REPORT No. 197

GEOLOGICAL SURVEY OF JAPAN

A STUDY ON THE CRETACEOUS SEDIMENTATION IN HOKKAIDO, JAPAN

By

Keisaku TANAKA

GEOLOGICAL SURVEY OF JAPAN

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Katsu KANEKO, Director

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CONTENTS

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Abstract

This paper is composed of three parts. In Part I, the Cretaceous deposits, especially the Middle Yezo and Upper Yezo groups in the Obirashibe Valley, northern central Hokkaido are described with special reference to their sedimentary facies. The cyclic sedimentation recognized in the Cretaceous and the facies distribution related to the disposition of the depositional environments are the two main subjects discussed here. In connection with the subjects relationships between the lithofacies and biofacies are considered. Furthermore, a preliminary note is offered on the petrographic characters of the sedimentary rocks, especially on the characters of sandstones in the Nakakinembetsu sandstone member to elucidate the facies change of the member.

In Part II, an outline of the Cretaceous rocks in the areas investigated by the writer other than the Obirashibe area is given, with some remarks on special features.

In Part III, some notes are presented on the stratigraphy and sedimentation of the Cretaceous rocks in the meridional zone of Hokkaido. First, on the rock-stratigraphic and time-stratigraphic units a brief discussion is offered. Then a stratigraphic classification based on the sedimentary cycles is proposed for the Cretaceous sequence. Thus the sedimentary cycles are stressed among other stratigraphical problems. Concerning the sedimentation, the sedimentary facies, especially the mutual relationships among thickness, lithofacies and biofacies, sedimentary provinces, the relationship between subsidence and deposition, cyclic sedimentation and so forth are explained. Furthermore tectonic influence upon the sedimentation and configuration of and conditions in the basin of sedimentation, i.e. the Yezo geosyncline are discussed in relation to Cretaceous sedimentary history.

Introduction and Acknowledgements

The Cretaceous deposits in the meridional zone of Hokkaido are extensively developed and provided with a great amount of fossil remains of good preservation almost throughout. Therefore they have been studied by many authors from the stratigraphical and paleontological standpoints and so forth. Of a number of geological investigations, epochmaking comprehensive and synthetic studies are as follows: (1) Dr. Hisakatsu Yabe's pioneer stratigraphical works (1926, 1927), (2) the succeeding works published by Dr. Tatsuro Matsumoto (1942–43, 1954, 1959) from the standpoint of biostratigraphy and (3) Dr. Wataru Hashimoto (1954, 1958) from the standpoint of geohistory or geotectonic development.

The detailed stratigraphic succession of the Cretaceous deposits has been established in several important areas within the meridional zone of Hokkaido by certain previous investigators. Especially Prof. T. Matsumoto (1942–43, 1954, 1959) did a fine work in connection with his biostratigraphic study. The geological conditions in many other Cretaceous localities, however, have remained to be not fully made clear. Accordingly, under the sheet-map survey conducted by the Geological Survey of Japan, the present writer has for several years carried out field work in selected Cretaceous areas, where detailed investigation has not been accomplished. On the basis of this investigation as well as the previous work he has endeavoured to elucidate the Cretaceous stratigraphy and sedimentation in Hokkaido, which is the main subjects of this work.

For this purpose the writer defined quantitatively the relative abundance of such lithologic elements as sandstone, tuff and calcareous concretion, and that of fossils. Thereby he has attempted to give special attention to both vertical and lateral changes in lithologic aspects and also in composition of fossil assemblage which is fundamentally represented by the ammonite-inocerami ratio, aberrant ammonite-coiled ammonite ratio, etc. Although previous works are not always useful for reference in a full discussion of Cretaceous stratigraphic sequence and sedimentary facies in Hokkaido from this point of view, much available data have already been obtained in certain limited Cretaceous areas. The areas are as follows, enumerated from north to south (Fig. 1).

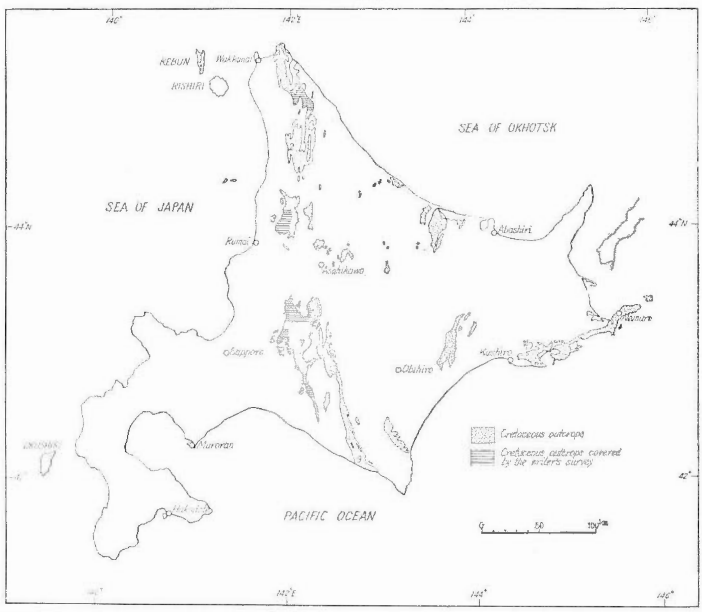

Fig. 1 Index map showing the distribution of the Cretaceous deposits in Hokkaido and location of the standard areas

1. Kamisarufutsu district
2. Abeshinai Valley
3. Obirashibe Valley
4. Sorachi anticlinal area
5. Ikushumbetsu Valley
6. Furano district
7. Shiyubari Valley
8. Tomiuchi district
9. Urakawa district

(1) The Abeshinai Valley, province of Teshio (Matsumoto, 1942–43, 1954)
(2) The Ikushumbetsu Valley, province of Ishikari (Fukada and others, 1953; Matsumoto, 1943, 1954, 1959)
(3) The Shiyubari Valley, province of Ishikari (Matsumoto, 1942–43, 1954)
(4) The Tomiuchi (or Hetonai) district, province of Iburi (Matsumoto, 1942–43, 1954)

(5) The Urakawa district, province of Hidaka (Matsumoto, 1942–43, 1954)

In addition, the Naibuchi Valley, southern Saghalien, offers many valuable data (Matsumoto, 1942–43, 1954). Furthermore, many contributions are now being made by many persons in regard to the Cretaceous stratigraphy of various areas.

Nevertheless, the writer feels it needful to gain by himself more sufficient knowledge on Cretaceous stratigraphic succession, sedimentary facies, and biofacies. Moreover, in the course of the writer's investigation he recognized cyclic features not only in the Hakobuchi group, the case of which has already been pointed out by Hanai and others (1952) and Matsumoto (1954), but also in the Cretaceous sequence lower than that. Thus, it has been another main purpose of the present study to ascertain how the cyclic phenomena took place in the Cretaceous sedimentation throughout the meridional zone of Hokkaido.

The areas covered by the writer's survey are from north to south as follows (Fig. 1).

(1) The Kamisarufutsu district, province of Soya
(2) The Obirashibe Valley, southern part of province of Teshio
(3) The Sorachi anticlinal area, province of Ishikari
(4) The Ikushumbetsu Valley, province of Ishikari
(5) The Tomiuchi district, province of Iburi

The results of the biostratigraphic study in each of the areas mentioned above are generally in harmony with the previous work (e.g. Matsumoto, 1942–43, 1954, 1959). In the Kamisarufutsu district, some new knowledge was obtained from the Cretaceous strata in the Kamuikotan zone. The zone is to the east of the other surveyed areas. The relationship between the lithofacies and biofacies was examined in various ways in the Cretaceous rocks of the Obirashibe Valley; also in the Cretaceous deposits in the Sorachi anticlinal area a stratigraphic correlation was done on the basis of cycle of sedimentation and the geological meaning of the deposition of the Tsukimi sandstone member was clarified. Further, as to the Cretaceous formations in the Ikushumbetsu Valley and Tomiuchi district, a detailed stratigraphic succession of the Upper Yezo group can be established respectively.

On the basis of the data obtained by the writer and contributed by many other persons the stratigraphy and sedimentation of the Cretaceous sequences in the meridional zone of Hokkaido are here discussed. This paper is composed of three parts. In Part I the geological conditions of the Cretaceous deposits along the Obirashibe Valley are described with special reference to the sedimentary facies and sedimentation. In Part II the writer intends to give an outline of the Cretaceous sequences in the areas investigated by the writer other than the Obirashibe area. In Part III he presents general account on the stratigraphy and sedimentation of the Cretaceous deposits in the meridional zone of Hokkaido.

Heartfelt thanks are expressed to a number of persons for their help and advice in numerous ways. The writer is much indebted first of all to Prof. Tatsuro Matsumoto of the Geological Institute, Kyushu University for his constant guidance and many valuable suggestions. Prof. T. Matsumoto read the manuscript and sincere gratitude should be offered to him. For the study of the sedimentary rocks, indebtedness is expressed to Mr. Yasuo Sumi of the Geological Survey of Japan for his help. Further thanks are offered to Messrs. Isao Imai and Eiji Inoue of the Geological Survey and to Mr. Yasuo Maeda of the Taisha Middle School, Hyogo Prefecture for assistance in field work, and to Prof. Wataru Hashimoto of the Geological and Mineralogical Institute, Tokyo University of Education for his suggestions.

PART I

SEDIMENTATION OF THE CRETACEOUS FORMATIONS IN THE OBIRASHIBE VALLEY, NORTHERN CENTRAL HOKKAIDO

I. Introduction

The Obirashibe (or Opiraushibets) Valley is in the so-called Rumoi coal-field, northern central Hokkaido (Fig. 2). The area has been known to exhibit a good display of Cretaceous deposits in Hokkaido from several decades ago as a result of some pioneer paleontological works on some ammonites from the area carried out by the late Dr. K. Jimbo (1894) and Dr. H. Yabe (1903–4, 1909, 1910). Nevertheless the Cretaceous strata of the present area have not been fully investigated since Dr. S. Yamane's provisional survey (1926)*.

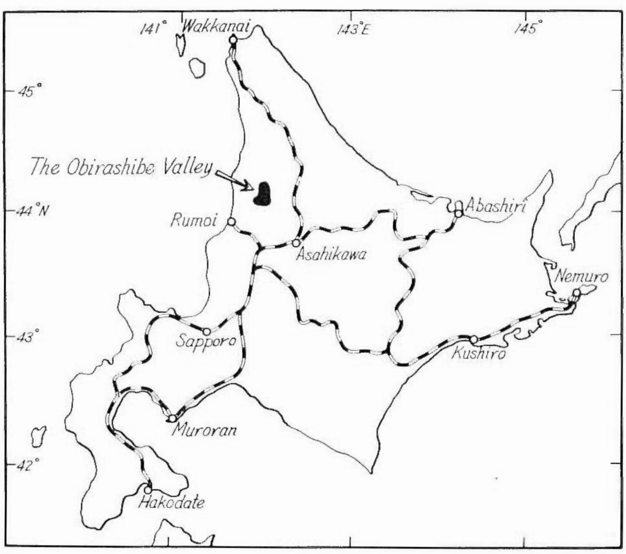

Fig. 2 Index map showing the Cretaceous locality of the Obirashibe Valley, northern central Hokkaido

In 1953 and 1954 the writer engaged himself to do field work on the Cretaceous formations of the Obirashibe Valley and an adjoining part of the northern Kotambetsu Valley. The general geological results have already been published in "Tappu and Horokanai," Explanatory Text of the Geological Map of Japan

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* The Cretaceous foraminifera of the present area were recently studied by Dr. Y. Takayanagi (1958, 1960).

with scale of 1:50,000 (Tsushima, Tanaka, Matsuno and Yamaguchi, 1958; Igi, Tanaka, Hata and Sato, 1958). For the Kotambetsu Valley there is a report by T. Shimada (in Agatsuma and Masatani, 1953). The Cretaceous rocks of the area under discussion are composed mainly of the two of the four major rock-stratigraphic divisions in the Cretaceous deposits of the meridional zone of Hokkaido, viz., Middle Yezo and Upper Yezo groups. In this area the highest, Hakobuchi group, is entirely lacking, and only a fraction of the Lower Yezo group is exposed in a very small area. In addition to the biostratigraphic study, the results of which are generally in harmony with the previous work (e.g. Matsumoto, 1942–43, 1954, 1959), writer's special attention has been paid to the sedimentary facies and sedimentation. The following description includes, among others, that of the relationship between the lithofacies and biofacies of the Cretaceous deposits. Furthermore, a preliminary study has been attempted on the sedimentary rocks themselves.

II. Outline of the Topography and Geology

The valley of the Obirashibe, running westward into the Japan Sea, is bordered on the eastern side by the Teshio mountain range of roughly N-S trend. The middle and upper valley occupied by the Cretaceous deposits under consideration is on the whole a hilly land; it adjoins the northern Kotambetsu and northwestern Sankebetsu valleys. The eastern backbone with the general altitude of 600 to 900 m is built up of the Cretaceous rocks themselves, while the western divide of the Tertiary. In this area, the main course of the Obirashibe is of nearly N-S trend in the upper stream and nearly ENE-WSW in the mid stream, showing incised meandering; it is joined by many larger and smaller tributaries. The northwestern and eastern tributaries are mostly rather consequent streams, on the other hand the southeastern ones, of which the three tributaries of the Kamikinembetsu-zawa, Nakakinembetsu-zawa and Shimokinembetsu-zawa are very long, are generally rather insequent streams.

The geological conditions of the area under discussion may be outlined as follows. In the first place, the geological map of the Obirashibe Valley and its neighbouring area is shown in Map I and Fig. 3 respectively. The Cretaceous deposits along the Obirashibe Valley occupy the western wing of a large scale anticlinal structure, the axial part of which exhibits the Kamuikotan metamorphics and Jurasso-Cretaceous Sorachi group accompanied by serpentinite masses which intruded near the close of the Cretaceous or the beginning of the Tertiary. Here, the Cretaceous rocks consist of the Lower Yezo, Middle Yezo and Upper Yezo groups in ascending order. The Lower Yezo group lying on the Sorachi group with unconformity is composed mainly of sandstone and shale in alternation of Flysch type; it is exposed in a very much small area at the northeastern extremity of the area under discussion*. This group and the Middle Yezo group are in disconformable relation, as is observed at the eastern adjoining area, i.e. along a western tributary of the Uryu. The relation between the Middle Yezo and Upper

* In the northeastern adjoining area covered by the Pliocene deposits (Fig. 3) *Puzosia* cf. *communis* SPATH was found in a boulder of siltstone which was probably derived from the middle or upper part of the Lower Yezo group. This fact may therefore suggest that the comparatively upper part of the Lower Yezo group is referred to the Albian stage.

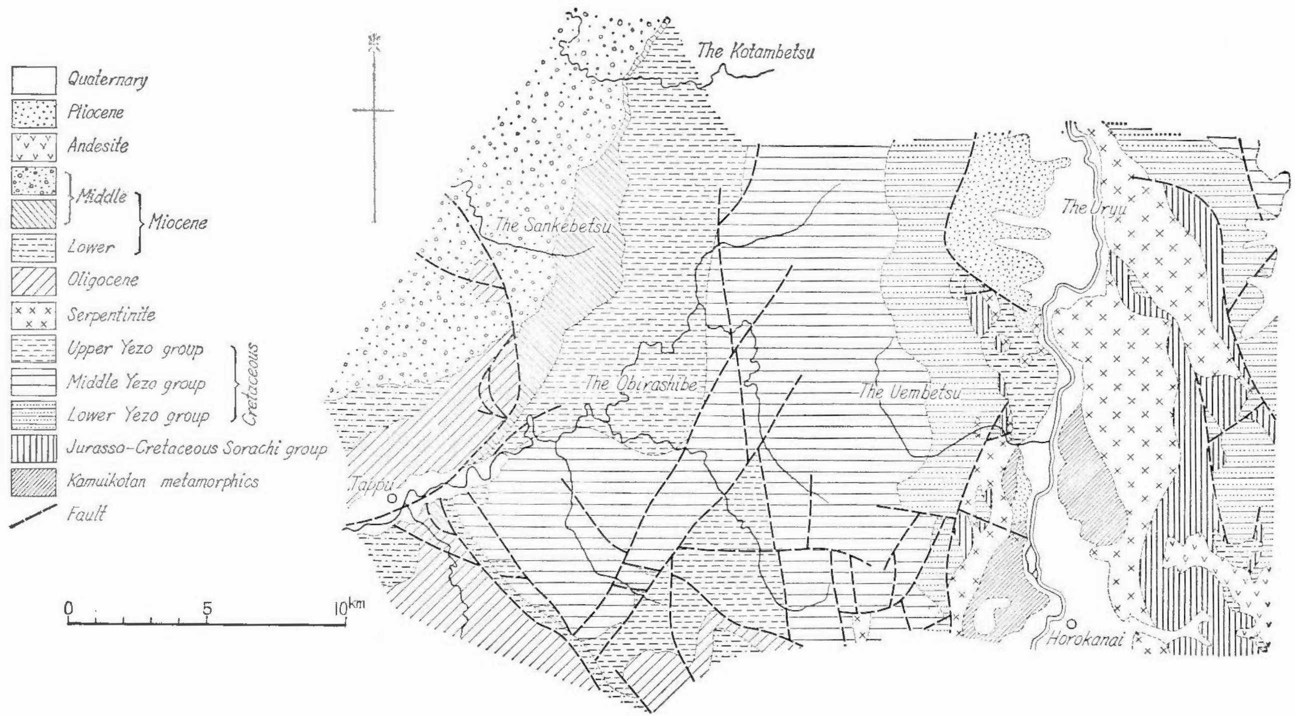

Fig. 3 A compiled geological map of the Obirashibe Valley and its adjacent area, northern central Hokkaido (Adapted from the Geological Map of Japan, Tappu and Horokanai Sheets, Scale 1 : 50,000)

Yezo groups is conformable. The latter, in turn, is unconformably covered by the Oligocene, Lower Miocene and lower part of the Middle Miocene. A considerable amount of the Cretaceous rocks were eroded away before the deposition of the lower part of the Middle Miocene at the western margin. In the present area, the Hakobuchi group, the uppermost strata of the Cretaceous deposits in the meridional zone of Hokkaido, is not exposed owing to the denudation before the deposition of the Tertiary, although it is supposed to have been originally deposited therein. Sandstone dykes, which intruded in the Cretaceous age, are found throughout the Cretaceous domain, being especially frequent in its southwestern and western central parts.

The Cretaceous rocks in the area show a remarkable tectonic gap in their relation to the Neogene formation, but none to the Paleogene. As described above, they occupy the western wing of a large scale anticlinal structure. The strata form a westward homoclinal, locally fluted structure in the north and east where faults of N-S trend are predominant, while they show a great nose structure projecting to the west in the southwest. The nose structure is disturbed by minor foldings, minor nose structures and numerous faults which run dominantly in directions of NE-SW and NW-SE.

III. Stratigraphic Sequence

III. 1 General Remarks

The minor rock-stratigraphic classification of the Cretaceous strata in the area can be made on the basis of the vertical changes of both the lithofacies and the biofacies. The lithofacies means rock characters such as grades of coarseness, stratification and fissility, sandstone–shale ratio, enclosed tuffs or tuffaceous rocks, calcareous concretions, megafossils, drifted plant remains or carbonaceous flakes.

The biofacies is represented by the composition of the gross fossil assemblages which are especially well represented by the dominance ratio of ammonites to inocerami and that of aberrant ammonites to coiled ones, and so forth.

The abundance of some lithologic elements and that of fossils are defined as follows in this paper.

(1) Thin beds or layers of sandstone and tuff (As to the abundance of sandstone, the case of sandstone and mudstone in frequent alternation is excluded.)

a) Abundance in a given exposure (in percentage of total thickness)

abundant: 10～20%
common : 5～10%
few : 1～5%
rare : 0.5～1%
very rare: less than 0.5%

b) The abundance in a given unit (e.g. a member) is represented by the approximate average grade of abundance varying from horizon to horizon within the unit.

c) Where thick beds of sandstone or tuff are almost exclusively intercalated in a given unit (e.g. a member), their abundance also is to be here determined on the basis of the percentage noted above [in a].

(2) Calcareous concretions (of moderate size)

a) Abundance in a given exposure (in number per a given square measure)

abundant: more than 1 per 1 metre square
common : 1 per 1~2 metres square
few : 1 per 2~4 metres square
rare : 1 per more than 4 metres square

b) The abundance in a given unit (e.g. a member) is shown in the same way as noted above.

c) Where huge concretions are almost exclusively contained in a given exposure, their certain abundance is to be here raised to the rank just superior to that determined by the same way as noted above.

(3) Fossils

For defining the fossil abundance of a given unit (e.g. a member) within a certain sequence, there should be taken into consideration the abundance of the following three categories within the unit: (1) abundance of a given species at a certain locality, (2) abundance of gross fossil assemblages at a given locality, and (3) fossil abundance at a given fossiliferous horizon.

a) With these items in mind, on the basis of the abundance of species at a given locality (i), the abundance of gross fossil assemblages at a given locality (ii) is defined as below; also on the basis of the fossil abundance at the fossiliferous horizons within a given unit (e.g. a member) (iii), the fossil abundance in a given unit (e.g. a member) (iv) is defined as below.

(i)	(ii)	(iii)	(iv)
2VA or more 3A or more	VA	2va or more 3a or more	VA
1VA 2A 2A+1C 1A+2C	VA	1va 2a 2a+1c 1a+2c	A
1A 1A+1C 2C or 3C	A	1a 1a+1c 2c or 3c	C
1C 2F or 3F	C	1c 2f or 3f	F
1F 5R~9R	F	1f 5r~9r	R
1R~4R	R	1r~4r	VR

VA, va: very abundant, A, a: abundant, C, c: common,
F, f: few, R, r: rare, VR: very rare
2VA in (i): two species occur very abundantly at a given locality.
2va in (iii): two horizons where fossils occur very abundantly are counted in a given unit (e.g. a member).

In the case of (i) and (iii) there are many other examples in each of all the ranks other than the base. For example, 1C + 2F (or 3F) is to be included into the third rank from the top, because 2F (or 3F) is of the same rank as 1C.

For the abundance of the above four categories the following explanations are given.

b) Abundance of a given species at a certain locality (in number of individuals)

very abundant	:	numerous, not easily countable
abundant	:	more than 16
common	:	6~15
few	:	3~5
rare	:	1~2

In the case of inocerami, the joined two valves are of course to be counted as one individual. A huge fossil such as an individual of a certain puzosid or pachydiscid, where it forms a calcareous concretion itself, is to be counted in the same way as a calcareous concretion.

c) Abundance of the gross fossil assemblages at a given locality

This value is to be represented by both number of species and abundance of each species within the locality. Thus, three species (e.g. the first example in the above table) which are respectively very abundant, abundant or common in number of individuals, are to be here counted per each locality. This should be done because in the Cretaceous deposits of this area three species as defined above are counted in many localities.

d) Fossil abundance at a given fossiliferous horizon

This value is to be represented by the approximate average grade of abundance of gross fossil assemblages as defined above varying from locality to locality within the fossiliferous horizon.

e) Fossil abundance in a given unit (e.g. a member)

This value is to be represented by both number of fossiliferous horizons and fossil abundance at each fossiliferous horizon within the unit. Thus, three fossiliferous horizons (e.g. the third example in the above table) where fossils are respectively very abundant, abundant or common are to be here counted per each sequence of 100 m thickness. This is the case because as to the Cretaceous deposits in the area under discussion, difference of both lithologic and faunal aspects are generally discriminated per each sequence of about 100 m thickness which ordinarily coincides with a member or its subdivision and three fossiliferous horizons as defined above are counted in many sequences.

Such definitions of the abundance of some lithologic elements and that of fossils as mentioned above are also applied to the Cretaceous deposits in other areas covered by the writer's survey which are described in Part II of this paper.

The stratigraphic succession thus established is shown in Fig. 4*. All of the minor stratigraphic units subdivided here may be equivalent to members in recent stratigraphy.

Before entering into a stratigraphic description the following notes [(1)–(7)] are briefly given on some of the rocks constructing the Cretaceous strata under discussion.

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* For the correlation of the Japanese Cretaceous time-stratigraphic classification to the European standard, see Fig. 29 in page 74 of this paper.

(1) The sandstones are generally greenish grey to bluish grey in colour where they occur as thick beds with several to ten metres or so, but grey to dark grey where intercalated as thin beds or layers with various thickness ranging from 3 or 4 cm to 30 cm or so. Some of them are calcareous or tuffaceous. In the alternating sandstone and mudstone graded bedding is well developed.

(2) The argillaceous rocks, ordinarily dark grey in colour, pass into blackish as their coarseness decreases and are at various horizons shaly, occasionally grading even into shale. In this paper, the general term "mudstone" is often, for convenience, to be used for rather clayey rock, i.e. indurated rock of silt–clay mixture, which is, in turn, to be classified into mudstone (clayey) and mudstone (silty) in some cases, discriminating the former from claystone (s. s.) and the latter from siltstone (s. s.). The mudstones become furthermore sandy, such being occasionally more or less greenish coloured. The term "laminated sandy mudstone" in this paper means mudstones very frequently interlaminated with sandstones.

(3) The tuffs or tuffaceous rocks (tuffaceous sandstones and mudstones), which are as a rule whitish to greenish in colour, are mostly intercalated as thin beds or layers with various thickness ranging from 3 or 4 cm to 30 cm or so and occasionally as thick beds, several to ten metres or so in thickness. They are occasionally well stratified or laminated, and generally rather loose. Some of them are hard, compact and of flinty appearance especially in the sandy facies. Furthermore they are in some cases altered into bentonitic.

(4) A great amount of greensand grains, the mineralogical characters of which must be left for future study, are disseminated in the mudstones as well as in the sandstones at several horizons.

(5) The calcareous concretions are rounded, generally ellipsoidal or spherical but occasionally irregular in shape, and of various sizes ranging from 3 or 4 cm to 1 m or more in diameter. Concretions are ordinarily spherical or irregular in shape in the massive rocks, while ellipsoidal or flattish in the stratified ones.

(6) The marine fossil remains represented chiefly by ammonites and inocerami occur abundantly with a random orientation or with an orientation subparallel to the plane of sedimentation in the concretions as well as in the host rocks themselves. They are however rather scarce in the ellipsoidal or flattish concretions as the drifted plant remains and carbonaceous flakes mentioned below.

(7) The drifted plant remains and carbonaceous flakes are included in both concretions and host rocks, the latter showing stripped patterns in some of the sandy rocks.

III. 2 Middle Yezo Group

The Middle Yezo group, about 3,500 m thick, lies on the Lower Yezo group with unconformity. Mudstones are rather predominant throughout the group, but sandstones commonly occur in the lowest and uppermost parts.

The lowest part of the group (Ma–Mc), 1,000 m or so in thickness, is named the Kanajirizawa formation and composed mainly of sandstones with subordinate mudstones and conglomerates. It is subdivided into three members, the middle one of which is finer grained than others and the upper one of which intercalates a thick tuffaceous rock. Calcareous concretions and fossil remains are very poor in this formation.

The main part (Md–Mk), nearly 2,000 m thick, is comparatively monotonous

Table 1 List of the fossils from the Nakakinembetsu sandstone member (Ml) in the type exposures along the Nakakinembetsu-zawa

Species \ Locality \ Area	Lower course of the Nakakinembetsu-zawa				Mouth of the Nakakinembetsu-zawa				
	91-a	91-b	91-c	91-d	60-a	60-b	60-c	60-d	59
Neophylloceras subramosum								R	
N. ramosum								R	
Tetragonites sp.		R				C			
Tragodesmoceroides subcostatus		R				?		R	
Tragodesmoceroides sp.					R				
Mesopuzosia pacifica			?					R	
M. yubarensis	R					R	?		
Mesopuzosia sp.			R						
Jimboiceras planulatiforme								R	
Hyphantoceras venustum						R		R	
Bostrychoceras otsukai		R				R			
Scaphites planus		A							
S. pseudoaequalis		A				R			
Scaphites sp.			R	R					
Otoscaphites puerculus		A				R		R	
Scalarites scalaris		F				R			
Scalarites sp.			R						
Inoceramus tenuistriatus		R			?	R		R	
I. hobetsensis						R			R
I. teshioensis						?		R	
I. incertus								R	
Inoceramus sp.		F	R			F	R		
Simple coral								R	
Fish scale						R			
Plant remains or carbonaceous flakes		A				C		A	

All the locality numbers in the lists of fossils are to have prefix NH.

A: abundant R: rare

C: common ?: identification indefinite; rare

F: few

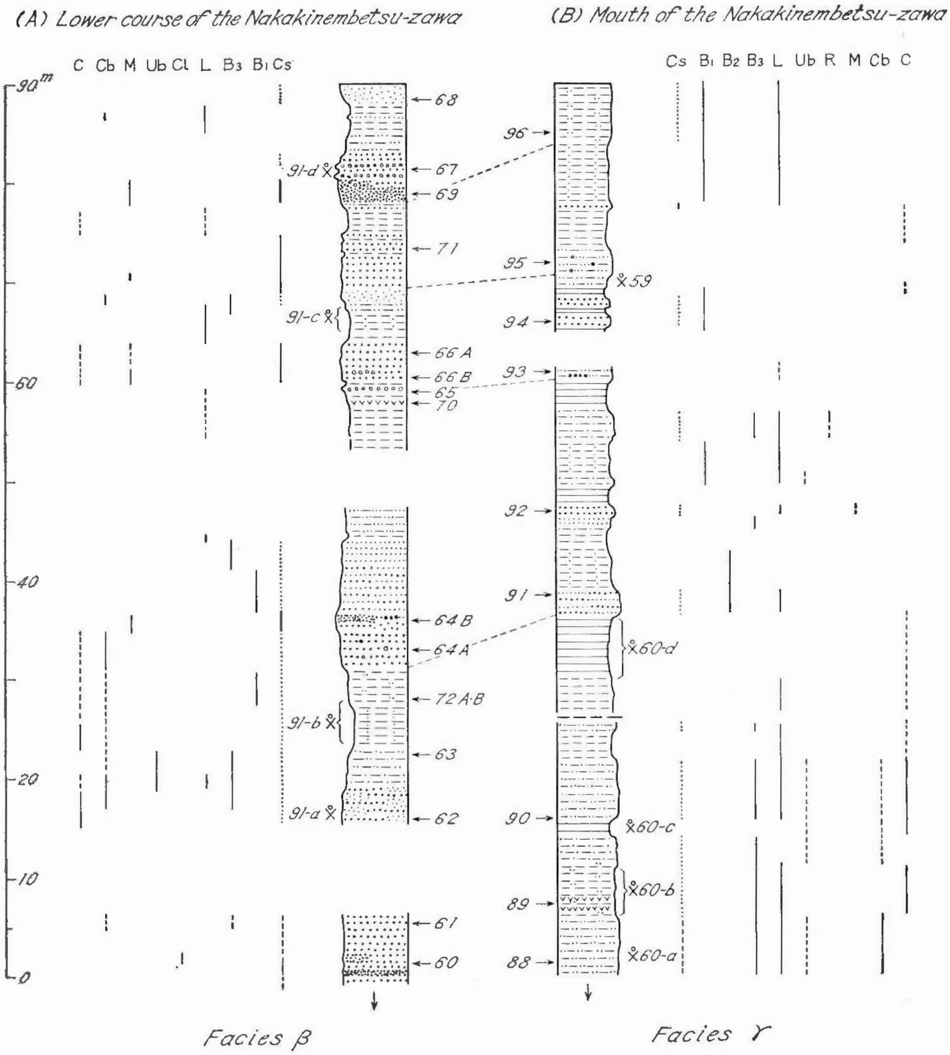
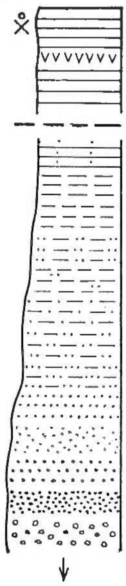


Fig. 5 Columnar sections and lithologic characters of the Nakakinembetsu sandstone member (Ml) in the type exposures along the Nakakinembetsu-zawa

Explanation of Fig. 5

Legends for the stratigraphic sections



Fossils of marine organisms, all the numbers being to have prefix NH
Tuff or tuffaceous rock
Mudstone
Fault relation
Thin beds or layers of sandstone being sporadically intercalated
Siltstone
Fine sandy siltstone
Sandstone and mudstone (or siltstone, in thin-bedded alternation
Mudstone (or siltstone) being predominant
Both being approximately in equal amount
Sandstone being predominant
} sandstone and mudstone (or siltstone) in medium- or thick-bedded alternation
Sandy siltstone to silty fine-grained sandstone
Silty fine-grained sandstone
Fine-grained sandstone
Medium-grained sandstone
Coarse-grained sandstone
Conglomerate
Near the lower limit, though not observable

←—Horizons of rock samples, all the numbers being to have prefix OB

Explanation of the abbreviations

Cs : colour of the sandstones
B_1 : thick-bedded
B_2 : medium- to thick-bedded
B_3 : thin- to medium-bedded
L : lamination
Cl : cross-lamination
Ub: uneven bedding plane
R : ripple mark
M : contemporaneous breccia of mudstone
Cb: carbonaceous matter
C : calcareous concretion

Explanation of the lines

Colour of the sandstones
Thick line: varigated
Thin line: greenish grey
Broken line: bluish grey
Dotted line: grey

Grades of abundance or frequency of the elements other than colour of the sandstones
Thin line: abundant or frequent
Broken line: not abundant or not frequent

and fine-grained deposits containing sporadic calcareous concretions, some of which are fossiliferous. However, beds or layers of sandstone are frequent in its lowest part and those of tuff or tuffaceous rock are found at several horizons.

The uppermost part (Ml–Mo), about 500 m thick, begins with a unit of relatively thick sandstone (Ml) named the Nakakinembetsu sandstone member (Fig. 5; Table 1), and grades upward into concretional and fossiliferous mudstone with frequent intercalation of sandstone, being finer grained in its middle part than in the other. This part is referable to the Saku formation of the Abeshinai and Shiyubari areas (Matsumoto, 1942–43, 1954) in its rock-facies and fossil contents. It occupies, however, a shorter stratigraphic range than the Saku formation in the standard areas. The Nakakinembetsu member, 50 to 90 m thick, are made up of sandstone and mudstone (or siltstone) in alternation of various thickness with some conglomerates in its upper part. Furthermore, the member shows a noticeable lateral change of the lithofacies and biofacies as mentioned below.

The fossils contained in the group are shown in Table 2. From this fossil evidence the age of the group is concluded as presented in Fig. 4*. *Inoceramus hobetsensis* characterizing the Upper Gyliakian stage occurs most abundantly in the upper part of Mn (Mn_2) and Mo, which are to be referred to the upper part of the stage. This species is abundant also in the middle and upper parts of Mj (Mj_2 and Mj_3), which belong to the middle part of the stage.

III. 3 Upper Yezo Group

The Upper Yezo group shows a gradual change of rock-facies to the Middle Yezo group and is no less than 1,700 m in thickness. The group is divided into the main and the uppermost parts.

The main part of the group (Ua–Ug) is made up largely of monotonous fine-grained sediments, containing calcareous concretions, with occasional tuffs or tuffaceous rocks, and is very fossiliferous throughout. The thickness is nearly 1,200 m. Of its minor rock-stratigraphic units, Ub, i.e. the Kamikinembetsu silty fine-grained sandstone member (Fig. 6), is 30 to 100 m thick and it begins with sandstone, 6 m or less thick, and grades upwards on the whole into fine-grained rock. It is characterized not only by its relative coarseness of the rock and great dissemination of greensand grains but also by abnormal sedimentary structures. The sediments are in the main ill sorted and provided with no few isolated pebbles. They show irregular stratification, e.g. corrugate lamination, crinkled bedding, and occurrence of disrupted layers or beds and irregular bodies of sandstone, and also contain no few concretions with very irregular shape (Fig. 7).

In the uppermost part (Uh–Ul), measuring up to 500 m in thickness, rocks are on the whole coarser grained and tuffs or tuffaceous rocks are scarce as compared

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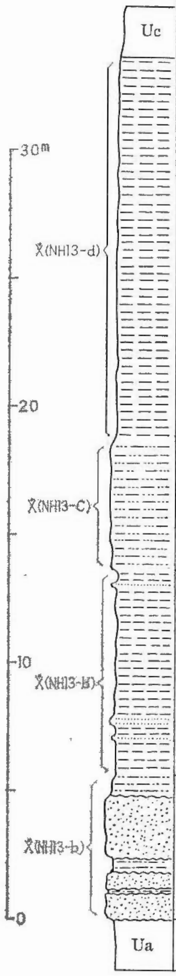
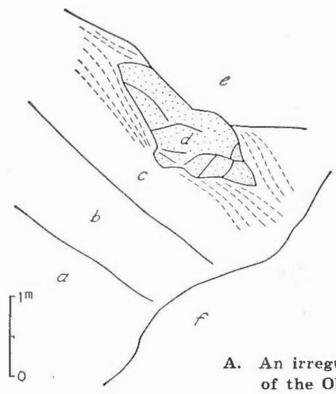
* The following list is an addition to the list of fossils given in the succeeding chapters.
Member: Specific name (Locality)
Mb: *Desmoceras* cf. *latidorsatum* (NH636)
D. (*Pseudouhligella*) cf. *dawsoni* (NH635)
Me: *Desmoceras kossmati* (NH5704)
Inoceramus aff. *cripsi* (NH618, 627)
Lower part of Mf (Mf_1): *Desmoceras* (*Pseudouhligella*) *ezoanum* (collected by T. Makino from his loc. Kanajiri-zawa 74)
Uppermost part of Mh (Mh_3): *Inoceramus hobetsensis* (NH 94, 97)



	Lithologic characters	Remarks
Uc	Laminated sandy mudstone, shaly; calcareous concretions and fossils very abundant	
	Massive siltstone, rather comparatively fine grained, partly shaly Calcareous concretions: depressed, ellipsoidal or disk-like and sporadic Fossils: sporadic in concretions and host rocks	
	Massive silty fine-grained sandstone to fine sandy siltstone, ill sorted Calcareous concretions: sphaerical and of irregular shape Fossils: very abundant in concretions	Showing abnormal sedimentary structures Calcareous concretions: contained in irregular orientation Irregular bodies (0.3～0.5m in size) of sandstone and contemporaneous breccias of mudstone: abundant Greensand grains: irregularly interlaminated and disseminated in network
	← Greensand grains irregularly interlaminated Massive siltstone, rather comparatively coarse grained Calcareous concretions: sphaerical and rather abundant Fossils: fairly abundant in concretions ← Greenish grey medium-grained sandstone, laminated	
	← Greenish grey medium-grained sandstone and silty sandstone in medium- and thick-bedded alternation Greenish medium- and coarse-grained sandstone, partly silty and tuffaceous, accompanied with sandy siltstone Fossils: rare in sandstone	Carbonaceous matters: abundant in sandstone Contemporaneous breccias of mudstone: not a few in sandstone Crinkled bedding: occasionally developed
Ua	Massive siltstone, rarely shaly; calcareous concretions and fossils sporadic	

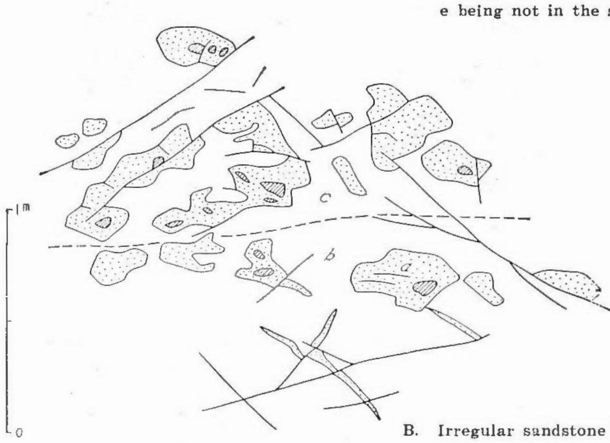
Fig. 6 Columnar section and lithologic characters of the Kamikinembetsu silty fine-grained sandstone member (Ub) in the type exposure, Takishita

Wave lines showing crinkled bedding



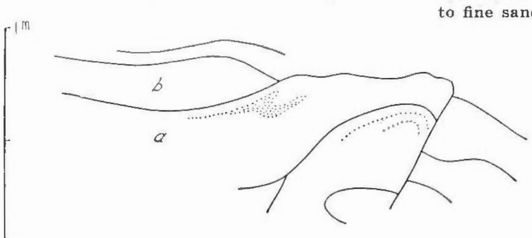
A

A. An irregular sandstone body in the outcrop along the left bank of the Obirashibe near the mouth of the Kamikinembetsu-zawa (vertical view) a: greensand-bearing silty fine- to medium-grained sandstone, b: silty fine-grained sandstone to fine sandy siltstone with sporadic calcareous concretions, c: fine sandy siltstone, laminated in the upper, d: medium-grained sandstone, e: silty fine- to medium-grained sandstone, f: river-beach d and e being not in the same plane



B

B. Irregular sandstone bodies and sandstone dikes in ill-sorted sediments in the outcrop along the right bank of the Obirashibe near Takishita (vertical view) a: coarse- to medium-grained sandstone containing patches of mudstone, b: silty fine-grained sandstone to fine sandy siltstone, c: fine sandy siltstone



C

C. Crinkled bedding in medium- to coarse-grained sandstone in the outcrop along the right bank of the Obirashibe near Takishita (vertical view) a and b being not in the same plane

Fig. 7 Showing some examples of the abnormal sedimentational features found in the Kamikinembetsu silty fine-grained sandstone member with the main part. This part is concretionary and fossiliferous throughout.

The fossils obtained from the group are shown in Table 3. The conclusion, from this fossil evidence, of the correlation of the members of the Upper Yezo group is indicated in Fig. 4*. *Inoceramus uwajimensis* characteristic of the Lower Urakawan stage occurs in a great amount in Uc and the lower part of Ud (Ud_1), which are to be referred to the middle to upper part of the stage. *I. naumanni*, the stratigraphic occurrence of which ranges from the Upper Urakawan stage up to the Uppermost Urakawan substage, is most predominant in the upper part of Ug (Ug_2), which belongs to the upper part of the Upper Urakawan stage. This species is abundant also in Uf and the lower part of Ug (Ug_1), which are to be referred to the middle part of the Upper Urakawan. The abundant occurrence of *I. schmidti* characterizing the Lower Hetonaian stage is known from Ui, which is to be assigned to the lower part of the stage. Thus, the Upper Yezo group ranges up to Paleohetonaian in age as in the case of the Abeshinai Valley (Matsumoto, 1942–43, 1954).

IV. Sedimentary Facies

IV. 1 Sedimentary Facies in General

Taking a wide view of the vertical change in the sedimentary facies of the Cretaceous strata under discussion (Fig. 4), one may say that sandstones are most dominant in the lowest part of the Middle Yezo group, being also intercalated as frequent beds or layers of various thickness in the uppermost part of the same group, while on the whole they are very sporadic in the other parts. The mudstones are shaly at various horizons and occasionally grade even into shale, the latter case especially occurring in the lower half of the Middle Yezo group where the mudstones are also frequently interlaminated with sandstones, i.e. nearly from the Upper Miyakoan to the Lower Gyliakian stage. Beds or layers of tuff and tuffaceous rock, calcareous concretions and fossils are more abundantly contained in the upper part of the main part of the Middle Yezo group, the uppermost part of the group and the Upper Yezo group, i.e. nearly from the Upper Gyliakian to the Lower Hetonaian stage than in the other strata. Greensand grains are on the whole disseminated throughout the Upper Yezo group and are abundant at several horizons. The middle part of the main part of the Middle Yezo group shows rather intermediate facies between the subjacent strata and superjacent ones. Furthermore, a lens of limestone, about 5 m in diameter is contained in the middle part of the Middle Yezo group.

Tuff and tuffaceous rocks occur dominantly in the upper part of the Lower Urakawan and the middle part of the Upper Urakawan stage and occasionally in the Uppermost Miyakoan substage, the transitional part from the Lower Gyliakian to the Upper Gyliakian stage, the lower and upper parts of the Upper Gyliakian and the upper part of the Upper Urakawan stage. A thick bed of tuffaceous rock is intercalated in the Upper Miyakoan stage.

The thickness and lithologic composition of the stages and substages recog-

* The conclusion that the uppermost part of Ug (Ug_3) is referred to the uppermost substage of the Urakawan series is tenable at least in the southeastern and northwestern parts of the area (Fig. 18; Table 27).

nized in the Cretaceous formations of the area may be summarized in Fig. 8. The thickness of each stage is more than 400 m, while that of each of the substages of the Miyakoan and Urakawan series does not exceed 200 m. It is noteworthy that the Lower Gyliakian and the Upper Gyliakian stages are much thicker than in other important Cretaceous areas in the meridional zone of Hokkaido. In connection with the greater thickness of the Upper Gyliakian stage there is to be seen a shorter stratigraphic range of the uppermost coarser part of the Middle

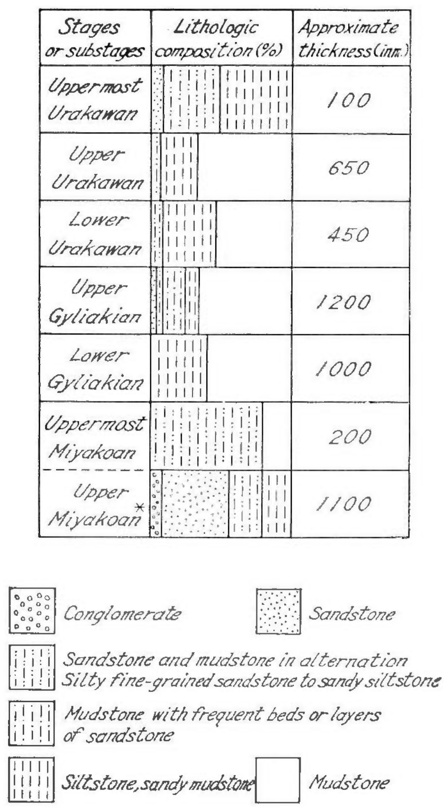


Fig. 8 Lithologic composition and approximate thickness of the stages and substages recognized in the Cretaceous deposits of the Obirashibe Valley
* It is represented by the lower part of the Middle Yezo group.

Yezo group, i.e. the equivalent of the Saku formation. Furthermore, it is also noticeable that proportion of fine-grained clastics is much greater in the Lower Gyliakian stage than in the subjacent Uppermost Miyakoan substage and the superjacent Upper Gyliakian stage.

IV. 2 Vertical Changes of the Sedimentary Facies

Stratigraphic changes of the sedimentary facies

Taking a look at the vertical changes of the rock-facies of the Cretaceous deposits under discussion, it is readily recognized that there are ten sequences show-

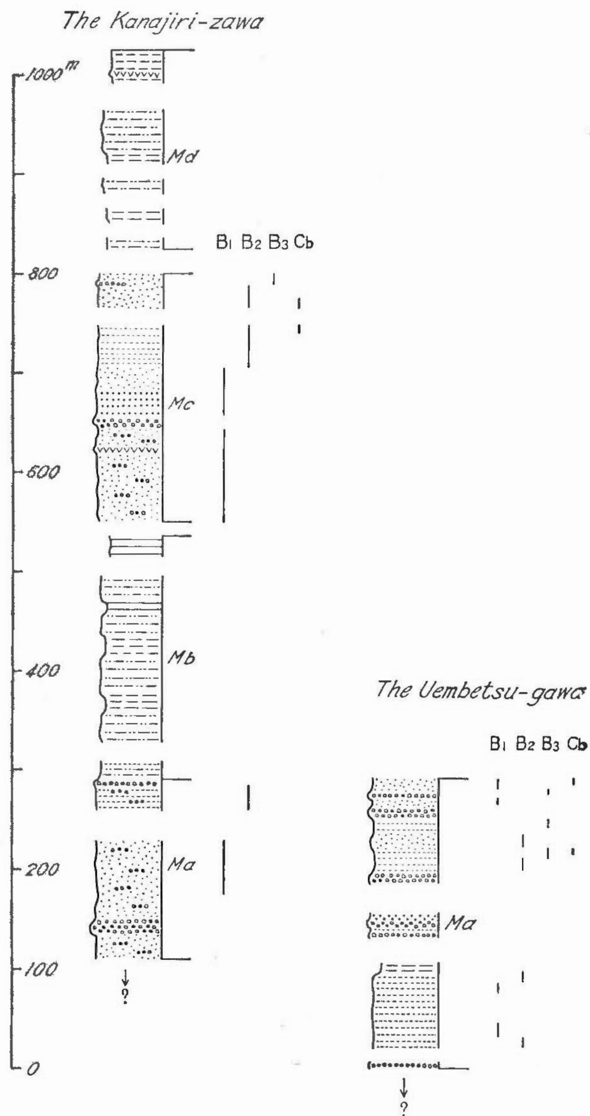
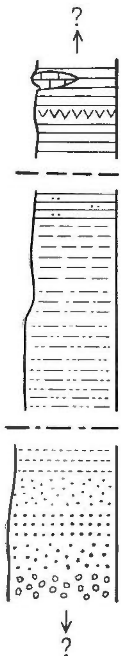


Fig. 9 Stratigraphic sections and vertical changes in the lithofacies of the Ma-Mb and Mc-Md sequences

Explanation of Figs. 9~16

Legends for the stratigraphic sections



Upper limit unknown
Limestone
Comparatively thick tuff or tuffaceous rock
Mudstone (clayey)
Fault relation
Thin beds or layers of sandstone being frequently intercalated
Mudstone (silty)
Siltstone, fine sandy siltstone or sandy mudstone
Mudstone (s. l.) with frequently interlaminated sandstone (laminated sandy mudstone)
Sandstone and mudstone (s.l.) in thin-bedded alternation
Sandstone and mudstone (s.l.) in medium- or thick-bedded alternation
Sandy siltstone to silty fine-grained sandstone
No stratigraphic record due to the localities being separated far from each other
Medium-grained sandstone
Medium- to coarse-grained sandstone
Coarse-grained sandstone
Coarse- to very coarse-grained sandstone
Conglomerate
Lower limit unknown

Number showing the fossil locality and prefix of the locality number showing abundance grades of fossils (VA: very abundant, A: abundant, C: common, F: few, R: rare)

Explanation of the abbreviations

B : bedding
L : lamination
Sb: thin bed or layer of sandstone
Sl : lamina of sandstone
T : thin bed or layer of tuff or tuffaceous rock
C : calcareous concretion
P : plant remain or carbonaceous matter

Explanation of the lines

Thick line: abundant or very frequent
Thin line: common or frequent
Broken line: few or occasionally developed
Dotted line: rare or scarcely developed

Explanation of the abbreviations in Fig. 9

B_1: thick-bedded to massive
B_2: medium- to thick-bedded
B_3: thin- to medium-bedded
Cb: carbonaceous matter

ing vertical changes in the grades of coarseness, viz., those from relative coarseness to fineness as exemplified by Ma–Mb, Mc–Md, Me–Mf, Mg–Mh, Mi–Mk, Ml–Ua, Ub–Ue, Uf–Ug, Uh–Uk_1, and Uk_2–Ul (Fig. 4). In this connection, vertical changes of both lithofacies and biofacies are to greater or less degree recognizable in the above-mentioned sequences. For detailed explanation of this statement, significant facts observed in selected sections of better exposure are described below.

Sequences Ma–Mb and Mc–Md (Fig. 9).— These strata are composed of thick sandstones with subordinate conglomerates and alternation of sandstone and mudstone of rather Flysch type; calcareous concretions and fossil remains are very scarce throughout. The sediments are generally massive or thick-bedded in the lower part of each sequence (i.e. Ma and Mc), while they are generally thin bedded or medium-bedded in the upper part, which occasionally includes laminae with abundant carbonaceous matters. Incidentally a thick bed of tuffaceous rock is intercalated in the lower part of Mc which occupies the lowest part of the sequence of Mc-Md*. It, furthermore, goes without saying that bedding and lamination are well developed in Mb and Md.

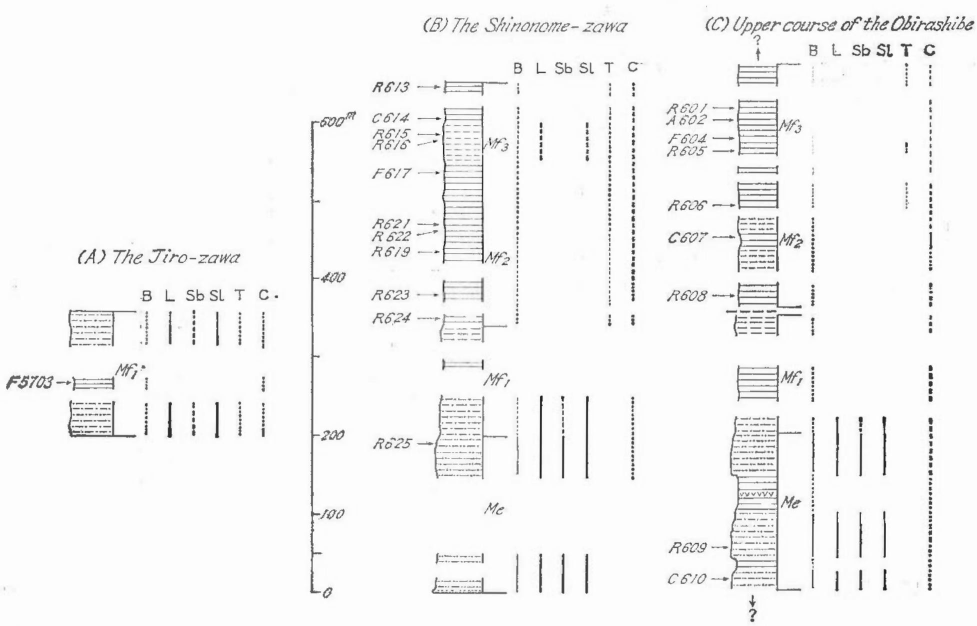


Fig. 10 **Stratigraphic sections and vertical changes in the lithofacies of the Me-Mf sequence**

* It is known that a thick bed of tuff, 10 to 15 m thick, is contained in the upper part of Ma in the eastern adjoining Horokanai district.

Sequence Me–Mf (Fig. 10; Table 4).— The most fine-grained part is represented by the middle and upper parts of Mf (Mf_2 and Mf_3) in which bedding and lamination are also poorly developed and arenaceous rocks are very poor. Many fossils are contained in the upper part of Mf. There are many tuffaceous beds, each of which has the thickness of a few metres, in the lower part of Me along the Jiro-zawa, although they are not illustrated in Fig. 10.

In the middle part of Mf the abundance of ammonites is not much different from that of inocerami, the former being slightly greater in number, while in the upper part of the same member the latter is more numerous than the former. All of the ammonites collected throughout from Me to Mf are coiled forms and no aberrant ones are found. The dominant ammonites from the middle part of Mf are ***Desmoceras (Pseudouhligella)***. Of inocerami, ***Inoceramus concentricus nipponicus*** and ***I. yabei*** are predominant in the upper part of Mf. Bivalves other than inocerami are dominant in Me.

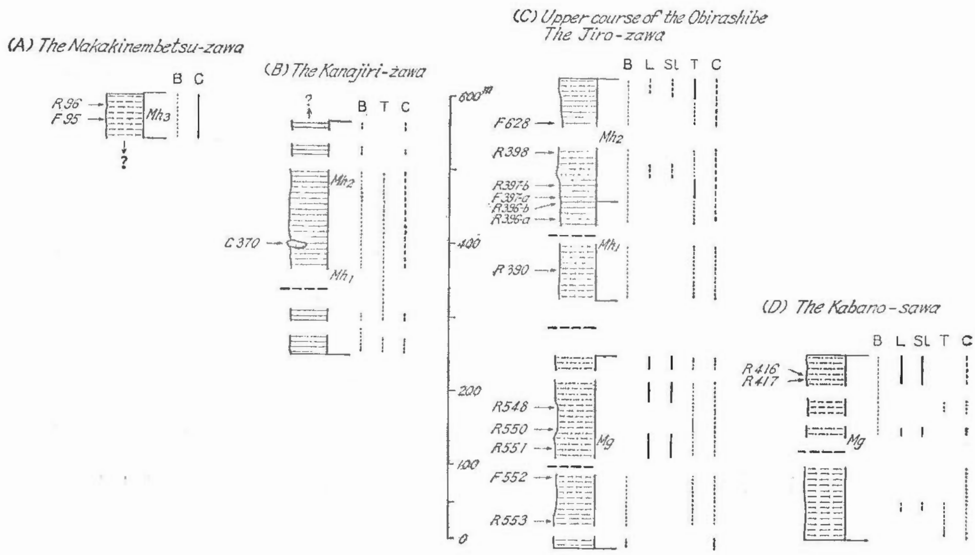


Fig. 11 Stratigraphic sections and vertical changes in the lithofacies of the Mg-Mh sequence

Sequence Mg–Mh (Fig. 11; Table 5).— The grade of coarseness is finer in Mh than in Mg. In Mh lamination is poorly developed and arenaceous sediments are scarce throughout therein. Tuffaceous rocks are frequent in the upper and uppermost parts of Mh (Mh_2 and Mh_3) and locally so at several horizons of Mg.

Fossils are sporadic throughout, although they are locally not few in the lower part of Mh (Mh_1). In consequence, the vertical change of the biofacies is not exactly readable. Nevertheless, roughly speaking, ammonites represented by coiled forms such as *Desmoceras* (*Pseudouhligella*) are rather predominant in the lower part of Mh, while inocerami are so in the upper part. Few aberrant ammonites are found in the sequence.

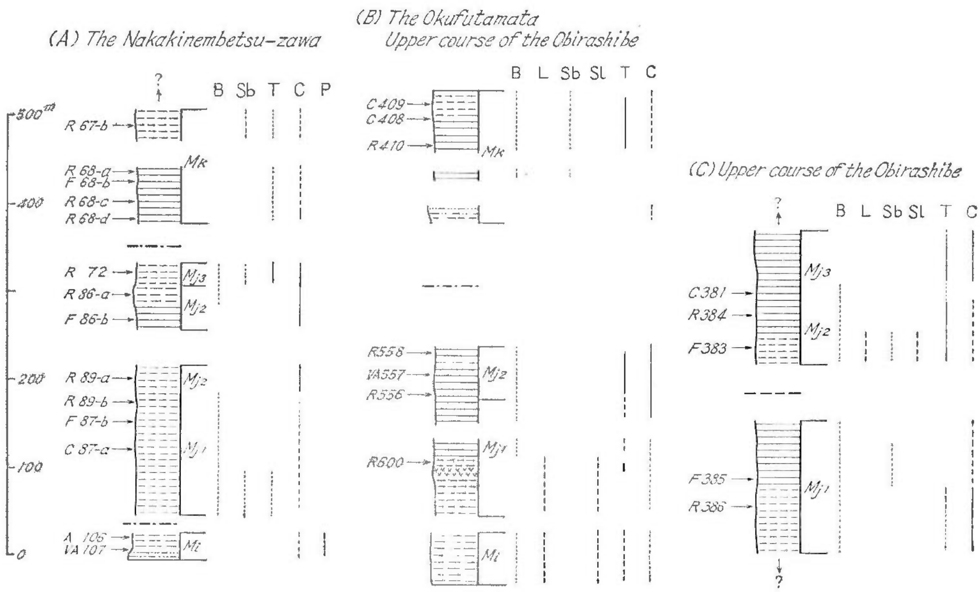


Fig. 12 Stratigraphic sections and vertical changes in the lithofacies of the Mi-Mk sequence

Sequence Mi–Mk (Fig. 12; Tables 6, 7).—The middle and upper parts of Mj (Mj_2 and Mj_3) carrying frequent tuffaceous rocks and calcareous concretions and Mk are composed mainly of fine-grained sediments. In Mi laminae of sandstone are occasionally contained. The occurrence of fossils is abundant in Mi, and is rather so in the middle and upper parts of Mj, being more dominant in the middle than in the upper. Drifted plant remains and carbonaceous flakes are abundantly contained in host rocks as well as in concretions of Mi, and moreover they are included in many of the concretions of Mj_2. The vertical changes of the biofacies are illustrated in tabular form in Table 7.

Sequence Ml–Ua (Fig. 13; Tables 8, 9).—The sediments of Ua in which calcareous concretions and fossil remains are on the whole scarce is not only the finest grained but also most poor in arenaceous rocks. Bedding is most frequently observable in Ml and Mm. Ml itself shows vertical changes in some detailed aspect of the lithofacies (Fig. 5). For example, the sediments are rather thin bedded in the lower part which is rich in concretions and drifted plant remains or carbonaceous flakes, while rather massive or thick bedded in the upper which is poor in concretions and carbonaceous matters. The predominance of carbonaceous matters in the thin-bedded part is harmony with the cases of Ma and Mc. Furthermore, it is noticeable that in Mo bedding is well developed, thin beds or layers and laminae of sandstone, and tuffaceous rocks are dominant, and concretions

Table 7 Vertical changes in the biofacies of the Mi-Mk sequence

Biofacies \ Stratigraphic division	Mi	Mj			Mk
		Lower part (Mj_1)	Middle part (Mj_2)	Upper part (Mj_3)	
Composition of the fossil assemblages	Ammonites$>$inocerami	Ammonites$<$inocerami	Ammonites$\doteqdot$inocerami	Ammonites$<$inocerami	
Composition of the ammonite assemblages	Aberrant ammonites $<$coiled ones	Aberrant ammonites$\ll$coiled ones (Aberrant ammonites being found more frequently in Mj_2 than in Mj_1 and Mj_3)			
Dominant coiled ammonites	*Tragodesmoceroides* $>$*Tetragonites*		*Mesopuzosia* $>$*Tragodesmoceroides*		
Dominant aberrant ammonites	*Sciponoceras*				
Dominant inocerami	*Inoceramus teshioensis*	*Inoceramus tenuistriatus*	*Inoceramus teshioensis and I. hobetsensis*		

Explanation of the signs in the tables on vertical changes in the biofacies

$\gg$ the left being much predominant over the right

$>$ the left being predominant over the right

$\doteqdot$ both the left and the right being approximately in equal amount

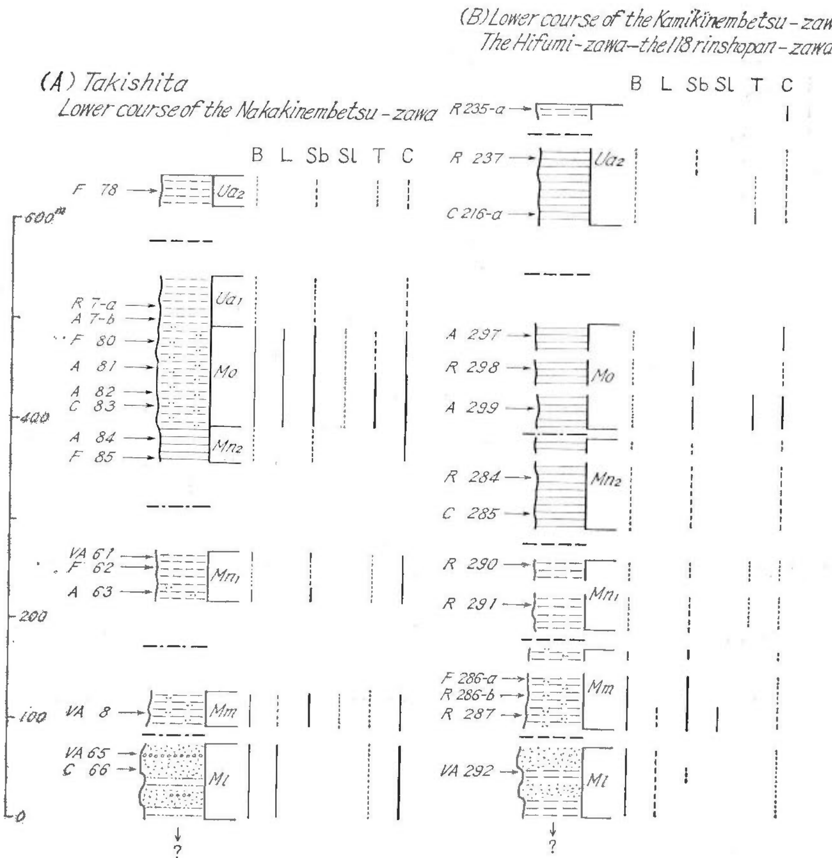


Fig. 13 Stratigraphic sections and vertical changes in the lithofacies of the Ml-Ua sequence

and fossils are found in a great amount. These features should be considered with reference to the biofacies of this member (Table 9). This point is discussed below. The vertical changes of the biofacies are illustrated in tabular form in Table 9.

Sequence Ub–Ue (Fig. 14; Table 10).— The rocks are finest in the upper part of Ud (Ud_3) and Ue, the latter of which scarcely contains arenaceous matters. Bedding or lamination and sandstones, interbedded or interlaminated, and tuffaceous rocks together with calcareous concretions and fossils are least in such strata. Drifted plant remains and carbonaceous flakes are most abundantly found in the concretions as well as in the host rocks themselves of Ub. Furthermore, it is worthy of mention that the sediments of Ub are provided with frequent abnormal sedimentary structures as mentioned before.

Inocerami occur more abundantly than ammonites throughout from Ub to Ud, especially so in Uc and the lower part of Ud (Ud_1). There are, however, contained not a few ammonites in Ub and Uc. Aberrant ammonites of which scaphitids and *Baculites* play the leading part are dominant in Ub, while coiled ones such

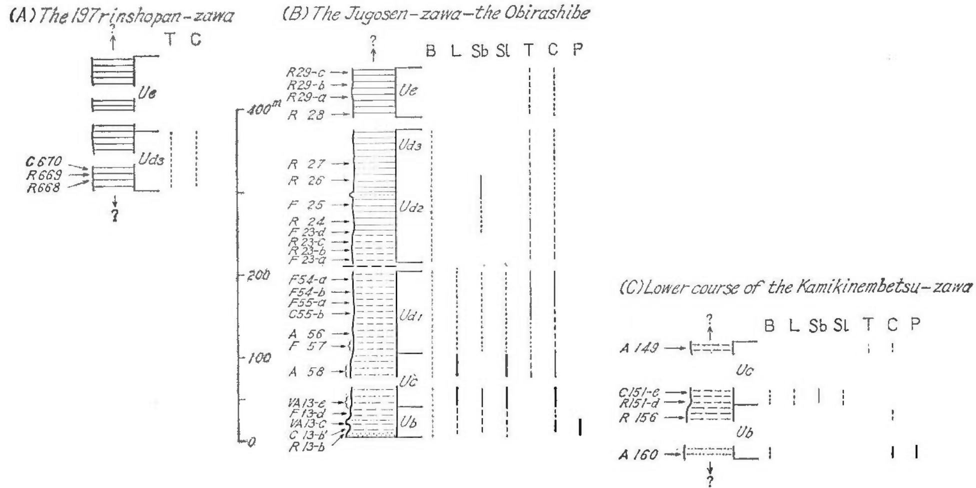


Fig. 14 **Stratigraphic sections and vertical changes in the lithofacies of the Ub-Ue sequence**

as *Damesites* and *Gaudryceras* are so in Uc. The representative species of inocerami, *Inoceramus uwajimensis* occurs throughout from Ub to Ud_1 in the greatest amount, followed by *I. mihoensis* in Uc and Ud_1. Furthermore, other bivalves are not scarce in Ub.

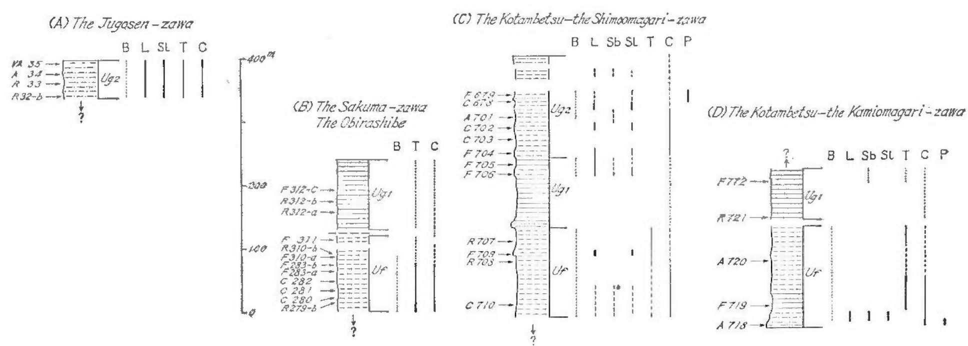


Fig. 15 **Stratigraphic sections and vertical changes in the lithofacies of the Uf-Ug sequence**

Sequence Uf–Ug (Fig. 15; Tables 11, 12).— The lower part of Ug (Ug_1) is the finest grained. Bedding and lamination are more frequently developed in Uf and the upper part of Ug (Ug_2) than in Ug_1; so are thin beds or layers and laminae of sandstone. Tuffs or tuffaceous rocks are dominant and calcareous concretions are abundant in Uf and Ug_2. The concretions of Ug_2, especially of its relatively

Table 12 Vertical changes in the biofacies of the Uf-Ug sequence

Biofacies \ Stratigraphic division	Uf		Ug		
	Lower part	Upper part	Lower part (Ug_1)	Upper part (Ug_2)	Uppermost part (Uppermost part of Ug_2 and Ug_3)
Composition of the fossil assemblages	Ammonites $\gtrdot$ inocerami ($>$ / $\doteqdot$)	Ammonites $<$ / $\doteqdot$ inocerami	Ammonites $<$ inocerami	Ammonites $<$ inocerami	Ammonites $<$ / $\doteqdot$ inocerami
Composition of the ammonite assemblages	Aberrant ammonites $\ll$ coiled ones			Aberrant ammonites $\ll$ coiled ones	Aberrant ammonites $<$ coiled ones
Dominant coiled ammonites	*Damesites* $>$ *Tetragonites*		*Damesites*	*Damesites* and *Gaudryceras*	
Dominant aberrant ammonites	*Polyptychoceras*				*Polyptychoceras* (abundant)
Composition of the inocerami assemblages	Group of *Inoceramus ezoensis* $\doteqdot$ group of *I. naumanni*		Group of *Inoceramus naumanni*		
Dominant inocerami	*Inoceramus ezoensis*, *I. amakusensis* and *I. mihoensis*: abundant in the upper part *I. naumanni*: not a few throughout the member		*Inoceramus naumanni* (abundant)		
Shells, chiefly bivalves (inocerami excluded)	Dominant				

For Ug_3 see Fig. 19 and Table 27.

upper part contain abundantly drifted plant remains and carbonaceous matters. Fossils are scarcely found in Ug_1. The vertical changes of the biofacies are illustrated in tabular form in Table 12.

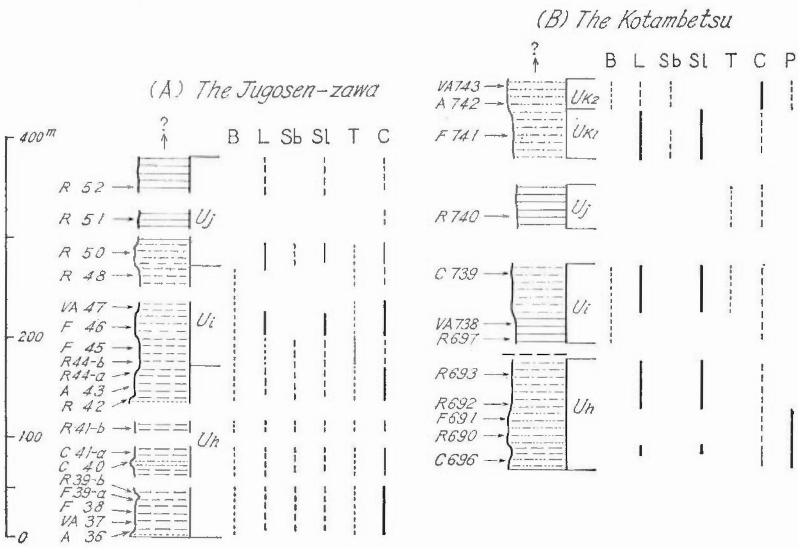


Fig. 16 Stratigraphic sections and vertical changes in the lithofacies of the Uh-Uk sequence

Sequence Uh–Uk_1 (Fig. 16; Tables 13, 14).— The rocks are on the whole finest grained in Uj which is not provided with frequent bedding and lamination and contains few calcareous concretions. Thin beds or layers and laminae of sandstone are rather predominant in Uh as well as in the lower part of Uk (Uk_1). Tuffaceous rocks are rather common in Ui, especially in its lower part. Uh which includes abundant drifted plant remains and carbonaceous matters in concretions as well as in host rocks themselves, and Ui are rich in fossils. The vertical changes of the biofacies are illustrated in tabular form in Table 14.

Sequence Uk_2–Ul (Fig. 16; Tables 13, 14).— The sediments of the upper part of Uk (Uk_2) are coarser and richer in calcareous concretions and fossil remains as compared with those of Uk_1. Drifted plant remains and carbonaceous flakes are abundantly contained in the former. From Ul which is scanty of concretions no fossils have been found. The biofacies of Uk_2 is shown in Table 14.

Vertical changes in lithofacies

The strata above Mh show definite vertical changes of the lithofacies in general throughout, although their sediments are too comparatively monotonous and fine grained to exhibit clear vertical change in grades of coarseness. In the typical sequences such as Ub–Ue and Uh–Uk_1, sandstones become less frequent upwards, bedding or lamination is relatively well developed and calcareous concretions and fossil remains are dominant in the lower half, and no few drifted plant remains and carbonaceous flakes are contained in the lowest part. Such tendencies are essentially recognizable also in the other sequences, i.e. Mi–Mk, Ml–Ua and Uf–Ug, all of which however show at the same time some difference of great or small degree. For example, the sequence of Mi–Mk carries abundant tuffaceous rocks, concretions, fossils and drifted plant remains or carbonaceous matters in both the lowest part (Mi) and the middle part (Mj_2) ; the Ml–Ua sequence includes quantities of thin beds or layers of sandstone and tuffaceous rocks, concretions and fossils even in its middle part (Mo), the sediments of which are well stratified. Accordingly, these two sequences may be thought to be composed of two minor ones respectively. Such may be also pointed out in the case of the Uf–Ug sequence with local sandstone and mudstone in alternation in the lower part of Ug_2. But, as mentioned below, these points should be taken into consideration with reference to the vertical changes of the biofacies in the sequences under discussion i.e. Mi–Mk, Ml–Ua, and Uf–Ug. As to the Uf–Ug sequence, conditions in the upper part (Ug_2) are similar to those in the lower part (Uf), and they exhibit features of the lower or lowest part of the typical sequence. Uk_2 also just presents conditions of the lower or lowest part of the typical sequence.

The typical changes of the lithofacies as described above are not fully indicated in each sequence of the strata lower than Mi, for tuffaceous rocks, concretions and fossils are sporadic throughout. While sandstones are predominant in its lower part or lower half of the sequence. Notwithstanding, some of the abovementioned general tendencies are barely discernible even in such strata. While it is needless to make mention of the Ma–Mb sequence, a thick bed of tuffaceous rock is contained in the lower or lowest part of the Mc–Md sequence. In the succeeding Me–Mf sequence bedding and lamination become inconspicuous upwards and tuffaceous rocks are of common occurrence in the lower part. In the Me–Mf sequence fossils are few in the lower part, where sediments are alternations of Flysch type, but abundant in the upper part, as in the case of the Uf–Ug sequence. In the Mg–Mh sequence, laminations are common in the lower part and tuffaceous rocks and fossils are dominant in the upper part. Thus, the upper part of each of the two sequences Me–Mf and Mg–Mh presents conditions more or less similar to those in the upper part of the Uf–Ug sequence.

In a word, as mentioned above similar vertical changes of the lithofacies are repeated throughout the Cretaceous deposits of the area. However, they are occasionally modified in great or small degree under the influence of conditions of sedimentation, such occurring especially in a given sequence which is occupied by thick coarse-grained sediments in its lower part. Furthermore, greensand grains are most disseminated in the lower or lowest part of a given sequence as exemplified in the cases of Me, Mi, Ub and Uh. And then, they are locally not few in the uppermost part as shown in the case of the upper part of Ua and that of Ug_2.

Vertical changes in biofacies

As described before, marine fossil remains and drifted plant remains or carbonaceous flakes are, generally speaking, abundant in the lower part or lower half of a given sequence, occasionally rather so also in the upper or uppermost part, but not in the middle.

In the first place, so far as the Cretaceous strata of the area are concerned, the composition of fossil assemblages may be approximately represented by the dominance ratio of ammonites to inocerami, although shells, most of which are bivalves other than inocerami and ammonites, are not always few in some beds or members (Fig. 4). Thus, on the basis of this dominance ratio, three facies, viz., ammonite facies, inocerami facies and mixed facies, can be discriminated. Explicitly, in the first facies ammonites are more abundant than inocerami, in the second a quite opposite condition is shown, and in the third ammonites and inocerami are contained in nearly equal amounts. The vertical changes in the composition of fossil assemblages in the typical sections of the Cretaceous deposits of the present area are shown in Table 15.

Each of the two sequences of Ml–Ua and Uf–Ug begins with the ammonite facies, which, in turn, is followed by the mixed facies and ends with the inocerami facies, although the final stage is accompanied again by the mixed facies which is transitional to the next sequence. Such a cyclic change may not always be presented, when it is under the influence of other conditions of sedimentation. But the tendency to a similar regularity is, in practice, shown in many sequences such as Me–Mf, Mg–Mh, Ub–Ue and Uh–Uk_1, if we exclude the minor modifications. Uk_2 which represents the lowest part of one sequence shows the mixed facies. From these facts it is concluded that the typical vertical change in the composition of fossil assemblages in a sequence is represented by an ammonite facies, a mixed facies and an inocerami facies in ascending order. In other words, inocerami gradually takes the place of ammonites upwards in dominance.

Judging from the above-mentioned general tendency, the Mi–Mk sequence should be thought to be composed of two minor sequences as previously mentioned, while the Ml–Ua sequence is not made up of two minor sequences but itself forms just one sequence of the scale under discussion in spite of the peculiarity of the lithofacies of Mo. Furthermore, shells other than inocerami and ammonites, though not always abundant, are more commonly found in the lowest or lower part of some sequences such as Me–Mf, Ml–Ua, Ub–Ue, Uf–Ug, and Uh–Uk_1; they are indeed locally abundant in Me, Ml and Mm.

In the next place, the writer has directed attention to vertical change of the composition of ammonite assemblages. For this purpose the abundance ratio of aberrant ammonites to coiled ones is first analysed (Fig. 4; Table 15). For example, in the Ub–Ue sequence aberrant ammonites are much more abundant than coiled ones in the lowest part, such being exemplified also in the lower part of the Uk_2–Ul sequence, while such conditions turn to the opposite in the succeeding part. The conditions in the Mi–Mk and Uh–Uk_1 sequences are also essentially similar to the case of the Ub–Ue sequence. Furthermore, as to the Uf–Ug sequence the abundance ratio under consideration is greater also in the uppermost part. Consequently, it is concluded that aberrant ammonites are predominant in the lowest or lower part and even in the uppermost or upper part of a given sequence, but not in the middle. Such is well shown also in the Ml–Ua sequence, it being undoubtedly one sequence itself, in which the vertical change of the abundance ratio under discussion is reflected in best order. All of the sequences lower than Mi–Mk are not provided with the above-mentioned change because of the lacking or scantiness of aberrant ammonites.

The second analysis is made about the vertical change in the occurrence of coiled ammonites themselves. For this purpose the coiled ammonites are divided in strongly ornate and less ornate or unornate groups. The latter are furthermore subdivided as follows on the basis of some external morphological characters of their adult stage. The specific names are given as examples of the proposed subdivisions (Plate I).

Group A thin-shelled; whorl inflated, with nearly circular cross-section.

1: involute, rather weakly ribbed. *Phyllopachyceras ezoense.*

2: rather evolute; smooth but constricted. *Tetragonites glabrus.*

Group B thin-shelled; whorl rather compressed and oval in cross-section.

Table 15 Schematic vertical changes of the biofacies in the typical stratigraphic sections of the Cretaceous deposits in the Obirashibe Valley

Stratigraphic division			Ammonite-inocerami ratio	Aberrant ammonite-coiled ammonite ratio	Occurrence of coiled ammonites: Groups A, B, and C	Occurrence of coiled ammonites: Group D
Upper Yezo group	Ul					
	Uk	Uk_2	M > A	a ≫ c		
		Uk_1	M			not found
	Uj		M > I			↑
	Ui		I > M	c ≫ a	dominant { A_1 ↑ B_3 }; dominant { C_1 ↑ C_3 }	rare
	Uh		M	a < c		
	Ug	Ug_3	M > I	a < c	B_3 { dominant ↓ rare }; dominant { C_3 ↕ C_1 }	rare
		Ug_2	I > M	c ≫ a		
		Ug_1			A_2 { not found ↑ rather dominant }; B_3 { less dominant ↑ more dominant }; C_3 { not found ↑ rather dominant }	
	Uf		M			
			M > A	a < c		
	Ue		M			
	Ud	Ud_3	I > M			
		Ud_2				
		Ud_1	I		B_3 { rare ↑ dominant ↑ rare }	
	Uc		I > (M)	c > a		
	Ub		I > M	a > c		
	Ua	Ua_2	I > M	a ≒ c		not found
		Ua_1		c ≒ a		
Middle Yezo group	Mo		I	c ≫ a		↑
	Mn	Mn_2	I > M	c ≒ a		rare
		Mn_1	A	a ≒ c	A_2 { dominant ↑ rare }	↑
	Mm			a ≫ c		not found
	Ml					
	Mk		I > M		B_2 { not found ↑ dominant }; dominant { C_2 ↑ C_3 }	not found ↑ rare
	Mj	Mj_3				
		Mj_2	M			
		Mj_1	I > M	c ≫ a	B_2 { rare ↑ dominant }; C_2 { dominant ↑ not found }	
	Mi		A > M	a < c	A_2 { dominant ↑ rare }; B_2 dominant	
	Mh	Mh_3	M		B_1 { not found ↑ dominant ↑ rare }	not found
		Mh_2	I			↑
		Mh_1	M > A			rare
	Mg					
	Mf	Mf_3	I		B_1 { rare ↑ dominant ↑ not found }	rare
		Mf_2	A > M			↑
		Mf_1	M?			not found
	Me					

Ammonite-inocerami ratio

- A: ammonite facies
- M: mixed facies
- I : inocerami facies
- A>M: ammonite facies rather akin to mixed facies
- ( ): exaggerated for the sake of explanation

Aberrant ammonite-coiled ammonite ratio

- a: aberrant ammonites
- c: coiled ammonites

Occurrence of coiled ammonites

- A_1, A_2 ... C_3, and D: see the text

Thick horizontal lines show the boundaries between the individual sequences.

Thick horizontal broken line shows the boundary between the minor sequences.

1: rather involute; smooth but constricted; whorl more compressed in some cases as compared with the following two subdivisions. *Desmoceras* (*Pseudouhligella*) *japonicum* and *D.* (*P.*) *ezoanum*.

2: involute; weakly ribbed. *Tragodesmoceroides subcostatum*.

3: involute; on the whole weakly ornamented, i.e. smooth or finely ribbed, with constrictions and a ventral keel. *Damesites damesi* and *D. semicostatus*.

Group C rather thick-shelled; evolute; moderately ribbed.

1: whorl less compressed, with rounded oval cross-section; less strongly ribbed than the following two subdivisions. *Gaudryceras tenuiliratum*.

2: whorl less compressed, with rounded oval cross-section. *Gaudryceras denseplicatum*.

3: whorl compressed, with elliptical cross-section. *Mesopuzosia yubarensis* and *Neopuzosia ishikawai*.

The strongly ornate ammonites are called here group D. Actually they are, however, at any given locality, very few in number. Genera belonging to this group are: *Yokoyamoceras*, *Anapachydiscus* (not so strongly ornamented), *Eupachydiscus*, *Menuites*, *Calycoceras*, *Yubariceras*, *Romaniceras*, *Collignoniceras*, *Reesidites*, *Peroniceras*, *Texanites*, etc. (Plates II, III).

The data obtained from the observations along several typical sections, which are suitable for this analysis, are shown in Tables 4, 5, 6, 8, 10, 11, and 13. From these data the vertical changes in the occurrence of the leading coiled ammonites under discussion may be summarized in Table 15. The noticeable types of upward changes are from C_3 to C_1 or C_2, from B_3 to A_1 and from B_2 to A_2 as shown in the Mi–Mk and Uh–Uk_1 sequences. Such being the case, vertical changes are recognizable as a general tendency from coiled ammonites with compressed whorl of elliptical section and with ornament of moderate intensity upwards to those with inflated whorl of circular section and without or with only weak ornamentation. Changing the expression, the leading occurrence of the former ammonites becomes gradually superseded upwards by that of the latter. B_1 becomes predominant upwards in the Me–Mf and Mg–Mh sequences and is the most abundant in the middle part of these sequences. Such fact is however essentially not in disharmony with the above-mentioned general tendency, if we consider that B_1 is provided with a smooth whorl and that its section is not elliptical. In the Ml–Ua sequence, A_2 is predominant in the rather middle part. This condition is in accord with the general tendency. The case of the Uf–Ug sequence also is not fundamentally different from this general tendency if we notice that B_3 is abundant not in the lowest part of the sequence (the lower part of Uf), but in the lower part (the upper part of Uf) and that B_3 is predominant over C_3. This is exemplified by the stratigraphic section of a limited area which is here dealt with as a substitute for the type sections*. Moreover, it is natural that A_2 is not few in the lower part of the sequence. The upward change from C_1 to C_3 in the upper part of the Uf–Ug sequence, though in reverse order, agrees with the general tendency. This is of course closely related to the fact that both the lower and the upper parts of the sequence,

* Leading ammonites from this stratigraphic section are as follows:
Upper part of Uf: NH 467, 468 (same horizon), *Damesites damesi* (abundant), *D. semicostatus* (abundant), and *Neopuzosia ishikawai* (not few)
Lower part of Ug (Ug_1): NH 470, *D. semicostatus* (abundant)

i.e. both Uf and Ug_2 (plus Ug_3) are similar in the relative coarseness of the rock and in the predominance of tuffaceous rocks, calcareous concretions and fossils. Furthermore, as to the Ub–Ue sequence, though *Inoceramus* is quite abundant throughout the sequence, the tendency is apparent in the same way, because B_3 is predominant not in the lowest part, but in the lower part*.

Furthermore, strongly ornate ammonites with inflated or rather compressed whorl section such as pachydiscids, kossmaticeratids and peroniceratids are occasionally found in the lower part of the Uf–Ug sequence, i.e. in Uf. In Mg which occupies the lower part of the sequence concerned (Mg–Mh), there are sporadically contained strongly ribbed and prominently tuberculate ammonites which have rather subquadrate whorl section such as acanthoceratids. Such tendency is, though inconspicuously, recognizable also in some other sequences, viz., Mi–Mk, Ml–Ua and Uh–Uk_1 (Table 15). Accordingly, it may be regarded as a general tendency that strongly ornate ammonites, i.e. group D, are more frequently found in the lower part of a sequence as here discussed than in the succeeding part.

When a species of *Inoceramus* has the same stratigraphic range as another but has different strength of ornament or convexity of shell, the prolific bed (within a given sequence) of the former is of different stratigraphic position from that of the latter (Plate III). For instance, a Neogyliakian species, *Inoceramus teshioensis,* the test of which is comparatively convex especially on the left valve and has ribs of moderate intensity, is dominant in the lower part of the lower minor sequence of Mi-Mk (Mi-Mj_1), while *I. tenuistriatus* with the same life period, the test of which is nearly as convex as the former species but weakly ornamented, is so in the upper part (Tables 6, 7). The prevalent species in the lower part of the Ml–Ua sequence is *I. teshioensis;* on the other hand, that of the middle and upper parts is *I. incertus,* another Neogyliakian species, the test of which is equivalve, only slightly convex and rather weakly ornamented (Tables 8, 9). And then, in the Uf–Ug sequence, *I. ezoensis* and *I. amakusensis* which are provided with expansive and roughly ornamented shells are the most abundant in its lower part, while *I. naumanni* which is provided with obliquely elongated and finely ornamented shells is so and very plentiful in the upper part, although these three species are co-existent with one another in the sequence (Tables 11, 12). In consequence, there seems sometimes to exist a certain relation between the predominant occurrence of certain inocerami and the sedimentary facies.

Cyclic sequences

The above-described sequence which essentially shows a cyclic vertical change of the lithofacies and biofacies could be regarded as a kind of cyclothem. However, it is not appropriate to use the prevailing term "cyclothem" for defining a series of beds deposited during a single sedimentary cycle in a geosynclinal area such as the Cretaceous geosyncline of Hokkaido. The term "cyclothem" was originally proposed with reference to the Pennsylvanian coal measures, the deposits on a comparatively unstable shelf. Such being the case, the term "cyclic sequence" is here for convenience used for the Cretaceous deposits under consideration as a substitute for the term "cyclothem." In some cases the cyclic sequence may be incomplete or even hemi-cyclic, as understood from actual examples. In the Cretaceous deposits under discussion there are recognizable ten cyclic sequences as exemplified by the sequences Ma–Mb, Mc–Md, Me–Mf, Mg–Mh, Mi–Mk, Ml–

* Leading ammonites from this stratigraphic section are *Damesites damesi* (common) and *D. sugata* (few) from Uc.

Ua, Ub–Ue, Uf–Ug, Uh–Uk_1, and Uk_2–Ul. Each of them is here, for convenience, defined with its lower limit at the base of a more or less thick, relatively coarse-grained sediments of a sequence. But, strictly speaking, the boundary between the two succeeding cyclic sequences should be naturally placed at a certain position within the comparatively coarse-grained sediments concerned. The absurdity on this point, however, may be practically almost negligible (Tanaka, 1960a). The cyclic sequence under discussion essentially represents the vertical change from relatively shallow environments to relatively deep ones.

Boundaries between the individual cyclic sequences do not always coincide with those of the chronologic scale, but are rather generally situated within the stage concerned. Each of the cyclic sequences is to be referred to one formation, a unit of rock-stratigraphic classification, being as a rule composed of several members. Its time-stratigraphic range is ordinarily not more than that of one stage and not less than half of it. The vertical changes of the lithofacies and biofacies which are recognizable in the lower half of a cyclic sequence should be repeated in reverse order in the upper half where the changes should be however very gradual. The cyclic sequences represented by Uf–Ug and Me–Mf are almost complete in such a sense, but others are not. It is reasonable and natural that the stratigraphic positions where *Inoceramus* occurs abundantly, as in the case of *Inoceramus hobetsensis, I. uwajimensis, I. naumanni,* and *I. schmidti,* are closely related to the positions of inocerami facies within the cyclic sequence concerned. In addition to the cyclic sequences of the above-mentioned scale, there are also those of minor scale, e.g. two minor cyclic sequences constituting a major one represented by Mi–Mk.

Takayanagi (1960) who recently examined the Cretaceous foraminiferal assemblages from the Obirashibe area presented several cycles in the frequency curve of species and individuals. Minor discrepancy between the foraminiferal cycles and the above-mentioned cyclic sequences recognized by the vertical change of both lithofacies and biofacies should possibly depend on the insufficiency of the foraminiferal samples as stated by Takayanagi. But most of the foraminiferal cycles especially in the uppermost part of the Middle Yezo group and in the Upper Yezo group are nearly equivalent to the corresponding cyclic sequences*. In foraminiferal cycle VIII referable to the eighth cyclic sequence represented by Uf–Ug, the conditions shown in the total number and composition of assemblage of the lower part and those of the upper part are similar to each other, differing from the conditions in the middle part. Therefore, from the foraminiferal assemblage as well as from the lithofacies and megafossil assemblage noted above, the cyclic sequence represented by Uf–Ug can be stated to be nearly complete.

The lithologic composition of the cyclic sequences recognized in the Cretaceous deposits under discussion are shown in Fig. 17. In this connection, the sandstone ratio, which is expressed by the ratio of coarse-grained sediments such as conglomerates and sandstones to the gross sediments of a given stratigraphic unit composed of clastic rocks, is smallest in the Mg–Mh sequence. Of course, this fact bears directly on the minimum ratio of the Lower Gyliakian stage as described before. Furthermore, the thickness of the cyclic sequence is, in general, not less than about 400 m and not more than nearly 700 m.

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* The boundary between the foraminiferal cycles IV and V is probably the same as that between the two minor cyclic sequences within the Mi-Mk sequence, the fifth cyclic sequence.

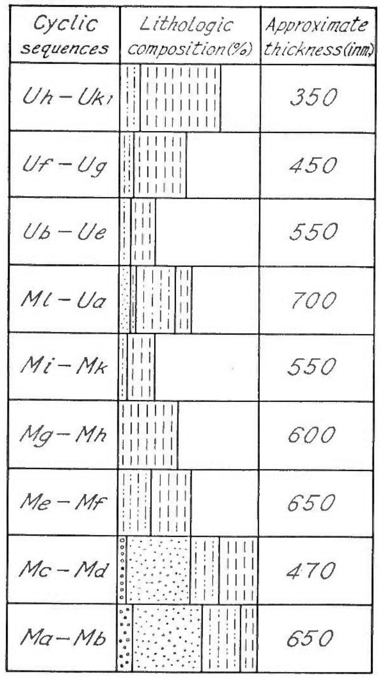

Fig. 17 Lithologic composition and approximate thickness of the cyclic sequences recognized in the Cretaceous deposits of the Obirashibe Valley For the legends see Fig. 8.

IV. 3 Lateral Changes of the Sedimentary Facies

Lateral changes in the sedimentary facies of the stratigraphic units

All of the members constituting the Cretaceous deposits in all parts of the area roughly show a similarity in their thickness, rock-facies and fossil contents. However, to speak more exactly, they exhibit lateral variation of great or small degree in the lithofacies and also in their thickness. In this connection, all of the members above Mh which are exposed almost throughout the area are here dealt with. Some of them can be divided into several facies due to a conspicuous lateral variation.

For recognizing the lateral variation of biofacies in a given member, localities of abundant occurrence of fossils should be here selected in the constant number and moreover they should be distributed at similar intervals of horizons from lowest to uppermost within the member of the individual facies concerned. In case of indistinctness of lateral change in the biofacies of a given member, the occurrence of aberrant ammonites, even if sparse, should be duly noted.

Taking into consideration the distribution of strata and lateral variation of the sedimentary facies, the Cretaceous area would be partitioned as shown in Map II.

Mi (Tables 6, 16).— The member can be differentiated into facies α (Fig. 12-A), β and γ (Fig. 12-B). In facies α aberrant ammonites are predominant*.

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* In facies β, *Inoceramus* cf. *hobetsensis* occurs in a small number only from loc. NH 412, which is not dealt with in Table 6.

Table 16 Lateral changes in the sedimentary facies of Mi

Sedimentary facies \ Facies division		Facies α	Facies β	Facies γ
Thickness		Thin (30～60m)	Thick (50～90m)	Thick (60m)
Lithofacies	Lithology	Silty fine-grained sandstone<fine sandy siltstone	Fine sandy siltstone	Mudstone and siltstone, commonly shaly
	Colour of the rocks	Greenish dark grey	Dark grey	Dark grey, occasionally greenish
	Sorting	Ill	Somewhat well	Well
	Bedding	Scarcely developed	Occasionally developed	
	Lamination	Scarcely developed	Occasionally developed	
	Sandstones		Beds or layers: common Laminae: common	Laminae: few
	Calcareous concretions	Few		Rare
	Plant remains or carbonaceous flakes	Abundant		
	Fossils	Abundant	Few	Not yet found
Biofacies	Composition of the fossil assemblages	Ammonites >inocerami	(Inocerami)	
	Composition of the ammonite assemblages	Aberrant ammonites <coiled ones		
	Dominant ammonites	*Tragodesmoceroides* and *Sciponoceras*		
	Dominant inocerami	*Inoceramus teshioensis*		

Explanation of the signs in the tables on lateral changes in the sedimentary facies

≫the left being much predominant over the right

\>the left being predominant over the right

≒both the left and the right being approximately in equal amount

Table 17 Lateral changes in the sedimentary facies of Ml

Sedimentary facies \ Facies division			Facies α	Facies β	Facies γ	Facies δ
Thickness			Thick (80m?)	Thick (90m)	Rather thick (60~90m)	Thin (50m)
Lithofacies		Lithology	Sandstone > siltstone > conglomerate		Sandstone ≑ siltstone and mudstone ≫ conglomerate	Sandstone ≑ mudstone
		Bedding	Occasionally developed	Not ill developed	Well developed	
		Lamination, cross-lamination, and ripple-mark	Lamination: scarcely developed Cross-lamination: frequent	Lamination: occasionally developed Cross-lamination: less frequent	Lamination: well developed Ripple-mark: scarcely developed	Lamination: scarcely developed
	Sandstones	Grades of coarseness	Coarse-grained ≑ medium-grained	Medium-grained > coarse-grained	Medium-grained	Medium-grained ≑ fine-grained
		Sorting	Ill		Well, partly ill	Well
		Contemporaneous breccias of mudstone	Not a few		Very rare	Not found
	Conglomerates	Sorting	Ill		Well	Conglomerates not found
		Size of the gravels	Pebble > cobble		Pebble	
		Contemporaneous gravels (Calcareous rock and mudstone)	Abundant	Few	Scarcely found	
		Matrix	Sandstone, partly siltstone		Mainly siltstone	
		Dominant muddy rocks	Fine sandy siltstone > siltstone		Fine sandy siltstone ≑ siltstone ≑ mudstone	Mudstone
		Plant remains or carbonaceous flakes	Abundant		Not a few	Very rare
		Fossils	Very abundant		Common	Rare
Biofacies		Composition of the fossil assemblages	Ammonites > bivalves other than inocerami ≫ inocerami	Ammonites ≫ inocerami	Ammonites > inocerami	(Inocerami)
		Composition of the ammonite assemblages	Aberrant ammonites ≫ coiled ones		Aberrant ammonites ≪ coiled ones	
		Dominant ammonites	Scaphitids > *Bostrychoceras* *Scalarites*	Scaphitids	*Mesopuzosia*	

Table 18 List of the fossils from Ml sorted in the individual facies

Species \ Facies division / Locality	Facies α				Facies β				Facies γ				Facies δ
	16-b	17	19	20	91-b	66	292	65	60-b	60-d	110	168	194
Neophylloceras subramosum						R				R	R		
N. ramosum										R	F		
Tetragonites glabrus							R						
T. epigonus		R											
Tetragonites sp.		R			R				C				
Anagaudryceras limatum				R									
Gaudryceras denseplicatum			R	F		R					R		
Tragodesmoceroides subcostatus					R				?	R			
Mesopuzosia pacifica				R						R	R		
M. yubarensis									R		C	R	
Jimboiceras planulatiforme										R			
Pachydesmoceras sp.												R	
Hyphantoceras venustum									R	R			
Bostrychoceras otsukai	A		R		R				R				
Bostrychoceras sp.				R		R		R					
Scaphites planus	A		A		A		A						
S. pseudoaequalis	A		A		A	F	A	A	R		R		
Otoscaphites puerculus	A		R		A	F	A	A	R	R			
Scalarites scalaris		A		?	F		R		R				
Scalarites sp.	R		R	R									
Inoceramus concentricus costatus											R		
I. tenuistriatus					R		R		R	R	R		
I. hobetsensis				R			R		R			F	R
I. hobetsensis nonsulcatus							R						
I. teshioensis						R			?	R			
I. incertus										R			
Inoceramus sp.					F				F				
Ostrea sp.				A									
Exogyra (?) sp.				A									
Simple coral										R			
Fish scale									R				
Plant remains or carbonaceous flakes	A		A	A	A	A	A	A	C	A	A		

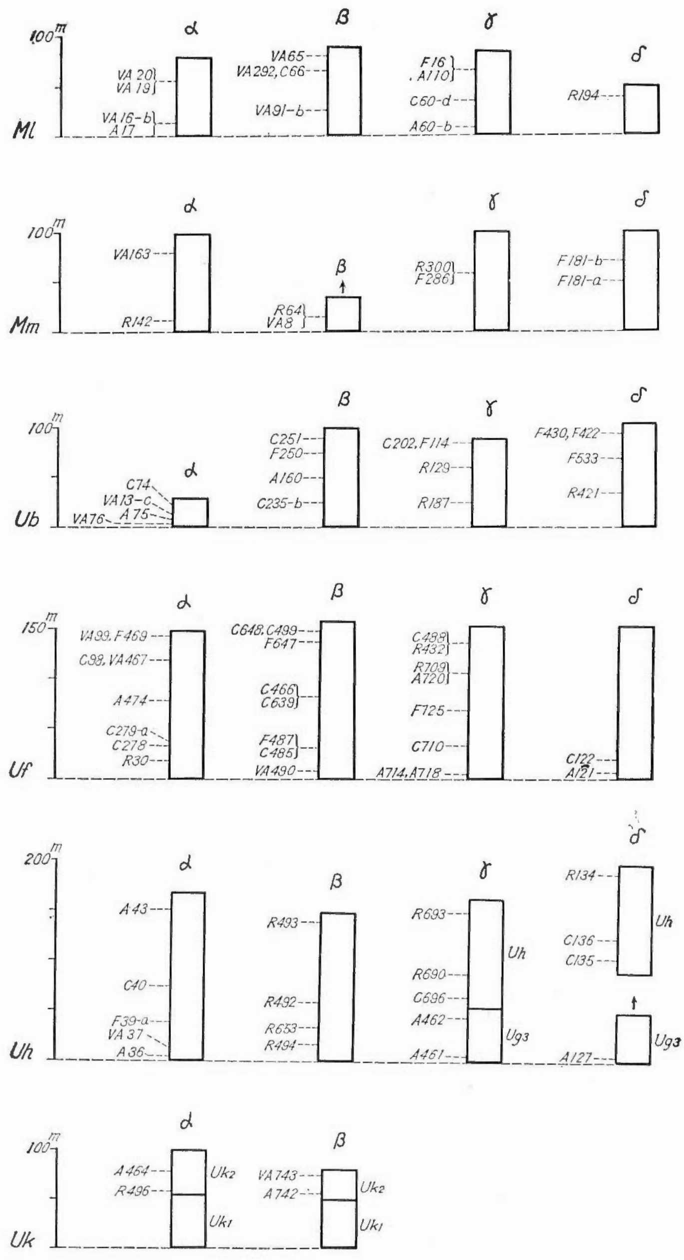

Fig. 19 Showing the stratigraphic positions of the fossil localities of the selected members in the Cretaceous deposits of the Obirashibe Valley

α, β, γ, and δ show the type of facies. The prefix of the locality numbers shows the abundance grades of fossils. In facies γ and δ of the second figure from the bottom, Ug_3 is added to Uh.

Table 19 List of the fossils from Mm sorted in the individual facies

Species \ Facies division / Locality	Facies α		Facies β		Facies γ		Facies δ	
	142	163	8	64	286-a	300	181-a	181-b
Neophylloceras sp.			R					
Tetragonites glabrus			R					
Gaudryceras denseplicatum						R		
Tragodesmoceroides subcostatus			R					
Mesopuzosia cf. *pacifica*			R					
Mesopuzosia sp.		R	R					
Hyphantoceras venustum			R					
Hyphantoceras sp.		R						
Bostrychoceras sp.			R					
Scaphites planus			F		R			
S. pseudoaequalis	R	A	R		R			
Otoscaphites puerculus		A	C					
O. puerculus teshioensis		A						
Scalarites scalaris		R	R	R				
Scalarites sp.		R	F		R			
Inoceramus concentricus costatus			F					
I. tenuistriatus			R					
I. hobetsensis		R	F		F		F	F
I. hobetsensis nonsulcatus						R		
I. iburiensis			R					
I. teshioensis			C					
I. incertus			R					
Inoceramus sp.	R							
Tessarolax acutimarginatus		R						
Plant remains or carbonaceous flakes	F	A			A			

Mj.— There is little lateral change in both lithofacies and biofacies. Aberrant ammonites are scarcely found in the southeastern part of the area, but in the southwestern no few of them occur in the middle and upper parts rather than in the lower part.

Mk.— The lithofacies and biofacies show barely a slight lateral variation. However, the upper part, about 30 m thick, is represented by massive siltstone in the southwestern part of the field, and thin beds or layers of sandstone, though not very frequent, are more commonly met with there than elsewhere.

Ml (Tables 17, 18; Fig. 19).— This member named the Nakakinembetsu sandstone presents the most noticeable lateral change of the sedimentary facies in the Cretaceous of the Obirashibe Valley. It is divided into four facies, viz., facies α, β (Figs. 5-A, 13-A), γ (Figs. 5-B, 13-B) and δ. Moreover, the occurrence of aberrant ammonites is abundant in the order of facies α, β and γ, yet unknown from facies δ.

Mm (Table 19; Fig. 19).— The lateral variation of the biofacies is not inconspicuous and therefore this member is classified into facies α, β (Fig. 13-A), γ (Fig. 13-B) and δ. The occurrence of fossils is common in facies α, and β, while sporadic in facies γ and δ. Ammonites are in facies α much more numerous than *Inoceramus* which, in turn, are nearly equal to the former in facies β and γ; facies δ is represented only by *Inoceramus.* Aberrant ammonites, the principal part of which are scaphitids, are predominant over coiled ammonites, and are more commonly found in the southwestern part. The dominant species of *Inoceramus* is represented by *Inoceramus teshioensis* in facies β, while *I. hobetsensis* in facies γ and δ.

Mn.— The lithofacies as well as the biofacies show little lateral variation. However, as to the biofacies, aberrant ammonites are dominant in the southwestern part, but not yet obtained from the upper part of this member in the southeastern part.

Mo.— The sedimentary facies does not show conspicuous lateral changes, but some variation can be pointed out; facies α (Fig. 13-A), β (Fig. 13-B), γ and δ are discriminated. The criteria are as follows. The thickness is about 100 m in facies α, while is more thick, i.e. nearly 150 m in the other facies. The mudstones, which are the main constituent of the sediments, are as a rule coarser in facies α, on the other hand on the whole finer in facies γ and δ. The mudstones of facies β are rather intermediate grained. Furthermore, aberrant ammonites are most scarce in facies δ.

Ua.— It hardly shows any lateral variation of the sedimentary facies. In the southeastern part, aberrant ammonites are not yet found from Ua_1, and only a few ones are found from Ua_2.

Ub (Tables 20, 21; Fig. 19).— This member named the Kamikinembetsu silty fine-grained sandstone is characterized by common occurrence of abnormal sedimentary structures, and is partitioned into four facies: facies α (Figs. 6, 14-B), β (Fig. 14-C), γ and δ. The abundance of aberrant ammonites decreases in the order of facies α, β and γ-δ. Facies α includes a number of isolated pebbles in the west, and therefore such facies is here distinguishable from it by the name of facies α'.

Uc (Table 22).— It is divided into facies α (Fig. 14-B), β (Fig. 14-C) and γ. *Inoceramus uwajimensis* occurs abundantly in every facies, but *I. mihoensis* so only in facies β (Table 10)*.

* *I. mihoensis* occurs commonly at loc. NH 230.

Table 20 Lateral changes in the sedimentary facies of Ub

Sedimentary facies \ Facies division			Facies α	Facies β	Facies γ	Facies δ
Thickness			Thin (30~50m)	Thick (70~100m)	Thick, locally thin (30~100m)	Thick (70~100m)
Lithofacies	Coarse-~medium-grained sandstone at the base		Thickness: 2~6m Patches of sandstone and mudstone: abundant	Thickness: 5~6m Patches of sandstone and mudstone: abundant	Thickness: less than 2m	Locally found; less than 2m thick
Lithofacies	Main part	Lithology	Fine sandy siltstone and siltstone>silty fine-grained sandstone			Siltstone and mudstone >fine sandy siltstone and silty fine-grained sandstone
Lithofacies	Main part	Sorting	Ill		Rather ill	Well
Lithofacies	Main part	Bedding	Scarcely developed		Occasionally developed	
Lithofacies	Main part	Abnormal sedimentary structures	Frequent and remarkable as in the basal part	Frequent, locally remarkable	Frequent, generally not remarkable	Not found
Lithofacies	Main part	Isolated pebbles	Locally abundant	Locally not a few	Not found	
Lithofacies	Main part	Sand-stones: Beds or layers	Few	Few	Abundant	Abundant
Lithofacies	Main part	Sand-stones: Irregular bodies	Abundant	Few		
Lithofacies	Main part	Sand grains in muddy rocks	Much disseminated	Much disseminated	Partly disseminated	
Lithofacies	Calcareous concretions		Abundant		Common	Few
Lithofacies	Plant remains or carbonaceous flakes		Abundant		Few	
Lithofacies	Fossils		Very abundant	Abundant	Few	
Biofacies	Composition of the fossil assemblages		Ammonites<inocerami		Ammonites≪inocerami	
Biofacies	Composition of the ammonite assemblages		Aberrant ammonites>coiled ones		(Aberrant ammonites≑coiled ones)	
Biofacies	Dominant ammonites		Scaphitids>Baculitids			

Table 22 Lateral changes in the sedimentary facies of Uc

Sedimentary facies \ Facies division			Facies α	Facies β	Facies γ
Thickness			Thin (60m)	Rather thick (60~100m)	Thick (100m)
Lithofacies	Bedding and lamination		Occasionally well developed		Occasionally developed
	Sandstones	Beds or layers	Common	ommon	Few
		Laminae	Common	Few	Few
	Calcareous concretions		Abundant	Common	Few
	Plant remains or carbonaceous flakes		Common	Few	Rare
	Fossils		Abundant		Common

Table 23 Lateral changes in the sedimentary facies of Uf

	Sedimentary facies \ Facies division	Facies α	Facies β	Facies γ	Facies δ
Lithofacies	Lithology	Mudstone > sandy mudstone			Mudstone ≫sandy mudstone
	Bedding	Occasionally developed			Scarcely developed
	Lamination	Occasionally developed			Scarcely developed
	Beds or layers of sandstone	Few			Rare
	Tuffs or tuffaceous rocks	Abundant			Rare
	Calcareous concretions	Abundant	Few	Common	Few
	Plant remains or carbonaceous flakes	Partly not a few			Rare
	Fossils	Very abundant	Abundant		Common
Biofacies	Composition of the fossil assemblages	Ammonites $\gtrapprox$ inocerami	Ammonites ≑ inocerami		
	Composition of the ammonite assemblages	Aberrant ammonites ≪ coiled ones		Aberrant ammonites ≑ coiled ones	Aberrant ammonites ≪ coiled ones
	Dominant ammonites	*Damesites* $\gtrapprox$ *Tetragonites*		*Polyptychoceras* and *Tetragonites*	*Tetragonites*

Ud.— The thickness, though being variable, shows no change in a definite direction. Tuffs or tuffaceous rocks occur more commonly in Ud_1–Ud_2 in the southwestern and southeastern parts than in the other areas, otherwise the lateral variation of the lithofacies is hardly recognizable as is the case of the biofacies. No aberrant ammonites are found in the southeastern.

Ue.— Although little lateral changes of both litho- and biofacies are shown, the thickness of this unit is about 100 m in the southwestern and southern central parts, while it is so great as attaining nearly 200 m in the other areas. No aberrant ammonites occur in the southeastern part.

Uf (Tables 23, 24; Fig. 19).— This member is divided into facies α (Fig. 15-B), β, γ (Figs. 15-C, D) and δ; the first and third of which are similar to each other in the sedimentary facies, but they can barely be distinguished by the composition of ammonite assemblages. The occurrence of aberrant ammonites diminishes in the order of facies α and β-δ except for facies γ in which it is predominant.

Ug (Table 25).— Ug_1 shows scarcely changes of the sedimentary facies. However, throughout the area exclusive of the southeastern part the lowest part of the member is occupied by massive medium-grained sandstone or fine sandy siltstone, about 10 m thick. Ug_2, from which its upper part (Ug_3) correlated to the Uppermost Urakawan substage is excluded in the southeastern and northwestern parts because the member is usually referred to the Upper Urakawan stage, shows lateral variation in its lithofacies. Therefore, it is partitioned into facies α (Fig. 15-A), β, γ (Fig. 15-C) and δ. The thickness of the part with facies α of Ug_2 possibly thins out to the southwest. Here, the thickness of the part with α type facies of Ug_2 is estimated to be nearly 50 m, while the total thickness of the member to be no more than 100 m. Accordingly, this part can be represented by facies α'. The biofacies, though the quantity of fossils is variable, exhibit essentially no noticeable lateral changes. However, aberrant ammonites are more dominant in facies α and γ than in the others. Aberrant ammonites are not yet collected from this member in the southeastern part. Furthermore facies γ is rather similar to facies α in lithofacies and biofacies.

Uh (Tables 26, 27; Fig. 19).— Ug_3 exposed only in the southeastern and northwestern parts is here included in Uh. This member is differentiated into facies α (Fig. 16-A), β, γ (Fig. 16-B), δ and ε, of which facies γ and δ are akin to facies α and β respectively. The thickness of the part with α type facies becomes nearly 30 m to the southwest. The sediments with such thickness can be distinguished from typical facies α and is here called facies α'. The occurrence of aberrant ammonites are much more dominant in facies α and γ than in facies β and δ.

Ui.— Any lateral variation of the lithofacies and biofacies is hardly observable. Thin beds or layers of sandstone, which are generally scarce in this member, are occasionally intercalated in the southwestern part where many laminae of sandstone are also met with (Fig. 16-A). No aberrant ammonites are obtained in the southeastern part.

Uj.— The sedimentary facies of the member, which is on the whole very poor in arenaceous rocks, is scarcely variable laterally. However, in the southwestern part frequent laminae of sandstone and a few beds or layers of sandstone are contained (Fig. 16-A).

Uk (Tables 28, 29).— Uk_2 is divided into facies α and β (Fig. 16-B). Aber-

Table 25 Lateral changes in the sedimentary facies of the upper part of Ug (Ug_2)

<table>
<tr><td colspan="3">Facies division / Sedimentary facies</td><td>Facies α</td><td>Facies β</td><td>Facies γ</td><td>Facies δ</td></tr>
<tr><td colspan="3">Thickness</td><td>Thin (100m)</td><td>Thick (150～200m)</td><td>Rather thin (150m)</td><td>Thick (?) (200m?)</td></tr>
<tr><td rowspan="8">Lithofacies</td><td colspan="2">Lithology</td><td>Laminated sandy mudstone</td><td>Mudstone>laminated sandy mudstone</td><td>Laminated sandy mudstone>mudstone</td><td>Mudstone</td></tr>
<tr><td colspan="2">Bedding</td><td>Occasionally developed</td><td>Rather scarcely developed</td><td>Occasionally developed</td><td>Scarcely developed</td></tr>
<tr><td colspan="2">Lamination</td><td>Well developed</td><td>Occasionally developed</td><td>Rather well developed</td><td>Scarcely developed</td></tr>
<tr><td rowspan="2">Sandstones</td><td>Beds or layers</td><td>Few</td><td>Few</td><td>Few</td><td>Rare</td></tr>
<tr><td>Laminae</td><td>Abundant</td><td>Common</td><td>Abundant</td><td>Rare</td></tr>
<tr><td colspan="2">Tuffs or tuffaceous rocks</td><td>Common</td><td colspan="2">Few</td><td>Rare</td></tr>
<tr><td colspan="2">Calcareous concretions</td><td>Abundant</td><td>Few</td><td>Common</td><td>Few</td></tr>
<tr><td colspan="2">Plant remains or carbonaceous flakes</td><td>Partly not a few</td><td></td><td>Partly not a few</td><td></td></tr>
<tr><td></td><td colspan="2">Fossils</td><td>Abundant</td><td>Few</td><td>Abundant</td><td>Rare</td></tr>
</table>

Table 26 Lateral changes in the sedimentary facies of Uh

Sedimentary facies \ Facies division			Facies α	Facies β	Facies γ	Facies δ	Facies ε
Thickness			Thin, locally thick (30～150m)	Thick (150m)	Rather thick (100～150m)	Thick (150m)	
Lithofacies	Lithology		Siltstone and fine sandy siltstone>silty fine-grained sandstone	Siltstone and mud-stone> fine sandy siltstone	Siltstone and fine sandy siltstone>silty fine-grained sandstone	Siltstone and fine sandy siltstone>silty fine-grained sandstone	Siltstone
	Sorting		Ill	Rather well	Ill	Rather well	Well
	Bedding		Scarcely developed			Occasionally developed	Scarcely developed
	Lamination		Occasionally developed	Scarcely developed	Occasionally developed	Not ill developed	Scarcely developed
	Sandstones	Beds or layers	Few	Rare	Few	Common	
		Laminae	Few	Rare	Few	Common	
	Calcareous concretions		Abundant	Few		Common	Few
	Plant remains or carbonaceous flakes		Abundant	Rare	Abundant	Not a few	
	Fossils		Abundant	Rare	Common		Not yet found
Biofacies	Composition of the fossil assemblages		Ammonites≒inocerami		Ammonites≒inocerami	Ammonites ≪inocerami	
	Composition of the ammonite assemblages		Aberrant ammonites ≪coiled ones		Aberrant ammonites >coiled ones	Aberrant ammonites ≒coiled ones	
	Aberrant ammonites		Not a few	Rare	Common	Rare	
	Dominant ammonites		*Damesites*		*Polyptychoceras*		

rant ammonites are predominant in facies β, while they are scarce in facies α. Uk_1 shows hardly any lateral changes of the sedimentary facies and yields no aberrant ammonites in the area where Uk_2 shows facies α.

Ul.— This member is so narrowly exposed that no definite remarks can be given.

Facies distribution

The lateral changes of both the lithofacies and the biofacies in the individual members as explained above show a general tendency which is quite similar to that shown by the vertical changes in the lower half of the individual cyclic sequences. It is the case, as mentioned above, that a vertical change of the lithofacies and biofacies recognizable in the lower half of each cyclic sequence is inferred to indicate essentially a vertical change from relatively shallow environments to relatively deep ones. If that be so, a similar change would be laterally applicable to the case of lateral variation of the sedimentary facies within a given unit. As are described in the preceding paragraphs, about half of the members here dealt with are divisible into several facies (e.g. α, α', β, γ and δ) respectively (Fig. 18). These facies are here for convenience grouped to relatively shallow, intermediate and deep facies, these three facies being approximately referable to near-shore, intermediate and offshore facies in relative sense respectively (Fig. 20).

The sediments of the relative shallow (or near-shore) facies under discussion are generally comparatively coarse grained, not well sorted, as a rule less thick and provided with abundant tuffaceous rocks, calcareous concretions, fossils and drifted plant remains or carbonaceous flakes. On the other hand, the sediments of the relative deep (or offshore) facies exhibit quite opposite features. Predominant occurrence of ammonites gradually takes the place of that of inocerami towards the deeper (or offshore) facies. Of ammonites, aberrant ones play the leading part in the shallower (or near-shore) facies. As exemplified by the case of Uf, the prevalent occurrence of coiled ammonites with compressed, oval and weekly ornamented whorl becomes gradually replaced by that of coiled ammonites with inflated, rounded and smooth whorl from the shallower (or near-shore) facies to the deeper (or offshore) ones (Tables 23, 24; Figs. 18, 20). Of course, there are some exceptions to such a generalization. Some comparatively coarse-grained members such as Mi and Ml are rather thick in their relative shallow (or near-shore) facies. As to the other members showing no or very slight lateral changes of the sedimentary facies, special attention should be given to the occurrence of aberrant ammonites besides the thickness, rock type or grades of coarseness, etc. Also in this case, the sediments in the southeastern part of the area are known to correspond nearly to the deeper (or offshore) facies. Furthermore, greensand grains are abundant in Ub and Uh throughout the present area. Such grains are also much more disseminated in the southwestern part of the area as may be seen in Uc, Ud, Ug and Uj, while they are few or likely not to be contained in the southeastern part.

The general tendency of the facies distribution in this area was kept nearly unchanged from the Upper Gyliakian to the Lower Hetonaian stage. Namely, during this period the southeastern or eastern part of the area was generally occupied by relatively deep facies and the southwestern or western part by relatively shallow facies. Therefore, the strata of the former are as a rule relative offshore facies, while those of the latter are relative near-shore facies. Moreover, paying special attention to the difference in the composition of ammonite assem-

Table 28 Lateral changes in the sedimentary facies of the upper part of Uk (Uk_2)

Sedimentary facies \ Facies division		Facies α	Facies β
Lithofacies	Bedding	Scarcely developed	Occasionally developed
	Lamination	Scarcely developed	Occasionally developed
	Sandstones	Beds or layers : rare	Beds or layers : few Laminae : few
	Calcareous concretions	Rare	Abundant
	Plant remains or carbonaceous flakes	Rare	Common
	Fossils	Few	Abundant
Biofacies	Composition of the fossil assemblages	Ammonites $<$ inocerami	Ammonites $\fallingdotseq$ inocerami
	Composition of the ammonite assemblages		Aberrant ammonites $\gg$ coiled ones
	Dominant ammonites		*Polyptychoceras*

Table 29 List of the fossils from Uk_2 sorted in the individual facies

Species \ Facies division / Locality	Facies α		Facies β*	
	496	464	742	743
Hauericeras (Gardeniceras) angustum				R
Polyptychoceras haradanum		R	F	A
Inoceramus orientalis	R	A	A	A

* In the northern just adjoining area, a northern tributary area of the Kotambetsu, *Baculites* occurs abundantly together with inocerami in the same strata.

blages between the sediments of facies α and those of facies γ in Uf and Uh, it may be said that the northwestern part of the area was occupied by somewhat shallower facies in comparison with the greater part of the southwestern part in the middle Neourakawan age and the Infrahetonaian subage. Relatively deep environments seem to have been expanded further to the north at least in the middle Paleourakawan age and then contracted to the south at least since the middle Neourakawan age. Traces of the comparatively deep branch were still retained in nearly the central part within the western side of the area. Among the strata lower than Mi (i.e. older than the Upper Gyliakian age), the middle and upper parts of Mf (Mf_2 and Mf_3) contain laminae of sandstone in the northern part and the northern central and mid-central parts of the area, while these strata scarcely contain arenaceous materials in the southern central part. Hence, it may be pointed out that the sediments of these strata become finer grained from north to south nearly in harmony with the case of the strata upper than Mh.

Regarding more detailed features in the facies distribution of the Cretaceous rocks under discussion, it is first of all noteworthy that the facies distribution of Ml in the southwestern part of the area is arranged in rather concentric form when the original state is restored. Such an outline, as well as the characters of sedimentary facies themselves, may suggest that the sediments of Ml are presumably the eastern extension of some delta-type sediments. In the second place, it should be mentioned that the uppermost part of Ug is in the northwestern and southeastern parts of the area correlated to the Uppermost Urakawan substage. This local part is called Ug_3, expressing the obliqueness between the rock-stratigraphic classification and time-stratigraphic one, and is distributed chiefly in the area where Ug_2 shows facies δ, i.e. deeper environments than in facies α', α and γ. Ug_3 is exposed also in the northern part of facies β area of Ug_2. In short, it is plausible that the southeastern part, the south of the northern part and the most of the central part of the present area were under deeper sea at the beginning of the Infrahetonaian subage. In this connection, the base of a cyclic sequence represented by Uh–Uk_1 is known to be different in age at different places, but such is beyond thinking so far as a limited area such as the present field is concerned. Accordingly, as noted above, the base of a given cyclic sequence in the Cretaceous deposits of the area should be naturally placed at a certain position within the comparatively coarse-grained sediments concerned.

Relation between the occurrence of ammonites and the sediments

Special attention should now be paid to the relations between the abundance of ammonites and the types of the sediments. From the field evidence (Table 30), it is known that ammonites are not abundantly contained in such sediments as represented by conglomerates, cross-laminated or ripple-marked sandstone containing a number of shallow sea bivalves, sandstone and mudstone in thin-bedded alternation in which sandstone is predominant, and also in black, very fine-grained and homogenous mudstones which are inferred to have been deposited under reducing condition. As can be seen in the tabulated data (Table 30), the abundant or common occurrence of the coiled ammonite species is ordinarily recognized at localities occupied by mudstone (clayey) ("M_2") to siltstone or sandy mudstone ("sM")*, while that of the aberrant ammonoid species is generally encountered

* From the writer's field observations in other areas, there are found in great amounts from localities occupied by "mS" the following two species: (1) *Reesidites minimus*, the whorl of which is much compressed subquadrate in cross-section, strongly ribbed, tuberculated and keeled, and (2) *Metaplacenticeras subtilistriatum* (JIMBO), which has much compressed, discoidal and rather strongly ribbed whorl with keels.

at localities where siltstone or sandy mudstone ("sM") to silty fine-grained sandstone ("mS") are exposed. The sediments of the category "M_2" and "M_1" (mudstone, silty), mudstones without sandy admixture, include no localities of abundant aberrant ammonoid species but many localities of abundant coiled ammonite species. Moreover, no species of aberrant ammonites, except for *Polyptychoceras haradanum* and *P. pseudogaultinum* are contained in large number even at any locality occupied by "M_1". Thus a species of the coiled ammonites and that of the aberrant ammonites do not show abundant co-existence at one and the same locality. However, there are some exceptions in the case of mudstones with frequently interbedded sandstones ("MS") in which also many other genera and species coexist to some extent. This seems reasonably relatable to the mechanism of the deposition of "MS", which was frequently under the influence of the so-called turbidity currents.

IV. 4 Preliminary Notes on the Sedimentary Rocks

Preliminary notes are here cited chiefly to the petrographic characters* from a recent work (Sumi and Tanaka, MS.), so as to supplement the megascopic features of the sediments described in the foregoing chapters.

Characters of the sandstones and conglomerates

The sandstones of the Lower Yezo, Middle Yezo and Upper Yezo groups in the present area are, generally speaking, rich in rock fragments and therefore belong chiefly to lithic sandstone and muddy lithic sandstone in Fujii's (1958) or to lithic graywacke and subgraywacke in Pettijohn's (1957) scheme of classification. In addition, though in much subordinate amount, there are sublithic, feldspathic and muddy feldspathic sandstones of the former definition to which arkose, subgraywacke and feldspathic graywacke in the latter definition approximately correspond. From the relative abundance of the main constituents of the sandstones (Table 31), one may say that as a common character of the sandstones of this area fragments of volcanic rocks are abundant throughout from the Lower Yezo to the Upper Yezo group. But the sandstones in the middle part of the Upper Yezo group proper are poor in fragments of volcanic rocks. The composition of rock fragments themselves is variable from horizon to horizon. Fragments of metamorphic rocks are more abundantly contained than those of sedimentary rocks in the Lower Yezo group and the lowest part of the Middle Yezo group. In the main and uppermost parts of the Middle Yezo group and the Upper Yezo group, sedimentary rocks are much more abundantly found than metamorphic rocks. Furthermore, Potash-feldspar is commonly found in the Lower Yezo group, while scarcely in the Middle Yezo and Upper Yezo groups.

Conglomerates occur frequently in the Kanajirizawa formation, i.e. Ma and Mc, and occasionally in the Nakakinembetsu sandstone member, i.e. Ml**. The pebbles of the conglomerates in the Kanajirizawa formation are those of granodiorite

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* Discrimination of the quartz and heavy minerals is left for further study. Rock samples from the Lower Yezo group were obtained in the eastern adjoining Horokanai area together with the greater part of those from the lowest part of the Middle Yezo group.

** Identification of the kinds of pebbles is done mainly by naked eye, but when necessary done under the microscope.

(biotite-granodiorite), altered diorite-porphyry (hornblende-diorite-porphyry), hornfels, dacite (hyaline dacite, biotite-dacite, hornblende-biotite-dacite, hornblende-dacite, etc.), altered andesite, basalt or basic andesite, older sandstone, meta-tuff, slate, and chert. The pebbles of the Nakakinembetsu member are granite (biotite-granite), quartz diorite, altered diorite-porphyry (pyroxene?-hornblende-diorite-porphyry), altered porphyrite (porphyrite, hornblende-porphyrite), gabbro, hornfels (low grade ones such as muscovite-biotite-quartz-hornfels), quartzite, older hyaline rhyolitic rock, altered dacite (biotite-dacite, hornblende-biotite-dacite, etc.), altered andesite (pyroxene-andesite), basalt, diabase (showing various textures), older sandstone (generally slightly hornfelsic), older conglomerate, older tuffaceous sandstone, slate and chert. In a word, the pebbles in the conglomerates of Ma, Mc and Ml are mainly sandstone, chert and hornfels, with dacite in subordinate amount. In Ma many of the gravels of dacite attain boulder size. It is worthy of special mention that the conglomerates of Ml contain a great number of pebbles of rocks quite resembling those of contemporaneous or just subjacent Cretaceous formations such as calcareous rocks of frequently fossiliferous concretions, sandstone, mudstone and shale, the last two of which are subordinate, besides pebbles of exotic origin. Accordingly, this fact may suggest the contemporaneous erosion during the deposition of Ml. Furthermore, isolated pebbles are found in the ill-sorted sediments of the Kamikinembetsu silty fine-grained sandstone member (Ub). The pebbles are biotite-hornfels, hornfels, altered pyroxene-dacite, altered andesite, older sandstone and chert of which dacite is the most abundant and followed by andesite. It is worthy of attention that the pebbles of this member with frequent abnormal sediments and sedimentary structures are, though not exclusively, volcanic rocks in contrast with the conglomerates of Ma, Mc and Ml in which the pebbles of sedimentary and metamorphic rocks are the normal constituents.

Petrographic characters of the sandstones of the Nakakinembetsu sandstone member

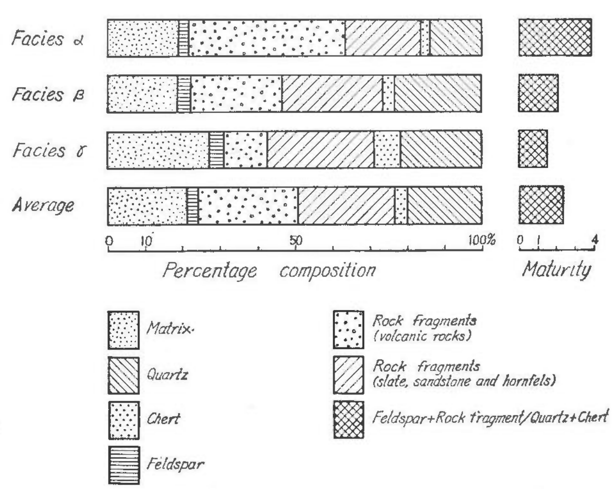


Fig. 21 Percentage composition and maturity of the sandstones in the Nakakinembetsu sandstone member (Sumi and Tanaka)

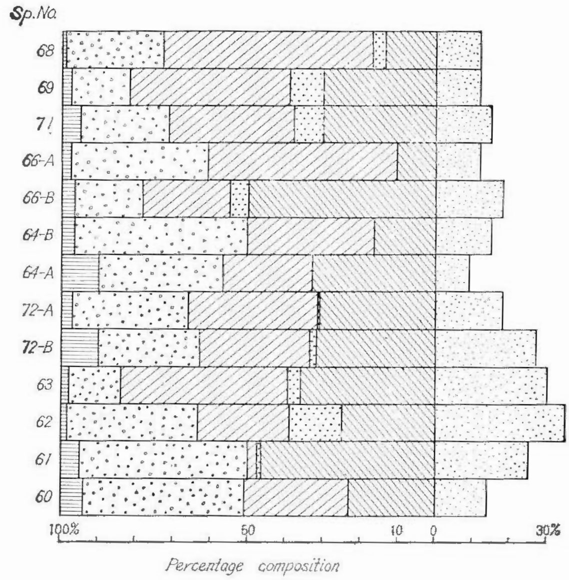


Fig. 22 Showing percentage composition of the sandstones in facies β of the Nakakinembetsu sandstone member (Sumi and Tanaka)
The legends for this figure are the same as those for Fig. 21. For the stratigraphic positions of the rock samples see Fig. 5.

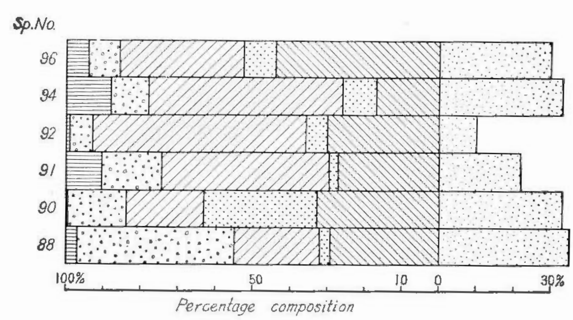


Fig. 23 Showing percentage composition of the sandstones in facies γ of the Nakakinembetsu sandstone member (Sumi and Tanaka)
The legends for this figure are the same as those for Fig. 21. For the stratigraphic positions of the rock samples see Fig. 5.

As noted above the Nakakinembetsu sandstone member shows noticeable lateral changes of the sedimentary facies and therefore can be discriminated into facies α, β, γ and δ. In connection with the changes from facies α to facies γ, one may be able to note lateral variation in the petrographic characters of the sandstones as follows. The sandstones constituting this member are mainly lithic and muddy lithic in Fujii's classification. The former is predominant in facies α and the latter is so in facies γ. As indicated in Fig. 21 the matrix shows a higher percentage in the sandstones of facies γ than in those of facies α and β, and quartz shows the lowest percentage in those of facies α. The percentage of rock fragments and especially that of volcanic rock fragments diminishes in the order of facies α, β and γ. In accordance with such a tendency, the maturity, as expressed by a Feldspar + Rock Fragment / Quartz + Chert ratio, also becomes low in the same order as mentioned above. Therefore, one can say that the lateral changes in the definite direction of the percentage composition and maturity are just in harmony with those of the depositional environments inferred from the megascopic observation of the sedimentary facies noted above.

In the next place, the vertical change of the characters of the sandstones in this member itself (Figs. 5, 22, 23) is examined. There seems to be no significant regularity in the vertical change. However, it may be pointed out that the percentage composition of the fragments of volcanic rocks diminishes upwards as compared with that of sedimentary and metamorphic rocks. Characters of the sandstones of selected horizons may support the adequacy of the stratigraphic division and correlation of both facies β and facies γ as indicated in Fig. 5. The reasons are as follows: (1) The sandstone of OB 62 in the lowest of the five divisions in facies β has chert of a comparatively large percentage, viz., 14 per cent of the total, and also in the sandstone of OB 90, at the same horizon in facies γ, chert shows a high content, viz., 30 per cent of the total, when the matrix is excluded. (2) In the bed succeeding to the lowest division of both facies β and facies γ, the sandstones are characterized by a smaller percentage of chert as compared with the subjacent and superjacent divisions. This is exemplified in the sandstones of OB 64-A and 64-B with chert of a negligible percentage in facies β and those of OB 91 and 92 in facies γ with chert of 2.5 and 5.5 per cent of the total respectively, when the matrix is excluded. Furthermore, it is interesting that even in the sandstones at the two horizons just mentioned chert content increases from facies β to facies γ in accordance with the case of the average percentage.

Characters of the tuffs and tuffaceous rocks

Tuff and tuffaceous rocks such as tuffaceous sandstone and tuffaceous mudstone are intercalated at various horizons throughout the Middle Yezo and Upper Yezo groups and are also found, though sparsely, in the Lower Yezo group. Their frequency in the stratigraphic sequence has already been illustrated in Fig. 4. Roughly speaking, the stratigraphic range of their frequent or dominant occurrence mostly occupies one-tenth to one-third of the stage concerned.

Some of the petrographic characters of such rocks are shown in Table 32. Tuffs are fine grained, consisting of particles smaller than lapilli size, and are mainly vitric crystal tuffs, and subordinately crystal and vitric ones. They are chiefly of dacitic nature, containing plagioclase, quartz and biotite, partly of andesitic nature. Very rarely there is tuff of rhyolitic nature which occurs at a single horizon within the Middle Yezo group. The tuffs in the Lower Yezo group are of dacitic nature. Tuffs and tuffaceous rocks in the Middle Yezo group are principally of dacitic nature and partly of andesitic nature. While, in the Upper Yezo group tuffs of andesitic nature become as common as dacitic ones. As to the tuffs and tuffaceous rocks in the Upper Yezo group it may be also pointed out that those on all of the four horizons of frequent or dominant occurrence are of various natures as in the case of Mf_3 and Mo in the Middle Yezo group. To sum up, it can be pointed out that the deposition of tuffs in the present area may have been attributed chiefly to volcanic eruptions belonging to calc-alkali rock series. However, no contemporaneous volcanoes have been recognized which can be actually tied with the tuffaceous rocks under discussion. Furthermore, in almost all of the cyclic sequences noted above, tuffs seem to show upward change from relatively acid to relatively basic nature which is succeeded again by relatively acid nature in the final stage.

V. Some Notes on the Sedimentation

Roughly speaking, the southwestern or western part of the present area was on the whole not only relatively near to the presumed land mass and under relatively shallow sea environments but also was less subsided, while the southeastern or eastern part was under the quite opposite conditions for a long time at least since the Neogyliakian (Turonian) age. Hence, it would be concluded that a part of the main land mass, the exact position of which is yet uncertain, was probably situated to the west of the present area. However, at least since the middle Neourakawan (Santonian) age the western central part of the area and its northern and southern adjoining areas were also brought into rather deeper and more subsided environments even though these areas were not far from the land mass.

The Lower Gyliakian (i.e. Cenomanian) stage is represented in the present area by much thicker, and more fine-grained sediments than in other areas. Related to this point is the fact that the sediments of the Upper Gyliakian stage also is very thick in the area. Accordingly, judging from the geographical and geological positions of the area within the Yezo geosyncline, and also geological conditions of the nearby areas such as the northern Abeshinai Valley (Matsumoto, 1942–43, 1954; Ijima and Shinada, 1952; Takahashi, 1958; Osanai, Mitani and Takahashi, 1960), one may point out that a kind of trough, which was also a much subsided part within the basin, was located therein at least in the Paleogyliakian and Neogyliakian ages. Such conditions, though being relieved to some degree, still continued until the earlier Paleohetonaian (Campanian) age.

That beds or layers of tuffs or tuffaceous rocks occur frequently throughout the strata in and later than the Neogyliakian age is one of the characteristics in the Cretaceous of the area. It is worthy of mention that less frequent intercalation of sandstones in the upper half of the Upper Gyliakian stage, and the shorter stratigraphic range of the strata referable to the Saku formation are closely related to the above-mentioned great thickness of the Upper Gyliakian stage. The facies distribution and deposition of the Nakakinembetsu sandstone member (Ml) which has been described in page 50 is also noteworthy. The sediments of this member are presumably a kind of deltaic sediments. The conglomerates of the same member contain in abundance pebbles of rocks quite resembling those of contemporaneous or just subjacent Cretaceous formations. Hence, such phenomena are thought to suggest the existence of local contemporaneous erosion during the deposition of Ml. The conditions of the source area during the deposition of the Nakakinembetsu member are inferred as follows (Sumi and Tanaka, MS.). The source area was extensively occupied by the slightly metamorphosed complex composed of argillaceous and arenaceous rocks with subordinate cherty rock and complex composed of slate with subordinate chert. All of such rocks were extensively developed in the inland area where also acid and intermediate plutonic rocks were considerably exposed. While the coastal area was, though narrowly, occupied by altered acid and intermediate volcanics and subordinate acid ones, slightly metamorphosed. There were also rather narrowly exposed contemporaneous or a little older sediments, e.g. mudstones containing calcareous concretions and sandstones. Furthermore, the frequent occurrence of isolated pebbles and abnormal sedimentary structures in the Kamikinembetsu silty fine-grained sandstone member (Ub) also attracts one's attention in that their origin is ascribed to the redeposition caused by subaqueous mudflow and sliding.

It is true, as already mentioned, that the Cretaceous deposits of the present area show cyclic sedimentations with regular vertical changes of both lithofacies and biofacies, and with rather constant duration and quantity of subsidence. The great thickness of the Upper Gyliakian stage owes its origin essentially to enormous subsidence. However, we should take into consideration the following: the present area may not have corresponded to the most offshore part, which was usually most intensely subsided as noted in Part III, within the Yezo geosyncline, but it was presumably situated on the western, less offshore part of the basin because the sediments are rich in tuffaceous rocks and fossils, and are not poor in aberrant ammonites. Accordingly, the great thickness of the Upper Gyliakian can be ascribed partly to the fact that the lower of the two cyclic sequences constructing the stage under discussion is composed of two minor cyclic sequences. In this case repeated occurrence of epicycles within one cycle probably rejuvenated the intensity of subsidence in the depositional area, and thus gave rise to thick sediments.

So far as the western side of the area is concerned, the Cretaceous rocks are overlain unconformably by the lower part of the Middle Miocene formation. The base of the Middle Miocene formation cuts the Cretaceous beds of various horizons, such as Ul in the northern part, Uk in the northern central part, Uj in the southern central part and then strata presumably referred to Uj in the southwestern part. The Cretaceous were thus subjected to deeper denudation before the deposition of the Middle Miocene to the south in the western marginal area. In the far southwestern part, i.e. in the valley of the Shimokinembetsu-zawa, the Cretaceous is covered by the Lower Miocene at a considerably lower horizon within the Upper Yezo group than the horizons mentioned above and even at the uppermost part of the Middle Yezo group. These facts may indicate that the southwestern part was upheaved much more intensely than the other parts of the area after the deposition of the Cretaceous strata. Accordingly, it would be concluded that such denudation had some connection with the disposition of the sedimentary environments in the Cretaceous age which was shallower and less intensely subsided in the southwestern part than in the southeastern part.

Lastly, the relation between the sedimentation of the Cretaceous formation and that of the Tertiary is here outlined. As previously noted, the southeastern part was under deeper sea and also more intensely subsided than the other parts of the area in the Cretaceous age at least since the Neogyliakian age. Similar circumstances appeared again during the deposition period of the Oligocene, Lower Miocene and lower part of the Middle Miocene strata which were also thicker in the south than in the north. However, the deposition of the upper part of the Middle Miocene represented by the deposits of so-called "Nagelfluh" type occurred under quite opposite conditions, that is, the sediments were deposited with a greater thickness in the north.

VI. Summary and Conclusion

As to the Cretaceous deposits of the Obirashibe Valley, northern central Hokkaido, the following is offered as concluding remarks.

(1) The Cretaceous rocks are divided into the Lower Yezo, Middle Yezo and Upper Yezo groups in ascending order, the latter two of which are here chiefly dealt with.

(2) The strata of the Upper Yezo and Middle Yezo groups, exclusive of the lowest part of the latter group, are generally finer grained and poorer in arenaceous rocks and contain more tuffaceous rocks in this area than in other standard areas in the meridional zone of Hokkaido.

(3) From the vertical changes of the sedimentary facies, it is known that the Cretaceous shows cyclic sedimentation in a definite order.

(4) Examining the lateral variation of the sedimentary facies, one can say that the southeastern part of the present area was under an offshore or comparatively deep and much more intensely subsided condition than the other parts.

(5) For analysing the biofacies, special attention is paid to the ratio of abundance of ammonites to inocerami, that of aberrant ammonites to coiled ones, and dominant occurrence of a certain ornate type of coiled ammonites.

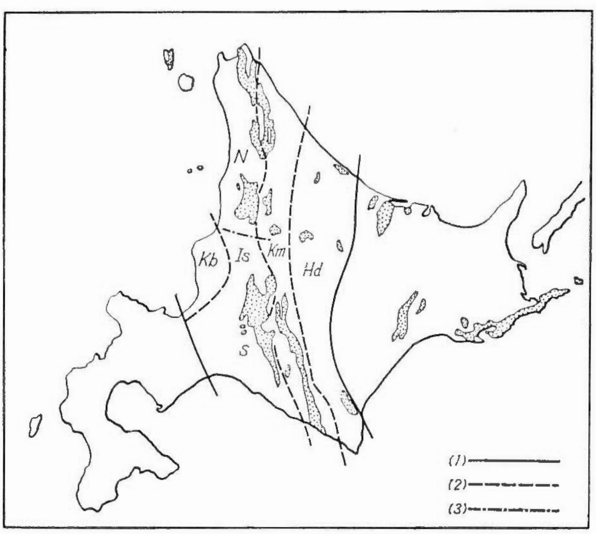
(6) The lateral variation of particular characters, especially percentage composition and maturity of sandstones, in the Nakakinembetsu member is in harmony with that of the general sedimentary facies.

PART II

A BRIEF SUMMARY OF THE CRETACEOUS DEPOSITS OF THE SURVEYED AREAS

I. Introduction

Attempting to develop the study on the basis of the previous works, the writer has carried out a survey on the Cretaceous deposits of the following selected areas in the meridional zone of Hokkaido: (1) the Sorachi anticlinal area in the Ishikari coal-field, (2) the Obirashibe Valley in the Rumoi coal-field, (3) the Kami-sarufutsu district in the Tempoku coal-field, (4) the Tomiuchi district, southern central Hokkaido, and (5) Ikushumbetsu Valley in the Ishikari coal-field (Fig. 1). Most of these areas are situated in the Ishikari zone where the folded Cretaceous and Tertiary rocks develop; a part of them is in the eastern Kamuikotan zone characterized by the occurrence of the Kamuikotan metamorphics and serpentinites



(1) and (2): Boundary of the tectonic provinces
(3): Boundary of the sedimentary provinces (Asahikawa-Rumoi Line)

Tectonic provinces

Hd :	Hidaka zone	Meridional zone of Hokkaido
Km:	Kamuikotan zone	
Is :	Ishikari zone	
Kb :	Kabato mountainland	

Sedimentary provinces
N: Northern province
S: Southern province

Fig. 24 Tectonic provinces and sedimentary provinces in the meridional zone of Hokkaido (Dotted area is the distributional area of the Cretaceous rocks.)

(Fig. 24). The Cretaceous deposits in these areas belong chiefly to the Middle Yezo, Upper Yezo and Hakobuchi groups.

Since the detailed descriptions have already been given in the Explanatory Text of the Geological Map or another report (see references below) for each of the surveyed areas, only an outline of the Cretaceous sequence is given, with some remarks on special features.

II. Cretaceous Deposits of the Sorachi Anticlinal Area in the Ishikari Coal-field, Central Hokkaido

(Fig. 25; Tables 33, 34)

The Cretaceous deposits of the present area (Shimizu, Tanaka, and Imai, 1953; Tanaka, 1959) are covered by the Paleogene Ishikari group with disconformity and afford a large scale anticlinal structure pitching to the north, named the Sorachi anticline.

The Mikasa formation on the western wing (the Bibai–Sunagawa area), carrying a local coaly seam, is thinner and on the whole coarser grained than that on the eastern (the mid-valley of the Ashibetsu). It becomes coarser grained and

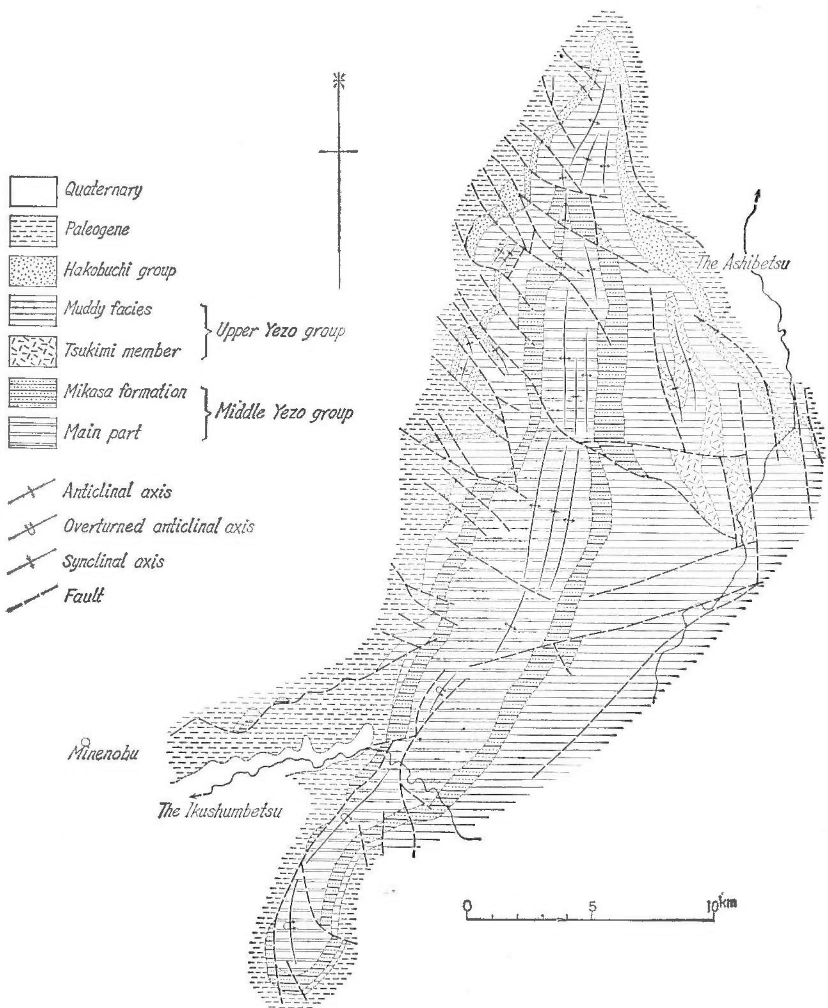


Fig. 25 A compiled geological map of the Sorachi anticlinal area and the Ikushumbetsu Valley, Ishikari coal-field, central Hokkaido

Table 33 Generalized stratigraphic sequence of the Cretaceous deposits in the mid-valley of the Ashibetsu. the eastern wing of the Sorachi anticlinal area

Rock-stratigraphic classification			Thickness (in m.)	Lithofacies: Basal rocks (thick. in m.)	Main lithology	s	t	c	f	p	Biofacies: Fossil assemblage	Ammonite assemblage	Fossils: Characteristic fossils	Other dominant fossils	Correlation
Hakobuchi group	Upper part	HE3 f-g	160→80		$S_3 \gg mS_2 (G_1)$			R	VR	F					K6
		HE3 e			$MS_1 \gg S_3$		A (2;5)			A					
		HE3 d		$G_1(6)$	$mS_2 > S_3 > G_1$										
		HE3 a-c			$S_3 \fallingdotseq S_2$ (C)										
	Lower part	HE2	120→60		$S_2 \fallingdotseq S_3 \gg G_2(C)$		VR	R(A)							
Upper Yezo group	Uppermost part	HE1	30	(G_1 : 0.3)	mS_1			C	C	A	I		Ij	Io	K5δ
		UE11	40→80	$S_3(5)$	$M_1 > sM_2$	F (gs)	VR	A	A	R	I	co ≫ ab	In	Gt, Ie	K5β
	Main part	UE10	90→120	$S_3(5)$	M_2 / MS_2	C (gs)	F	A	R / A	F	I > M	ab ≒ co	Ia		
		UE9	100→80		M_1	R	F	F	F	R					
		UE8	120→90		sM_1 / $MS_2 \leftrightarrow sM_1$	A	C	C	R / A	F	I		Im, Iu	My?	K5α
	Tsukimi member	UE7	170(+) (40~130 (+))		$S_2 \fallingdotseq G_1 > sM_2$ / $TS > sM_2 > M_2$		A	F	F	C	I > M				
		UE6	(40~110)		SM_2		F	F							
		UE5	120→80	G_2	M_1	F		F	F		I				
		UE4	150	$S_3(15)$, $G_1(3)$ ↔ $S_3(5)$	M_1 / $MS_2 \leftrightarrow M_1$	C	F	A	F / A	F / C	M	co / ab ≪ co	Ih	Tg, Mi, It / Tg, It	K4β
		UE3	110	$G_1(5?)$	$sM_2 \leftrightarrow M_2$	F		F	C	F	I	co > ab			
	Lowest part	UE2	110→70	$S_3(10)$	sM_2	F		F	VR						
		UE1	180→110		$SM_2 \leftrightarrow sM_2$ / SM_2, sM_1 ↔ sM_2	A	R	A	A	A	A / I / A > M	ab > co / co		Op, Ts / Ini / De, Ini	K4β / K4α
Middle Yezo group	Uppermost part (Mikasa formation)	TE3	80→40		$S_4 \fallingdotseq mS_2$			R	C		A > M				K4α
		TE2	80→50		sM_2	R (gs)	R	F	C			co			
		TE1	90~140		$mS_2 > S_4$ / $mS_2 \fallingdotseq sM_2$		A (10)	F(A) / F	A / VR	A / C	S > I / S > A	ab ≪ co	Co ×, × Dk	Ini / Di	K4α / K3γ
	Main part	ME3	50~90		sM_1	F		R							K3γ
		ME2	120		$SM_2 \fallingdotseq sM_1$		R	C	(C)	C	S				
		ME1	30υ(+)		sM_1	R		R(A)							K3β

Explanation of Tables 33～37

Thickness and lithology

⟷ Showing lateral variation
from west (left) to east (right): Table 35 and Tsukimi member in Table 33
from south (left) to north (right): Tables 33 and 34

Lithofacies

Lithology

G_1	:	conglomerate
G_2	:	conglomeratic sandstone
S	:	sandstone
S_1	:	very coarse-grained sandstone
S_2	:	coarse-grained sandstone
S_3	:	medium-grained sandstone
S_4	:	fine-grained sandstone
SM_1	:	sandstone and mudstone in thick- or medium-bedded alternation
SM_2	:	sandstone and mudstone in thin-bedded alternation
mS_1	:	silty fine-grained sandstone
mS_2	:	silty fine-grained sandstone to fine sandy siltstone (the former being predominant or both approximately in equal amount)
MS_1	:	fine sandy siltstone to silty fine-grained sandstone (the former being predominant)
MS_2	:	mudstone with frequently interbedded sandstone
sM_1	:	mudstone with frequently interlaminated sandstone (laminated sandy mudstone)
sM_2	:	siltstone, fine sandy siltstone or sandy mudstone
M_1	:	mudstone, partly sandy
M_2	:	mudstone
T	:	tuff
TS	:	tuffaceous sandstone
gs	:	green sandstone
c	:	coal or coaly shale
( )	:	thin beds or layers
$\gg$	:	the left being much predominant over the right
$>$	:	the left being predominant over the right
$\fallingdotseq$	:	both the left and the right being approximately in equal amount
s	:	thin beds or layers of sandstone
t	:	thin beds or layers of tuff or tuffaceous rock (thickness of thick bed being shown)
c	:	calcareous concretions
f	:	marine megafossils
p	:	drifted plant remains or carbonaceous flakes

Grades of abundance

VA	:	very abundant
A	:	abundant
C	:	common
F	:	few
R	:	rare
VR	:	very rare
( )	:	local

Biofacies

Fossil assemblage

S	:	shell facies
A	:	ammonite facies
M	:	mixed facies
I	:	inocerami facies
A>M	:	ammonite facies rather akin to mixed facies

Ammonite assemblage

co	:	coiled ammonites
ab	:	aberrant ammonites
≫	:	the left being much predominant over the right
>	:	the left being predominant over the right
≒	:	both types of ammonites being approximately in equal amount

Fossil

An	:	*Anapachydiscus* sp.
Ba	:	*Baculites* sp.
By	:	*B. yokoyamai*
Ca	:	*Calycoceras* sp.
Co	:	*C. orientale*
Dd	:	*Damesites damesi*
De	:	*Desmoceras (Pseudouhligella) ezoanum*
Dj	:	*D. (P.) japonicum*
Dk	:	*Desmoceras kossmati*
Eh	:	*Eupachydiscus haradai*
Gt	:	*Gaudryceras tenuiliratum*
Mi	:	*Mesopuzosia indopacifica*
My	:	*M. yubarensis*
Nh	:	*Neophylloceras hetonaiense*
Nr	:	*N. ramosum*
Ns	:	*N. subramosum*
Op	:	*Otoscaphites puerculus*
Ph	:	*Polyptychoceras haradanum*
Pp	:	*P. pseudogaultinum*
Rm	:	*Reesidites minimus*
Sc	:	*Sciponoceras* sp.
Sp	:	*Scaphites planus*
Sps	:	*S. pseudoaequalis*
Sy	:	*Subptychoceras yubarense*
Tg	:	*Tetragonites glabrus*
Ts	:	*Tragodesmoceroides subcostatus*
Ia	:	*Inoceramus amakusensis*
Iaw	:	*I.* (?) *awajiensis*
Ie	:	*I. ezoensis*
Ih	:	*I. hobetsensis*
Ij	:	*I. japonicus*
Im	:	*I. mihoensis*
In	:	*I. naummani*
Ini	:	*I. concentricus nipponicus*
Io	:	*I. orientalis*
Is	:	*I. schmidti*
Ish	:	*I. shikotanensis*
It	:	*I. teshioensis*
Iu	:	*I. uwajimensis*
Iy	:	*I. yabei*

Vertical line: stratigraphic range of species

× : stratigraphic position of the occurrence of species

Thick line and thick sign: abundant occurrence

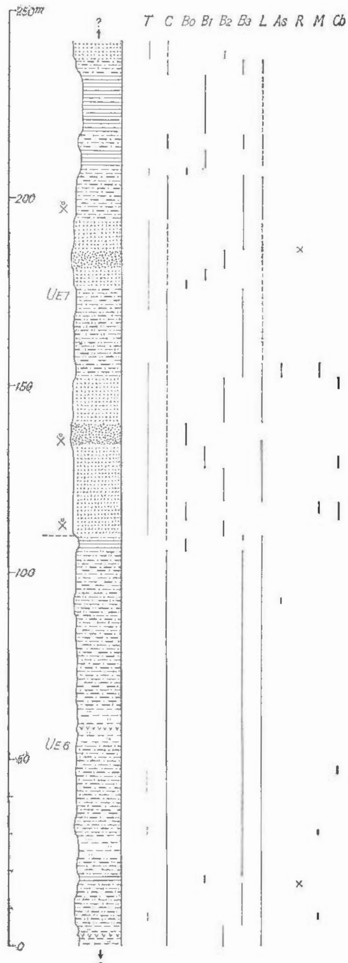
Correlation

K3	:	Miyakoan series
K4	:	Gyliakian series
K5	:	Urakawan series
K6	:	Hetonaian series
α	:	Lower stage
β	:	Upper stage
γ	:	Uppermost substage

Table 34 Generalized stratigraphic sequence of the Cretaceous deposits in the Bibai-Sunagawa district, the western wing of the Sorachi anticlinal area

Rock-stratigraphic classification			Thickness (in m)	Lithofacies							Biofacies		Fossils		Correlation
				Basal rocks (thick. in m)	Main lithology	s	t	c	f	p	Fossil assemblage	Ammonite assemblage	Characteristic fossils	Other dominant fossils	
Hakobuchi group	Upper part	Hw_3	30~40	G_1(0.3)	S_2 ≒ S_3 / S_2≒S_3≒mS_2		C	R(C)	R						K6
	Lower part	Hw_2	40↔60		S_2 ≒ S_3 / G_1		C (3)	R		F					
Upper Yezo group	Uppermost part	Hw_1	0↔50		mS_1			F(C)	(C)	C	A	ab>co	In	Ph	K5γ
		Uw_7	80~90	S_2≒S_3(3)	sM_2 / sM_2↔MS_2	A	F	C	F / A	C / F	I	co≒ab	Ij		K5β
	Main part	Uw_6	40↔20	S (gs) (2~3)	Ms_1 → sM_2			A	VA	F / C	A > M	ab>co	Eh ×	Ph	
		Uw_5	40~50		M_1 / sM_2 → M_1			F	F	F	I > M		Ia		
		Uw_4	30~40	S (gs) (2~5)	sM_2	F	R	A	A	C	I	co>ab	Im ×	Dd	
		Uw_3	40~50	S (gs) (2)	mS_2 ↔ sM_2		R	C	VA	A	I / I > M	ab>co	Iu	By	K5α
		Uw_2	50~60	S (gs) (2~4)	sM_2			F(C)	F	F	A	ab>co		By	
	Lowest part	Uw_1	90↔70	S_4(10)	mS_2 / MS_1 → sM_2	R		C / C	A / C / A	A / A	I / A > M / I / A > M	ab≒co / co≥ab / ab>co	Ih	Rm / Sp, Op	K4β
Middle Yezo group	Uppermost part (Mikasa formation)	Tw_3	110↔140		S_3 ≫ G_1 / S_2≒S_3>G_1(C)		R	(A) / R	R(A)	A	A > M	ab>co		Op / Ini	K4α
		Tw_2	40~50		sM_2		R	C	C		I	co	Dj	Iy, Ini	
		Tw_1	60↔80		S_4 ≒ mS_1		F	R	R(A)	A	S				
	Main part	Mw_5	70~80		sM_2	F	VR	R							K3
		Mw_4	150	S_3(5)	SM_2		F (3)	VR							
		Mw_3	300		MS_2	A	VR	R							
		Mw_2	100~140		S_3										
		Mw_1	650(+)		sM_1 > SM_2			VR							

richer in calcareous concretions and fossil remains to the south on both wings. The Upper Yezo group on the eastern wing is as a whole thicker and finer grained as compared with that on the western wing. The Tsukimi member, the middle part of the group, which occurs only on the eastern wing, is composed mainly of



Explanation of some abbreviations
T : tuffaceous
B_0 : massive
As: abnormal sedimentary structures
Explanation of the lines
Colour of the sandstones
Thin line: grey to dark grey
Broken line: bluish white
Dotted line: varigated
Thin line for the elements other than the colour of the sandstones shows more abundant or more frequent occurrence than the broken line.

Fig. 26 Columnar section and lithologic characters of the Tsukimi sandstone member (U_{E6}-U_{E7}), its eastern facies in the type exposure along the Ashibetsu
For the legends and abbreviations see Fig. 5.

well-stratified tuffaceous sandstones in the east (Fig. 26). On the other hand, in the west the member is rich in pebbly mudstones or muddy conglomerates, carrying abnormal sedimentary structures such as irregular stratification and a random orientation of disrupted layers of sandstone or irregular bodies of contemporaneous sediments presumably due to sliding and slumping at the time of deposition. The Upper Yezo group shows an increase as a whole in the grades of coarseness and the occurrence of concretions and fossils towards the south on both the eastern and the western wings. On the eastern wing, especially in its southern part coarse-grained sediments are frequently intercalated in the group. In the group on the western wing aberrant ammonites are rather common and green sandstones, a few metres thick, are occasionally found. The Hakobuchi group, though more deeply eroded away on the western wing than on the eastern, was also originally much thicker on the eastern wing than on the other as is the case of the subjacent strata. The lower half of the group is as a whole coarser grained on the western wing than on the eastern. Furthermore, the group on the eastern wing carries coal seams which thicken toward the south, and increases in thickness to the south in spite of the denudation subsequent to the deposition. The group on the western wing decreases in thickness to the south and is more deeply eroded away in the south than in the north.

Judging from the lateral variation of sedimentary facies throughout the whole sequence from the Mikasa formation to the Hakobuchi group, it is suggested that these deposits on the eastern wing were represented by offshore and deeper facies. On the other hand, the sediments of the above strata on the western wing show near-shore and shallower facies. The southern part of the western wing was continuously in relatively shallow water and nearer the presumed western land at least during the deposition of the Upper Yezo and Hakobuchi groups. Furthermore, it is plausible that the coarse-grained sediments such as the Tsukimi member in the lower half of the Upper Yezo group on the eastern wing were not derived from the west but rather from the southwest where an upwarping belt (the Minenobu upwarping belt) of nearly ENE-WSW direction is thought to have existed (Tanaka, 1959).

III. Cretaceous Deposits along the Obirashibe Valley, Northern Central Hokkaido

The geological conditions of the Cretaceous rocks in the area have been fully described and discussed in Part I.

IV. Cretaceous Deposits of the Kamisarufutsu District, Northern Hokkaido

(Fig. 27; Table 35)

The Cretaceous strata of this area (Tanaka, 1960b), form, roughly speaking, a large scale anticlinorium structure pitching to the north. They are disconformably overlain by the Oligocene and unconformably by the Miocene, being more deeply eroded away in the western part of the area than in the eastern. The Lower Yezo group is found only in scattered small areas. Therefore it does not deserve general discussion.

The Hoshin formation, the uppermost part of the Middle Yezo group, is rather similar to the Mikasa formation in the predominance of coarse-grained sediments, but as a whole younger than the Mikasa formation, being equivalent to the Saku formation. The uppermost part of the Upper Yezo group is correlated to the Uppermost Urakawan substage to the Lower Hetonaian stage, as in the cases of the

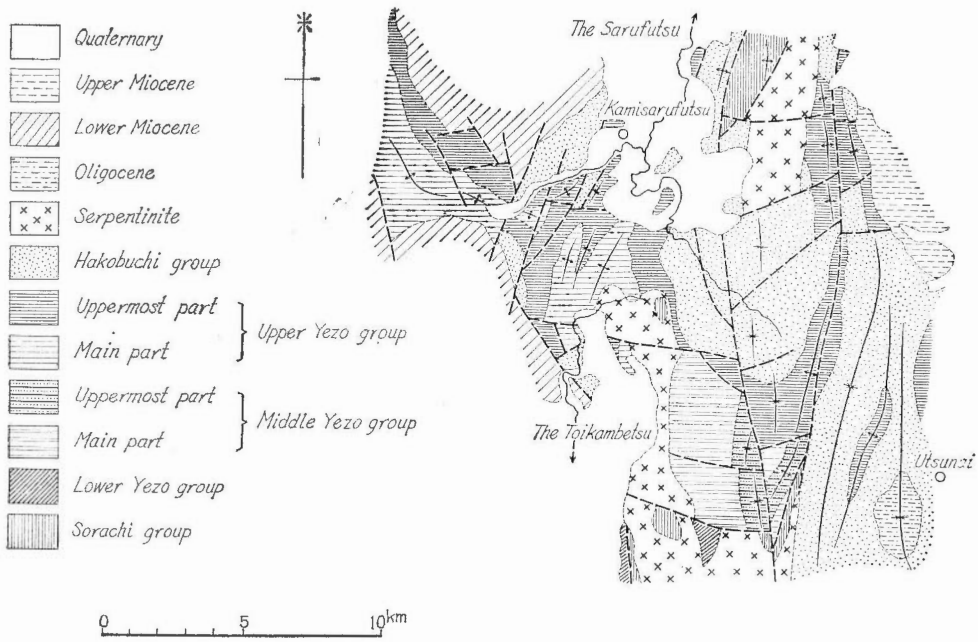


Fig. 27 A compiled geological map of the Kamisarufutsu district, Tempoku coal-field, northern Hokkaido

Obirashibe Valley (see Part I) and Abeshinai Valley (Matsumoto, 1942–43, 1954). The Hakobuchi group is comparatively thick. While sandstones are dominant in its lower part, siltstones and mudstones predominate in the upper. Accordingly, it shows an intermediate facies between the typical Hakobuchi group of the Ishikari province and the Chinomigawa formation (Matsumoto, 1942–43, 1954) of the Urakawa area. It is furthermore worthy of special mention that *Inoceramus*(?) *awajiensis* MATSUMOTO occurs in the uppermost part of the group.

The Cretaceous rocks in the present area show such lateral changes in thickness and rock-facies as follows. The upper part of the Hoshin formation (M_9), which is concealed in the eastern part of the area, is on the whole thicker and coarser grained in the central than in the western part. Abnormal sediments such as pebbly mudstone or muddy conglomerate and abnormal sedimentary structures as displayed in the Tsukimi member noted before are found in the central part. Pebbles of volcanic rocks and those of rocks quite resembling those of contemporaneous or just subjacent Cretaceous formations, such as calcareous rocks forming concretions, are abundant in the central part, while they are scarce in the western. The sandstones in the central part are rich in volcanic fragments, but those of the western part are very poor in such fragments. The Upper Yezo group decreases in grades of coarseness to the west. As to the Hakobuchi group, the strata from member H_1 to member H_4 are on the whole finest grained in the central part and member H_4 there seems thicker than in other parts; member H_5 is finer grained in the eastern than in the central part. From the facts mentioned above the following inference is drawn: the sediments of the eastern coarser facies of these strata may have been derived from the east. Furthermore, in the eastern part

Table 35 Generalized stratigraphic sequence of the Cretaceous deposits in the Kamisarufutsu district

Rock-stratigraphic classification			Thickness (in m.)	Lithofacies: Basal rocks (thick. in m.)	Lithofacies: Main lithology	s	t	c	f	p	Biofacies: Fossil assemblage	Biofacies: Ammonite assemblage	Fossils: Characteristic fossils	Fossils: Other dominant fossils	Correlation
Hakobuchi group	Upper part	H_5	200(+)	$S_2 \fallingdotseq S_3$ (20)	$sM_2 \gg MS_1$ $MS_1 > mS_1$		F	C	R A		I S		× Iaw		K6β
		H_4	200	$S_3>S_2(G_2)$ (20 ~ 30)	$sM_2 \gg MS_1$ $MS_1 \fallingdotseq mS_1$		A R	F A	VR C	A			× Ish		
		H_3	100		$M_1 \leftrightarrow sM_2$	F	R	F	F		I				
	Lower part	H_2	150	$G_1(3\sim6)$	mS_1 $S_3 \fallingdotseq S_4$	/	VR	C	C	C	S			Io	
		H_1	150	$G_1(2)$	S_3 $mS_1>S_2=S_3$	/	VR	VR	R A	A	S				K6α
Upper Yezo group	Uppermost part	U_7	200↔300		$M_1 \gg sM_2$	R	R C	F A	F A	C	I	co=ab	Is		
		U_6	150↔100	mS_1↔ S (5) (5)	$sM_2 \leftrightarrow SM_2$	R	VR	C	A	C	M	ab>co	In	Ba, Io	K5γ
	Main part	U_5	300		sM_2 M_1 $M_1 > sM_2$	F	R C R F	F A C	F A		I I >M		Eh × Ij Ia		K5β
		U_4	100	$S_2 \fallingdotseq S_3$ (5~6)	$sM_1 > SM_2$	C	A	C	C		M			An	
		U_3	300		M_1 M_2		VR F	R F	F R		I >M I		Iu	Ie	
		U_2	100	SM_2(5)	sM_1	C A	F	C	A	F	I >M				K5α
		U_1	200		sM_2 M_2		F	R	R						
Middle Yezo group	Uppermost part, Hoshin formation	M_9	150	$G_1(3)$	$SM_2 \leftrightarrow sM_2 > G_1$ $S_3 > S_2$	/		VR	VR	C					K4
		M_8	150		sM_2 sM_1 SM_2	C	R	R F		F					
		M_7	300		S_3 $S_3 > S_2(G_1)$	/	VR			A					
	Main part	M_6	450	S_4(20)	sM_2 M_2 $M_2 > sM_1$ $sM_2 = sM_1$	F R F	F A	R							
		M_5	250		$M_1 \gg sM_1$ sM_1	R	VR F								
		M_4	100		$S_4>S_3>SM_2$	/	F								
		M_3	100		$sM_1 \fallingdotseq sM_2$	F	C	R							
		M_2	60 ~ 100		$S_3 > S_2 \fallingdotseq S_4$	/	F			A					
		M_1	300(+)		$M_1 \gg sM_1$ SM_1	F		VR	R						

of the area the Hakobuchi group shows in general an increase in grades of coarseness to the south as in the case of member U_7, the uppermost part of the Upper Yezo group; the group contains abundant shallow sea bivalves in the south.

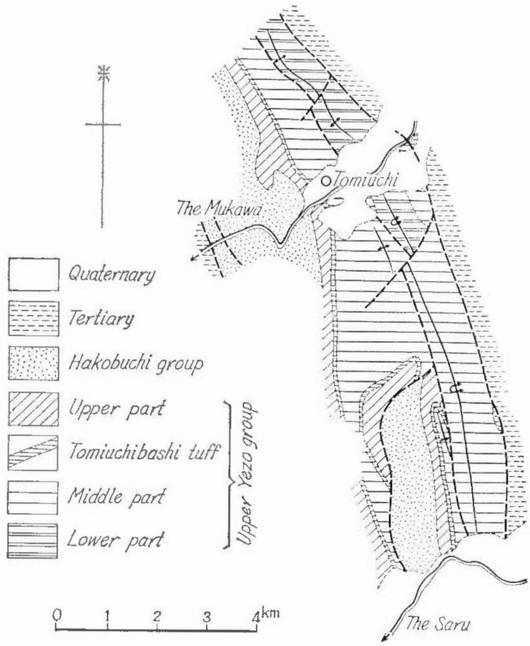


Fig. 28 A compiled geological map of the Tomiuchi district, southern central Hokkaido

V. Cretaceous Deposits of the Tomiuchi District, Southern Central Hokkaido

(Fig. 28; Table 36)

The Cretaceous deposits of this area (Tanaka, 1960a) are chiefly in fault relation to the Tertiary on both the eastern and the western sides, showing in themselves an intensely overturned folding. Throughout the Upper Yezo group, the sediments are more uniform and finer grained in comparison with those of other surveyed areas. It is also noteworthy that the thickness of the Upper Urakawan stage is great, attaining to 900 m. Further, a thick tuffaceous rock, about 30 m thick, named the Tomiuchibashi tuff member is contained in the upper. The Hakobuchi group differs from that of the Sorachi anticlinal area in its great thickness, predominance of fine-grained deposits, and abundant fossil remains.

VI. Cretaceous Deposits along the Ikushumbetsu Valley in the Ishikari Coal-field, Central Hokkaido

(Fig. 25; Table 37)

The area is famous as the classical and typical field of the Cretaceous deposits in Hokkaido. The Cretaceous strata (Tanaka, Matsuno, Mizuno and Ishida, MS.) are disconformably covered by the Paleogene Ishikari group, and afford an anti-

Table 36 Generalized stratigraphic sequence of the Cretaceous deposits in the Tomiuchi district

Rock-stratigraphic classification				Thickness (in m)	Lithofacies: Basal rocks (thick. in m)	Main lithology	s	t	c	f	p	Biofacies: Fossil assemblage	Ammonite assemblage	Fossils: Characteristic fossils	Other dominant fossils	Correlation
Hakobuchi group	Up. sdy siltst.	Hd		20(+)		S_3										
	Fukaushi formation	Hc	C_6	15		S_2 ≒ S_3										
			C_5	20		MS_1	C			VR						
			C_4	25		S_3 > S_2				C						
			C_3	50		MS_1		F	A	R	F					
			C_2	20		S_2 ≒ S_3										
			C_1	30		$S_2 > S_3 \gg G_1$										
	Lower siltstone	Hb	b_3	30		mS_2			A	F		I > S				K6β
			b_2	230		sM_2			F	VR	F	I			Ish	
			b_1	40	$S_{3(gs)}$ ≒ mS_1(3)	MS_1			F	C		M			Nh, Ish	
	Tomiuchi formation		a_7	30~50		$S_3 > S_2$(C)		R								K6α
			a_6	60	G_1(2)	$SM_1 > S_4 \gg G_1$(C)		A (5)								
			a_5	40~50		$S_2 > S_3$ / $S_3 > S_2$(C)		VR		A		S ≒ I		Is		
			a_4	40		MS_1(C)				R						
			a_3	70		S_2 ≒ S_3(G_1) / $S_3 > S_2$(C)		C		A	F	S ≒ I			Io	
			a_2	20		MS_1				A		I			Io	
			a_1	20		$S_2 > S_1 \gg G_1$				F		S				
Upper Yezo group	Uppermost part	Uh		10		sM_2			A	A	F	I		Eh, In	Io	K5γ
		Ug		200		M_1				A	F	I > M	ab < co	Ij	Gt	K5β
							C	A	A	C		I	co			
							F	F	F	F						
	Main part	Uf*		35		T ≒ TS		A								
		Ue		200	MS_1(1)	sM_2	F		F		VR	I	co > ab			
						M_2		R	R	C				Ia		
		Ud		200	sM_2(2)	M_2		R	R	A	F	A	co ≥ ab		Gt	
							R	C	A				ab < co		Nr	
										VA			ab ≒ co		Ph, Pp, Sy, Tg, Gt, Dd	
		Uc		200	MS_1(2)	M_2		R	R	F	R	M	co > ab	Im		
								F		R		I				
		Ub		150~200	sM_2(7)	M_2		F	R	R			co	Iu		K5α
						M_1	R	F / C	C	A	C	I > (M)	ab ≒ co		Sps., Ns	
		Ua		300(+)	$sM_2 > S_3$ (10+)	M_1		F	R	R	R		co > ab			K4β
						M_2	R									
						M_1		C	F	A		I		Ih	My	

* Tomiuchibashi tuff member

Table 37 Generalized stratigraphic sequence of the Cretaceous deposits in the Ikushumbetsu Valley, the eastern wing of the Ikushumbetsu anticlinal area

Rock-stratigraphic classification				Thickness (in m.)	Lithofacies							Biofacies		Fossils		Corre-lation
					Basal rocks (thick. in m.)	Main lithology	s	t	c	f	p	Fossil assemblage	Ammonite assemblage	Characteristic fossils	Other dominant fossils	
Upper Yezo group	Main part		Um	20(+)		M1	F		F	A		I > M		In		K5β
			Ul	50		M1	F	R	C	C		I	co>ab			
			Uk	40	S1(6)	sM2	F	R	F	C	F	I	co>ab	× Ij		
			Uj	30		M1	R	R	R	F		I	co>ab			
			Ui	25	T~TS(6~12)	sM2	C	A	C	VA	C	A > M	ab>co		Pp, Sy, Tg, Ia.	
			Uh	40	sM2 (gs) (1)	M1	F (gs)	R	F	A	F	M	co≒ab		Pp	
			Ug	60		M2	F	F	R	F			co≒ab			
								C		C		I				K5α
			Uf	20		sM2	F (gs)	R	C	C	VA	I		Iu		
			Ue	30		MS1	R		A	A	C	I > M	ab≫co		Bj	
			Ud	30		sM2	R		F	F	F	I				
			Uc	30	S3(gs)(4~5)	MS1	F (gs)		F	F	F	I > M	co<ab			
	Lowest part		Ub	60	S3(2.5)	sM2 / MS1	A (gs)		A	VA	A	M	ab≫co	× Rm	Sc, It	K4β
			Ua	80		MS1	F	VR	A	A	A	I		Ih	It	
						mS2										
Middle Yezo group	Uppermost part	Mikasa formation	Td	170	S3(gs)(0.6)	S3 ≫ G1	/		F	A		S > I				
						mS1	/		F	F						
						sM2	F		F	R						
			Tc	65		sM2	R		C	A (F)	F	I			Iy	K4α
			Tb	140		mS2	F (gs)		A	A		S ≒ I			Iy	
												A ≒ S			Dj	
						mS1	/		A	VA	A	S > A			Ca	
						S4	/		A	A		S				
			Ta	35	MS1(0.3)	sM2 > MS1	R	F	R	F		S				K3γ
	Main part		Me	110		S3 > sM1	/		VR	VR						K3β
			Md	300		sM1	C	R	F	R	F			Mi		
						sM1 > sM2	F	R	C	F	F					
						sM2	R	R	R		F					
			Mc	120		S3 > S2	/				C					
			Mb	180		sM1>SM1≒SM2	/	R	VR	VR	F					
						SM1≒SM2>S3	/	F	VR	VR						
			Ma	300(+)		sM1	C	R	C	R	F					
							R	R	F	F						
						SM2	/				C					

clinal structure pitching to the south, named the Ikushumbetsu anticline. They are more deeply eroded away in the western part of the area than in the eastern and moreover than in the western part of the northern Sorachi anticlinal area.

The Mikasa formation and the Upper Yezo group on the eastern wing of the Ikushumbetsu anticline are rather similar to those on the western wing of the Sorachi anticline in the sedimentary facies. The Mikasa formation becomes, on the whole, coarser grained on the western wing of the Ikushumbetsu anticline and moreover frequently contains *Ostrea* beds in its detached localities further west outside of the anticline. It also becomes, in general, thinner and coarser grained southward on both the eastern and the western wings like the main part of the Middle Yezo group. Thus, the Mikasa formation in the southernmost part of the Ikushumbetsu anticline is much similar to that in the southern Yubari area* where its stratigraphic range is considerably long** and *Ostrea* is abundantly contained at certain horizons. Furthermore, ammonites and inocerami are much more abundant on the eastern wing than on the western wing and in the southernmost part of the anticline. In the Upper Yezo group green sandstones of a few metres thick are found at several horizons like on the western wing of the Sorachi anticline. This group also becomes considerably thin in the southernmost part of the anticline in harmony with the underlying strata. In this connection, it is noteworthy that an *Ostrea* bed occurs therein.

To sum up, judging from the lateral variation of sedimentary facies throughout the whole sequence from the Middle Yezo group to the Upper Yezo group, it is evident that the sediments of the above strata on the eastern wing of the anticline show offshore and deeper facies. While, the deposits on the western wing and in the southernmost part are represented by near-shore and shallower facies.

* The Yubari area, about 20 km south of the Ikushumbetsu area, where the Cretaceous strata form two dome structures is now under the writer's survey.

** The Mikasa formation in the Yubari area ranges from the whole Uppermost Miyakoan substage to near the top of the Upper Gyliakian stage, although this matter is not illustrated in Fig. 29.

PART III

NOTES ON THE CRETACEOUS SYSTEM IN THE MERIDIONAL ZONE OF HOKKAIDO

I. Introduction

For establishing the reasonable scheme of stratigraphy of the Cretaceous deposits in the meridional zone of Hokkaido, there should be taken into consideration on the geological conditions in the individual localities the following points: (1) sedimentary facies, and position within the basin of sedimentation, i.e. in the Yezo geosyncline, (2) province within the basin, (3) history of sedimentation, and (4) tectonic province. In this connection, the sedimentary facies are discriminated into relatively near-shore or (shallow) and offshore (or deep) facies. Two sedimentary provinces are discriminated: northern and southern, their boundary being called the Asahikawa-Rumoi Line (Tanaka, 1959). There are contrasting features in the sedimentary facies between the northern and the southern provinces. One should also bear in mind that the sedimentation of the Cretaceous rocks was fundamentally controlled by both the geosynclinal sinking particular to this region and the epeirogenic movements of much wider extent (Matsumoto, 1941). Lastly it should be remembered that there is a certain geological relationship between the position within the Cretaceous basin of sedimentation and the tectonic configuration of the Ishikari and Kamuikotan zones (Fig. 24).

The history of sedimentation of the Cretaceous sequence in the meridional zone of Hokkaido has been hitherto discussed by (1) T. Matsumoto (1942–43, 1954) from the standpoint of facies development, by (2) W. Hashimoto (1954, 1958) who took into consideration the connection of sedimentation with tectonic history throughout the Mesozoic, and by (3) M. Hunahashi (1957) who ascribed the sedimentation to the products of his Alpine-type Hidaka orogenic movement. For the discussion of the sedimentation of the Cretaceous formations in the meridional zone of Hokkaido, first of all, the detailed stratigraphic sequence and sedimentary facies of all parts of the area should be clarified. Petrographical studies on the sedimentary rocks which are not yet fully accomplished except for those in some areas (Fujii, 1958; Iijima, 1959; Tanaka, 1960b; Sumi and Tanaka, MS.) are also necessary in order to discuss the sedimentation, especially about the conditions of source areas. Furthermore, the configuration of the basin, i.e. the Yezo geosyncline has not yet been clarified, even in an outline. In short, sufficient data are indeed not now available for this purpose. Notwithstanding, it would not be a waste of time to discuss the sedimentation of the Cretaceous deposits from the present knowledge.

From these points of view, on the basis of the data described in Part I and Part II and contributed by many investigators the writer presents here general account on the stratigraphy and sedimentation of the Cretaceous deposits in the meridional zone of Hokkaido. As to the stratigraphy, first of all, some notes are offered on the rock-stratigraphic units and time-stratigraphic units. And then, for excluding the inconsistency between the two types of stratigraphic classification, cyclic sedimentation is taken into consideration. Thus a stratigraphic classification based on cyclic sedimentation is stressed among other stratigraphical problems. As regards the sedimentation, the sedimentary facies, sedimentary provinces, the relationship between subsidence and deposition, cyclic sedimentation, and so forth are explained. Furthermore, the writer would like to discuss the tectonic control of sedimentation and development of the basin of sedimentation. In addition to the data from the areas covered by the writer's survey, those form the Abeshinai and Shiyubari valleys and the Urakawa and Furano districts (Fig. 1), contributed by other persons, are largely cited in the following description.

II. Notes on the Stratigraphy

II. 1 Note on the Rock-Stratigraphic Units

Since the stratigraphic classification from the standpoint of facies-development of the Cretaceous deposits in the meridional zone of Hokkaido is summarized by T. Matsumoto (1942–43, 1954), only some notes are here presented on the rock-stratigraphic units (Fig. 29).

Lower Yezo group

The Lower Yezo group is composed essentially of sandstone and shale in alternation, in which shale dominates in the middle part rather than in the lower and upper parts. The lowest part of the group is represented by the Onodera sandstone member (Ijima and Shinada, 1952) in the northern province, and by the Tomitoi sandstone member (Hashimoto, 1936) in the southern. The base of the upper part is occupied by sandstone, carrying *Orbitolina* limestone, which chiefly occurs in the southern province.

Middle Yezo group

The lowest or basal part consists mainly of sandstone with subordinate conglomerate. This part is called in the Obirashibe area the Kanajirizawa formation which represents a western facies in the northern province. The Kanajirizawa formation is considerably thick, its middle part being finer grained than its lower and upper parts. Other representatives are the Moihoro sandstone member (Ijima and Shinada, 1952) of the Abeshinai area in the northern province and the Kasamorizawa sandstone and conglomerate member (Hashimoto, 1953) of the Furano district in the southern province. The last one indicates an eastern facies. In this part or at a certain horizon a little upper than that, thick beds of tuff, ordinarily presenting flinty appearance, are intercalated. Furthermore, it is said that the Middle Yezo group covers the Sorachi group with unconformity in some areas within the Kamuikotan zone (Hashimoto, 1953, 1958; Osanai and others, 1958).

The main part of the group consists largely of muddy or silty rocks, but in the uppermost part sandstone is more predominant. The western near-shore facies is represented by the Mikasa formation in the Ishikari coal-field, which is as a rule subdivided into three parts, of which the middle is finest grained and the upper is coarser grained than the lower. The stratigraphic range of the Mikasa formation is the longest in the Yubari area, while the shortest on the eastern wing of the Sorachi anticline. The occurrence of trigonians characterizing this formation is much more abundant in the lower part than in the middle and upper parts. On the other hand, the Hoshin formation is regarded as representing the eastern near-shore facies in the northern province, and the Kondoyama sandstone formation

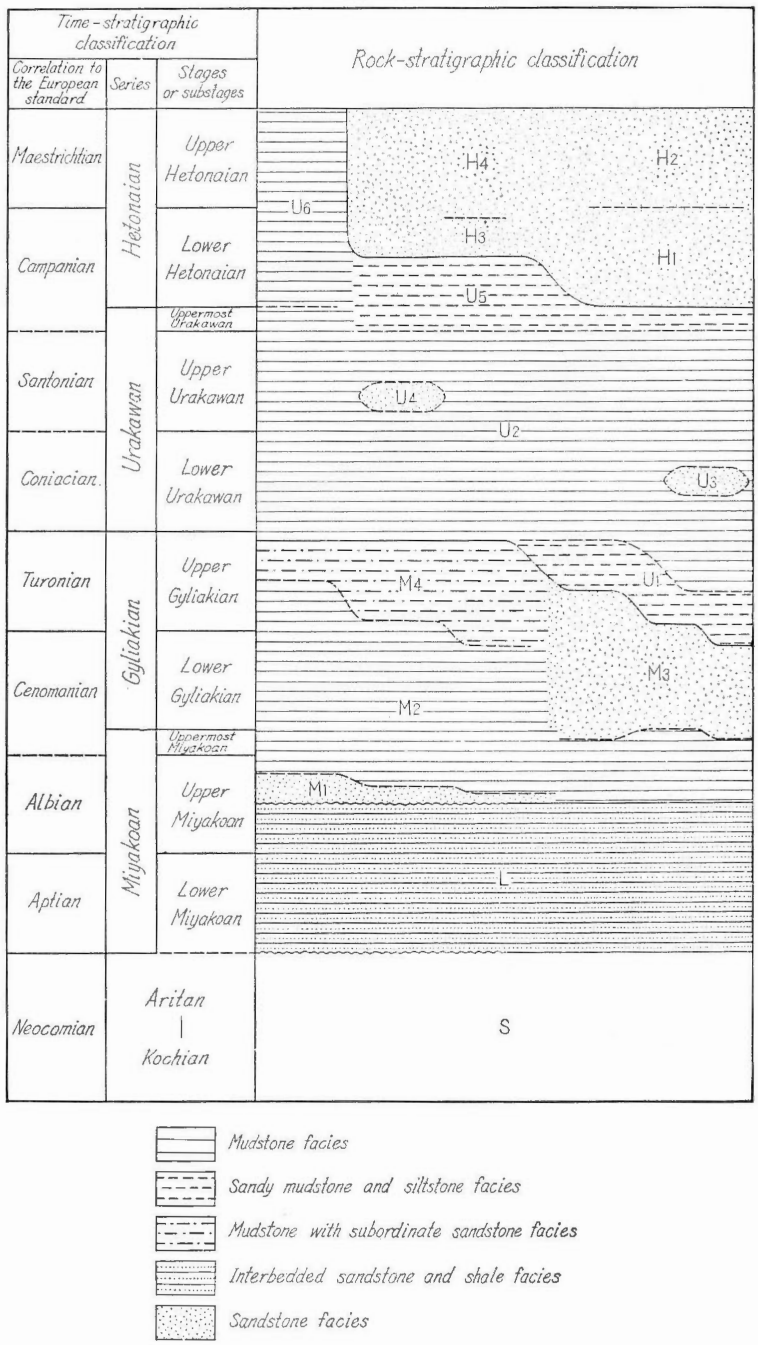


Fig. 29 Schematic illustration of the stratigraphic classification of the Cretaceous deposits of the standard areas in the meridional zone of Hokkaido

Explanation of Fig. 29

Explanation of the lines

~~~~~ Boundary line of the group; unconformity

——— Boundary line of the group; conformity

- - - - Boundary line of the minor rock-stratigraphic unit

Explanation of the abbreviations

Rock-stratigraphic units (thickness in m)

S : Sorachi group (in part)

L : Lower Yezo group (1,000~1,700)

M: Middle Yezo group (2,000(?)~3,500)
M_1: Lowest or basal part (20~900)
M_2: Main part (1,500~2,200)
M_3: Uppermost part, Mikasa formation (Kondoyama formation contained) (180~400)
M_4: Uppermost part, Saku formation (Hoshin formation contained) (400~600)

U: Upper Yezo group (450~2,000)
U_1: Lowest part (70~300)
U_2: Main part (300~1,200)
U_3: Tsukimi member (80~240(+))
U_4: Omagari member (250)
U_5: Uppermost part (10~50, 180~450)
U_6: Chinomigawa formation (1,100(+))

H: Hakobuchi group (70~800)
H_1: Tomiuchi formation (40~300)
H_2: Lower sandy siltstone to Sanushibe formation (30~500)
H_3: Lower part (300)
H_4: Upper part (500)

The conformable relation between the Sorachi and Lower Yezo groups is recently recognized as being doubtful by some investigators.
~~~~~

(Hashimoto, 1936) that in the southern. These two formations occur in the Kamuikotan zone as well as in the Ishikari zone. Each of the three formations noted above shows on the whole coarse-grained facies. The comparatively fine-grained facies is represented by the Saku formation which in general begins with comparatively coarse-grained sediments as exemplified by the Nakakinembetsu sandstone member in the Obirashibe Valley and grades upwards into comparatively fine-grained sediments. The Saku formation also is finer grained in its middle part than in the other ones like the Mikasa formation. The uppermost part with this facies shows an offshore facies in some areas as exemplified by the case of the Obirashibe area where its stratigraphic range is the shortest.

Upper Yezo group

Although this group is made up chiefly of comparatively monotonous fine-grained deposits throughout, the lowest, main and uppermost parts can be discriminated therein.

The lowest part, a local stratigraphic unit developed only in the Ishikari coal-field, shows some resemblance to the Saku formation mentioned above in respect to the predominance of comparatively coarse-grained sediments. But it does not show frequent graded bedding which prevails in the Saku formation.

In the main part, there are to be found some local coarse-grained facies such as the Neourakawan Omagari member (Matsumoto, 1942–43, 1954) in the Abeshinai Valley, the Paleourakawan Tsukimi member on the eastern wing of the Sorachi anticline and the Paleourakawan Kamikinembetsu member in the Obirashibe Valley. They are on the whole ill sorted, and provided with frequent abnormal sedimentary structures and a large amount of muddy conglomerates or pebbly mudstones. In the Tsukimi member, especially in its eastern facies, the sediments are derived mainly from an acid volcanic source, being somewhat different from those of the Omagari member which are derived chiefly from an andesitic source. The main part of the group contains thick tuffaceous rocks at certain horizons within its middle and upper parts: the representatives are the Tsukimi member and the Tomiuchibashi tuff member.

The uppermost part of this group in the northern province consists of the Infrahetonaian comparatively coarse-grained clastics and the succeeding Paleohetonaian fine-grained deposits characterized by the abundant occurrence of *Inoceramus schmidti* MICHAEL. In the southern province, the part under discussion is a just transitional member to the Hakobuchi group noted below and is Infrahetonaian in age. The Chinomigawa formation (Matsumoto, 1942–43, 1954) exposed in the Kamuikotan zone, representing more offshore facies than the contemporaneous part of the Hakobuchi group, is built up essentially of a thick sequence of muddy or silty rocks, although its lowest part is as coarse grained as the Hakobuchi sandstone. Furthermore, green sandstones are intercalated at several horizons in the Upper Yezo group, especially in its lower half of the western part of the Ishikari coal-field.

Hakobuchi group

This group is characterized by the predominance of sandstone but exhibits considerable vertical changes in rock-facies. In the southern province, this group is on the whole coarser grained in the lower part named Tomiuchi formation than in the upper which, in turn, is classified into the Lower sandy siltstone, Fukaushi formation, Upper sandy siltstone and Sanushibe formation in ascending order. In the northern province, the Hakobuchi group of the Kamisarufutsu district, which is also coarser grained in the lower part than in the upper, shows an intermediate facies between the typical of the same group and the Chinomigawa formation mentioned above. The group in this area is developed not only in the Ishikari zone but also in the Kamuikotan zone as is the case in the Chinomigawa formation. It is therefore worthy of mention that the Hakobuchi group shows no remarkable difference in facies between the Ishikari and Kamuikotan zones. In the present group comparatively thick beds of tuff, occasionally flinty in appearance, are intercalated at some horizons.

II. 2 Note on the Time-Stratigraphic Units

Because the biostratigraphic foundations for the definition of stages and substages in the Cretaceous deposits under consideration have been established by Matsumoto (1942–43, 1954, 1959), only a few notes are here given on the stratigraphic occurrence of some important fossils and the sedimentary features concerned.

Stratigraphic occurrence of some important fossils

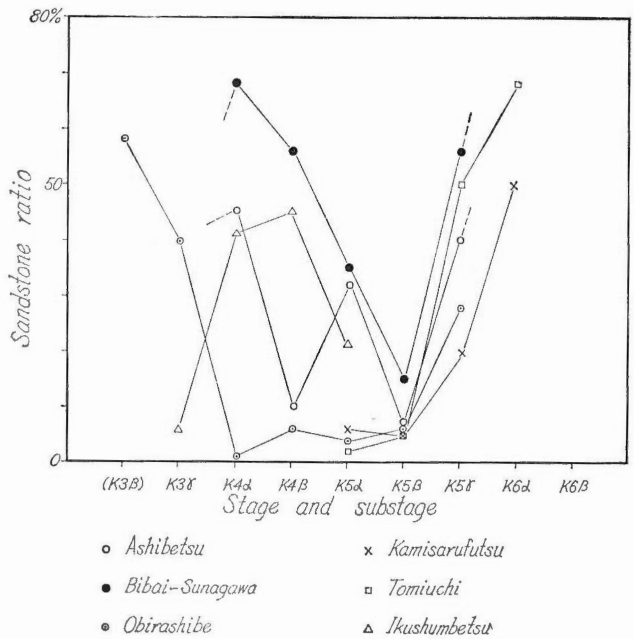
Almost all the species of *Inoceramus* are characteristic respectively to a certain stage and generally occur in great number. The stratigraphic occurrence of several of them is here discussed.

Inoceramus hobetsensis NAGAO and MATSUMOTO occurs abundantly in the middle part of the Upper Gyliakian stage, *I. uwajimensis* YEHARA from that of the Lower Urakawan, and *I. naumanni* YOKOYAMA from the middle and upper parts of the Upper Urakawan. Therefore it is known that these three species occur abundantly in the middle part of their own stratigraphic ranges. *I. japonicus* NAGAO and MATSUMOTO characteristic to the Upper Urakawan stage is of common occurrence in the rather middle part of this stage, it being superjacent to the horizon of dominant occurrence of *I. amakusensis* NAGAO and MATSUMOTO characteristic to the same stage and subjacent to that of *I. orientalis nagaoi* MATSUMOTO and UEDA. The lower half of the Lower Hetonaian stage is marked by the abundant occurrence of *I. schmiti* MICHAEL, and the upper half of the Upper Hetonaian by that of *I.* (?) *awajiensis* MATSUMOTO. Furthermore the common occurrence of *I. shikotanensis* NAGAO and MATSUMOTO is known from the lower half of the Upper Hetonaian stage. Consequently, the horizons of dominant occurrence of certain species mentioned above may give a clue for deciding the stratigraphic position of a given fossiliferous bed.

Sandstone ratio of the stages and substages

The sandstone ratio of a given stratigraphic unit is defined as the ratio of the coarse-grained sediments such as conglomerates and sandstones to the gross sediments concerned. The sediments of a given stratigraphic unit are classified into coarser, intermediate and finer facies on the basis of the value of sandstone ratio. Generally speaking, sediments of coarser facies were formed under near-shore environment, while those of finer facies were formed under offshore environment.

The approximate sandstone ratio of the stages and substages in the surveyed areas is given in Fig. 30. In each stage or substage of the sequence from the upper part of the Upper Miyakoan stage to the Upper Hetonaian stage, the boundaries between the coarser facies, the intermediate facies, and the finer facies are for convenience defined by the sandstone ratios of 50 per cent and 20 per cent respectively. However, there are some exceptions to such a definition. For example, in the Lower Urakawan stage there are no sediments of the coarser facies



K3: Miyakoan series
K4: Gyliakian series
K5: Urakawan series
K6: Hetonaian series
α : Lower stage
β : Upper stage
γ : Uppermost substage
(K3β) is represented by the lower part of the Middle Yezo group. The Ikushumbetsu area is represented by the eastern wing of the Ikushumbetsu anticline.

Fig. 30 Approximate sandstone ratio of the stages and substages in the Cretaceous deposits of the surveyed areas in the meridional zone of Hokkaido

of this definition. Thus, so far as this stage is concerned, the sediments of intermediate facies as defined above are here regarded as a coarser representative. Further, the Upper Urakawan stage is represented exclusively by sediments of finer facies of the above definition. Thus they are discriminated into relatively coarser and finer parts with the boundary at the sandstone ratio of 10 per cent. The sequence of the entire Lower Yezo group ranging from the Lower Miyakoan stage to the lower part of the Upper Miyakoan stage shows the ratio of 30 to 50 per cent.

So far as present knowledge extends, it is noteworthy that a remarkable difference of sandstone ratio exists between the northern and the southern provinces. For example, in the northern province the ratio of the Lower Gyliakian stage is very small, being smaller than that of the superjacent Upper Gyliakian stage and the subjacent Uppermost Miyakoan substage. On the other hand, in the southern province it is, though not always, relatively larger than that of the Upper Gyliakian stage and the Uppermost Miyakoan substage, and very high in some areas, e.g. in the Ishikari coal-field*. The Lower Hetonaian stage possesses a much higher sandstone ratio as compared with the Uppermost Urakawan substage, except in the Urakawa district where it is only slightly higher.

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* In the eastern part of the Ikushumbetsu area the sandstone ratio is somewhat larger in the Upper Gyliakian stage than in the Lower Gyliakian. This fact is, though not exclusively, closely related to the intense upheaval of the Minenobu upwarping belt noted below. But the conditions of the western part are of course in accord with those of the Ashibetsu and Bibai-Sunagawa areas, although they are not shown in Fig. 30.

Table 38 Showing approximate thickness of the stages and substages recognized in the Cretaceous deposits of the surveyed areas in the meridional zone of Hokkaido

Area / Stage or substage	Eastern wing of the Sorachi anticline (m)	Western wing of the Sorachi anticline (m)	Obirashibe (m)	Kamisarufutsu (m)	Tomiuchi (m)	Ikushumbetsu (m)
Upper Hetonaian	160 (+)			400 (+)**	480 (+)*	
Lower Hetonaian	120 (?)	60 (?)		650*	300	
Uppermost Urakawan	40*	50	100*	150*	10	
Upper Urakawan	250**	200	650**	550**	900**	240 (+)**
Lower Urakawan	350	100	450**	450**	250**	130
Upper Gyliakian	400**	110	1,200**			310*
Lower Gyliakian	300*	200	1,000**			200*
Uppermost Miyakoan	250*	230 (?)*	200*			80**
Upper Miyakoan (in part) †		1,100 (+)*	1,100 (?)			970 (+)*

Explanation of Tables 38 and 41

Strata without asterisk are represented by coarser facies.

* Strata represented by intermediate facies

**Strata represented by finer facies

† It is represented by the lower part of the Middle Yezo group.

After all, the sandstone ratio of the stage or substage, generally speaking, decreases upwards from the upper part of the Upper Miyakoan stage to the Lower Gyliakian stage in the northern province, while it increases in the southern. The ratio is higher in the Upper Gyliakian stage than in the Lower Gyliakian in the northern province; on the other hand it is, though not always, lower in the southern. In the two provinces, the ratio of the Upper Urakawan stage is smaller than that of the Uppermost Urakawan substage. Consequently, in both the northern and the southern provinces two conspicuous discontinuities in the vertical change of the sandstone ratio are recognized between the Lower Gyliakian and the Upper Gyliakian stages, and between the Upper Urakawan stage and the Uppermost Urakawan substage.

Thickness of the stages and substages

The approximate thickness of the stages and substages in the surveyed areas is shown in Table 38. So far as present knowledge extends, the upper part of the Upper Miyakoan stage is nearly 1,000 m thick throughout the three facies of the above definition. In every stage or substage above the Upper Miyakoan the finer the facies, the thicker the sediments. Generally speaking, in a given stage the sediments of the coarser and intermediate facies are not more than 400 m thick, while those of the finer facies measure over 400 m thick; those of certain stages, e.g. the two stages of the Gyliakian, are 1,000 m thick or a little more than that in some places. The thickness of the sediments of coarser facies is usually less than 200 m. To the Uppermost Miyakoan substage the general tendency mentioned above may be applicable except in the case of the Ikushumbetsu Valley.

In contradiction to the general tendency, the Upper Gyliakian stage in the Kamisarufutsu area, which is presumably represented by the Hoshin formation, is exceptionally 600 m thick, in spite of its representation by a coarser facies. Such an abnormality is probably due to the difference in the source area. The general tendency noted above is deduced from data on the sediments derived from the presumed western source area, while the sediments of the Hoshin formation were derived chiefly from the presumed eastern source area (Tanaka, 1960b). Another exception is the case of the Lower Urakawan stage on the eastern wing of the Sorachi anticline. There the stage is represented by very thick sediments of a coarser facies, such as the Tsukimi member which possesses abnormal sediments and sedimentary structures (Tanaka, 1959). Furthermore, the sediments of coarser facies of the Lower Hetonaian stage is exceptionally 300 m thick in the Tomiuchi area. This may be partly due to the fact that a single cycle of sedimentation recognized therein comprises exceptionally three minor cycles as shown in Table 40. The Lower Hetonaian stage in the Kamisarufutsu area is considerably thick, although it is represented by the intermediate facies. Such an exception may be, though not exclusively, related to the fact that this area is located in the Kamuikotan zone as well as in the Ishikari zone, the sediments of which offer data on generalization mentioned above. The thickness of the Lower Urakawan stage is ordinarily less than that of the Upper Urakawan stage and two stages of the Gyliakian series in each area. As to the Uppermost Urakawan substage, generally speaking, the thickness of the sediments of coarser facies is less than 50 m, and on the other hand that of the sediments of intermediate and finer facies does not measure up to 200 m. Moreover the Upper Gyliakian stage is less than 600 m thick in the southern province, while it is nearly 600 m or more in the northern province.

In a word, it is concluded that each of the stages from the upper part of the Upper Miyakoan to the Upper Hetonaian attains 1,000 m or so in maximum thickness. Furthermore, the thickness of the sequence from the Lower Miyakoan to the lower part of the Upper Miyakoan stage ranges from 1,000 to 1,500 m or so throughout the three facies noted above. Similarly the upper part of the Upper Miyakoan stage shows little difference in thickness between the sediments of the three facies.

II. 3 Stratigraphic Classification based on Cyclic Sedimentation

It has already been pointed out that the Hakobuchi group shows four cycles of sedimentation (Matsumoto, 1954). Inconsistency between the rock-stratigraphic classification and the time-stratigraphic classification has been recognized throughout the Cretaceous deposits in the meridional zone of Hokkaido (Fig. 29) (see also Matsumoto, 1943; 1954). To know a general regularity in the sedimentary history the present writer attempted to pay special attention to the cycles of sedimentation not only in the Hakobuchi group but also in the Cretaceous sequences lower than that. Thus, a scheme of classification from the standpoint of

Table 39 Chronologic position of the cyclic sequences in the Cretaceous deposits of the standard areas in the meridional zone of Hokkaido

Stages or substages	Northern province	Southern province	Formations
K6β	XII, XI	XII, XI, X	Middle Yezo group – Hakobuchi group
K6α	X, IX	IX	
K5γ	IX	VIII	
K5β	VIII	VIII, VII	
K5α	VII, VI	VII, VI	
K4β	V	V	
K4α	IV, III	IV	
K3γ	III	III	
K3β	II, I, II′	II, I, II′	Lower Yezo group (II′, I′)
K3α	I′	I′	

cyclic sedimentation has been established for the Cretaceous formations in the meridional zone of Hokkaido. The scheme is here summarized in Table 39. Notes are further extended onto cycles of sedimentation recognized in some other Cretaceous deposits of Japan.

Cyclic sedimentation and cyclic sequence

For recognition of the cyclic sedimentation showing change from shallower to deeper sedimentary environments through the Cretaceous sequence in the meridional zone of Hokkaido, one should consider both lithofacies and biofacies. Important elements of the lithofacies are the grade of coarseness, the sedimentary structure such as lamination, bedding, surface markings on the bedding plane and intraformational deformation, and the occurrence of greensands, tuffaceous rocks, calcareous concretions, marine fossils, drifted plant remains or carbonaceous flakes and so forth. Those of the biofacies are the quantity of the enclosed marine fossils, the composition of the gross fossil assemblages, especially the dominance ratio of ammonites to inocerami, composition of ammonite assemblages, and so forth. In case of insufficiency of the data on both lithofacies and biofacies, the beginning of a cyclic sequence can however for convenience be accepted as the base of a rather thick comparatively coarse-grained sediments. Although cyclic sequences in the Cretaceous deposits under discussion are on various scale, they should be in this case recognized, taking into consideration their site of deposition within the sedimentary basin, that is, the Yezo geosyncline, and time-space magnitude.

The cyclic sequences of a given scale universally recognized from this point of view are two in the Lower Yezo group and twelve in the sequence from the Middle Yezo group to the Hakobuchi group. Also, cyclic sequences of minor scale, two or three of which constitute one cyclic sequence, are of course locally found (Table 40). In addition, cyclic sedimentation on major scale can be recognized. The individual cyclic sequences of the second order, that is, of the standard scale discussed here, are to be referred to one formation, a unit of rock-stratigraphic classification, being generally composed of several members. The stratigraphic range of the individual cyclic sequences under discussion is as a rule not more than that of one stage concerned, and moreover not less than half that of one stage concerned (Table 39).

Vertical change of lithofacies and biofacies in the cyclic sequence

The vertical changes of lithofacies may be generalized as follows. First of all, the sediments grade upwards into comparatively fine-grained ones. In the ideal case a cyclic sequence begins with arenaceous rocks which, in turn, are followed by argillaceous ones and end with arenaceous ones. In a cyclic sequence composed of fine-grained deposits the intercalation of sandstone becomes less frequent upwards. Lamination and bedding well prevailing in the lower part of a cyclic sequence decline gradually upwards. In a cyclic sequence consisting of coarse-grained sediments, the rocks in the lower part are frequently massive and cross-laminated or ripple-marked. The abundant occurrence of calcareous concretions, marine megafossils and tuffaceous rocks is characteristic to the lower part. Green sandstones, thought not always glauconitic, are commonly contained in that part. Furthermore, the quantity of drifted plant remains or carbonaceous flakes diminishes upwards.

The following vertical changes of biofacies tend to be exhibited in an ideal cyclic sequence. The megafossils, the main constituents of which are ammonites and inocerami, are abundant in the lower half. As exemplified by the case of the Obirashibe Valley, in such fossiliferous part, there are as a general tendency discriminated in ascending order three facies: ammonite facies in which ammonites are more numerous than inocerami, mixed facies in which inocerami are as abundant as ammonites, and inocerami facies in which inocerami dominate over ammonites. Thus, it is seen that the dominant occurrence of ammonites becomes replaced upwards by that of inocerami. In other words, inocerami become more numerous upwards. This general tendency is recognizable also in other areas covered by the writer's survey (Tables 33–37, 40). However, the lowest or lower part of a given cyclic sequence, where it is occupied by comparatively thick, fossiliferous, arenaceous sediments, contains abundant shells of littoral or shallow sea origin such as oysters, glycimerids, trigonians and other bivalves. Such a part is to be called "shell facies." This is best displayed in some cyclic sequences within the Mikasa formation and Hakobuchi group. Accordingly, in an ideal cyclic sequence four facies, viz., shell facies, ammonite facies, mixed facies and inocerami facies, can be discriminated in ascending order. Regarding ammonites, aberrant forms occur abundantly in the lower part of an ideal sequence, while coiled forms become predominant over aberrant forms upwards. Changing the expression, aberrant ammonites decrease upwards in number. This generalization can be derived not only from the conditions of the Obirashibe area but also from those of the other surveyed areas (Tables 33–37, 40). As regards the coiled ammonites, the following tendency is recognized in the Obirashibe area. Here, the predominant forms in the lower part of the cyclic sequence are thin-shelled, compressed and moderately ornamented, with elliptical whorl section, while those in the upper part are thin-shelled and smooth or weakly ornamented, with inflated whorl of nearly circular section. From the conditions in the Obirashibe Valley, it is further known that strongly ornate forms are more common in the lower part than in the succeeding parts. This is best expressed by the following examples. Acanthoceratids occur in a large number in the lower part of sequence IV in the Ikushumbetsu Valley (Fukada and others, 1953; Matsumoto, 1959; Tables 37, 40), and *Reesidites minimus* is abundant in the lower part of sequence VI in both the Bibai-Sunagawa area (Tables 34, 40) and Ikushumbetsu area (Fukada and others, 1953; Matsumoto, 1959; Table 40). Such a tendency is shown also in the sequence VIII of the Kamisarufutsu (Tables 35, 40) and Tomiuchi areas (Tables 36, 40) as can be seen from the occurrence of pachydiscids. Therefore, it is generalized that thick-shelled, highly ornamented coiled forms with nearly quadrate or compressed whorl section predominate in the lower part of an ideal sequence. Changing the expression, such forms decrease upwards in number.

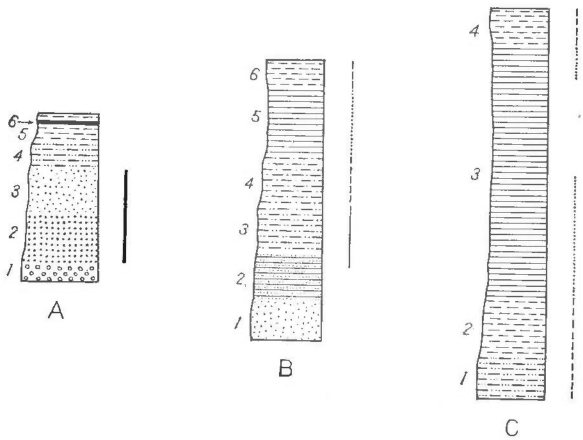
The above-noted typical vertical changes of lithofacies and biofacies are, in practice, not often recognized as they are described, but rather commonly modified depending upon the condition of sedimentation. For example, in certain cyclic sequences which are occupied by a kind of coarse-grained sediments at their lower or lowest part, calcareous concretions and fossils are sporadic and tuffaceous rocks are comparatively less frequent. Sequence VII shows essentially the typical tendency of the vertical changes in the biofacies; nevertheless fossils of inocerami especially *Inoceramus uwajimensis* YEHARA are dominant throughout.

The general tendency of vertical changes recognized in the lithofacies and biofacies of the lower half of the ideal cyclic sequence is of course presented in reverse order in the upper half. But the conditions shown therein are not so conspicuous as those in the lower half, for example, the inclusion of calcareous concretions, tuffaceous rocks, megafossils, and moreover green sandstones are less abundant than in the lower half. Furthermore coaly seams are occasionally intercalated near the top of cyclic sequences showing near-shore facies. Judging from the vertical changes of the lithofacies and biofacies actually observed in the cyclic sequence, it is known that almost all of the cyclic sequences are rather incomplete or some of them are even hemi-cyclic. In the strata lower than the Hakobuchi group, only sequence VIII is exceptionally complete. Some cyclic sequences within the Hakobuchi group also are complete. In a word, such vertical changes of both the lithofacies and the biofacies reflect essentially the changes from shallower to deeper environments. The vertical changes mentioned above are well exhibited from sequence IV to XII, but are not from I to III and in the two cyclic sequences (I' and II') constructing the Lower Yezo group, which are scanty of concretions and fossils because of Flysch-type sediments. Furthermore, a similar change of lithofacies and biofacies would be laterally applicable to the case of lateral variation of the sedimentary facies within a given unit. Hence, it may give a clue to an understanding of lateral changes in sedimentary environments as exemplified by the case of the Obirashibe area described in Part I and the Sorachi anticlinal area (Tanaka, 1959).

Lateral variation of lithofacies and biofacies in the cyclic sequence

The ideal cyclic sequence is modified by greater or minor variation, depending on the conditions in the source areas as well as in the depositional areas. The effects are shown not only in the lateral variation of gross aspect of lithofacies and biofacies but also in that of detailed lithologic and faunal composition. Thus, a cyclic sequence occurs in three types, viz., in the sediments of coarser, intermediate, and finer facies, of which the first type ordinarily corresponding to near-shore or shallower facies, while the third to offshore or deeper facies (Fig. 31).

It is needless to say that the thickness of a given cyclic sequence ordinarily increases from the sediments of coarser facies to those of finer one. In the typical case a coal or plant bed is intercalated near the top of the cyclic sequence of the coarser facies, where tuff is ordinarily met with. The best example of this case is the lower part of the typical Hakobuchi group, i.e. the sequence IX and minor sequences within that in the southern province. In the Tomiuchi area, the second minor cyclic sequence within the sequence IX shows a minor erosion surface at its base (Tanaka, 1960a). The sequence IV within the Mikasa formation of the Bibai-Sunagawa area is another example of the cyclic sequence in coarser facies (Tables 34, 40). The sequences IV and V within the Mikasa formation to the lowest part of the Upper Yezo group in the Ikushumbetsu area are rather intermediate type between the sediments of coarser facies and those of intermediate facies (Tables 37, 40). In the sediments of intermediate facies sandstones are frequently interbedded and interlaminated, thus graded bedding is well developed. This facies is represented by the sediments of the cyclic sequence within the Saku formation, and by those of the sequence V, ranging from the upper part of the Mikasa formation to the lower part of the Upper Yezo group, on the eastern wing of the Sorachi anticlinal area (Tables 33, 40). The sequence VI in the Obirashibe area, which is nearly equivalent to the Saku formation, shows a rather intermediate facies (Fig. 4; Table 40). A finer facies is best displayed in the muddy facies of the Middle Yezo group and the considerably fine-grained facies of the Upper Yezo group.



A Coarse-grained or shallower (near-shore) facies
1: conglomerate 2: coarse- to medium-grained sandstone, partly stratified and cross-laminated 3: medium- to fine-grained sandstone, partly stratified 4: silty fine-grained sandstone to fine sandy siltstone 5: siltstone or sandy mudstone 6: coal or coaly shale

B Intermediate facies
1: medium- to fine-grained sandstone, stratified 2: sandstone and mudstone (or siltstone) in thin-bedded alternation 3: siltstone or mudstone, laminated, with frequently interbedded sandstones 4: siltstone or sandy mudstone, laminated 5: mudstone 6: siltstone or sandy mudstone

C Fine-grained or deeper (offshore) facies
1: silty fine-grained sandstone to fine sandy siltstone, partly laminated 2: siltstone or sandy mudstone, partly laminated 3: mudstone 4: siltstone or sandy mudstone

Thick line: shell facies thin line: ammonite facies broken line: mixed facies dotted line: inocerami facies

Fig. 31 Three types of cyclic sequences recognized in the Cretaceous deposits of the meridional zone of Hokkaido

In addition to lithologic and faunal aspects shown in Fig. 31, the following features of sediments are noted in the three types of cyclic sequences. Tuff is, if any, very sporadic, but is occasionally thick, hard, and compact, presenting flinty appearance in the sandy part of the coarser facies. The sediments of coarser facies are in some cases fairly fossiliferous, containing numerous fossils in a particular part. Huge calcareous concretions are, though not always abundantly, contained especially in such sediments as is often the case with the comparatively coarse-grained part within the sediments of the other two types. In the sediments of finer facies the upper part is commonly nearly unfossiliferous. Carbonaceous matters or drifted plant remains are contained abundantly in the coarser facies and occasionally in the lowest part of the intermediate or finer facies.

Chronologic position of the cyclic sequences

The individual cyclic sequences on the standard scale under discussion are recognized in the same number in both the northern and the southern provinces.

They occupy in many cases nearly the same chronologic position all over the areas under consideration (Table 39). Even if there is such a contemporaneity of chronologic position, the duration of tectonic movement which caused a given cycle seems reasonably different to some extent among different areas. On the other hand, the chronologic positions of certain cyclic sequences such as IV, V, IX, X and XI considerably differ from each other between the northern and southern provinces, and moreover at different places within the same province. In the Gyliakian and Hetonaian epochs during which the chronologic positions of cyclic sequences are different as mentioned above, local epicycles appear in some places (Table 40). One epicyclic sequence within a sequence in a given area sometimes occupies nearly the same chronologic position as the corresponding sequence in another area within the same province. For example, the upper epicyclic sequence of the sequence V in the Obirashibe Valley and on the eastern wing of the Sorachi anticline is respectively almost equivalent to the sequence V in the Abeshinai Valley and the Ikushumbetsu Valley. Furthermore, the Hetonaian series of the Urakawa district in the southern province consists of four cyclic sequences, at least lower two of which are correlated to the Lower Hetonaian stage. This exception depends upon the fact that, although this area is included in the southern province, it is situated at nearly the same position within the basin and also in the same tectonic zone, i.e. the Kamuikotan zone, as in the case of the Kamisarufutsu district.

In short, the above-mentioned consistency or inconsistency in the chronologic position of cyclic sequences and the local occurrence of epicyclic sequences in some restricted ages noted above are regarded as being closely related with the history of sedimentation in the Cretaceous deposits under consideration; the geological meaning will be discussed below.

Mention, furthermore, is made of the fossils significant to the determination of the stratigraphic position of the cyclic sequences recognized from the Middle Yezo to the Hakobuchi group. For this purpose, one must take into consideration the dominant occurrence of certain fossils characteristic to one stage or substage and occurring abundantly all over the area, and moreover the frequent occurrence of some fossils characteristic to one subzone and supplementary zonules (Matsumoto, 1954, 1959).

Mortoniceras imaii (YABE and SHIMIZU) is characteristic to sequence II. *Desmoceras (Pseudouhligella) japonicum* YABE, *Calycoceras orientale* MATSUMOTO, SAITO, and FUKADA, and *C. asiaticum* (JIMBO) are dominant in sequence IV. In sequence VI *Reesidites minimus* (HAYASAKA and FUKADA) is characteristic to the lower part, and *Inoceramus hobetsensis* NAGAO and MATSUMOTO dominates in the lower and middle parts. *Inoceramus uwajimensis* YEHARA is predominant in the lower half of sequence VII, *I. amakusensis* NAGAO and MATSUMOTO in the lower part of sequence VIII, *I. japonicus* NAGAO and MATSUMOTO in the rather middle part of sequence VIII, and *I. naumanni* YOKOYAMA in the rather middle and upper parts of the same sequence. *Gaudryceras tenuiliratum* YABE and *Eupachydiscus haradai* (JIMBO) show dominant occurrence throughout sequence VIII. Furthermore *I. orientalis* SOKOLOW dominates at the uppermost part of sequence VIII in the southern province. The lower part of sequence IX is marked by the dominant occurrence of *I. orientalis*, while the middle part by that of *I. schmidti* MICHAEL. *I. shikotanensis* NAGAO and MATSUMOTO is characteristic to sequence X of the southern province, and to sequence XI of the northern province. The characteristic species of sequence XII is *I.* (?) *awajiensis* MATSUMOTO.

Sandstone ratio of the cyclic sequences

The approximate sandstone ratio of the cyclic sequences in the surveyed

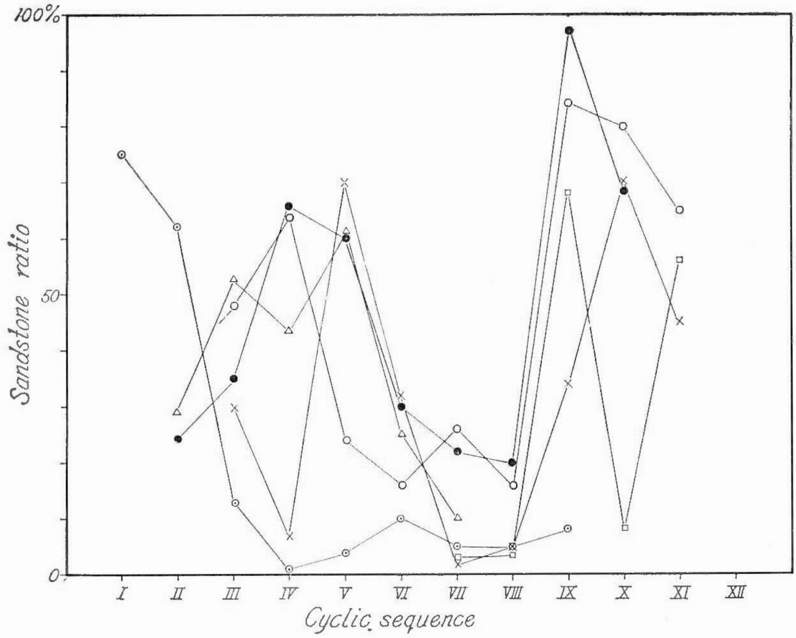


Fig. 32 Approximate sandstone ratio of the cyclic sequences in the Cretaceous deposits of the surveyed areas in the meridional zone of Hokkaido
For the legends see Fig. 30.

areas is given in Fig. 32. It is needless to say that the sediments of a given cyclic sequence within the Middle Yezo to the Hakobuchi group (sequences I–XII) are discriminated into coarser facies, intermediate facies and finer facies on the basis of the same values of sandstone ratio as in the stages and substages previously discussed. However, some exceptions to such a definition are found in sequences VI to VIII. Specifically, sequences VI and VII do not show coarser facies. In such strata, the intermediate facies itself is for convenience regarded as representing the coarser part. In the VIII sequence the sediments are exclusively of finer facies of the above definition. They are, however, for convenience divided into the relatively coarser and finer parts, with the boundary at the sandstone ratio of 10 per cent.

So far as present knowledge extends, between the northern and southern provinces a noticeable difference of sandstone ratio exists. For example, in the northern province the ratio of sequence IV is very small, being smaller than that of sequences III and V. On the other hand in the southern province sequence IV, though not always, possesses a relatively higher ratio than the underlying or overlying sequence, and a very high one in some areas, e.g. in the Ishikari coal-field*.

* In the eastern part of the Ikushumbetsu area the sandstone ratio is considerably higher in the sequence V than in the sequence IV against the case of the western part, which is not illustrated in Fig. 32. This is naturally explained by the same reason as discussed on the sandstone ratio of the two stages of the Gyliakian series in the present area (see p. 78 of this paper).

Table 41 Showing approximate thickness of the cyclic sequences recognized in the Cretaceous deposits of the surveyed areas in the meridional zone of Hokkaido

Area / Cyclic sequence	Eastern wing of the Sorachi anticline (m)	Western wing of the Sorachi anticline (m)	Obirashibe (m)	Kamisarufutsu (m)	Tomiuch (m)	Ikushumbetsu (m)
XII				200(+)**		
XI	110			200*	180(+)	
X	25	20		250	300**	
IX	120	60	350**	550*	300	
VIII	200	170	450**	400**	650**	160(+)
VII	300	130	550**	400**	400**	150
VI	300**	90	700**	350		120
V	400*	120	550**	450		130
IV	150	160	600**	450**		330*
III	250*	230*	650**	530*		150
II	300(+)*	420*	470			420*
I		650(+)*	650(?)			480(+)*

For the asterisk see Table 38.

In the northern province a very high sandstone ratio is exhibited at sequence X. On the other hand, in the southern province the ratio of sequence IX is very large, being larger than that of sequences VIII and X except in the Urakawa area where it is small and only slightly larger. In the Lower Yezo group the lower sequence (I′) shows the ratio of 40 to 60 per cent and the upper sequence (II′) that of nearly 20 per cent.

After all, as a general tendency the sandstone ratio of the cyclic sequence decreases upwards from sequence I to sequence IV in the northern province; on the other hand it increases in the southern. The ratio is larger in sequence V than in sequence IV in the northern province, while it is, though not always, smaller in the southern. In the two provinces, the ratio of sequence VIII is lower than that of sequence IX. Accordingly, in both the northern and the southern provinces the vertical change of the sandstone ratio shows two conspicuous discontinuities between sequences IV and V, and between sequences VIII and IX.

Thickness of the cyclic sequences

The approximate thickness of the cyclic sequences in the surveyed areas is shown in Table 41. So far as present knowledge extends, the thickness of each of sequences I and II ranges from 400 to 700 m regardless of the difference in the three facies at most places*. Similarly each of the two sequences (I′ and II′) in the Lower Yezo group exceeds 400 m in thickness and attains in many places 1,000 m or so regardless of the facies difference. In almost all of the succeeding sequences, III to XII, the thickness of sediments, generally speaking, increases in the order of coarser, intermediate and finer facies. As a general tendency, the sediments of the coarser and intermediate facies are not more than 400 m thick except in certain sequences in the Kamisarufutsu area; while those of the finer facies is more than 400 m thick and less than 700 m. Moreover, the sediments of the coarser facies are usually not more than 200 m thick.

There are, however, some exceptions for such a generalization. First of all, it attracts one's attention that sequences V and VI in the Kamisarufutsu district are exceptionally thick, although they are represented by the coarser facies. This fact is closely similar to the case of the Upper Gyliakian stage which was mentioned in my another paper (Tanaka, 1960b). The reason is the same as discussed on that occassion (see also p. 80 of this paper). It is a matter of course that sequence VII including the Tsukimi member on the eastern wing of the Sorachi anticlinal area is exceptionally thick as also in the case of the Lower Urakawan stage of this area. Moreover, in the Tomiuchi district the sequence IX is exceptionally thick in spite of its representation by a coarser facies. This may be naturally explained by the same reason as in the Lower Hetonaian stage of the area. The abnormally greater thickness of the sequence IX, which shows the intermediate facies, in the Kamisarufutsu area is of course related to that of the Lower Hetonaian stage in the area.

After all, it is known that the thickness of each cyclic sequence, recognized throughout from the Middle Yezo to the Hakobuchi group, is not more than 700 m. The thickness of a cyclic sequence is bounded at nearly 400 m between the finer facies and the intermediate one and usually not more than 200 m in the coarser facies. This is similar to the case of the thickness of the stages and substages

* In the southernmost part of the Ikushumbetsu anticline the sequence II shows coarser facies and is less than 400 m thick.

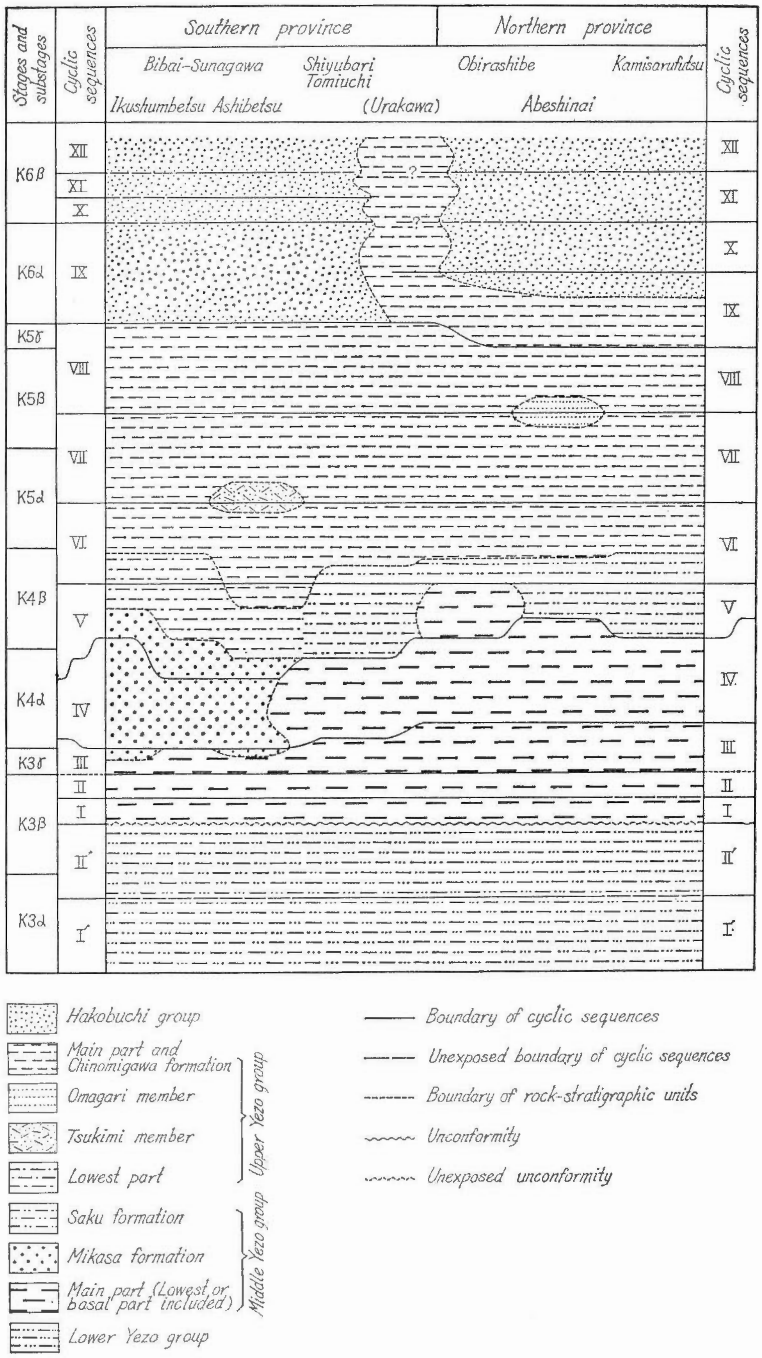


Fig. 33 Schematic illustration of the relation between the rock-stratigraphic units and cyclic sequences in the Cretaceous deposits of the standard areas in the meridional zone of Hokkaido

described in page 80. Furthermore, the average thickness of cyclic sequence decreases in approximate order of I′–II, III–VIII and IX–XII.

Stratigraphic classification based on cyclic sedimentation

The stratigraphic classification based on cyclic sedimentation as previously described may be summarized as follows. The cyclic sequence on the standard scale under discussion is minor stratigraphic unit recognized throughout the Cretaceous rocks of the meridional zone of Hokkaido. As has already been mentioned, the Lower Yezo group is divided into two cyclic sequences, and the whole sequence from the Middle Yezo to the Hakobuchi group is divided into twelve. All of these cyclic sequences exclusive of those of the Lower Yezo group can ordinarily be subdivided into two or three members and in some cases into four or five as rock-stratigraphic units. The relationship between the stratigraphic classification from the standpoint of cyclic sedimentation and that from the standpoint of facies-development is shown in Fig. 33.

The cyclic sequences now under discussion may be grouped into three sequences of larger scale which, in turn, can be divided into several parts respectively on the basis of sedimentary facies on major and minor scales. This stratigraphic classification founded on sedimentary cycles of a major scale is concluded after all to be nearly coincident with the existing major rock-stratigraphic classification. The Lower Yezo group which consists of Flysch-type sediments is divided into two parts, viz., the lower and upper parts represented by sequences I′ and II′ respectively. The deposits nearly equivalent to the Middle Yezo group are classified into three parts, the lower (I–II), middle (III) and upper parts (IV–V). The former two are sometimes rather Flysch-type sediments or an intermediate facies between the Lower Yezo group and the succeeding strata. Especially the lower part is essentially similar to the Lower Yezo group in sedimentary facies. The sediments nearly equivalent to the sequence from the Upper Yezo to the Hakobuchi group can be discriminated into the lower (VI), middle (VII–VIII), and upper parts (IX–XII), the last of which corresponds to the Hakobuchi group. It is noteworthy that the third sequence mentioned above is represented by conglomerates with a great number of contemporaneous pebbles at or near the base as exemplified by conglomerates in the Saku formation and its equivalent of several places.

Application of the stratigraphic classification based on cyclic sedimentation to the stratigraphy of the Cretaceous deposits in the Yezo geosyncline and its allied areas

The stratigraphic classification based on cyclic sedimentation is useful in the correlation of some formations which contain no fossils available for age determination. For example, the stratigraphy of the Cretaceous deposits in certain areas are here discussed.

In the Kamisarufutsu district (Table 35), any fossils available for correlation have been found nowhere from the Middle Yezo group, except *Anagaudryceras* cf. *sacya* (FORBES) from the upper part of member M_1. The cyclic sedimentation of the Cretaceous deposits of the present area is in harmony with that of the other areas within the northern province. Therefore member M_1 is suggested to belong to the sequence II, which is referred to the upper part of the Upper Miyakoan stage (Tables 39, 40). This inference seems to be plausible judging from the sandstone ratio and thickness of the cyclic sequences recognized and those of the stages and substages supposed in the Middle Yezo group and moreover from the dominant intercalation of tuffaceous rocks in some horizons of the group (Tanaka, 1960b).

In the Sorachi anticlinal area (Tables 33, 34), the main part of the Middle Yezo group is lower than the sequence IV and divided into three cyclic sequences. From the thickness and sandstone ratio these three sequences are suggested to belong to the sequences I, II and III. Therefore the age of the main part of the Middle Yezo group may range down to the Neomiyakoan age (Tables 39, 40).

In the Naibuchi Valley, southern Saghalien, the Cretaceous strata are northern extensions of those in the meridional zone of Hokkaido, and composed of the "presumably equivalent of the Lower Yezo group," the Kawakita subgroup, and the Miho and Ryugase groups (Matsumoto, 1942–43, 1954) in ascending order. Through these strata, at least twelve cyclic sequences are recognized (Table 40). The discrimination of the sequences IV to VIII in the lithologically monotonous Miho group can be carried out by means of the biofacies. The Kawakita subgroup itself represents the sequences II, III, and lower part of IV. Accordingly, it is suggested that the sequence I, i.e. the lowest part of the Middle Yezo group or the rather middle part of the Upper Miyakoan stage, is contained in the "presumably equivalent of the Lower Yezo group." Furthermore, the chronologic positions of some cyclic sequences in southern Saghalien may differ a little from those of the corresponding ones in the northern province of the meridional zone of Hokkaido. Namely the boundary between the sequences III and IV corresponds to that between the Uppermost Miyakoan substage and the Lower Gyliakian stage. The base of the sequence IX is situated near the top of the Uppermost Urakawan substage. These points are greatly similar to the case of the southern province of Hokkaido. However, each of the two stages in the Hetonaian series is composed of two cyclic sequences as in the northern province.

Notes on deposition of the cyclic sequences

Cyclic sedimentation of various natures has been recognized in a number of strata of various ages throughout the world (Lombard, 1956)*. A famous example is presented in "cyclothems" which prevail in the Pennsylvanian coal measures. Also in Japan cyclic successions approximately conforming to cyclothems are recognized in some coal-bearing formations: (1) the Upper Trias Mine group in Southwest Japan, sediments of Molasse type (Tokuyama, 1958), (2) the Paleogene Ishikari group in Hokkaido which is said to be geosynclinal sediments (Tashiro, 1952; Teshima, 1954), and (3) the Tertiary in the Joban coal-field, sediments on a comparatively stable shelf (Eguchi and Shoji, 1953; Shoji, 1960). Cyclic arrangement is displayed also in the sediments of the Upper Cretaceous Izumi group in Southwest Japan as has already been and will be again pointed out by myself together with

* Lombard uses the term of rhythmic sedimentation (or sequence) for the sedimentation showing such a serial change of various characters and on various scales as recognized in a cyclothem, other allied cases, an alternation of coarse and fine sediments, or a varve. The term of cyclic sedimentation here used is of broader sense, implying the sedimentation of various successions which range from a complete cycle to a quite incomplete hemi-cycle. However, the sedimentation of a very small or microscopic order as shown in an alternation of coarse and fine sediments or a varve is here to be excluded from the cyclic sedimentation, but the term rhythmic sedimentation may be appropriate for it. In addition to the numerous examples given in Lombard's work, a serial succession of clay–sand–limestone is known also in the Jurassic of England (Arkell, 1933).

other authors (Matsumoto [Editor], 1954, p. 136). Furthermore, it is known that the Miocence Kawabata formation or Kotambetsu formation in Hokkaido, represented by the deposits of "Nagelfluh" type, shows a serial succession of conglomerate–sandstone–mudstone (Tsushima and others, 1958).

A number of hypotheses have been proposed to account for cyclic sedimentation of various natures (Lombard, 1956). For example, as to the cyclothem within the Pennsylvanian coal measures, the deposition has been ascribed to diastrophic control (Weller, 1930, 1956) or glacially controlled eustatic changes in sea level (Wanless and Shepard, 1936; Wheller and Murray, 1957). Further, cyclic calcareous sedimentation of the Cretaceous in the Helvetic zone is thought to owe its origin to climatic changes (Brückner, 1951, 1953) or oscillation of the sea-bottom (Carrozi, 1951). At any rate, it appears an overwhelming opinion that no few of cyclic sedimentation of various natures are, though not exclusively, attributed to tectonic movements. Such an opinion may be also reasonable. Thus, cyclic sedimentation is considered as ordinarily taking place in comparatively mobile or unstable areas. Also, the cause of the cyclothemic sedimentation observed in the Japanese coal-bearing strata, all of which have no limestones, has been discussed by some authors (Tashiro, 1952; Eguchi and Shoji, 1953; Teshima, 1954; Shoji, 1960). Above all, it is worthy of mention that Shoji (1960) attaches great importance to volcanic action for the cyclic sedimentation in some coal-bearing formation of Japan.

However, the stratigraphic division based on cyclic sedimentation may have been little attempted for marine sediments deposited within a geosyncline. Under the circumstances, it attracts one's attention that the Cretaceous sequences in the meridional zone of Hokkaido show in themselves several cyclic successions. Further, it is noteworthy that in the Upper Cretaceous geosynclinal sediments of North Spain, which are very thick, i.e. 5,000 m in maximum thickness and rich in calcareous rocks, are recognized fifteen cycles (Lotze, 1960). The cyclic sedimentation of this Cretaceous may have been not only due to tectonic movements causing change in depth of the basin but also to climatic change causing change in temperature of surface water of the oceanic sea.

On the other hand, "cycles of sedimentation," which is a concept proposed for the deposition of the Eocene of the Anglo-Franco-Belgian basin (Stamp, 1921), are similar to the cyclic sedimentation noted above in sedimentation of cyclic fashion, but are not necessarily attributed to the same origin as in the latter. They are said to be best and typically displayed in sediments on stable shelves. The concept of cycles of sedimentation has been applied in a number of stratigraphical studies in Japan as well as in foreign countries. Yabe's pioneer synthesis of the Japanese Cretaceous stratigraphy (1927) is of course based on this concept. After all, it has been a prevailing opinion that cycles of sedimentation recognized by many authors extending Stamp's idea are attributed to repeated rise and fall of the sea level or transgression and regression caused by epeirogenic movements. Yabe's major stratigraphic division of the Cretaceous in Hokkaido were, of course, made in accord with such a view.

Now, the cause of the cyclic succession in the Cretaceous deposits in the meridional zone of Hokkaido is briefly discussed. It goes without saying that the vertical changes of lithologic and faunal aspect observed in each of the cyclic sequences show change from shallower environments to deeper ones as noted above. Such change itself, of course, results from change in the position of the sea level relative to the depositional area. The relative changes in sea level may be attributed to: (1) repeated uplift and subsidence of the depositional area, with subsidence greater than uplift, when sea level is constant, (2) repeated subsidence of the depositional area without uplift, when sea level is constant, thereby shallowing of the depositional area being due to saturation of sediments in the area, and to (3) repeated rise and fall of sea level when depositional area is stable. Furthermore, cyclic deposition may be ascribed to (1) such tectonism as mentioned above, (2) periodic volcanism and to (3) cyclic climatic change.

As to the cyclic sequences recognized in the Cretaceous deposits in the meridional zone of Hokkaido, judging from the stratigraphic range, extension, thickness, and features of sediments of individual cyclic sequences, it seems that repeated uplift and subsidence of the depositional area, with subsidence greater than uplift was fundamentally responsible for the deposition of the cyclic sequences. After all, repeated movements of the depositional area in such fashion is closely related to periodicity of the tectonism taking place in the source area where volcanism accompanied tectonism. However, relative duration and intensity of such tectonism are not always the same in different areas and in different ages. Thus the stratigraphic range, extension, thickness, and features of sediments of the cyclic sequence show sometimes great similarity, sometimes much difference. It is a matter of course that the deposition of the cyclic sequences under consideration may be fundamentally controlled by both the geosynclinal sinking particular to this region and epeirogenic movements of much wider extent, although the deposition results from such tectonism as discussed above. Accordingly, from the standpoint of the development of the Yezo geosyncline, the deposition of each of the cyclic sequences is known to be not always attributable to the same cause. For example, the deposition of the cyclic sequences in the Gyliakian and Hetonaian series may have been controlled largely by tectonism in the depositional areas as well as in the source areas, the duration and intensity of which show considerable difference from part to part of the basin. It is noteworthy that cyclic sequences in the Lower Hetonaian stage, especially in the lower part of the typical Hakobuchi group present much similarity to the cyclothem under the original definition although they have no limestones. On the other hand the deposition of the cyclic sequences in the Urakawan series may have been controlled by the so-called Urakawan transgression accompanied with mild tectonism. Furthermore, the deposition of the cyclic sequences in the Lower Yezo group is supposed to have been much subjected to intermittent change of tectonism of minor scale accompanied with turbidity current in the depositional areas.

After all, the cyclic sedimentation or the deposition of the cyclic sequences observed in the Cretaceous strata in the meridional zone of Hokkaido can essentially be attributed to a cause rather similar to the case of the Pennsylvanian cyclothems in that in both cases tectonic control in a broad sense may be responsible for the deposition. The tectonic environments are however considerably different between the two cases. That is, the Cretaceous cyclic sequences in Hokkaido are geosynclinal sediments, while the cyclothems sediments on unstable shelf. In this connection, it is worthy of mention that the Cretaceous cyclic sequences are generally incomplete, and that volcanism took part in their origin. The cyclic sequences under discussion are of considerably longer stratigraphic range or larger formational order than the case of the Cretaceous in North Spain and the Pennsylvanian cyclothems or the so-called cyclothems in the Japanese coal-bearing formations. Furthermore, it may be suggested that the one major cycle shown by the Lower Yezo group and the two major ones from the Middle Yezo group to the Hakobuchi group as described in the preceding pages can be ascribed to epeirogenic movements of much wider extent.

Notes on cycles of sedimentation in other Cretaceous deposits of Japan

In the Cretaceous sequences of the areas other than Hokkaido, unconformity occurs at various horizons. Thus, any formation or group bounded by unconformity itself shows a single cycle of sedimentation. Then, in some of such formations are recognized sedimentary cycles of ordinary or broader sense (Matsumoto, 1954). Under the circumstances, some brief discussion is here offered on the cycles of sedimentation in some Cretaceous deposits of the areas other than Hokkaido*.

The Cretaceous formations of the Yuasa district in the western part of the Kii Peninsula, Outer Zone of Southwest Japan (Matsumoto, 1947, 1954; Hirayama and Tanaka, 1956a, b) are sediments on an unstable or mobile area. They show in themselves six major cycles (or often better to say hemi-cycles), three in the Lower Cretaceous and three in the Upper Cretaceous (Table 42)**. Each of these major cycles, which corresponds to one series in stratigraphic range is, in turn, generally composed of two or three minor cycles (or often better to say hemi-cycles). The stratigraphic range of a minor cycle is in a general way from one stage to about half. The thickness of each minor cycles within the sequences lower than the Urakawan series is, generally speaking, from 150 to 250 m, and that in the Urakawan and Hetonaian series exceeds 300 m and is less than 700 m. In the Cretaceous deposits in the Yatsushiro area, Middle Kyushu (Matsumoto and Kanmera, 1952; Matsumoto, 1954), major and minor cycles as noted above are recognizable in the same way as in the case of the Yuasa area (Table 42)***. However, it should be noticed that the stratigraphic relation between given two major or minor cycles is often different between the two areas, being conformable in one area while unconformable in the other. The major and minor cycles discussed here may be regarded as being referable to the individual stages of uniform or differential sedimentation (see p. 98 of this paper) and cyclic sequences in the Cretaceous deposits of Hokkaido in scale and origin respectively.

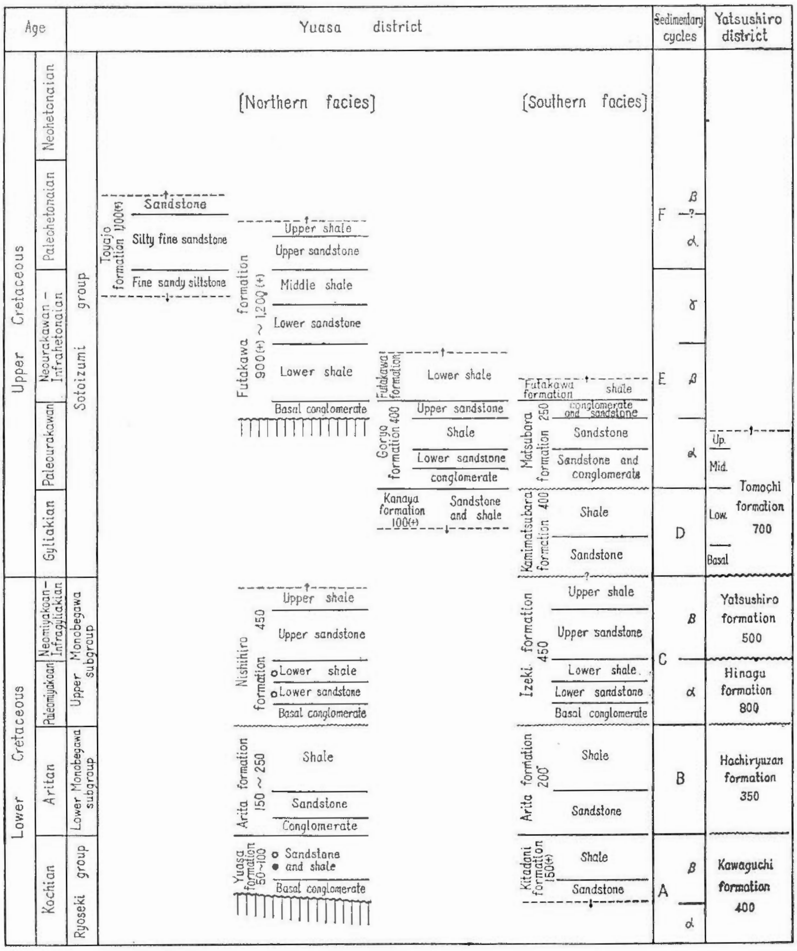
It has already been pointed out that the Izumi group lying with distinct unconformity on granitic rocks, quartz-porphyry and the Ryoke metamorphic rocks reveals in itself four cycles of sedimentation (Matsumoto, 1954). In the central part of the Izumi mountain range, the Izumi group is best displayed from base to top; it is said to be composed of sediments within a parageosyncline. Here, the group, over 6,700 m in thickness, shows in itself five major cycles (or better to say hemi-cycles), the upper four being, in turn, composed of several epicycles (or

* The Cretaceous strata in the Kushiro coal-field, southeastern Hokkaido, measuring up to about 2,000 or 3,000 m in thickness, are overlain by the coal-bearing Paleogene with unconformity. They are composed mainly of fine-grained sediments in the lower part and coarse-grained ones in the upper, being rich in volcanic materials at certain horizons but rather poor in fossils. The formation, though its lower limit is unknown, comprises three cycles; the lower is referred to the Lower Hetonaian stage and the succeeding two to the Upper Hetonaian.

** The case of the Lower Cretaceous has already been pointed out by Matsumoto (1954).

*** According to the personal communication from Professor Matsumoto, recently ammonites indicating the early Neocomian was found in a part of the strata, which is provisionally referred to the Upper Jurassic, within the Kawaguchi formation.

Table 42 Stratigraphic sequence and sedimentary cycles in the Cretaceous deposits of the Yuasa and Yatsushiro districts, Outer Zone of Southwest Japan



Unconformity: basement rocks (Paleozoic)

Disconformity

o Fossils of lacustrine or brackish-water organisms being much predominant over those of marine organisms

• Plant bed

Fossils of marine organisms occur at various horizons other than the horizons containing fossils of lacustrine or brackish-water organisms.

Numbers: approximate thickness in m.

A, B, ·····E, and F: major cycle

α, β, and γ: minor cycle

Some of the boundaries between the individual cycles are here for convenience to be artificially defined.

Table 43 Stratigraphic succession and cycles of sedimentation in the Upper Cretaceous Izumi group in the central part of the Izumi mountain range, Inner Zone of Southwest Japan (Tanaka 1958 emend.)

Major cycles (thickness in m)	Subdivision	Thickness (in m.)	Lithology	Correlation	Age
A (450)				Kasayama conglomerate; Azenotani shale	Paleohetonaian
B (1,300~1,500)	B_1, B_2, B_3, B_4	100~250	Sandstone, conglomerate, and subordinate shale in alternation	Kinyuji sandstone and conglomerate / Warazuhata shale and sandstone	Paleohetonaian
	B_5, B_6, B_7, B_8	150~250	Shale and subordinate sandstone in alternation		
C (2,100~2,400)	C_1, C_2, C_3	150~350	Sandstone and subordinate shale and conglomerate in alternation	Tsuzurahata sandstone and shale / Negoro shale and sandstone	Neohetonaian
	C_4, C_5, C_6	200~350	Sandstone and subordinate shale in alternation		
	C_7, C_8	250~350	Shale and sandstone in alternation		
D (1,800+)	D_1, D_2, D_3, D_4, D_5, D_6	250~350	Sandstone and subordinate shale in alternation	Shigo sandstone and shale	Neohetonaian
Fault relation					
E (850+)	E_1	450(?)	Sandstone, siltstone, and conglomerate	Nate formation	Neohetonaian
	E_2	400(+)			

better to say hemi-epicycles) respectively (Table 43; Hirayama and Tanaka MS.). One's attention is attracted by the fact that the sediments of epicycles, generally speaking, increase in thickness step by step upwards, from generally 200 m in the lowest epicycle to 400 m in the uppermost. Tuff is ordinarily intercalated in the lower or upper part of minor cycle, and never in the middle. It is noteworthy that the stratigraphic occurrence of tuff in the minor cycles as mentioned above is in harmony with the case of the cyclic sequences in the Cretaceous deposits in the meridional zone of Hokkaido. The Hakobuchi group of Hokkaido, which is almost the same age as the Izumi group, comprises four cycles as noted before. It may be suggested that the major cycles recognized in the Izumi group are nearly equivalent to the cyclic sequences in the Cretaceous of Hokkaido in formational order and the former owed their origin to conditions nearly similar to the case of the latter. Minor cycles within the second, third and fourth major cycles of the group under discussion showing much frequently rhythmic alternation of (conglomerate–) sandstone–shale are, of course, of much smaller scale; their origin owed, though not exclusively, to periodical change of tectonism (rate of uplift–erosion) in the source areas accompanied with acid volcanism taking place in the northern source area and to that of tectonism (rate of subsidence) in the depositional areas. Furthermore, it is a matter of course that the Izumi group itself presents a single cycle of sedimentation.

The Himenoura group in Middle Kyushu (Matsumoto, 1938; Ueda and Furukawa, 1960) lying with a distinct unconformity on the basement of granodiorite and gneiss is about 1,200 m thick, and is chiefly referable to the Upper Urakawan stage; it ranges up to the Lower Hetonaian and presumably down to the Lower Urakawan stage. This group is said to be sediments within a basin akin to the Izumi parageosyncline. It reveals in itself a cycle of sedimentation, which, in turn, seemingly comprises two minor cycles as in the case of the Upper Urakawan stage in the Yuasa district. Regarding the biofacies of the cyclic sequence, four facies, viz., shell, ammonite, mixed and inocerami facies, are discriminated in ascending order as noted in the Cretaceous of Hokkaido. Furthermore, also in the Himenoura group, generally speaking, aberrant ammonites and strongly ornate coiled ammonites are predominant in the ammonite facies, and weakly or moderately ornamented coiled ones in the mixed facies in common with the case of Hokkaido.

III. Notes on the Sedimentation

III. 1 Sedimentary Facies and Sedimentation

Large scale vertical changes in the sedimentary facies

One would note that the sedimentary facies, especially as represented by the thickness and lithologic composition or sandstone ratio, indicates conspicuous regional variations in some periods while in others it indicates opposite conditions. From this point of view, the vertical changes on a large scale in the sedimentary facies, that is, the depositional history of the sediments since the Miyakoan epoch would be divisible into the following five stages: (1) the first stage of relatively uniform sedimentation (Paleomiyakoan age – earlier Neomiyakoan age), (2) the second stage of uniform sedimentation (later Neomiyakoan age – Infragyliakian subage), (3) first stage of differential sedimentation (Paleogyliakian age – early Neogyliakian age), (4) the third stage of uniform sedimentation (late Neogyliakian age – Urakawan epoch), and (5) the second stage of differential sedimentation (Hetonaian epoch).

The vertical change on a large scale in the sedimentary facies through these five stages is illustrated in Fig. 29. The cyclic sedimentation took place almost simultaneously between the northern and southern provinces in the stages of uniform sedimentation, but at considerably different times between them or from place to place within the same province in the stages of differential sedimentation. The stratigraphic range of a cyclic sequence is small in (1) and (2), while large in (4), and then either small or large in (3) and (5), but yet on the whole rather large in (3); rather small in (5) (Table 39). The discontinuity in the vertical changes of the sandstone ratio of the cyclic sequences (see p. 89 of this paper) is recognized within (3) and nearly at the transition from (4) to (5) as in the case of the sediments of the time-stratigraphic units (see p. 80 of this paper). The average thickness of a cyclic sequence decreases in approximate order of (1)–(2), (3)–(4), and (5). Furthermore, fossil remains are poor in (1) and (2), while abundant in (4) and rather so in (3) and (5). The occurrence of calcareous concretions shows the same tendency of abundance as in the case of fossils. Lastly, tuffaceous rocks are, generally speaking, more frequent in (4) and (5) than in (2)–(3), and scarce in (1) (Fig. 36).

In conclusion, the vertical changes of the sedimentary facies mentioned above are closely related to the following points: the stage (1) was characterized by rather Flysch-type sedimentation; the stage (2) often represented the conditions similar to those in the stage (1); the stage (3) was subjected to some mobility of the basin where the rising part and the sinking part were differentiated and the upheaval of the adjacent source area, thus showing sedimentation differing from place to place; the stage (4) marked by the general transgressive sedimentation, whereas the stage (5) by the general regressive sedimentation; and moreover between the stages (1) and (2) a temporary emergence of some parts of the basin happened; in other words, the stages (1), (2)–(3), and (4)–(5) coincide with, and are correlatives of the first, second and third major cycles of sedimentation noted above respectively.

Large scale lateral changes in the sedimentary facies and sedimentary provinces

It is pointed out that the depositional basin was not always under similar conditions of sedimentation throughout but sometimes under remarkable different ones between the northern and southern provinces. Namely, one should note the essential differences recognizable from (1) the chronologic position of the base of the Hakobuchi group (Figs. 29, 33), (2) the sandstone ratio of the Lower Gyliakian stage (see p. 78 of this paper) and of sequence IV (see p. 87 of this paper), and (3) the chronologic position of the sequences such as IV, V, IX, X and XI (Fig. 33; Table 39). The base of the Hakobuchi group is situated within the Lower Hetonaian stage (or sequence IX) in the northern province, while it corresponds to the base of the same stage (or the same sequence) in the southern. The approximate boundary between the two provinces is here named the Asahikawa-Rumoi Line (Fig. 24), it being a kind of discontinuous part within the basin. In addition to the above-mentioned dissimilarity, the *Orbitoliana* limestone of the Lower Yezo group occur mainly in the southern province, but scarcely in the northern.

It is furthermore noteworthy that difference between the two provinces as noted in the Cretaceous seems to be reflected in some of the succeeding geological condition. Examples may be found in facies development, deformation and structural behaviour of the Paleogene and Neogene deposits, and upheaval caused by tectonic disturbances. Moreover, tectonic behaviour of the so-called Hidaka orogenic zone (Kizaki, 1959) may be also applicable to this explanation.

Subsidence and deposition

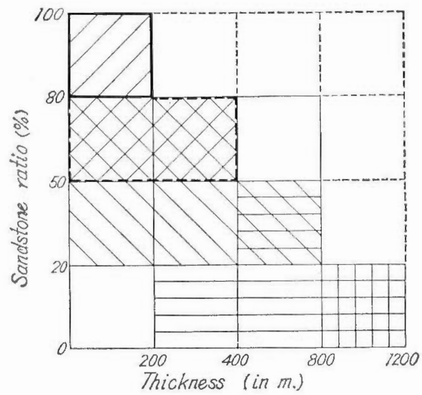
The facies variation in the Cretaceous deposits under consideration is shown in Fig. 34* in which boundary of the stages or substages is also indicated. As previously stated, the thickness of any one stage is measured up to about 1,000 m in maximum. However, the sediments of the relatively fine-grained facies of the Lower Gyliakian and Upper Gyliakian stages are a little more than 1,000 m thick in some places. Generally speaking, the Upper Gyliakian stage is thicker in the northern province than in the southern. The sandstone ratio of the Lower Gyliakian stage conversely differs between the two provinces. The sediments of the lower part of the Lower Hetonaian stage represent muddy facies everywhere in the northern province, while they ordinarily represent sandy facies in the southern. Moreover, on the assumption that each age is nearly constant in duration, for which absolute age determination is necessary, the approximate rate of deposition may be known to be large in the Miyakoan series, small in the Hetonaian series and moderate in the Gyliakian and Urakawan series.

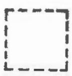
Although the sedimentary facies are variable all over the area, relationship among the thickness, lithofacies and biofacies in the various stages of the Upper Cretaceous may be generalized in Fig. 35**. Some remarks on this figure are as follows. Aberrant ammonites usually, if not always, occur more abundantly than coiled ones where the thickness of the sediments is less than 200 m per stage, while the former usually, if not always, occur less abundantly than the latter when the thickness of the sediments is 200 to 400 m per stage. Where the sediments are over 400 m thick per stage, coiled ammonites always predominate over aberrant ones.

The most offshore part in the basin normally corresponds to the most subsiding part. The Gyliakian series in the Obirashibe Valley represents far offshore sediments as compared with that in the Ikushumbetsu and other areas. However, the area may not have corresponded to the most offshore part within the Yezo geosyncline, but it was presumably situated in the western, comparatively offshore part of the basin. Since the series is very thick the area is regarded to have greatly subsided. This area, furthermore, remained in great or small degree under such conditions at least until the Paleohetonaian age. In the southern province, the most offshore part subsided most intensely, as exemplified by (1) the Shiyubari Valley in the Paleogyliakian age, (2) the Tomiuchi district in the Neourakawan age where the Hetonaian series is also considerably thick, and (3) the Urakawa district in the Hetonaian epoch. It is noteworthy that the three most subsiding parts mentioned above are situated from north to south in the present geographical position. In the sediments of the Hetonaian series are recognized facies change from the near-shore facies in the Ishikari coal-field through the intermediate facies in the Tomiuchi area to the offshore facies in the Urakawa area. It is needless to say that the intensity of subsidence increased in the order of the

* The first type of coiled ammonites illustrated in Fig. 34 includes groups C_3 and D, and the second type groups A, B, C_1 and C_2.

** The first type of coiled ammonites illustrated in Fig. 35 includes groups A, B, C_1 and C_2, and the second type groups C_3 and D.

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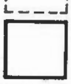

Occurrence of ammonites being always not abundant


Occurrence of ammonites being usually, if not always, not abundant


Coiled ammonites of smooth or weakly ornamented and inflated whorl with nearly circular section being usually, if not always, predominant over coiled ammonites of highly ornamented whorl with nearly quadrate or compressed section


Of the above-mentioned two types of coiled ammonites, the former type always showing dominant occurrence as compared with the latter type


Predominant occurrence of shallow sea bivalves such as trigonians, glycimerids, and oysters

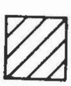

Occurrence of plant beds or coaly seams, one or a few metres thick

Fig. 35 Showing the relationship among the thickness, lithofacies and biofacies in the stages or substages of the Upper Cretaceous deposits in the meridional zone of Hokkaido first, the second and the third areas.

Furthermore, judging from the lateral variation of facies in the uppermost part of the Upper Yezo group and the lower part of the Chinomigawa formation in the Urakawa area it would appear that the far offshore part (or more intensely subsided part) shifted northeastwards, or better to say, eastwards in the original situation, in the Paleohetonaian age (Tanaka, 1960b). A similar change of facies and thickness took place from west to east within the basin of the Kamisarufutsu area in the Hetonaian epoch (Tanaka, 1960b). The conditions of this area are in common with those of the Urakawa area, as reflected in some resemblance between the two areas in the rock-facies of the Lower Hetonaian stage and in conditions of the cyclic sequences concerned, as has previously been mentioned. Thus such a fact suggests that the two areas which are located in the Kamuikotan zone were placed under very similar conditions of sedimentation, although they are geographically much separated.

In the next place, the writer outlines the variation in the constituents of the Cretaceous deposits under discussion. The Paleomiyakoan coarse-grained sediments are represented by the Tomitoi member as an eastern facies in the southern province, and by the Onodera member in the northern. In the sediments of the former member, the materials derived from granitic rocks are predominant, and those derived from schistose rocks are also in subordinate amounts (Fujii, 1958). However, the sandstones of the Lower Yezo group, which is presumably referred to the Lower Miyakoan stage to the lower part of the Upper Miyakoan stage, of the Horokanai district in the northern province are rather rich in fragments of volcanic rocks (Table 31). In the Paleomiyakoan age, limestones containing *Oribitolina* were deposited mainly in the southern province. As the coarse-grained sediments in the western facies of the basal or lowest part of the Middle Yezo group, which is probably referred to the middle part of the Upper Miyakoan stage, there are the Kanajirizawa formation and the Moihoro member in the northern province, both of which intercalate comparatively thick tuffs. The tuffs are rhyolitic and dacitic in the former and rhyolitic in the latter. The Kasamorizawa member in the southern province represents the eastern facies. The coarse-grained sediments of the Kanajirizawa formation are rather rich in materials derived from acid and intermediate volcanic rocks (Table 31).

The Gyliakian Mikasa formation, the coarse-grained sediments of which are not necessarily poor in materials derived from volcanic rocks, is the sediments of the western near-shore facies in the southern province. In the formation, one facies containing abundant shallow-sea fossils such as trigonians and the other facies which is coarser grained than the former and intercalates several *Ostrea* beds or a coal seam are discriminated from east to west. On the other hand, the Gyliakian eastern coarse-grained facies of the same province is shown in the Kondoyama formation. The comparatively fine-grained facies of the Upper Gyliakian stage is represented by the Saku formation. This formation shows an offshore facies in some places such as the Obirashibe area. Of the component in the coarse-grained sediments of the Saku formation volcanic rocks are, generally speaking, subordinate as in the Mikasa formation (Fujii, 1958), but they are rather fairly predominant in the Obirashibe district (Table 31). Also in the Hoshin formation, the sediments of the eastern near-shore facies in the northern province, materials derived from andesitic rocks are rather predominant (Tanaka, 1960b). Furthermore, it is noteworthy that conglomerates of the western facies of the Saku formation and those of the Hoshin formation contain a large number of contemporaneous pebbles (Fig. 37).

In the Urakawan series fine-grained sediments are predominant with frequently intercalated acid tuffs. As the representative coarse-grained sediments locally contained in the rather offshore facies of the same series, there are (1) the Paleourakawan Tsukimi member with rhyolitic tuffs in the southern province, and (2) the Paleourakawan Kamikinembetsu member and (3) the Neourakawan Omagari member in the northern province. The sediments of the first are derived principally from an acid volcanic source, and those of the third essentially from an andesitic one; the pebbles of the second are chiefly dacite and andesite. Furthermore, the Neourakawan Tomiuchibashi tuff in the Tomiuchi area is dacitic (Tanaka, 1960a).

In the succeeding Hetonaian series, there are distinct lateral changes of facies in the southern province; one facies of the Hakobuchi group intercalating coal seams passes into another facies of the group containing abundant marine organisms which, in turn, changes into the Chinomigawa formation composed mainly of muddy facies from west to east or from north to south. The coarse-grained sediments of the Hakobuchi group which occasionally contain beds of tuff or tuffaceous rock, mainly of dacitic nature (Tanaka, 1960a, 1960b), are largely of volcanic origin (Fujii, 1958; Tanaka, 1960b). Moreover, as far as the pebbles of conglomerate are concerned, those of rhyolite are frequently found on the western wing of the Sorachi anticline (Shimizu, Tanaka and Imai, 1953), while those of andesite in the Kamisarufutsu area where the sandstones also are rich in fragments of andesite (Tanaka, 1960b).

Tuffs or tuffaceous rocks are intercalated as layers or beds of various thickness, ranging from a few centimetres to a few tens of metres, at various horizons throughout from the Middle Yezo to the Hakobuchi group, but are scarcely found in the Lower Yezo group. Abundant or dominant occurrence of such rocks is seen in thirteen horizons of which T_3 (T_1)–T_4, T_8–T_{10}, and T_{13} are three remarkable ones (Fig. 36)*. Roughly speaking, the stratigraphic range of the abundant or dominant tuffs often occupies one-tenth to one-third of the stage concerned. It is noteworthy that each of the above three remarkable horizons occurs in the earlier half or in the rather final stage of the major cycle of sedimentation concerned, i.e. the second (cycles I–V) or third major cycle (cycles VI–XII) in harmony with the horizon of abundant or dominant tuffs within the cyclic sequence. Such a tendency may be, though inconspicuously, recognized also in the first major cycle which is represented by the Lower Yezo group. Tuffs or tuffaceous rocks, almost all of which contain plagioclase, quartz and biotite, are chiefly dacitic. Some of them are rhyolitic or andesitic. Hypersthene is contained not only in some tuffs or tuffaceous rocks of the Hetonaian series but also in those of the Upper Urakawan stage. Moreover, it attracts one's attention that in the cyclic sequences of the Obirashibe area tuffs seem to show, as a general tendency, upward change from relatively acid to relatively basic nature which is succeeded again by relatively acid nature in the final stage. To sum up, it can be pointed out that the deposition of tuffs in the Cretaceous deposits of the meridional zone of Hokkaido may have been attributed chiefly to volcanic eruptions belonging to the calc-alkali rock series. In this connection, one's attention is attracted to the fact that basic volcanism represented by pillowed basalt took place during the deposition of the Jurassic and Lower Neocomian Sorachi group, and that in southeastern Hokkaido a

* T_{12} prevails in the southern province, but it is very inconspicuous in the northern.

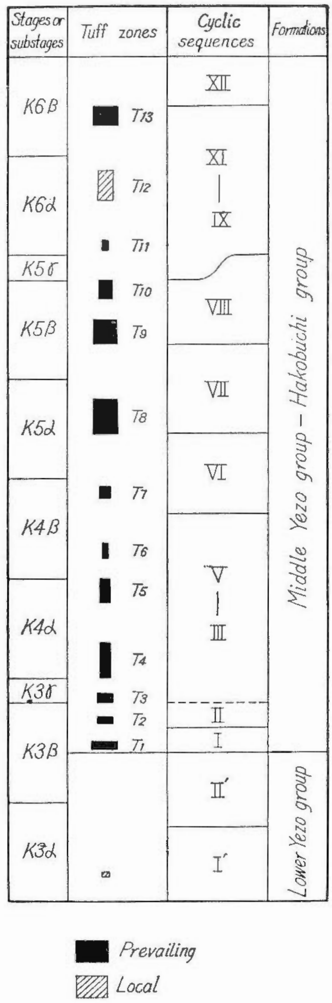


Fig. 36 Showing stratigraphic positions of frequent or dominant occurrence of tuff or tuffaceous rock in the Cretaceous deposits in the meridional zone of Hokkaido

T_1, T_2....T_{12}, and T_{13}: showing horizons of tuff zones

The width of symbols indicates grades of frequent or dominant occurrence.

volcanism represented by trachydolerite, rather abnormal in Japan, played an important part during the Hetonaian epoch.

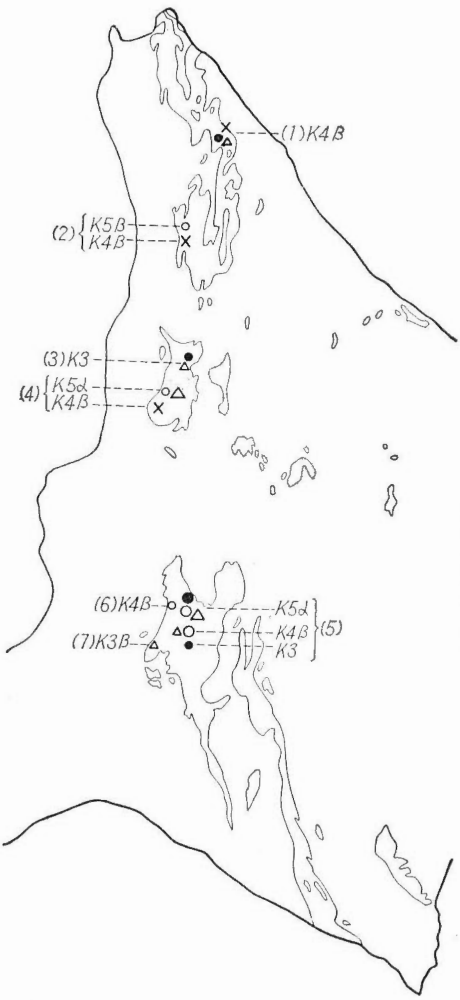
Greensand grains are disseminated at various horizons throughout from the Middle Yezo to the Hakobuchi group. They are abundant especially in the Uppermost Urakawan substage at many places. Greensand grains are moreover much disseminated at several horizons in the sequence from the upper part of the Upper Gyliakian to the Lower Urakawan stage in the western part of the Ishikari coalfield.

It is furthermore worthy of mention that at various horizons throughout the Cretaceous deposits under discussion, especially in the Upper Yezo group, some strata show abnormal sedimentary structures or contain abnormal sediments in such places as indicated in Fig. 37. Representatives of the abnormal sediments are the Tsukimi, Kamikinembetsu and Omagari members. All of them display or even are rich in muddy conglomerates or pebbly mudstones which are also frequently contained in the lower half of the Upper Yezo group on the eastern wing of the Sorachi anticline. These strata occupy mostly the lowest and partly the uppermost parts of cyclic sequences, and were deposited at intermediate positions between the near-shore and offshore parts in the basin. Their deposition is presumed to be due to the so-called turbidity currents, subaqueous mudflow or subaqueous sliding, and furthermore closely related to a sort of tectonism which was in some cases accompanied with remarkable differential subsidence as exemplified by the case of the Tsukimi member and its allied sediments in the mid-valley of the Ashibetsu (Tanaka, 1959).

Cyclic sedimentation

As has previously been mentioned, the Lower Yezo group represents one major cycles of sedimentation comprising two minor cycles, and the sequence from the Middle Yezo to the Hakobuchi group two major cycles of sedimentation comprising twelve minor cycles. The vertical changes of lithofacies and biofacies in the cyclic sequences of the standard scale under discussion have already been described. The thickness of each cyclic sequence never exceeds 700 m in the Middle Yezo, Upper Yezo and Hakobuchi groups, but reaches 1,000 m or so in the Lower Yezo group. Furthermore the relationship among the thickness, lithofacies, and biofacies of the cyclic sequences recognized in the sediments from the Gyliakian to the Hetonaian series is essentially the same as in the case of the stages or substages noted in page 100 of this paper. There is, however, no example of cyclic sequence with the thickness ranging from 800 to 1,200 m, so the corresponding section is left blank in Fig. 35.

It goes without saying that a cyclic sequence shows a vertical change from shallower to deeper environments and, in turn, to another shallower ones (Fig. 38). The cyclic deposition under consideration owes its origin essentially to periodical or intermittent tectonism taking place in the depositional area as well as in the source area. Volcanic activity is presumed to have been also in some degree related to this periodic tectonic movement (Fig. 38). Furthermore, the cyclic sedimentation discussed here not only represents repetition of the vertical changes of both lithofacies and biofacies but also implies changes in the time-space magnitude of a cycle during the sedimentary history of the Cretaceous deposits. The changes in time-space magnitude of a cycle mean those in the stratigraphic range and average thickness of cyclic sequences formed since the deposition of the Lower Miyakoan stage, as noted before. Thus, it may be pointed out that the average



1: Kamisarufutsu district, its eastern part
2: Abeshinai Valley
3: Soeushinai district
4: Obirashibe Valley
5: Ashibetsu Valley
6: Bibai Valley
7: Ikushumbetsu Valley
The size of symbols indicates grades of predominance or frequency

● *Muddy conglomerates or pebbly mudstones*
○ *Isolated pebbles contained in mudstone*
× *Contemporaneous pebbles contained in conglomerate*
△ *Abnormal sedimentary structures*

Fig. 37 Distribution of abnormal sediments and abnormal sedimentary structures of the Cretaceous deposits in the meridional zone of Hokkaido

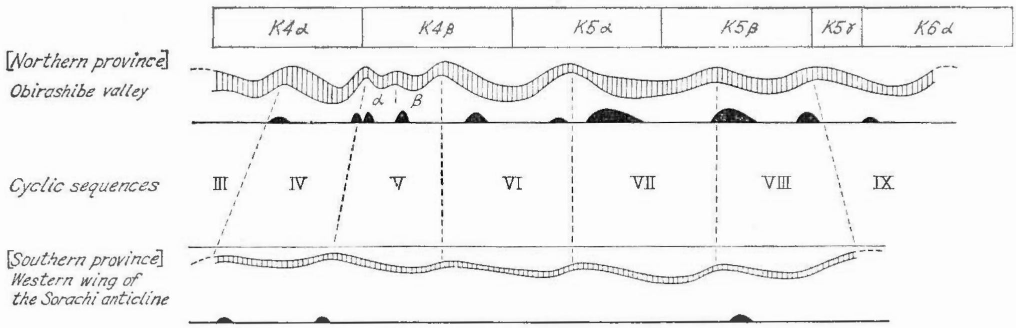


Fig. 38 Schematic illustration of the cyclic sedimentation in the Cretaceous deposits of the selected standard areas in the meridional zone of Hokkaido

Upper curves show absolute depth of the environments and lower curves absolute amount of subsidence. Interval between the two curves shows approximately the relative rate of subsidence.

Black area shows frequent or dominant occurrence of tuff.

rate of deposition of a cyclic sequence decreases in approximate order of I′–III, IV–VIII and IX–XII. After all, the deposition of the individual cyclic sequences is not always attributable to the same origin. The origin of each cycle is of course closely related to the depositional history of the Cretaceous rocks or development of the Yezo geosyncline, as is discussed in p. 98 of this paper. Moreover, the major cycles of sedimentation may can be fundamentally ascribed to epeirogenic movements of much wider extent.

As exemplified in the Upper Gyliakian stage of the Obirashibe Valley and the Lower Hetonaian stage of the Tomiuchi district, a certain stage is represented by sediments of abnormally greater thickness in several areas, in spite of the fact that the sediments were not originally in far offshore or the most offshore part within the basin. This may be partly due to that one cyclic sequence within this stage is composed of two or three epicyclic sequences. The repeated occurrence of epicycles in one cycle possibly rejuvenated intensity of subsidence in the depositional area. Hence, it may be suggested that in the Cretaceous deposits in the meridional zone of Hokkaido cyclic sedimentation played an important part to the deposition in local areas as well as in the whole basin.

III. 2 Tectonic Control of the Sedimentation

For exploring tectonic control of sedimentation of a given thick conformable series such as the Cretaceous deposits in the meridional zone of Hokkaido, consideration of cyclic sedimentation, if it is recognizable, may be appropriate. As already mentioned, the Cretaceous cyclic sedimentation in Hokkaido may be ascribed to repeated uplift and subsidence of the depositional area, with subsidence greater than uplift. Such a movement is closely related to periodical tectonism taking place in the source area where volcanism accompanied tectonism. Judging from the chronologic position, stratigraphic range, thickness, lithologic aspect, and average rate of deposition of the cyclic sequences as mentioned before, one would notice that generally speaking, tectonism responsible for the cyclic sedimentation was comparatively intense in the Miyakoan epoch, while mild in the Urakawan epoch and that it was partly intense and partly mild, in other words, not uniform in the Gyliakian and Hetonaian epochs. In this connection, the Miyakoan series is indeed represented essentially by Flysch-type sediments and moreover shows an unconformity within its rather middle part in several areas. On the other hand, the Urakawan series consists largely of comparatively monotonous fine-grained sediments. The sedimentary facies of the Gyliakian and Hetonaian epochs changes from place to place throughout the basin, and moreover exhibits considerable vertical changes in many areas. The tectonism, which was related to the cyclic sedimentation, lasted for different lengths of time in some cases. For example, several cycles in the Gyliakian and Hetonaian epochs differed in duration between the northern and southern provinces and also between the areas within the same province. Furthermore, the upper of two minor cyclic sequences constructing the sequence V of the Obirashibe area is equivalent to the sequence V of the Abeshinai area in its chronologic position and stratigraphic range. The same is also recognizable in the relationship between the Ashibetsu and Ikushumbetsu valleys. Such conditions in the Obirashibe area are thought to reflect the fact that the area was greatly subsided, and those in the Ashibetsu area to be connected with the formation of the Minenobu upwarping belt (Tanaka, 1959).

Much subsiding parts and upwarping belts as mentioned above, which were formed in different places and in different ages, owed their origin to comparatively intense tectonism of different types at or near their sites. For instance, the great thickness of the Upper Gyliakian stage in the Obirashibe area fundamentally depends upon the comparatively intense tectonism in the depositional area as well as in the adjacent source area, which caused rapid subsidence and the formation of the two epicycles within cycle V respectively. In the Sorachi anticlinal area, tectonism was comparatively intense in both the western adjoining source area and the depositional area during the Neogyliakian and Paleourakawan ages; the former is reflected in the existence of the Minenobu upwarping belt and the latter in the greatly differential subsidence. The most offshore part within the basin normally subsided most greatly and most rapidly. This may suggest that tectonism in the depositional area was ordinarily most intense in such a part. Examples are given in p. 100 of this paper. Furthermore, abnormal sediments such as muddy conglomerates, pebbly mudstones, etc. and abnormal sedimentary structures which are found especially in the Upper Yezo group at some places are thought to reflect rising conditions of the adjacent source area, although such sediments and structures may have been originated under various conditions of sedimentation. In this connection, it is worthy of mention that the case of the Tsukimi member in the Ashibetsu area may reasonably have been affected by differential subsiding conditions of the depositional area and by the existence of the Minenobu upwarping belt. Moreover, the predominant occurrence of contemporaneous pebbles is found in the conglomerates of the Saku formation, which on the whole represents rather offshore facies and its equivalent at several places (Fig. 37). Such a fact seems to be connected with the tectonism (rapid upheaval) in the source area and that (rapid subsidence) in the depositional area. In a word, it may suggest the existence of local contemporaneous erosion during the deposition of such strata.

In addition to the above-mentioned two types of tectonic effect upon the sedimentation, there was also tectonism on a large or extensive scale. As mentioned before, the tectonism responsible for the cyclic sedimentation was not always of the very same origin. It was, of course, controlled largely by tectonism of the above type from which the major cycles of sedimentation resulted as in the tectonism related to subsiding–upwarping parts. It goes without saying that tectonism on a large or extensive scale had influence on the configuration of and conditions in the basin and on the circumstances in the source area. When such a tectonism was on the whole comparatively intensive and differential, it resulted in the heterochronism of the cycles in the Gyliakian and Hetonaian epochs and the remarkable difference of the sedimentary facies between the northern and southern provinces in the Paleogyliakian age and earliest Hetonaian epoch. Geanticlinal islands which originated from upheaval of some parts of the basin are inferred to have existed on the eastern side of the southern province, i.e. in the area nearly equivalent to the present Kamuikotan zone at least in the Neomiyakoan age, judging from data concerning the Furano district (Hashimoto, 1954, 1958). A land mass on the eastern side of the northern province was under the conditions of enormous upheaval in the presumed Neogyliakian age and retreated far eastwards in the succeeding Paleourakawan age, as reflected in the sedimentary facies of the Hoshin formation and its very abrupt change to the sedimentary facies of the superjacent and subjacent strata (Tanaka, 1960b). As mentioned before, much subsiding parts or far offshore parts may have shifted eastward in the Hetonaian epoch throughout the two provinces. Such a movement is presumed to have been affected by an outrider of the intense tectonism, followed by the intrusion of serpentinite and the upheaval of the Kamuikotan metamorphics at the close of the Cretaceous or at the beginning of the Tertiary, which took place in the east, i.e. on the site nearly equivalent to the present Kamuikotan zone, in addition to an effect of the contraction and displacement to the east of the over-all basin (Tanaka, 1960b). Furthermore, it is said that an unconformity between the Lower Yezo and Middle Yezo groups in the Furano area becomes remarkable to the east, i.e. the Kamuikotan zone where the Middle Yezo group lies directly on the Sorachi group at certain places (Hashimoto, 1955, 1958). On the contrary, in the western part of the Horokanai area the two groups show a disconformable relation which, in turn, passes into a conformable one in the east (Igi and others, 1958). The conditions in and around the western part of the basin seems to have not as a whole changed so remarkably as in and around the eastern since the Miyakoan epoch. This can be explained from the sedimentary facies of the Cretaceous in the western part.

To sum up, as tectonic control of the sedimentation, three different types may be discriminated: one originating cyclic sedimentation, another related to subsiding–upwarping parts, and lastly the over-all configuration of and conditions in the basin. Each of the three types of tectonism did not always take place in the same way in and around the basin. Thus, the western part of the basin under consideration is presumed to be under rather stable conditions although much subsiding parts or upwarping parts originated in some places in the Gyliakian epoch; on the contrary the eastern part is considered to be under rather unstable conditions at least in the Miyakoan, Gyliakian and Hetonaian epochs. Moreover, the conditions in the basin were considerably different between the northern and southern provinces especially in the Paleogyliakian and early Paleohetonaian ages. Such a difference is also, though not noticeably, recognized in the case of the Paleomiyakoan age, as explained from the deposition of *Orbitolina* limestone.

Some notes should be furthermore extended to the geological relationship between the deposition of the Cretaceous and that of the Tertiary of some areas in the meridional zone of Hokkaido. In the Sorachi anticlinal area, the Cretaceous deposits were more deeply eroded away in the west than in the east before the deposition of the Paleogene Ishikari group. The area has subsided more intensely in the east than in the west since the Gyliakian epoch. The Minenobu upwarping belt, which existed in the area, had continuously tilted to the north after its appearance in the late Paleogyliakian age. It had influence on such denudation of the Cretaceous as noted above and the deposition of the Ishikari group in the over-all Ishikari coal-field in the same manner as in the case of the deposition of the Cretaceous in the area (Tanaka, 1959). The Obirashibe area, which subsided more intensely in the southeast than in the west at least since the Neogyliakian age, may have been subjected to a similar tendency in the Oligocene to early middle Miocene. However, the present area seems to have been brought to a different condition in the late middle Miocene, when the depositional area may have, roughly speaking, subsided more intensely in the north than in the south. Here, the Cretaceous formation was more deeply eroded away in the southwest than in the east before the deposition of the Miocene. Furthermore, in the Kamisarufutsu area the depositional area of the Oligocene formation is presumed to be closely related to the final effect of the progressive displacement to the east of the relatively far offshore part of the basin during the Hetonaian epoch. In the Oligocene epoch the western part of the area was under rising conditions which, in turn, were replaced by sinking conditions in the earlier Miocene. In this connection the Cretaceous rocks of the area were more deeply eroded away in the west than in the east before the deposition of the earlier Miocene (Tanaka, 1960b). In a word, so far as the areas discussed above are concerned, it seems likely that deposition of the Paleogene was closely related to that of the Cretaceous. On the contrary, the Neogene deposition had as a whole little relation to the Cretaceous. Such deposition and denudation of the Cretaceous strata as common to the three areas mentioned above are also known in the Ikushumbetsu district.

III. 3 Development of the Sedimentary Basin (Fig. 39)

The configuration of and conditions in the sedimentary basin of the Cretaceous deposits in the meridional zone of Hokkaido naturally changed under the influence of both the geosynclinal sinking particular to this region and epeirogenic movements of much wider extent. The basin, called the "Yezo geosyncline" may have continuously been margined by a land mass entirely on the western side, although the exact position of the main land bordering the basin has not been ascertained yet. This point is exemplified by the lateral changes of the sedimentary facies and features of sediments in the Ishikari coal-field, Obirashibe Valley, Abeshinai Valley and in the Kamisarufutsu area. It is, however, questionable whether the basin was bordered entirely by a land mass all the time on the eastern side. It is supposed that a portion of another land mass, named the "Okhotsk Land" (Hashimoto, 1958), continuously existed to the east of the northern part of the northern province at least since the Neogyliakian age. This is warranted from the geological condition of the Kamisarufutsu district (Tanaka, 1960b). On the other hand, in the southern province the existence of geanticlinal islands to the east is presumed at least in the Neomiyakoan age considering the lateral facies change of the Kasamorizawa member in the Furano district and its environs (Hashimoto, 1954, 1955). Although the later conditions in the southern province are almost entirely obscure, it is plausible to believe that the basin expanded much more eastwards than supposed by some investigators, from the new finding of the presumed Upper Cretaceous rocks in the Hidaka zone (Minato and others, 1954; Suzuki and others, 1959).

It goes without saying that the bottom of the basin was not always simple throughout but was occupied by great or small reliefs extending in longitudinal or transversal direction here and there. For example, the Minenobu upwarping belt on the western side of the southern province is a representative of nearly E–W trend. It came into existence in the later Paleogyliakian age and since then had controlled the sedimentation of the Upper Yezo group in the Sorachi anticlinal area. Representatives of nearly N–S trend are geanticlinal islands in the Neomiyakoan age and less intensely subsided parts or rising parts within the basin, which perhaps emerged in the form of geanticlinal islands at some places, in the Hetonaian epoch, both of which were located in the area nearly equivalent to the present Kamuikotan zone. The latter may have been closely related to the subsequent intrusion of serpentinite or upheaval of the Kamuikotan metamorphics. Furthermore, it is said that an upwarping part of nearly N–S direction within the basin sprung out as an embryo of the Sorachi anticline in the later Hetonaian epoch (Ogasawara, 1953). On the other hand, the opposite downwarping or much subsiding bottoms were of course present in some places and in some ages. The basin ordinarily most greatly subsided in the most offshore part; examples are the Shiyubari area in the Paleogyliakian age, the Tomiuchi area in the Neourakawan age, and the Urakawa area in the Hetonaian epoch. These three areas are situated in the southern province. In addition, less offshore part of the basin also greatly subsided in some places. For instance, on the southwestern side of the northern province, a kind of trough, named the Obirashibe trough with nearly N–S trend, which was also a rapidly subsiding part, has existed since the Paleogyliakian age. The trough is supposed to have been located in the western, less offshore part of the basin rather than in the most offshore part.

The late Jurassic and earliest Cretaceous Periods were marked by submarine, basic volcanism represented by pillowed basalt and deposition of pyroclastic sediments, radiolarian chert and fossiliferous limestone. The very abrupt change of conditions from that time to the succeeding Miyakoan epoch suggests a particular phase in the development of the Yezo geosyncline. This is also reflected in an unconformity between the Sorachi group and the superjacent Lower Yezo group.

During the Miyakoan epoch, the basin seemed to retain rather similar conditions although it suffered a temporary emergence as shown in an unconformity between the Lower Yezo and Middle Yezo groups. It was in general under comparatively mobile tectonic environments. The basin seems to have been as a whole more greatly subsided than in the succeeding epochs. The deposits were on the whole relatively uniform throughout the basin, being composed essentially of sandstone and shale in alternation of Flysch type. Volcanic activity which has belonged to calc-alkali rock series ever since was episodic throughout the epoch, but rather intense especially in the later Miyakoan epoch. Furthermore, in the Paleomiyakoan age an organic limestone was deposited mainly in the southern province.

In the succeeding Paleogyliakian age, the conditions in the basin were different from place to place depending on unstable tectonic environments. First of all, conspicuous differences of conditions are recognized between the northern and southern provinces. Regarding the northern province it may be suggested that the basin was on the whole subjected to progressive subsidence in this age. In connection with such conditions, a trough originated in the Obirashibe area at the southwestern part of the northern province. This trough subsided more intensely than other part of the basin, although it was not located in the most offshore part. On the other hand, the basin may have been under considerably differential conditions in the southern province; some areas were rather under sinking conditions, while some others under rising conditions. For instance, the Minenobu upwarping belt was produced on the western side of the northern part of the southern province. During this age deposition of neritic coarse-grained sediments prevailed in some parts of the basin, while that of thick mudstones in some other parts. Such diversity, although as a whole to some extent relieved, remained until the Neogyliakian age. That is to say, the Obirashibe trough and Minenobu upwarping belt were still present. In the northern province, the adjoining source area on the eastern side was all the time greatly upheaved, while that on the western side was temporarily subjected to comparatively intense rising in some places. The former case is exemplified by the thick coarse-grained sediments of the presumed Neogyliakian age in the Kamisarufutsu district, and the latter by the predominance of contemporaneous pebbles in the conglomerate of the Saku formation and its equivalent. In brief, during the Gyliakian epoch the basin was generally under mobile tectonic environments and noticeable facies variation therein has resulted. There seems, however, no doubt that in the later Neogyliakian age the basin became as a whole tectonically less mobile. Volcanism was not frequent and rather inactive throughout the Gyliakian epoch.

Throughout the Urakawan epoch the basin spread in the southern province as well as in the northern province under the influence of the so-called Urakawan transgression of extensive scale (Matsumoto, 1941), the inundation phase of which was perhaps in the latest Paleourakawan or earliest Neourakawan age. In this epoch, comparatively monotonous fine-grained sediments which reflected comparatively stable tectonic environments became to prevail all over the basin. In spite of the general tectonic stability, the continuous rising of the Minenobu upwarping belt where volcanism became rather active seems to have come to a climax in the Paleourakawan age as inferred from the deposition of the Tsukimi member. Moreover, judging from the predominant occurrence of abnormal sediments in the Obirashibe and Abeshinai valleys, it may be suggested that the adjoining source area on the western side of the basin suffered for a time comparatively great uplift in some places. Volcanic activity, rather episodic in the preceding epochs, took place rather frequently or intensely in the Urakawan and the succeeding Hetonaian epochs. The most offshore part within the northern part of the northern province where land masses were situated to the east and also to the west, possibly shifted westwards as compared with that in the Neogyliakian age (Tanaka, 1960b). The basin, however, showed on the whole some signs of shallowing at the end of the Urakawan epoch.

Then in the succeeding Hetonaian epoch, the basin was generally contracted and became shallower than in the Urakawan epoch, although it must have still continued to subside. This can be deduced from the fact that the sediments are rich in neritic sandstones and sandy siltstones with intercalated conglomerates, coaly seams and plant beds. The deposits of this epoch displayed facies variation throughout the basin which was under unstable tectonic environments. Moreover, in the early Neohetonaian age the basin is presumed to have been subjected to slight deepening. In the northern province, conditions similar to those of the previous epoch were kept in the early Paleohetonaian age; accordingly fine-grained sediments were still deposited. The most offshore part within the northern part of the northern province shifted back to the east, correctly speaking, far eastwards, at any rate progressively removed eastwards throughout the epoch (Tanaka, 1960b). On the other hand, within the southern province the basin may have expanded and become deeper to the south as inferred from the sedimentary facies of the Chinomigawa formation*. Also in the southern part of this province, i.e. in the Urakawa area, the far offshore part, which was at the same time the intensely subsiding part, shifted to the east in the Hetonaian epoch as compared with that of the Urakawan epoch as in the case of the above-mentioned northeastern part of the northern province, i.e. the Kamisarufutsu district (Tanaka, 1960b). At the close of the Cretaceous Period the basin was subjected to retreat of the sea and subsequent emergence and denudation.

IV. Summary and Conclusion

Summarized notes on the stratigraphy and sedimentation of the Cretaceous strata in the meridional zone of Hokkaido which range from the Lower Yezo group upwards to the Hakobuchi group are briefly presented as follows:

(1) A stratigraphic classification based on the cyclic sedimentation is applicable to the Cretaceous of the entire area under discussion. The Cretaceous is divided into two cyclic sequences in the Lower Yezo group and into twelve in the succeeding sequence of strata. These cyclic sequence show definite stratigraphic ranges, certain limits and ranges of thickness, definite sandstone ratios, and changes in regular order of both lithofacies and biofacies.

(2) The stages and substages recognized in the Cretaceous show also certain limits and ranges in thickness and definite sandstone ratios.

(3) The vertical changes on a large scale in the sedimentary facies, that is, the history of sedimentation since the Miyakoan epoch would be divisible into five stages marked by uniform sedimentation or differential one respectively.

(4) Concerning the sedimentary facies of the stages and substages or that of the cyclic sequences, there are definite mutual relationships among the thickness, lithofacies, e.g. sandstone ratio and dominant occurrence of a particular rock such as coal or plant bed, and the biofacies, e.g. dominant occurrence of certain fossils such as shallow sea bivalves, aberrant ammonites, coiled ones, and so forth.

(5) From the regional difference of the sedimentary facies, the Cretaceous area is divided into the two provinces, northern and southern, its boundary being called the Asahikawa–Rumoi Line.

(6) Cyclic sedimentation played an important part in the deposition of the Cretaceous. Occurrence of abnormal sediments such as pebbly mudstone also should be taken into consideration as one of the characters of the sedimentation.

(7) Regarding the configuration of and conditions in the basin of sedimentation, i.e. the Yezo geosyncline, there is inferred the existence of eastern source

* It would appear that the present extensive distribution of the sediments of the Hetonaian series in the southeastern Hokkaido was to a certain degree connected with such conditions.

areas besides western ones, troughs, subsiding and upwarping parts with longitudinal or transversal direction. It is worthy of mention that displacement of subsiding part was closely related with the development or changes of the basin as a whole.

(8) As tectonic influence upon the sedimentation, three different types may be discriminated: one originating cyclic sedimentation, another related to subsiding–upwarping parts, and lastly the over-all configuration of and conditions in the basin.

(9) Judging from the tectonic influence upon the sedimentation, it may possibly be pointed out that the northern and southern provinces were under considerably different conditions from each other in some ages, e.g. in the Paleogyliakian and early Paleohetonaian ages. Furthermore, at least in the Miyakoan, Gyliakian, and Hetonaian epochs the eastern part of the basin was under unstable condition in distinct contrast to the western part where a rather stable condition was maintained.

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(Written in March 1961)

要　旨

北海道中軸帯白堊系の堆積について

田　中　啓　策

筆者は，北海道中軸帯白堊系の層序および堆積を明らかにするために，これまでに (1) 石狩炭田空知背斜地域，(2) 留萠炭田小平蘂川流域，(3) 天北炭田上猿払地域，(4) 日高炭田東方富内地域，および (5) 石狩炭田幾春別川流域に発達する白堊系の調査研究を行なってきた。その結果，北海道中軸帯白堊系の層序および堆積についていくつかの新知見が得られたので，それらについて論述する。この報告は下記の三部からなる。

第1部では，小平蘂川流域（留萠郡小平村）の白堊系を，とくに堆積相に重点をおいて記述した。それは次のように要約される。

（1） この地域の白堊系は，下位から下部蝦夷・中部蝦夷および上部蝦夷層群に区分される。下部蝦夷層群は分布がきわめて狭いので，ここでは主として中部蝦夷・上部蝦夷層群を取り扱った。

（2） 白堊系の層相は，この地域の南方石狩炭田に発達する白堊系よりも，北方の天塩安平志内川流域のものに類似する。中部蝦夷層群最下部には粗粒堆積物が厚く発達し，この部分にたいして今回新たに金尻沢砂岩層の名称を与えた。さらに，岩相的に他層から容易に識別され，かつ鍵層となるものには，中部蝦夷層群最上部の最下部を占める中紀念別砂岩層，および上部蝦夷層群主部の下部を占める上紀念別シルト質細砂岩層がある。

（3） 中部蝦夷層群（最下部を除く）および上部蝦夷層群は，北海道中軸帯内の標準地域のものに較べて，全体としてより細粒で，砂質岩に乏しく，かつ凝灰質岩をひんぱんに挟む。また，ギリヤーク統上部階は，標準地域のものに較べてきわめて厚く，佐久層相当層（中部蝦夷層群最上部）の層序的範囲はかなり小さい。

（4） 堆積相の垂直的変化から，中部蝦夷・上部蝦夷層群を通じて一定の規模（層序的範囲および厚さ）をもった11層の〝堆積輪廻層〟を識別できる。これらの堆積輪廻層は，岩相・化石相の垂直的変化について一定の傾向を示し，相対的に浅い環境から深い環境への変化を反映している。

（5） 堆積相の水平的変化から，少なくともギリヤーク世新期以後，この地域の西側に供給地の存在が推定され，また南東部は沖合の，より深く，より大きく沈降した環境にあったことがいえる。なお，中紀念別砂岩層は堆積相の側方変化を最も顕著に示している。

（6） 化石相の解析にあたっては，とくにアンモナイトのイノセラムスにたいする量比，異常型アンモナイトの正常型アンモナイトにたいする量比，種々に形態を異にした正常型アンモナイト間の量比に注目し，またイノセラムス以外の二枚貝の産出をも考慮した。以上の点に基づいて化石相と岩相との相互関係を検討した。さらにアンモナイトの産出と堆積物の粒度との関係，およびイノセラムスにおける殻の形態上の差異と層序的産出順序との関係をも吟味した。

（7） 礫岩の礫種は，金尻沢砂岩層・中紀念別砂岩層および上紀念別シルト質細砂岩層との間にかなりの差異が認められ，とくに中紀念別砂岩層のものに同時礫が多いことは注目すべきである。白堊系の全層を通じて，砂岩の構成分として火山岩片の多いことは，この地域の1特徴である。また，堆積相の水平的変化に

関連して，中紀念別砂岩層の砂岩の岩石学的性質における水平的変化を検討した結果，両者の間には調和性がみいだされた。凝灰岩は流紋岩質のものから安山岩質のものまであるが，おもに石英安山岩質である。

（8） この地域は，少なくともギリヤーク世を通じて，北海道中軸帯白堊系の堆積盆地一蝦夷地向斜内の著しい沈降部であったと推察される。なお，中紀念別砂岩層における相の分布，同層の堆積期間中に同時侵食が行なわれたこと，および上紀念別シルト質細砂岩層にみられる異常堆積は注目すべき堆積現象である。

第2部では，小平蘂川流域以外の調査地域の白堊系を取り扱った。ここでは，層序および堆積上注目すべき事項に重点をおいて概要を記述するにとどめた。

第3部では，前述の調査地域の資料および従来の諸知識に基づいて，北海道中軸帯白堊系の層序および堆積の考察を行なった。層序については，岩相的層序単位を概述し，また，年代的層序単位を堆積相の観点から説明した。さらに“堆積輪廻”に基づく層序区分を論議し，これが層序学的記述の主題をなしている。堆積については，堆積相と堆積，堆積にたいする構造運動の制約，および堆積盆地の発展について論述した
これらを要約すると次のとおりとなる。

（1） 白堊系は従来より下位から下部蝦夷・中部蝦夷・上部蝦夷および函渕層群に区分されている。この岩相層序区分について若干の新知見を加えることができた。とくに，中部蝦夷層群最下部の層相，同層群最上部の佐久層およびその相当層の層相，上部蝦夷層群下部の層相，上部蝦夷層群中の局地的粗粒相（たとえば月見層），および標式的な函渕層群（砂岩相）と同年代の乳香川層（泥岩相）との中間的な層相などについてである。

（2） 年代的層序単位については，若干の重要化石（アンモナイトおよびイノセラムス）の層序的産出，とくにイノセラムス種の多産帯の層序的位置を述べた。また白堊系に認められる階または亜階の厚さおよび砂岩比にはある一定の限界ないし範囲があることを指摘した。たとえば，階の厚さは最大1,000 m内外に達する。

（3） 下部蝦夷層群から函渕層群までを通じて，堆積輪廻層に基づく層序区分を行なうことができた。下部蝦夷層群には2層，それより上位の地層全体を通じては12層が識別される。これらの堆積輪廻層は，一定の規模（層序的範囲・拡がり，および厚さ）をもち，また岩相・化石相の垂直的変化について一定の傾向を示す。たとえば，輪廻層の層序的範囲は一般に階から階の半分位までの大きさである。なお，ここでいう堆積輪廻層は，より大きい単位の3輪廻層にまとめられる。

（4） 堆積輪廻層における化石相の垂直的変化についてみると，標式的な場合，下半部では下位から貝相（アンモナイト・イノセラムス以外の貝化石が優勢）・アンモナイト相（アンモナイトが優勢），混合相（アンモナイトとイノセラムスとがほぼ同じ位に優勢），およびイノセラムス相（イノセラムスが優勢）が識別される。また，異常型アンモナイトは堆積輪廻層の下部に多く，上部では正常型アンモナイトが異常型アンモナイトよりも優勢になる。さらに，正常型アンモナイトでは，殼が厚く，強い装飾を帯び，かつ横断面が亜四角形または扁平な螺環をもつものが輪廻層の下部に優勢である。

（5） 堆積輪廻層の年代的位置は，北海道中軸帯全域を通じてほぼ同じ場合と，地域ごとにかなり異なる場合とがある。なお，輪廻層の厚さおよび砂岩比は，階および亜階の場合と同様にある一定の限界および範囲を示す。たとえば，輪廻層の厚さは700 mを超えない。

（6） 堆積輪廻層に基づく層序区分の適用を北海道中軸帯内の若干の地域および南樺太の白亜系について試み，また堆積輪廻層の成因を考察した。堆積輪廻層の生成には火山活動が関与していると考えられる。さらに，ここにいう堆積輪廻層と本邦の他地域における若干の白亜系に認められる堆積輪廻との比較検討をも行なった。

（7） 堆積相の巨視的にみた垂直的変化から，白亜系の堆積史には5段階，すなわち比較的均一な堆積を行なった3時期（宮古世古期—同世新期の前半，宮古世新期の後半—同世末亜期およびギリヤーク世新期の後半—浦河世）と分化的・差別的堆積を行なった2時期（ギリヤーク世古期—同世新期前半およびヘトナイ世）が識別される。

（8） 堆積相の広域的水平変化から，北海道中軸帯の北部区と南部区とで堆積相に大きな差異のあったことが指摘される。このことは，とくにギリヤーク統下部階・ヘトナイ統下部階の層相発達および砂岩比，さらに堆積輪廻層の年代的位置および層序的範囲についていえる。なお，北部区と南部区との境界をここでは旭川—留萠線と呼ぶ。

（9） 階または亜階の堆積相については，厚さ・岩相（砂岩比，特徴的な地層の発達状況など）と，化石相（瀕海ないし浅海棲二枚貝・異常型アンモナイト・正常型アンモナイトなどの多産）との間にはある一定の相互関係がみいだされる。堆積輪廻層の場合にも同様な傾向が指摘される。

(10) 白亜系の堆積には，周期的堆積が重要な役割を演じた。前記の堆積史の5段階に関連して，堆積輪廻層は年代的位置の同時性または異時性を示し，さらに層序的範囲・厚さなどを異にした。なお諸地域に，また種々の層準に異常堆積層が存在することは注目すべきである。

(11) 凝灰岩は下部蝦夷層群に乏しいが，それより上位の地層を通じて顕著に発達する13層準が認められる。凝灰岩は流紋岩質のものから安山岩質のものまであるが，そのうち石英安山岩質のものが多く，カルクーアルカリ岩系に属する。

(12) 白亜系堆積盆地—蝦夷地向斜—の西側には終始，また若干の時期では東側にも，供給地が存在したと推定される。堆積盆地内には，沈降部（最沖合部における最大沈降部，小平蘂地域における沈降部など）および隆起部（峯延曲隆帯など）が存在した。これらの沈降部・隆起部の生成および変遷は堆積盆地全体の変遷と密接な関連がある。

(13) 堆積を規制した構造運動には，周期的堆積，堆積盆地内における沈降部—隆起部の生成および変遷，さらに堆積盆地全体の形態・状態それぞれを規制した3様式のものが識別される。また，構造運動の強さおよび構造環境の時間的変化は前述の堆積史を規定した。

(14) 堆積を規制した構造運動の強さおよび構造環境は，堆積盆地の東部と西部とで，また北部区と南部区とで異なっていた。すなわち，西部ではむしろ安定した状態が終始保たれていたのに反して，東部はしばしば不安定な状態におかれた。堆積盆地は，ギリヤーク世古期では，北部区において全面的に沈降を続けたが，南部区では沈降状態と隆起状態とに分化していた。さらにヘトナイ世古期の前半では，北部区は浦河世と同様にひきつづき沈降状態にあったが，南部区では全面的に浅化した。

PLATES
AND
EXPLANATIONS

(with 3 Plates)

Plate I

Phyllopachyceras ezoense (YOKOYAMA)
Figs. 1a-b. 1a, Lateral view, ×1. 1b, Frontal view, ×1. Loc. NH738, upper course of the Kotambetsu. Hor. Ui, Upper Yezo group.

Tetragonites glabrus (JIMBO)
Fig. 2. Lateral view, ×2/3. Loc. NH122, upper course of the Nakakinembetsu-zawa, a tributary of the Obirashibe. Hor. Uf, Upper Yezo group.

Damesites semicostatus (YABE MS.) MATSUMOTO
Figs. 3a-b. 3a, Lateral view, ×1. 3b, Frontal view, ×1. Loc. NH467, middle course of the Obirashibe. Hor. Uf, Upper Yezo group.

Gaudryceras denseplicatum (JIMBO)
Fig. 4. Lateral view, ×1. Loc. NH138, middle course of the Nakakinembetsu-zawa, a tributary of the Obirashibe. Hor. upper part of Mn (Mn_2), Middle Yezo group.

Mesopuzosia yubarensis (JIMBO)
Figs. 5a-b. 5a, Lateral view, ×1. 5b, Peripheral view, ×1. Loc. NH110, middle course of the Nakakinembetsu-zawa, a tributary of the Obirashibe. Hor. Mo, Middle Yezo group.

Photo by Y. Masai

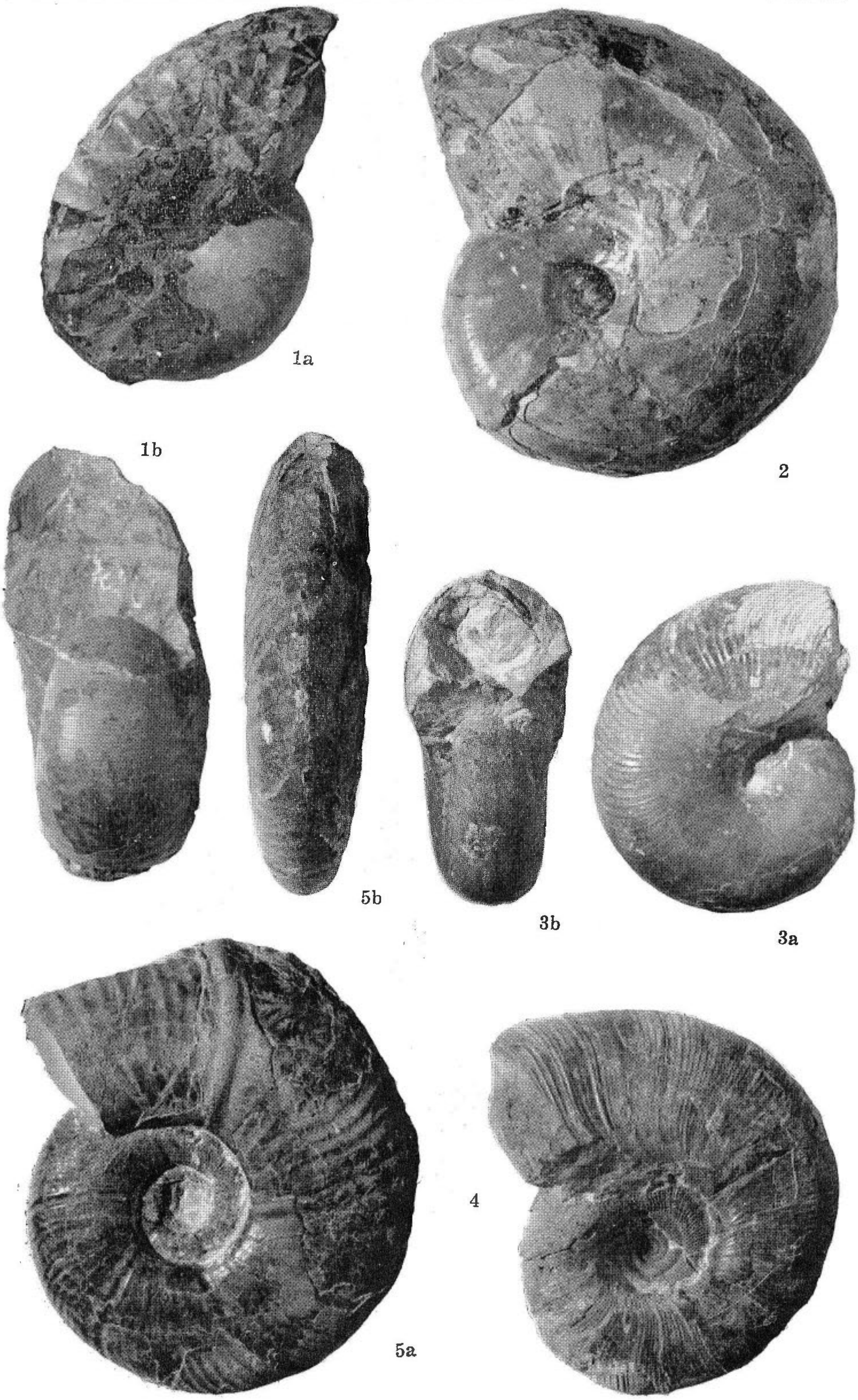

1a
1b
2
5b
3b
3a
4
5a

Plate II

Yokoyamoceras jimboi MATSUMOTO

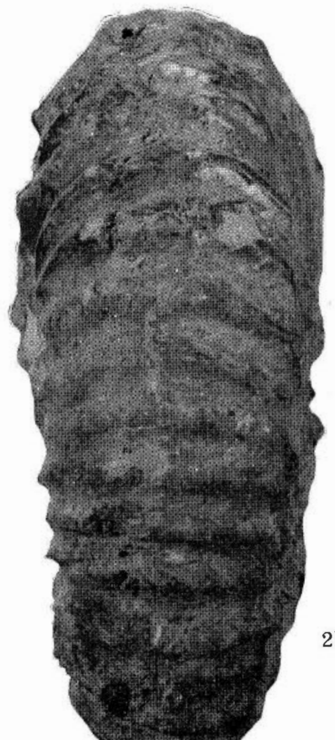
Figs. 1a-b. 1a, Lateral view, ×1.5. 1b, Peripheral view, ×1.5. Loc. NH473, middle course of the Obirashibe. Hor. Uf, Upper Yezo group.

Calycoceras cf. *orientale* MATSUMOTO, SAITO, and FUKADA

Figs. 2a-b. 2a, Lateral view, ×2/3. 2b, Peripheral view, ×2/3. Loc. NH608, upper course of the Obirashibe. Hor. middle part of Mf (Mf_2), Middle Yezo group.

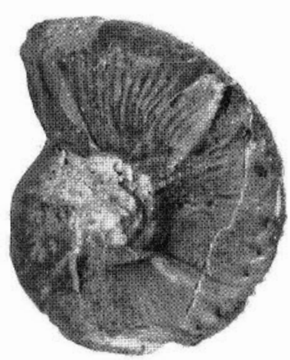
Photo by Y. Masai

2a



2b

1b



1a

Plate III

Menuites japonicus MATSUMOTO

Figs. 1a-b. 1a, Lateral view, ×1. 1b, Peripheral view, ×1. Loc. NH121, upper course of the Nakakinembetsu-zawa, a tributary of the Obirashibe. Hor. Uf, Upper Yezo group.

noceramus amakusensis NAGAO and MATSUMOTO

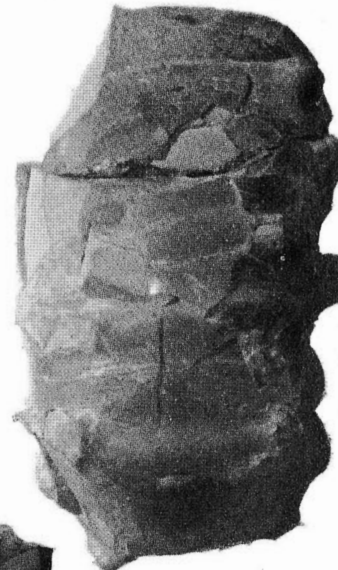
Fig. 2. Left valve, lateral view, ×2/3. Loc. NH29-c, Jugosen-zawa, a tributary of the Obirashibe. Hor. Ue, Upper Yezo group.

Inoceramus naumanni YOKOYAMA

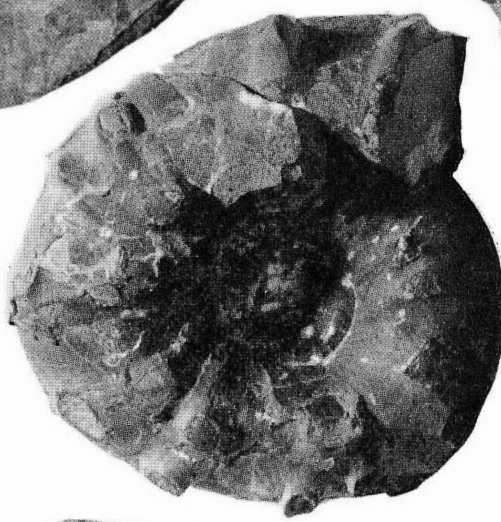
Fig. 3. Right valve, lateral view, ×1.5. Loc. NH467, middle course of the Obirashibe. Hor. Uf, Upper Yezo group.

Photo by Y. Masai

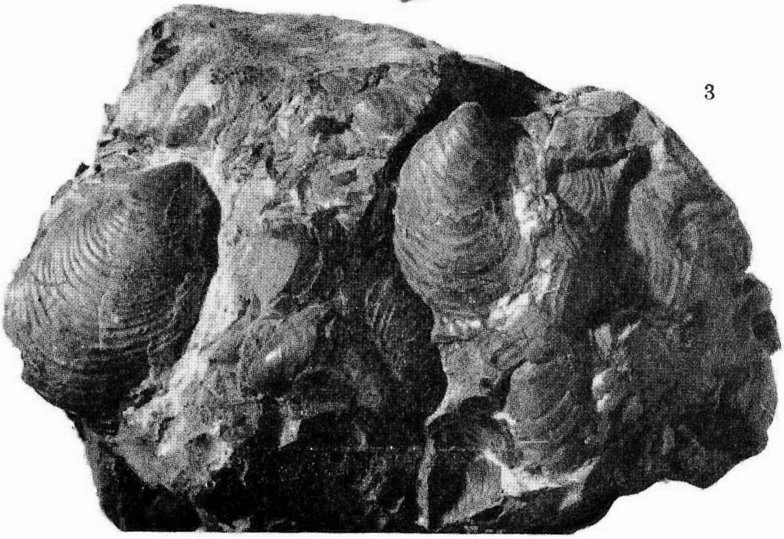
2



1b



1a



3

地 質 調 査 所 報 告

第192号
中村久由：本邦諸温泉の地質学的研究，1962

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Motojima, K., Maki, S., Makino, T., Itō, S. & Shibata, K.: On coal field gas from Shoro district, Hokkaido, 1962 (in Japanese with English abstract)

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- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B. 応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C. その他

D. 事業報告

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- b. Petrology and Mineralogy
- c. Paleontology
- d. Volcanology and Hot spring
- e. Geophysics
- f. Geochemistry

B. Applied geology
- a. Ore deposits
- b. Coal
- c. Petroleum and Natural gas
- d. Underground water
- e. Agricultural geology, Engineering geology
- f. Physical prospecting, Chemical prospecting & Boring

C. Miscellaneous

D. Annual Report of Progress

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A Study on the Cretaceous Sedimentation in Hokkaido, Japan

Keisaku Tanaka

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Part I: The Cretaceous deposits along the Obirashibe Valley are described with special reference to their sedimentary facies. Part II: An outline of the Cretaceous rocks in the areas surveyed by the writer other than the Obirashibe area is given, with some remarks on special features. Part III: General account is presented on the stratigraphy and sedimentation of the Cretaceous sequences in the meridional zone of Hokkaido; the sedimentary cycles are stressed among stratigraphical problems, and analysis of the biofacies is a main subject of this paper.

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