Stratigraphic Notes on the Kumano Group : A Study of the Tertiary Formations of the Kumano Coal-field in the Kii Peninsula, Southwest Japan, Part 1

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Stratigraphic Notes on the Kumano Group

(A Study of the Tertiary Formations of the Kumano Coal-field in the Kii Peninsula, Southwest Japan, Part 1)

Kazutoyo CHIJIWA and Suzuomi TOMITA

Abstract

A thick series of the Miocene sediments, about 1800 m in thickness, is widely distributed in the Kii Peninsula, Southwest Japan, and is called the Kumano Group. This group lies on the Shimanto Supergroup with an unconformity and comprises three formations, namely the Onuma, the Koguchi and the Mitsuno Formation in ascending order. This group is characterized by a noticeable variation of lithological facies, but generally represents an upward-coarsening sedimentation. The lowermost formation, Onuma, is limitedly existent to the northern half of the area in which this group is distributed. Workable coal seams mined formerly are inserted in the lowermost horizon of the Mitsuno Formation. Based on the lithofacies, the Koguchi Formation is divided into three members which are found in the whole distributed area of the formation, whereas the Mitsuno Formation is subdivided into four members in the northern district and into seven members in the southern one, respectively.

The sedimentary basin of the Kumano Group had been initially generated under offshore circumstance, and, hence forward, had continuously been under the progradational one. In the later stage of development of the basin, however, it was separated into northern and southern districts. The clastics of the Mitsuno Formation were, in the northern district, accumulated in lagoonal swamps in which coaly matter or fluviatile sediments deposited, but, in the southern one, the littoral environments had been persisted and thick beach sediments or shallow marine sediments were formed.

Introduction

Thick sediments of the Kumano Group is distributed in most part of the southeastern region of the Kii Peninsula. Much attention had been paid to this group because it is one of few coal-fields rarely found in the Outer Zone of Southwest Japan, in which marine sediments are generally predominated. It is also noticeable that several epithermal vein-type ore deposits closely related with the Kumano acidic rocks are discovered in this group, and both resources of coal and mineral were formerly produced.

Although the geological and economical reports on the Kumano Group and related rocks were given by many authors, several important problems like a consolidated stratigraphy of the Kumano Group applicable to the greater part of distributed area have been left unsettled. It is needless to mention that the

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lithological and biostratigraphical division of sediments and the tracing of each division are indispensable to critical interpretation of tectonic or environmental history of such thick sediments as the Kumano Group. Clarification of the geohistory of Kumano Group has also a close relationship to the understanding of other questions including the sedimentary environment of coal-formation in the Outer Zone of Southwest Japan. It remains, furthermore, to be proved that the degree of coalification attains to the anthracite stage for the relatively younger sediments, middle Miocene in age.

We re-examined the Kumano Group from the stratigraphical and sedimentological viewpoints with special reference to the lithological succession and geohistory of coal-bearing strata in and around the Kumano Coal-field. Especially K. CHIJIWA, one of the co-authors, has been engaged in the field research of this area as a part of graduate work. As the first report of this study, the comments are given to the results obtained on stratigraphy, lithology, sedimentary structure, and so on, and the environmental and the geotectonical history of the sedimentary basin of this group including coal-bearing formation will be discussed in another paper.

I. Brief note on the stratigraphy

The studied area covers the central and northern regions of the distributed area of the Kumano Group with the exception of the southernmost part. The Kumano Group is distributed in a really wide area covering three prefectures, the Nara, Mie and Wakayama in the southeastern region of the Kii Peninsula, and stretches about 80 km northeast to southwest with the width of 5 to 25 km. This group overlies the Shimanto Supergroup with a distinct unconformity and is overlain by the Kumano acidic rocks. The total thickness of the group is about 1800 m in general, but may exceeds 2000 m in the southernmost area. The Kumano Group is dated to the middle Miocene by the paleontological evidence (SUZUKI and ITO, 1946).

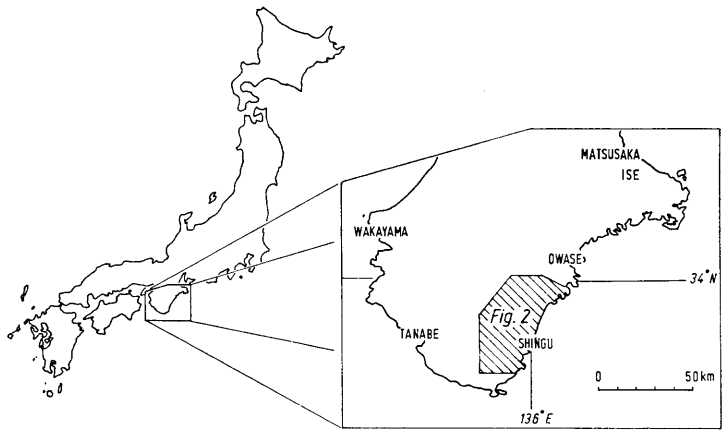

Fig. 1. Index map.

The basement Shimanto Supergroup is distributed in the Shimanto terrane which is separated into several belts bounded by some remarkable tectonic lines generally running in parallel with each other from east to west. Its northernmost part is the Hidakagawa belt composed of the Mesozoic Hidakagawa Group (SUZUKI, 1938). The southernmost part of this belt is located in the north of surveyed area. The Hidakagawa Group is composed mainly of silicified shale-rich formations and shows an eugeosynclinal facies. Broad lands spreading to the south of Hidagagawa belt beyond the Gobo-Hagi Tectonic Line is so-called the Muro belt, consisting of the Tertiary Otonashigawa and Muro groups. The Otonashigawa Group (Hatenashi Research Group, 1977), formerly called the Otonashigawa-muro Subgroup, outcrops in a narrow area of the Otonashigawa subbelt between two major faults, the Gobo-Hagi Tectonic Line and the Hongu Fault, the latter of which separates this subbelt from the main part of Muro belt. This group comprises upward-coarsening sequence of flysh-type clastics, and may be assigned to the Eocene (SUZUKI *et al.*, 1979). The greater part of Muro belt is occupied by the Muro Group (SUZUKI *et al.*, 1979), which consists mainly of flysh-type

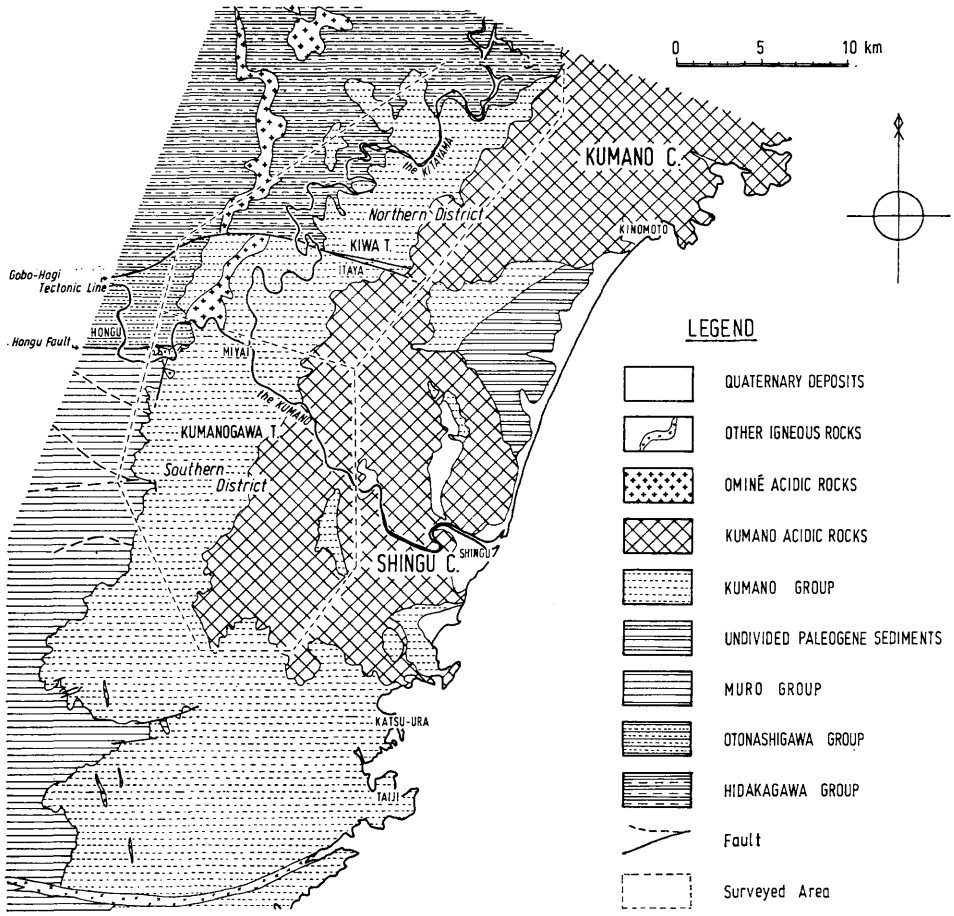

Fig. 2. Generalized geological map.

thick deposits ranging from the upper Oligocene to the lower Miocene (HARATA, 1964 and SUZUKI *et al.*, 1979).

Of the igneous rocks, the Kumano acidic rocks and Omine acidic rocks are distinctive in this area. The former covers and intrudes into the Kumano Group and forms a sharp mountainous area of about 900 m or more above the sea level. The Kumano acidic rocks are composed of various complex of acidic igneous rocks such as rhyolitic lavas, crystalline tuffs and thick masses of granite porphyry (ARAMAKI and HADA, 1965 and ARAMAKI, 1965). They are also related to the ore deposits, some of which were flourishingly worked by several mines up to few years ago. The latter, Omine acidic rocks, is mainly quartz porphyry and granitic rocks intruded into the Hidakagawa and a part of the Kumano Group in this area, and outcrops nearly along the axis of Omine Mountain Range running north to south in the central part of the Kii Peninsula. On the basis of K-Ar dating, the igneous activities of both acidic rocks are regarded to be immediately after the deposition of the Kumano Group, the middle Miocene in age (MITI, 1979). Besides the above mentioned igneous bodies, several dykes of quartz porphyry are met with, which are found in the neighbourhood of the riverside of the Kumano and run generally northwest to southeast with 5 to 20 m in width.

The distribution of all the stratigraphic units and igneous bodies is shown in Fig. 2.

II. Summary of geological structure

The formations belonging to the Shimanto Supergroup show complicated geological structures. The general trends of the northern two belts, the Hidakagawa and the Otonashigawa belt, are in accord with that of the Outer Zone of Southwest Japan. The formations in these belts were folded in various degree and crop out repeatedly by several faults. The Muro Group, which was cut by many faults of various trends and was disturbed by dominant foldings, forms a major synclinorium trending northeast to southwest with westward plunging.

Contrary to the complicated structure of the basement formations, the Kumano Group is characterized by a gentle geological structure. The members of this group run along the mass of Kumano acidic rocks as if the former surrounds the latter with gentle inclination. That is to say, strike of WE~N45°E with dip of 10–20°S in the northern district*, and strike of N45°E~NS with dip of 10–25°E in the southern one. They show a semi-trough structure stretching NNE–SSW (MATSUSHITA, 1971). In the southern part of northern district, the formations are cut by many minor faults, some of which are accompanied with ore deposits of mineralized zone.

The two major tectonic lines, the Gobo-Hagi Tectonic Line and the Hongu

* For convenience of description, the northern half of studied area limited by the Kumano River is called the northern district, and the south side of the same river is named the southern district in this paper (Fig. 2). The south of studied area in the distribution of the Kumano Group is so-called southernmost district in the same manner.

Fault, run roughly parallel to each other. The latter is a great reverse fault with a wide shear zone and is concealed by the sediments of Kumano Group. The former, on the other hand, is a thrust zone by which Mesozoic terrane is separated from the Tertiary one. The Itaya Fault, a part of the Gobo-Hagi Tectonic Line, runs easterly and cuts also the members of Kumano Group at the central part of the northern district. Judging from dislocation of the Kumano Group, the Itaya Fault may split into two faults at the north of Itaya.

III. Stratigraphy of the Kumano Group

I. Historical review

A series of thick sediments including workable coal in the Kii Peninsula have been briefly reported since 1890's. OTSUKI (1903) surveyed this area to draw the geological sheet map of 'Nachi (1:200,000)' and regarded the coal-bearing formation as the Miocene sediments. Afterwards, IIZUKA (1931) and SADO (1932) studied this series and related rocks mainly in the northern part of the distributed area of the sediments, and SUZUKI (1934) and others reported on the same series in the southern regions. These thick sediments was called the Miyai Series by SUZUKI after the name of locality where is a center of coal production. He divided the Miyai Series into four formations by lithofacies. SUZKI and ITO (1946) recognized, furthermore, that the thick formations, so-called the Shimosato Series, is overlain by the Miyai Series with an unconformable relationship. TAKEICHI (1950) studied the Kumano Coal-field and divided the Miyai Group into three formations. Both of the Miyai and Shimosato Series in the southernmost district were studied by MIZUNO (1953 and 1957) who was positive in denying the relationship of unconformity between the Miyai and the Shimosato Series. MURAYAMA (1954) surveyed these sediments in the vicinity of Shingu City and classified into two sequences.

The Kumano Group was settled by TANAI and MIZUNO (1954) for the succession including the Shimosato and Miyai series. They established also several members in the formations of the Kumano Group in the vicinity of Kumano Coal-field based on the lithological facies. Because the northern extension of this group, on the other hand, is situated in a mine-field of ore deposits of epithermal vein-type, exploration and development of deposits had been continued till 1978 by the Kishu Mine, and several information on the geology and ore deposits were published by the research group of the same mine (SATO, 1958; SAEKI, 1961; ONO, 1961·1969 and 1971; ABE and ONO, 1967; and SAEKI and KOTO, 1972). In the vicinity of Kishu Mine, the Kumano Group falls into four formations, the Onuma, Taketo, Itaya and Ohkochi formations in ascending order, of which the Itaya Formation is further separated into four members for convenience of exploration.

Table 1 shows schematically a comparison of stratigraphical classification of the Kumano Group published up to 1979.

Table 1. Subdivisions of the Kumano Group

SUZUKI (1934)		TAKEICHI (1950)	MURAYAMA (1954)	TANAI & MIZUNO (1954)		SAEKI & KOTO (1972)	CHIJIWA & TOMITA (1980)		
								South	North
Miyai Series	Uppermost	J M.	E	Mitsuno Formotion	Hyoren M.	Ohkochi F. (A)	Mitsuno Formation	Hyoren Member	Ohkochi Member
		I M.	D		Oyama Member			Oyama Member	
		H M.			Kowase M.	B		Kowase Member	Upper Taniguchi M.
		Shiko F. G M.	Shiko F. C		Akagi Member			Akagi Member	
	Upper part	F M.			Shiko Member	C		Shiko Member	Lower Taniguchi M.
		E M.	B		Taniguchi M.	Itaya F. D		Taniguchi Member	
		A–D M.	A		Miyai coal-bearing M.	E		Miyai coal-bearing Member	
	Middle part	Koguchi Formation	Koguchi F.	Koguchi F.	Wada Member	Taketo F.	Koguchi F.	Koguchi Member	
					Takimoto M.				
					Wadagawa M.				
					Kamazuka M.				
	Lower part	Matsuhata F.			Shikiya M.			Shikiya Member	
					Ohara Member	Onuma F.		Ohara Member	Onuma F.

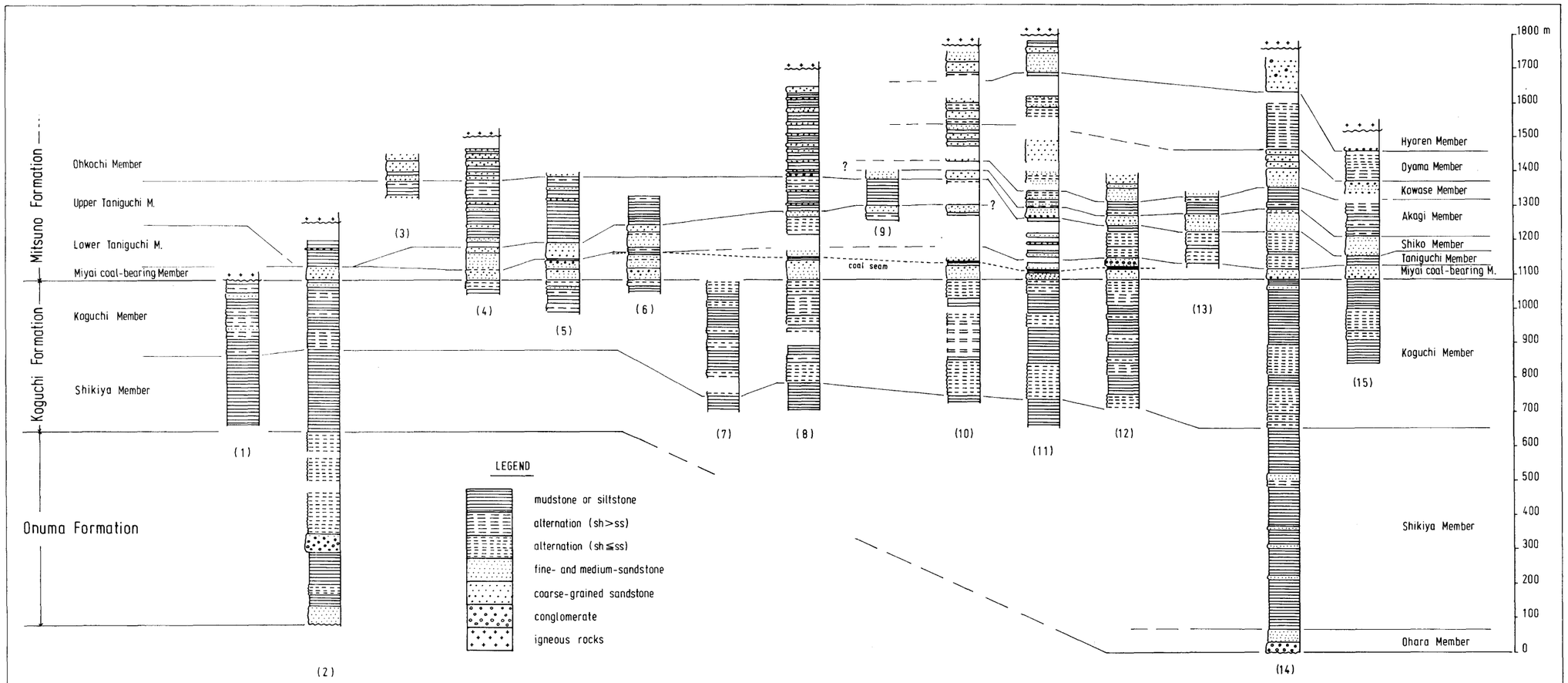

Fig. 3. Comparative columnar sections of the Kumano group.

(1) Hiratani
(2) Komatsu—Maruyama
(3) Iruka
(4) Itaya
(5) Yunoguchi
(6) Opposite side of Kitayama at Kuju
(7) Kawane
(8) Ohkochi
(9) Jyosen
(10) Along the left side of Kumano River
(11) Along the right bank of Kumano River
(12) Taniguchi
(13) Nagai
(14) West of Wada—Hyoren
(15) Kamazuka

II. Division and definition

The present new classification of the Kumano Group is shown in Table 1. This group is roughly divided into three formations based on the lithological facies, namely the Onuma, Koguchi and Mitsuno formations in ascending order.

The lowermost Onuma Formation is limited in distribution to the northern district. The Koguchi Formation is further subdivided into three members by lithofacies distinguishable throughout the whole area. However, for the Mitsuno Formation four members are distinguished in the northern district and seven in the southern one, since the facies and successions of lithology alter distinctively or sharply between both districts. Seven members in the latter district correspond generally with those defined by TANAI and MIZUNO (1954). Each member of the Mitsuno Formation settled in the northern district, on the other hand, differs somewhat from the sequences divided by the research group of Kishu Mine. That is, the succession called the Ohkochi Formation by SATO and others (SATO, 1958) belongs to the uppermost member of the Mitsuno Formation, because both of the thickness and the geographical distribution of this sequence are poor as compared with other stratigraphic units settled as one formation.

III. Descriptive notes on each formation

A. Onuma Formation (SATO, 1958)

The basal part of the Onuma Formation is massive fine-grained sandstone lying unconformably on the basement Hidakagawa and Otonashigawa Groups. The lower part of this formation consists of massive mudstone of various thickness.

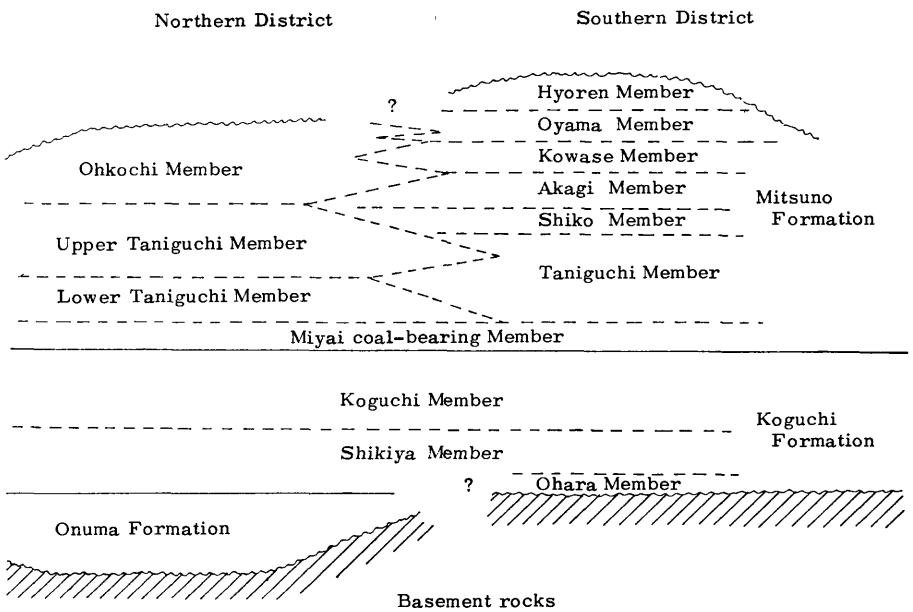

Fig. 4. Simplified relationship of each member.

Furthermore, this formation contains a remarkable pebble and/or cobble conglomerate in the middle part and alternation of sandstone and mudstone in the upper (Fig. 5). The total thickness of the formation attains about 600 m in the Komatsu-Kawabata area. Some of fossils of gastropods including *Turritella* sp. are found in the basal sandstone bed at Komatsu. Black mudstone of the lower part is hard and dense with rare intercalation of very fine sandy laminae. This muddy rock is quarried as 'Nachi-guro' stone at several localities. Both of the basal sandstone and black mudstone are hardened by silicification. Conglomerate is massive but is partially stratified with intercalation of thin mudstone

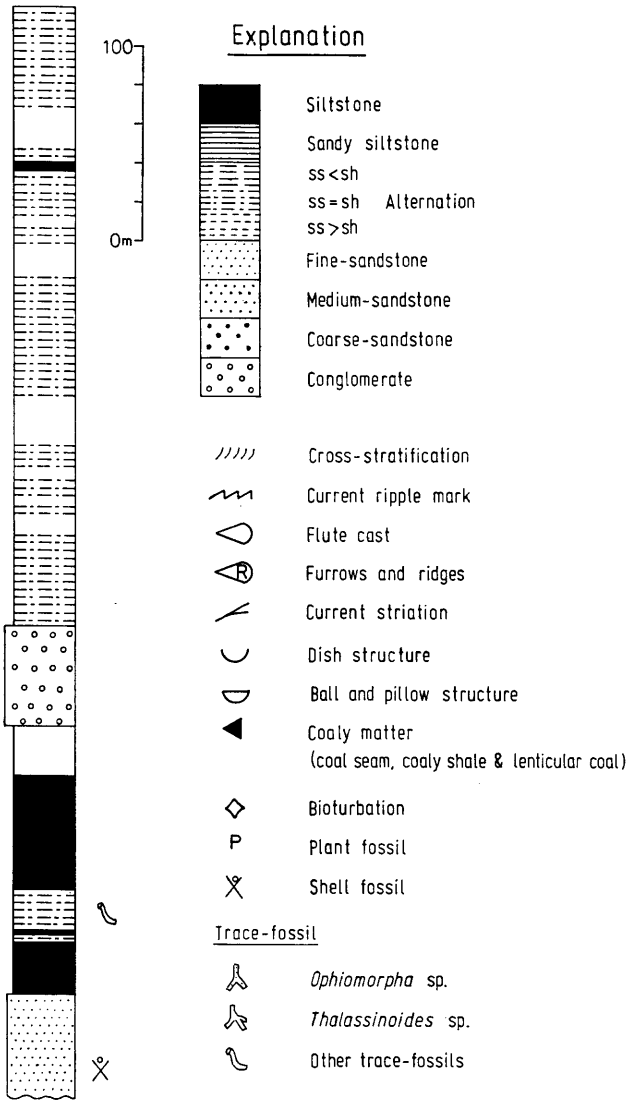

Fig. 5. Type section of the Onuma Formation.
(Explanation is also applicable to Figs. 6 & 7)

layers. Graded bedding is found near the uppermost horizon of conglomerate. Pebbles of conglomerate are subangular to subrounded in shape, and granule to boulder in size, and are mainly composed of sandstone with siltstone, volcanic and tuffaceous rocks. Alternation of sandstone and mudstone, the uppermost sequence of the Onuma Formation, show well stratification with sharp boundaries and has many pipe-shaped trace-fossils at the bases of sandstone layers.

The Onuma Formation is thinning out towards the south.

B. Koguchi Formation (TANAI and MIZUNO, 1954)

The Koguchi Formation is the same formation which was called the Taketo Formation by the research group of Kishu Mine in the northern district*.

In the southern district, the Koguchi Formation lies directly on the basement Muro Group with an unconformity, while this formation develops conformably on the Onuma Formation in the northern district. This formation is thickened to southwards from 450 m to 1100 m, and is fallen into three members, the Ohara, the Shikiya and the Koguchi Member in ascending order.

1. Ohara Member (TANAI and MIZUNO, 1954)

The Ohara Member of about 60 m thick consists of massive conglomerate in the lower part and fine- and medium-grained sandstone in the upper one. The former covers unconformably the basement Muro Group as the basal conglomerate in the southern district, and is composed of pebble to boulder of various size, round and/or subround gravels, containing mainly sandstone with siltstone, volcanic rocks and chert. Maximum size of boulder attains about 70 cm. Clastic rock of this member is weakly silicified. The Ohara Member is indistinct in the northern district.

2. Shikiya Member (TANAI and MIZUNO, 1954)

Massive and/or stratified and black or dark mudstone of 240–600 m thick is recognized upon the Ohara Member. It contains intermittently ill-sorted fine sandstone layers, some of which show a graded bedding and scarcely have pipe-shaped trace-fossils on the basal plane. The thickness of this member varies noticeably between northern and southern districts (Figs. 3 and 6). A remarkable slump structure is found in the uppermost horizon of this member near Taketo of the northern district.

Some species of marine microfossils are reported from this member (IKEBE *et al.*, 1975 and MITI, 1979).

3. Koguchi Member** (newly defined)

i) *Type locality*: Koguchi, Kumanogawa-cho, Wakayama Prefecture.

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* In the southernmost district, the extension of this formation is called as the Shikiya Formation (IKEBE *et al.*, 1975; and others). Since the village of Shikiya is located in the distributed area of basement Otonashigawa Group at the west of Miyai, it is unsuitable for the name of this formation.

** 小口層 (模式地: 和歌山県東牟婁郡熊野川町小口)

Fig. 6. Type section of the Koguchi Formation.
(1) Northern district (2) Southern district

ii) *Distribution*: Koguchi–Yanahara–Kawane–Itaya and Hiratani.

iii) *Thickness*: 200–400 m.

In the southern district, the Koguchi Member corresponds to the upper four members of Koguchi Formation settled by TANAI and MIZUNO. These four members are obscure in the northern district, because their lithological facies varies irregularly along the strike-side. Then, in this paper, they are regarded as a single unit, the Koguchi Member, throughout the whole area.

This member is composed mainly of massive siltstone and alternation of well-bedded sandstone and mudstone. In the northern district, well foliated shale, thin-bedded sandstone alternated with mudstone and platy fine- and medium-grained sandstone are observed. Sometimes, shale includes concretions and coaly matters of various modes such as lenticular seam and thin discontinuous streak. Dish structure is rarely found in stratified sandstone. On the other hand, coaly layer has not yet been recognized in this member in the southern district. A small vertical sandstone dyke trending east to west with a width of 5 cm intersects a part of this member at Kamazuka, the southern middle of the southern district.

C. Mitsuno Formation (TANAI and MIZUNO, 1954)

The upper half of Kumano Group, namely the Mitsuno Formation of about 700 m or more in thickness, is composed of thick sediments containing arkosic medium- and coarse-grained sandstone, platy or foliated shale and alternation of sandstone and mudstone. The Kumano acidic rocks overlie on various horizons of this formation. The Mitsuno Formation is distinguished from the underlying two formations of this group by several sedimentary features as follows:

a) A good deal of coaly matters is found as coal seam, coaly shale, patches and fragments. Especially, workable seam mined formerly is contained at the lowermost horizon.

b) Various species of trace-fossils and plant fossils are abundantly found. The former is available for indicator of sedimentary environments.

c) Many kinds of sedimentary structures including diagonal bedding are recognized.

d) Coarse-grained clastics are dominant.

As mentioned previously, the Mitsuno Formation is divided by TANAI and MIUZNO (1954) into seven members in the southern district. But, in the northern district, four members newly defined on the basis of lithological characteristics distinctly cover the most of this district. Of these members, the lowermost Miyai coal-bearing Member is common to both districts. In the northern district, the other three members are quite well distinguished each other, but discrimination of these members becomes gradually impossible toward the south, especially near the Mie-Wakayama prefectural border. Likewise, in the southern district the six members except the lowermost one are abruptly indistinguishable from each other in lithofacies towards the border of prefectures (Figs. 3 and 7).

The interfingering relationships of each member between both districts are

schematically shown in Fig. 4.

1. Miyai coal-bearing Member (TANAI and MIZUNO, 1954)

Among the members of the Mitsuno Formation, the Miyai coal-bearing Member characterized by workable coal seam is only a member which can be continuously traced throughout the whole districts. This member consists of massive and/or bedding arkosic coarse- and medium-grained sandstone intercalating pebbles of chert, sandstone, siltstone and crystalline schist, the last of which may be derived from the north of Shimanto terrane. One or two coal seams are noticeable and workable in a restricted area from Nagai to Yunoguchi, the middle of the southern district to the central part of the northern one. Coal rank reaches to the anthracite stage. The Miyai Member has a thickness of 30–80 m.

2. Taniguchi Member (TANAI and MIZUNO, 1954)

The alternation of 25–140 m lying on the Miyai coal-bearing Member in the southern district are called the Taniguchi Member. It is composed of thinly alternated bed of sandstone and mudstone with intercalation of massive siltstone at Koguchi near the center of this district, but alternation of thick beds, several meters in thickness, of medium- or coarse-grained sandstone and shale develops at Miyai near the junction of two rivers, the Totsugawa and the Kitayama.

The Taniguchi Member has about 25 m in thickness at Kamazuka, and increases gently its thickness towards the north, attaining about 140 m at Miyai. The grain-size becomes coarse towards the same direction.

3. Shiko Member (TANAI and MIZUNO, 1954)

In the southern district, the third member is called the Shiko Member which consists of massive and stratified arkosic or quartzose medium- and coarse-grained sandstone intercalating thin shale, and attains 30–60 m in thickness. Very thin coaly bands of 2–3 mm in thickness are recognized in the intercalations of shale at Nagai.

Lithological feature of sandstone bears resemblance to that of the Miyai coal-bearing Member. This is also characterized by development of parallel and diagonal stratification and long pipes of trace-fossil. Sometimes, calcareous nodules and pseudo-nodules are found in sandstone strata near Shiko on the riverside of the Kumano.

Minor intraformational foldings are rarely observed.

4. Akagi Member (TANAI and MIZUNO, 1954)

The fourth member in the southern district is composed of massive or stratified siltstone or sandy siltstone containing thin sandstone layer and some plant fossils. This member thickens northwards from 0 m to 120 m. Intercalation of sandstone layer increases gradually its thickness and frequency upwards, and finally changes to thick massive sandstone of the overlying Kowase Member. Discontinuous thin coal layer with a thickness of several centimeters is found at Taniguchi, northern central of this district.

5. Kowase Member (TANAI and MIZUNO, 1954)

Massive arkosic coarse- and medium-grained sandstone with some silty layers is remarkable in the fifth member in the southern district. Sandstone shows frequently conglomeratic lithofacies, containing lenticular pebble conglomerate with noticeable horizontal and vertical variations in grain-size. Graded bedding is sometimes found. Such characteristic sedimentary structures as large-scale parallel lamination, planar- and trough-type cross-stratification and ripple drift lamination are also exhibited in this member. In places, bioturbite is present in silty layer which has a homogeneous bedding. Several sole marks are rarely recognized on the bottom of massive sandstone. Silty or shaly bed is visible towards the north. The Kowase member has a thickness of about 160 m at Hitari, northernmost of this district, and is thinning to the south, about 40 m in the central part.

6. Oyama Member (TANAI and MIZUNO, 1954)

A considerable lateral variation in lithofacies is observed in the Oyama Member in the southern district. This member consists of sandy siltstone and alternation of thin-bedded silstsone and sandstone at Oyama, near the southern part, but is composed of pebbly coarse-grained sandstone and siltstone at Hitari in the northern part in this district. Various sedimentary structures are recognized in alternated bed. Silty bed has some plant remains and thin lenses or banded streaks of coal. Towards the northernmost part of this district, the boundary between this member and the underlying Kowase Member becomes obscure.

The Oyama Member is 100–180 m in thickness.

7. Hyoren Member (TANAI and MIZUNO, 1954)

The uppermost division of the Mitsuno Formation in the southern district is loose massive arkosic medium- and very coarse-grained sandstone containing sometimes mudstone and conglomerate. Sandstone, which is ill-sorted and shows distinctive variation in grain-size, contains lenses and patches of coal and has rarely boulders of mudstone.

The top of this member is unknown due to the covering of Kumano acidic rocks. The maximum thickness of this member is estimated about 100 m.

8. Lower Taniguchi Member* (newly defined)

i) *Type locality*: Yakushi, Kiwa-cho, Mie Prefecture.
ii) *Distribution*: Yakushi–Yunoguchi–Itaya and Sobo.
iii) *Thickness*: 0 to about 100 m.

In the northern district, a sequence composed of massive and/or stratified medium- and coarse-grained sandstone, mudstone and interbedded sandstone and mudstone lies on the Miyai coal-bearing Member. The Lower Taniguchi Member is characterized by visible lateral variation of lithofacies and by variation in thickness ranging from 0 m to 100 m. Near Yakushi, southernmost part of this

* 下部谷口層（模式地：三重県南牟婁郡紀和町薬師）

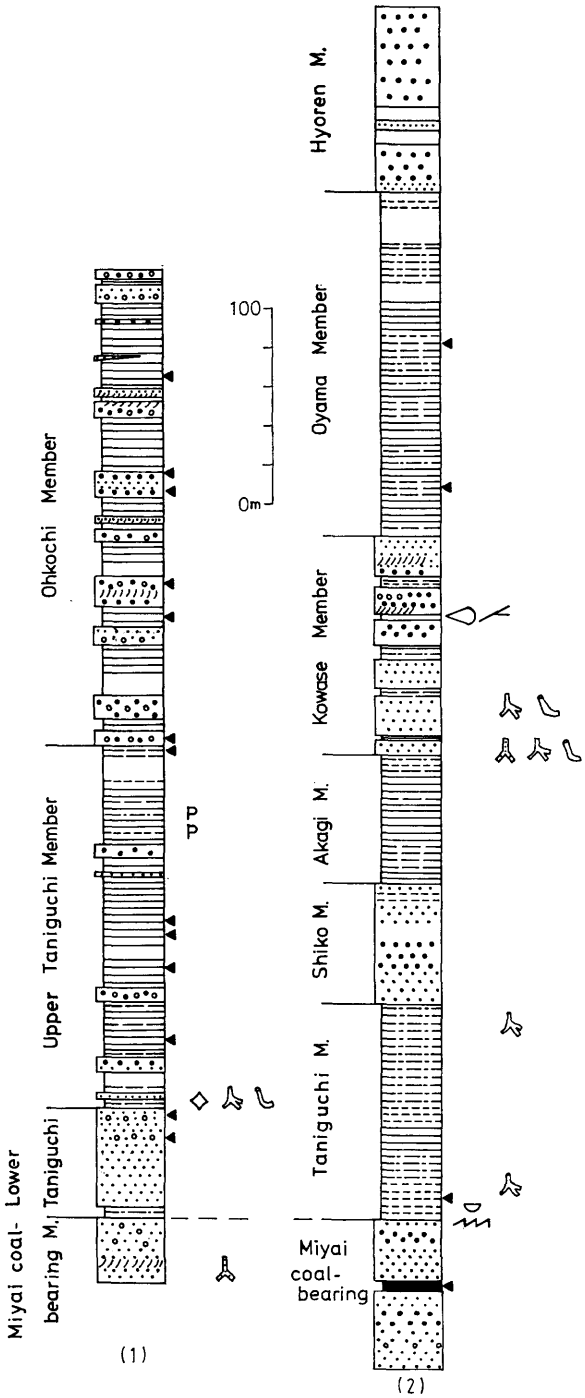

Fig. 7. Type section of the Mitsuno Formation.
(1) Northern district (2) Southern district

district, the alternation of sandstone and mudstone with a thickness of several meters develops, and it is similar to the Taniguchi Member at Miyai, opposite of the Kitayama River. Towards the central part near Yunoguchi, this member has dominantly massive medium-grained sandstone. Parallel and diagonal stratification, the latter of which exceeds sometimes 1 m in thickness of foreset bed, are frequently found in sandstone layer. Some species of trace-fossil are also recognized in massive bed. Rarely, coaly shale and lenticular coal are observed in massive sandy bed.

9. Upper Taniguchi Member* (newly defined)

i) *Type locality*: Itaya, Kiwa-cho, Mie Prefecture.
ii) *Distribution*: Yakushi–Yunoguchi–Itaya–Maruyama and Jyosen.
iii) *Thickness*: 70–180 m.

The Upper Taniguchi Member consists characteristically of dominant well-laminated shale intercalating discontinuous layers of massive coarse- or medium-grained sandstone with partially interbedded sandstone and mudstone. Well-bedded calcareous mudstone is also recognized at Iruka, central part of the northern district. Coaly shale is found at several horizons of shale, and sometimes lenticular coaly matters are contained together with nodules and many plant fossils. Trace-fossils are observed only near the lowermost horizon of this member with a bioturbite bed of 1 m thick at the outcrop behind the Kishu Mine in Itaya, middle of this district. Most of coarse-grained sandstone intercalated in shale are lenticular in shape and show rarely parallel or diagonal stratification. Channel-type coarse-grained graded sandstone layer crops out near the site of Iruka Primary School and contains patches of coaly matter (Fig. 8a).

It may be regarded that both of the Upper Taniguchi and the underlying Lower Taniguchi Member are correlative with the Taniguchi Member of the southern district as shown in Fig. 4.

10. Ohkochi Member** (redefined)

i) *Type locality*: Ohkochi, Kiwa-cho, Mie Prefecture.
ii) *Distribution*: Ohkochi–Ohtani–Kogurusu.
iii) *Thickness*: 100–260 m.

A sequence similar to the underlying Upper Taniguchi Member in lithological facies is distributed as the top division of the Mitsuno Formation in the northern district. The basal boundary is discriminated by sandstone-rich strata above the shaly bed of the Upper Taniguchi Member.

The Ohkochi Member is composed of massive coarse- or medium-grained sandstone and well-bedded platy mudstone. The former is ill-sorted and loose, frequently shows lateral and vertical changes in lithofacies, and varies sometimes laterally to shaly layer. Cross-lamination is observed in sandstone layers many times, but most of it is hard to trace continuously. Lenticular and/or laminated coaly matter is abundantly found in both of sandstones and shales.

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* 上部谷口層（模式地：三重県南牟婁郡紀和町板屋）
** 大河内層（模式地：三重県南牟婁郡紀和町大河内）

Coarse-grained sandstone cropping out at Kogurusu in central part has been correlated to this member by SATO and others. It seems, however, that this sandstone bed is referred to the Miyai coal-bearing Member by its lithofacies and compactness.

IV. Sedimentary structures

Various types of sedimentary structure as briefly mentioned in previous chapter are observed in the Kumano Group. They are sole mark, ripple mark, various beddings, organic origin structure and so on (PETTIJOHN and POTTER, 1964). Further discussion including paleocurrent analysis and basin analysis based on the sedimentary structures will be afforded in another report.

A. Sole mark and scouring

On the basal plane of sandstone of the Koguchi and the Mitsuno Formation, many sole markings and scouring marks are frequently found. They include current-directional structure such as channel-fill, flute cast, minor groove cast, bounce cast, furrows and ridges, and current striation, and penecontemporaneous deformation structure such as load cast and ball and pillow structure. Of which, channel-fill sandstone having several meters in cross-section is recognized in the Upper Taniguchi Member (Fig. 8a). It is supposed that this channel-fill sandstone was formed on an intertidal flat because of its asymmetrically and steeply inclined beddings (REINECK and SINGH, 1973). Flute cast, groove cast and load cast are sometimes found together in the same plane of the bottom of sandstone layer of the Koguchi Formation. The fact said above suggests what their load cast was resulted from. That is to say, the former two casts probably had a

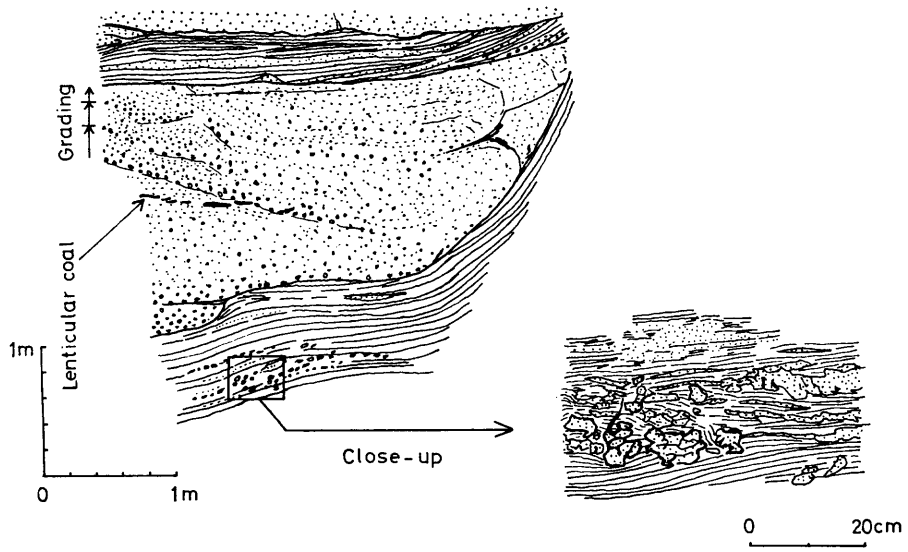

Fig. 8a. Channel-fill sandstone in the Upper Taniguchi Member at Iruka.

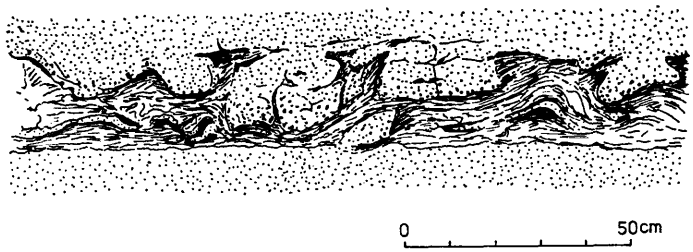

Fig. 8b. Pseudonodule in the Shiko Member at Shiko.

tendency to sinking down into the underlying soft muddy layer, and the clastics of this formation were likely rapidly deposited under the current water with scouring action. Furrows and ridges are exhibited on the base of sandstone bed which has well-stratified dish structure in the same formation. Various scales of load cast are generally observed in sandstone layers of the Mitsuno Formation. Load cast develops occasionally into convolute structure and pseudo-nodule on the basal plane of sandstone layer (Fig. 8b). Flute cast, current striation and bounce cast are also rarely produced on the bottom of massive coarse-grained sandstone of the Mitsuno Formation.

B. Ripple mark

Small ripple marks are occasionally recorded in medium- and coarse-grained sandstones of the Mitsuno Formation. Especially, asymmetrical transverse ripple mark and interference ripple mark are well recognized on the top plane of massive or stratified sandstone of the Miyai coal-bearing Member. At Taniguchi, northern central of the southern district, asymmetrical ripple mark and rill mark, both of which are crossed each other, are observed together on the same plane of the top of sandstone layer of the Miyai Member. This fact indicates such sedimentary condition which changed from subaqueous to subaerial one as an intertidal flat, longshore bar, flood plain or so. General mean length of ripple mark is 15 cm or so. Asymmetrical ripple mark is generally regarded as one of good indicators of paleocurrent analyses. The fact that this ripple mark is recorded in such coal-bearing strata as the Miyai Member is suggestive of the sedimentary environment of coaly matters.

C. Bedding structures

1. Cross-bedding

Cross-bedding or diagonal stratification is one of common structures observed in coarse-grained sediments of the Mitsuno Formation. Cross-beddings are almost planar-type defined by NAGAHAMA (1965) and few are trough- and ridge-types. Most of foreset bed of cross-stratification are 50 cm or less in thickness with a few exceptions of over 1 m. Maximum inclination vary from 6° to 30°, similar to that in the Tertiary coal-bearing formations of Northwest Kyushu described by NAGAHAMA (1965). Paleocurrent direction measured from cross-bedding varies in different localities, but has a tendency toward southeast in general.

2. Graded bedding

Graded bedding is frequently found in the sandstone of the Shikiya Member of the Koguchi Formation, whose bedding is hardly laminated. Sandstone layer of the Koguchi Member of the same formation having generally sharp bedding planes at the top and bottom shows sometimes graded bedding. Occasionally, reverse grading is also observed in the same member. Sometimes, graded bedding is found together with sole marking such as flute cast or groove cast in the same sandstone layer of the Koguchi Formation. It is roughly estimated from the fact said above that several sandstones of this formation were influenced by turbidity current. In the Mitsuno Formation, graded bedding is rarely discovered in the massive sandstone, but both sides of sandy layer alternated with mudstone have sharp boundaries.

3. Deformed bedding structures

Deformed bedding structure, some of which may be originated from slumping, is discriminated in a few localities of limited horizons (Fig. 8c). Most remarkable one of them with about 4 m or less in thickness is successionally observed along the outcrops of about 1 km from Taketo to Kuju, central to southern part of the northern district. This lies in the Koguchi Member of the Koguchi Formation near the boundary between this member and the Shikiya Member, and is inserted between undisturbed strata. This contains imbricated slump folding and chaotic mixture of brecciated sandstone layer and muddy matrix. Minor slump bed of about 80 cm in thickness is found in the alternated sandstone with mudstone of

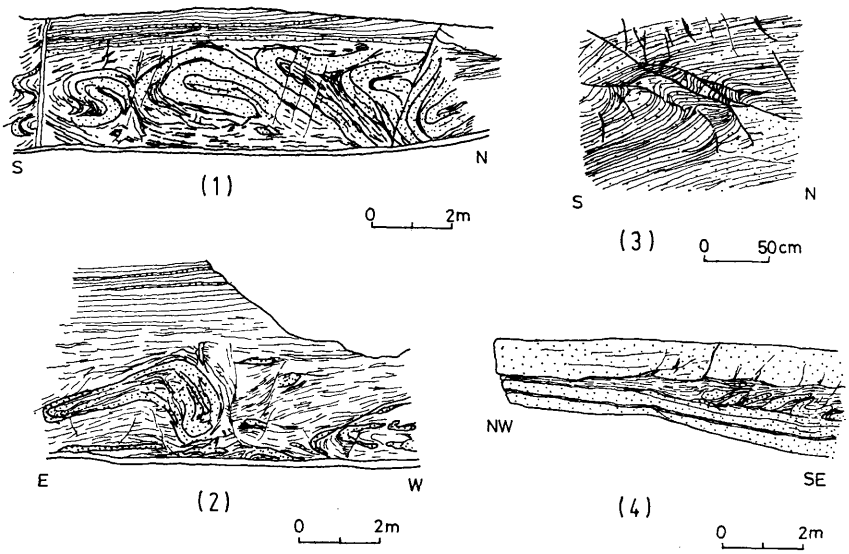

Fig. 8c. Various intraformational disturbances.
(1) in the Koguchi Member at Taketo
(2) in ditto. at Kuju
(3) in the Shiko Member at Yoji
(4) in the Koguchi Member at Aisu

the Koguchi Member at Aisu, southwesternmost of northern district (Fig. 8c). It seems that the slump bed is a deformed and imbricated alternation caused by slipping down of overlying sandstone bed. Disturbed structure observed in the massive sandstone probably belonging to the Shiko Member of the Mitsuno Formation at Yoji changes laterally to undisturbed sandstone strata by so-called planeless fault.

D. Biogenic sedimentary structures

Various species of biological hieroglyph such as dwellings and tracks and bioturbation are found on the bottom of sandstone and mudstone layers and also in the sandstone strata. Of them, so-called pre-depositional biogenic structures including many types of traces on the bedding plane are observed on the bottom of each bed throughout whole clastic sequences of various lithofacies of the Kumano Group. Sometimes, they are accompanied with directional structures. Dwelling structure, most of which are burrows, called post-depositional structure, on the other hand, is mainly contained in massive sandstone of the Mitsuno Formation with various shaped sandpipes, winding or branching. Burrows are scarcely found in the Onuma and Koguchi Formations.

Two species of trace-fossil, *Ophiomorpha* sp. and *Thalassinoides* sp., are specified in this group. The former is regarded as the indicator of littoral or shallow marine environments (HOWARD, 1972).

Bioturbation is left in the muddy intercalation of massive sandstone of the Kowase Member of the Mitsuno Formation and in the sandy siltstone at the lowermost horizon of the Upper Taniguchi Member of the same formation.

Fig. 9 illustrates an occurrence of trace-fossils observed in the Kumano Group.

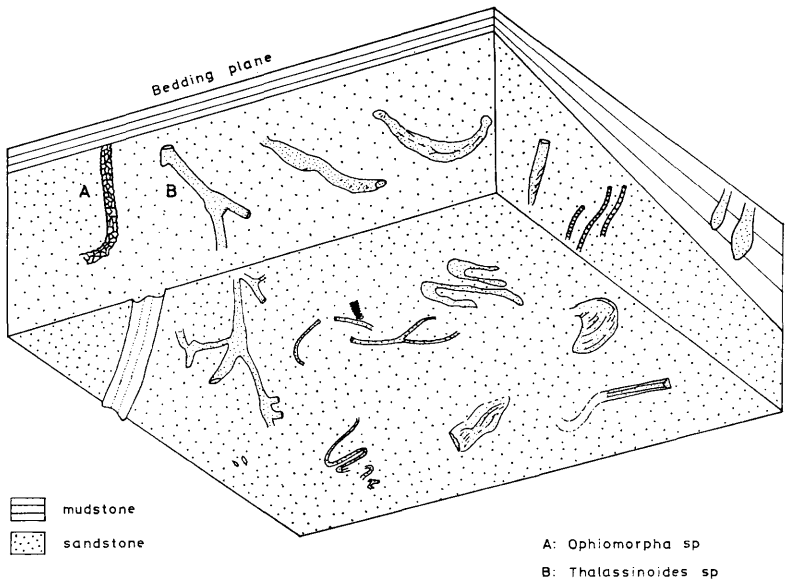

Fig. 9. Schematic diagram of the occurrence of various trace-fossils commonly found in the Kumano Group.

V. Preliminary comments on the sedimentary basin of the Kumano Group

As the critical examination and discussion on the geohistory of the Kumano Group and on the circumstances of coal-formation will be provided in another report, some comments on the sedimentary basin of this group is preliminarily presented in this paper.

On the basis of the distribution of members of this group and on the analysis of variations in lithological facies and thickness and of paleocurrent directions, the sedimentary basin of the Kumano Group is presumed to have been formed under paralic condition, facing open sea on one side and hinterland on the other.

The lowermost Onuma Formation is limited in distribution to the northern district. In the southern district, the overlying Koguchi Formation develops directly on the basement rocks with the basal conglomerate as mentioned previously. It is introduced that the basin of the Kumano Group was originated locally just in the northern part, and thereafter stretched gradually towards the south. The fact that the Koguchi Formation increases its thickness to the south indicates the southward transition of depositional center of this basin. The Onuma Formation shows generally fine- or medium-grained lithofacies except the conglomeratic sequence in the lower middle horizon. On the other hand, a series of sequences from the Koguchi to the Mitsuno Formation has a tendency of upward-coarsening in general lithofacies, from the fine-grained facies of silty sequence in the Shikiya Member and silty sandstone of the Koguchi Member of the Koguchi Formation to the coarse-grained facies of the sandy members of the Mitsuno Formation. The data of microfossils show that the Shikiya Member was presumably deposited on a kind of shelf of open sea (IKEBE *et al.*, 1975).

The sediments of Mitsuno Formation, which show mainly coarse-grained lithofacies, are regarded as a product of shallow water basin. In the southern district, the sequences of this formation are composed alternately of the massive sandstone member and the alternation member containing siltstone. They exhibit cyclic lithofacies in general. On the contrary, the sediments of the same formation in the northern district are devoid of sedimentary cycle. It is roughly supposed from the knowledge on the lithological facies and sedimentary structures that the sediments of the Mitsuno Formation were accumulated in a littoral environment in the southern district, and that the sequence in the northern district were deposited in a lagoon or embayment generally separated from southward open sea by the barrier or thick sand bar near the boundary between both districts.

Based on the consideration on lithology and structure of sediments and on trace-fossils, the sandstone strata in most of the Miyai coal-bearing Member, the lowermost division of the Mitsuno Formation, were presumed to be beach sand originated under the coastal environment (REINECK and SINGH, 1973). The fact that the remarkable and productive coal seam develops in a restricted distribution area of the Miyai Member suggests a coal-formation in peat swamp occasionally developed behind the coastal area. However, the fact that any coal seam is hardly to be observed in the subsequent overlying sequences is suggestive

of an unstable sedimentary basin, which is unsuitable for coal-formation, intermittently influenced by sea water from ocean.

Concluding remark

The lithological facies and the sedimentary structures of clastic deposits of the Kumano Group distributed in the southeastern region of the Kii Peninsula are described in this paper along with its stratigraphic subdivision and geographic distribution. The results of this investigation are summarized as follows;

1. The Kumano Group of the total thickness of about 1800 m or more lies unconformably on various horizons of the Shimanto Supergroup including the Hidakagawa, Otonashigawa and Muro Groups.

2. The Kumano Group is divided by the lithofacies into three formations, namely the Onuma, the Koguchi and the Mitsuno Formation in ascending order. The upper two formations are recognized throughout the whole of distribution area of the group, but the basement Onuma Formation is limited in distribution to the northern half and is thinning out toward the south.

3. The upper two formations are further subdivided respectively into several members. The two members belonging to the Koguchi Formation are traceable from north to south continuously. However, except for the lowermost Miyai coal-bearing Member, all the members of the Mitsuno Formation in the southern district are not traceable to the northern one where different member names are given because of variation of lithological facies.

4. The sediments of the Mitsuno Formation were made under the transitional environment from offshore to beach as a progradational sequence in the southern district, whereas they were accumulated in lagoonal embayment in the northern district. Peat swamp, in which coaly matters had been deposited, appeared intermittently behind the beach area.

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We dedicate this paper to the memory of the late Professor Emeritus Hisamichi MATSUSHITA of Kyushu University.

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Appendix

Alphabetical index of place names with Japanese writing

Aisu	相須	Miyai	宮井
Akagi	赤木	Muro	牟婁
Gobo	御坊	Nachi	那智
Hagi	萩	Nagai	長井
Hidakagawa	日高川	Nara	奈良
Hiratani	平谷	Ohara	大原
Hitari	日足	Ohkochi	大河内
Hongu	本宮	Ohtani	大谷
Hyoren	兵連	Omine	大峯
Iruka	入鹿	Onuma	大沼
Itaya	板屋	Otogawa	音川
Jyosen	上川	Otonashigawa	音無川
Kamazuka	鎌塚	Oyama	大山
Kawabata	川畑	Shikiya	敷屋
Kawane	河根	Shiko	志古
Kii	紀伊	Shimanto	四万十
Kishu (Mine)	紀州(鉱山)	Shimosato	下里
Kitayama	北山	Sobo	惣房
Kiwa	紀和	Taketo	竹筒
Koguchi	小口	Takimoto	滝本
Kogurusu	小栗須	Taniguchi	谷口
Komatsu	小松	Totsu-gawa (river)	十津川
Kowase	小和瀬	Wakayama	和歌山
Kuju	九重	Wada	和田
Kumano	熊野	Wadagawa	和田川
Kumanogawa	熊野川	Yakushi	薬師
Maruyama	丸山	Yanahara	柳原
Mie	三重	Yoji	楊枝
Mitsuno	三津野	Yunoguchi	湯ノ口

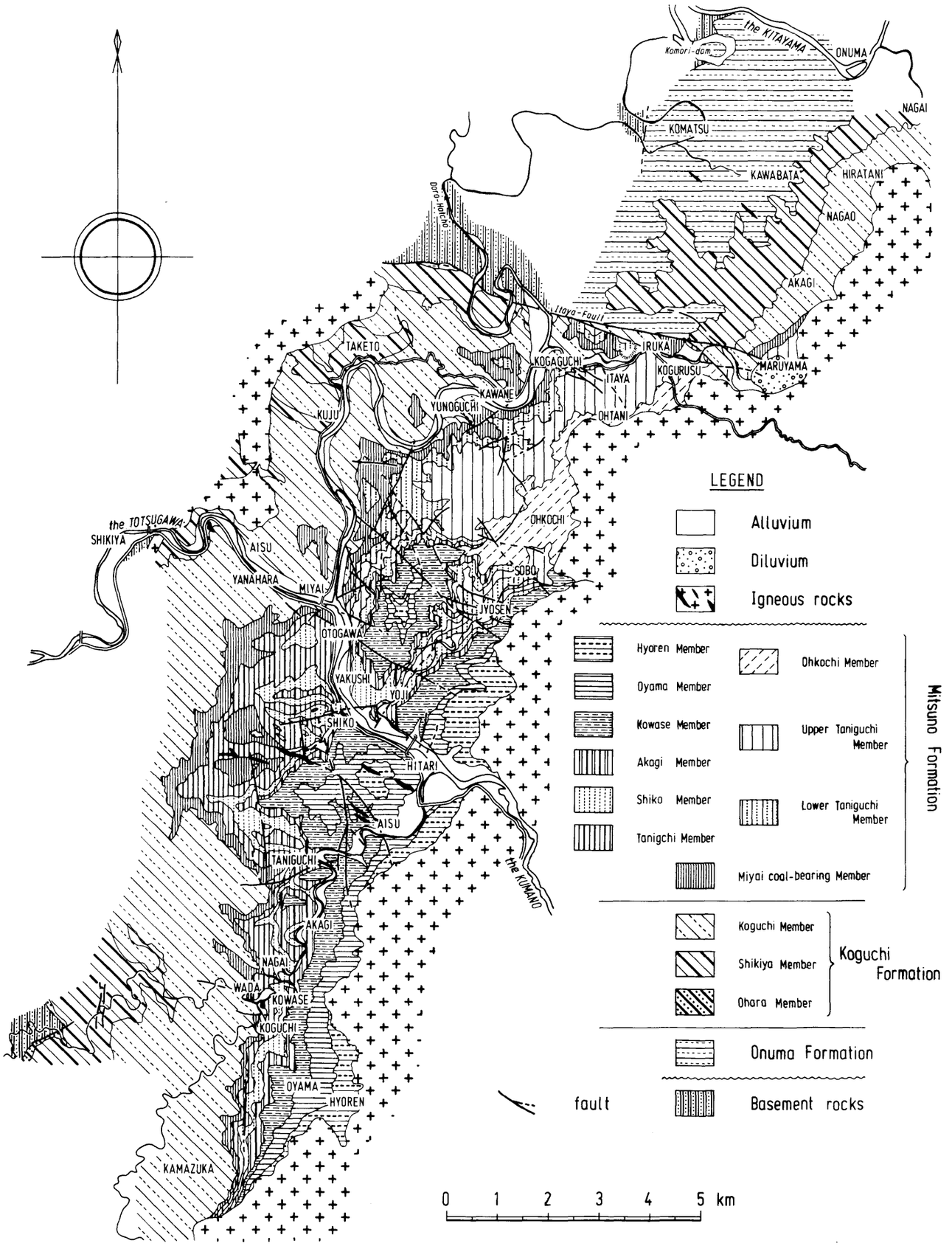

Fig. 10. Geological map of the vicinity of Kumano Coal-field.