Study of the Sasebo Coal Field, Northwestern Kyushu, Japan : Part 1. Stratigraphy of the Tertiary Sasebo Group

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Study of the Sasebo Coal Field, Northwestern Kyushu, Japan*

Part 1. Stratigraphy of the Tertiary Sasebo Group

By

Tôru IWAHASHI

Abstract

The author deals with the stratigraphy and lithofacies changes of the Sasebo group in the Sasebo coal field on the basis of the data obtained in drilling with additional ones from the surface and underground observations. The lithofacies changes are on the whole rather small except in the Fukui and Kasé formations which are the upper portion of this group, and generally muddy facies increase toward the west while the sandy facies increase toward the east. Each formation shows a tendency of decreasing in thickness toward the west. The variation of the thickness is considered to have a relation with the sediments.

The relation between the Nojima and Sasebo groups is regarded as an unconformity, and that between the Kasé, the uppermost formation of the Sasebo group, and the underlying Fukui formation as a disconformity.

Contents

Introduction

The Tertiary Sasebo group has been described already and discussed by many

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authors since 1917. In 1927, Dr. T. NAGAO proposed the name Sasebo group first for the coal bearing formations which are prevailing in white thick and well-sorted sandstones and distinguishable from rather dark colored and marine molluscs bearing Kishima group. Concerning to the geological age of this group he assumed that a part of the group is of the middle or upper Oligocene age, based on the fossil contents, *Brachiodus japonicus* MATSUMOTO and other shells.

In 1938, T. UEJI presented an important contribution in which he dealt with stratigraphy, fossils, geological structure, correlation of coal seams, and quality of coals, with an appended geological map of a scale of 1/75,000. Since the UEJI's study was evaluated high, his scheme of division of the groups and the name of the formations have often been used by many mining geologists and investigators. As for the geological age, he presumed that the upper portion in the Sasebo coal field, especially the uppermost of the Nojima formation is of the lower Miocene. With respect to the geological structure he pointed out the geotectonical significance of a remarkable thrust fault, the Sasagawa fault which intersects the medial part of the coal field with a general trend of about NNE-SSW. According to him, in the east side of this fault formations dip gently while in the west they are disturbed by foldings and faults, and the beds are inclined steeper (dipping at angles of 10°-45°) than in the east. He also treated the problem of coalification, concluding that the local variation of the quality of coal might have been caused by the difference of the affect of structural movement.

In 1949, H. MATSUSHITA published a paper entitled "Geology of the coal fields in northern Kyushu" in which he described stratigraphy, fossils, characteristic beds, geological structure, and the palaeogeography of this coal field. He pointed out that the most of the invertebrate fossils obtained from the Masaru and the Yataké* "fossil zones"** in the Sasebo group are also found in the Ashiya "fossil zone"***, therefore, he concluded that no striking difference in geological age**** is recognizable between these three "fossil zones".

There are still many opinions in regard to the division and definition of a group and the stratigraphical relation between the formations. However, since it is not a scope of this paper to describe them in detail, results of some important studies are listed in the Table 1. So far as this study concerns, the definition of the Sasebo group follows to that of H. MATSUSHITA et al. (1956).

The present study is chiefly founded on the data obtained from drilled holes in additions to the field observation. It is also based on the lateral succession of the lithofacies of the Sasebo group that has never been expressed in such a concrete

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* The Yataké fossil zone corresponds to the "Sechibaru fossil zone" in the Upper Yunoki formation (H. MATSUSHITA, 1953, '56)

** "Fossil zone" used by MATSUSHITA does not mean paleontologically difined faunizone nor biozone, but is a fossiliferous bed.

*** The Ashiya "fossil zone" is witnessed in the Kishima group in the Kishima-Karatsu coal field and in the Ashiya group in the Chikuhô coal field etc.

**** The geological age of the Ashiya and the Kishima groups is inferred to be of the Oligocene by the majority of stratigrapher.

way as columnar sections appended in this paper. More than thirty logs of the boreholes are selected carefully from more than two hundred holes which were drilled in this area, and they are checked whether or not that they are intersected by faults, that the data are fairly dependable, and that they represent their surrounding logs respectively. Based on this cross section of lithofacies and field observation, remarkable stratigraphic breaks are recognized below and above the Kasé, the uppermost formation of the Sasebo group. The geological structure of this coal field and the mechanism in what way these stratigraphical breaks were made will be discussed in Part 2 of this series of papers.

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Outline of stratigraphy in the Sasebo coal field

The stratigraphical sequence of the sedimentary and volcanic rocks in this coal field is given in Table 2. The following is the remarks for them.

1. Kishima group (H. MATSUSHITA, 1949a, b and R. TAKAHASHI et al., 1957)

The whole of this group is exposed in Daitô-Haiki-Arita district, adjacent to the southeast of the mapped area. In this district, the group is estimated 1200 m. in total thickness, and divided into five formations, lying conformably in order. Their lithological characters and the frequent occurrence of marine fossils evidently indicate that nearly the whole of the group was accumulated under marine environment.

This group is also developed in the medial part of the coal field, along the west side of the "Sasagawa" fault which is the most distinguishable thrust in the northwestern Kyushu. Since almost the lower three formations are not visible on the surface owing to the presence of this thrust, the drilling was operated by the Geo-

Tabel 1. Correlation of the Tertiary

NAGAO, T. 1927		UEJI, T. 1938			MATSUSHITA, H. 1949		
Sasebo group	Emukaé f.	Matsuura group		Nojima f.	Genkai series	Sasebo group	Nojima f.
			Shikamachi f.	Fukui f.			Fukui f.
				Sechibaru f.			Sechibaru f.
	Sechibaru f.		Ôsc f.	Yunoki f.			Yunoki f.
				Nakazato f.			Nakazato f.
	Hiu f.			Ainoura f.			Ainoura f.
Ashiya group	Hatatsu shale					Kishima group	Yunokibaru f.
	Hatatsu ss.						Wakagi f.
	Yukiaino ss.						Komanaki f.
	Sari ss.						Hiéda f.
	Kishima f.						Ôkawano f.
							Jyôno f.

* T. IWAHASHI (1957, 1960) ** T. IWAHASHI (1961b)

System in the Sasebo Coal Field

NAGAHAMA, H. 1954			SAWATA, H. 1958		IWAHASHI, T. 1957–1961	
		Hirado formation	Hirado complex	Tabira formation		Hirado formation
Kitamatsuura series	Nojima group	Minamitabira formation	Tsukumojima group	Daito formation	Nojima group	Minamitabira formation
		Fukazuki formation		Fukazuki formation		Fukazuki formation
		Ôya f. Upper		Ôya f. Upper		Ôya formation
		Ôya f. Lower		Ôya f. Middle		
	Sasebo group	Kasé formation		Ôya f. Lower		
				Kasé f.		Kasé f.
		Fukui f. Upper	Sasebo group	S_4 formation	Sasebo group	Fukui f.
		Fukui f. Lower				Sechibaru f.
		Sechibaru f.				Upper Yunoki formation
		Yunoki f. Upper				Lower Yunoki formation
		Yunoki f. Lower				Nakazato f.
		Nakazato f.				Éinoshima f.
		Ainoura f. Upper		S_3 formation	Ainoura group **	Masaru f.
		Ainoura f. Middle		S_2 formation		Tanakata f.
						Usunoura f.
		Ainoura f. Lower		S_1 formation		Sida f.
Genkai series	Kishima group	Furukawa f.	Kishima group	K_9 f.	Kishima group *	Daitô f.
		Kuroishi f.		K_8 f.		Haiki f.
		Mikaéribashi f.		K_7 f.		Mikawachi f.
				K_6 f.		Magarikawa f.
				K_5 f.		Kishima f.
				K_4 f.		
				K_3 f.		
				K_2 f.		
				K_1 f.		

logical Survey of Japan to check the unexposed formations.

The upper two formations consist mainly of dark gray, ill-sorted and somewhat tuffaceous sandstones, with subordinate amount of dark gray siltstones and intercalations of tuffs and thin conglomerates. *Chlamys ashiyaensis* NAGAO, *Crassatellites subnipponica* NAGAO, *C. yabei* NAGAO, *Acila* sp., *Pitar* sp., *Ostrea lunaeformis* NAGAO, *O.* sp., *Glycymeris cisshuensis* MAKIYAMA, *Venericardia* cf. *vestioides* MIZUNO, *V.* sp., *Linthia* sp., *Cyclammina incisa* (STACHE), *C.* sp., and *Haplophragmoides renzi* ASANO are reported from the group*.

2. Ainoura group (H. MATSUSHITA et al., 1956 and T. IWAHASHI, 1961b)

This group is exposed in a wide extent along the south and east belts of the coal field and also in the west belt along the Sasagawa thrust.

Some geologists presumed that the relation between the Ainoura group and the underlying Kishima group is unconformable** or locally unconformable***, but R. TAKAHASHI et al. (1957) and the others**** have been regarded that the boundary between the two groups is conformable. The evidences shown by R. SAITO, H. TAKEHARA, H. NAGAHAMA et al. and T. YAMASAKI et al., are not enough to assert the unconformity in this coal field. The recent report undertaken by H. SAWATA (1958) has maintained the view that the relationship between them is conformable in this field, with a doubt of local unconformity.

The Ainoura group which is measured 500 to 600 m. thick, is stratigraphically divided into five formations as given in Table 2. The Shida, Tanakata and Éinoshima formations are coal bearing formations and some of the coals such as Shindengoshaku, Ainoura-yommai, Ainoura-sammai, Shinden-yonshaku-kasô, Shinden-yonshaku, Moézu-kasô, Kawazuru (or Goshaku-shita-nimai) and Ôse-goshaku are workable. Ôse-goshaku develops almost all around the coal field, being one of the most important coal seam in northwestern Kyushu.

Other two formations which are alternated with the former three formations are regarded as deposits between neritic and brackish environment. The identified species from the Ainoura group are *Venericardia subnipponica* NAGAO, *V.* sp. *Glycymeris* cf. *cisshuensis* MAKIYAMA, *Yoldia* sp., *Balanus* sp., *Callista* sp., *Ostrea* sp., *Dentalium* sp., and ? *Pitar* sp.*****

The upper four formations of this group is conformable in order, but the relation between the lower two formations is not. More than 50 m. thick of the top of the Shida formation is eroded off locally.

3. Sasebo group (H. MATSUSHITA et al., 1956)

The Sasebo group lies conformably the Ainoura group and boundary between

* H. SAWATA (1958) and T. IWAHASHI (1960).

** R. SAITO (1953), H. TAKEHARA (1953), H. NAGAHAMA (1954) and H. NAGAHAMA et al. (1958).

*** T. YAMASAKI et al. (1954).

**** H. MATSUSHITA (1949), H. MATSUSHITA et al. (1956), M. NODA et al. (1955) and T. IWAHASHI (1960, '61b).

***** H. SAWATA (1958) and T. IWAHASHI (1961b).

them is quite gradual. The Sasebo group of about 840 m. in average thickness is divided into six formations as shown in Table 2. Each formation is composed of three to five cyclothems. Excepting for the uppermost Kasé formation, it is considered that the Sasebo group was accumulated mainly in the brackish to fresh water environment. This group consists of monotonous homogeneous whitish sandstones, with intercalated subordinate mudstones, sandy mudstones and alternations of sandstone and mudstone. Coal seams and coaly shales are mostly embedded in the upper part of each cyclothems.

On the other hand, the Kasé formation is characterized by a foraminiferous mudstone which is interbedded in the lower part of the formation, and by molluscan remains in the same horizon. This formation lies unconformably the erosion surface of the Fukui formation, the top of which had been eroded not less than 20 m. in thickness.

The coals produced from the Ainoura and Sasebo groups in this coal field are coking, bituminous (B_1)*, weak-coking, sub-bituminous (D)* and strong-coking, bituminous (B_2)* cited in the order of quantity**.

4. Nojima group (H. NAGAHAMA, 1954)

This group, being estimated at more than 2000 m. thick, is divided into three formations as presented in Table 2. The Nojima group (H. NAGAHAMA, 1954) *plus* the Kasé formation (ibid.) approximately corresponds to the UEJI's Nojima formation.

The Nojima group is mainly composed of sandstones and mudstones in alternation, associated with massive sandstones in subordinate amount, and intercalated with a few thin layers of coal and coaly shale (less than 15 cm.). The most noteworthy is that the lower part of this group (*i.e.*, the Ôya formation and the base of Fukazuki formation) is characterized by remarkable pyroclastic rocks such as tuff breccias, tuffaceous conglomerates and tuffs. The relation between the Nojima and Sasebo groups is unconformable.

5. Hirado formation (H. NAGAHAMA, 1954)

It is exposed in the northwestern vicinity of this area, in Tabira-machi, islands of Hirado and Ôshima. It consists of sandstones, conglomeratic sandstones, sandy mudstones and intercalations of mudstone and tuff which are not sufficiently consolidated. Although the boundary between the Hirado formation and the underlying Nojima group is not observed on the surface, the relation between the two is presumed to be unconformable*** from the difference in the geological structure and the lithofacies. This formation is overlain by basalts and andesites. Plant remains as *Salix* sp., *Smilax* sp., *Liquidambar* ? sp., *L.* cfr. *formosana* HANCE, *Acer* sp., *Cinnamomum* sp. and *Juglans* sp. are collected*** from this formation, however, the geological age of the formation is not certain.

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* Coal classification following to the Japanese Industrial Standard M 1002-1953.

** T. MURAKOSHI et al. (Editors, 1956).

*** H. NAGAHAMA (1954) and H. URATA (1956).

6. Andesites

They are developed in the islands of Hirado and Ôshima, composed chiefly of pyroxene andesite, with associated volcanic breccias and tuffs. They lie on the Hirado formation unconformably and are overlain by the Tasuké lignite bearing tuffaceous member.

7. Tasuké lignite bearing tuffaceous member (H. SAWATA et al., 1955)

This member is limited in distribution to the northern part of the island of Hirado, and is directly overlain by the Matsuura basalts. According to S. MIKI (1950), the plant fossils yielded from this member indicate the stage of I_1 of N. IKEBE (1948). IKEBE considered that I_1 stage is corresponding nearly to Plio-Pleistocene, while recently S. OGOSE (1959) is of an opinion that it belongs to lower Pleistocene.

8. Hachinokubo gravel bed (T. IWAHASHI, 1961a)

Distributing in very wide extent in this field and its surrounding areas, this bed covers clino-unconformably the flat plain of almost all the formations above mentioned and the Palaeozoic metamorphic complex which is also one of the basement rocks of the Tertiary formations. It is intruded by dikes of dolerite and overlain by lavas of the Matsuura basalts. The gravel bed is composed chiefly of round shaped pebbles and cobbles of white quartzite, quartz schist, dark grey sandstone and grey conglomerate, with subordinate amount of those of granites, rhyolites, basalts and andesites. Fossil Radiolarias are frequently found in the gravels of chert and chert fragments contained in the grey conglomerate. No evidence has been found to determine the geological age of this bed, however, a few fossil plants are collected from near Sechibaru*, such as *Sequoia* sp., *Cladium*? sp. (Cyperacidae), *Salix* sp., *Liquidambar* sp., *Styrax* sp., ? *Benzoin* sp. (Lauraceae) and on the other hand, *Meretrix* sp. is found near Yobuko** far northwest from this field.

9. Matsuura basalts (T. YAMASAKI, 1959)

The Matsuura basalts are known in the southwestern margin of the so-called circum Japan Sea alkaline petrological Province, and occur as dikes, sills, and lavas of trachytic basalts and siliceous basalts. Between the lavas, tuff breccias, agglomerates, volcanic breccias and tuffs are intercalated, and sometimes beds of gravel, sand and clay are interbedded. In the muddy silt near Mammbagoé, north of Hiu, Sasebo city, *Meretrix lusoria* (RÖDING) and *Cyrtopleura japonica* (YOKOYAMA) are collected***, which indicate that a part of the beds between the lavas was at least accumulated under the shallow sea environment. Geological age at the beginning of the eruption is not certain, but it is presumed that it was between the upper Pliocene and lower Pleistocene.

* T. YAMASAKI (1959).
** H. SAWATA (1958).
*** I. IMAI et al. (1958).

Table 2. A generalized stratigraphy in the Sasebo Coal Field, Northwestern Kyushu, Japan

Series	Stage	Group	Formation	Thickness in m.	Rock facies
			Alluvium	—	gravel sand, mud and clay
Pleistocene ?			younger gravel bed	2–5	coastal terrace deposits and fluvial deposits
			Matsuura Basalts	400	lavas of quartz basalts and trachytic basalts
			Hachinokubo Gravel Bed	0–20	consists of graunles, pebbles and cobbles of quartz-schists, chert, hard siltstone, sandstone, conglomerate, granites, rhyolites, basalts and andesites with sandy matrix.
Plio-Pleistocene	Nishihizen stage		?		partly turns into beds of sand and clay
			Tasuké lignite bearing tuffaceous member	30±	tuffaceous conglomerate, sandstone, lignite and tuffaceous mudstone
			Andesites	200 ?	lavas of pyroxene andesite and its ejecta. dome, dykes and sheets of biotite-hornblende-quartz andesite and hypersthene andesite
			Hirado formation	500+	thick sandstones, alternating sandstones and mudstones with intercalated coaly shales and thin coal seams
Miocene		Nojima group	Minamitabira formation	750+	alternations of sandstone and mudstone, thick siltstone with a few beds of tuff and thin coal
			Fukazuki formation	1100–1300	sandstones and shales in thick-bedded alternation, with 2–3 beds of thin coals and coaly shales, and notable tuff breccia and tuff in the base.
			Ôya formation	210–310	alternating sandstone, sandy shale and siltstone, with intercalated remarkable tuffaceous rocks such as tuff breccia, tuffaceous conglomerate and tuff, and yields non-marine molluscs
Oligocene (with a doubt of Lower Miocene)	Upper Chikushi stage	Sasebo Group	Kasé formation	45–120	the lowermost; conglomeratic sandstone, lower; siltstone~mudstone, with molluscs and foraminifera, upper; alternating sandstone and siltstone, massive sandstone
			Fukui formation	145–180	Tuffs and more than 10 layers of coal (1 or 2 are workable) are intercalated with sandstone and siltstone.
			Sechibaru formation	150–190	White~greyish white sandstones are predominant. Coals Goma-sô, Nakabando, Rokusuntan, Iwaishi and Sunaban are inbedded in sandy shale, mudstone.
			Upper Yunoki formation	146–182	massive greyish white sandstones prevailing with subordinant amount of grey shale and mudstone. Coal Yunoki-nimai and other thin anormous coal are inbedded.
			Lower Yunoki formation	97–156	massive sandstones predominated in three cyclothems except the two cyclothems. Coals are Hassun, Shakuni, Iwaishi-nimai and Eri-nimai.
			Nakazato formation	112–150	Coals Ôsé-yommai, Ôsé-sammai and Yunoki-sammai are intercalated with massive greyish white sandstones with subordinant amount of mudstones and sandy mudstones.
		Ainoura group	Éinoshima formation	55–100	Greyish white massive sandstones are prevailing, and coal Ôsé-goshaku in the uppermost. It is inferred to be deposited in brackish or fresh water condition.
			Masaru formation	115–155	Sandstones are predominant with intercalated mudstone and alternated sandstone and mudstone. Marine shells are abundant but in the top of the formation coal Kawazuru is inbedded.
			Tanakata formation	55–100	non-marine sediments; sandstone in the base, alternated sandstones and mudstone in the upper, with coals Sinden-Yonshaku-kasô, Sinden-yonshaku, Moézu-kasô and Moézu-jôsô.
			Usunoura formation	55–155	mainly consists of marine sediments; four cyclothems composed of sandstone and conglomerate in the lower part and sandy shale, mudstone in the upper.
			Sida formation	55–155	chiefly composed of greyish white sandstone, inbedded with coals Sinden-goshaku-kasô, Sinden-goshaku, Ainoura-yommai and Ainoura-sammai. Diastem is recogniz-ed on the top of this formation.

Description of the Sasebo group

The Sasebo group, about 840 m. in total thickness, develops in a wide extent in this field, and generally lies conformably upon the Kishima group and is overlain clino-unconformably by the Nojima group, Hachinokubo gravel bed and Matsuura basalts.

It is divided into six formations, namely the Nakazato, Lower Yunoki, Upper Yunoki, Sechibaru, Fukui and Kasé formations in ascending order. In general, thickness and lithofacies vary laterally rather to a slight degree, except in the upper two formations. To the east sedimentary formations show the tendency of increasing in the component of sandstone and the total thickness. Each formation is composed of three to five cyclothems, each of which commonly consists of the following sequence in ascending order:

1. Massive sandstone, sometimes locally unconformable (diastem) on underlying beds
2. Sandy siltstone and mudstone
3. Underclay (sometimes lacking)
4. Coal and coaly shale
5. Shale, sandy shale and mudstone

Cyclothems are respectively different in thickness, ranging from 30 to 60 m. and on the whole, the unit 1 is far thicker than the total thickness of the rest (the unit 2 to 5). Sometimes basal part of the unit 1 (sandstone) gradually turns into sandy mudstones, mudstones and alternated sandstones and mudstone in local extent, where the boundaries facing to the lower cyclothems are not clearly discriminated. On such occasion, the lower boundary of the cyclothem is artificially defined to the upper limit of the coal seam and coaly shale. In spite of that coal seams commonly being rather thin*, they are considerably continuous in a wide extent, so that they are available for the key bed together with tuffaceous beds.

Adopting cyclothem** for the subdivision of formations, some of the boundaries of formations cross only a little those which are proposed by H. MATSUSHITA (1949) and H. MATSUSHITA et al. (1956). Differences in the definition of the formations between the present study and the previous works will be described in each of the following paragraphs if necessary.

1. Nakazato formation (T. UEJI, 1938)

The typical exposures of this formation are at the southeast of the Eri Pass, north of Saza-machi, subordinately near Takahazu and Yoshioka, respectively, southeast and northeast from Nakazato, north of Sasebo city.

The lower limit of this formation is on the base of the sandstone which lies

* Most of the coal seams are less than 1.0 m. thick and coals more than 30 cm. are workable in this field.

** The cyclothems adopted in this paper are different from the cyclothems proposed by H. SAWATA (1958).

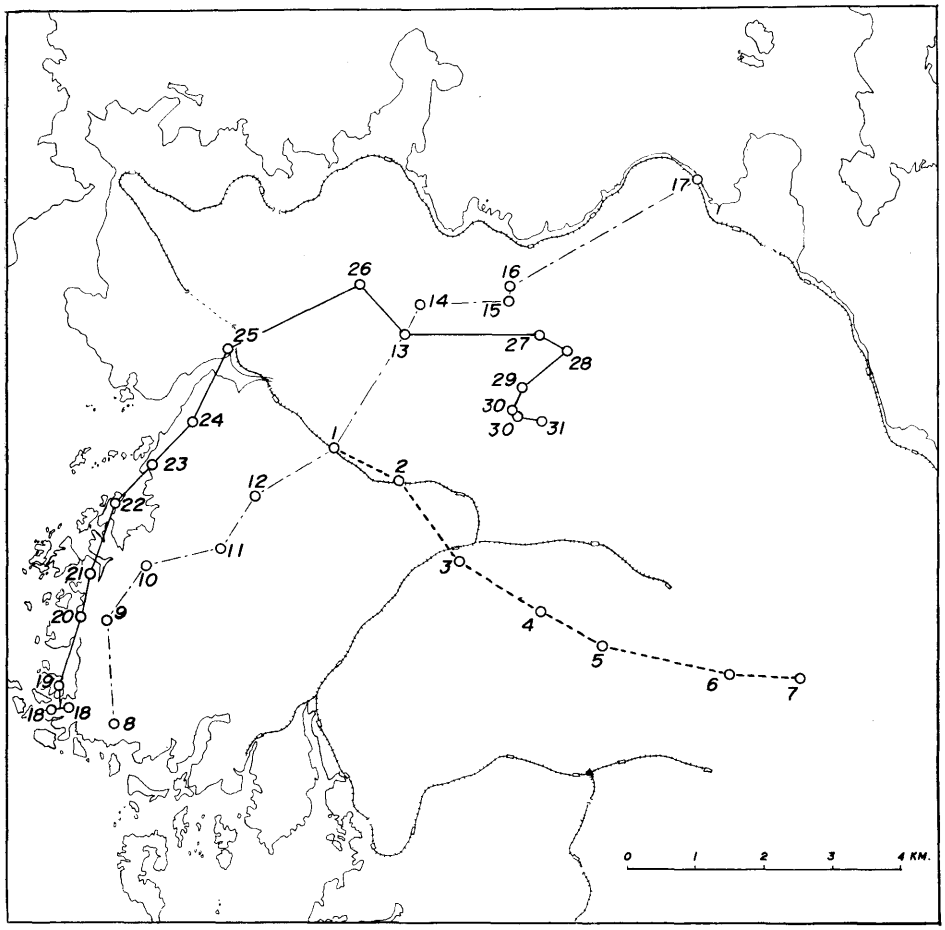

Fig. 1. Index map of the location of boreholes and lithological cross sections. Lithological cross sections along the broken line 1-7, dots and bars line 8-17, and solid line 18-31 are shown respectively in Fig. 2, 3, and 4.

above the coal seam Ôsé-goshaku (or Fukushima-nishaku, Ôzuru-nishaku, C 21*) and the upper limit is up to the shale or mudstone** which covers the coal seam Yunoki-sammai (or Bantoyama, Nabezuru-nimai, C 28).

The formation consists of four cyclothems, No. 1 to No. 4. They are composed of greyish white massive sandstone, with subordinate amount of mudstone, sandy siltstone and alternations of sandstone and mudstone, interbedded coal, coaly shale, tuff and tuffaceous sandstone. In this formation, coal seams of Ôsé-yommai (or Fu-

* H. SAWATA (1958) named the coal seams of the Ainoura and Sasebo groups with numbers in ascending order.

** In places very thick mudstone and sandy mudstone overlie the coal seam Yunoki-sammai, where the upper boundary of this formation is artificially situated on the top of the coal seam.

kushima-sunaban), Ôsé-sammai, Ôsé-nimai (or Enshô-doya) are included in ascending order. Tuffaceous beds are chiefly developed in the middle and western parts of this area and they are intercalated in each cyclothems. Among them tuffs above and beneath the Ôsé-yommai and Yunoki-sammai respectively are distinguishable one.

The thickness of the formation varies from 112 m. in minimum to 150 m. in maximum. Toward the south and west total thickness of this formation tends to decrease, while toward the east it tends to increase.

Batissa procera SUZUKI, "*Cerithium*" sp. (n. sp.), *Phaxas* n. sp., *P.* sp., and *Ostrea* sp. have been reported by H. NAGAHAMA (1954) in the Cyclothems No. 2 and No. 3, and *Brachiodus japonica* MATSUMOTO has been found by S. TOKUNAGA (1925) in the mudstone which is including the coal seam Yunoki-sammai in the Ikeno Colliery. Fossil plants and their fragments are observed in the drilled cores near Nakazato in many horizon of this formation.

2. Lower Yunoki formation* (nom. nov.)

The typical exposures of this formation are at the southeast of the Eri Pass, and it develops considerably in a wide extent around the Yunoki-Ikeno district, north of Sasebo city. This formation lies conformably on the Nakazato formation and the upper limit is defined on the base of the so-called "Eri tuff"**. The maximum thickness of the formation is 156 m., minimum 97 m. and the total thickness of the formation varies nearly in the same way as in the Nakazato formation.

This formation is composed of five cyclothems, namely the Cyclothems No. 5 to No. 9 and the vertical sequences of them commonly resemble those of the underlain Nakazato formation with the exception of the Cyclothem No. 5 and No. 7. Concerning with the Cyclothem No. 5 and No. 7 sandstones are predominant toward the east while sandy mudstones and mudstones are prevailed in the west and medial parts of this field. In the west, the coals and coaly shales in the upper part of the above mentioned two cyclothems are locally covered by massive thick mudstones or sandy mudstones, therefore the boundaries of the cyclothems are indistinct in such places. In the upper part of each cyclothem, coal seams are respectively intercalated such as "Hassun" (or Iwaishi, C 29), Nanaheda (or Hajikiyama, Shiraiwa-hassun, C 30), Shakuni, Iwaishi-nimai (or Yunoki-nimai***, Nanaheda-sô, C 33), and Eri-nimai. Among them the Hajikiyama and Iwaishi-nimai extend almost continuously over the whole area, and the latter one is a workable coal in the southern part of this coal field. Tuff and tuffaceous rocks are interbedded in every cyclothem with the exception of the uppermost one, and they are mainly developed in the southwestern part of the area as those in the Nakazato formation. Fossil *Ostrea* and *Meretrix* are found in the Cyclothem No. 6 and the base of No. 9 at Ikeno in the northern part of Sasebo city,

* It is equivalent to the lower part of Yunoki formation of H. NAGAHAMA (1954). (下部柚ノ木累層)

** Described in the next paragraph.

*** Although it is called the Yunoki-nimai in the southeastern part of the field, it is different from the coal seam which has the same name and is contained in the cyclothem No. 10 in the western part.

and in the mudstone of Cyclothem No. 7. Y. KITAGAWA collected *Marlea aequalifolia* (GOEPPERT) ÔISHI and FUJIOKA,* and many fossil plants are founded in the coal seam "Yunoki-nimai" (Cyclothem No. 8) near Yamada, in the north of Sasebo city and in the horizons above and below the other coals in the drilled cores.

3. Upper Yunoki formation** (nom. nov.)

This formation is exposed typically from Akazaki to Shitazaki along the south coast of Kozasa-machi, developing to a comparatively wide extent around the Yunoki-Ikeno district in the northern part of Sasebo city, and between Takeda and Yamanoda north by northeast from the type locality.

This formation lies conformably upon the Lower Yunoki formation, with the total thickness ranging from 146 m. to 182 m. The upper boundary of this formation is between the coal seam Shikamachi-sanjaku*** (or the mudstone which covers the same coal) and the overlying sandstone. This formation is composed of four cyclothems from No. 10 to No. 13, which are generally much more arenaceous than the cyclothems of underlying two formations. Namely, the greater part of each cyclothem excluding the Cyclothem No. 12, consists of massive whitish coarse to fine grained sandstones. In the uppermost part of the Cyclothem No. 10 and No. 12 is found respectively the coal seam, Yunoki-nimai (or Iwaishi, Iwaishi-nimai, C 34)**** which develops mainly in the western district and the coal seam Hedamono-sô. The Shikamachi-sanjaku of the Cyclothem No. 13 is one of the most important workable coal seam in this coal field, extending almost continuously all around the coal field.

Tuff and tuffaceous beds are embedded in each cyclothem of this formation, among which the Eri tuff bed is the most distinguishable one developing almost throughout this field.

The identified species from the mudstone which covers the coal Shikamachi-sanjaku are as follows.

Molluscs

Corbicula hizenensis UEJI
C. matsushitai SUZUKI
C. nakayamana UEJI
Lamprotula nojimensis UEJI
Semisulcospira sp.

Terrapin

Senryuemys kiharai SHIKAMA

Plants

Metasequoia japonica (ENDO)
Glyptostrobus europaeus (BRONG.)

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* Identified by S. ENDO reported by H. NAGAHAMA (1954).

** It is equal to the Upper part of the Yunoki formation proposed by H. NAGAHAMA (1954) (上部柚ノ木累層).

*** This coal corresponds to the coal seams of Matsuura-sanjaku, Kuhara-sanjaku and C38.

**** This coal is different from the one embedded in the Cyclothem No. 8 in Ikeno-Yunoki district which has the same name.

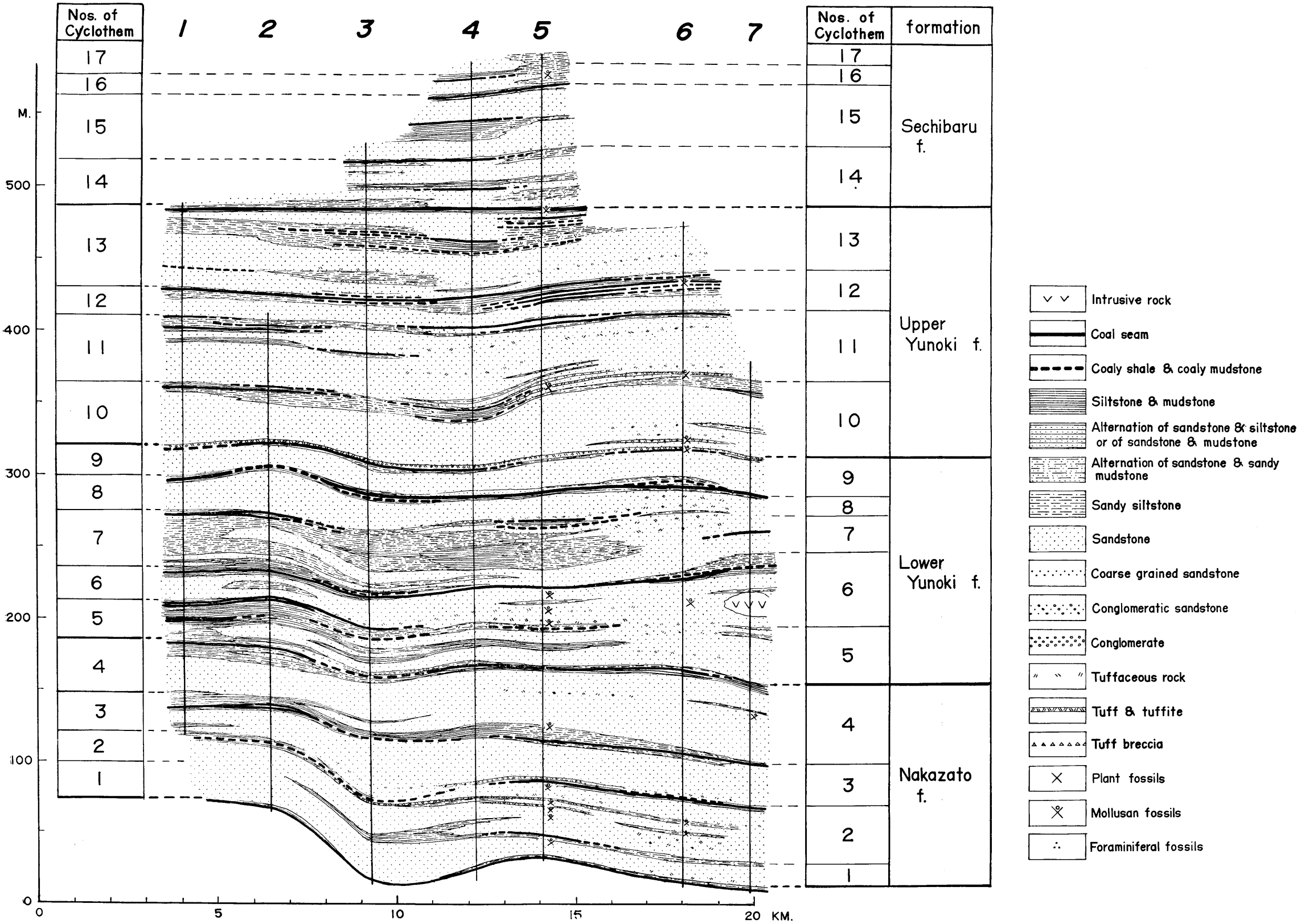

Fig. 2. Lithological cross section of the Sasebo group. (Northwest-southeast profile)
Location of the section is shown in Fig. 1 with the broken line.

Alnus Kefersteinii (GOEPP.)
A. prenepalensis HU et CHANEY
Carpinus miocordata HU et CHANEY
Ulmus pseudolongifolia OISHI et HUZIOKA
Zelkova Ungeri ETTING
Acer subpictum SAPORTA
Marlea aequalifolia (GOEPP.)
etc.*

4. Sechibaru formation (revised)

Since T. UEJI (1938) provided that the Sechibaru formation is the one between the top of the coal Shikamachi-sanjaku and that of Sunaban-sô, this definition has long been used by many investigators and mining geologists. However, overlying the coal of Sunaban-sô conformably, there still comes mudstone and sandy mudstone of 30 m. to 45 m. thick which is locally intercalated with sandstones, coals, coaly shales and a tuff. Judging from the view of cyclic sedimentation for dividing formation, it is quite reasonable to say that the above mentioned mudstones should be included in the underlying Sechibaru formation. Therefore the boundary between the Sechibaru and Fukui formations is defined here on the top of the above stated mudstones.

This formation lies with a disconformity of a slight order, i.e., a diastem, on the Upper Yunoki formation, and in some places** upper part of the coal of Matsuura-sanjaku or Shikamachi-sanjaku is eroded.

The typical exposures of this formation are along the coast from near Shitazaki to Kusudomari, southwest coast of this area. There are also good exposures along the coast of Kurosé, west from Shisa-machi, Matsuura city. Furthermore, it develops extensively along the drainage of the river Saza around Sechibaru-machi.

Thickness of the formation at Kusudomari and Kasé district in the western part of this field is 150 to 155 m. On the other hand, at Shisa and Imafuku district in the northern part of this area, it attains 190 m. or so. Namely, the thickness of the formation increases from the southwest to the northeast in this field. This formation is divided into five cyclothems, No. 14 to No. 18 in ascending order.

Cyclothems No. 14, No. 17, and No. 18 are comparatively prominent with fine grained rock facies such as sandy mudstones, mudstones and alternations of sandstone and mudstone, and the component of sandstone is considerably lower than those in the other cyclothems belonging to the Sasebo group. Especially the mudstones in the upper half of the Cyclothem No. 18, including the Utagaura tuff near the top, are distinguishable. They are traceable for a long distance from the southwestern end to the northeastern border in this area accompanied with the underlying coal Sunaban-sô, which is workable in a broad extent in this coal field.

The Utagaura gyôkai-kakurekigan-sô (or Utagaura tuff breccia bed) proposed by

* Collected and identified by T. TANAI and K. ONOÉ reported by H. SAWATA (1958).

** A study on the diastem in this field is reported by R. SAITO (1951), T. IWAHASHI (1952) and H. SAWATA (1958).

H. NAGAHAMA (1954) is identified in the drilled cores and is also observed on the surface to a wide extent from the island of Yakéshima on the southwest to Imafuku on the north. Furthermore, according to NAGAHAMA this tuff is confirmed in the island of Shô-tobishima and in Hatsuzaki in the north of island Fukushima, respectively 5 and 7 km. north from the coast of Imafuku. Colour of tuff turns from dark gray into yellowish gray if weathered. The tuff is sometimes interbedded with tuff breccia, sandstone, mudstone, thin bed of coal and coaly mudstone. This is the most distinguishable, wide spread tuff through the Sasebo group and is one of the most important key bed accompanied with the Sunaban-sô for coal prospecting and geological mapping.

Lithofacies of the Cyclothems No. 15 and No. 16 are practically similar to the average type of cyclothem of the Sasebo group which is characterized by the predominance of massive sandstone.

In the Sechibaru formation coal seams named Rokusun (or C 39), Daisan-rinjô (or C 40), Daini-rinjô (or C 41), Daiichi-rinjô (or C 42), Shita-iwaishi (or Iwaishi, Ichimai-mono, C 43), Sunaban-sô (or Hédamono-sô, C 46) and other unnamed thin coals and coaly shales are intercalated. These coals and coaly shales are commonly concentrated in the upper portions of each cyclothem. With the exception of Sunaban-sô and other one or two coals, most of coal seams are usually developed rather in a local area and laterally turn into inferior coals and coaly shales in both quality and thickness.

Under the Sunaban-sô, fossils of *Ostrea* sp. are collected in the island of Tobishima above mentioned and near the Nakayama Pass in Shikamachi-machi. In addition, "*Cerithium*" sp. (n. sp.) and "*Phaxas*" sp. (n. sp.) have been identified by H. NAGAHAMA (1954) in the same horizon. The superjacent mudstones of the coal Sunaban-sô contain *Lamprotula* sp., *Corbicula hizenensis* UEJI, *Ostrea* sp., and "*Phaxas*" sp. (n. sp.) in the lower part and *Corbicula nakayamana* UEJI in the uppermost part. Besides these, H. MATSUSHITA (1949a) collected *Acila mirabilis* AD. and RVE., *Glycymeris cisshuensis* MAKIYAMA, *Callista matsuraensis* (NAGAO), *Turritella karatsuensis* NAGAO, *T.* sp., *Calyptraea* sp. and *Cerithium* sp. from the horizon above the same coal in the north of the Takeshita Colliery, some of which are characteristic species in the Oligocene Kishima group. On the other hand, H. NAGAHAMA (1954) and H. SAWATA (1958) reported the following fossils in the mudstone superjacent the Utagaura tuff breccia bed;

Corbicula nakayamana UEJI,
C. (*C.*) sp.
Cyclina (*C.*) *japonica* KAMADA
Batillaria takeharai MIZUNO
"*Cerithium*" sp. (n. sp.)
Ostrea sp.
Septifer sp.
Venerupsis (*Amigdala*) sp. (n. sp.)
Melanatria sp.
"*Potamides*" sp.

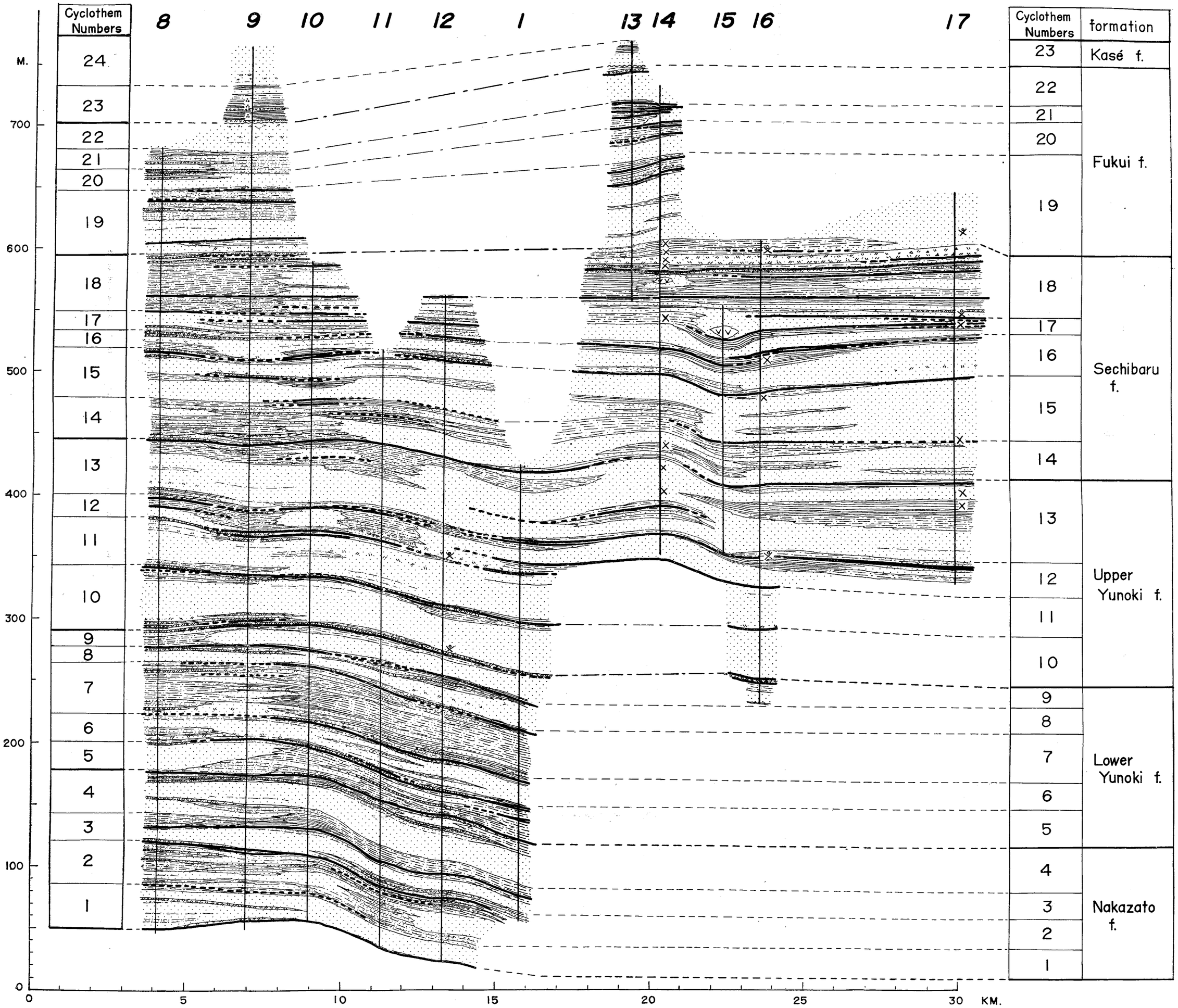

Fig. 3. Lithological cross section of the Sasebo group. (Southwest–northeast profile)
Location of the profile is shown in Fig. 1 with the dots and bars line.

Balanus sp.

cf. *Cerithidea* (*C.*) *sugaii* MIZUNO et FUJII.

They also reported *Corbicula nakayamana* UEJI and *Potamides* sp. from the mudstone embedded in the Utagaura tuff breccia bed. The fossiliferous bed underlain by Sunaban-sô is formerly called the Nakayama-, Ota- and Mukaéyama-"fossil zones" by T. UEJI (1938) and Yatake "fossil zone" by H. MATSUSHITA (1949, '53, '56).

5. Fukui formation (revised)

T. UEJI (1938) and H. MATSUSHITA (1949) defined this formation as the formation lies between the two coals—Sunaban-sô and Fukui-ichimai (or Sammaimono-sô). Since then, H. NAGAHAMA (1954) emphasized the significance of the stratigraphical break superjacent the coal Sammaimono-sô, and revised the formation as a part between the Sunaban-sô and the disconformity. It is reasonable to define the upper limit of the formation as in H. NAGAHAMA's way. However, as already stated in the preceding paragraph, the lower boundary of this formation should be placed on the upper limit of the thick mudstones in which coal Sunaban-sô is inbedded.

The Fukui formation exposed typically around Utagaura and along the highway between Funénomura and Hongaura, Shikamachi-machi, develops in the inner belt along the west coast from the island of Yakeshima to Emukaé-machi, along the north coast from Shirahama to the south of Imafuku, and along the north side of the Sechibaru line of the Japanese National Railways.

As for the disconformity which prescribes the upper boundary of this formation, H. SAWATA (1958) has attached a great importance to it, setting the upper boundary of the Sasebo group on this horizon. However many other geologists have hitherto been of an opinion that the upper boundary of the Sasebo group should be placed on the top of the Kasé formation, not on the top of this formation. As will be referred to in the Part 2, the hiatus of the unconformity is considered to be smaller than the one represented by the unconformity above the Kasé formation. Therefore the author is agreeable to the latter's view.

The Fukui formation varies from 106 m. to 156 m. in thickness, showing a general tendency in decreasing thickness toward the southwest. But, correlating the columnar sections made out in nearly the whole of the coal field, it is clear that the Fukui formation was eroded out in thickness of less than 20 m. along the distance of 25 km.*

This formation is divided into four cyclothems from No. 19 to No. 22 in ascending order.

Cyclothem No. 19, 47-75 m. thick, takes the minimum at Kanzaki, southwest corner of this field, gradually gains the thickness to 51 m. at Ôtaké, northeast from Emukaé, and then suddenly increases to the maximum (75 m.) but again decreases to 62-66 m. Sandy mudstone and mudstone gradually prevail in the component of this cyclothem, while the formation becomes thinner toward the southwest. Sandstone is predominant in the cyclothem when it becomes thicker toward the northeast.

* According to N. HATAE et al. (1961), local erosion about 100 m. in thickness was reported in the upstream of the Shisa River.

Coals named Gomatan (or Soko-rokusun, C 50) and Uwa-iwaishi* (or Nishaku, Shita-sammai, Fukui-sammai, C 51) are included in the upper portion of this cyclothem.

Cyclothems No. 20—No. 22 are fairly distinctly discriminated each other in the northeast area, where the coals lie near the top of each cyclothems; the coal Kaéshi-bori* and Sammai-tan (or Fukui-nimai) in the Cyclothem No. 20, Hassun* and Fukui-ichimai (or Fukui-sammai) in No. 21, Ichimai-tan (or Fukui-ichimai), and Sammai-mono in No. 22 in ascending order.

Contrary to the above fact, in the southwestern part, these three cyclothems No. 20—No. 22 reduce their thickness, turn into one or two cyclothems, and become indistinguishable each other. Namely, the lower half of the one or two cyclothems corresponds to the Cyclothem No. 20 *plus* No. 21 of the northeast, and it consists of thick sandstone reaching 40 m. at the maximum. This cliff forming sandstone is called Iwaishi shagan-sô or Iwaishi sandstone bed by H. NAGAHAMA (1954) and Takaiwa-shagan or Takaiwa sandstone by H. SAWATA (1958). Coals of Yonsun (C 52), Hassun (C 53), Gamé or Gamé-tan (C 54) and Sammaimono-sô (C 55) occur in ascending order in the upper half portion superjacent the Takaiwa sandstone and all of them are workable in this area.

A noteworthy tuff lies in the upper portion of the Cyclothem No. 22, named Hongaura gyokaigan-sô or Hongaura tuff bed by H. NAGAHAMA (1954) and T 26 by H. SAWATA (1958). It typically exposes near Hongaura, Shikamachi-machi, maximum 6 m. or so, and also is identified during the progress of drilling. This dark greenish tuff turns into greyish white colored one if weathered, and yields pisolites in the base and sometimes inserts tuff breccias in it.

Rest of the strata above this tuff consists mainly of mudstone (maximum: 12–13 m. thick), containing coals named Hachimaki and Uwa-hachimaki. The top of this Cyclothem No. 22 is worn off in a different amount due to the disconformity as already stated above.

Due to the diastem on the top of the Fukui formation, the coal Sammaimono sometimes disappears locally, e. g., on the east of Kammbayashi, Shikamachi-machi and the south of Shisa-machi, Matsuura city,

Near the coal seams in this formation sometimes fossil plants are contained, and in the mudstone between the coal Goma-tan and Uwa-iwaishi, the upper portion of Cyclothem No. 19, fossil shells of *Corbicula hizenensis* UEJI and other unidentified pelecypods are found. Among the fossil molluscs in the upper part of Cyclothem No. 20 *Corbicula* (*Cyrenobatissa*) *procera* SUZUKI and *C.* (*Corbicula*) *matusitai* SUZUKI have been identified.

6. Kasé formation (H. NAGAHAMA, 1954)

This formation, the uppermost formation of the Sasebo group, is typically exposed along the coast-line of a point jutting out into inlet in the west of Kasé, Shikamachi-machi. It is developed in a general way along a belt inside both the Rias coast in the west of this coal field and the north coast from the west of Shisa to

* locally workable.

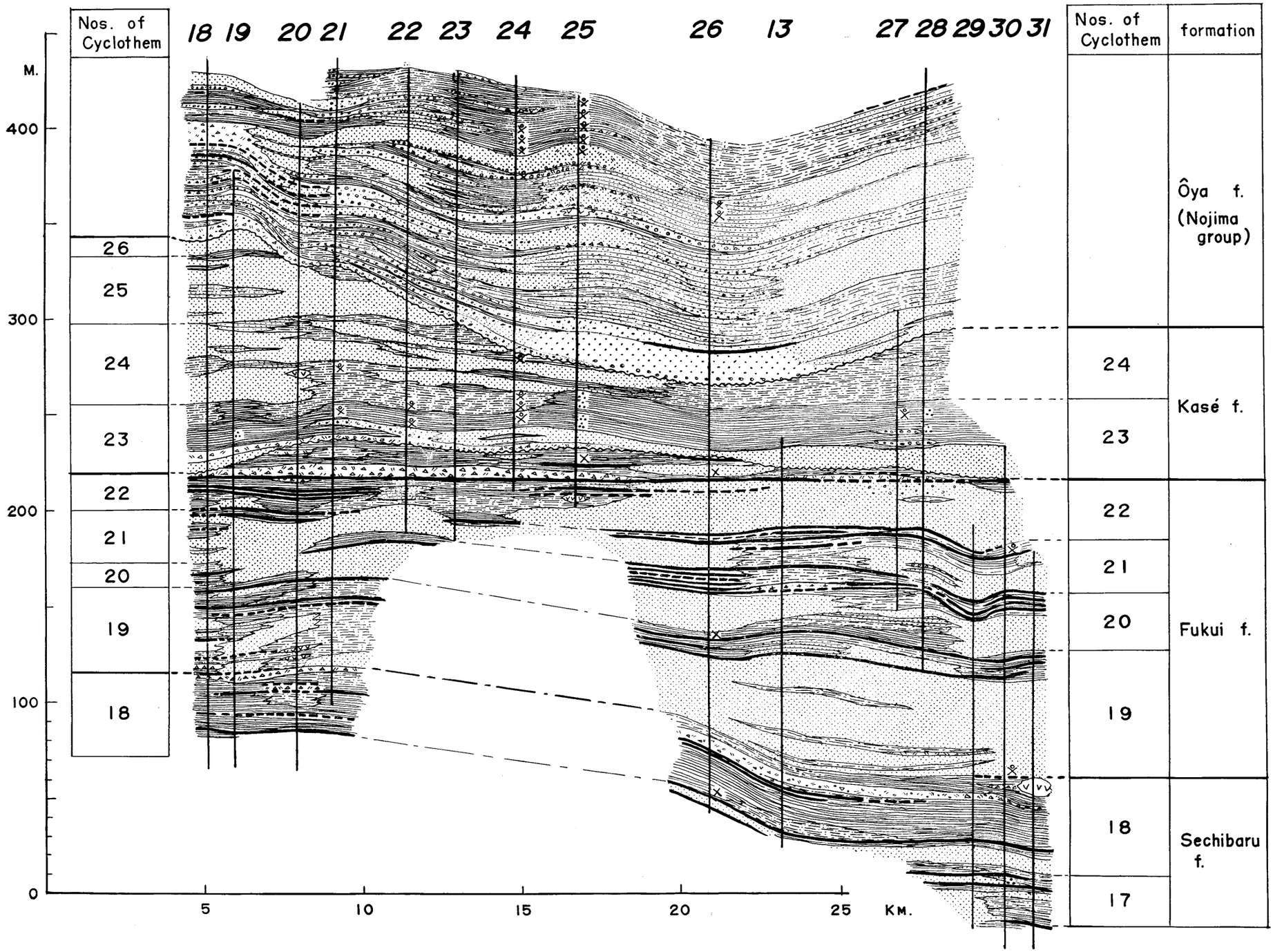

Fig. 4. Lithological cross section of the upper part of the Sasebo group. (Southwest-northeast profile)
Location of the section is shown in Fig. 1 with the solid line.

the south of Imafuku. The Kasé formation lies disconformably, namely with a diastem, on the underlying Fukui formation as aforementioned, and overlain unconformably by the Nojima group. The upper part of the Kasé formation is locally eroded off not less than 86 m. thick. Although the original thickness of the formation is not known exactly due to the unconformity, the apparent maximum thickness attains 124 m. being measured in the borehole at the islet Maéjima, the south corner of this field, and the minimum 38 m. at near Otaké, northeast of Emukaé. The thickness is decreasing gradually from the southwest to the middle-north and again increasing toward the northeast. This variation in thickness of the formation is owing mainly to the magnitude of the erosion.

In this formation no coal was accumulated, but many molluscan and foraminiferal remains which indicate from marine to brackish environment are preserved. The lithofacies of the formation is so variable laterally except in the lowest part that the formation is subdivided with much difficulty into four cyclothems, Cyclothem No. 23 to No. 26.

The Cyclothem No. 23 is subdivided into two members as below:

The lower member is called by H. NAGAHAMA (1954) the Kusudomari conglomeratic sandstone member or by H. SAWATA (1958) Kusudomari gravel bearing sandstone member. It consists mainly of greyish white fine to medium grained sandstone bearing pebbles and granules with a thickness of 2-17 m. The pebbles and granules are of pre-Tertiary rounded and subrounded chert, slate, quartzite and greenish coloured metamorphic rocks and Tertiary tuffaceous rocks, pumice, fine sandstone, mudstone, coaly mudstone and coal.

This member yields marine molluscs and sandpipes. The contents of the fossils are as follows;

Balanus sp.
Epitonium sp.
Venericardia subnipponica NAGAO
Spisula sp.
Chlamys sp.
Callista sp.
Pitar sp.
etc.

On the other hand, the upper member of this cyclothem, 20 to 25 m. thick, is composed chiefly of dark grey mudstone and is named by H. NAGAHAMA (1954) the Maégasé black shale member or by H. SAWATA (1958) Maégasé dark grey mudstone member. The uppermost portion of the mudstone is intercalated with sandstone which gradually increase their frequency and thickness upward, and turns into the overlying cyclothem by degrees. Therefore the boundary between this and the superjacent cyclothems is artificially placed on the base of massive sandstone which is overlying the alternation. In this alternation about 50 to 150 cm. thick, hard and indurated greyish white tuff is inserted and it collapses into blocks such as hornstone if hammared. In the middle portion of this member many fossils of foraminiferas and pelecypods are contained. Contents of the fossil foraminifera reported by

H. NAGAHAMA and T. SUZUKI (1955) are;

Cribrostomoides kyushuense ASANO
Cyclammina tani ISHIZAKI
C. obesa CUSHMAN et LAIMING
C. formosensis YABE et HANZAWA
C. japonica ASANO
C. bradyi CUSHMAN
C. orbicularis BRADY
C. sp.
Ceratobulimina ? sp.
Globigerina spp.
Haplophragmoides spp.
Milliolinella ? sp.
Nonion spp.
Plectina ? sp.
Robulus calcar (LINNE)
R. sp.
Trochammina ? sp.

In the upper portion of this member just beneath the alternation of mudstone and sandstone, fossil of *Portlandia nagahamai* MIZUNO (MS.) are abundant. The following fossils are known in this member:

Portlandia nagahamai MIZUNO (MS.)
Nucula sp.
Acila sp.
Astroidea
Notidanus sp.
fish scales

The Cyclothems No. 24 to No. 26 were together called the Kaki shagan-sô or *Ostrea* sandstone member by H. NAGAHAMA (1954) and the Nagiri sandstone member by H. SAWATA (1958). They are composed chiefly of greyish white, massive, fine to medium grained sandstones with subordinate mudstones and alternations of sandstone and mudstone. Among them mudstones and alternations occur in the upper portion and in other several horizons of each cyclothem, which are not laterally continuous.

In the Cyclothem No. 24, many shells are contained;

Glycymeris cf. *matsumoriensis* NOMURA et HATAI
Crassatellites yabei NAGAO
C. sp.
Protothaea tateiwai (MAKIYAMA)
Venerupis cf. *siratoriensis* (OTUKA)
Cyclina japonica KAMADA
Anadara sp.
Ostrea gravitesta YOKOYAMA
Pitar cf. *itoi* MAKIYAMA
Corbicula sp.

Siphonalia ? sp.
Arca ? sp.
"Cerithium" nagahamai MIZUNO (MS.)
Cerithium sp. nov.
Acila sp.
Saxidomus purpuratus SOW.
Callista sp.*

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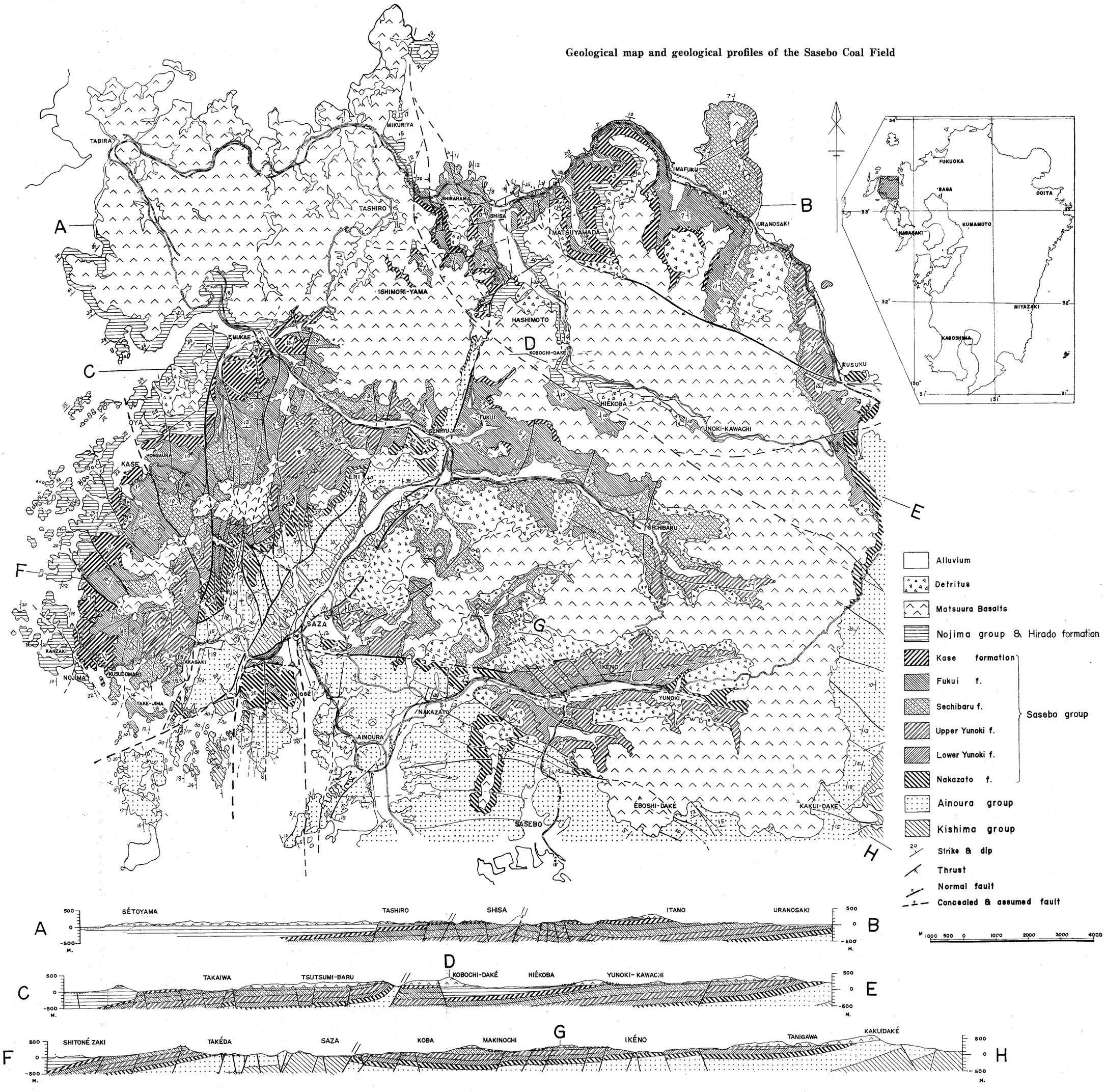
Geological map and geological profiles of the Sasebo Coal Field



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