose to quartzose sandstone, with abundant molluscan fragments in the lower part. The mollusca has been reported by Hasegawa (1971 MS).

The unconformity between the Isohara and Tempisan formations can be observed

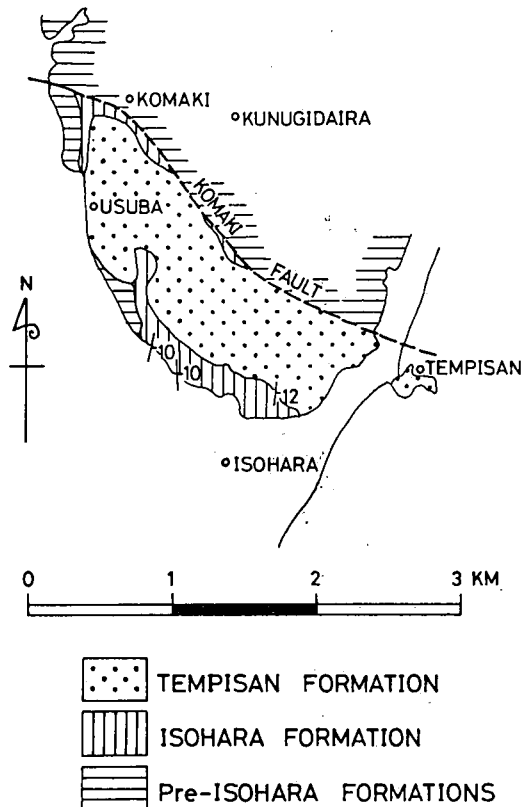


Fig. 14. Geological map of the Isohara Area, Kita-Ibaraki City.

at Komaki, namely; at this locality, the basal conglomerate, composed of chert, slate and shale, etc., of the Tempisan Formation lies with unconformity upon the massive tuffaceous mudstone of the Isohara Formation. The unconformable relationship between the two formations is also upheld by the structural difference, namely the dips of the Isohara Formation are about  $10^{\circ}$  to  $15^{\circ}$ , and those of the Tempisan Formation are nearly horizontal.

From the new outcrops by construction of the industrial area, it was clarified that the Sandstone at Tempisan ("Tempisan Sandstone") is equivalent to the Sandstone at Usuba ("Usuba Sandstone").

## VI. Takahagi Area

The Takahagi Area is the area between Onoyasashi and Takahagi. The Taga Group in this area is subdivided into the Shimotezuna Formation and the Kohama Formation, and the former is superposed by the latter with unconformity, but with partial conformity (Fig. 15).

### VI-A. Shimotezuna Formation

The Shimotezuna Formation (Hasegawa, 1971 MS) lies on the Shiramizu Group with unconformity, and is superposed by the Kohama Formation with unconformity (partial conformity). The type locality of this Formation is Shimo-Tezuna, Takahagi City, Ibaraki Prefecture (Fig. 16).

In this area the formation, about 160 meters in thickness, makes a homoclinal structure with general strike of  $N10^{\circ}W$  to  $N10^{\circ}E$  and dips of about  $10^{\circ}E$ .

The lower part of the formation, observed at Kami-Tezuna, consists mainly of basal conglomerate and coarse grained arkose sandstone (about 30 meters in thickness). This sandstone is considered a correlative of the Iwamoto Formation of Eguchi and Suzuki (1953), although the distribution of this sandstone is not well known.

The middle and upper parts of the formation, about 130 meters in thickness, is

AGE	FORMATION	COLUMN	TH	ROCK FACIES
PLIOCENE	KOHAMA FORMATION		70 m	medium arkose sandstone
				massive or roughly stratified sandy mudstone and muddy sandstone pumiceous, med. to c. sandstone
MIOCENE	SHIMOTEZUNA FORMATION		160 m	massive or roughly stratified sandy mudstone and muddy sandstone
				coarse grained arkose sandstone

Fig. 15. Generalized stratigraphic sequence of the Takahagi Area, Takahagi City, Ibaraki Prefecture.

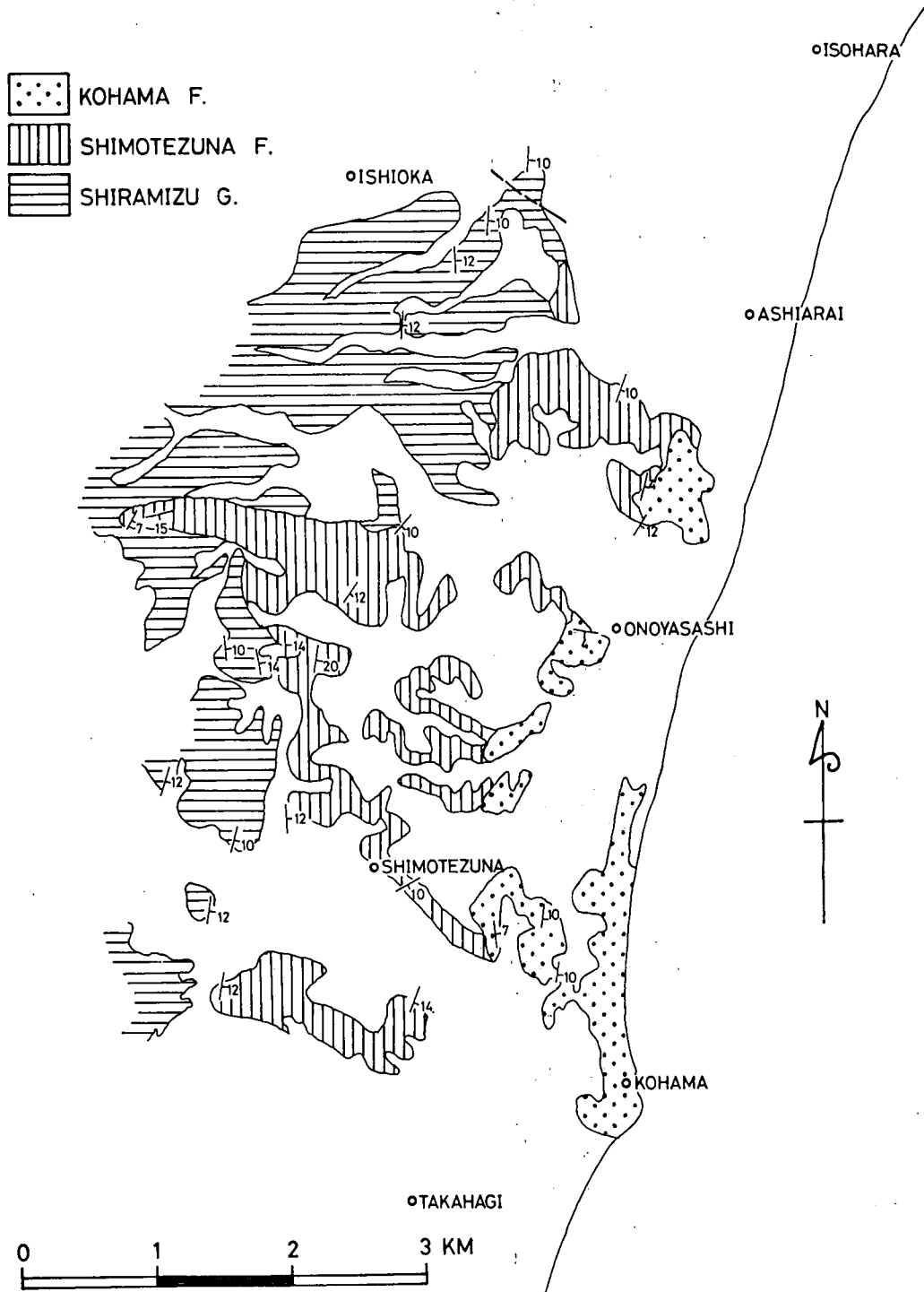


Fig. 16. Geological map of the Takahagi Area, Takahagi City.



composed mainly of dark gray or dark olive, massive or roughly stratified sandy mudstone and muddy sandstone intercalated with thin layers of pumiceous sandstone and arkose sandstone. The muddy rocks contain pumice, mica, carbonaceous fragments and *Makiyama*(=*Sagarites*). Foraminifera and diatoms have been found from this formation (Hasegawa, 1971 MS).

## VI. Kohama Formation

The Kohama Formation overlies the Shimotezuna Formation with unconformity (partial conformity). The unconformity between the Shimotezuna and Kohama formations can be observed at the north of Nakago Station of the National Railways, and, at this locality, an alternation of fine tuff and coarse to medium grained pumiceous sandstone lies with angular unconformity upon the mudstone of the Shimotezuna Formation. A conformable contact of the two formations can be observed in the cliffs of the Sekine River.

The general strikes and dips of the Kohama Formation are N10°W to N10°E and of 10°E respectively.

The lower part of this formation comprises pumiceous, medium to coarse grained sandstone of about 20 meters in thickness, intercalated with thin layers of fine tuff and pumice tuff. Massive or roughly stratified sandy mudstone and muddy sandstone in the middle and upper parts of the formation are intercalated with layers of arkosic sandstone (about 1.5 meters in thickness).

## Geological Age and Correlation

In this section the correlation between the so-called Taga Group distributed in each area and their geological ages are outlined.

This first consideration is the correlation based upon the paleontological evidence to determine the geological age of the formations underlying the unconformity present in the so-called Taga Group.

The Kurosuno Formation in the Izumi-Ueda Area yielded planktonic foraminifera as; *Globigerina bulloides bulloides*, *G. bulloides concinna*, *G. foliata*, *G. parabulloides*, *G. venezuelana*, *G. sp.*, *Globigerinoides quardrilobatus immaturas*, *G. quardrilobatus sacculifer*, *G. quardrilobatus trilobus*, *Globigerinita glutinata*, *Sphaeroidinellopsis seminulina*, *S. subdehiscens*, and *Globoquadrina dehiscens dehiscens* (Mitsui and Ouchi, 1972). These planktonic foraminifera from the range chart of Blow (1969) suggest that the Kurosuno Formation can be correlated within the range from N16 to the middle part of N18 and is thus Late Miocene in age (Table 1). The main diatom fossil species from this Formation are; *Cosinodiscus yabei*, *C. endoi*, *C. vetutissimus*, *Actinocyclus ingens*, *A. tugaruensis*, *Stephanogonia hanzawae*, *Stephanopyxia schenckii* + *ferox*, *Mediatia splendida*, *Hemidiscus cuneiformis*, *Denticulina hustedtii*, *Rauxia peragalli* and *vor* (Ouchi, 1972 MS). According to Ouchi (1972 MS), *Cosinodiscus yabei* disappears in the upper part of the Kurosuno Formation and *Denticulina hustedtii* is dominant. Further, *Rauxia peragalli* and its variety is dominant and *Actinocyclus ingens* is poor in individuals. From the diatom fossils, Ouchi (1972 MS) considers that the Kurosuno Formation is Miocene in age. Therefore, the geological age of the Kurosuno Formation is considered to be Late Miocene based upon the foraminifera and diatoms.

The following planktonic foraminifera from the type Kokozura Formation (Iwai, 1950) in the Hirakata-Otsu Area reported by Saito (1963) are; *Globigerina bulloides*, *G. foliata*, *Globigerinoides ruber*, *Sphaeroidinellopsis subdehiscens*, *Globoquadrina dehiscens*, *G. obesa*, *Globorotalia minutissima*, etc. Saito (1963) pointed out that from the foraminifers the formation corresponds to a position within the range from the *Sphaeroidinella seminulina* zone to the *Globorotalia menardii* / *Globigerina nepenthes* zone and therefore may be Tortonian to Sarmatian in age. When these planktonic foraminifera, described by Saito (1963), are plotted in the range chart of Blow (1969) the Kokozura Formation can be correlated within the range from N16 to the middle part of N18 and is thus Late Miocene in age (Table 1). The Late Miocene age of the Formation is also upheld by the planktonic foraminifera from the muddy rocks at Izura, Otsu-cho, (Endo, 1971 MS). However, the molluscan fossils from this formation point to Middle Miocene, from the following species; *Anadara watanabei*, *A. ogawai*, *Mizuhopecten kimurai*, *M. kimurai nakosoensis* (Endo, 1971 MS). At present, the writers consider the geological age of the Kokozura Formation to be Late Miocene based upon the foraminifera.

On the other hand, the muddy rocks of the Kurosuno and Kokozura formations are remarkably similar. And, although it is necessary to investigate in detail, it is thought that the Futatsushima Formation which underlies the Kokozura Formation, is compared with the Yokoyama Sandstone Member of the Kurosuno Formation.

Hence, from stratigraphic and paleontological considerations, it is thought that the the Kokozura Formation is a correlative of the Kurosuno Formation.

The following planktonic foraminifera occurred from the Isohara Formation in the Isohara Area (Hasegawa, 1971 MS); *Globigerina bulloides bulloides*, *G. parabulloides*, *G. parabulloides*, *G. venezuelana*, *Globigerinoides bolli*, *G. obliquas*, *Globoquadrina dehiscens dehiscens*, *Globorotalia (T.) acostaensis acostaensis*, *G. (T.) acostaensis humerosa*, *G. (G.) cultrata limbrata*, *G. (G.) tumida tumida*, *G. (G.) cultrata menardii*, *G. (G.) margaritae*, *G. (G.) merotumida*. These planktonic foraminifera fall within the range from N16 to N18 (or N19?) of Blow (1969) and is thus Late Miocene in age (Table 1).

The muddy rocks of the Isohara Formation almost coincide with similar rocks of the Kokozura and Kurosuno formations. Therefore, it is thought that the Isohara Formation can be compared with the Kokozura and Kurosuno formations, from the

Table 1. Chronological range of the planktonic foraminifera (from Blow(1969)) from the Yotsukura-, Kurosuno-, Kokozura-, Isohara- and Shimotezuna formations.

FORMATION \ AGE ZONE	MID. MIO.		LATE MIOCENE			PLIOCENE	
	N.14	N.15	N.16	N.17	N.18	N.19	N.20
YOTSUKURA F.			████████████████████				
KUROSUNO F.			████████████████████				
KOKOZURA F.			████████████████████				
ISOHARA F.			████████████████████			██	██
SHIMOTEZUNA F.			████████████████████			██	

evidence mentioned above.

From muddy rocks of the Shimotezuna Formation in the Takahagi Area, the following planktonic foraminifera were recorded by Hasegawa (1971 MS); *Globigerina bulloides bulloides*, *G. parabulloides*, *Globigerinoides obliquas obliquas*, *Sphaeroidinellopsis subdehiscens subdehiscens*, *Globoquadrina dehiscens dehiscens*, *Globorotalia (T.) acostaensis acostaensis*, *G. (G.) crassula conomiozea*. These planktonic foraminifera fall within the range from N16 to N18, but partly to N19 and thus the Shimotezuna Formation is Late Miocene in age (Table 1). In lithology and stratigraphic position, the Shimotezuna Formation almost agrees with the Kokozura Formation (Fig. 11, Fig. 15).

From the muddy rocks of the Yotsukura Formation, planktonic foraminifera as *Orbulina universa* and *Globorotalia tumida* were reported by Iwao and Matsui (1961), and, when these planktonic foraminifera are plotted in the range chart of Blow (1969), the Yotsukura Formation is considered to be younger than Late Miocene in age. The following benthonic foraminifera were also reported by Iwao and Matsui (1961); *Robulus limbosus*, *R. psuedorotulatus*, *Nodosaria insecta*, *Lagena globosa*, *L. striata*, *Nonion pompilioides*, *Uvigerina subperegrina*, *Epistomina elegans*, *Pullenia bulloides*, and *Sphaeroidina austriaca*. Iwao and Matsui (1961) described that large size *Robulus* specimens are dominant and that the benthonic foraminifera from the Yotsukura Formation closely resemble those of the Kokozura Formation (Asano, 1949). Because the Kokozura Formation is Late Miocene in age, the geological age of the Yotsukura Formation is thought to be Late Miocene.

Because no fossils available for determination of the geological age were reported from the Sekinoue Formation in the Futaba Area, its age could not be determined. But, from the stratigraphic correlation with the so-called Taga Group distributed in the Izumi-Ueda Area, as mentioned next, the Sekinoue Formation may be Late Miocene in age.

From the above considerations, the strata below the unconformity, that is to say, the Sekinoue-, the Yotsukura-, the Kurosuno-, the Kokozura-, the Isohara- and the Shimotezuna formations are thought to be Late Miocene in geological age (Table 2).

The next problem was an attempt to determine the geological age of the strata above the unconformity.

As no planktonic foraminifera were found from the Nagisa Formation in the Izumi-Ueda Area, the geological age of the Formation is doubtful. But fortunately, *Turritella nipponica* Yokoyama, which is an index fossil of the Pliocene age, was discovered from the

Table 2. Correlation table of the so-called Taga Group in the Joban Coal-Field.

AGE AREA	TOMIOKA AREA	YOTSUKURA AREA	IZUMI-UEDA AREA	HIRAKATA-OTSU AREA	ISOHARA AREA	TAKAHAGI AREA
PLIOCENE	YAMADAHAMA FORMATION	TODA FORMATION	NAGISA FORMATION	OTSU FORMATION	TEMPISAN FORMATION	KOHAMA FORMATION
MIocene	SEKINOUE FORMATION	YOTSUKURA FORMATION	KUROSUNO FORMATION YOKOYAMA Sst. M.	KOKOZURA FORMATION FUTATSUSHIMA F.	ISOHARA FORMATION	SHIMOTEZUNA FORMATION

Nagisa Formation, hence, the geological age is Pliocene. The Pliocene age is also upheld by such diatoms as; *Denticulina kamtehatica*, *Thalassiosira autigua*, *T. nidulus*, *T. usatchvii* + *zabelina* (Ouchi, 1972 MS). From this data, Ouchi (1972 MS) stated that the Nagisa Formation can be correlated with the Tatsunokuchi Formation of the Sendai Group in the Sendai district, Miyagi Prefecture (Hanzawa, *et al.*, 1953), which is also Pliocene in age. Accordingly, the geological age of the Nagisa Formation is Pliocene.

The Yamadahama Formation in the Futaba Area may be Pliocene in age, because Kamada (1962) reported the following molluscs from his Futaba-Tomioka Formation; *Glycymeris yamaguchi*, *Chlamys miurensis*, *Patinopecten ibaragiensis*, *Venericardia ferruginea*, *Lucinoma gracilistriata*, *Clinocardium hataii*, *Nemocardium samarangae*, *Mercenaria chitaniana*, *Turritella aff. ikebei*, *Neverita didyma*, *Tectonatica janthostomoides*, *Fusitxition oregonensis*. From these molluscan fossils, Kamada (1962) considered that the Futaba-Tomioka Formation is Early Pliocene in age. The localities, from where Kamada (1962) recorded the molluscan fossils, belong to the Yamadahama Formation, mentioned already. Further, Koizumi (1972) described a Pliocene diatom flora from the localities which belong to the Yamadahama Formation. Therefore, the Yamadahama Formation is thought to be Early Pliocene in age.

The so-called Tago Group in the Futaba Area is correlated with the Tatsunokuchi Formation in the Sendai district, Miyagi Prefecture, north of the present area (Kamada, 1962; Koizumi, 1972). The writers consider that only the Yamadahama Formation can be correlated with the Tatsunokuchi Formation.

The writers could not discover any index fossils for determination of geological age of the Tempisan Formation in the Isohara Area. But, as previously reported by Yabe (1949) his type Tempisan Formation, which is nearly the same as the Tempisan Formation in this paper, may be Pliocene in age.

From the following reasons, it is considered that the Toda Formation in the Yotsukura Area can be correlated with the Nagisa Formation distributed in the Izumi-Ueda Area; that is to say, (1) muddy rocks form the main part of both formations, and are diatomaceous and contain carbonaceous fragments, pumice, mica, mollusca and diatoms. (2) The Toda Formation lies on the Yotsukura Formation with angular unconformity and the Nagisa Formation lies with angular unconformity upon the Kurosuno Formation, the latter of which is thought to be a correlative of the Yotsukura Formation. (3) Both the Toda and Nagisa formations are superposed by the Quarternary Sodedamayama Formation (Sugai and Matsui, 1957) with angular unconformity. (4) The only unconformity recognized in the so-called Tago Group in the Yotsukura and Izumi-Ueda districts is that between the formations stated above. Since the Toda Formation is inferred to be a correlative of the Nagisa Formation, the geological age of the Toda Formation is also Pliocene.

Because no planktonic foraminifera or mollusca were discovered from the Kohama Formation in the Takahagi area and from the Otsu Formation in the Hirakata-Otsu area, its geological age could not be determined. But, from the following reasons, the Kohama and Otsu formations are also inferred to be Pliocene in age, namely; (1) As stated in the foregoing paragraph, in lithology and stratigraphic section, the Kohama and Otsu formations almost coincide with the Nagisa Formation. (2) The Kohama Formation with unconformity, but with partial conformity, lies upon the Shimotezuna Formation, and, the Otsu Formation covers the Kokozura Formation with angular unconfor-

mity. As stated before, the Shimotezuna and Kokozura formations are correlated with the Kurosuno Formation, which is overlain by the Nagisa Formation with angular unconformity. (3) The only unconformity recognized in the so-called Taga Group in the Izumi-Ueda, Hirakata-Otsu and Takahagi areas is that among the formations stated above.

From the considerations given above, the Yamadahama-, the Toda-, the Nagisa-, the Otsu-, the Tempisan- and the Kohama formations are Pliocene in age. Namely, the Neogene strata above the unconformity existing in the Taga Group is thought to be Pliocene in the geological age (Table 2).

From the evidence presented it can be said that the unconformity between the strata is Miocene-Pliocene boundary in the Joban coal-field (Table 2).

### Summary

The results of the present study can be summarized as follows.

1. The so-called Taga Group (Sugai and Matsui, 1957) can be subdivided into the two formations (Table 2), and the stratigraphic relationship between them is an unconformity.
2. The geological age of the strata below the unconformity is Late Miocene and that above the unconformity is Early Pliocene. Hence, the unconformity marks the Miocene-Pliocene boundary in the Joban coal-field.

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