The Tertiary Ideyama Formation

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The Tertiary Ideyama Formation

By

Suzuomi TOMITA

Abstract

The Tertiary Ideyama Formation of the Otsuji Group, named and defined by NAGAO (1925), occupies a considerable portion of the Chikuho Coal-field. This formation is found between two coal measures, the underlying Uwaishi and the ovelying Onga Formation. It is distributed in the region extending over the Nogata and Tagawa districts and in the southeast areas of the Iizuka district.

The Ideyama Formation is mainly composed of non-marine coarse-grained sediments with small amounts of fine deposits and coaly matter, and lies unconformably on the Uwaishi Formation of the Nogata Group. From the cycle of sedimentation, this formation is divided into several members, which are traceable and mappable in every district. The relationships of their members among three districts are shown as the Table 3 based on the stratigraphical and sedimentological correlation.

The sedimentary basin of the Ideyama Formation is characterized by having the rapid local streams and by the rhythmical and cyclical subsidence. Subsequently to the northward expansion of the basin at the last stage of deposition of the Nogata Group, subsidence of the basin proceeded followed by an eastward tilting to result eastward leaning center of deposition at the initial stage of the Ideyama Formation. The basin was differentiated into two basins by the movement at the middle of the same depositional age. It was perfectly cut off from a channel connecting with the southern sea area in the later half of the same age, and subsidence of the basin was propagated to result northward expansion of the sedimentary area. The series of these movements is referred to the transitional period from the regression of the Paleo-Ariake Bay to the transgression of the Paleo-Genkai embayment. Then the Ideyama Formation is a product formed during a mobile phase in the basin, the Chikushi tilting phase proposed by MATSUSHITA (1967), which is corresponding to the presecessor of the Takachiho disturbance in south Kyushu.

Contents

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Introduction

The Chikuho Coal-field, which extends about 50 km north to south from the Ashiya Coast to Yamada City with a width of about 15 km, lies in drainage area of the Onga River running through the northern central part of Fukuoka Prefecture, north Kyushu. It is one of the greatest coal-fields of Japan considering the thickness and number of coal seams and its wide distribution. Historically, coal has been produced from this field since the 15th century. The Chikuho Coal-field has been known as the first of the Japanese coal-fields, which was developed on a large scale, from the latter half of the 19th century to the first half of 1950's, and it continues to be productive. Regarding the geology of this coal-field, an outline of the Tertiary coal measures was reported first by SUZUKI (1892), and later KIDO and MATSUDA (1904) tried to divide the Tertiary sediments. Thereafter, NAGAO (1922–1928), who studied the stratigraphy of the Tertiary System in the coal-fields of Kyushu, classified and described the Tertiary sediments of the Chikuho Coal-field and correlated them to the formations of other Tertiary coal-fields of Kyushu on the basis of the fossiliferous zones. Moreover, MATSUSHITA (1949) studied and reported a new correlation and paleogeography of the Tertiary coal-fields in northern Kyushu. Besides these references, many other authors have reported on the Chikuho Coal-field, but many of them concern the coal seams and/or the geological features related to coal or fossils themselves.

Many problems, especially those concerning the genetical relation of non-marine coal-bearing sediments and the geotectonics proposed by MATSUSHITA and others have been left unsolved, despite of the fact that all the aspects of the Tertiary coal-field have been gradually confirmed by activities of both academic workers and mining engineers. Although the Ideyama Formation of the Otsuji Group, which is one of the non-marine Tertiary sequences and situates in the lower half of the Otsuji Cycle, occupies a considerable and important portion of the coal-field for its distribution and geohistory, the investigation on this formation have not been thorough enough with a few exceptions due to the absence of workable coal. The results of the present investigation show that the Ideyama Formation is composed of several cycles of sedimentation of the standard type for Tertiary coal-bearing strata, and also that this formation was formed under the tilting phase of the sedimentary basin. This will be a great suggestion to

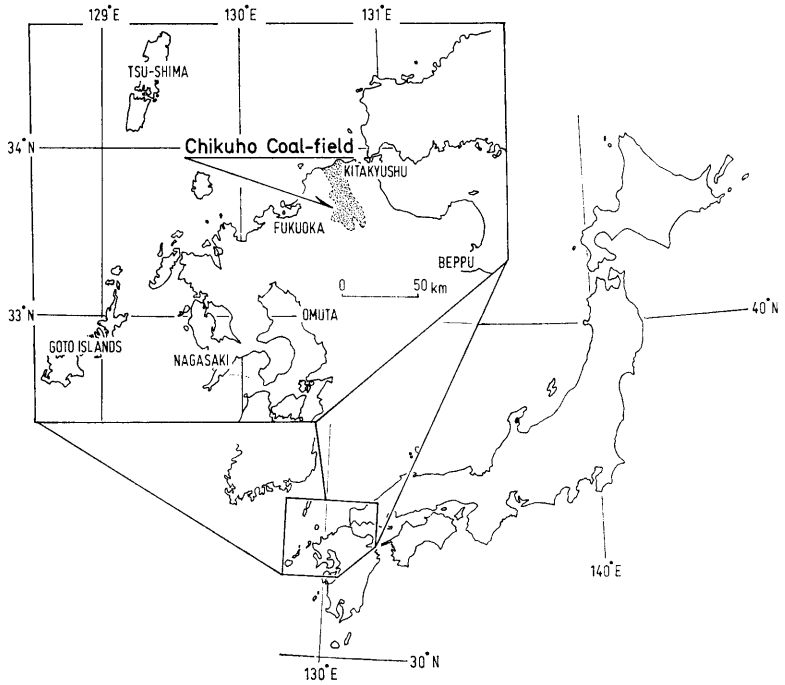

Fig. 1. Index map.

the geohistory of the Chikuho Coal-field and further to the problems on the coal-fields having similar geohistorical process.

I would like to add in this paper some of the contents which have described in previous reports to provide a lucid narration.

Acknowledgements

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Chapter I

General geology in and around the Chikuho Coal-field

I. Outline of the stratigraphy

The Tertiary rocks developed in the Chikuho Coal-field are divided into three groups, the Nogata, Otsuji and Ashiya groups in ascending order, which are further subdivided by NAGAO (1925c) as indicated in Table 1. They are now found in three areas separated by the pre-Tertiary outcrops: the eastern zone extending north to south from the river-mouth of the Onga to the south of Soeda, the western zone distributing from the neighbourhood of Okagaki to the southern end of Yamada City, and the southwestern block lying in the detached areas extending over the Keisen and Daibu districts. Coal-development in these wide areas is so divergent that the areas are also divided into the Nogata, the Tagawa and the Iizuka district (Fig. 2).

Of the Tertiary System, the Ashiya Group consists of marine sediments containing many marine molluscan fossils and microfossils, and is devoid of any workable coal. On the other hand, the Nogata and Otsuji groups are generally composed of non-marine deposits* and have many prominent coal seams once actively exploited. Coal measures of the Nogata Group are distributed in whole area of the Chikuho Coal-field, but the sediments above the Onga Formation of the Otsuji Group are limited in distribution to the eastern zone of the Nogata district.

The basement rocks of the Tertiary of the coal-field are the Paleozoic complex and the Mesozoic Systems. The former is composed of metamorphosed (schistose and phyllitic) and non- and/or weakly metamorphosed sediments, pyroclastics and basic igneous rocks, and is called the Sangun metamorphic terrane (KOBAYASHI, 1941). They are exposed at the Fukuchi-yama and Hiraodai mountain region to the east of this coal-field, a part of the Kanakuni mountain block and the Asakura mountain region, the southern part of the field, and the Inunaki and the Sangun mountain range to the west of the Chikuho Basin. A part of the non-metamorphic Paleozoic is called the Aida Formation in the Inunaki area (KOBAYASHI, 1941). The latter, Mesozoic, is divided into the Cretaceous Kwanmon Group, the Yahata Formation and granitic rocks. The Kwanmon Group (MATSUMOTO, 1951a) is subdivided into the lower Wakino Subgroup mainly composed of non-marine sediments, and the upper Shimonoseki Subgroup mainly of pyroclastic rocks and andesitic lavas. They are distributed throughout the Yurino~Mutsugatake block to the west of Nogata City and the mountain areas surrounding the northern half of the Chikuho Coal-field such as the Wakamatsu Peninsula, the Sarakura-yama mountain area and the Kodaiji-san~Kasagi-yama areas (KOBAYASHI *et al.*, 1935 and 1936; MATSUMOTO, 1951b and 1954; OTA, 1953–1960; YAMASAKI *et al.*, 1956; MATSUSHITA *et al.*, 1957; and HASE, 1959). The Yahata Formation contains acidic igneous rocks and lacustrine deposits and crops out in the Sarakura-yama area (OTA, 1957; HASE, 1959). Granitic rocks

* In places, brackish and/or marine molluscan fossils were found.

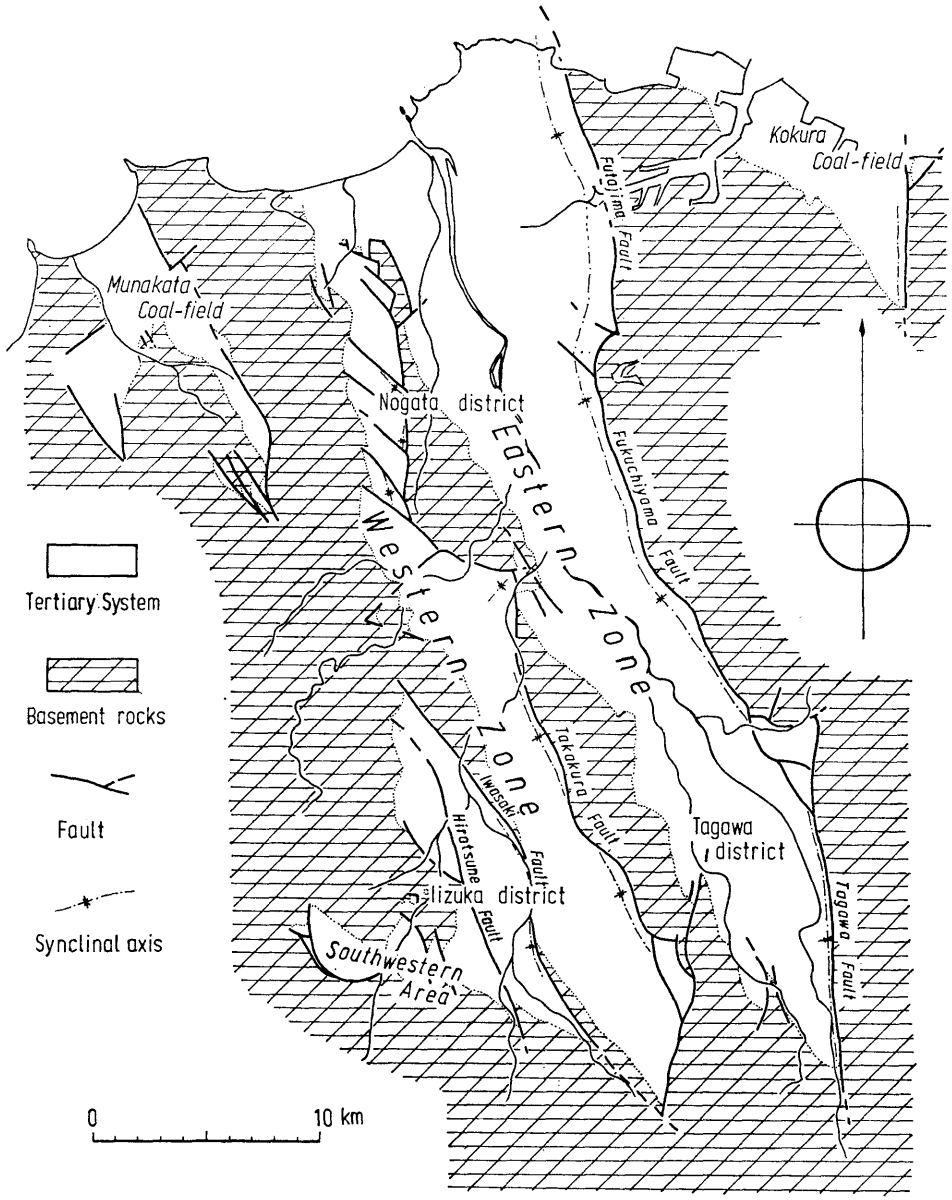

Fig. 2. General distribution and structure of the Tertiary in the Chikuho Coal-field.

are subdivided into the Asakura granodiorite, the Kurate granodiorite, the Hirao granodiorite, the Masaki granite, the Kaho granite, and the Sawara granite (MATSUMOTO, 1951b; KARAKIDA, 1952 and 1969; TOMITA *et al.*, 1957). All of them exert a wide thermal influence on the Kwanmon Group and the Paleozoic rocks. These Mesozoic Systems are of the Cretaceous in age. Distributions of these systems described above are exhibited in Fig. 3.

In the Chikuho Coal-field, the extensive Quaternary System is divided into

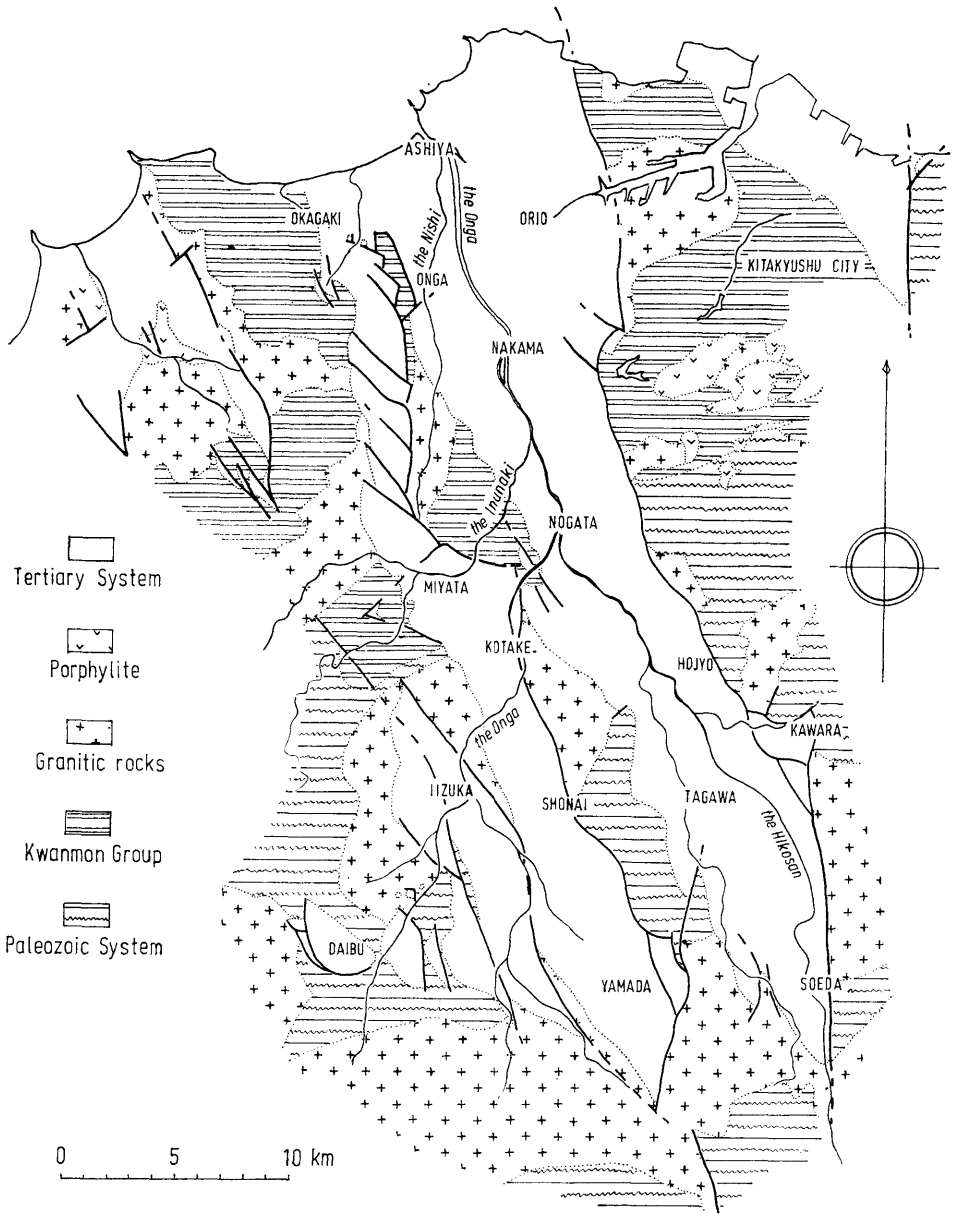

Fig. 3. Geological map around the Chikuho Coal-field (without the post-Tertiary rocks).

the Diluvium and the Alluvium. The former consists of deposits on two terrace levels occupying the wide area from the western foot of the Fukuchi-yama~Sarakura-yama mountain mass to the right-bank of the Onga, the southwest part of the Tagawa district and the western margin of the Iizuka district. Another Diluvium is a volcanic ash deposit, called the "Hai-ishi" mainly developed in the southern half of the Tagawa district. The latter, the Alluvium, is dis-

tributed in the low-leveled and flattened drainage areas of the Onga and its tributaries, and contains peat deposits of "Sôra-so" (MATSUSHITA *et al.*, 1966).

Other rocks developed in this coal-field are the upper Neogene or Quaternary basaltic intrusive rocks which influence a part of the coal seams (UEJI, 1927, 1932 and 1940; ASANO, 1958–1964; and others) and partly crop out.

II. Brief notes on the geological structure

As mentioned by MATSUMOTO (1951b), general structural trend of the Tertiary System in the Chikuho Coal-field differs essentially from that of the pre-Tertiary; while the former runs mainly north to south* and lies unconformably on the latter with dipping to the east in general, and is limited to the eastern boundary by the great faults**, the latter, except a part of the Kwanmon Group, runs from east or northeast to west or southwest, showing a continuation of the Inner Zone of Southwest Japan. Near the great faults, the Tertiary System shows characteristically an asymmetric synclinal structure, an axis of which runs in parallel with the faults. Characteristic structures similar to those of the Chikuho Coal-field are also found in the Kokura, Munakata and a part of Fukuoka coal-fields, and are called the "Chikuho-type" geological structure named by MATSUSHITA (1951).

The marginal fault drawing the eastern boundary of the Chikuho Coal-field runs across the foot of the Wakamatsu Peninsula, extends southwards beneath the Dokai Bay and the alluvial plain to the west of Kurosaki and turns southwestward at Kôjaku. Furthermore, the fault which runs through the western foot of the Fukuchiyama mountain area, winds gently southwest to southeast and joins another fault extending to the south from Kawara. Of these faults, the one extending north of Kôjaku is called "the Futajima Fault", the other from Kôjaku to Kawara is called "the Fukuchiyama Fault", and another one extending south of Kawara is called "the Tagawa Fault" (TOMITA, 1968). On the other hand, remarkable faults of the eastern margin of the western zone are recognized in the southern half of the field. "The Takakura Fault" runs through the foot of the Funao-Kanakuni mountain block, and "the Kumagahata Fault" runs north to south on the east of Yamada City. In the northern half of the western zone, however, the marginal fault is only a convergency of multiple NW-SE trending faults in the Tertiary (SAKAMOTO, 1954). General structure of the Tertiary System is shown as Fig. 2.

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* Such a N–S tectonic line is called as "the Korean Trend (Chôsen Hôkô)" by TATEIWA (1952).

** These faults are sometimes called as "the marginal faults" hereinafter. "Marginal fault" or "Kiban-danso" means a fault bordering Tertiary and the basement rocks, and the term, "Kiban-danso", is used by many colliers in the Chikuho Coal-field as a semi-proper noun.

Chapter II

Lower and upper limits of the Ideyama Formation

I. Historical review

Table 1 shows a transition of the stratigraphic classification of the Tertiary in the Chikuho Coal-field by the studies up to this time. The Ideyama Formation was settled and named by NAGAO (1925c) for the barren part of lower half of "the Upper Tertiary Coal Measures" of KIDO and MATSUDA (1904). NAGAO (1927c) mentioned that "the Ideyama Formation" was 'tentatively' settled as one formation, 'for convenience', to distinguish from the coal-bearing Onga Formation and the Nogata Group. The Ideyama and the underlying Uwaishi Formation are continuous and nearly similar in lithological facies. The former is only distinguished from the latter by absence of workable coal. However, MATSUSHITA (1949) mentioned that the fossil bed at the lower part of the Ideyama

Table 1. Transition of the stratigraphic classifications of the Tertiary in the Chikuho Coal-field

KIDO & MATSUDA (1904)	YABE & NAGAO (1920)	NAGAO (1925)	
Upper Tertiary Coal Measures	Ashiya Group	Ashiya Group	Waita Formation Sakamizu Formation Yamaga Formation
	Otsuji Group	Otsuji Group	Onga Formation Ideyama Formation
Lower Tertiary Coal Measures	Nogata Group	Nogata Group	Uwaishi Formation Takeya Formation Sanjaku-goshaku Formation Oyake Formation

Table 2. Comparison of the geological ages by different authors

	NAGAO (1928)	MATSUSHITA (1949)	MIZUNO (1963)	SHUTO (1969)
Ashiya Group	Lower Oligocene	(Chikushi stage)	? Upper Oligocene (Nishisonogian stage)	Burdigalian (Miocene)
Otsuji Group	Upper Eocene	Oligocene (Otsuji stage)	Lower Oligocene (Mazean stage)	Aquitanian (Miocene) ?
			Lowermost Oligocene (Funazuan stage)	Oligocene~pre-Aquitanian ?
Nogata Group		Upper Eocene (Nogata stage)	Upper Eocene (Okinoshiman stage)	Priabonian (Up. Eocene)

Formation (the Iwasaki fossil bed, discovered and named by NAGAO, 1927c) was correlated with the Oligocene and that the Nogata Group with the Upper Eocene. He described further the unconformable relation between the Nogata and Otsuji groups, and pointed out distinction between the two not only from biostratigraphical but also paleogeographical standpoint (1949, 1953 and 1956). SAITO (1955), TAKAHASHI (1957), MURATA (1961) and MIZUNO (1963) discussed also on the geological age and the correlation of the Ideyama Formation, but, their stratigraphic scheme followed that established by NAGAO. Based on molluscan faunae MIZUNO recently has made a correlation of the Ideyama Formation, and considered that it was not older than the lowermost Oligocene. Most recently, the geological age of the Tertiary formations in the stratigraphic table established by MATSUSHITA and MIZUNO was modified by SHUTO (1969) through the study of the mega- and micro-fossils. He mentioned that the "Funazuan" age (MIZUNO, 1962) was perhaps the Oligocene~earliest Miocene, the pre-Aquitanian Miocene (Table 2).

Thus, it is clear now that the Ideyama Formation, though it was 'tentatively' settled by NAGAO, has an important bearing on the stratigraphy and geological history of the Chikuho Coal-field.

II. Boundaries of the formation

A. Base of the formation and the relationship to the Uwaishi Formation

As precisely described in the preceding report (TOMITA, 1971), the Iwasaki fossil bed is found not only at the type locality (Fig. 4*) and its neighbourhood (Fig. 5**) but also in the whole areas of the hilly part ranging from Akasaka, Shonai Town, to the northern part of Yamada City***. Especially in the latter areas, the Shonai-Yamada areas, many fossil localities were newly found (Fig. 6). In the eastern zone, on the other hand, shell remains are few and had been reported in the lower part of the Ideyama Formation in the Tagawa district (SAITO and OMARU, 1961; OMARU, 1966), but they had not been recognized as a fossil bed.

As mentioned in the preceding section, the Iwasaki fossil bed is important for stratigraphical correlation being regarded as an important key bed near the base of Ideyama Formation in the Iizuka district. Thus, in the Iizuka district, the Ideyama Formation including the Iwasaki fossil bed near the base is recognized in two separated areas, the Iwasaki and the Shonai-Yamada. With an exception of the southern part of Shonai-Yamada areas (Fig. 7)****, the Ide-

* From the description of NAGAO, a small hill standing on the opposite side of the Onga River from Iwasaki of Inatsuki Village (commonly called as "Sagi-yama").

** tentatively called as "the Iwasaki area".

*** tentatively called as "the Shonai-Yamada areas".

**** Lithological facies of the sediments of the upper part of Uwaishi Formation varies laterally into the coarser one towards the south, and this feature and boundary of the Uwaishi Formation were discussed in the preceding report.

Fig. 4. Type locality of the Iwasaki fossil bed (seeing from the east)

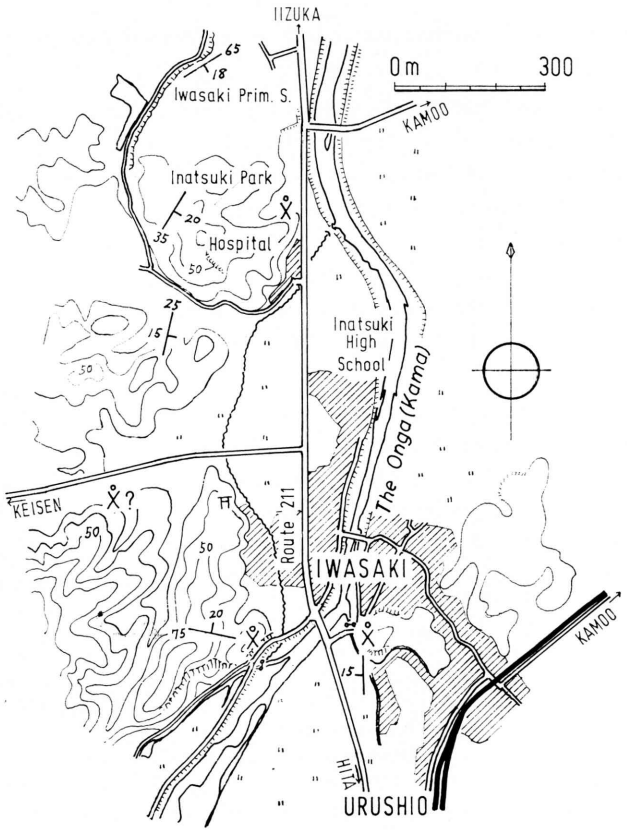


Fig. 5. Type locality and its neighbourhood of the Iwasaki fossil bed.

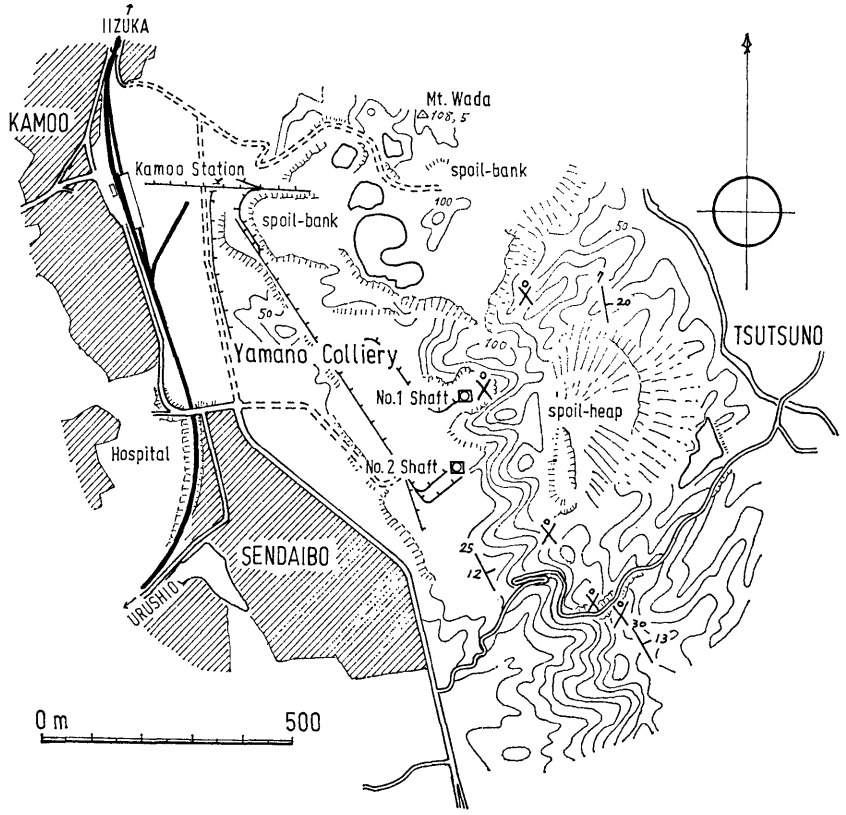


Fig. 6. Fossil localities near Kamoo.

yama Formation in this district is rather distinguished from the conformably underlying Uwaishi Formation of the Nogata Group by their lithological differences; coarse sediments with dominant conglomerates in the former and mainly fine members frequently containing many coaly layers in the latter.

Although I (TOMITA, 1967) reported a diastem between the Ideyama Formation and the Uwaishi Formation of the Tagawa district, I regard that the Ideyama Formation in the eastern zone, at least, lies unconformably on the Uwaishi Formation, based on the later informations such as the "outcrop at Kominé" (Fig. 15) and the "unconformity at Komaki"* in the Nogata district (TOMITA, 1968). These new data and already-known informations such as the erosion plane at Hirabaru in the Tagawa district (Figs. 8 and 9)** suggest that this unconformity may possibly extend wider than it is confirmed.

It should be emphasized that the successive change in lithology from the Uwaishi to Ideyama is quite harmonions in the Iizuka and Tagawa districts

* This outcrop is missed from a road repairing at recent.

** This exposure has also been missing in the present time by the construction of industrial road.

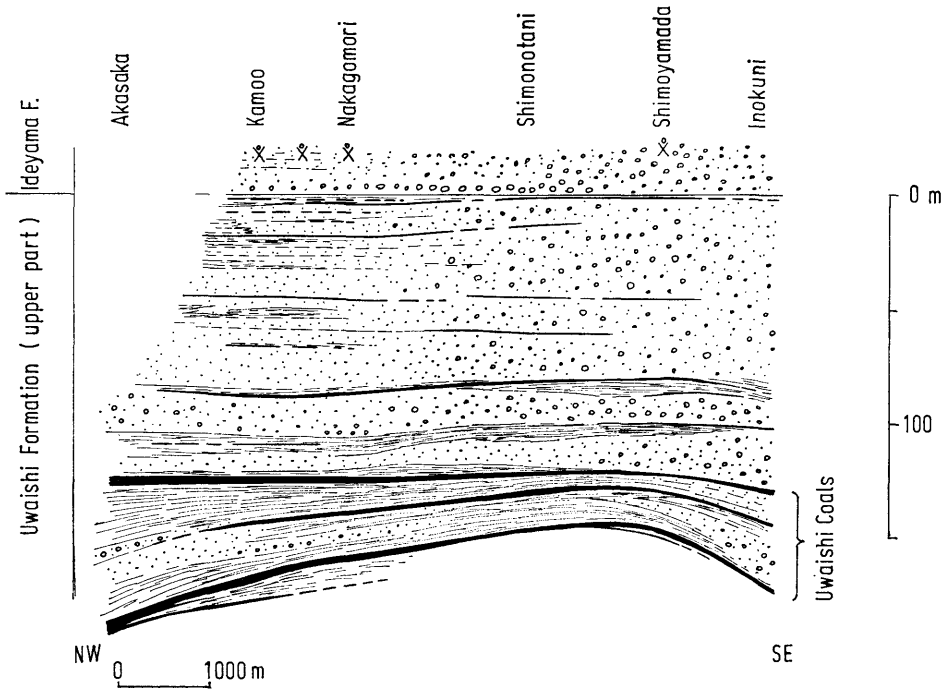


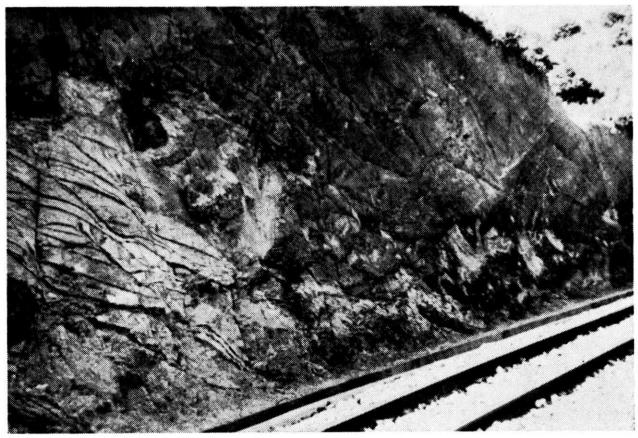
Fig. 7. General lithofacies variation of upper part of the Uwaishi Formation from Akasaka to Yamada in the Iizuka district.

despite the difference in stratigraphic relation of the two units in the two districts as mentioned above.

B. Upper limit of the Ideyama Formation

The Onga Formation, the upper half of the Otsuji Group, which consists mainly of fine sediments containing abundant remarkable coals, is easily distinguished from the underlying Ideyama Formation. Then it is accepted by usage that the lower limit of the Onga Formation is the base of Takaé Seam, the lowermost workable coal of this formation. I discussed on the problems of the boundary between the Onga and Ideyama formations including the paleontological questions in the preceding report (TOMITA, 1968). Anyway, it is not difficult to separate the two formations in the Nogata district by the lithological facies.

On the other hand, the Tertiary sediments in the Imato area of the Tagawa district, now referred to a part of the Ideyama Formation, were correlated formerly to the Onga Formation by some geologists and colliers with their many good coals (MATSUMOTO *et al.*, 1962).



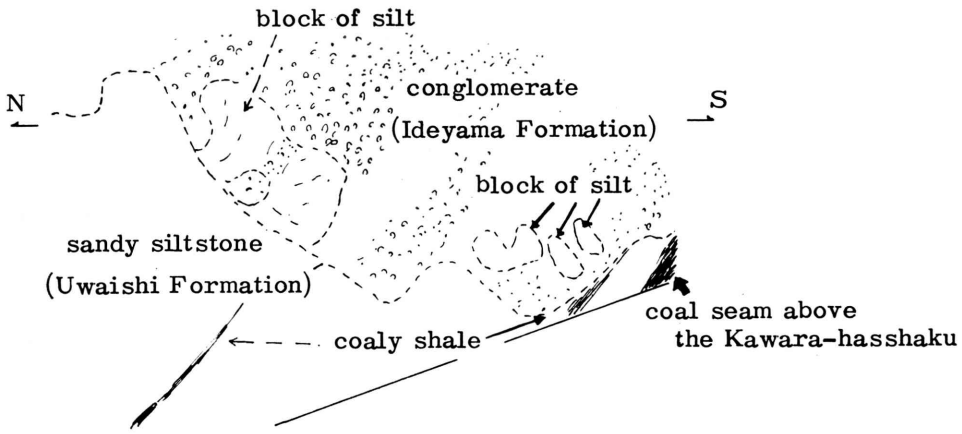
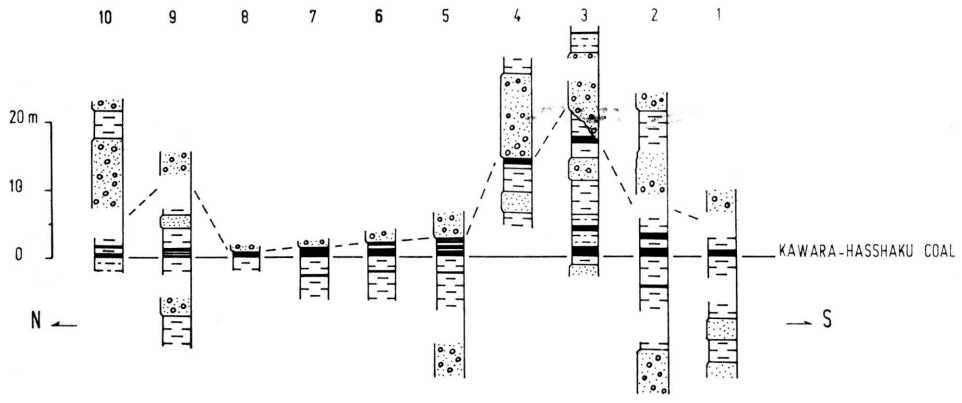


Fig. 8. Unconformity at Hirabaru, Tagawa City (photo in 1957).



1. Yasunaga 2. Oka 3. Hirabaru (Fig. 8.) 4~7. Yoshigatani~Ita 8. Jyodôji Park 9. Natsuyoshi 10. Benjyo

Fig. 9. Detailed sections of the base of Ideyama Formation in the Tagawa district.

Chapter III

Descriptive notes of the Ideyama Formation

I. On the cyclic member

The Ideyama Formation is the thick sediments composed of coarse-grained clastic rocks, exceptionally of a few coal. The detailed observation clarifies that the Ideyama Formation shows a rhythmical or cyclical variation of the lithological facies in the vertical column.

In the area near Ideyama of the Nogata district, the type locality of the Ideyama Formation of NAGAO, the accessible part of this formation consists mainly of remarkable conglomerates and sandstones and subordinate sandy siltstones and siltstones with intercalation of several coals and coaly shales. Some of these coaly layers are developed widely with a variation of coal property and of thickness, although majority of them shows only local distribution. Coal and coarse and fine clastics are not distributed at randam through the formation, but in cyclic order to exhibit a regular successive change of lithology from coarse clastic to coal in each cycle, although succession in one cycle tends to vary both laterally and vertically.

Local columns of every area of the Ideyama Formation are illustrated in Fig. 13. As understood from this figure, the typical order of lithology in the Ideyama Formation is as follows:

(1) the base is conglomerate or conglomeratic sandstone
(2) the lower part consists mainly of sandstone with pebbles
(3) the upper part is composed of siltstone and/or sandy siltstone with coal or coaly shale

The coal or coaly shale is overlain by some silty matter or directly by conglomeratic sediments of the next upper cycle. The conglomerate at the base of the cyclic sequence lies conformably on the underlying sediment in most exposures, and its undulated plane of the base has not been found yet. This successive order of sediments is shown schematically in Fig. 10a.

A tendency of the coal measures for cyclic sedimentation was described at first by FORSTER (1809) and has been discussed by many authors, especially

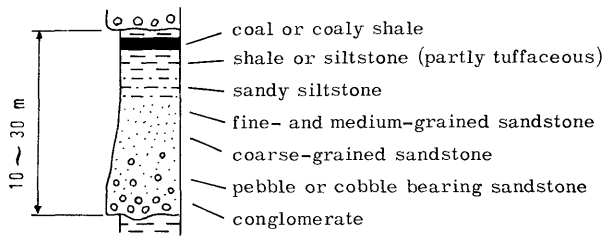


Fig. 10a. Typical profile of the sedimentary cycle of the Ideyama Formation.

UDDEN (1912) who described "cyclic sedimentation". Examples of sedimentary cycles or rhythms of various kinds have been reported. Sedimentary packets of a particular constitution in the Pennsylvanian Interior basins of United States (the Illinois, Missouri, Iowa and Kansas coal-fields) were termed "cyclothem" by WELLER (in WANLESS and WELLER, 1932), and this term is now commonly used in other areas and in other geological systems*. Sedimentary types of "cycle" and "rhythm" have been used strictly as different types from each other (FEANSIDES, 1950, cited by WESTOLL, 1968), however it is difficult to find a better general definition. DUFF and WALTON (1962) regarded that "cyclothem" was essentially a synonym of the cycle or rhythm of sedimentation. Therefore, an example of the Ideyama Formation is one of the asymmetrical types explained by BEERBOWER (1964), and it does not belonging to cycle or cyclothem in the strict definition of the term.

Coal-bearing sedimentary cycles of the Japanese coal-fields have been reported by TASHIRO (1952), SHIBAOKA (1957), HYAKKOKU (1966), SOGABE (1966), and others in Hokkaido, EGUCHI and SHOJI (1953 and 1955), ASANO (1956) and SHOJI (1960) in Joban, KIHARA (1955), SAWADA (1958) and IWAHASHI (1961) in northwestern Kyushu, and SAKAMOTO (1969) and others in other coal-fields**. TASHIRO showed various types of the cyclic units, but any of his types is hardly comparable with the type of the Ideyama Formation. The "ideal cycle" of the Shiramizu Group in the Joban Coal-field, eastern Honshu, reported by EGUCHI and SHOJI is similar to the cycle of the Ideyama Formation, although they are different in thickness of one cycle. EGUCHI and SHOJI mentioned that in the Joban Coal-field the sedimentary cycle, "Rinne-so", was successively traced in the mapped area, although the coaly bed at the top of the cyclic unit varied frequently to very fine-sandstone passing into shale or sandy shale. If the sediments were deposited almost uniformly in one basin, the number of cyclic units should not be different in any part of the basin regardless of ebb and flow of coaly layer.

In the case of the Ideyama Formation, however, it is extremely difficult to trace the extent of each minor cyclic unit because of paucity of necessary information. Whole stratigraphic successions of every member can be observed only in few places, the outcrops being limited because of the Quaternary cover. Besides no drilling information has been available. Under such circumstance, minor cycle cannot be recognized as an unit valid throughout each district, but is only effective to estimate the sedimentary condition in local section. Minor units in each column of the Ideyama Formation are clearly grouped in several higher units with remarkable coals or coaly shales at the top. These units are traceable and mappable in each district, regarded as the mid-cyclic units, and

* The term "cyclothem" is tend to be applied to deviated types than an original definition, so this term is not used in this paper to avoid from confusion.

** SAKAMOTO (1957) and other authors reported on the mega cyclic units following the movement of transgression and regression in the continental coal-bearing basins essentially differing from the cyclic member or "Rinne-so" in the Japanese coal-fields.

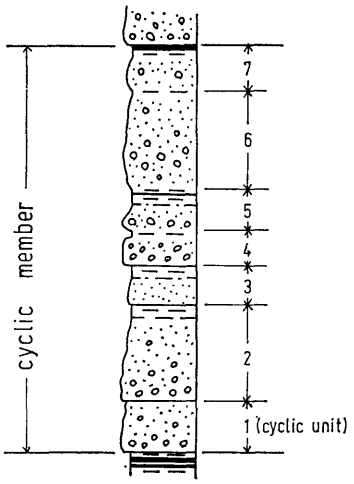


Fig. 10b. Representative section of cyclic member.

termed as "cyclic member" here (Fig. 10b)*.

Number of the cyclic members in the Ideyama Formation is different by district. That is to say, two in the Iizuka district, five in the northern part of the eastern zone and three and one undivided part in the southern area of the same zone are distinguished.

As many minor cyclic units in cyclic member as possible were also examined in several selected sections in order to know the local condition of the sedimentary basin. In this instance, a coaly bed was taken as the primary indicator of the sedimentary cycle. While a shale bed of areal extent was chosen as the secondary indicator when a coaly bed was not found. However, it was difficult to discriminate minor cyclic units on the outcrops because of variable development of coaly and shaly layers from thick stratum to mere streak.

II. Ideyama Formation in the eastern zone

A. Subdivision in the Tagawa district

1. General lithology and subdivision

The Ideyama Formation distributed in the Tagawa district is generally represented by coarse-grained clastics, with a thickness of about 800 m. This formation is composed mainly of conglomerates and sandstones in the lower and middle parts, and of sandstone intercalated with some conglomerates and several coals in the upper part. It ranges from the conglomerates, which are lying unconformably on the Kawara-hasshaku Coal of the Uwaishi Formation, to the

* EGUCHI and SHOJI (1953) used the term "Cycle (Rinne-so)". The term "cyclic member" of this paper is essentially the same.

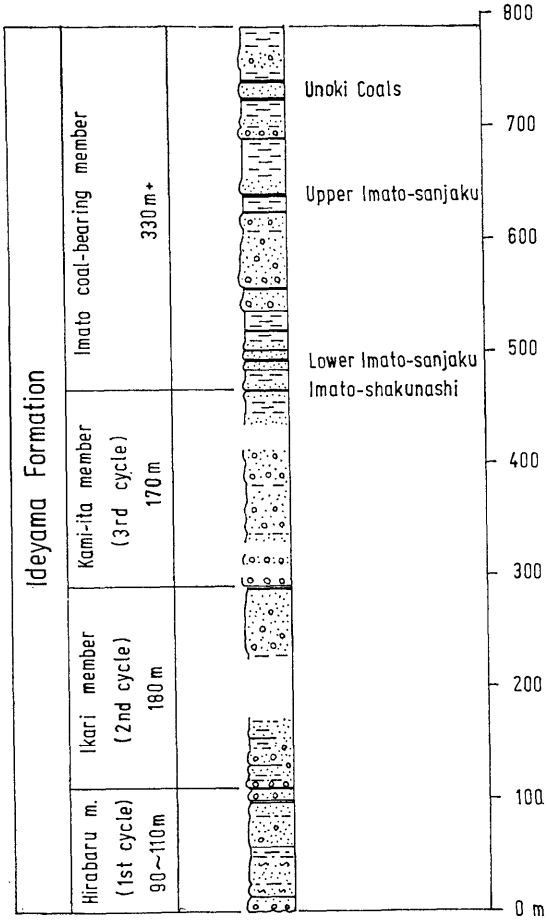


Fig. 11a. Generalized section of the Ideyama Formation in the Tagawa district.

top of sediments developed at the axial part of syncline near the Tagawa Fault, one of the marginal faults described already. In the lower part of the Ideyama Formation, coaly layers, which are found in several horizons and traceable in the whole area of this district, are good indicators of cyclic members. Thus, the lower part of this formation in the Tagawa district is divided into three cyclic members. While the upper one of the same formation is distinctive with its many coals and lithofacies, which differs from the lower three members and also from standard cyclic features illustrated in Fig. 10a.

In the following description, the cyclic members in the Tagawa district are called by the names of type localities, while the equivalent or corresponding members in the Nogata district are given numbers in ascending order for convenience of description. They are the **Hirabaru** (first), the **Ikari** (second), and the **Kami-ita** (third) **cyclic member** in the lower and the **Imato coal-**

bearing member in the upper in ascending order (Fig. 11a)*. Of these members, the lower three ones are distributed in both the main and the northern areas of the Tagawa district, but the upper cyclically undivided member is limited to the Imato area, the eastern part of this district.

2. Minor cycles in each member

In the Hirabaru and the Ikari member, the maximum number of minor cycles was found at the Hojyo area where the lithology of these members is the finest in this district. There are four cycles with coaly shales, and another ten or more cycles detected by siltstone in the first member. In the central part of this district including the area from the Ita to the Hirabaru in Tagawa City, four cycles are distinguished in each member.

The Kami-ita member is not necessarily examined in detail because of the development of the Quaternary cover.

Six coal seams are predominant in the Imato coal-bearing member. They are the Lower Imato-sanjaku, the Upper Imato-sanjaku, the Unoki-chûkan, the Unoki-lower, the Unoki-main, and the Unoki-upper Coal in ascending order. However it is difficult to distinguish minor cyclic units from one another, because any unit between two coaly beds is sometimes composed of sediments of various grain-sizes and does not show cyclic feature.

According to TASHIRO (1952), who gave several examples of the cyclic type of sedimentation containing a coal seam, the Imato coal-bearing member may be divided into nine or more cycles based on coaly layers and shales, but the type of cycles in this case differs from that in other members.

3. Brief description of each member

Descriptive notes of the cyclic members, especially their stratigraphical and lithological features were mentioned in the preceding reports (TOMITA, 1967, 1968 and 1971). In this chapter only the modified part and the items required in this paper are described.

a. Hirabaru member** (1st cyclic member)

(i) *Type locality*: Hirabaru, Tagawa-shi; and Hirabaru, Akaike-machi, Tagawa-gun

(ii) *Distribution*: Yasunaga, Ooto-machi~Ita, Tagawa-shi; Natsuyoshi, Tagawa-shi; Akisato, Tagawa-shi~Ideyama, Nogata-shi

In the municipality of Nogata, only the upper part of this member is exposed, and the major part of the member is concealed below the alluvial plain in the areas of Ideyama and northwards. The "unconformity" at Komaki, Kurate Town, described in the preceding paper is tentatively considered as the base of the Ideyama Formation in spite of lack of any precise information.

(iii) *Thickness*: 90–100 m in the Tagawa district, and presumably about

* In the preceding papers, members in the Tagawa and the Nogata district are tentatively called under the alphabetical name of A~E members. New division modifies former members formally.

** 平原層 (第1輪廻層)

90 m in the Nogata district

b. **Hadaka-Ikari member*** (2nd cyclic member)

(i) *Type locality*: Hidaka, Nogata-shi

(ii) *Distribution*: Kakiharu, Ooto-machi; Ikari, Tagawa-shi; Akisato~Hirabaru, Akaike-machi; Hadaka~Ganda, Nogata-shi

The greater part of this member in the Tagawa district is widely concealed by the bank-deposits of the Hikosan. At the north of Ikata and at the Hojyo area, the northernmost part of Tagawa district, only the lowermost part remains on the axis of syncline as described in the following section.

(iii) *Thickness*: 180 m in the Tagawa district; 110–150 m in the Nogata district

c. **Kami-ita member**** (3rd cyclic member)

(i) *Type locality*: Kami-ita, Tagawa-shi

(ii) *Distribution*: Kami-imato, Ooto-machi; Kami-ita; Natsuyoshi

(iii) *Thickness*s about 170 m

Observation of successive sections of this member is difficult at the outcrop. Especially, concealed by the Alluvium of the Hikosan and the Diluvium in the Kami-ita~Natsuyoshi areas, this member cannot be observed completely at the surface. Therefore the name and the type locality of the member is tentatively set for convenience of description.

d. **Imato coal-bearing member*****

(i) *Type locality* and *Distribution*: The whole neighbourhood of Imato-baru areas containing Shimo-imato, Dôzen and Kuwahara, Ooto-machi

(ii) *Thickness*: about 370 m

This member mostly corresponds with the D and E members in the preceding report, but contains also the sequence above the Imato-shakunashi Coal of the C member. This new division will be dealt with in the following section.

B. Subdivision in the Nogata district

1. General lithology

Except for the southernmost part, the boundary between the Uwaishi and the Ideyama Formation in the Nogata district is covered by the Quaternary deposits. The Ideyama Formation is about 750 m in thickness, and its upper limit is defined by the base of pebble-bearing sandstone some 10 m below the Takaé Seam of the Onga Formation.

This formation in the Nogata district is predominated by coarse-grained sediments containing especially dominant conglomerates with association of sudden and complicated variation of lithofacies, cross-stratification, local erosion, contemporaneous unconformity and wash-out. In these respects it is similar to

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* 羽高-伊加里層 (第2輪廻層)

** 上伊田層 (第3輪廻層...田川地区)

*** 今任夾炭層

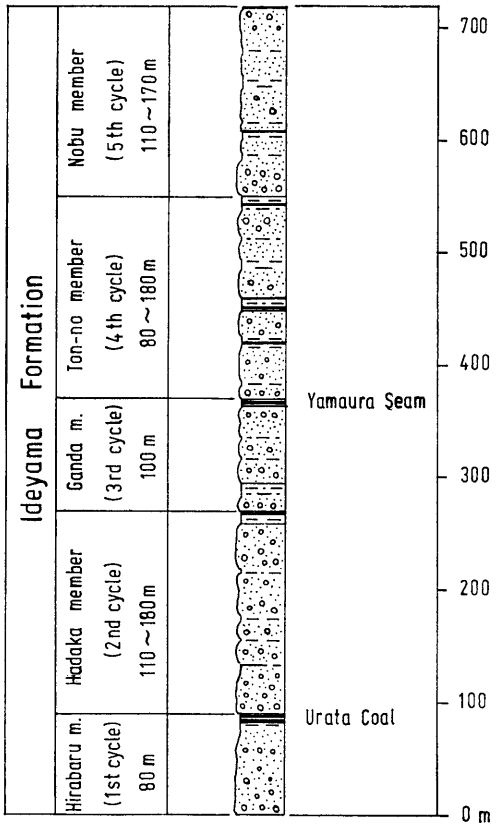

Fig. 11b. Generalized section of the Ideyama Formation in the Nogata district.

the lower members in the Tagawa district. On the basis of the coaly beds developed almost in whole area of Nogata district, the Ideyama Formation falls into five cyclic members, each of which is consisting of several minor cycles. The lower two members extending continuously from the Tagawa district are called by the same names as the latter district. While the third cyclic member is not continuous from the correlative sequence of the Tagawa district, and is named by the locality of this district. The upper two members differ in the sedimentary type and lithology from the Imato coal-bearing member in the Tagawa district.

Thus, the Ideyama Formation in the Nogata district is divided into the **Hirabaru** (first), the **Hadaka** (second), the **Ganda** (third), the **Ton'no** (fourth), and the **Nobu** (fifth) cyclic member in ascending order (Fig. 11b).

2. Minor cyclic units

In the western part of the Agano area, the southernmost part of this district, the first cyclic member crops almost completely, and is divided into four minor cycles in the same way as that in the main area of the Tagawa district.

The minor cycles in the Hadaka member, three in number, are traceable in the areas north of Nogata, but to the south, the minor cycles turn out into one undifferentiated cycle with gradual change of the marker shales to sandstones.

Based on coal or coaly shales four cycles are respectively recognized in the Ganda and the Ton'no member in the Ton'no~Ganda areas. Towards the north and the south extrimities, the coaly shales of the Ganda member thin out. Likewise the coaly layers of the Ton'no member change into shales at the north of Ton'no, and furthermore they are thining out at the Habu area.

The Nobu member may be possibly divided into three cycles in the area extending over Kami-ton'no and east of Ganda. The boundaries of these cycles, however, fade away towards the north. This member consists of one complete cycle at the Habu area.

3. Brief description

Because the first and second cyclic members are described in the preceding section, this paragraph deals with the rest of the members in this district.

a. Ganda member* (3rd cyclic member)

(i) *Type locality*: Ton'no and Ganda areas, Nogata-shi

(ii) *Distribution*: Takuma, Nogata-shi; Eimanji, Nogata-shi~Ton'no~Yamaura, Yahata-ku, Kitakyushu-shi

(iii) *Thickness*: 100–170 m

b. Ton'no member** (4th cyclic member)

(i) *Type locality*: Ton'no, Nogata-shi

(ii) *Distribution*: Eimanji~Yamaura; Habu, Nakama-shi

(iii) *Thickness*: 80–180 m

c. Nobu member*** (5th cyclic member)

(i) *Type locality*: Kami-ton'no, Nogata-shi

(ii) *Distribution*: The whole neighbourhood of Ton'no area~Takaé, Yahata-ku, Kitakyushu-shi~Sasada, Yahata-ku, Kitakyushu-shi; Nobu, Yahata-ku, Kitakyushu-shi; the western area of Kusuhashi, Yahata-ku, Kitakyushu-shi; Habu

(iii) *Thickness*: 110–170 m

C. Correlation between the Tagawa and the Nogata district

Of the cyclic members of the Ideyama Formation described in the preceding section, the lowermost Hirabaru member is traceable continuously over the Tagawa and Nogata districts, and its upward continuation either to the lower part of the Ikari member in the Tagawa district and to the Hadaka district is also recognized. Accordingly it is concluded that the first and the second cyclic member are continuous laterally and vertically in both districts.

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* 感田層 (第3輪廻層...直方地区)

** 頓野層 (第4輪廻層)

*** 野面層 (第5輪廻層)

The third and the upper cyclic members are distributed separately in both districts and the lateral relation of members between both districts cannot be detected. The Ganda member of the Nogata district does not show depositional thinning at the southern termination, but suffered thinning by erosion caused by the geological movement as will be described in the following chapter. Likewise, the northern extrimity of the Kami-ita member of the Tagawa district near the north end of Tagawa City must have been eroded out. Considering their present thicknesses, the distribution and the variation of thickness of the underlying first and second cyclic members, it seems impossible that both the Ganda and Kami-ita members were abruptly thinned out through sedimentation near the margin. It may be reasonable, therefore, to conclude that the third cyclic member was once deposited almost continuously in most of the area between the Nogata and the Tagawa district, but was completely eroded out.

The fourth and the fifth cyclic member in the Nogata district and the Imato coal-bearing member of the Tagawa district are further differentiated in distribution and lithofacies. The Imato member is limited in distribution to the Imato area of the Tagawa district, and its northward extension is cut by faults. The Ton'no and the Nobu member are now found in the northern half of the Nogata district and considered to have been eroded out at their southern ends like as the underlying third cyclic member. It is presumed, therefore, that they were deposited in a wider area than the present distribution with a southward extension, but they are not verified to have deposited near the Tagawa district. Furthermore, they do not show the same type of sedimentation to the Imato coal-bearing member.

From the facts mentioned above, a question arises whether or not the Imato member was formed in a separated basin which was contemporaneous but different in environmental condition from those in which the fourth and fifth cyclic members of the Nogata district were deposited. Contemporaneity of the basins in the two districts is another question. Both the Imato and the Ton'no member lie conformably over the third cyclic member in every district, and moreover, according to TAKAHASHI (1961), the pollen association in coals of the Imato coal-bearing member belongs to the Karatsu pollen group and is an equivalent

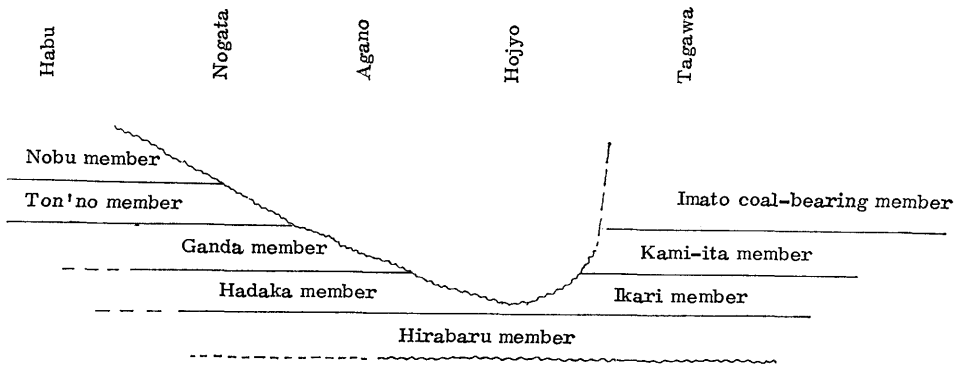

Fig. 12. Relationships of each member between the Tagawa and Nogata districts.

to that found in the Yamaura Coal of the Ganda member of the Nogata district.

Considering the stratigraphic relation of the Imato and Nobu members to the Onga Formation, it is most probable that the Imato member in the Tagawa district is correlated to the whole or a part of the fourth and the fifth cyclic member in the Nogata district, but is different in sedimentary facies from the latter members. The relationship of each member of both districts is illustrated in Fig. 12.

III. Ideyama Formation in the Iizuka district

A. Subdivision of the formation

1. General lithology and cyclic member

The Ideyama Formation distributed in the Shonai-Yamada areas of the Iizuka district is a sequence of about 300 m ranging from the base of thick conglomeratic sandstone below the Iwasaki fossil bed up to the sandy siltstone in which the synclinal axis lies. This formation is composed dominantly of coarse- or medium-grained sediments intercalating coal seams at the middle and the uppermost horizon. Based on the coal of the middle part, this formation falls into two divisions.

While the formation in the Iwasaki area is composed mainly of pebble-

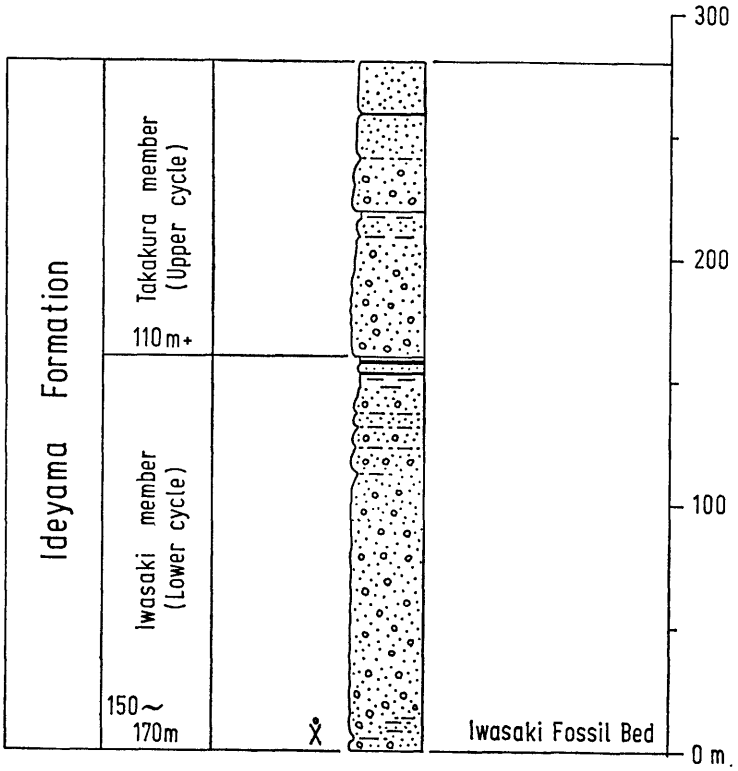

Fig. 11c. Generalized section of the Ideyama Formation in the Iizuka district.

bearing sandstone of a thickness of 90 m. It is correlated to the lower and middle parts of the lower member of the formation in the Shonai-Yamada areas on the basis of the stratigraphical relation of the key bed, the Iwasaki fossil bed. From the facts mentioned above, the Ideyama Formation in the Iizuka district is divided into two members, the lower Iwasaki and the upper Takakura. Fig. 11c exhibits the stratigraphy and lithological facies of each member.

2. Minor cycle of sedimentation

No silty bed has been recognized among the coarse-sediments of the Iwasaki member in the southern part of Shonai-Yamada areas. Although siltstones are intercalated in the Iwasaki member in the northern part of the same areas, they do not afford a basis for recognition of minor cycles because of shortage of information. Then the Iwasaki member is regarded as one cycle of sedimentation without any minor cycle (Fig. 13b).

In the northern and the central part of the Shonai-Yamada areas, the overlying Takakura member falls into four minor cycle, but only two cycles have been recognized in the southern part, where the upper part of this member is not developed. It is uncertain that two cyclic units in the southern part correspond to the lower cycles in the northern part.

B. Brief description of each member

a. Iwasaki member* (Lower cyclic member)

(i) *Type locality*: Kamoo, Inatsuki-machi~Tsutsuno, Shonai-machi, Kaho-gun

(ii) *Distribution*: Yamakura, Shonai-machi~the westward of Tsutsuno~the eastwards of Shimo-yamada, Yamada-shi~Inokuni, Tagawa-shi: Yamano~Iwasaki, Inatsuki-machi

(iii) *Thickness*: 150–170 m; in the Iwasaki area the only lower 90 m being observed

The name of this member is originated from the Iwasaki fossil bed.

b. Takakura member** (Upper cyclic member)

(i) *Type locality*: The whole area neighbourhood of Takakura, Shonai-machi, Kaho-gun

(ii) *Distribution*: Irimizu, Shonai-machi~Takakura~the northwestwards of Inokuni

(iii) *Thickness*: 130 m

IV. Ideyama Formation cropping out in isolated areas

Besides the Ideyama Formation distributed in the preceding sections, there are still several formations which have been referred to the Ideyama Formation.

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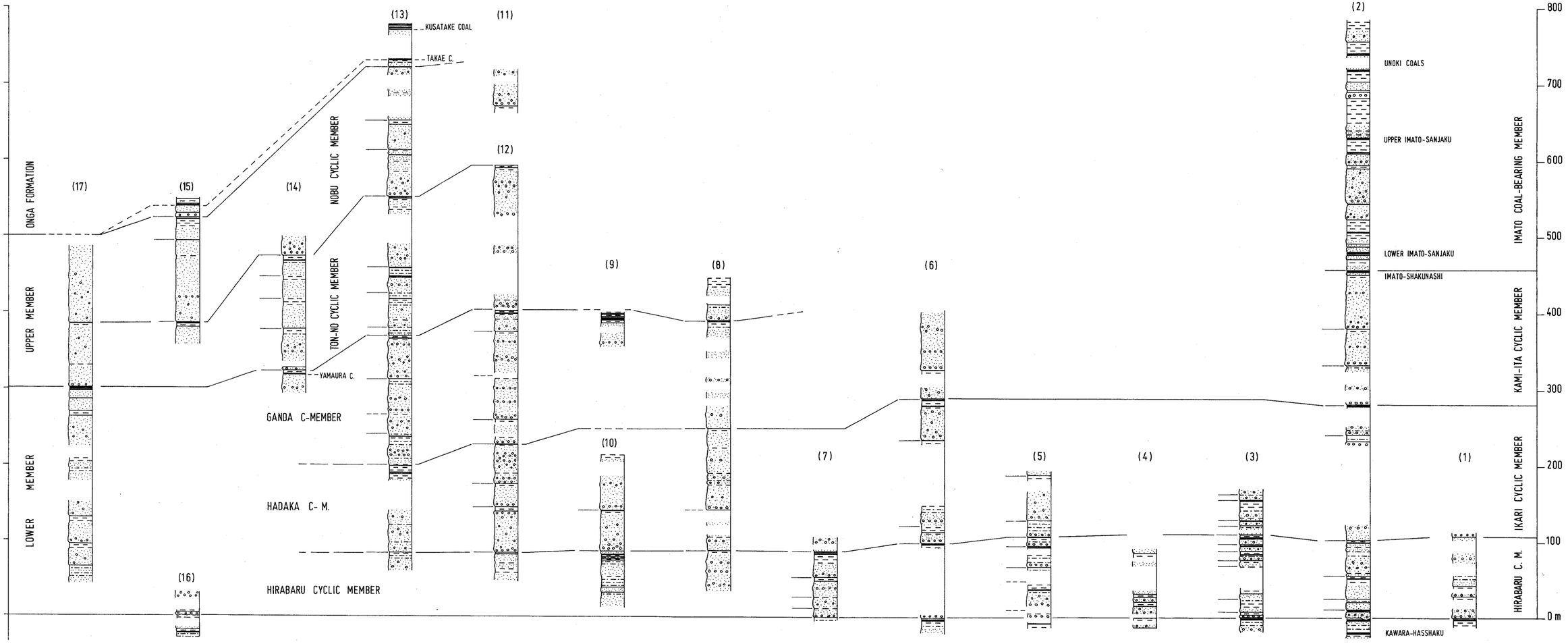
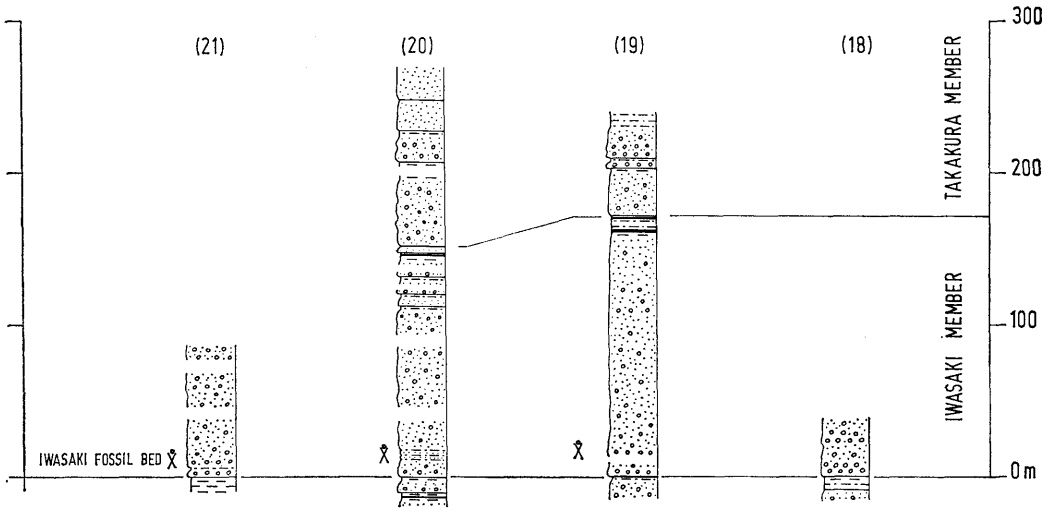
* 岩崎層 (下部層)
** 高倉層 (上部層)



(1) Oka～Yasunaga
(2) Imato～Hirabaru
(3) Akisato
(4) Ikata
(5) Benjô
(6) Agano～Akaike
(7) Yakuwoji
(8) Eimanji～Hirabaru
(9) Northeast of Shimozakai
(10) Shimozakai～Kamizakai
(11) Yamagata
(12) Hata～Ideyama
(13) Ton'no area
(14) Ganda～Yamaura
(16) Komaki
(17) Habu area

Fig. 13a. Comparative vertical sections of the Ideyama Formation in the eastern zone.



(18) Inokuni
(19) Shimo-yamada
(20) Kamoo~Takakura
(21) Iwasaki~Yamano

Fig. 13b. Comparative vertical sections of the Ideyama Formation in the Iizuka district.

However, their stratigraphical position is not confirmed because they occur in narrow and scattered isolated areas. This section deals with some of them for further references.

A. Eastern wing of the syncline in the Nogata district

Coarse-grained strata below the Takaé Seam of the Onga Formation crop in a long and narrow strip extending from Kôjaku to Sasada in Yahata Ward of Kitakyushu City between the Fukuchiyama Fault and the distribution area of the Onga Formation. The sediments of this formation are similar in lithology to that of the Ideyama Formation of the west of the synclinal axis being composed mainly of sandstone and conglomerate. It is sure that the strata are referable to a part of the Ideyama Formation, because of its stratigraphical relation to the Onga Formation and its similar lithological characters to its counter-part found at the axis of syncline in the southern part of the same district.

The Ideyama Formation in this area, about 500 m in thickness, does not show any distinctive sedimentary cycle. Nevertheless, a coal, which is identified to the Yamaura Coal of the middle part of the Ideyama Formation (Fig. 11b), is traced on the surface of this area, these sediments can be divided into the upper and the lower part; the former is correlated to the fourth and the fifth cyclic member, and the latter to the sequence up to the third cyclic member of the formation (Fig. 14a).

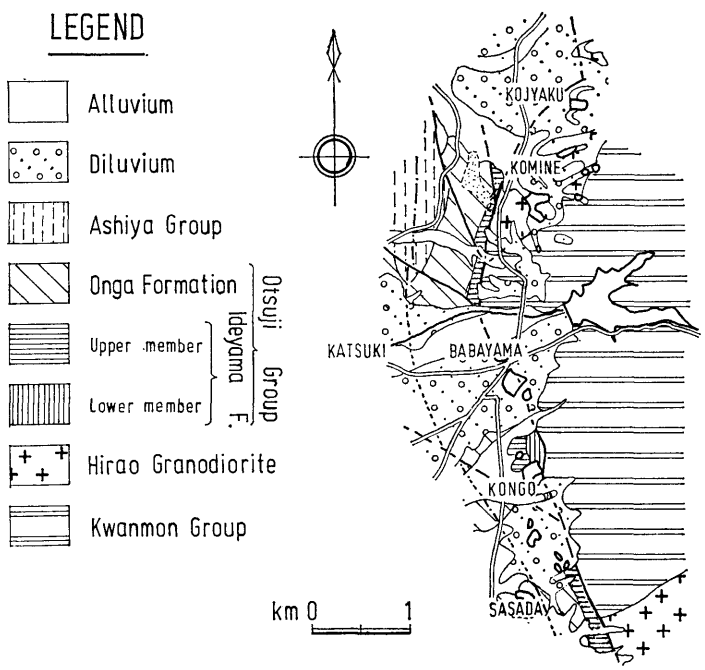


Fig. 14a. Geological map of the Sasada-Kôjaku area (Legend; refer also to Fig. 27).

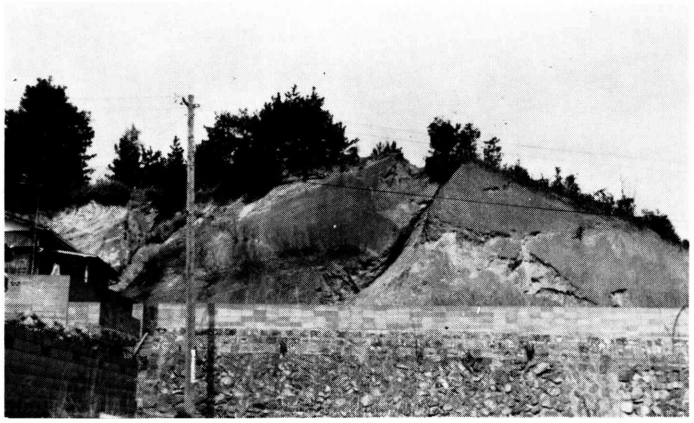
The conglomerate regarded as the base of Ideyama Formation lies unconformably on the Cretaceous Hirao granodiorite, and covers a part of the Fukuchiyama Fault at Kominé, Yahata Ward of Kitakyushu City (Fig. 15). This is a fine example that the faulting movement had begun before the deposition of the Ideyama Formation.

B. Habu area

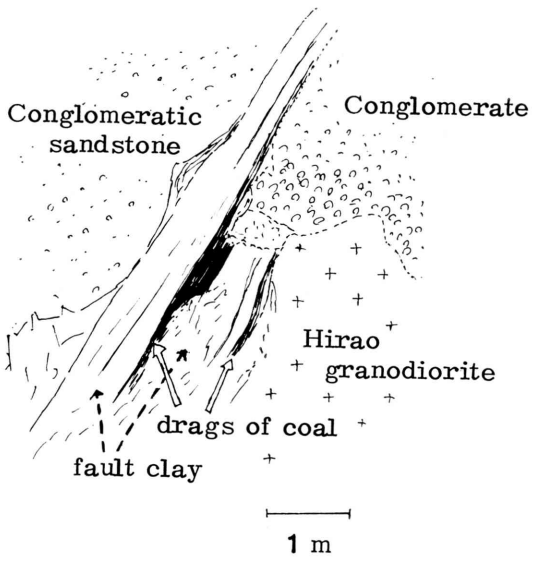
Several small hills of the Tertiary rocks are scattered something like islets in the Quaternary low swampy land extending from Habu in Nakama City to Kami-kizuki in Kurate Town. The Tertiary of these hills is composed mainly of sandstone and conglomerate with some shales, rarely intercalating coal and coaly shales. The stratigraphical relationships to the over- and under-lying formations cannot be recognized on the surface.

The successions exposed in the areas extending from the Arate and Dotenouchi areas in Nakama City to the Kusuhashi area in Kitakyushu City are considered to range from the upper part of the Ideyama Formation up to the lowermost part of Onga Formation. Furthermore the Takaé Seam near the base of Onga Formation was confirmed and was mined at the west of Habu Station of the Chikuho Line of the Japanese National Railways, in the eastern margin of the Habu hills area.

Supposing that an unconformity at Komaki mentioned before is the boun-



(a)



(b) (c)

Fig. 15. Fukuchiyama Fault at Kominé, Kitakyushu City.

dary between the Ideyama and the underlying Uwaishi Formation (Figs. 13a and 27), about 500 m are calculated for the thickness of the Ideyama Formation in this area. Two sedimentary cycles are recognized between the inferred Yamaura and the Takaé coal seam and they may be correlated to the fourth and fifth cyclic members in the main part of the Nogata district. While seven or more cyclic units are found below the inferred Yamaura Coal. These cyclic units, however, do not show any identical feature to the ordinary cyclic member and they are treated as one lower member of the Ideyama Formation without sub-

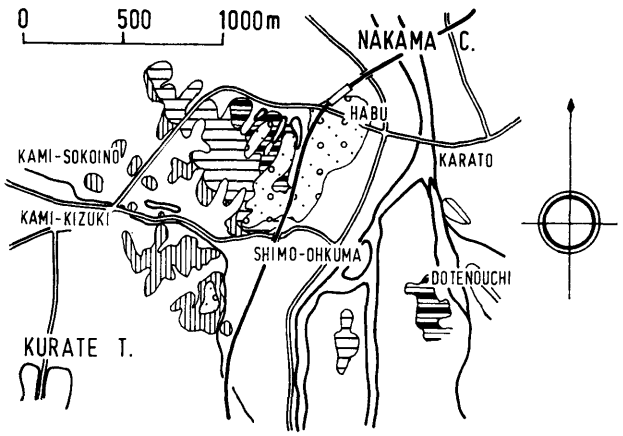


Fig. 14b. Geological map of the Habu area.

division as exhibited in Figs. 13a and 14b.

C. Near the Onga Estuary

A long stretch of hills well known as the Orio hills, rocks of which are composed mainly of the marine Tertiary Ashiya Group, is developed along the

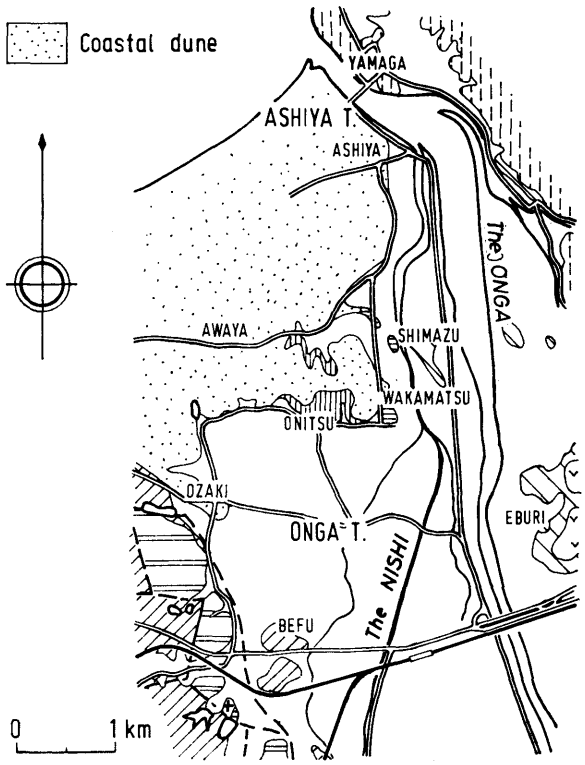


Fig. 14c. Map of the areas near the river-mouth of the Onga.

right-bank of the Onga, but, in striking contrast to these hills, a broad low damped field develops on the left side of the same river north of Habu area.

A coastal sand dune, a part of the Genkai Dunes, develops widely southwest of Ashiya at the river-mouth of the Onga with a width of about 2 km. Some small outcrops of the Tertiary sediments are scattered under the sand-hills at Ooshiro, Onizu and Wakamatsu in Onga Town on the southern border of dune area. Other exposures of the Tertiary sediments are also found on small hills at and near Shimazu in the same town, opposite side of the Nishi-kawa. The rocks at Shimazu contain several thin coal seams and are correlated to the lowermost part of Onga Formation from the drilling data of the coal-mine in Mizumaki Town. The Tertiary at other outcrops under the sand-hill consists mainly of pebble-bearing sandstones and is regarded as the Ideyama Formation by comparison of it with the above drilling records and by it stratigraphic relation to the Uwaishi Formation at the Ozaki and Nakatsuka areas in Okagaki Town, southwestwards of Onizu (Fig. 14c), but its exact correlation to the members of the Ideyama Formation in the main part of the Nogata district is uncertain.

D. Katsuno area

NAGAO (1929) reported the occurrence of the lower part of Ideyama Formation in the hilly area extending from vicinity of Katsuno Station of the Chikuho Line in Miyata Town southward to Naraura in Kotake Town, but he did not give any description on its distribution. Afterwards, the Committee of Geology of the Association of Coal-Mining Technologists of Kyushu showed that all the Tertiary distributed in this area belonging to the Uwaishi Formation on a map published in 1955. The Tertiary of this area consists predominantly of sandstones and siltstones with frequent intercalation of coals and coaly shales. From only its lithology, it is hardly referred to the Ideyama Formation. A small ex-

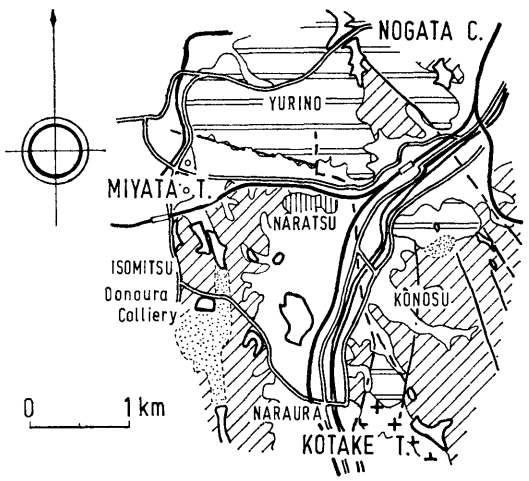


Fig. 14d. Geological map of the Katsuno area.

posure of conglomerate very similar to the Ideyama Formation of the Nogata district is found at Naratsu of Kotake Town, however this conglomerate cannot necessarily correlated to the Ideyama Formation, since its relation to the underlying beds and to the Ideyama Formation in other areas are unknown (Fig. 14d).

V. Correlation of the eastern and western zones

The Ideyama Formation of the Iizuka district differs from that of the eastern zone (Nogata~Tagawa district) in the apparent relationship to the underlying beds, lithology and stratigraphical succession, resulting difficulty in its correlation between the districts.

As shown in Fig. 31, correlation of even coal seams of the Nogata Group between eastern and western zones is also difficult in spite of all similarity in the succession, lithological facies, tendency of lithofacies variation, the thickness of sediments, and the development of coal in two zones. Being characterized by only a thick coarse-grained facies lying on the Uwaishi Formation of the Nogata Group, the correlation of the formation referred to the "Ideyama Formation" is much more difficult. Therefore, correlation at the level of "member" between districts needs several measures besides th comparison of lithological succession. This section deals with several means for the east-west correlation.

A. Lithology and sedimentary cycle

1. Regional variation of lithological facies

It is obvious that the lithological facies of the Ideyama Formation vary by place. That is to say, the sediments in the Iizuka district are characterized by remarkable coarse-grained lithofacies at the southern part, changing gradually into fine facies toward the north. Conglomeratic facies is more predominant in the Nogata district than in the Tagawa district, especially in the Ideyama~Ton'no areas of the Nogata district.

On the other hand, the fine-grained deposits, particularly the siltstones intercalated by coaly layers, are remarkable in the Hojyo area of the Tagawa district, and are also predominantly found in the members near Ton'no. Still in the former area, very coarse sediments are very rare, notwithstanding conglomerates and coaly layers are together remarkably found in the latter suggesting rhythmical oscilation during deposition. In a part of the lower members in the Hojyo area, there is one example suggesting a relatively stable sedimentary condition, under which relatively fine clastics were deposited together with coaly matters. The fact also suggests that the Hojyo area was situated at a particular position in the sedimentary basin of the Ideyama Formation.

In the main part of the Tagawa district, the lower members of this formation do not so commonly yield coaly matter as in the sediments of the Nogata district. They show very coarse-grained lithofacies, being composed mainly of pebble-bearing sandstones.

These features are illustrated in Figs. 11, 13 and 16.

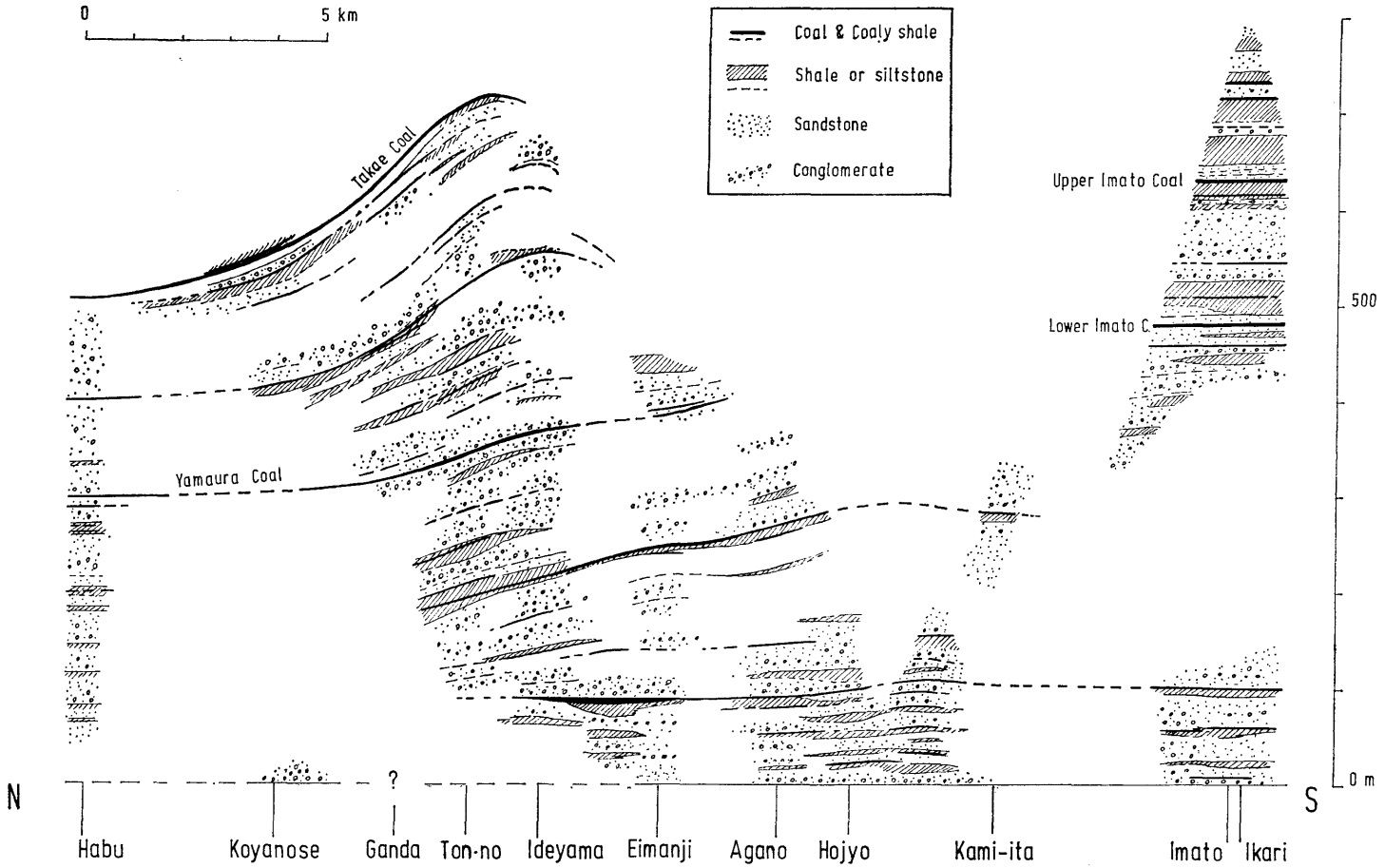


Fig. 16. General variation of lithofacies of the Ideyama Formation in the eastern zone.

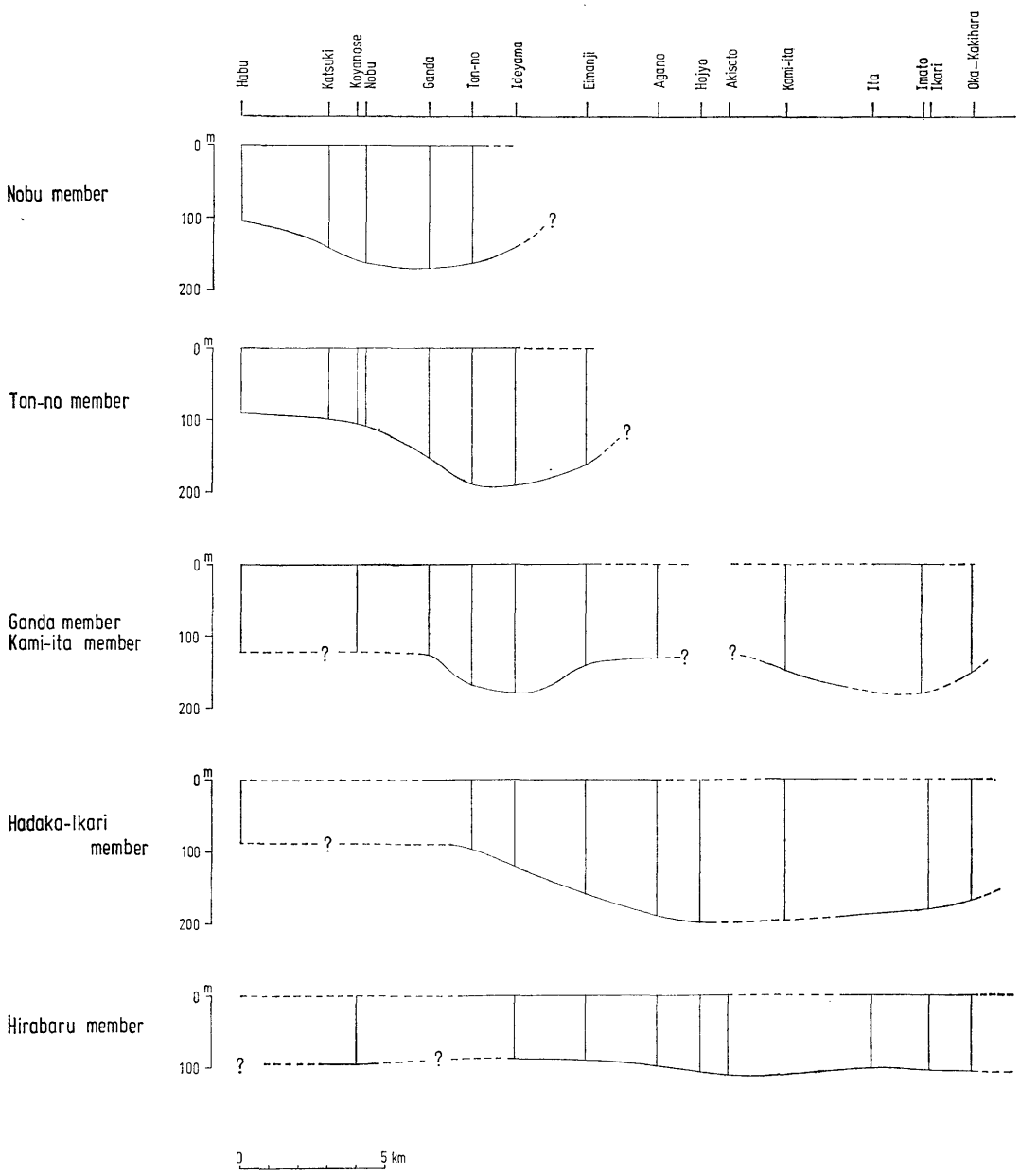


Fig. 17. General thickness variation of each cyclic member of the Ideyama Formation in the eastern zone.

2. Variation of minor cycles

Generally, each cyclic member of the Iizuka district is represented by a single sedimentary cycle. Situation is the same in the cyclic members of the Ideyama Formation distributed in the eastern wing of the syncline in the Nogata district. The number of minor cycles is the greatest in the Hojyo area of the Tagawa

district and the Ideyama~Ganda~Ton'no area of the Nogata district, although the sedimentary facies of the two area is quite different, being finest in the former, and apparently coarse in the latter area. Towards the north, distinction of minor cyclic unit becomes difficult because of gradual thinning of conglomerates and thinning out of coaly or shaly layers. It may be surmised from Figs. 13 and 16 that the area with maximum cyclic units shifts slightly to northwards in the Nogata district through Ideyaman age.

B. Variation of thickness

Although the possibility of the post-depositional erosion cannot be excluded, thickness of strata may be an indicator for subsiding movement of the sedimentary basin. Tentatively, I tried to consider the local variation of thickness of each member from extant data.

The Ideyama Formation in the Iizuka district is only half as thick as the same formation in the Nogata district. The lower member in the Iizuka district is about 150–170 m thick throughout. The upper 130 m of the formation remain as the upper member. While the maximum thickness of the lower and upper parts in the Nogata district is respectively about 400 m and 350 m. This difference in the ratios of thickness of the lower and upper parts in two districts suggests inharmonious subsidence of the sedimentary basins.

A thickness of the first to the third cyclic member is nearly uniform throughout the Nogata~Tagawa districts, although the total thickness is somewhat greater in the Tagawa than in the Nogata district (Fig. 17). Furthermore, the lower three members are gently thinning northwards, and are estimated to have thickness of about 300–350 m at the Habu area where cyclic members are difficult to distinguish. The fourth and the fifth cyclic member in the Nogata district show the maximum total thickness of some 350 m at the Kami-ton'no area, and also decrease in thickness gradually towards the north. They attain about 200 m at the Habu area. This decreasing ratio is larger than that of the lower sequence (Fig. 13a). On the contrary, the Imato coal-bearing member, the upper half of this formation in the Tagawa district, shows no variation in thickness since it has a limited distribution.

C. Fossiliferous and coal-bearing horizons

The Iwasaki fossil bed is found in almost the whole area of the Iizuka district, as already-described (TOMITA, 1971), and is regarded as an important key bed indicating the lower limit of the Ideyama Formation (Figs. 4–7, 11c and 13b). The fossiliferous bed correlative with the Iwasaki fossil bed is not found in the Tagawa and the Nogata district, however the reportedly fossiliferous sequence in the inferred first cyclic member is presumed to correspond with the Iwasaki fossil bed*.

* NAGAO (1927a) reported a dark greenish sandstone which contained sand-pipes with onion structure at Natsuyoshi in Kanagawa Village (in Tagawa City at present). SAITO and OMARU (1961) reported the occurrence of marine fossils in the lowermost part of Ideyama Formation in the area of old Mitsui-Tagawa Colliery. OMARU (1966) mentioned that the irregularly alternated fossil-bearing member in the lower part of Ideyama Formation in the Tagawa district corresponded with the Iwasaki fossil bed, but I have not recognized the former as the fossil bed.

It may be possible that the Iwasaki member of the Iizuka district is partly correlated with the Hirabaru member of the Tagawa district merely by having a common fossiliferous horizon. However, more substantial information is required for explaining the conspicuous differences of the thickness, lithology and coal developments in both members.

Two coal seams lying at the middle horizon of the Ideyama Formation of the Iizuka district were correlated respectively to the Lower and Upper Imato-sanjaku coals by colliers in Yamada City based on the thickness and properties of workable coal seams. However, the correlation of coal seams in the Ideyama Formation is, as is generally known, more difficult than in the underlying Uwaishi Formation, and the above correlation is not necessarily reliable (Fig. 31).

D. Paleocurrent system and source rock

1. Paleocurrent directions

a. Summarized notes on the diagonal bedding

Various diagonal beddings, which are a very common, if not most common, feature in the coal-bearing strata (HEMINGWAY, 1968), are also found in the Ideyama Formation (Fig. 18). Generally speaking, cross-stratification in this formation is found in medium- or coarse-grained sandstone or conglomeratic sandstone. Sometimes many patches of tuffs or pumice graines show diagonal arrangement in the sandstone. Conglomeratic sandstones illustrate occasionally converged pebbles on the cross-stratified plane. Thickness of a set of diagonal beddings varies from 10 cm to 1 m or more. The maximum dip angle varies also from 10° to 40° and is somewhat greater than those of other Tertiary sediments measured by NAGAHAMA (1962–1965) and TAKAHASHI (1966), so it may be estimated that the sediment-loading current were relatively more rapid than that given by them.

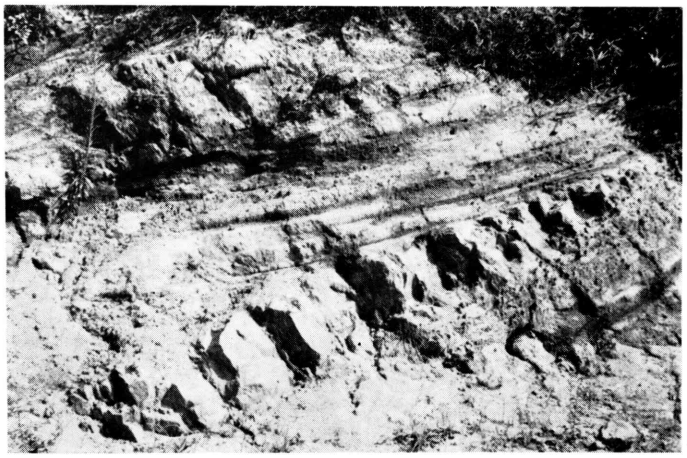
Almost all the current directions measured in the Ideyama Formation are illustrated in Fig. 19, and their frequency diagrams respectively of the upper and the lower part of the formation are shown in Fig. 20*, following the method of POTTER and PETTIJOHN (1963).

b. Paleocurrent in each region

(a) Main part of the Tagawa district

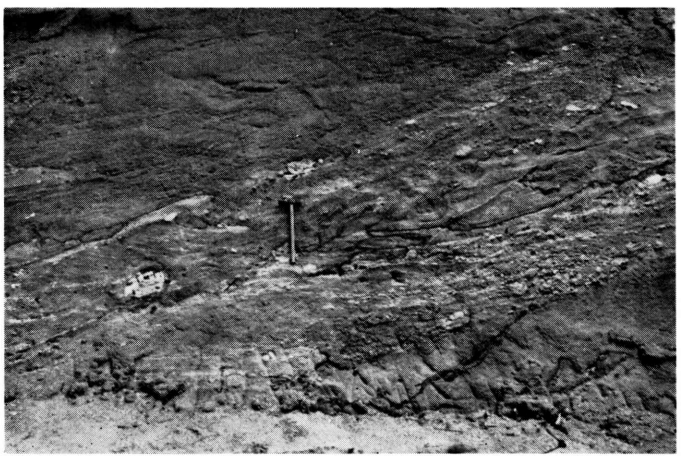
This area is separated into the Ita~Hirabaru area and the Kami-ita~Imato area by the Hikosan River. Cross-bedding azimuths measured in the lower three members apparently extend to south or southeast at the northern and central area of this part, but chiefly to the east or east-northeast and to west-southwest at the southern part. On the other hand, in the Imato coal-bearing member, most diagonal beddings range from a westerly to a southerly direction. It is remarkable that trend of transportation of the lower three cyclic members and that of the Imato member are crossing each other in the frequency distributions, al-

* The members of Ideyama Formation are broadly divisible into the upper and lower parts. This will be discussed in the following paragraph.



(a)

(b)



(c)

Fig. 18. Various cross-stratification.
(a) 1st member in the Tagawa district.
(b) Lower member in the Iizuka district.
(c) 4th cyclic member in the Nogata district.

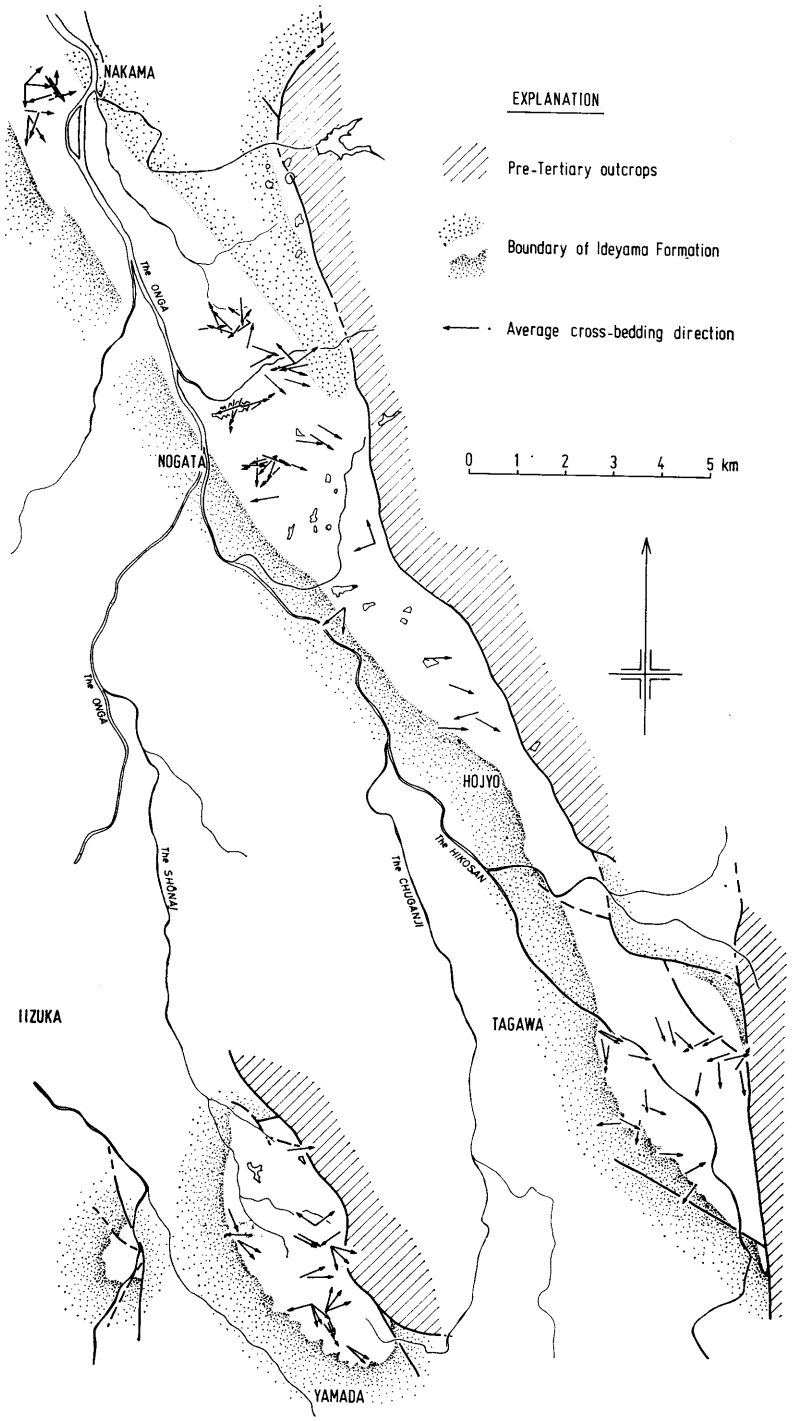
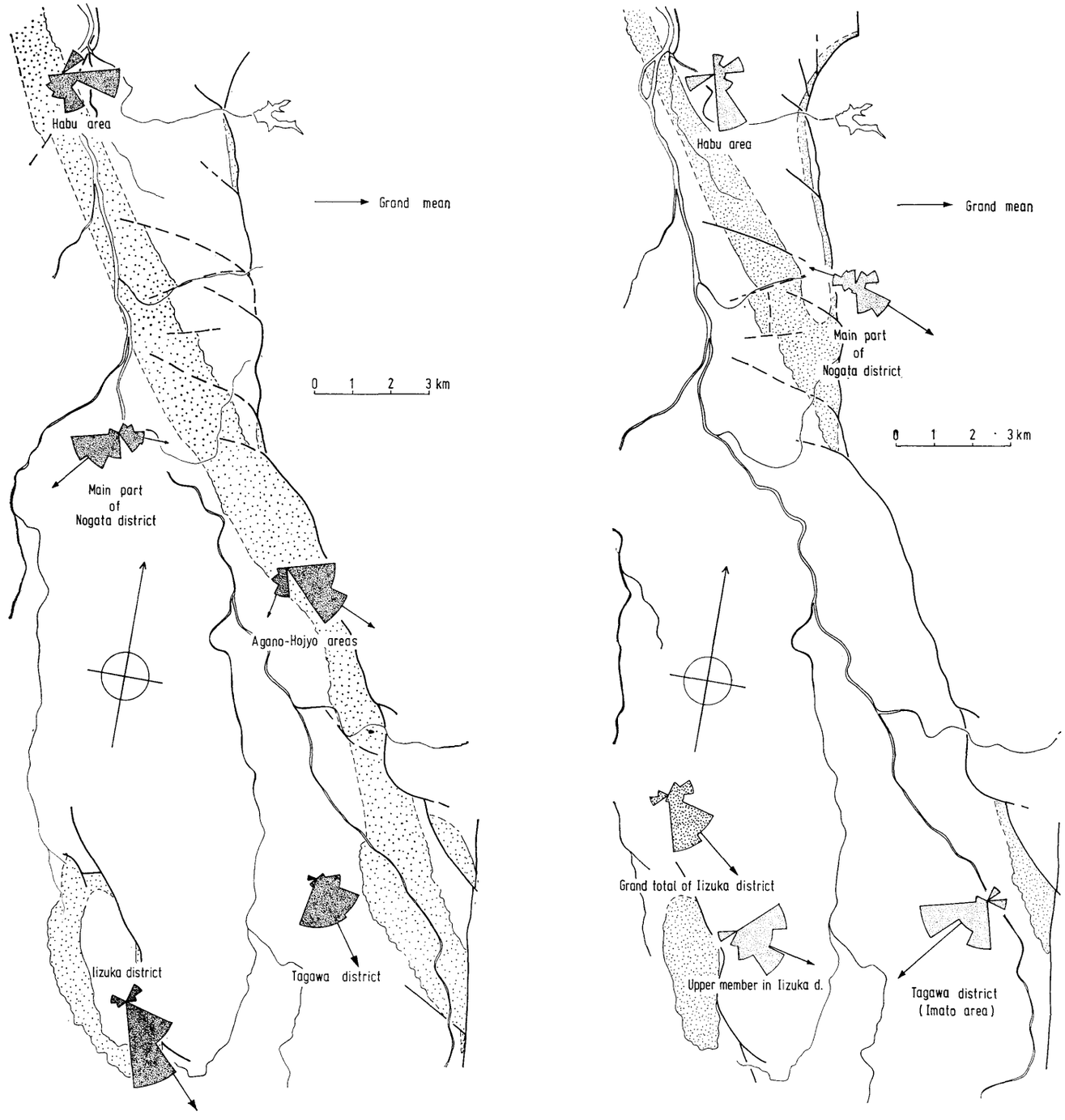


Fig. 19. Cross-bedding directions of the Ideyama Formation.



(a) Lower part (b) Upper part

Fig. 20. Frequency diagrams of the cross-bedding directions in the Ideyama Formation.

though they are almost harmonious in the southern area.

(b) Agano-Hojyo areas

Only the lower member of the formation are distributed in these areas. Almost all the diagonal beddings take an extent to the east, but a few northward azimuths have been measured at the north of Agano.

(c) Main part of the Nogata district

The cross-beddings of the lower three members mainly extend southward or southwestward but also westward and eastward. The diagonal beddings in the upper two members show southeast or east-southeast direction with some southward and northward azimuths. Similar to the main part of the Tagawa district, main directions both in the lower and the upper member cross each other.

(d) Habu area

Various directions except to the northwest one were measured from the cross-bedding of the sediments.

(e) Iizuka district

Diagonal beddings of this area show various directions, of which, however, south and east-southeast directions are predominant. Azimuths both in the lower and the upper member are generally identical to each other.

2. Source area of the Ideyama Formation

The analytical data of diagonal beddings suggest that there is no overall difference in the paleocurrent system between the lower and the upper part of the Ideyama Formation (Fig. 20), although there are divergencies in the lithological facies and heavy mineral compositions as mentioned in the preceding and following paragraphs. It may be further said that manifold azimuths of diagonal beddings at several areas may be attributed not to a single great stream running through in this coal-field, but to several local ones. Hence source rocks of the Ideyama Formation are presumed from synthesis of the current directions determined by cross-bedding, the lithological facies and the lithological characters of gravels found in the coarse-grained sediments.

(a) Tagawa district

Except for the upper part of the Imato coal-bearing member, gravels in the whole sequence of the Ideyama Formation in the Tagawa district consist mainly of hard sandstone, altered tuff, chert, and aplite, the latter two being especially predominant. Other pebbles, such as hornfels of slate, greenish schist and sometimes quartz schist, are also found. The gravels of the upper part of Imato member are mostly vein-quartz, and there is few aplitic pebbles. From these gravels, it may be estimated that the clastic materials of the lower members and the lower half of the Imato coal-bearing member of this formation in the Tagawa district were mainly derived from the metamorphosed Paleozoic rocks and granitic rocks, and partly from the non-metamorphic Paleozoic System. On the other hand, it is assumed that the clastic materials of the upper part of the Imato member were mostly supplied from granites and/or silicified metamorphic rocks.

All of these rocks are distributed in the areas surrounding this district. It

is presumed from the current directions that the source rocks of the lower three members were situated to the north or northwest of this district, and that the clastics of the Imato member were derived from the granites and the Paleozoic complex which were widely developed to the east or northeast.

(b) Iizuka district

The gravels found in this formation in the Iizuka district are similar to those in the Tagawa district except for the upper part of Imato coal-bearing member. They are chiefly quartz schist, vein-quartz, milky and reddish chert, granule pyroclastic conglomerate, hard sandstone, liparitic tuff, and microgranite. Among them, liparitic rocks and brecciated granule conglomerates are characteristically found in the Cretaceous Kwanmon Group. It is supposed that the source areas of the sediments in this district situated in the northwest region occupied by the Paleozoic and Mesozoic systems including the granitic rocks, because the grand mean of the diagonal bedding directions suggests a great stream or countless parallel currents from northwest to southeast. The Kanakuni-Funao mountain block rises immediately to the east of this district bounded by the Takakura Fault. Around this fault the maximum size and roundness of gravels of conglomerates are practically similar regardless of distance of the location from the fault. This fact suggests that the rocks of this mountain block were not supplied to the depositional basin of the Ideyama Formation in this district.

(c) Nogata district

Most of gravels of the Ideyama Formation developed in and near Nogata City are composed of aplites, porphyrites, hornfelses of sandstone and shale, and pyroclastics, with a little amount of metamorphosed Paleozoic rocks. Hornfelses and pyroclastics are common in the Kwanmon Group, especially in the Shimonoseki Subgroup, which is distributed east and west of this district. From these gravels and current directions, it is presumed that the sediments of the formation in this area were originated in the mountain areas of the Mesozoic formations and granitic rocks located east and northwest of the coal-field.

Throughout the whole area of the Chikuho Coal-field, pebbles of granite or granodiorite are rare in the Ideyama Formation, but porphyrites and aplites are predominant. Also, since most of the gravels are rounded, the source area must not be so close to the deposited area.

Fig. 29 shows a map of the estimated distribution of source rocks of the Ideyama Formation without having consideration of the distance from the sedimentary basin. This figure suggests that the sediments of the Ideyama Formation were drifted into the sedimentary basin by way of many local rapid currents* with various directions.

* Rough and rapid currents running into the basin are also estimated from the dominant pumice grains diagonally arranging in the sandy sediments and from the various sized patches of slit and tuff scattering in the massive coarse-grained sediments (Fig. 18a and 18c).

E. Heavy mineral association

1. Heavy mineral zones

Detailed and noteworthy reports have been published by KATO (1957 and 1960) and OHARA (1961 and 1962) on the petrographic study of the Tertiary sedimentary rocks in the Chikuho Coal-field. KATO established the standard section in each formation of the Tertiary mainly based on the drilling cores. Then he compared the heavy mineral associations collected from various localities in this coal-field with those of the standard sections in order to reestablish the boundary of formations at every locality. On the contrary, OHARA distinguished several groups of Tertiary sandstones with characteristic heavy mineral content in the coal-fields of Kyushu and divided them into several "heavy mineral zones". He discussed also the relationship between the heavy mineral zones and the extensive crustal movements in north Kyushu.

OHARA divided the Tertiary successions in the Chikuho Coal-field into four heavy mineral zones, CH-1 ~ CH-4 zones in ascending order. The boundaries between each zone are drawn in the lower part of the Sanjaku-goshaku Formation, in the middle part of the Ideyama Formation, and at the base of the Yamaga Formation, respectively.

Following the method of OHARA (1955–1961a) and MILNER (1962), I have applied a heavy mineral analyses of sandstones of the Ideyama Formation in this coal-field: in the Iizuka district, the boundary between the CH-2 and the CH-3 zone coinsides with the top of the Iwasaki member, the lower division of the formation. The Iwasaki and the Takakura member thereby belong to the CH-2 and the CH-3 zone respectively. It is noticeable that the boundary of sedimentary cycles accords with that of heavy mineral assemblages.

In the Tagawa district, on the other hand, some noteworthy facts are found. In the first, second and third cyclic members, colourless zircon is predominant, but tourmaline and garnet are little. Many of tourmaline are dark greenish in colour. Hornblende and pyroxene are scarcely found. Being provided with similar composition of heavy minerals, this part belongs to OHARA's CH-2 zone (Fig. 22b). Zircon is contained at a remarkable frequency as both rounded and angular forms. In the sandstones of the Hojyo area, rounded zircon is abundant. The fact mentioned above suggests that the source rocks of the sediments of this district are at least of two or more kinds. Furthermore long-prismatic zircons with high elongation (L/B>10.0) are found in the specimen from Hojyo area (Fig. 23b). Long-prismatic zircons were reported to occur largely in the acidic intrusive or acidic volcanic rocks (POLDERVAART, 1956; and KARAKIDA, personal information), and are also found in the granite (Sawara granite?) near Fukuoka City (OHARA, personal information). Therefore, the fact that elongated zircons are limited to the Hojyo area suggests the acidic igneous or granitic rocks cropped out close to this area.

The overlying Imato coal-bearing member is considerably abundant in garnet, nevertheless the frequency of tourmaline is almost the same as that of the lower members. Sometimes epidotes and hornblendes are found. Such a heavy mineral association is not found in the CH-3, which is characterized by abun-

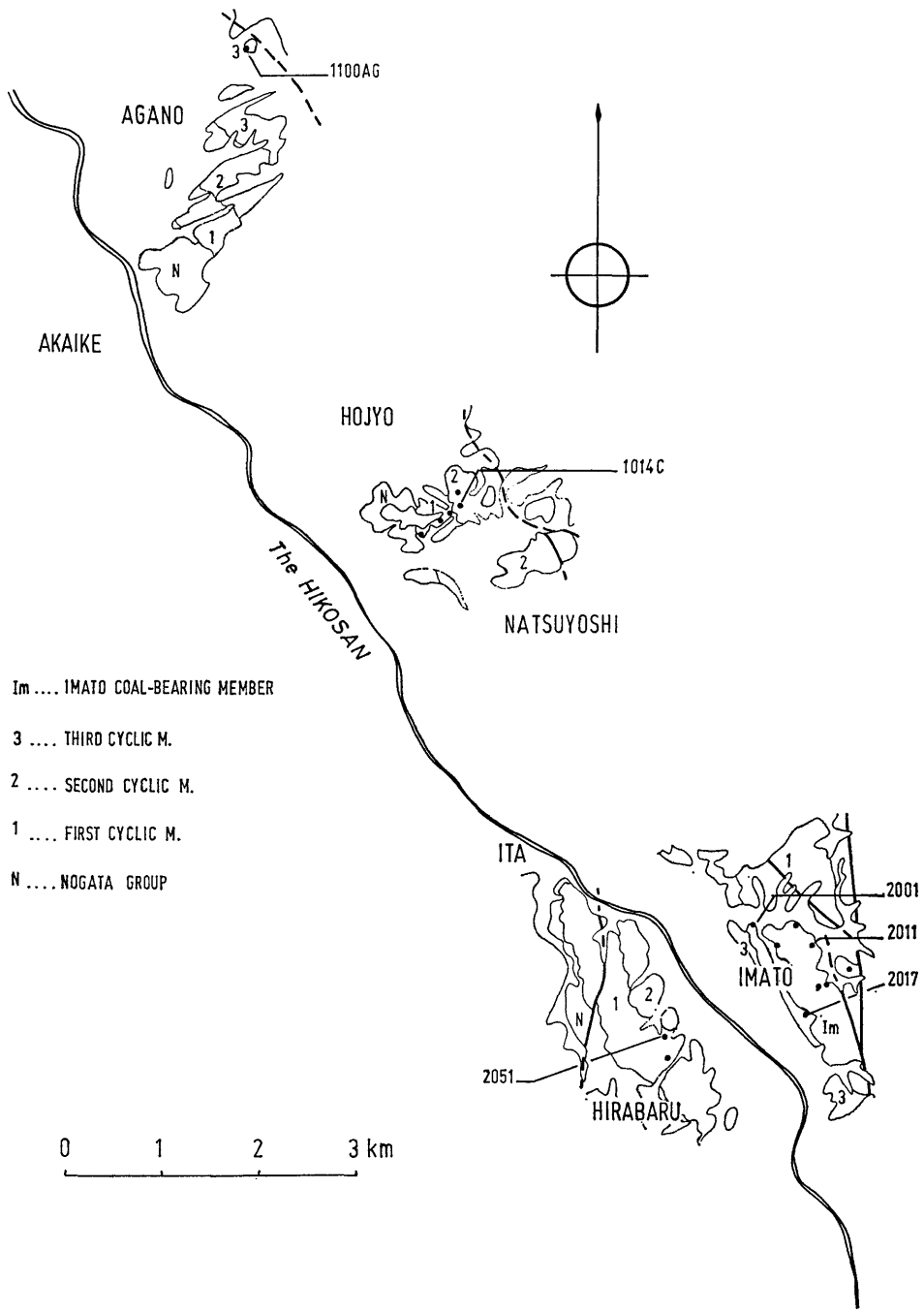
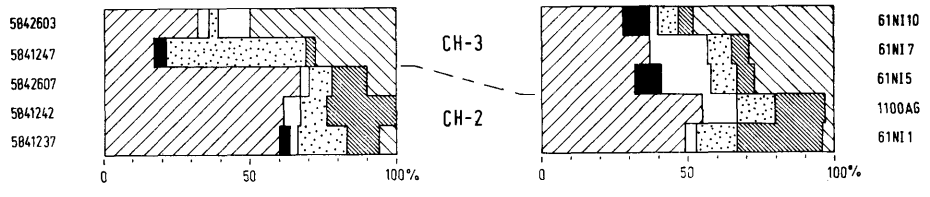


Fig. 21. Sampling localities of sandstone for heavy mineral analyses in the Tagawa district.

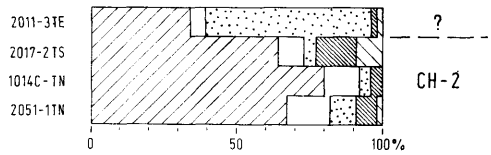
dance of greenish brown tourmaline, colourless zircon, and magnetite, but is rather similar to the CH-4 composition.

In the Nogata district, heavy mineral of the fourth and the fifth cyclic mem-



(a)

Left: Iizuka district Right: Nogata district
(after J. OHARA, 1960, except 1100 AG)



(b) Tagawa district

Fig. 22. Graphs showing heavy mineral compositions and heavy mineral zones in the Ideyama Formation.

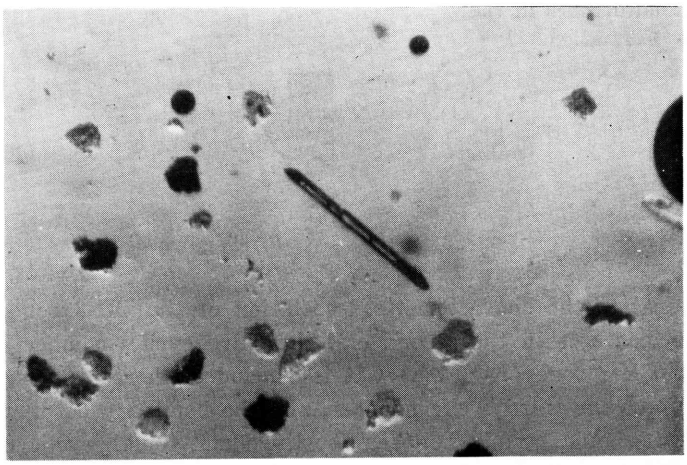
ber are identical to the characteristic association of the CH-3 zone, while the heavy mineral contents in the second and the third cyclic member are similar to that of the CH-2 zone (Fig. 22a). It is concluded, therefore, that the CH-2 zone ranges up to the third cyclic member, and the boundary between the CH-2 and CH-3 zones should be laid between the third and fourth cyclic members in the Nogata district. Circumstance is quite the same in the Tagawa district. Furthermore the Iwasaki member of the Iizuka district may be correlated to the sediments up to the third cyclic member of the Nogata and Tagawa districts, and the Takakura member of the former corresponds with both the fourth and the fifth cyclic member of the Nogata district.

2. ZGT ratio

Another distinctive feature of the heavy mineral associations of the Imato coal-bearing member in the Tagawa district is found in the zircon-garnet-tourmaline ratios plotted on the ternary diagram of Fig. 25a.

SATO (1969) studied the heavy mineral content of Paleogene sandstones in the coal-fields of northwestern Kyushu, paying a special attention to the geological significance of the zircon-garnet-tourmaline ratio (ZGT ratio). He classified the sandstones into four types of ZGT distribution patterns as illustrated in Fig. 24. He described that a sandstone of the type I composition was probably of granitic origin; the type II composition of marine condition; and the type III composition of derivatives originated from crystalline schist. No explanation was given by him to the type IV.

(a)



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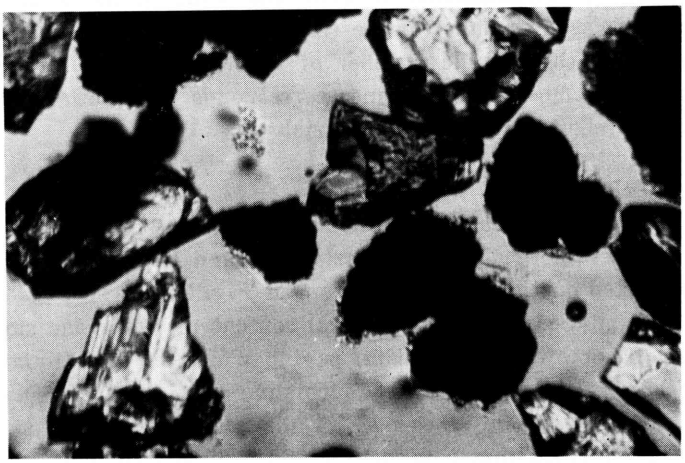


(c)

Fig. 23. Heavy minerals in the Tagawa district. (×100)
(a) rounded zircon and garnet (1st member)
(b) long prismatic zircon (1st member)
(c) abundant large garnet (Imato member)

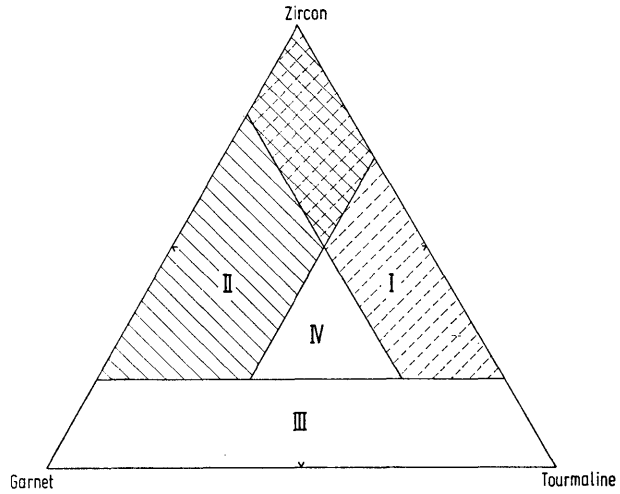


Fig. 24. Classification of the ZGT distribution pattern. (after Y. SATO, 1969)

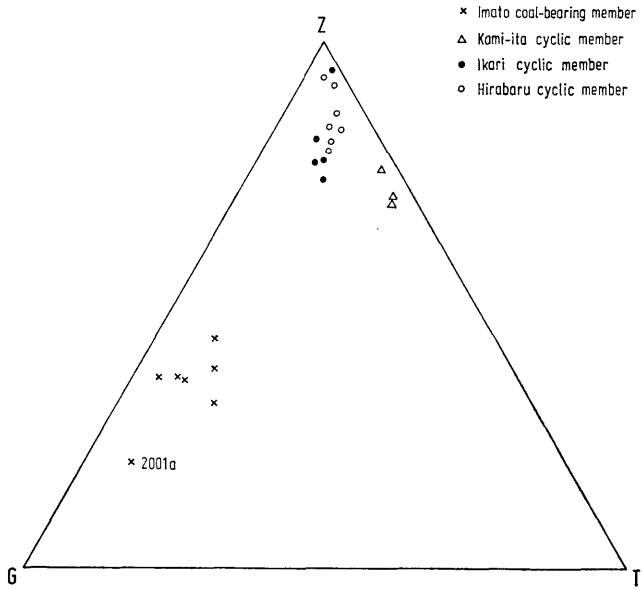


Fig. 25a. ZGT ratio of the Ideyama Formation in the Tagawa district.

The CH-2 and CH-3 zones cannot be distinguished by this ZGT ternary diagram of heavy mineral content in the Nogata district, although they are barely divided in the Iizuka district (Fig. 25b). Anyway, in the ZGT ratio, the Imato coal-bearing member differs extremely from other members of the Ideyama Formation in the same coal-field. This difference is well in accordance with the differences on the lithology and cyclic type of sedimentation mentioned before.

In the Ideyama Formation the lower member in the Iizuka district belongs to the type I+II, the upper is separated into types I and III, and the formation

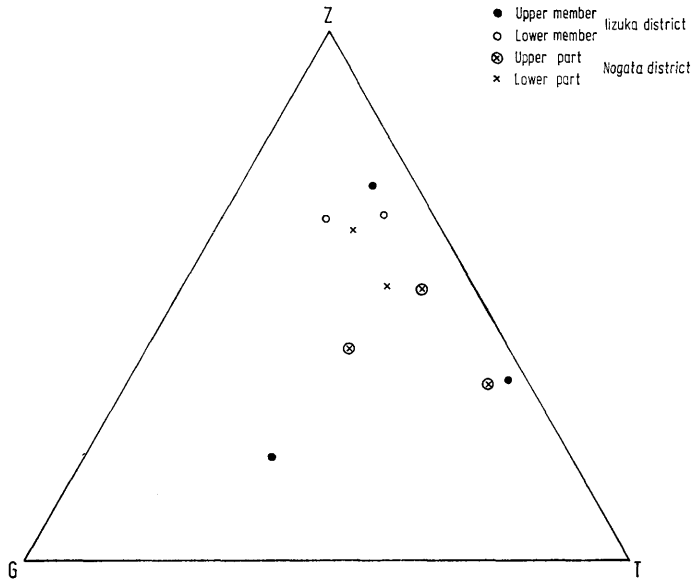


Fig. 25b. ZGT ratio of the Ideyama Formation in the Nogata and Iizuka districts.

in the Nogata district belongs to types I and IV. It is well inferred that the lower member in the Iizuka district, which is characterized by the type I+II of the ZGT ratio and yields littoral or brackish faunae, consists of the material derived from the granitic rocks and deposited in marine condition (Fig. 25b). The same inference is given to the lower member in the Tagawa district, because it is composed of fossiliferous sediments with glauconites, and belongs to the type I+II. The Imato coal-bearing member in the same district belongs to types II and III (Fig. 25a). The upper part of this member shows obviously arkosic lithofacies being predominant in quartz, and the uppermost part is characterized by the so-called granitic granule conglomerates, with frequent intercalations of coaly matter. Thus, it is presumed that this member was formed in a non-marine environment with the granites or quartzose schists terrain as provenance of sediments. The result does not necessarily conform with that of the study on pebbles in conglomerates mentioned above. Therefore the hypothesis of SATO's ZGT ratio appears not to be applicable to a detailed analysis of the provenance and the sedimentary circumstance, at least, in the case of the Ideyama Formation.

The ZGT ratio, however, verified a stratigraphic availability. The sediments between the Imato-shakunashi Coal and the Lower Imato-sanjaku Seam of the Tagawa district (Fig. 13a) has referred to the uppermost part of the C member in the preceding report. Its ZGT ratio is, however, undoubtedly characteristic to the Imato coal-bearing member (Figs. 21, 22b and 25a, sample number 2001-a) and the definition of the Imato member is revised in this paper, placing its base on the top of the third cyclic member.

In conclusion, some clues to the east-west correlation are found. Every member of both the Tagawa and the Nogata district are correlated to each other from their geological succession, and the fossiliferous Hirabaru member of the Tagawa district is also comparable to the Iwasaki member containing the Iwasaki fossil bed of the Iizuka district. It is possible, therefore, that the sequence ranging from the first to the third cyclic member in the Tagawa and the Nogata district is correlated to the Iwasaki member in the Iizuka district. However the upper part of the formation in the Tagawa district, the Imato coal-bearing member, is difficult to compare directly to the same formation in the Iizuka district from the heavy mineral zones.

Thus the correlation of the all Ideyama Formation in the Nogata, Tagawa and Iizuka districts is depicted on the Table 3.

Table 3. Correlation of each member

Nogata district	Tagawa district	Iizuka district
(5th cyclic member) Nobu member	Imato coal-bearing member	Takakura member (Upper member)
(4th cyclid member) Ton'no member		
(3rd cyclic member) Ganda member	Kami-ita member	Iwasaki member (Lower member)
(2nd cyclic member) Hadaka-Ikari member		
(1st cyclic member) Hirabaru member		

Chapter IV

Geological structure and its bearing

In the Shonai-Yamada areas of the Iizuka district, the Ideyama Formation is distributed with a semi-oval shaped pattern on the west of a synclinal axis running parallel with the Takakura Fault. It has a bilge-shaped structure whose axis of syncline is sinking near the center of distribution area and undulating slightly at the north and the south of Takakura (Figs. 26a and 28b).

In the Iwasaki area of the same district, on the other hand, the formation shows a fan-shaped distribution, extending something like a basin structure, the eastern half of which is cut off (Fig. 26a). The Iwasaki area is separated from the Shonai-Yamada areas by the Iwasaki Fault, which runs generally parallel to the Takakura Fault. The Iwasaki Fault forms a boundary between the Tertiary formations and the basement granites in the northern and the southern part of the Iizuka district except for the areas extending from Yamano to Urushio including Iwasaki. Hence the Iwasaki Fault may also be said to be one of the "marginal faults".

However, it is known that the formation of Nogata Group distributed on both side of the Iwasaki Fault are common in lithological successions and coal developments, and that the overlying Ideyama Formation with the fossiliferous bed extends over both sides. From these facts it is presumed that the areas of

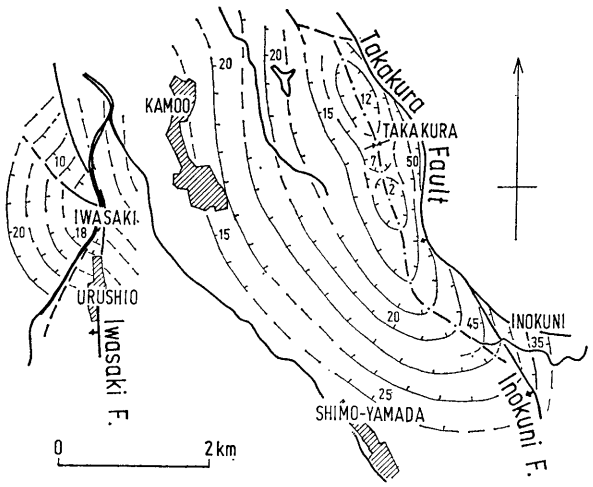


Fig. 26a. Geological structure in the Iizuka district.

sedimentation on either side of the Iwasaki Fault might have been under similar conditions or more preferably combined together as one basin. This means that the Iwasaki Fault might have not been originated at the time of deposition, or, if existed, it might have been so minor in scale that it did not divide the basin.

The other synclinal axis runs nearly in parallel with and close to the marginal faults in the eastern zone. Exactly speaking, they do not keep constant interval between the faults. The axis of syncline goes farther from the faults towards the north at Nogata and northward, and on the contrary, the former runs very close to the Tagawa Fault in the Tagawa district.

In the Tagawa district, the axis of syncline along the Tagawa Fault has a northward plunging. This inclined synclinal axis is interrupted by the faults bordering the Kawara complicated area (NODA, 1968) where two major faults, the Fukuchiyama and the Tagawa, meet together. The axis is again found at the north of Natsuyoshi, northernmost of Tagawa City. Along the Fukuchiyama Fault, the axis has a northward plunging in the Nogata district, but is also sinking southwards at the southern part of Hojyo area, showing a saddle-shaped structure*. These faults and synclinal axis are shown in Fig. 28a.

Many of the major faults bordering the eastern margin of the Tertiary formations run flexuously, showing normal dipping. But the Tagawa Fault, which trends almost straight north to south, is seemingly a reverse fault. And axis plane close to the fault leans also to the west (TAKAHASHI *et al.*, 1971). It is commonly considered that these reverse hades are due to the lateral pressure from the east after the fault was formed.

The other geological structure resulting from the same lateral pressure is found near the Fukuchiyama Fault in a part of Nogata district. Besides, two apparent reverse faults separating the Tertiary from the basement rocks are also found in the southwestern areas of Nogata district. Warping trends of the marginal faults may be concerned with the lithological character of the basement

* Tentatively called as "the Hojyo saddle structure".

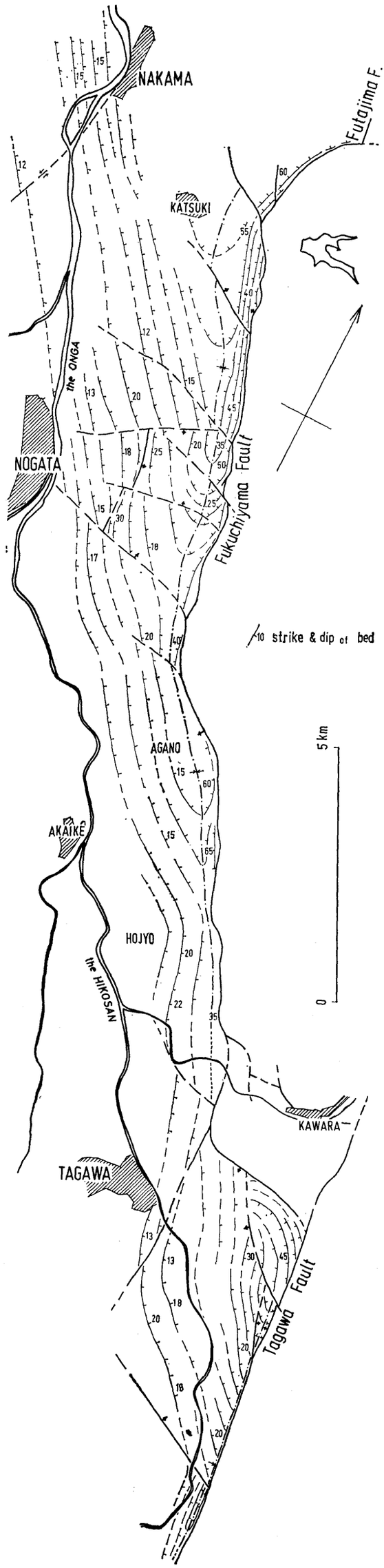


Fig. 26b. Geological structure in the Nogata-Tagawa districts.

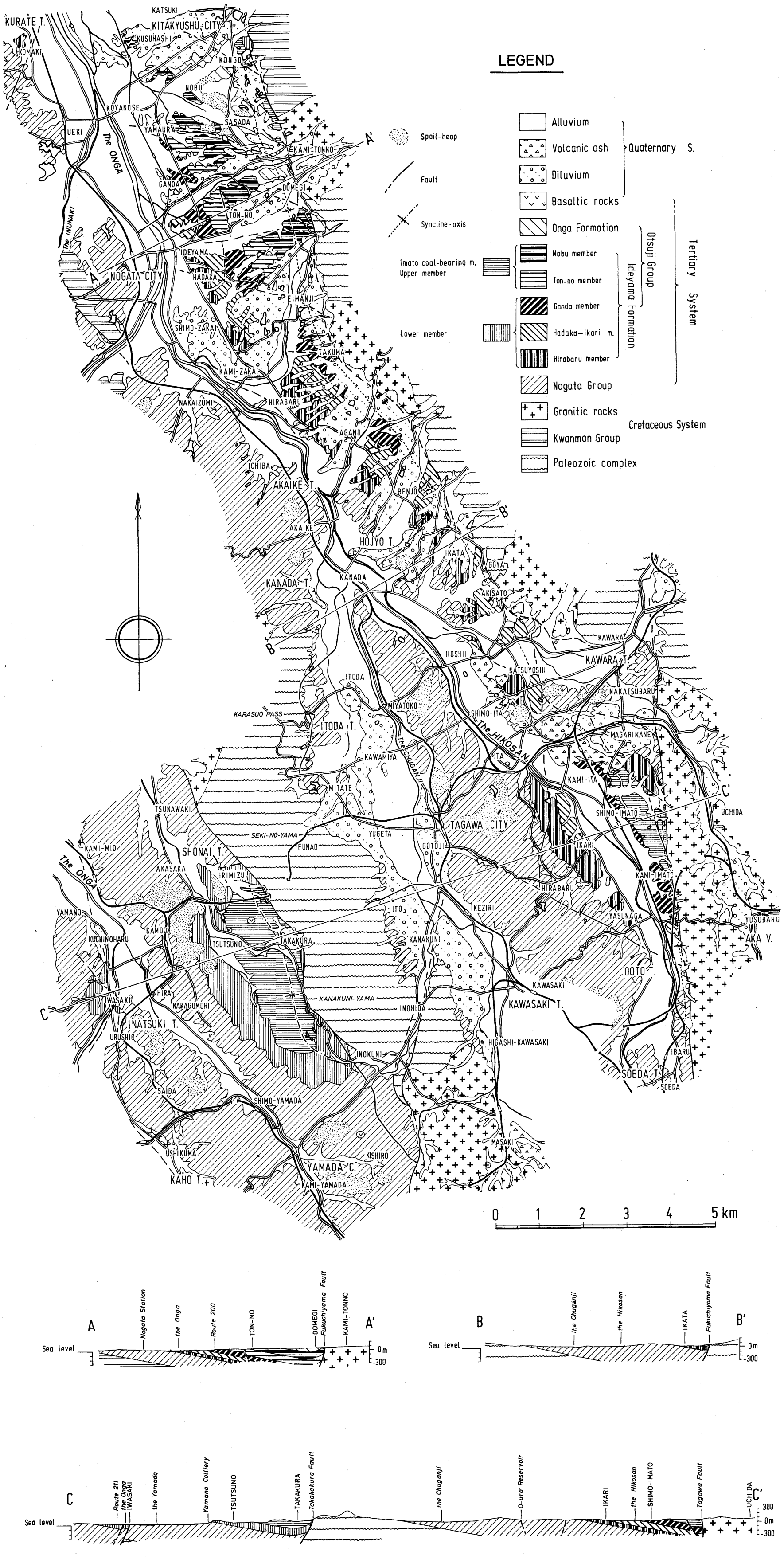
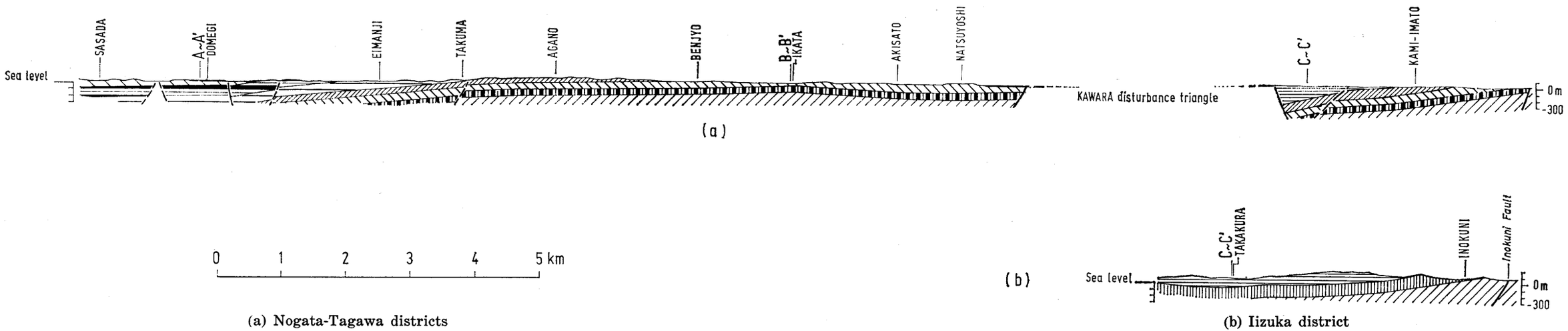


Fig. 27. Geological map.



(a) Nogata-Tagawa districts

(b) Iizuka district

Fig. 28. Vertical section along the axis of syncline.

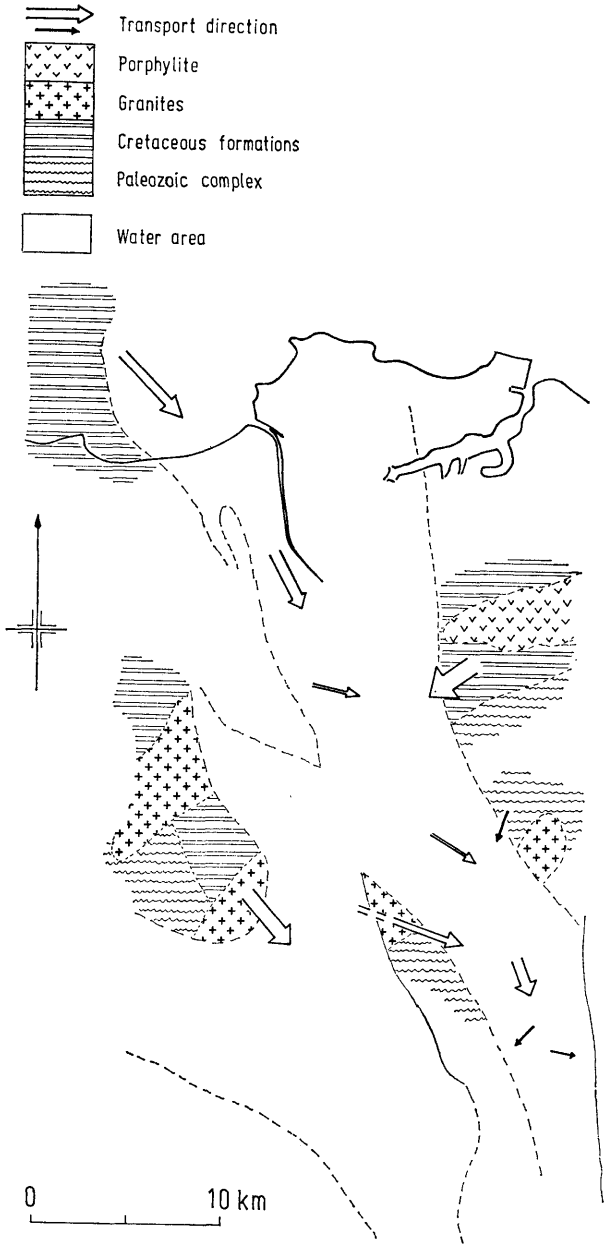


Fig. 29a. Interpretive map of the transport of clastics at the early Ideyaman age.

rocks and the sinking movement of the Tertiary basin at and after the time of deposition.

It is considered that the faulting on the eastern margin of the sedimentary basin of the Chikuho Coal-field was originated at the earliest period of the history of the basin as described by TAKAHASHI (1966 and 1971) and MATSUSHITA

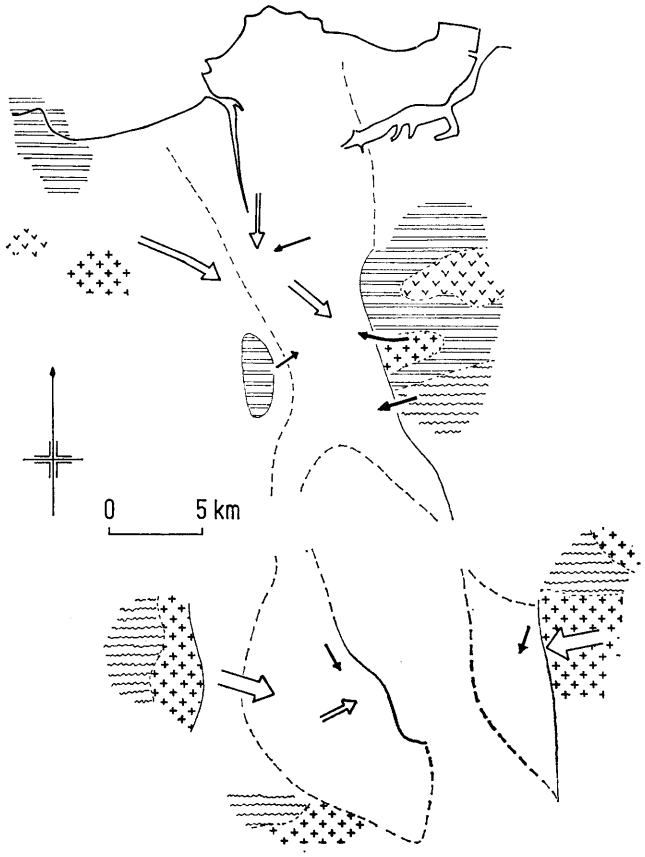


Fig. 29b. Interpretive map of the transport of clastics at the late Ideyaman age.

(1967 and 1971), and that the faults had been considerably thrown prior to the deposition of the Ideyama Formation as exhibited at the outcrop of Kominé (Fig. 15).

Chapter V

Sedimentary basin of the Ideyama Formation

I. On the Paleo-Nogata Basin

SUZUKI (1894) mentioned that the Tertiary sediments were accumulated in the damped areas separated by the mountain blocks which were formed by the pre-Tertiary tectonic movement. According to him, the characteristic geological structures of the Chikuho Coal-field were formed by the lateral pressure after the deposition of the Tertiary formations. YABE (1912 and 1926) and NAGAO (1925b and 1928b) were of the opinion that the Tertiary deposits were once extensively developed in almost whole area of north Kyushu before deformation, denudation and segregation into several present day coal-fields by the block

movements. YABE (1926), furthermore, pointed out that the characteristic structural trend of the Chikuho Coal-field was in accordance with the so-called "dislocations of the Thai-Paik-san range" or "Peri-Tunghai tectonic line" named by KOTO (1903 and 1906). Thereafter, MATSUSHITA (1949) mentioned that segregated basins were originally formed by the pre-Tertiary tectonic movement, and received sediments during the Tertiary subsidence. MATSUMOTO (1951b) was of nearly the same opinion. The Paleogene sediments in the Chikuho Coal-field do not occur generally outside the marginal faults on the eastern boundary of the Tertiary with a few exception observed at Kawara, Katsuno and the north of Miyata areas, etc. This fact is consistent with MATSUSHITA's opinion mentioned above.

The Chikuho-type geotectonic structure defined by MATSUSHITA are characterized by the marginal faults and developed in several coal-fields in the northern part of Fukuoka Prefecture. It has been generally considered that the prototype of the marginal faults was formed by a series of tectonic movements trending in N-S or NNW-SSE at the last stage of the Cretaceous as shown by some evidences such as the Kokura Fault, the marginal fault on the eastern boundary of the Kokura Coal-field (TOMITA, 1970), along which nearly 10 km of lateral displacement of the Cretaceous Kwanmon Group was taken place. This kind of movements must have resulted grabens or half gravens. These low lands might have been chiefly in lacustrine or fluviatile condition* and sometimes connected with marine areas of Paleo-Ariake Bay (MATSUSHITA, 1949) that lay south of the Chikuho Coal-field, and covered the present areas of the Miike and Asakura coal-fields. One of these basins in the northern part of Fukuoka Prefecture is called as "the Paleo-Nogata Basin"** by MATSUSHITA (1949).

MATSUSHITA mentioned that the Paleo-Nogata Basin was connected at times with Paleo-Ariake Bay during deposition of the Nogata Group as verified by several fossil beds in it, and that the basin became a land area immediately after the Nogata age. Subsequently the Paleo-Nogata Basin was inundated with a new marine transgression of the Paleo-Genkai embayment from the north, resulting sedimentation of the Ideyama Formation. This is, accordingly to him, verified by the Iwasaki fossil bed of marine facies coarser lithofacies of the Ideyama Formation at the southern area of this coal-field.

MATSUSHITA mentioned, moreover, that this basin was filled with the Onga Formation during the regressive phase, and that the southern part of the basin upheaved and became a land area in the Ashiya age. He called this movement "the Chikushi tilting" (1967).

However, it is noted that the marine Iwasaki fossil bed does not occur in the greater part of this field, but is limited to the southern part. On the basis of the above fact and the comparison of fossil assemblages of the Chikuho and

* Similar example to the Chikuho basin was shown as the Oligocene Elbe Bay by TEICHMÜLLER (1958, cited by TEICHMÜLLER and TEICHMÜLLER, 1968). But the Paleo-Nogata Basin differs from the former in the absence of great river such as the old Elbe or the old Rhein.

** This name is used only for the sedimentary basin of the Chikuho Coal-field in this paper.

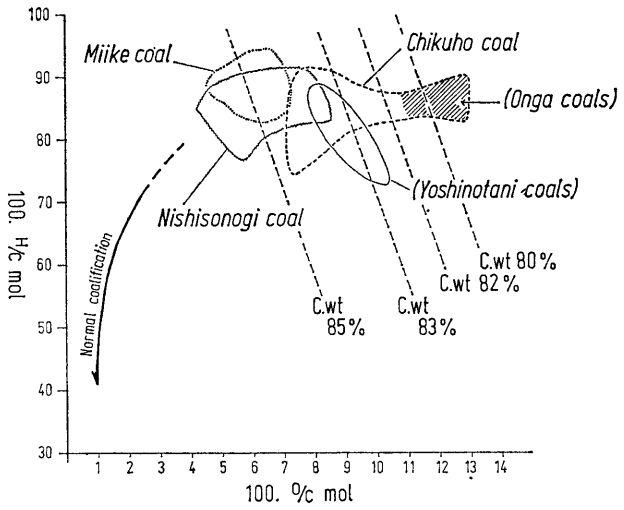


Fig. 30. Coal-band of Kyushu coals (after R. TAKAHASHI, 1959)

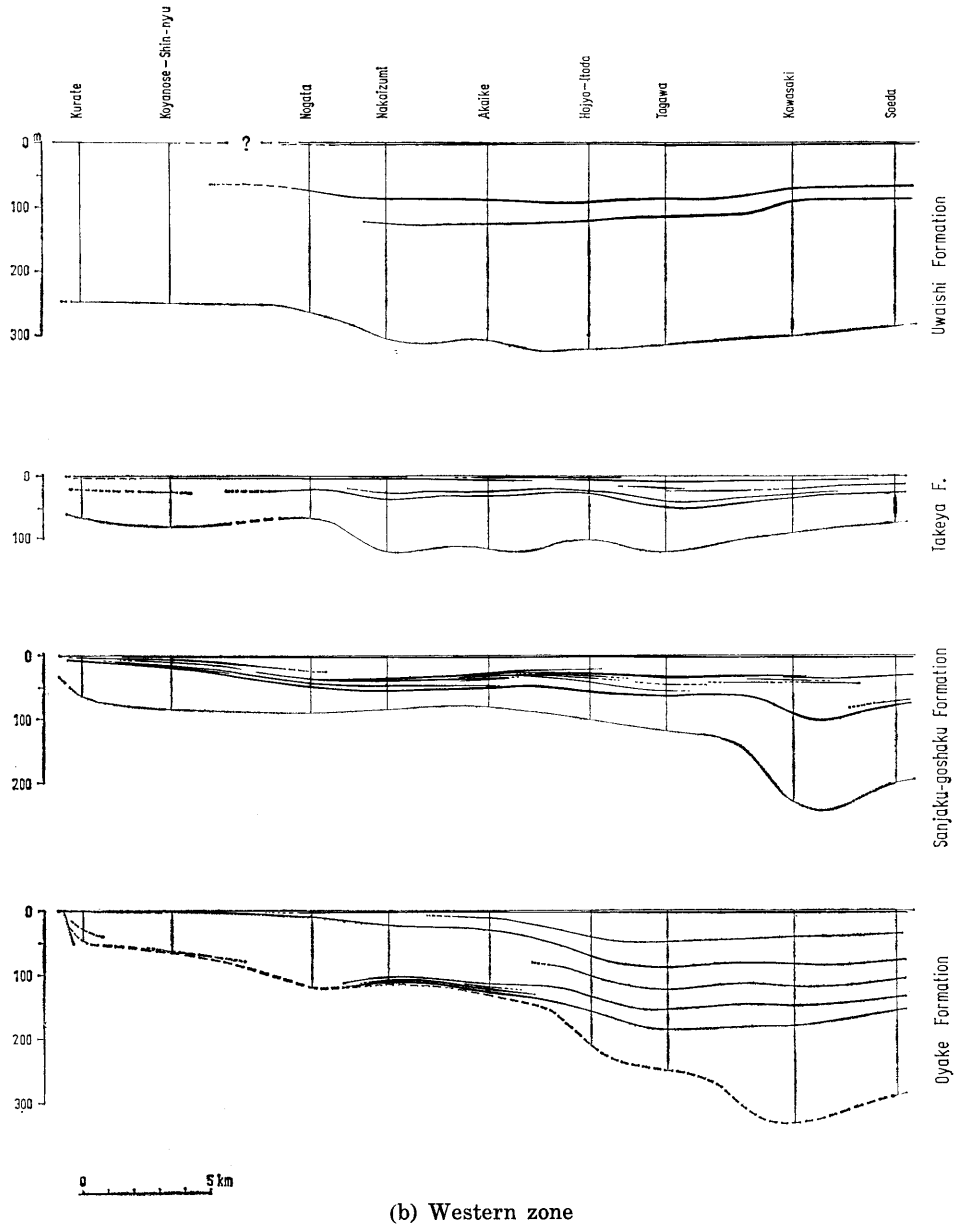
Asakura coal-fields, MIZUNO (1964) concluded that the northernmost part of the Paleo-Shiranui Sea* (KOBAYASHI, 1941) was filled fresh water by the time what he called the Funazuan age (Table 2). This body of fresh water was extended to cover the Chikuho (the Ideyama Formation) and the Fukuoka (the Najima Formation) coal-field in the period from the Okinoshiman to the Funazuan age. MIZUNO mentioned also that the major part of the Onga Formation was formed in the non-marine basin during the Mazean age except for the upper part, which is intercalated with marine bands of the "Ashiya marine invasion" from north**. However, his idea cannot explain the fact that the Iwasaki fossil bed in the Chikuho Coal-field and the corresponding Katsuta fossil bed in the Kasuya district of the Fukuoka Coal-field are strictly limited in distribution to the southern part of respective coal-field***.

TAKAHASHI (1958, 1959a and 1959b) discussed the coalification of several coals of the coal-fields in Kyushu. He stated that the coal-band (coalification band, VAN KREVELEN, 1957) of the prominent coals of the Onga Formation in the Chikuho Coal-field took the lower rank of coalification than the coals of the Yoshinotani Formation in the Karatsu Coal-field which was correlated with the former (Fig. 30). As it is regarded that both formations have been under a similar condition in post-depositional factors, such as an overburden, the difference of coal-bands may be attributed to the conditions of the sedimentation

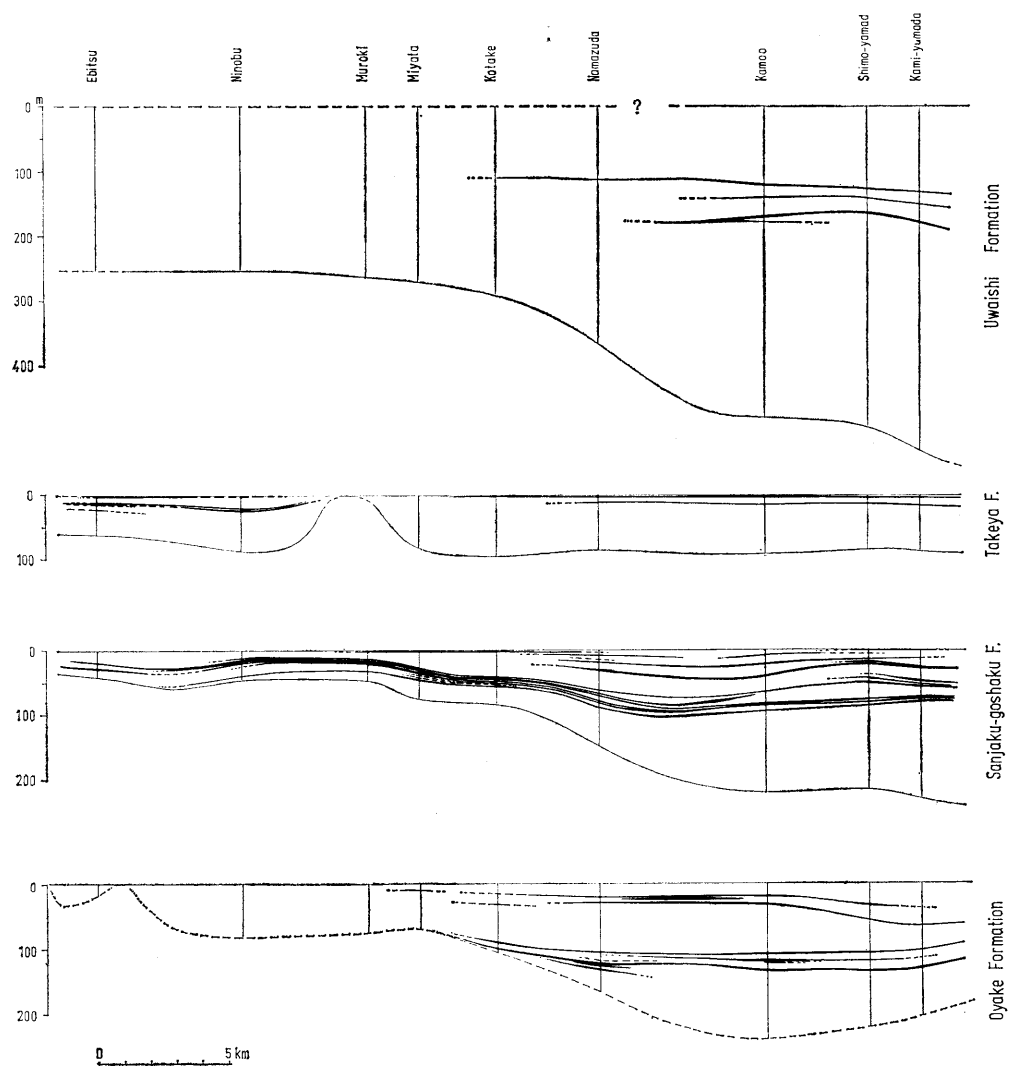
* The great sea area on the western region of Kyushu contains the Paleo-Ariake Bay and the Paleo-Genkai embayment of MATSUSHITA.

** TAKAHASHI (1966) called as "the Onga subsidence".

*** It is also difficult to decide whether or not the Asakura Coal-field was a channel linking the Paleo-Shiranui Sea or the Paleo-Ariake Bay and the Paleo-Nogata Basin, since the stratigraphic relationship between three fossil beds of the Nogata Group in the Chikuho Coal-field (MATSUSHITA, 1949) and two formations in the Asakura Coal-field—the marine Kawamagari and the unconformably overlying coal-bearing Doshi Formation—are not clear.



(b) Western zone



(a) Eastern zone

Fig. 31. General thickness variation and coal developments of each formation of the Nogata Group (compiled from the Assoc. Coal-Mining Techn., Kyushu, 1952)

of the basins. Difference in the total sulpher content of coal, 0.3–0.7% in the Onga Formation, and 1–3% in the Yoshinotani Formation, may also have causal relation to the sedimentary condition*. Thus it should be concluded that the Paleo-Nogata Basin was an almost closed lake separated from the sea area such as the Paleo-Ariake Bay or the Paleo-Shiranui Sea including the Asakura, Miike and Karatsu coal-fields during the Onga age.

II. Paleo-Nogata Basin and the Ideyama Formation

A. Paleo-Nogata Basin at the pre-Ideyaman age

Fig. 31 illustrates the regional variation of thickness and coal-development in each formation of the Nogata Group. It is noticeable in this figure that the tendency of both lateral variations in the thickness and coal-developments in the northern and southern parts within the eastern and western zones is similar to each other. Furthermore, the equivalent formation of respective zone is similar in thickness, notwithstanding the fact that they are separated from each other by the basement rocks. It is also a remarkable fact that each coal seam has a considerable continuity in distribution, being traceable extensively from south to north in one zone, but, at the same time, it is difficult to correlate any coal seam of one zone with that of other zone.

Based on these facts the following alternative presumptions are given; one is that the Paleo-Nogata Basin was a broad expanse of water. The other is that two parallel minor basins divided by a barrier of the basement rocks sank simultaneously with some connecting channel such as in the Kotake-Katsuno area. Anyway it may be sure that either a barrier or non-deposited area situated between the eastern and western halves of the basin. Thus, as mentioned by MATSUSHITA (1967b), the marginal faults had been developed as the deposition of the Nogata Group was going on.

The Nogata Group is better developed in the southern part of the Chikuho Coal-field than in the northern one showing greater thickness of formations and more numerous coal seams in the former part, whereas formations, especially the lower two of the Nogata Group are thinning out in the northernmost part. It is apparent therefore that the southern part of the basin subsided more greatly and was under more favourable condition for coal formation than the northern part during the time of deposition of the Nogata Group.

However it is noticeable that the Uwaishi Formation, the uppermost division of Nogata Group, is developed with a considerable thickness in the Okagaki-Onga areas which cover the eastern and western zones near the northernmost part of the coal-field (Figs. 14c and 31). This fact verifies that the basin was expanded to the north beyond the northern limit of the basin of the lower formations of the Nogata Group. The expansion of the sedimentary basin in the Uwaishian age cannot be regarded as the result of a rapid change of the tectonic frame-work of the basin, but is attributed to a forerunner of a regional sub-

* It may also be proved this assumption by the fact that the total sulpher content of coal of the Onga Formation incleases toward the north in the mine of old Nittan-Takamatsu Colliery.

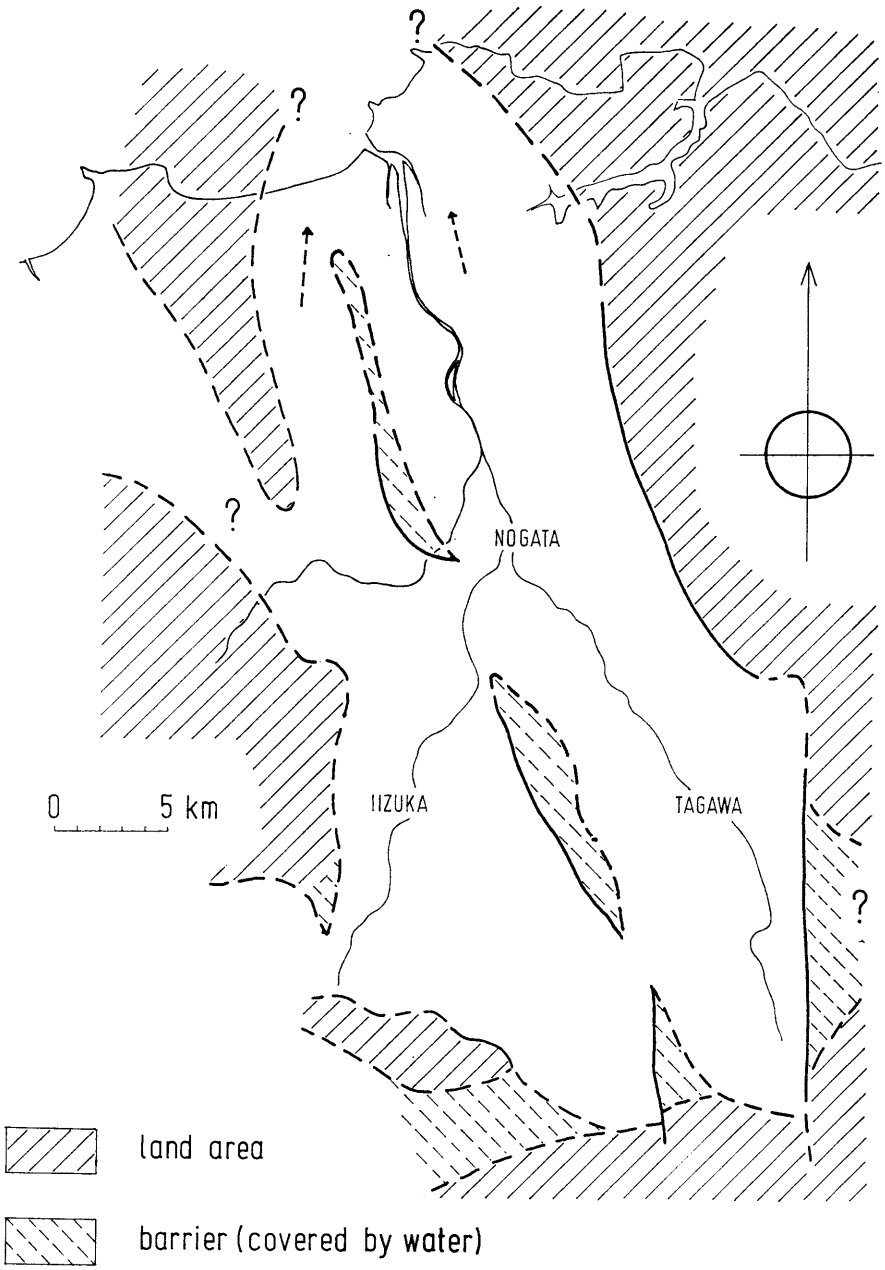


Fig. 32a. Paleo-Nogata Basin at the last stage of Uwaishian age.

sidence, by which the Paleo-Nogata Basin was linked with Paleo-Ariake Bay at early Ideyaman age. This is suggested by the greater coal-development in the southern part and a conformable relationship of the Uwaishi Formation with the underlying Takeya Formation. Thus the change of basin at the Uwaishian age described above is considered to show a transitional stage to the Ideyaman age (Fig. 32a).

B. Paleo-Nogata Basin at the Ideyaman age

1. Early Ideyaman age

It is noticeable that the Ideyama Formation of the Otsuji Group differs in lithological facies and sedimentary features from the underlying Uwaishi Formation of the Nogata Group. That is to say, the former characteristically has coarse-grained lithofacies and several 'typical' cycles of sedimentation, and is devoid of any remarkable coal. Besides, there is a broad unconformity between the two formations in the Tagawa and Nogata districts. These facts imply the changes in the sedimentary environment of the Paleo-Nogata Basin during the time concerned.

The Uwaishi Formation is distributed extensively in all the areas of this coal-field. While, the Ideyama Formation occurs in the eastern zone and the southern half of the western zone. The formation in the southern half of the western zone, the Iizuka district, is characterized by its thinner thickness, coarser lithofacies and the absence of minor sedimentary cycle, comparing with its counterpart in the eastern zone. That is to say, the Ideyama Formation of the Iizuka district represent a marginal facies being in contrast to the facies of the greater subsidence in the eastern one.

Thus, it is assumed that the basin once expanded to the north during the Uwaishian age, upheaved at the eastern half to cause the broad unconformity just prior to the deposition of the Ideyama Formation and then tilted down eastward in the earliest Ideyaman age. In consequence of this eastward tilting, the Paleo-Nogata Basin stretched to the east across the marginal fault on the eastern border of the basin and laid the sediments on the fault as is shown by the so-called "unconformity at Kominé". In spite of this tilting, the basin seems to have hold the tendency of greater subsidence in the southern than in the northern area (Fig. 17). In consequence of above mentioned nature of the basin conspicuous results appeared. On one hand, the northern part of the western zone became a non-depositional area by a slight upheaval of the basin, and, on the other hand, the southern part of the Paleo-Nogata Basin was flooded by sea water of Paleo-Ariake Bay. Thus the Iwasaki fossil bed was formed (Fig. 32b).

During the subsiding movement after the tilting, the center of the subsidence of the Paleo-Nogata Basin in the Ideyaman age is assumed to have been located in an area covering the main part of the Nogata district and the Tagawa district of the eastern zone and to have sunk with a rhythmical or cyclical oscilation. The most coarse sediments are found in the main part of the Nogata district, and less coarser ones in the Tagawa district. On the contrary, most favourable circumstance for the formaion of coal might have been present in the main part of Nogata district~the Hojyo area of the Tagawa district. The Iizuka district, southern part of the western zone, had been remained as a marginal area of the sedimentary basin.

It is concluded that the clastic materials found in the lower part of the Ideyama Formation were derived from the pre-Tertiary rocks mainly of the northwest except for those in the main part of Nogata district, which were transported from the east. The whole area of the Paleo-Nogata Basin including the

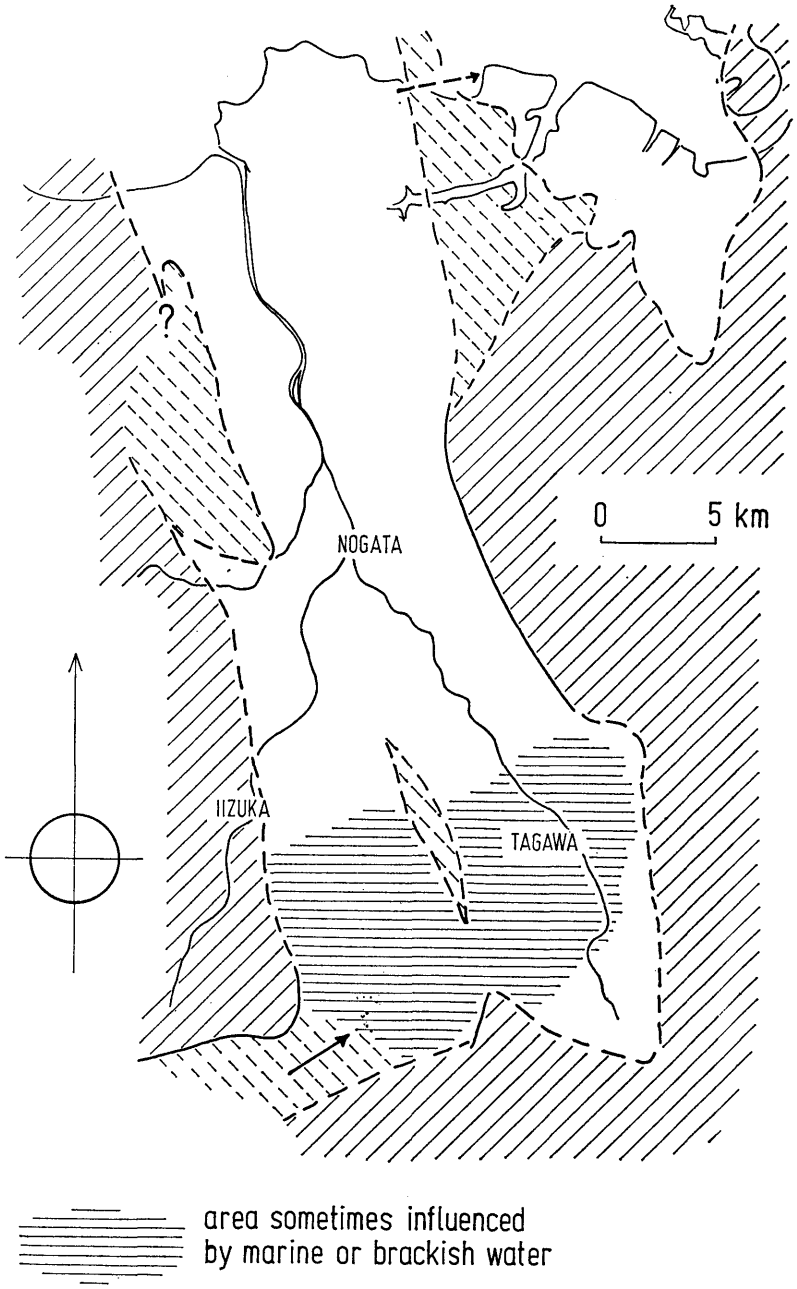


Fig. 32b. Paleo-Nogata Basin in the early Ideyaman age.

Iizuka district had a quiet environment at the end of the earlier half of the Ideyaman age, then the noticeable coals were formed in the greater part of the basin (Figs. 11 and 13).

2. Late Ideyaman age

There is almost nothing in common in lithological characters among the upper part of the Ideyama Formation in the Iizuka, Nogata and Tagawa districts. Especially, the difference is conspicuous in the latter two districts. Consequently, it is considered that these three districts was under different sedimentary conditions in the Late Ideyaman age.

It is noted that the upper part of the Ideyama Formation both in the Nogata and Iizuka district is in common in lithofacies with the lower part in respective district, and one and common lake for the two districts so as to result the same heavy mineral composition, although a great variation is present in the heavy mineral contents between the lower and the upper half of the Ideyama Formation in both districts.

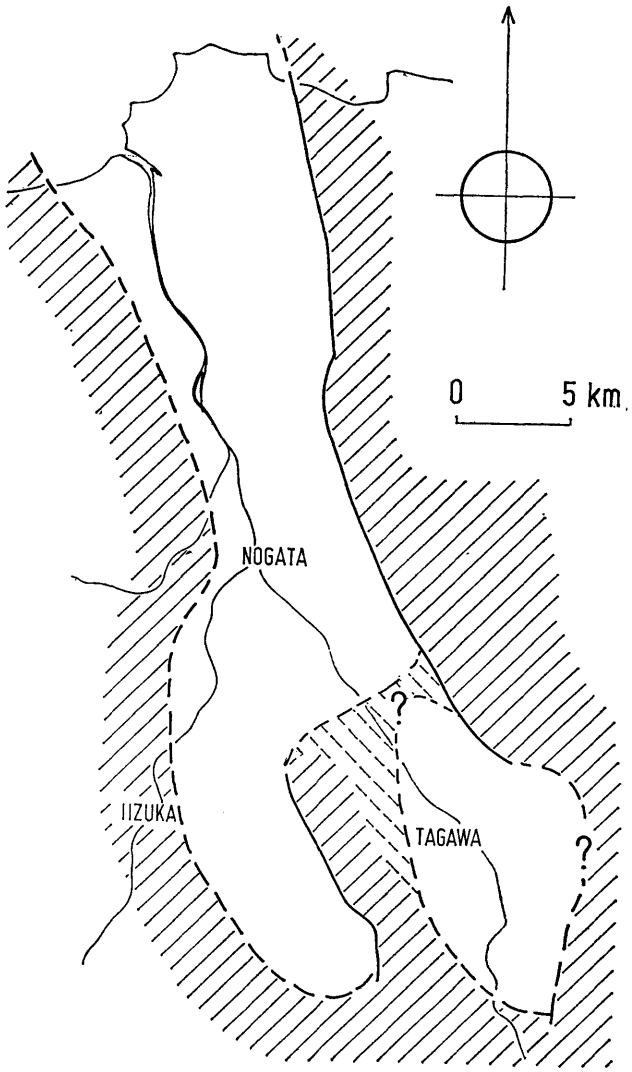


Fig. 32c. Paleo-Nogata Basin in the late Ideyaman age.

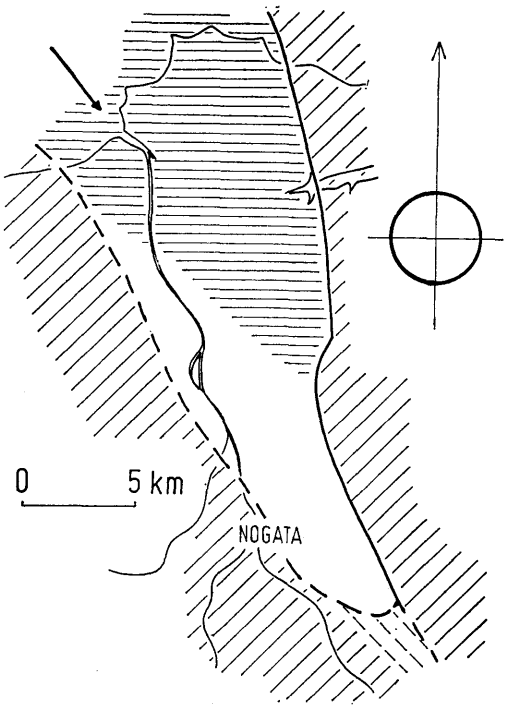


Fig. 32d. Paleo-Nogata Basin in the Ongaan age.

On the contrary, the Imato coal-bearing member in the Tagawa district differs considerably from the lower three members of the same district to have a distinctive lithofacies, containing much coal matters, but to be devoid of the sedimentary cycle characteristic to the Ideyama Formation. Moreover, the Imato member has peculier characteristics not only in lithological facies, the lithological character of gravels and the paleocurrent direction, but also in the heavy mineral association, especially in its zircon-garnet-tourmaline ternary ratio. Hence it is emphasized that the sedimentary basin of this member was isolated and separated from that of the Nogata and Iizuka districts.

The Paleo-Nogata Basin was thus split into the Imato and the Nogata-Iizuka basin by a movement at the transitional period from the early to the late Ideyaman age. During this period the heavy mineral assemblage was changed in whole areas.

Differentiation of the Paleo-Nogata Basin into the Imato and the Nogata-Iizuka is attributed to the upheaval of the Kanakuni area, consisting of the pre-Tertiary complex, as a barrier between two basins. It is also partly attributed to the northward tilting of the coal-field. The Hojyo area is considered to have had important role as a channel intermittently connecting the Nogata-Iizuka and the Imato basin (Fig. 32c). Thus the Imato basin was presumably under as appropriate condition for the deposition of coal-bearing member. In the main part of the Nogata district, a rhythmical subsidence continued and coarse-grained clastic detritus was supplied, and the center of subsidence shifted slightly to the north with the lapse of time from the third cyclic

member to the Onga Formation (Figs. 16, 17, 32c and 32d).

There is no evidence to indicate a remarkable event at the boundary between the Ideyama and the Onga Formation, except for the development of coal and the change of lithofacies. The coal-bearing Onga Formation is presumed to have been formed in the last stage of Otsuji Cycle rather than in a new tectonic phase occurred in the Paleo-Nogata Basin. Since the upper part of the Ideyama Formation is exclusively of non-marine or fresh water facies, it is regarded that this basin was not invaded by sea water from the Paleo-Ariake Bay. Judging from the above mentioned northward tilting in the Late Ideyaman age and the marine bands of the upper Onga Formation in the northern Paleo-Nogata Basin, the basin of the upper Ideyama Formation might have been opened into the Paleo-Genkai embayment*.

In the series of sedimentary process, the clastic detritus must have been scarcely supplied from the neighbouring pre-Tertiary areas bordering the marginal faults like as the examples in the Tertiary sediments of the coal-fields of northwest Kyushu (NAGAHAMA, 1965) and in the Cretaceous Onogawa Group of the eastern Kyushu (TERAOKA, 1970).

Conclusion

The Ideyama Formation of coarse-grained clastics is situated between two coal measures. Its stratigraphic relation to the lower coal measure, the Uwaishi Formation, is seemingly partial unconformity. That is to say, it covers the Uwaishi unconformably in the eastern zone and conformably in the western zone. While the Ideyama Formation is overlain by the upper coal measure, the Onga Formation, conformably throughout the areas. The Ideyama Formation exhibits cyclic sedimentation and is divided into two to five cyclic members according to the differentiation in lithofacies by district. Diagonal bedding and lithology of pebbles indicate that clastics of the formation were generally derived by rather short distance from northwest land area with exceptions of lower Ideyama Formation of the Nogata district and the upper one of northeast of Tagawa district.

The basin was probably something like half graben bordered to the east by marginal faults, which originated before the deposition of the Eocene Nogata Group and continued their movement after the Tertiary in the Chikuho Coal-field was laid to give severe influence to the structure of the Tertiary beds. After regression in the Paleo-Nogata Basin, especially at its eastern part, the eastern area was the field of main subsidence and sedimentation at the beginning of the Ideyama age and a temporal and local marine invasion from Paleo-Ariake Bay is verified by the Iwasaki fossil bed.

Subsidence proceeded followed by an eastward tilting to result eastward

* Grauconite-bearing dark greenish coarse sandstone was found below of the coal-bearing Onga Formation in the borehole drilled at the An'ya Coast of Wakamatsu Ward, Kitakyushu City. It is supposed that the marine water of Paleo-Genkai embayment invaded into the Paleo-Nogata Basin at the Late Ideyaman age, if the sandstone belongs to the Ideyama Formation.

leaning center of deposition. The basin was seggregated by a rising narrow terrain at the middle of the Ideyaman age. In keeping pace with rising on this barrier block, subsidence of the basin was propagated to result northward expansion of the sedimentary area. Seemingly this was followed by the northward Chikushi tilting. The Chikushi tilting in the Chikuho Coal-field roughly corresponds in age and nature with the northwestward Karatsu tilting (YAMASAKI, 1959) in the northwest Kyushu. TAKAHASHI and SHUTO (1971) regarded these tiltings as a part of the tectonic expression of outward drift of the foredeep basin in accord with the upheaval of the geanticlinal mass and correlated to the birth of the Nichinan basin in south Kyushu. The Chikushi tilting began in Late Ideyaman age, while the Karatsu tilting did at the beginning of the Masean stage. That is to say, the former began considerably earlier than the latter, as a result of shorter distance of the Chikuho Coal-field from the geanticlinal area than northwest Kyushu. Furthermore the basin of the upper Ideyama Formation inherited practically the same area as that of the lower Ideyama Formation and the Nogata Group, as it is that the basin formed by the Karatsu tilting had originated at the Funazuan stage. The cause of this peculier phenomenon is not clear, but it should be pointed out that the movement of the grabens along the marginal faults of Ryukyu Trend gave a noticeable modification to the general movement of the region. This also implies more rigid character of the basement eastward in the western Japan in Mid-Tertiary age and suggests a more mobile basin to the west of northwest Kyushu.

References

ASANO, Goro (1956): Problems on the prospecting for the coal seams in the Taira district, Joban Coal-field, Fukushima Prefecture (in Japanese with English abstract). *Jour. Soc. Mining Geol., Japan,* **6**, 87–97.

——— (1958–1959): Igneous intrusives into coal-bearing formations and thermal metamorphism of coal in the Chikuho Coal-field (1–3, in Japanese with English abstract). *ibid.*, 8, 283–301, **9**, 33–49, 224–241.

——— (1964): Mode of occurrence and microscopic structure of the so-called "Matsuiwa" (a silicified wood) (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* **32**, 181–201.

ASANO, G. and TANAKA, Nobuya (1962): Occurrences and properties of anthrasite in Tagawa district, Chikuho Coalfield (in Japanese with English abstract). *ibid.*, **30**, 109–123, 159–178.

ASANO, G., TANAKA, N., TAKEMOTO, Yoshiaki and YAMAMURA, Masahiko (1964): Mode of occurrence of "senseki" (a sort of cinder coal) and petrological properties of the igneous rocks associated with it, forming sills, in Chikuho Coal Field, Japan (in Japanese with English abstract). *ibid.*, **32**, 368–376.

DUFF, P. McL. D. and WALTON, E. K. (1962): Statistical basis for cyclothems: a quantitative study of the sedimentary succession in the East Pennine Coalfield. *Sedimentology,* **1**, 235–255.

DUFF, P. McL. D., HALLAM, A. and WALTON, E. K. (1965): *Cyclic sedimentation (Developments in Sedimentology, 10)*, 1–280. Elsevier, Amsterdam.

EGUCHI, Motoki and SHOJI, Rikii (1953): A study on the sedimentation of coal in the Joban Coal Field (1)—Environs of Isohara-machi, Ibaraki Prefecture (in Japanese with English abstract). *Jour. Geol. Soc. Japan,* **59**, (690), 99–109.

——— and ——— (1955): On the relationship between the development of coal-seams and the relief of the basement rocks in the Joban Coalfields (in Japanese

with English abstract). *ibid.*, **61**, (712), 19–29.

EGUCHI, M., SHOJI, R. and SUZUKI, Shun-ichi (1953): Coal sedimentation in the Jôban Coal Field (2)—Vicinity of Hirono-machi, Futaba district, Fukushima Prefecture (in Japanese with English abstract). *ibid.*, **59**, (699), 544–551.

FEANSIDES, W. G. (1950): Rhythm in sedimentation: Introduction. *18th Intern. Geol. Congr., London, 1948, Rep.*, [4], 4.

FORSTER, W. (1809): A treatise on a section of the strata from Newcastle upon Tyne to the Mountain of Cross Fell in Cumberland, with remarks on mineral veins in general. *Alston and Newcastle upon Tyne.*

Geological Committee of Association of Coal-Mining Technologists of Kyushu (1952): *Correlation chert and its explanatory text of coal seams in each coal-field of Kyushu.* Association of Coal-Mining Technologists of Kyushu.

——— (1955): *Geological map of the Iizuka district.* ditto.

——— (1965a): *Geological map of the Tagawa district.* ditto.

——— (1965b): *Geological map of the Nogata district.* ditto.

Geological Survey of Japan (1960): *Mineral resources of Japan* (*Nippon Kosan Shi*, in Japanese), Part B, **V-a**, *Coal*, 1–775. Shobundo, Tokyo.

HASE, Akira (1959): The stratigraphy and geologic structure of the late Mesozoic formations in western Chûgoku and northern Kyûshû (in Japanese with English abstract). *Geol. Repts., Hiroshima Univ.*, (6), 1–50, pls. 1–14.

HEMINGWAY, J. E. (1968): Sedimentology of coal-bearing strata. in D. G. MURCHISON and T. S. WESTOLL [editors]: *Coal and coal-bearing strata*, 43–69. Oliber & Boyd, Edinburgh and London.

HYAKKOKU, Hiroshi (1966): Studies on the sedimentation of the Harutori Formation in the eastern half of the Kushiro Coal-field (in Japanese with English abstract). *Jour. Soc. Mining Geol., Japan,* **16**, (78), 172–182.

IWAHASH, Toru (1961): Study on the stratigraphy of the Tertiary Ainoura Group in the Sasebo Coal Field, northwestern Kyushu, Japan (in Japanese with English abstract). *Sci. Repts., Fac. Sci., Kyushu Univ.*, [Geol.], 5, (3), 111–128.

IWAHASHI, T. and OHARA, Jyonosuke (1959): A study on the stratigraphy and geological structure of the Kokura Coal-field, northern Kyushu, Japan (in Japanese with English abstract). *Jour. Geol. Soc. Japan,* **65**, (768), 528–536.

KARAKIDA, Yoshifumi (1952): Geological relations between granitic rocks in Northern Kyushu (abstract, in Japanese). *Jour. Geol. Soc. Japan,* 58, (682), 277.

——— (1969): On the relationship between both origin of schistose and massive granodiorites of North Kyushu (in Japanese). *Studies, Liter. & Sci., Seinan Gakuin Univ.*, **9**, (2), 75–85.

KARAKIDA, Y., TOMITA, Toru and MATSUMOTO, Tatsuro (1962): Some problems on granitic rocks in North Kyushu (in Japanese). *Jour. Geol. Soc. Japan,* **68**, (802), 373–376.

KARAKIDA, Y., YAMAMOTO, Hirosato, MIYACHI, Sadanori, OSHIMA, Tsunehiko and INOUE, Tamotsu (1969): Characteristics and geological situations of metamorphic rocks in Kyushu (in Japanese with English abstract). *Mem. Geol. Soc. Japan,* (4, Recent progress in the studies on the historical development of the metamorphic belts in Japan), 3–21.

KATO, Kazuyoshi (1957a): The mineral species in the Tertiary rocks of the Onoura district (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* **25**, (3), 102–105.

——— (1957b): Mineral species found in the Ideyama Formation in the eastern part of Nogata City (in Japanese with English abstract). *ibid.*, 25, (10), 215–219.

——— (1960a): Heavy mineral study of the Paleogene sediments in the Chikuho coalfield, North Kyushu (in Japanese with English abstract). *ibid.*, 28, (10), 453–475.

——— (1960b): Vertical distribution on heavy minerals in the Paleogene Nogata Group of the Ono-ura area, Chikuho Coal-field, North Kyushu. *ibid.*, 28, (11), 534–537.

——— (1960c): Heavy minerals in the Paleogene Onga Formation of the Otsuji

Gruop, Otsuji Coal Mine, North Kyushu. *ibid.*, 28, (11), 538–540.

KIDO, Chutaro and MATSHDA, Shigeru (1904): *Report on the geology of the Chikuho Coalfield* (in Japanese), 1–321. Fukuoka Mining Inspectorial Office.

KIHATA, Toshio (1955): Research of the Karatsu Coal-field. (1) On the coal bearing formation and marine facies of the Karatsu Coal-field, Kyushu (in Japanese with English abstract). *Jour. Soc. Mining Geol., Japan,* 5, (8), 248–252.

KOBAYASHI, Teiichi (1941): The Sakawa orogenic cycle and its bearing on the origin of the Japanese Islands. *Jour. Fac. Sci., Tokyo Imp. Univ.,* [II], 5, (7), 119–578, pls. 1–4.

——— (1948): The geotectonics of the Japanese Islands (in Japanese) I, 1–93, II, 1–278. Meguro-shoten, Tokyo.

KOBAYASHI, T. and OTA, Isamu (1953): On the Wakino Series of northern Kyushu, Japan (in Japanese). *Jour. Geol. Soc. Tokyo,* 48, (569), 298–302.

KOBAYASHI, T. and SUZUKI, Koichi (1936): Non-marine shells of the Naktong-Wakino series. *Japan. Jour. Geol. Geogr.,* 13, (3–4), 243–257.

KOTO, Bunjiro (1903): An orogenic sketch of Korea. *Jour. Sci. Coll. Imp. Univ., Tokyo,* 19, (1).

——— (1916): The great eruption of Sakurajima in 1914. *ibid.,* 38, (3), 1–237.

MACKOWSKY, M.-Th. (1968): Europian Carboniferous coalfields and Permian Gondowana coalfields. in D. G. MURCHISON and T. S. WESTOLL [editors]: *Coal and coal-bearing strata,* 325–345. Oliver & Boyd, Edinburgh and London.

MATSUMOTO, Tatsuro (1951a): The Yezo Group and the Kwanmon Group (in Japanese with English abstract). *Jour. Geol. Soc. Japan,* 57, (666), 95–98.

——— (1951b): An outline of the fundamental geologic structure in North Kyûshû and West Chûgoku (in Japanese). *Sci. Repts., Fac. Sci., Kyushu Univ.,* [Geol.], 3, (2), 298–302.

——— [editor] (1954): *The Cretaceous System in the Japanese Islands,* 1–324, pls. 1–36. Japan. Soc. Prom. Sci., Tokyo.

——— (1969): Geochronology and historical geology in Japan. *Jour. Mass Spectroscopy Soc. Japan* 17, (1), 434–444.

MATSUMOTO, T. and KURODA, Hidetaka (1952): Geological study of the southern part of the Hiuga Province (abstract, in Japanese). *Jour. Geol. Soc. Japan,* 49, (585), 255–256.

MATSUMOTO, T., NODA, Mitsuo and MIYAHISA, Michitoshi (1962): *Regional geology of Japan; Kyushu Province* (in Japanese), 1–423. Asakura-shoten, Tokyo.

MATSUSHITA, Hisamichi (1949a): Paleogene stratigraphy of northern Kyushu (in Japanese). *Sci. Repts., Fac. Sci., Kyushu Univ.,* 3, (1), 1–57.

——— (1949b): A summary of the Paleogene stratigraphy of northern Kyushu. *Mem. Fac. Sci., Kyushu Univ.,* [D], 3, (2), 91–107.

——— (1951): On the geological structure of the northern Kyushu coalfields (in Japanese). *Sci. Repts., Fac. Sci., Kyushu Univ.,* [Geol.] 3, (2), 49–54.

——— (1953): On the unconformities in the northern Kyushu coalfields (in Japanese). *Jour. Assoc. Geol. Collab. Japan* (*Chikyu-kagaku*), (9), 1–8.

——— (1956): Again on the unconformity in the northern Kyushu coalfields (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* 24, (2) 49–55.

——— (1967a): Some faults in the Chikuho and the Kasuya coal fields (in Japanese with English abstract). *Sci. Repts., Fac. Sci., Kyushu Univ.,* [Geol.], 8, (3), 181–189.

——— (1967b): The deposition basin of the Chikuho Coal Field (in Japanese with English abstract). *Jubilee Publ. Commem. Prof. Yasuo Sasa 60th Birthday,* 425–530.

——— (1971): A study on the formation of the depositional basins of the coal-fields in Kyushu (in Japanese with English abstract). *Sci. Repts. Dept. Geol., Kyushu Univ.,* 11, (1), 1–16, 4 maps.

MATSUSHITA, H., TAKAHASHI, Ryohei, OHARA, J., IWAHASHI, T. and INOUE, Eiji (1956): On the Paleogene System of the northern Kyushu (in Japanese). *Yukochu,* (5), (Spec. ed., I. Palaeogene of Japan), 13–22.

———, ———, ———, ———, ——— (1957): *Report of the geological survey around the Dokai Bay* (in Japanese, mimeograph), 1–28, 1 map. Wakamatsu Office, Japan Highway Pub. Corp.

MATSUSHITA, H., TAKAHASHI, R., URATA, Hideo, OHARA, J. and HOJO, Yoshio (1966): Review on the depositional environments of coal (Part 1, A study of peat bogs in Kyushu) (in Japanese). *Preprint for Symposium, 1966 Congr., Soc. Mining Geol. Japan* (Sedimentary environments of coal), 77–85.

MATSUSHITA, H., TAKAHASHI, R., KARAKIDA, Y., URATA, H., OHARA, J., TOMITA, Suzuomi, FURUBE, Hiroshi, KANEKO, Norikatsu and NAGAI, Toshiaki (1968): *Geological map of Kitakyushu City.* Kitakyushu City.

MATSUSHITA, H., MIKI, Takashi and YAMASHITA, Akio (1971): An overturned structure observed in the southern part of Fukuoka City (in Japanese with English abstract). *Sci. Repts., Shimabara Inst. Volcano. Kyushu Univ.*, (7), 1–8.

MERRIAM, D. F. [editor] (1964): Symposium on cyclic sedimentation. *Bull. Kansas Geol. Survey,* **169**, 1–636.

MILNER, H. B. (1962): *Sedimentary petrography,* 4th ed., 2 vol., 1–1358. Macmilan, New York.

MIZUNO, Atsuyuki (1962–1963): Paleogene and lower Neogene biochronology of West Japan (in Japanese with English abstract). *Jour. Geol. Soc. Japan,* **68**, (806), 640–648, (807), 687–693, **69**, (808), 38–50.

——— (1964): Paleogene and Early Neogene molluscan faunae in West Japan. *Rept. Geol. Surv. Japan,* (204), 1–71.

MIZUNO, A. and TAKAHASHI, Kiyoshi (1962): Marine molluscan fossils found from the Onga formation in the Chikuho coal-field of northern Kyushu, Japan (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* **30**, 22 (22), 62–67.

MÔRI, Shigeki (1940): On the relationship between "Don (intrusive rocks into the Tertiary sediments)" and anthrasite in the Tagawa district, Chikuho Coal-field (in Japanese). *Jour. Mining Inst. Kyushu,* **11**, (5), 220–227.

MUKAIYAMA, Hiromu (1965): Clay minerals in sedimentary rocks in the Karatsu Coal-field, Saga Pref., Japan (in Japanese with English abstract). *Jour. Mining Inst. Kyushu* **33**, (2), 57–64.

MUKAIYAMA, H., MIYAGI, Satoshi, ARIMITSU, Tadashi and MORI, Ken (1964): Clay minerals in sedimentary rocks of Paleogene Tertiary in Chikuho Coal Field, Fukuoka Prefecture, Japan (in Japanese with English abstract). *ibid.,* **32**, (6), 139–154, (8), 235–243, (12), 401–412.

MURATA, Shigeo (1961): Paleogene microbiostratigraphy of North Kyushu, Japan. *Bull. Kyushu Inst. Techn.,* [M. & N.S.], (7), (Spec. Publ.), 1–57.

NAGAHAMA, Haruo (1962): Some consideration on the Paleogeography of Kyushu in Tertiary Period (abstract, in Japanese). *Bull. Geol. Surv. Japan,* **13**, (10), 915.

——— (1963): The diagonal bedding of the lower Tertiary formations in the Joban Coal field, with special reference to the definition and classification of the diagonal bedding (in Japanese). *ibid.,* **14**, (7), 45–51.

——— (1964a): Diagonal bedding and sedimentation of the Tertiary System of Northwest Kyushu (in Japanese). *ibid.,* **15**, (8), 501–508.

——— (1964b): Tertiary paleocurrents in Northwest Kyushu with special reference to diagonal bedding. *Proc. Japan Acad.,* **40**, (7), 522–527.

——— (1964c): Relation between the azimuths of diagonal bedding pattern and isopack map pattern on the Fukui Formation of the Sasebo Coal Field, Nagasaki Prefecture. *Jour. Geol. Soc. Japan,* **70**, (828), 500–507.

——— (1965a): Transport directions of the sediments of the Matsushima Group and the basal part of the Nishisonogi Group, Sakito-Matsushima Coal Field, Nagasaki Prefecture, Kyushu, Japan, estimated from the diagonal bedding and maximum pebble size (in Japanese with English abstract). *Bull. Geol. Surv. Japan,* **16**, (4), 181–192.

——— (1965b): Diagonal bedding and accumulation of Tertiary sediments in northwestern Kyushu, Japan (in Japanese with English abstract). *Rept. Geol. Surv. Japan,* (211), 1–66, pls. 1–56.

NAGAHAMA, H., HIROKAWA, Osamu and ENDA, Tokiko (1970): History of researches on paleocurrent in reference to sedimentary structures—with paleocurrent maps and photographs of sedimentary structures—(in Japanese with English abstract). *Bull. Geol. Surv. Japan,* **19**, (1), 1–17, pls. 1–22.

NAGAO, Takumi (1924–1925): Geological age of the coal-bearing group of Kyushu, with remarks on the leading fossils (in Japanese). *Monthly Repts. Chikuho Coal-Miners Assoc.*, **20**, (246), 1079–1084, **21**, (249), 216–222.

——— (1925a): Leading zones of the coal-bearing groups of the Chikuho Coal-field (in Japanese). *ibid.*, **21**, (255), 803–811.

——— (1925b): Boundary between the coal-bearing deposits and the basement complex in the Chikuho Coal-field (in Japanese). *ibid.*, **21**, (255), 803–811.

——— (1925c): Stratigraphic order of succession of the Tertiary rocks in the Chikuho Coal-field (in Japanese). *ibid.*, **21**, (257), 1002–1012.

——— (1927a): Palaeogene sediments of Kyushu (in Japanese). *ibid.*, **23**, (272), 115–122.

——— (1927b): Geology of the Asakura Coal-field, Fukuoka Prefecture (in Japanese). *ibid.*, **23**, (279), 855–864.

——— (1927c): Palaeogene stratigraphy of Kyushu (17); the Chikuho Coal-field (in Japanese). *Jour. Geogr. Soc. Tokyo,* **39**, (465), 655–674.

——— (1927d): Palaeogene coal-bearing formations of the Island of Kyushu. *Sci. Repts., Tohoku Imp. Univ.* [II], **11**, (2), 1–21.

——— (1928a): Palaeogene stratigraphy of Kyushu (18); Fukuoka, Kasuya, Munakata and Asakura coal-fields (in Japanese). *Jour. Geogr. Soc. Tokyo,* **40**, (476), 7–23.

——— (1928b): Palaeogene stratigraphy of Kyushu (19); Palaeogeography of north Kyushu (in Japanese). *ibid.*, **40**, (468), 83–89.

——— (1928c): Palaeogene stratigraphy of Kyushu (20–23); Geohistory (in Japanese). *ibid.*, **40**, (469), 143–155, (470), 193–215, (471), 278–288, (472), 344–358.

——— (1928d): A summary of the Palaeogene stratigraphy of Kyushu, Japan, with some accounts of the fossiliferous zones. *Sci. Repts., Tohoku Imp. Univ.*, [II], **12**, (1), 1–10.

——— (1928e): Palaeogene fossils of the Island of Kyushu. *ibid.*, [II], **12**, (1), 11–40.

——— (1929): *Geological sheet map of the Chikuho Coal-field and explanatory text* (in Japanese). Chikuho Coal-Miners Assoc.

NODA, Mitsuo (1968): Peripheral faults in, and the geological structure of Kawara district, Chikuho Coal-field (in Japanese with English abstract). *Repts. Earth Sci., Kyushu Univ.*, (15), 1–6.

——— (1971): Geological structure of Yamada district in the Chikuho Coal-field (in Japanese with English abstract). *ibid.*, (16), 1–16.

OHARA, Jyonosuke (1960): The heavy minerals of the Takashima coal field, Kyushu, Japan (in Japanese with English abstract). *Jour. Soc. Mining Geol. Japan,* **10**, (42), 197–209.

——— (1961a): The heavy mineral of the Miike coal field, Kyushu, Japan (in Japanese with English abstract). *Sci. Repts., Fac. Sci. Kyushu Univ.*, [Geol.], **5**, (2), 62–79, pls. 1–2.

——— (1961b): The heavy minerals of the Sakito coal field, Kyushu, Japan (in Japanese with English abstract). *ibid.*, **5**, (3), 129–148, pls. 1–3.

——— (1961c): Heavy mineral associations in the Paleogene Systems of some coal fields, north Kyushu, Japan. *Mem. Fac. Sci., Kyushu Univ.*, [D], **11**, (3), 381–418, pls. 28–30.

——— (1962): The heavy minerals in the Tertiary coal fields in north Kyushu, Japan (in Japanese with English abstract). *Sci. Repts., Fac. Sci., Kyushu Univ.*, [Geol.], **6**, (1), 33–76, pls. 4–6.

OHARA, J., URATA, H. and OSHIMA, T. (1971): Paleogene formations in the northern area of Higashi-taku, Taku City, Saga Prefecture (in Japanese with English abstract). *Memorial vol., Prof. H. Matsushita,* 333–339, pl. 15.

OMARU, Ikuo (1966): Explanatory note of the geological map of the Tagawa district, Chikuho Coalfield (in Japanese). *Jour. Assoc. Coal-Mining Techn. Kyushu,* **19**, 93–97.

OTA, Yoshihisa (1953): The Mesozoic of the Kasagiyama–Wakino district, Fukuoka Prefecture (Geological studies on the Late Mesozoic in northern Kyushu, Part 1) (in Japanese). *Bull. Fukuoka Gakugei Univ.*, [N. S.], **2**, 206–213.

——— (1955): The Mesozoic stratigraphy and geologic structure in the Dobaru area, Kokura, Kyushu (ditto, Part 2) (in Japanese). *ibid.*, **5**, 29–39.

——— (1957): On the Mesozoic System in the northern Kokura and Yahata City, Fukuoka Prefecture (ditto, Part 3) (in Japanese). *ibid.*, **7**, 63–73.

——— (1958): The Mesozoic of the Tennobo–Nabikiyama area, Fukuoka Prefecture (ditto, Part 4) (in Japanese). *ibid.*, 8, 47–53.

——— (1960): The zonal distribution of the non-marine fauna in the upper Mesozoic Wakino Subgroup. *Mem. Fac. Sci., Kyushu Univ.*, [D], **9**, (3), 187–209.

OTUKA, Yanosuke (1939): Tertiary crustal deformation in Japan (with short remark on Tertiary paleogeography). *Jubilee Publ., Commem. Prof. H. Yabe 60th Birthday,* 1, 481–519.

OYAMA, Katsura, MIZUNO, A. and SAKAMOTO, Toru (1960): *Illustrated handbook of Japanese Palaeogene molluscs,* 1–244, pls. 1–71. Geol. Surv. Japan.

PETTIJOHN, F. J. (1956): *Sedimentary rocks,* 2nd ed., 1–718. Harper & Bros., New York.

POLDERVAART, Arie (1955): Zircon in rocks, 1, Sedimentary rocks. *Amer. Jour. Sci.,* **253**, 433–461.

——— (1956): Zircon in rocks, 2, Igneous rocks. *ibid.*, **254**, 521–154.

POTTER, Paul Edwin and PETTIJOHN, F. J. (1963): *Paleocurrents and basin analysis,* 1–296, pls. 1–30. Springer-Verlag, Berlin.

SAITO, Jinzo and OMARU, I. (1961): The relation of Kawara 8-shaku Coal seam and diastem in the upper part of Uwaishi Formation, Nogata Group, in Tagawa district, Chikuho Coal Field (in Japanese with English abstract). *Jour. Soc. Mining Geol. Japan,* **11**, (45–46, 10th Anniversary vol.), 263–268.

SAITO, Rinji (1953): On the correlation of Palaeogene formations of Kyushu and Hokkaido (in Japanese). *Bull. Geol. Com. Hokkaido,* (23), 1–14.

——— (1955a): On the correlation of Palaeogene formations of Hokkaido, Kyushu and Formosa (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* **23**, (1), 9–13.

——— (1955b): On the correlation of Palaeogene formations of Japan (in Japanese with English abstract). *ibid.*, **23**, (6), 215–220.

——— (1958): Problems of Palaeogene formations of Japan (in Japanese with English abstract). *Jubilee Publ. Commem. Prof. Jun Suzuki 60th Birthday,* 482–489.

SAKAKURA, Katsuhiko (1969): On the low-angle faults and strike-slip faults in the coal fields of Japan (in Japanese with English abstract). *Jour. Soc. Mining Geol. Japan,* **11**, (50), 595–609.

——— (1964): *Coal geology* (in Japanese), 1–218. Gijutsu-shoin, Tokyo.

SAKAMOTO, Hidehiko (1969): On the base and sedimentary cycles of the Miné group (in Japanese with English abstract). *Sci. Repts., Dept. Geol., Kyushu Univ.,* **10**, (1), 25–30.

SAKAMOTO, Michiyasu (1954): Depositional basin of the Palaeogene sediments in Ebitsu-Miyata area, Chikuho Coal Field (in Japanese with English abstract). *Jour. Mining Inst. Kyushu,* **22**, (12), 399–408.

SAKAMOTO, Takao (1957): Cycle of sedimentation in the later Paleozoic coal-bearing formation in the Kailan Coal-field, north China. 20ª. *Congr. Geol. Intern., Mexico 1956,* [5], Relacions entre Tectónica y Sedimentación, 375–378.

SATO, Yoshiaki (1969): Geological significance of zircon-garnet-tourmaline ratio of the Paleogene sandstones of northwest Kyushu, Japan. *Rept. Geol. Surv. Japan,* (235), 1–46.

SAWADA, Hideho (1958): *Explanatory text of the Hokushô Coal Field (Geological maps of the coal fields of Japan, II)* (in Japanese with English abstract), 1–130.

Geol. Surv. Japan.

SHIBAOKA, Michio (1958): Origin of coal-seam and cyclothem (in Japanese). *Jour. Mining Inst. Hokkaido*, **13**, (1), 1–17.

SHIMOGAWARA, Toshio (1963): Geology and structural development in the Yûbari Coalfield, Hokkaido, Japan (in Japanese). *Geol. Soc., Hokkaido Assoc. Coal-Mining Techn.*, Spec. Publ., (Studies of coal geology, 5), 1–243.

SHOJI, Rikii (1960): On the origin of the cyclothemic arrangement in the coal bearing strata of Japan (in Japanese with English abstract). *Jour. Geol. Soc. Japan*, **66**, (781), 660–674, (782), 733–741.

——— (1971): *Sedimentology* (in Japanese), 1–284. Asakura-shoten, Tokyo.

SHUTO, Tsugio (1958): A prolliminary note on the Medial and Late Caenozoic history in Kyushu, Japan (in Japanese). *"Shinseidai no kenkyu" (the Cenozoic Research)*, (28), 8–18.

——— (1963): Geology of the Nichinan area, with special reference to the Takachiho disturbance (in Japanese with English abstract). *Sci. Repts., Fac. Sci., Kyushu Univ.*, [Geol.], **6**, (2), 135–166, pls. 14–15.

——— (1969): The Takachiho and the Greentuff movement (in Japanese). *76th Congr., Geol. Soc. Japan, Symposium*; Problems on the greentuff, 15–21.

STOUT, W. E. (1931): Pennsylvanian cycles in Ohio. *Bull. Illinois State Geol. Surv.*, **60**, 195–206.

SUZUKI, Toshi (1892): 1 : 200,000 *Geological map and explanatory text of Fukuoka* (in Japanese). Geol. Surv. Japan.

——— (1893): 1 : 40,000 *Geological map of coal-fields and explanatory text of Buzen and Chikuzen provinces, Fukuoka Prefecture* (in Japanese). Geol. Surv. Japan.

——— (1894–1895): Geological reports of Buzen and Chikuzen coalfields (in Japanese). *Jour. Geogr. Soc. Tokyo*, **6**, (63), 126–135, (65), 259–268, (66), 315–325, (67), 377–383, (68), 436–444, (69), 486–493, (70), 540–549, (71), 602–611, (72), 655–665, **7**, (74), 73–82, (75), 133–137, (76), 183–190, (77), 249–256, (79), 357–366.

——— (1898): Geological report of the coal fields in Kurate, Onga and Kaho, Province of Chikuzen (in Jaapnese). *Bull. Geol. Surv. Japan*, 12, (2), 1–101.

——— (1899a): Coal field surrounding of Otsuji, Onga district, Province of Chikuzen (in Japanese). *Jour. Geogr. Soc. Tokyo*, 11, (122), 114–125, (123), 194–203.

——— (1899b): Coal field surrounding of Nishikawa, Kurate district, Province of Chikuzen (in Japanese). *ibid.*, 11, (124), 257–263, (125), 329–337.

——— (1899c): Geology of the Kaho Coalfield, Province of Chikuzen (in Japanese). *ibid.*, 11, (126), 423–427, (127), 505–511, (128), 560–566, (129), 612–630.

TAKAHASHI, Kiyoshi (1961): Pollen und Sporen des westjapanischen Alttertärs und Miozäns. *Mem. Fac. Sci., Kyushu Univ.*, [D], 11, (2) 151–255, (3), 279–345, pls. 13–27.

——— (1966): On the Onga subsidence.—with special reference to the problems from the pollen stratigraphic standpoint—(in Japanese with English abstract). *Bull. Fac. Liberal Arts, Nagasaki Univ.*, [N. S.], 6, 37–47.

——— (1967): Diagonal bedding of Paleogene sediments in northeastern Kyushu (in Japanese with English abstract). *ibid.*, 7, 33–40.

TAKAHASHI, Ryohei (1958): Die Beziehung zwischen der geologischen Struktur und der Inkohlung im Chikuho-Kohlenbecken, Japan. *Mem. Fac. Sci., Kyushu Univ.*, [D], 8, (1), 1–18.

——— (1959a): Über die geologischen Struktur "Amakusa-Typ" im Karatsu-Kohlenbecken, under Berücksichitung der Inkohlungsvorgänge (in Japanese with German abstract). *Jour. Soc. Mining Geol. Japan.*, 9, (37), 287–296.

——— (1959b): Die Beziehung zwischen der Inkohlung und der geologischen Struktur im Karatsu-Kohlenbecken, Saga Präf., Japan. *Mem. Fac. Sci., Kyushu Univ.*, [D], 9, (1), 1–15.

——— (1966): Explanatory note of the geological map of the Nogata district, Chikuho Coalfield (in Japanese). *Jour. Assoc. Coal-Mining Techn., Kyushu*, 19, 159–163.

TAKAHASHI, R. and OHARA, J. (1955): Neue Method der geologischen Aufnahme im submarinen Kohlenfelde—Petrographische Untersuchung der Sandstein des Takashima Kohlenfelds, Nagasaki Präfectur (in Japanese with German abstract). *Jour. Soc. Mining Geol. Japan*, **5**, (15), 33–47.

TAKAHASHI, R. and SHUTO, T. (1971): Cenozoic history in Kyushu (in Japanese). *Associated Congr., Japanese Earth Sci. Societies, 1971, Symposium*; Geological problems on the sea area surrounding of Kyushu, 5–10.

TAKAHASHI, R., URATA, H., OHARA, J., TOMITA, S. and OTA, Kazuya (1971): Geological structure of the Chikuho Coal-field interrupted from the new data (in Japanese with English abstract). *Sci. Repts., Dept. Geol., Kyushu Univ.*, **11**, (1), 115–132.

TASHIRO, Shuichi (1952): Deposition of coal and sedimentary cycle (in Japanese). *Jour. Geol. Soc. Japan*, 58, (682), 529–536.

TATEIWA, Iwao (1952): On the structures along the "Korean Trend (Chôsen hôkô)" (in Japanese). *Jour. Geol. Soc. Japan*, 58, (682), 236–241.

TEICHMÜLLER, Maries and TEICHMÜLLER, Rolf (1967): Diagenesis of coal (coalification). in Gunner LARSEN and George V. CHILINGAR [editors]: *Diagenesis in sediments (Developments in sedimentology, 8)*, 391–415. Elsevier, Amsterdam.

——— and ——— (1968): Cainozoic and Mesozoic coal deposits of Germany. in D. G. MURCHISON and T. S. WESTOLL [editors]: *Coal and coal-bearing strata*, 347–349. Oliver & Boyd, Edinburgh and London.

TERAOKA, Yoji (1970): Cretaceous formations in the Onongawa basin and its vicinity, Kyushu, southwest Japan (in Japanese with English abstract). *Rept. Geol. Surv. Japan*, (237), 1–84.

TESHIMA, Jun (Atsushi) (1954): Sedimentological studies on the coal-field (1), On the cyclothems observed in the Yubari Formation developed in the Heiwa area, the middle part of Yubari Coal-field (in Japanese with English abstract). *Jour. Geol. Soc. Japan*, **60**, (709), 428–435.

TOMITA, Suzuomi (1967): On the Ideyama Formation in the Tagawa district, Chikuho Coal-field, Fukuoka Pref. (A study of the Ideyama Formation in the Chikuho Coal-field, 1) (in Japanese with English abstract). *Sci. Repts., Fac. Sci., Kyushu Univ.*, [Geol.], 8, (3), 171–180.

——— (1968): On the Ideyama Formation in the Nogata district, Chikuho Coal-field, Fukuoka Pref. (ditto, 2) (in Japanese with English abstract). *ibid.*, 8, (4), 237–251.

——— (1970): Geology under the Kokura alluvial plain—with special reference to the Tertiary System of the Kokura Coal-field—. *Mem. Fac. Sci., Kyushu Univ.*, [D], **20**, (1), 1–16.

——— (1971): On the Ideyama Formation in the Iizuka district, Fukuoka Pref. (A study of the Ideyama Formation in the Chikuho Coal-field, 3) (in Japanese with English abstract). *Sci. Repts., Dept. Geol., Kyushu Univ.*, **10**, (3), 123–134.

TOMITA, Toru, KARAKIDA, Y. and MOMOI, *Hitoshi* (1957): The evolution and zircon of the Cretaceous granites, northern Kyushu (in Japanese). *Paps. Thermal Springs Research, Okayama Univ.*, (19), 27–32, 1 pl.

UDDEN, J. A. (1912): Geology and mineral resources of the Peoria Quadangle, Illinois. *Bull. U. S. Geol. Surv.*, (506), 1–103.

UEJI, Torajiro (1927): Igneous rocks and its influences to coal in the Chikuho Coalfield (in Japanese). *"Suiyo-kai-shi" (Trans. Mining & Metal. Assoc., Kyoto Imp. Univ.)*, 5, (9).

——— (1932): On the bronzite andesite in the Chikuho Coalfield (in Japanese). *"Chikyu"*, **17**, (4), 243–257.

——— (1940): A study on the intrusive rocks into the coal-seams of the Chikuho Coalfield (in Japanese). *"Suiyo-kai-shi"*, **10**.

URATA, Hideo (1961): On the stratigraphy of the Sangun metamorphics in Inunaki area, Fukuoka Prefecture (in Japanese with English abstract). *Repts. Earth Sci., Kyushu Univ.*, (7), 57–68.

VAN KREVELEN, Dirk Willer (1961): *Coal*, 1–514. Elsevier, Amsterdam.

VAN KREVELEN, D. W. and SCHUYER, Johannes (1957): *Coal science; Aspect of coal constitution*, 1–352. Elsevier, Amsterdam.

WANLESS, Harold R. and WELLER, J. Marvin (1932): Correlation and extent of Pennsylvanian cyclothems. *Geol. Soc. Amer. Bull.*, **43**, 1003–1016.

WANLESS, H. R. and SHEPARD, Francis P. (1936): Sea level and climatic changes related to late Paleozoic cycles. *ibid.*, **47**, 1177–1206, 2008–2014.

WELLER, J. Marvin (1930): Cyclical sedimentation in the Pennsylvanian period and its significance. *Jour. Geol.*, **38**, (2), 97–135.

——— (1931): The conception of cyclical sedimentation during the Pennsylvanian period. *Illinois State Geol. Surv. Bull.*, **60**, 163–177.

WELLER, H. E. and MURRAY, H. H. (1957): Base-level control patterns in cyclothemic sedimentation. *Amer. Assoc. Petrol. Geol. Bull.*, **41**, 1985–2011.

WESTOLL, T. Stanley (1968): Sedimentary rhythms in coal-bearing strata. in D. G. MURCHISON and T. S. WESTOLL [editors]: *Coal and coal-bearing strata*, 71–103. Oliver & Boyd, Edinburgh and London.

YABE, Hisakatsu (1917): Problems concerning the geotectonics of the Japanese Islands; Critical reviews of various opinions expressed by previous authors on the geotectonics. *Sci. Repts., Tohoku Imp. Univ.*, [II], 4, 75–104.

——— (1921): Recent stratigraphical and paleontological studies of the Japanese Tertiary. *Spec. Publ. Bernice P. Bishop Museum*, (7), 775–796.

——— (1926): A brief summary of the Tertiary and post-Tertiary history of Kyushu (in Japanese). *Geogr. Review, Japan*, **2**, (1), 1–16.

YABE, H. and AOKI, Renjiro (1924): Correlation of the Cenozoic of the Japanese Islsands (in Japanese). *Tohoku Imp. Univ. Inst. Geol. & Paleont., Contrib.*, (4), 1–14.

YAMASAKI, Tatsuo (1959a): Geologic structure and its relation to the volcanic activities of the Karatsu Coal-field, Kyushu (in Japanese). *Repts. Research Inst. Industsrial Sci., Kyushu Univ.*, (26), 33–54.

——— (1959b): Stratigraphic relation between the Paleogene Kishima and Nishisonogi groups, Kyushu (in Japanese). *ibid.*, (26), 74–83.

YAMASAKI, T., NODA, M. and TANEDA, Sadakatsu (1956): Geology of the envirous of Mt. Sarakura, Yahata City (in Japanese). *Techn., Repts., Kyushu Univ.*, **29**, (1), 63–73.

YAMASAKI, T., MATSUMOTO, Yukio and MORINAGA, Yoichiro (1960): Stratigraphic relation between the Paleogene Ôchi and Kishima groups in northern Karatsu Coal-field, Kyushu (in Japanese). *Repts., Research Inst. Industsrial Sci., Kyushu Univ.*, (27), 54–65.

Appendix

Alphabetical index of place names with Japanese writing

Akaike	赤池	Kakihara	柿原
Akasaka	赤坂	Kami-imato	上今任
Akisato	秋里	Kami-ita	上伊田
An'ya	安屋	Kami-kizuki	上木月
Arate	新手	Kami-ton'no	上頓野
Asakura	朝倉	Kami-yamada	上山田
Ashiya	芦屋	Kamizakai	上境
Benjyo	弁城	Kamoo	鴨生
Chikuho'	筑穂	Kanakuni	金国
Chikuho	筑豊	Karatsu	唐津
Chikushi	筑紫	Katsuno	勝野
Chûganji	中元寺	Kasagi-yama	笠置山
Daibu	大分	Kawara	香春
Dokai Bay	洞海湾	Keisen	桂川
Dotenouchi	土手ノ内	Kimigahata	君ケ畑
Dôzen	道善	Kodaiji-san	孔大寺山
Ebitsu	海老津	Kôjaku	上津役
Eimanji	永満寺	Kokura	小倉
Fukuchi-yama	福智山	Komaki	小牧
Funao	船尾	Kominé	小嶺
Futajima	二島	Kotake	小竹
Ganda	感田	Koyanose	木屋瀬
Genkai	玄海	Kumagahata	熊ケ畑
Habu	垣生	Kurate	鞍手
Hadaka	羽高	Kurosaki	黒崎
Hikosan (River)	彦山 (川)	Kusuhashi	楠橋
Hirabaru	平原 (田川市)	Kuwabara	桑原
Hirabaru	平原 (田川郡赤池町)	Masaki	真崎
Hirao	平尾	Miike	三池
Hirao-dai	平尾台	Miyata	宮田
Hojyo	方城	Mizumaki	水巻
Honami	穂波	Muroki	室木
Ideyama	出山	Mutsugatake	六ケ岳
Iizuka	飯塚	Naijyu	内住
Ikari	伊加里	Nakaizumi	中泉
Ikata	伊方	Nakama	中間
Imato	今任	Namazuta	鯰田
Imatobaru	今任原	Naratsu	南良津
Inatsuki	稲築	Naraura	南良浦
Inokuni	猪国	Natsuyoshi	夏吉
Inunaki	犬鳴	Ninobu	新延
Irimizu	入水	Nishi-kawa	西川
Ita	伊田	Nobu	野面
Iwasaki	岩崎	Nogata	直方
Kaho	嘉穂	Nyoraida	如来田

Oka	岡
Okagaki	岡垣
Onga	遠賀
Onga (River)	遠賀(川)
Onizu	鬼津
Ooshiro	大城
Ooto	大任
Orio	折尾
Otsuji	大辻
Ozaki	尾崎
Sangun	三郡
Sarakura-yama	皿倉山
Sasada	笹田
Shimazu	島津
Shimo-imato	下伊田
Shimo-yamada	下山田
Shimozakai	下境
Shin-nyu	新入
Shonai	庄内
Soeda	添田
Tagawa	田川
Takaé	高江
Takakura	高倉
Takuma	宅間
Ton'no	頓野
Tsutsuno	筒野
Wakamatsu	若松
Wakamiya	若宮
Yahata (or Yawata)	八幡
Yakuwoji	薬王寺
Yamano	山野
Yamaura	山浦
Yasaunaga	安永
Yoshikuma	吉隈
Yurino	百合野