FUNDAMENTALS IN THE CRETACEOUS STRATIGRAPHY OF JAPAN PARTS Ⅱ & Ⅲ

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FUNDAMENTALS IN THE CRETACEOUS STRATIGRAPHY OF JAPAN

PARTS II & III *

By

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* Part I of this article is contained in Vol. I, No. 3 of this Memoir.

PART II

STRATIGRAPHIC CLASSIFICATION OF THE CRETACEOUS DEPOSITS IN THE MERIDIONAL ZONE OF HOKKAIDÔ AND KARAHUTO

From the facts made available as mentioned in Part I, it is now possible to deal with the general problem of stratigraphic classification of the Cretaceous deposits in the meridional zone of Hokkaidô and Karahuto. This classification will be done in two distinctly separate ways, one from the purely chronologic standpoint, the other being a stratigraphic classification from the standpoint of facies-development. I shall begin with the former problem, reserving the latter for the last chapter.

Chapter I

The True Range of Species

Introduction
Basic facts
Standard sections
Biostratic data from several standard sections
Time-range of the important species

Introduction.——For the chronologic classification of strata the biostratigraphic method is the most useful, and the one most available, especially in the case of such richly fossiliferous deposits as those under consideration.

Although in biostratigraphy, subdivision of strata is usually based on differences in both the lithologic characters and the fossil-contents, or solely on differences in the fossil-contents, irrespective of lithologic characters, these empirical methods usually need reexamination as to whether or not they do exactly represent chronologic division of strata.

The **Fossil-contents** of a formation depend on various factors which may be grouped into three categories, namely, (1) *the chronologic factors affecting the organisms*, i.e., *their evolutional* *history*, (2) *the ecologic, the chorologic, and other biologic factors affecting organisms*, and (3) *the processes of sedimentation and fossilization of the organic remains.* Consequently, the assemblage of fossils by itself does not always directly indicate the character of a fauna or flora, nor do their successions necessarily represent their evolutional history. Through analysis and deduction, however, it is possible to recognize each of these three factors. From the observed facts, I shall now attempt to avail myself of these two methods in order to arrive at the chronologic factors affecting the organisms and thus ascertain the true time-range of the important species, and with the aid of the knowledge gained regarding their evolutional history, construct a chronologic scale.

Basic facts.——Before proceeding with this study it is necessary to note the following basic facts: the Cretaceous deposits of the meridional zone of Hokkaidô and Karahuto are those of a continuous area of sedimentation belonging to a single unit of a biogeographic province, the life-period of each species within the province being constant and not variable with place.

The foregoing, however, is virtually an indisputable fact, seeing that strata distribution are fairly continuous, and that the strata in the different localities within the area under discussion, ignoring local and minor differences, have much in common both in stratigraphic sequence and in rock-facies. The deposits, furthermore, are mostly marine sediments, yielding everywhere similar fossils.(1)

From what we know of the chorology of recent and geologic times, it is recognized that organisms are distributed over a certain limited area, forming a number of biogeographic provinces throughout the world, these arrangements of biogeographic provinces, often changing with time, and that an organism has not necessarily the same time-range of existence everywhere, for example, appearing early at one place and disappearing late in another.(2) But within a biogeographic province of such extent as that under

(1) Owing to scantiness of fossils, in this paper, the lowest group of Mesozoic strata in the region under consideration is omitted from the exact chronologic problem.

(2) Largely because of differences in the world's physiographic conditions and in those of evolutional phenomena of organic life, an organism does not necessarily appear or disappear contemporaneously everywhere, so that notwithstanding the

discussion, the appearance and disappearance of a species or a genus is usually contemporaneous everywhere, geologically speaking, provided, of course, that all the other ecological factors are constant.

Standard sections.—— With the preceding facts as basis, and from biostratigraphic studies of *ideal sections,* we can know the life-period of species, its relative duration, and its order in time compared with those of the different species, all of which, though, are in connection with the province under review.

What I call here an ideal section is that locality which satisfies the following conditions, namely, (1) in which there is continuous development of strata, that is, there is no break in sedimentation nor any omission of strata, owing to unfavourable structural behavior; (2) the series of strata is fossiliferous throughout its entire thickness. The conditions of sedimentation of organic remains and those of fossilization has been both constant throughout the entire series as well as favourable for the preservation and yielding of fossils; (3) the ecological conditions of the fossil-organism were constant throughout the entire series, and if they changed at all, the defect in record has been supplemented by processes of sedimentation and transportation of the organic remains.

If there is an ideal section completely satisfying all the foregoing conditions, the chronologic changes of organisms should show themselves directly on the succession of fossil-contents. Unfortunately, no such ideal locality can be found in the area under consideration; there are, however, a few sections which closely approach the ideal, and we can, besides, fill the consequent deficiency in knowledge with data from other localities. Suitable sections and localities have been selected and their respective stratigraphies described in detail in Part I, namely, (1) the Naibuti district, or the Mid-valley of the Naibuti, and adjacent area, in the southern part of Japanese Karahuto, (2) the Abesinai district, province of Tesio, northern part of middle Hokkaidô, (3) the so-called Isikari Coal-field, especially the Siyubari district along the upper valley of the Yubari, province of Isikari, central Hokkaidô, (4) near Hetonai, along the Mukawa, province

ability of animals to rapidly migrate (s. str.), as proved by countless examples, the life-period of an organism in one province sometimes differs from that in another.

of Iburi, southern part of central Hokkaidô, and (5) near Urakawa, province of Hidaka, southern part of median Hokkaidô.

Biostratigraphic data from standard sections.——The biostratigraphic data necessary for solving the problem may be summarized from a description of Part I, based on observations of the standard localities just mentioned, as follows:

(1) *The Naibuti district.*

From the facts given in detail in Part I, we get the following Tables and charts (Table I and Figs. 1–3). The first Table gives the stratigraphic sequence and occurrence of fossils in concise form. The charts indicate clearly and accurately the stratigraphic distribution of the important species.

Of standard sections, that of Naibuti valley comes nearest the ideal. As shown in the first Table, the fossiliferous strata have accumulated without any noticeable break, and is exposed continuously, except its lower limit, which is not exposed, owing to faulting. The deposits are mostly those of the neritic sea, the whole thickness of the Miho Group, formations Rayl, Rby, and Rdy of the Ryugase Group, and formations Kx and Ky of the Kawakita Group consisting of fine-grained sediments. Conditions were not only the most favourable for deposition and preservation of organic remains, but also the yielded fossils are remains of marine invertabrates which are said to stand the best chances for preservation. Considering, besides, the ecological conditions, those represented on the rock-facies are fairly constant. The sediments were formed under a similar environment which continued for a considerable period of time. If there were any differences in the ecologic distribution of organic life, owing to the pseudoplanktonic distribution of many ammonoid shells, they did not markedly influence the occurrence of organic remains in the sediments.

Notwithstanding these favourable conditions, the material cannot be said to be ideal, because both the rock-facies and the mode of fossil-occurrence are not rigidly constant throughout the entire thickness, as will be noticed by the differences in the main part of the Kawakita Group from that of the Miho Group, and in those between the Miho Group and the formations Ray2, Rcy, Rey, and Rfy of the Ryugase Group. Since, in these cases, the

TABLE I

Generalized stratigraphic Succession of the Cretaceous strata in the Naibuti Valley and its adjacent area, South Karahuto.

Stratigraphic division		Thickness in m.	General lithologic character	Occurrence of fossils.	Fossil-zone
Palaeogene			Conglomerate, sandstone and coal Parallel unconformity		
Ryûgase Group	Rfy	50+	Dark coloured siltstone or fine-sandstone	Very rare	
	Rey	50−	Sandstones of various degrees of coarseness, stratified, tuffaceous in part.	Not yet discovered	
	Rdy	110	Dark coloured siltstone or fine-sandy mudstone, with occasional intercalation of thin marly layer and with nodules. Green sandstone is intercalated in the upper part.	Common	Rdy 2β Rdy 1
	Rcy	90	Greenish sandstone of various degrees of coarseness, including silty fine-sandstone in the upper part.	Found at two horizons in the upper part	Rcy 2 {γ, α}
	Rby	70	Dark coloured fine-sandy mudstone with marly nodules.	Fairly common	Rby
	Ray	270	Green sandstones, andesitic and glauconitic, mainly coarse and partly fine-grained (especially in the upper and the lower parts).	Common in the upper part, rather rare in the middle, and extremely rich in ther lower	Ray 3 Ray 1 {γ, β, α}
	Mh–Ry	20	Concretionary silty rock. Volcanic conglomerate and sandstone.	Sometimes found in the nodules	Mh–Ry

Miho Group	Mh	2700	Argillaceous rock, mostly composed of grey mudstone, rich in marly nodules and in marine molluscan fossils. Beds of sandstone and laminae of marly fine-sandstone and of bentonite are sometimes intercalated. Although fossils generally abundant, there are fossiliferous parts and less fossiliferous ones of various dimensions in lenticular or in bed-like form. Each of these zones characterized by a certain assemblage of species.			Mh 7 Mh 6 {β, α·β, α} Mh 5 Mh 4 Mh 3 Mh 2 Mh 1
	Mho	100±	Fine-sandy mudstone with nodules, bluish or greenish dark grey.		Abundant	Mh 0
Kawakita Group	Kz	200	Greenish fine-sandstone with calcareous nodules.	(Ai-kawa valley) Greenish-grey sandstones predominant, with subordinate conglomerate, shale and alternations of sh + ss. (K'w)	Fairly common	Kz-Mh
			Sandstone and shale in alternation, sandstone, and conglomerate. Lateral change of facies is found.		Found sporadically except for the upper fossiliferous part	Kz-1
	Ky	150—300	Mudstone with nodules, laterally changed to thin bedded sandstone and shale in alternation.		Common	Ky
	Kx	600—450	Shale with nodules, sandstone and shale in alternation, sandstone and conglomerate. Lateral change of facies and local erosion notable.		Not selden found in the argillaceous layers	(Kx)
	Kw	200 –	Greenish-grey sandstone containing carbonaceous flakes.		Not yet found	
Lower Ammonite Group (Kv)		500+ | 1500+	Shale or shale and sandstone in frequent alternation. Sandstone, sometimes tuffaceous, is intercalated.		Rare	

Lower limit unexposed, owing to faulting

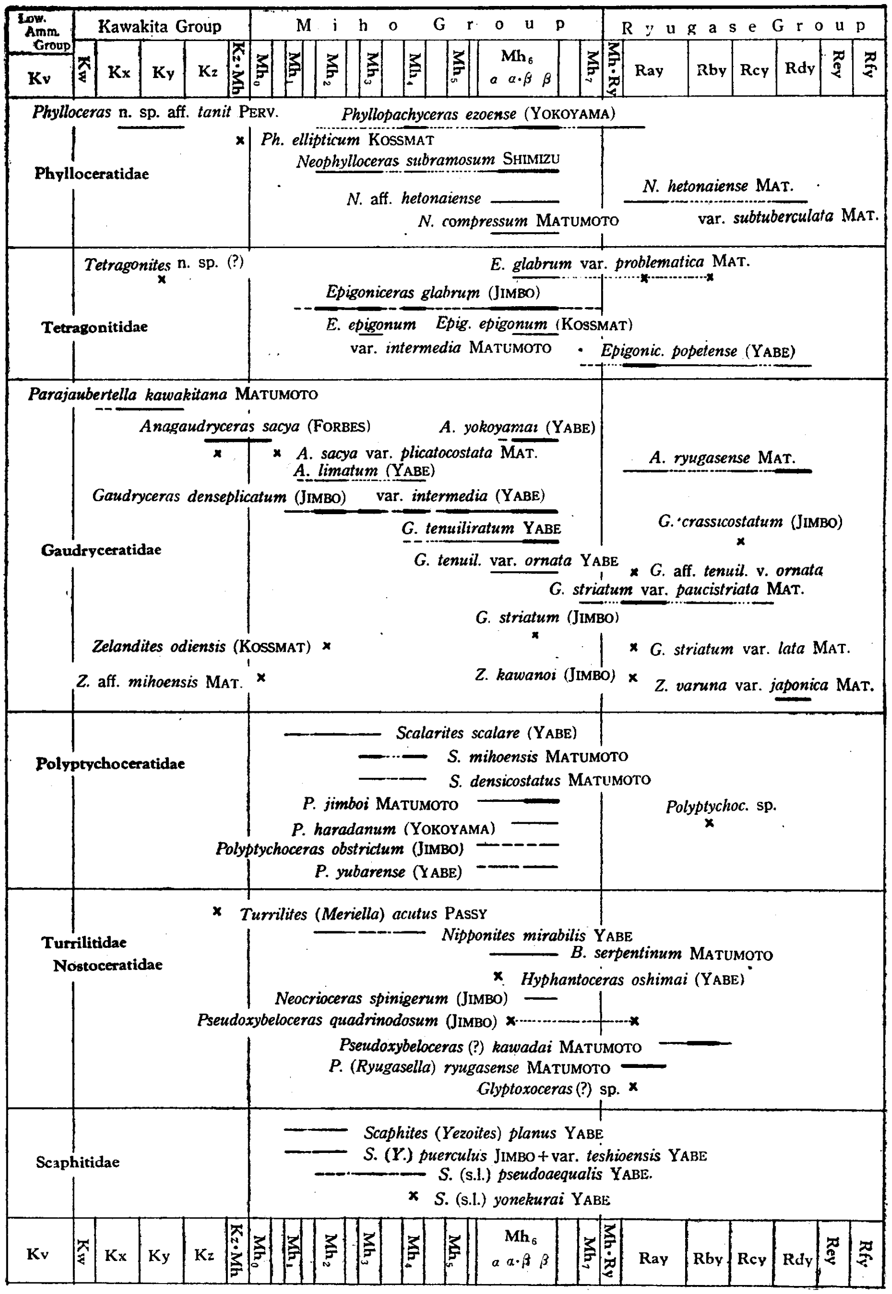

Fig. 1 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Naibuti district —— Ammonoidea I

Horizontal lines are the apparent stratigraphic ranges of species, thick lines indicate abundant occurrence, broken lines mean that the occurrence of the species in question is represented by the ill-preserved specimens which are presumably referable to it, and dotted lines that the specimen has not yet been discovered, but certainly existed at the time of deposition of the strata concerned. Rare occurrence is shown by the sign x. These explanations apply also to Figs. 1—13.

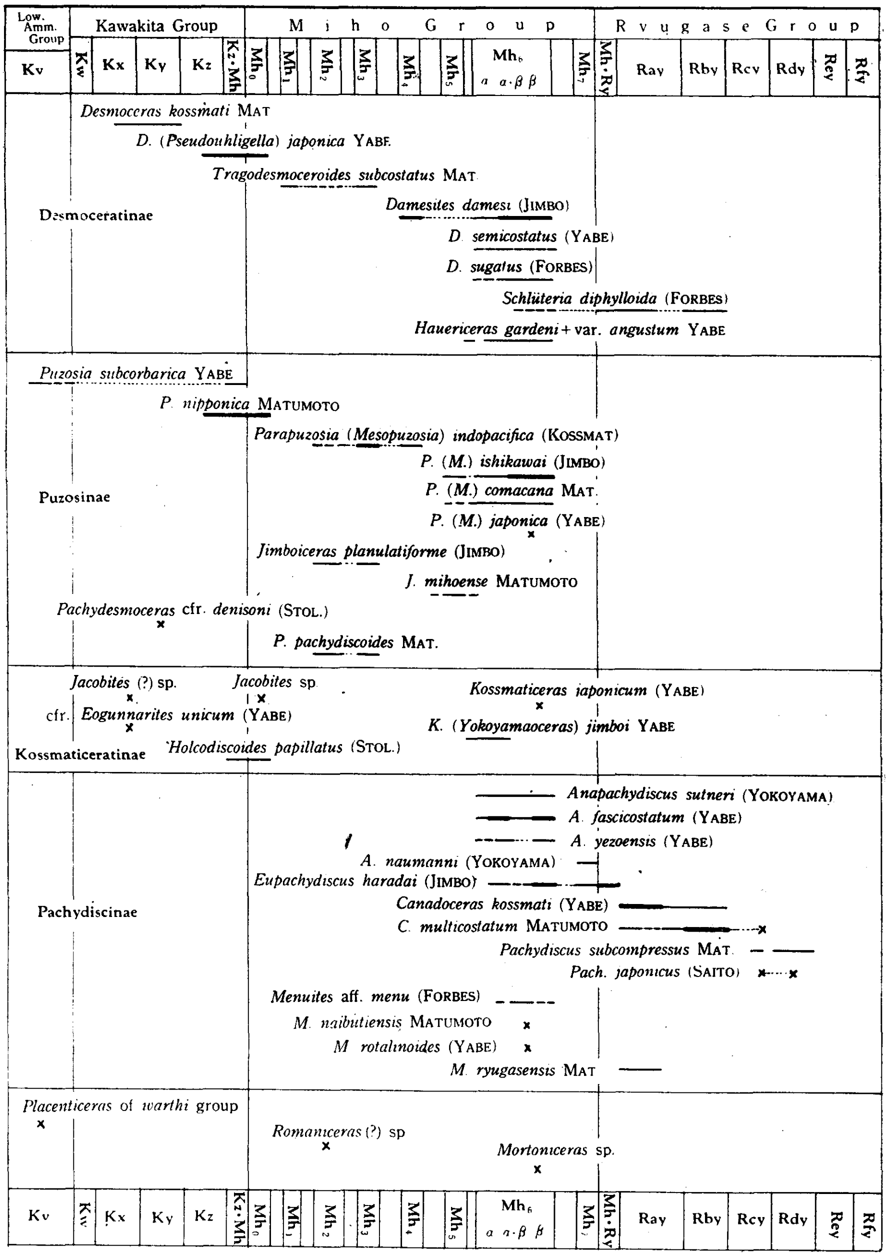

Fig. 2 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Naibuti district.—Ammonoidea II

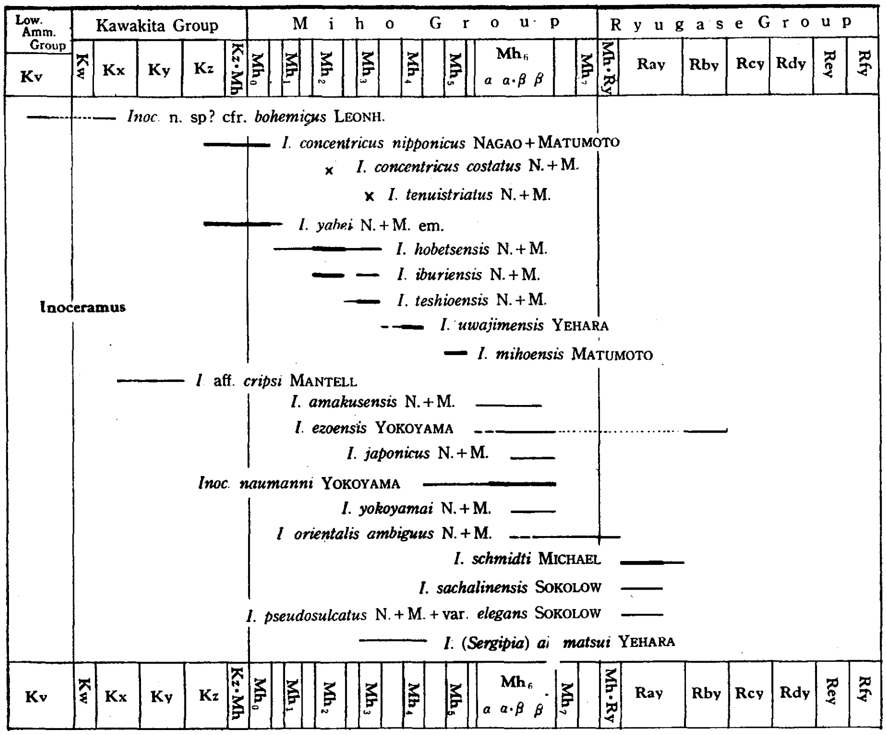

Fig. 3 Stratigraphic occurrence of the species of *Inoceramus* in the Cretaceous deposits of the Naibuti district.

ecologic conditions and the factors for fossilization in formations of different lithological characters were probably dissimilar, it is not possible to decide readily whether the marked differences in fossil-contents, for example, between the upper part of the Miho Group (Mh6) and the lower part of the Ryugase Group (Ry–Mh and Ray1), represents a rapid change in the evolutional history of organic life or whether it merely represents a change in ecologic environment. Even in the case of sediments of like character, differences in the factors for distribution of organisms is possible, seeing that some of the factors (e.g. nature of the medium, nourishment, local currents, etc.) do not always leave their marks on the character of the sediments.

For these reasons, the stratigraphic distribution of some of the important species shown in the *standard section*, being apparent range, may not represent the true range of species. Ambiguity and deficiency in knowledge of this kind should be satisfied with data from other sections.

(2) *The Abesinai district.*

Summarizing the observed facts as stated in Part I, we represent here in tabular form the sequence of strata, occurrence of fossils, and the stratigraphic distribution of the important species in connection with the Cretaceous of the present district (Table 2, Figs. 4–6).

This area is one of the standards, if not quite ideal. Generally speaking, strata of rather similar rock-facies (i.e. the Ammonite Group) are developed continuously and, except for the lower part (Onisasi Group and Lower Ammonite Group), are either fairly or richly fossiliferous. In the middle of the Ammonite Group, we find two formations of rather different character, being what are called the Saku Formation and the Omagari Formation. Fortunately, however, the coarse-grained sedimentaries of the Saku Formation are frequently intercalated with fine-grained rocks which, in turn, have both their lithologic characters and features of fossil-occurrence similar to those of the proper part of the Ammonite Group. The Omagari Formation also comprises a member consisting of fine-grained sediments, although this last occurs less frequently. Besides, the processes of transportation and deposition of the organic remains seem to have been favourable enough to furnish us with some data even from these formations. (Full details will be found in the descriptions in Part I.) Consequently, notwithstanding the minor changes in rock-facies and the intermittent occurrence sometimes of fossils, the Middle and Upper Ammonite Groups of the present district give us some information in connection with the chronologic occurrence of the fossil-species. The most important data here are that (1) we find a parallel in the Naibuti and the Abesinai districts in the range of species, the relative length of the range, and in the order of occurrence. Examples of the species are those belonging to the Gaudryceratidae, the Tetragonitidae, the Phylloceratidae, certain other ammonoid families, and *Inoceramus*. These are mostly represented by numerous specimens, the group occuring at every horizon. We are here undoubtedly dealing with the true, or a nearly true,

Table II

Generalized stratigraphic succession of the Cretaceous Strata in the Abesinai Valley and the Mid-valley of the Tesio, Northern Hokkaidô.

Stratigraphic division (Major)	(Minor)	Thickness in m.	Lithological character	Occurrence of fossil	Fossil-zone
Miocene Wakkawenbetu Formation			Massive sandstone, with conglomerate and sandy mudstone.	Kawabata "fauna"	
			(Unconformity, apparent parallel)		
IV. Hakobuti Group (in part)		6–150	Sandstone	Rare	
III. Upper Ammonite Group. Fine-grained and monotonous sediments rich in concretions and fossils of ammonite, *Inoceramus*, etc. A formation of minor or local unit, characterized by frequent occurrence of coarse-grained rock, is intercalated in the lower middle part: i. e. the Omagari Formation.	IIId+e	150–200	Siltstone or very fine-sandy mudstone.	Abundant	1IIe
		2000 (±)	Greensandstone occurs in the upper part.	Abuudant	IIId
	IIIc	200 (+)	Mudstone, with a bentonitic tuff	Not abundant	(IIIc)
	IIIb	250 (+)	Greywacke-sandstone, sandy-mudstone, and mudstone; often thick bedded in the upper part and thin bedded in the lower part; local conglomerate in subordinate amount.	Fossiliferous bed is intercalated at several horizons.	(IIIb)
	IIIa	200 (+)	Mudstone	Common, at least in part.	IIIa
			(Conformable)		

II. Middle Ammonite Group	Comparatively fine-grained and homogeneous sediments containing concretions and fossils of ammonites, *Inoceramus*, etc. In the upper part, beds of coarse-grained, sedimentary rocks occur frequently, resulting in formation of minor unit. i.e.	Saku Formation	IId	400–450	Thin bedded fine-sandy mudstone, mudstone, and sandstone in frequent alternation predominant, with intercalated thick bedded sandstone, mudstone, and intraformational conglomerate.	Details of rock-facies change at places. (α, β, γ, δ)	Generally not rare, very abundant in some parts	IId
			IIc (IIb–c)	150–300	Mudstone, partly fine-sandy.		Not abundant / Common	IIc (β, γ,) IIb–c / IIc(α)
			IIb	370	Siltstone, or fine-sandy mudstone		Abundant or Common	IIb + Uppermost IIa
			IIa	250	Mudstone		Rare	
					(Comformable, but with rapid change of facies)			
I. Lower Ammonite Group				Ca 2000	Thin bedded shale and sandstone in alternation, shale or mudstone; with predominant sandstone and some conglomerate in the lower part.		Rare	
					(Relation not accurately investigated)			
O. Onisasi Group				Thick	Older pyroclastic sedimentary rocks, cherts, shale and sandstone.		Radiolarian remains in chert.	

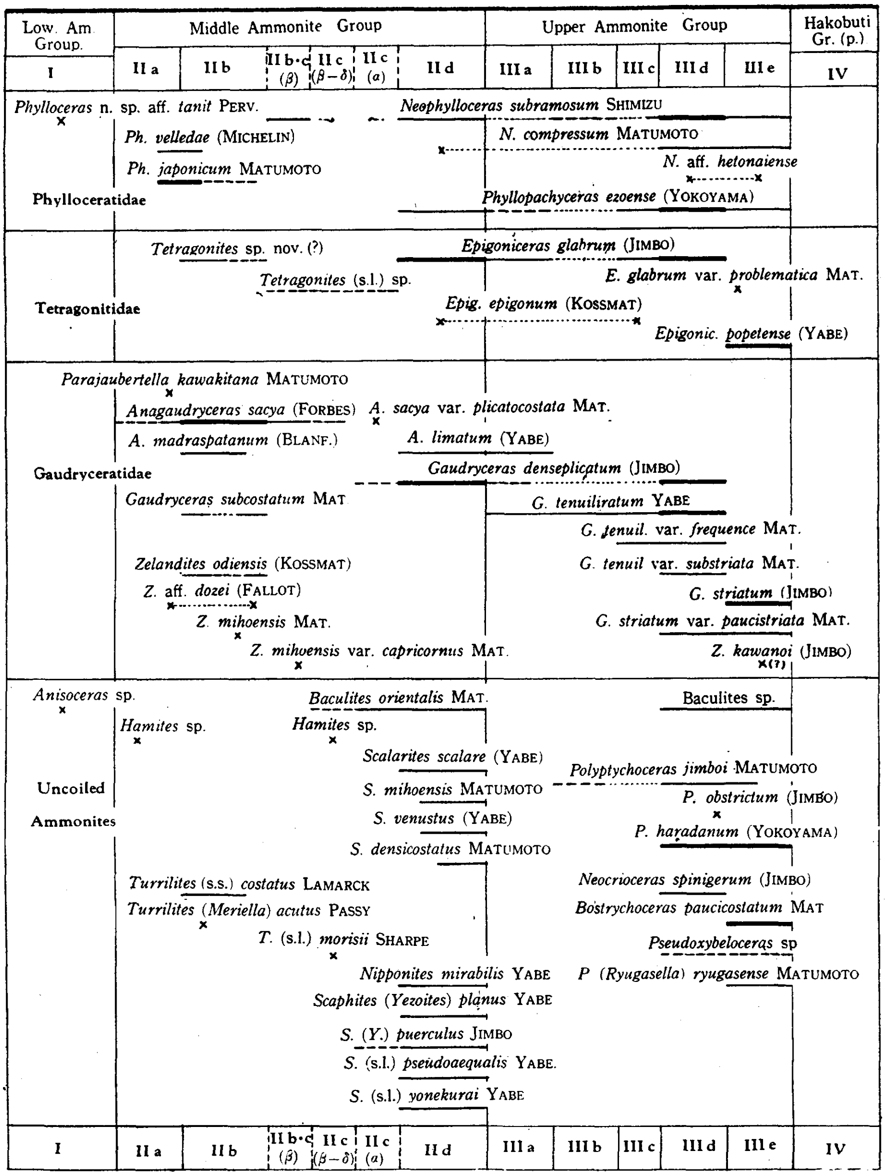

Fig. 4 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Abesinai — Ammonoidea I

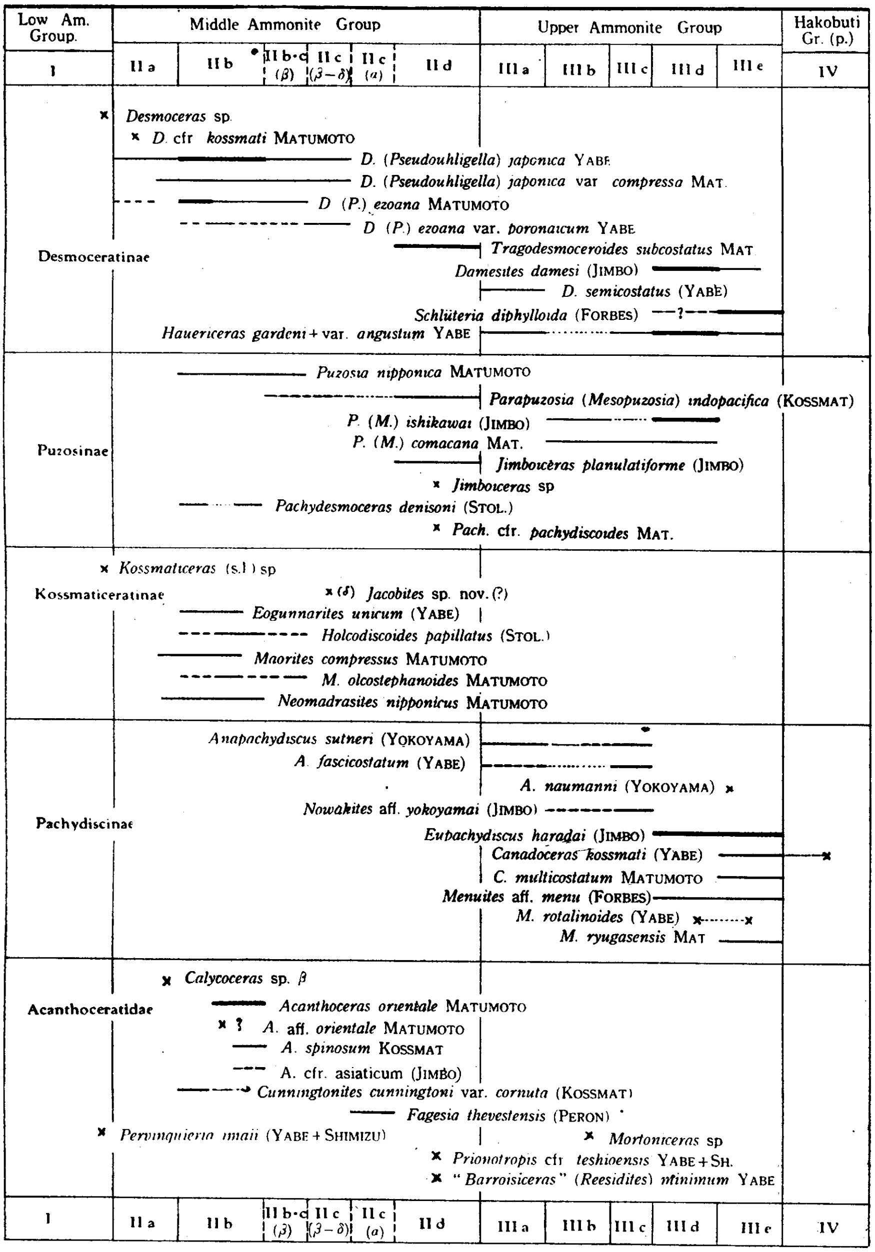

Fig. 5 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Abesinai district — Ammonoidea II

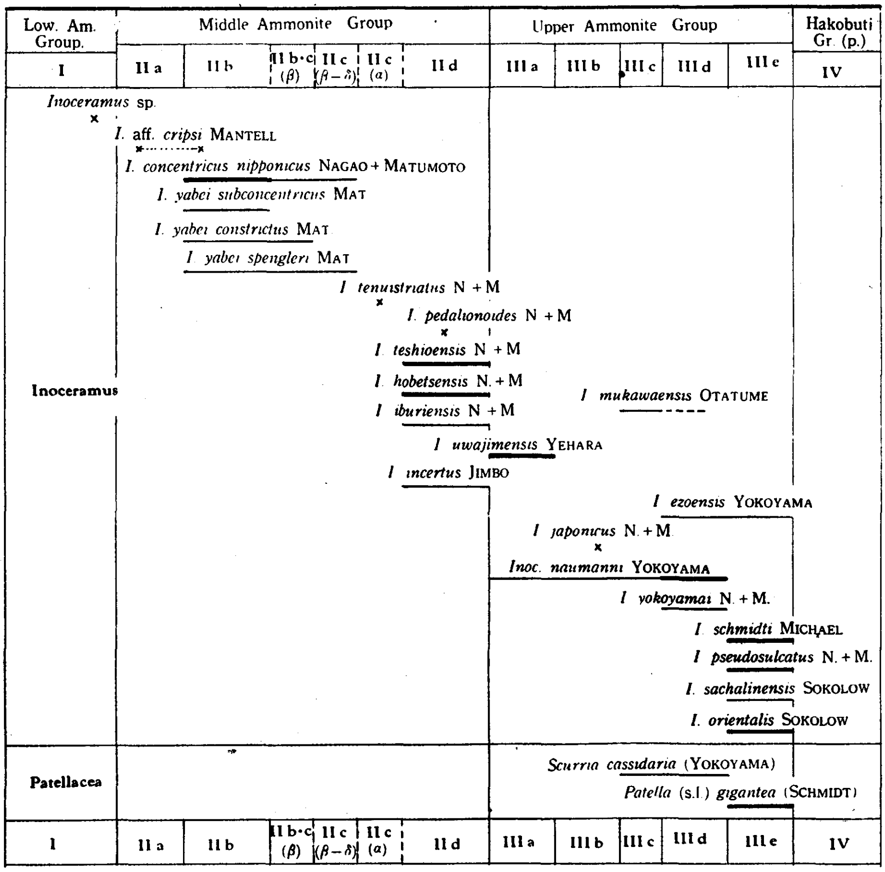

Fig. 6 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Abesinai district—*Inoceramus* and the Patellacea

range of species; (2) with the aid of the preceding knowledge it is possible to distinguish in certain other species the apparent range from the true range. For example, the vertical range of *Damesites semicostatus*, *Hauericeras gardeni*, and *Anapachydiscus* spp. shown in the section of the Miho Group of the Naibuti district, is only apparent, while in the strata of the Abesinai district, these forms have a longer vertical range, probably showing the true range. The converse is true of the range of *Damesites damesi*, shown in two districts; (3) a number of species that either occur rather sparsely or are entirely absent from the Naibuti district, namely, those of *Acanthoceras, Turrilites* (s. 1.), *Desmoceras*, its allied form, etc. Besides, we could gain certain knowledge of the stratigraphic occurrence of these forms, such as those given in the Table; (4) the ambiguity that was pointed out in the paragraph headed *The Naibuti District*, in connexion with the occurrence of fossils from the upper part of the Miho Group and the lower part of the Ryugase Group, has been clarified in the case of the present district. That is, the assemblage of fossils in the Ry—Mh+Ray 1 of Naibuti and the IIIe of Abesinai, and that in the Mh 6 of Naibuti and the III d of Abesinai are very similar; lithologically, III e and III d have the same character, while Ry—Mh+Ray 1 and Mh 6 differ. It will thus be seen that the marked change in the assemblage of species from one horizon to the other, in this case, is certainly chronologic, if other factors are not absent at all. This question can be reexamined in connexion with another district, the Urakawa, which, in turn, provides us with additional accurate and precise knowledge. Although the data from the present district contribute much to our solution of the problem, there are still certain information lacking. (1) The uppermost part (main part of the Hakobuti Group) is absent from the present district; (2) contrary to the fossiliferous Upper and Middle Ammonite Groups, the Lower Ammonite Group is not only poor in fossils, but its rock-facies differs somewhat from that of the two groups, with the result that the question whether or not the species occuring in the lower part of the Middle Ammonite Group extends, in its true vertical range, still further downward is yet undecided, (3) as described in detail in Part I, in the upper half of the Middle Ammonite Group, incongruence occurs between the stratigraphic succession on lithologic grounds and the sequence of fossils, this part, moreover, having local differences in rock-facies and in fossil-contents, all of which prevent exact determination of the true range of certain species.

(3) *The Siyubari district.*

Being also one of the standard sections, this one is particularly important in that it supplies the biostratigraphic data to fill the deficiencies (2) (3) in our knowledge mentioned in the preceding paragraph.

The stratigraphic sequence exposed in the area surveyed is

Table III
Generalized Stratigraphic Succession of the Mesozoic Rocks in the Si-yubari District, Central Hokkaidô.

Major division		Subdivision	Symbol	Thickness in m.	Occurrence of fossils
Habobuti Group (Distributed outside of the district)					
Upper Ammonite Group Dark grey mudstone or shale of monotonous and homogeneous character, containing abundant concretions and generally rich in fossil of ammonites and *Inoceramus*. Rarely a bed of calcareous sandstone and more frequently thin layers of white tuff occur.		Upper fossil-zone	IIId	?	Very abundant
		Intermediate part	IIIc	?	Common
		Lower fossil-zone	IIIb	100	Abundant
		Lowest part	IIIa	300	Rare
(Conformable, with gradual change of facies)					
Middle Ammonite Group Comparatively fine-grained sedimentary rocks predominating. Many nodules are contained. White tuff sometimes occur as an intercalated thin layer. The uppermost part, 400 m. thick, is characterized by frequent occurrence of more coarse-grained rock, being composed mainly of alternating shale, sandy mudstone and sandstone. This is the equivalent of the Saku Formation in the Abesinai district.	Saku Formation	Subdivisible in 6 members on account of detailed lithological characters.	IIs	50	Abundant
			IIr	70	
			IIq	50	
			IIp	30—50	Rare
			IIn	100	Abundant
			IIm, m′	100(−)	Not rare
		(Gradual change of facies)			
	Main part	Lithological character essentially similar to that of the Upper Ammonite Group. Total thickness ca 2,400 m. Subdivisible on account of details in grain-size or of frequency of the intercalated thin laryes of fine-sandstone.	IIk	120—200	Common
			IIj	250—150	
			IIi	50—70	Rare
			IIh	250	Not rare
			IIg	250	Not common
			IIf	450	Common
			IIe	50	Not rare
			IId	400	Common
			IIc	80	Not comom
			IIb	500	
		Basal sandstone, with a local conglomerate and siliceous shale.	IIa	50—20	Not yet found

— (Comformable, but partly disconformable) —

Lower Ammonite Group Alternations of shale and sandstone or sandstones, generally thin bedded. Sandstone predominates in the lower part. Except for the organic limestone in the middle part, very few fossils. Thickness 1300 m.	Concretionary siltstones or fine-sandy shale	If	120	Rare
	Sandstone and shale	Ie	60	Not yet found
	Thin bedded shale and sandstone in alternation	Id	150	Rare
	Orbitolina-limestone and fine sandstone	Ic	100(−)	Abundant
	Thin bedded shale and fine sandstone in alternation	Ib	350	Not yet found
	Thin bedded sandstones	Ia	500(−)	Poor plant remain
— (Conformable, at least in part) —				
Onisasi Group A peculiar group of formations composed of cherts, siliceous shales, greywackes, tuffite, and sandstones. Radiolarian remains occur in the cherts and siliceous shale. Relation to the schalstein formation which is developed outside of the surveyed area not yet fully investigated	Siliceous shale	Oz	350	Macroscopic fossils not yet found
	Andesitic greywacke and tuffite	Oy	70	
	Cherts and calcareous chert	Ox	230	
	Andesitic greywacke and tuffiite	Ow	100	
	Red chert	Ov	200	
	Vitric tuff and tuff-breccia	Ou	35	
	Compact sandstone and siliceous shale	Ot	?	

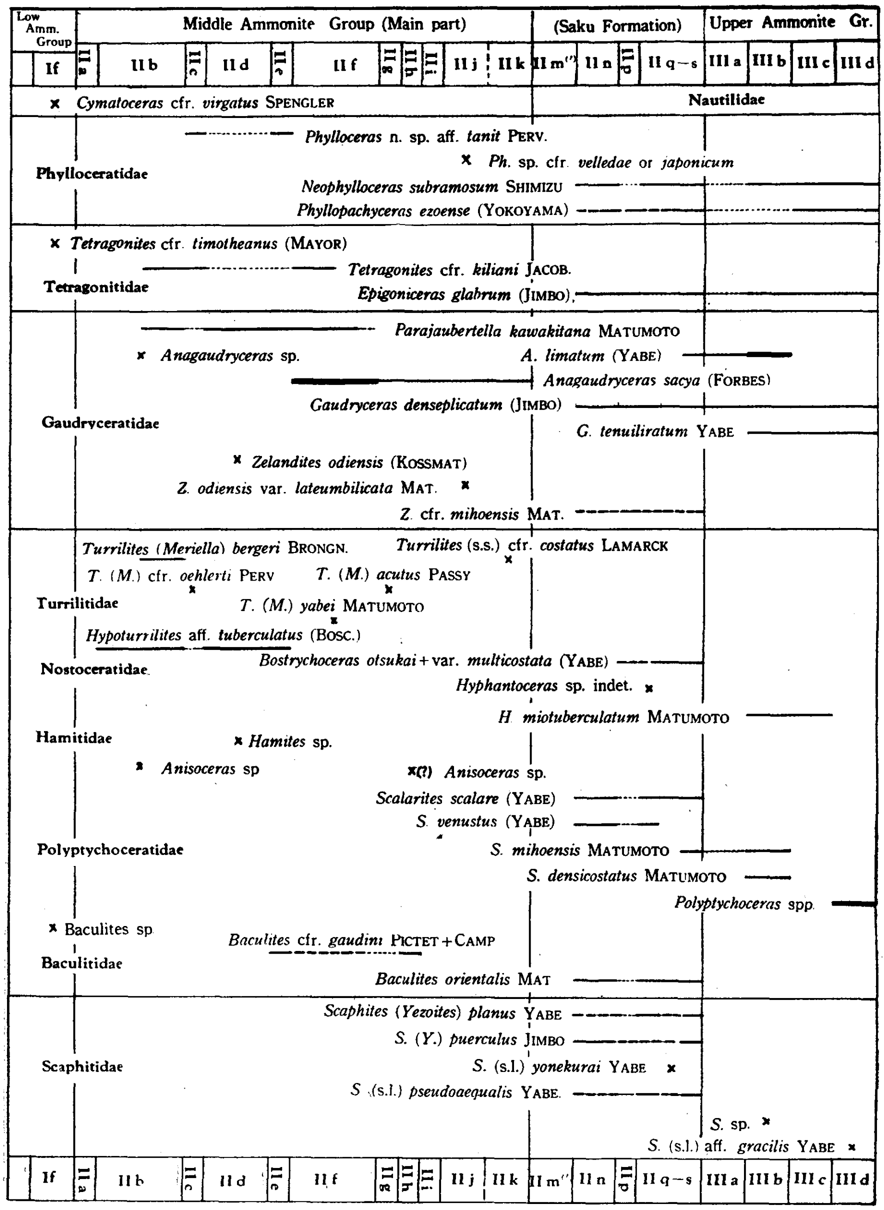

Fig. 7 Stratigraphic occurence of the important species in the Cretaceous deposits of the Siyubari district — Cephalopoda I

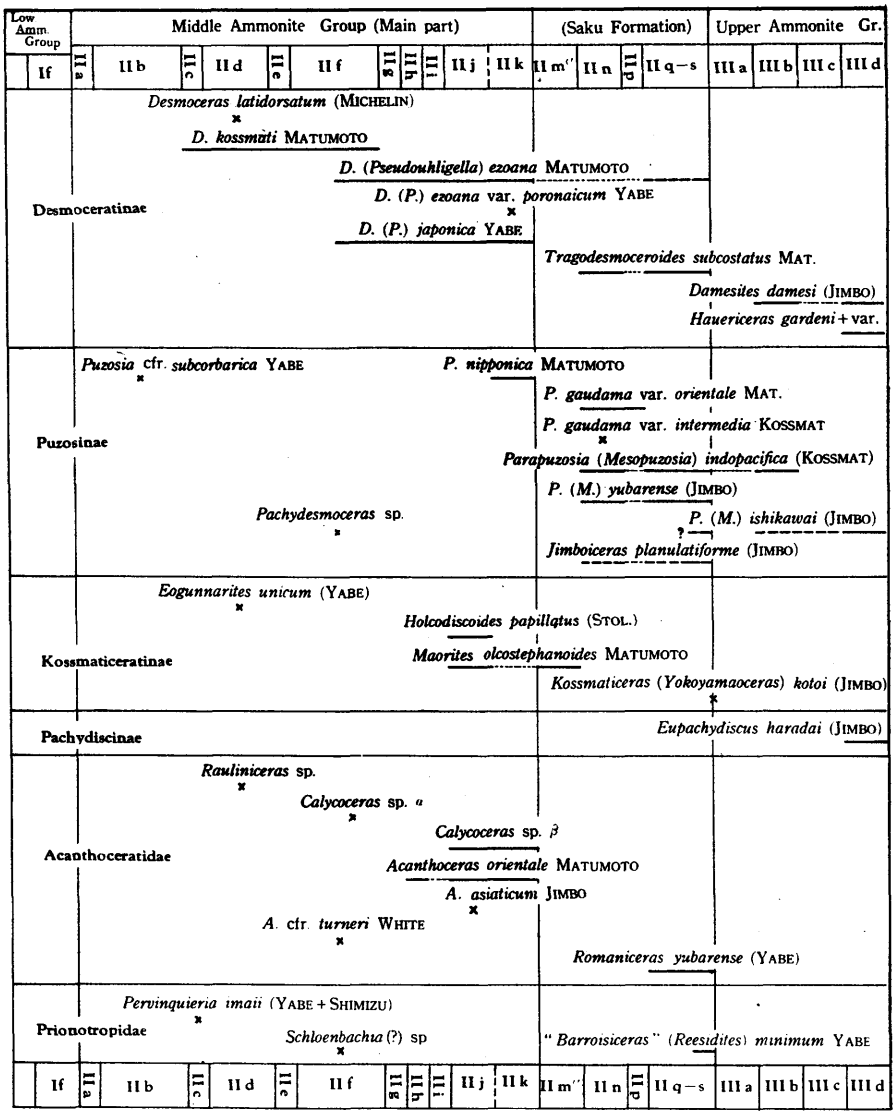

Fig. 8 Stratigraphic occurrence of the important species in the Cretaceous deposits of the Siyubari district — Cephalopoda II

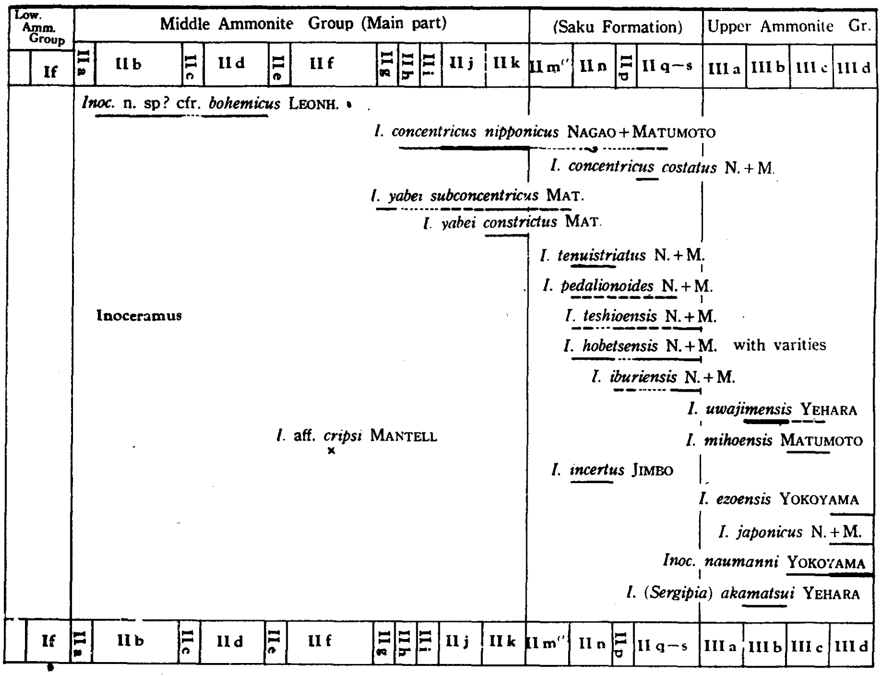

Fig. 9 Stratigraphic occurrence of the species of *Inoceramus* in the Cretaceous deposits of the Siyubari district.

summarized in Table 3, while the distribution of the important species in this stratigraphic column may be seen from Figs. 7, 8, 9.

Since, in the present district, the fine-grained fossiliferous sedimentaries extend fairly downward, it is possible to know the range of some of the Middle Cretaceous species (especially those belonging to the Desmoceratidae) more accurately than in the other districts, although, even here, we lack good biostratigraphic data from the lowest part of the sedimentary series.

As many of the upper Cretaceous species, in their range and order of stratigraphic occurrence correspond with the present and the two foregoing districts, our conclusions regarding the true range of these species are borne out.

(4) *The Hetonai district.*

Although the biostratigraphic data for the uppermost Cretaceous in the Abesinai and Siyubari districts are very scanty, they

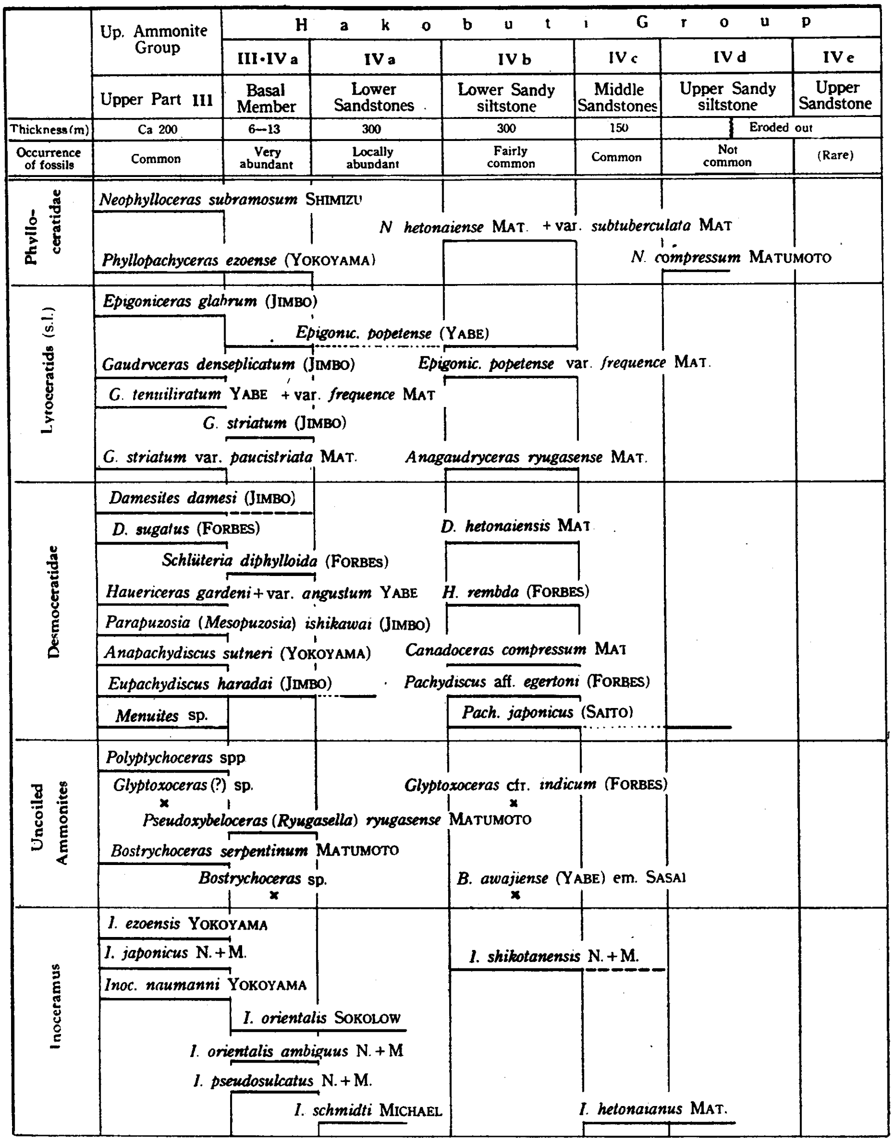

Fig. 10 Stratigraphic occurrence of the more important species in the Upper Cretaceous deposits of the Hetonai district.

are to be found in some degree from the Naibuti and this Hetonai districts. Generally speaking, in the meridional zone of Hokkaidô and Karahuto, the fossiliferous Upper Ammonite Group and its equivalent facies are overlain by a group of strata that have somewhat different rock-facies from them (i.e. the Hakobuti Group and the Ryugase Group), whence it would seem that the ecologic factors and conditions of fossilization (s. l.) have changed to a certain extent. Besides, from later erosion, the uppermost part is somewhat lacking. That is to say, the condition of the Hakobuti-Ryugase Group is less satisfactory for our purpose than that of the Upper and Middle Ammonite Groups or the Miho Group, only the Naibuti and Hetonai districts supplying fairly good data. The reason for this is that in these districts, the uppermost group, at several horizons, comprizes formations whose rock-facies are similar to that of the Ammonite Group, and contains fossils of similar classes (i.e. *Inoceramus* and ammonites). The lack of strata is almost of no consequence in the first locality and of very slight consequence in the second.

Summarizing the stratigraphic occurrence of the more important species in the Hetonai district, we get the annexed chart (Fig. 10).

(5) *The Urakawa district.*

Here we find the strata typically exposed, the fossil-contents of which resemble those of Mh 6—Ray of the Naibuti district, IIId+IIIe of the Abesinai district, and III—IVa of the Hetonai district. This fossiliferous part is divisible by means of minor markings of rock-facies, although, in its general characters, the facies is similar throughout the entire thickness.

A summary of the biostratigraphic data from investigations made in this district follows Table 4 and Figs. 11, 12, 13.

Time-range of the important species.——From what has been said in the preceding article, I have extracted from the data the true time-range of the more important species and its relative order of occurrence in the Cretaceous province of Hokkaidô and Karahuto. I have, at the same time, correlated the principal parts of the deposits with the standard localities, resulting in the charts annexed (Table 5 and Figs. 14–25).

TABLE IV
Generalized Stratigraphic Succession of the Upper Cretaceous Deposits of the Urakawa District, Southern Hokkaidô.

Major stratigraphic division	Subdivision	Thickness in m.	Lithological character	Occurrense of fossils	Fossil-zone
Upper Part of the Upper Ammonite Group. (Tinomigawa Formation) Comparatively fine-grained sediments (mudstone and fine-sandy mudstone) containing concretions and fossils of ammonites, *Inoceramus*, etc; members of the sandstone intercalated at horizons.	Ur 7	—— 20	Fine-sandy mudstone Sandstone	Fossiliferous	
	Ur 6	30	Mudstone	Rare	
		10 (?)	Fifth Sandstone Member		
	Ur 5 γ	250 (±)	Mudstone	Rare	
	β	350 | 230	Sandy mudstone	Common	Z. Ur 5β
	α	20	Fourth Sandstone Member	Fossiliferous	
	Ur 4 β	300 | 200	Fine-sandy siltstone	Common	Z. Ur 4β
	α	30	Third Sandstone Member	Fossiliferous	
	Ur 3 β, β′	60—40	Sandy mudstone	Common	Z. Ur 3
	α, α′	10—50	Second sandstone and conglo. or s.s. + sh. in alternation	Fossiliferous	

Main Part of the Upper Ammonite Group Fine-grained and homogeneous sedimentary rocks predominant; concretions of marl and fossils of ammonites, *Inoceranus*, etc. are contained.	Ur 2 β, β′	100–150	Mudstone	Abundant	Z. Ur 2
	α, α′	30—50	Glauconitic sandstone		
	Ur 1 β	500	Mudstone	Abundant	Z. Ur 1β
	α			Common	
		60—70	First Sandstone Member	Not yet found	
	Ur 0	500	Mudstone, sometimes with intercalated thin sandstone.	Rare	
Trigonia Sandstone					
Lower Ammonite Group					
Onisasi Group					

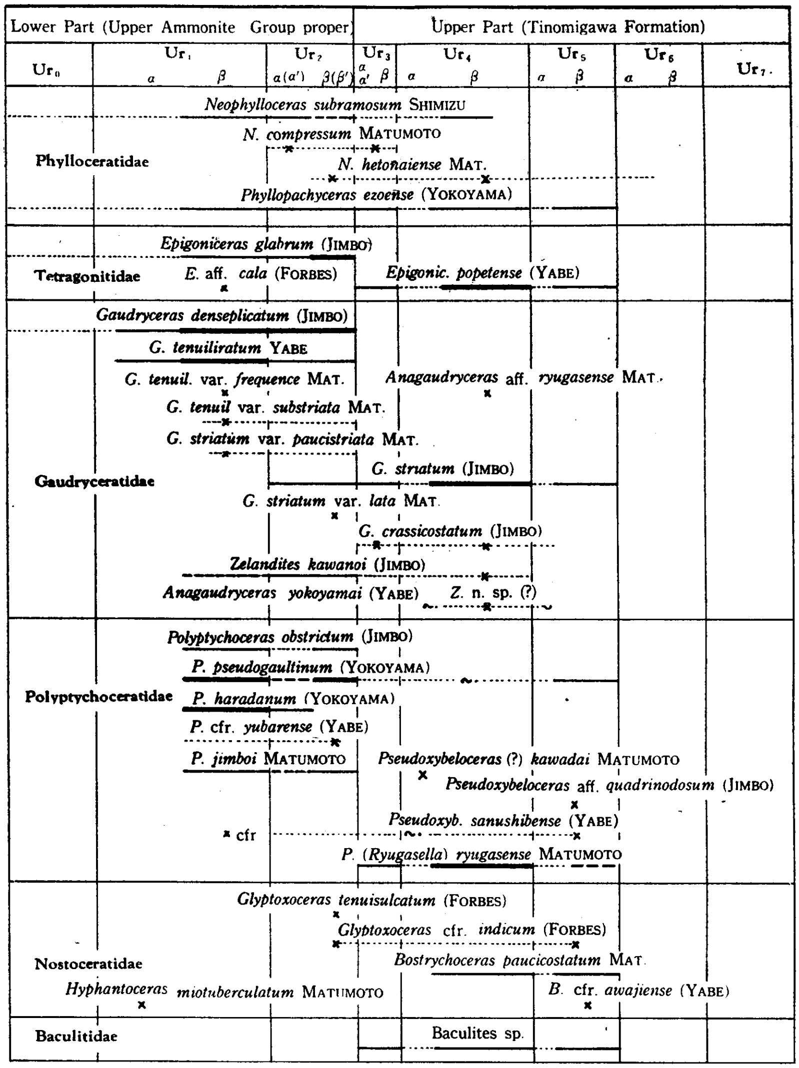

Fig. 11 Stratigraphic occurrence of species of the Ammonoidea in the Upper Ammonite Group of the Urakawa district — I

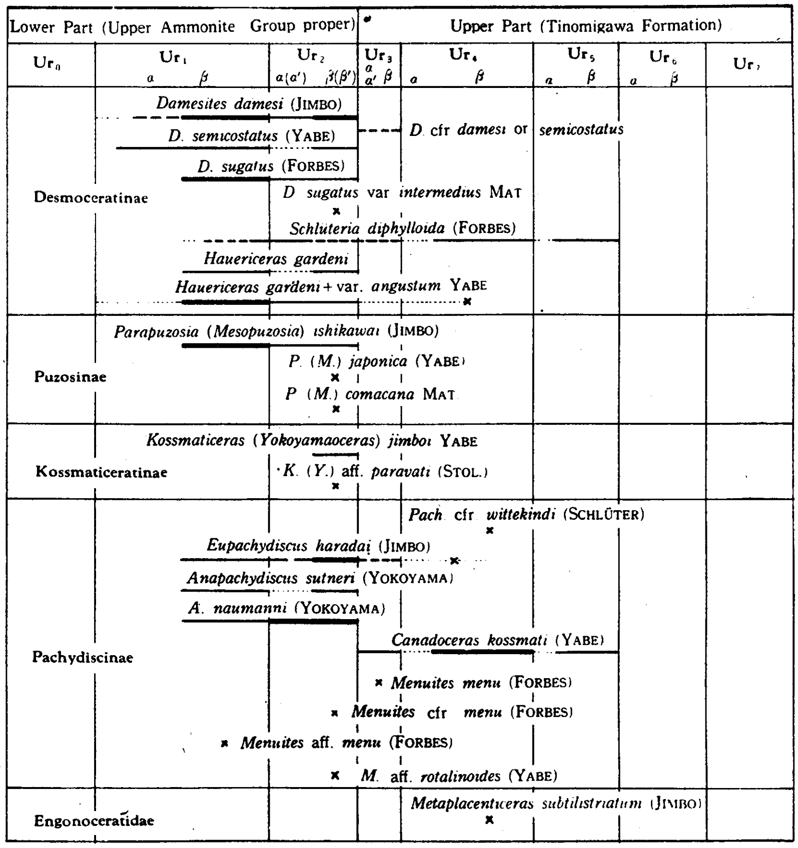

Fig. 12 Stratigraphic occurrence of species of the Ammonoidea in the Upper Ammonite Group of the Urakawa district — II

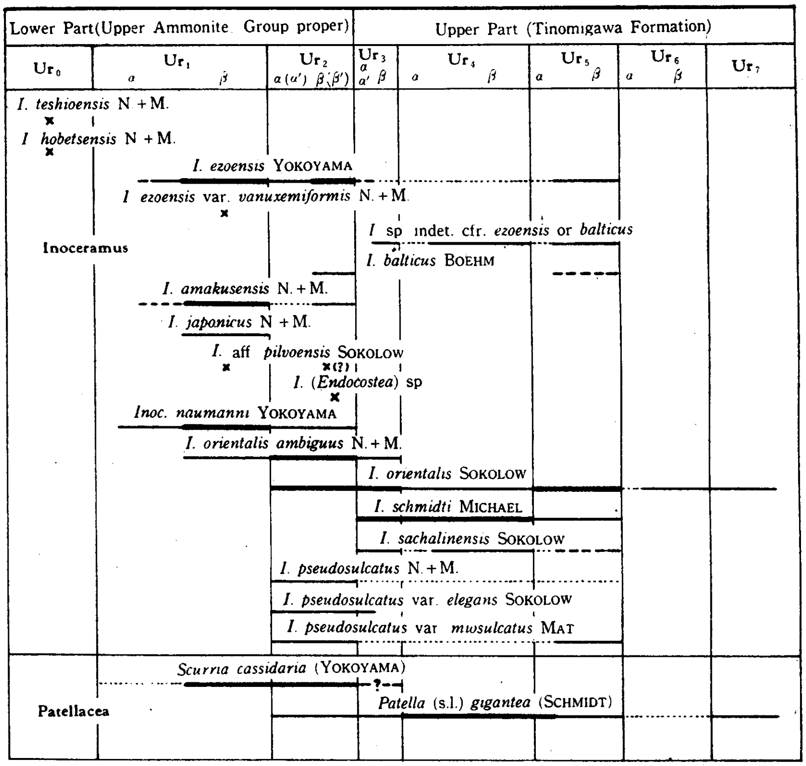

Fig. 13 Stratigraphic occurrence of species of *Inoceramus* and Patellacea in the Upper Ammonite Group of the Urakawa district.

Although the boundary and nomenclature of the chronologic scale, shown in the Tables, will be fully discussed in the next chapter, it may be added here that, obviously, besides a certain part of the stratigraphic succession being indefinite, it is impossible to know anying accurate regarding the true range of some of the species, the reason for it being the insufficient biostratigraphic data the possession of which would enable us to analyse out the chronologic factor. When the upper or lower limit of the life-period is uncertain, a query mark has been added at the end of the line in the chart, and when the existence of a species is represonted by an illpreserved specimen which, being merely comparable to, but is not referable to the species beyond doubt, its range is shown by a broken line (--------). These gaps in our knowledge should be filled by future investigations.

Table V

Chronologic Scale Applicable to the Cretaceous Deposite of Yezo-Saghalin Province, and Correlation of the strata of the Standard Localities.

Period (System)		Paleocretaceous (in part)			Neocretaceous						
Epoch (Series)		Miyakoan			Gyliakian		Urakawan			Hetonaian	
Age (Stage or substage)		Paleo-miyakoan	Neo-miyakoan	Infra-gyliakian	Paleo-gyliakian	Neo-gyliakian	Paleo-urakawan	Neo-urakawan	Infra-hetonaian	Paleo-hetonaian	Neo-hetonaian
Standard localities	Naibuti		Kv	Kw, Kx, Ky	Kz Mho	Mh1 Mh2 Mh3	Mh4	Mh5 Mh6	Mh7 Mh-Ry	Ray Rby Rcy	Rdy Rey Rfy
			Low. Am. Gr.	Kawakita Group		Miho Group				Ryugase Group	
	Abesinai	I		IIa	IIb / IIb-c / IIc	IId (Saku F.)	IIIa IIIb IIIc IIId		IIIe	IV	(eroded)
		Lower Ammonite Group		Middle Ammonite Group			Upper Ammonite Group			Hakobuti Group	
	Siyubari	Ic—If	IIa-IId, IIe	IIf	IIg-IIk,	IIm, IIn—IIs (Saku Formation)	IIIa IIIb	IIIc IIId	IV		
		Low. Amm. Gr.	Middle Ammonite Group				Upper Ammonite Group				
	Hetonai, etc.							III	III-IVa	IVa	IVb IVc IVd IVe
						(abbr.)	Upper Ammonite Group		Hakobuti Group		
	Urakawa					Ur0	Ur1		Ur2	Ur3—Ur7	
						(abbr.)	Upper Ammonite Group (Main Part)			Tinomigawa F.	

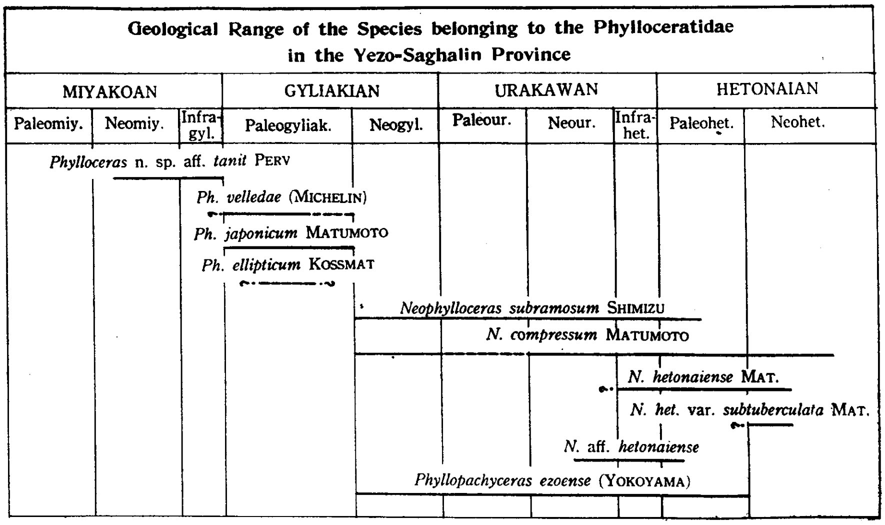

Fig. 14 The geological range of a species is represented by a horizontal line. The broken line means that the range is represented only by specimens which are comparable to the species in question. Query mark at the end of the line means that the upper or lower limit of the range is uncertain. These explanations are applicable to Figs. 14—25.

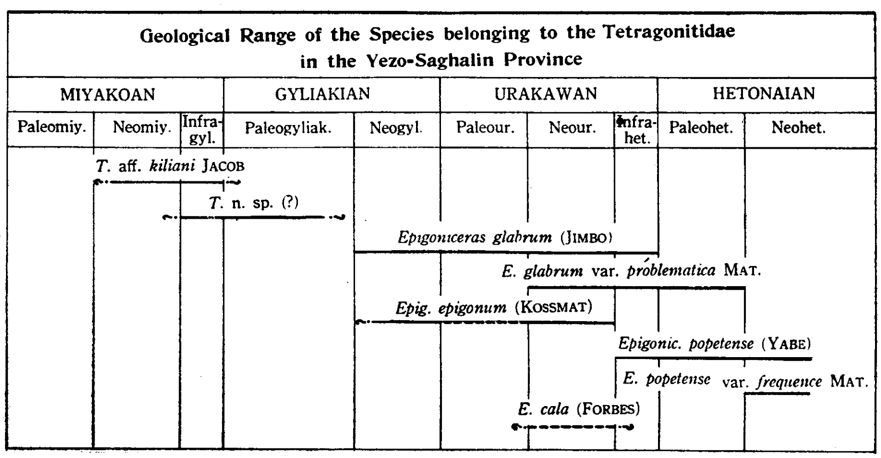

Fig. 15

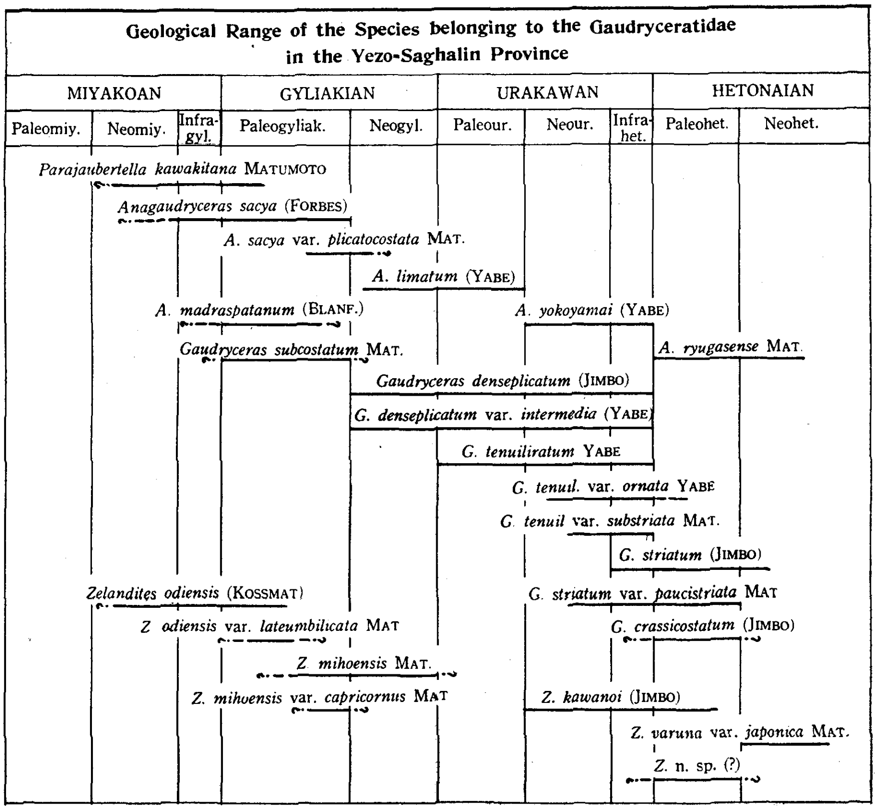
Geological Range of the Species belonging to the Gaudryceratidae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Parajaubertella kawakitana MATUMOTO
Anagaudryceras sacya (FORBES)
A. sacya var. plicatocostata MAT.
A. limatum (YABE)
A. madraspatanum (BLANF.)
A. yokoyamai (YABE)
Gaudryceras subcostatum MAT.
A. ryugasense MAT.
Gaudryceras denseplicatum (JIMBO)
G. denseplicatum var. intermedia (YABE)
G. tenuiliratum YABE
G. tenuil. var. ornata YABE
G. tenuil var. substriata MAT.
G. striatum (JIMBO)
Zelandites odiensis (KOSSMAT)
G. striatum var. paucistriata MAT
Z odiensis var. lateumbilicata MAT
G. crassicostatum (JIMBO)
Z mihoensis MAT.
Z. mihoensis var. capricornus MAT
Z. kawanoi (JIMBO)
Z. varuna var. japonica MAT.
Z. n. sp. (?)

Fig. 16

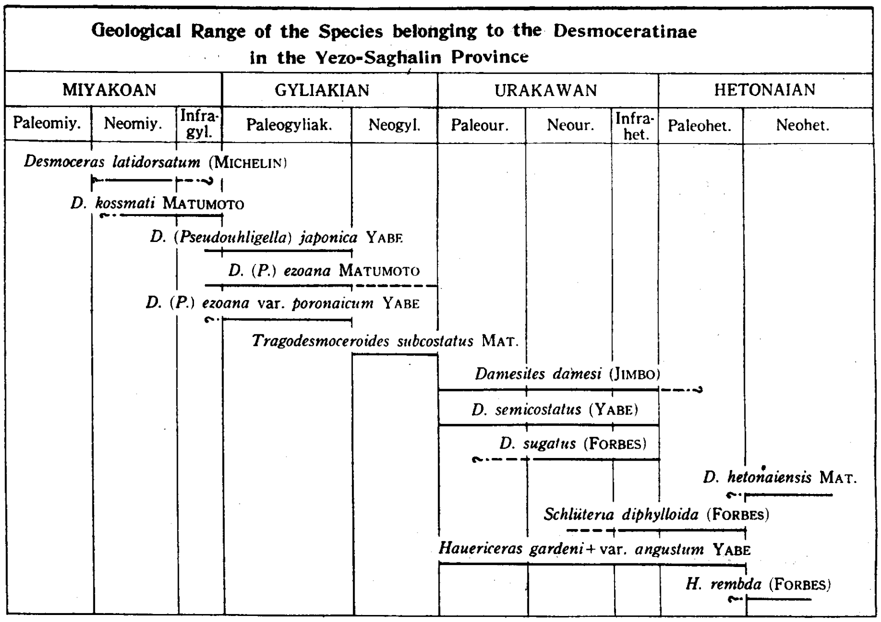
Geological Range of the Species belonging to the Desmoceratinae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Desmoceras latidorsatum (MICHELIN)
D. kossmati MATUMOTO
D. (Pseudouhligella) japonica YABE
D. (P.) ezoana MATUMOTO
D. (P.) ezoana var. poronaicum YABE
Tragodesmoceroides subcostatus MAT.
Damesites damesi (JIMBO)
D. semicostatus (YABE)
D. sugatus (FORBES)
D. hetonaiensis MAT.
Schlüteria diphylloida (FORBES)
Hauericeras gardeni + var. angustum YABE
H. rembda (FORBES)

Fig. 17

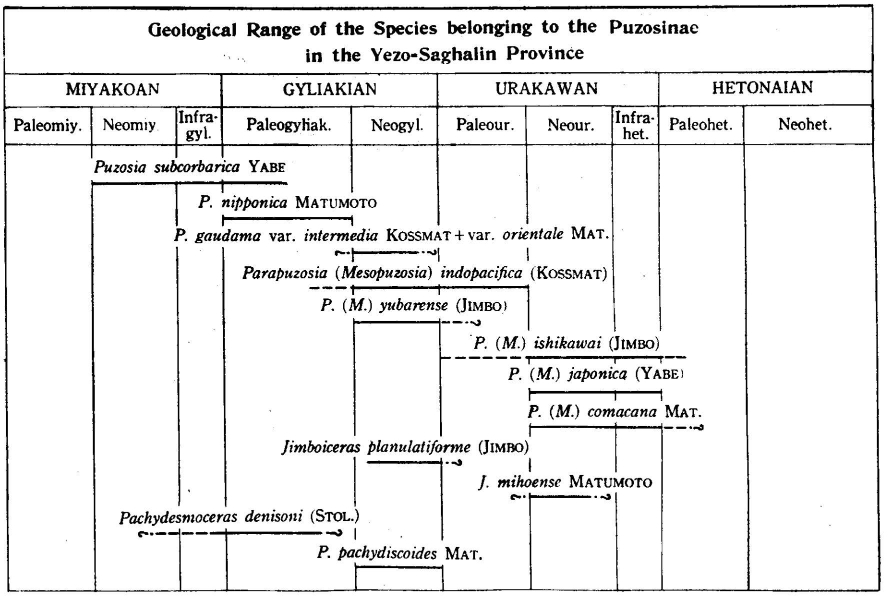
Geological Range of the Species belonging to the Puzosinae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Puzosia subcorbarica YABE
P. nipponica MATUMOTO
P. gaudama var. intermedia KOSSMAT + var. orientale MAT.
Parapuzosia (Mesopuzosia) indopacifica (KOSSMAT)
P. (M.) yubarense (JIMBO)
P. (M.) ishikawai (JIMBO)
P. (M.) japonica (YABE)
P. (M.) comacana MAT.
Jimboiceras planulatiforme (JIMBO)
J. mihoense MATUMOTO
Pachydesmoceras denisoni (STOL.)
P. pachydiscoides MAT.

Fig. 18

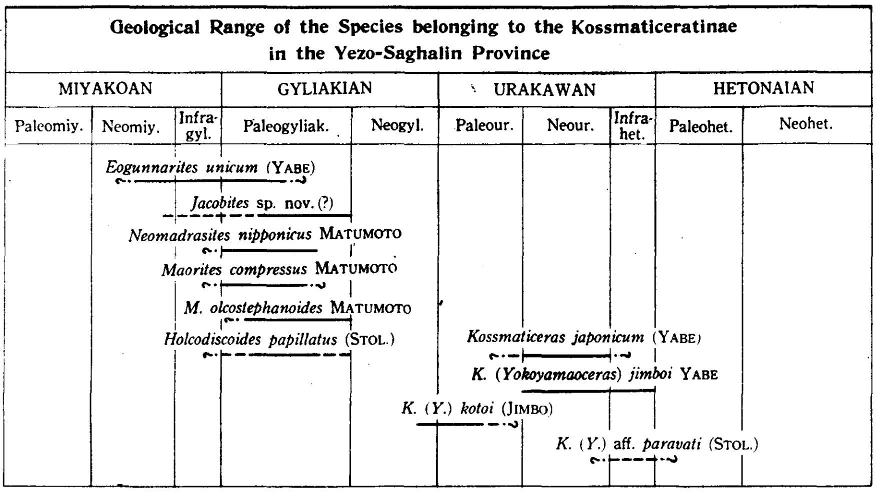
Geological Range of the Species belonging to the Kossmaticeratinae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Eogunnarites unicum (YABE)
Jacobites sp. nov. (?)
Neomadrasites nipponicus MATUMOTO
Maorites compressus MATUMOTO
M. olcostephanoides MATUMOTO
Holcodiscoides papillatus (STOL.)
Kossmaticeras japonicum (YABE)
K. (Yokoyamaoceras) jimboi YABE
K. (Y.) kotoi (JIMBO)
K. (Y.) aff. paravati (STOL.)

Fig. 19

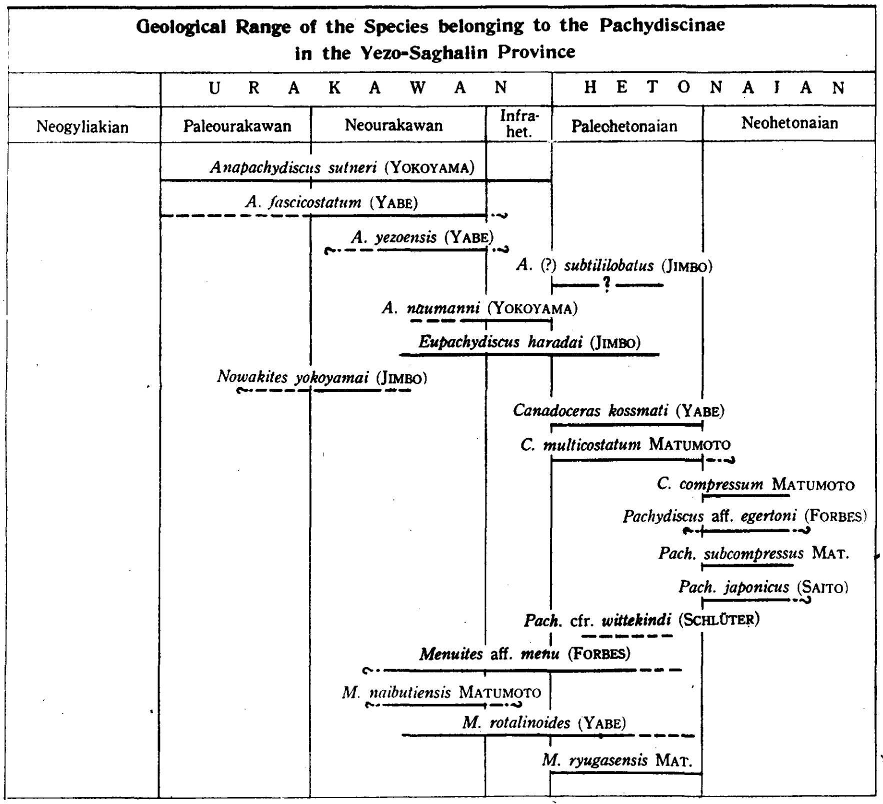
Geological Range of the Species belonging to the Pachydiscinae in the Yezo-Saghalin Province
URAKAWAN
HETONAIAN
Neogyliakian
Paleourakawan
Neourakawan
Infra-het.
Paleohetonaian
Neohetonaian
Anapachydiscus sutneri (YOKOYAMA)
A. fascicostatum (YABE)
A. yezoensis (YABE)
A. (?) subtililobatus (JIMBO)
?
A. naumanni (YOKOYAMA)
Eupachydiscus haradai (JIMBO)
Nowakites yokoyamai (JIMBO)
Canadoceras kossmati (YABE)
C. multicostatum MATUMOTO
C. compressum MATUMOTO
Pachydiscus aff. egertoni (FORBES)
Pach. subcompressus MAT.
Pach. japonicus (SAITO)
Pach. cfr. wittekindi (SCHLÜTER)
Menuites aff. menu (FORBES)
M. naibutiensis MATUMOTO
M. rotalinoides (YABE)
M. ryugasensis MAT.

Fig. 20

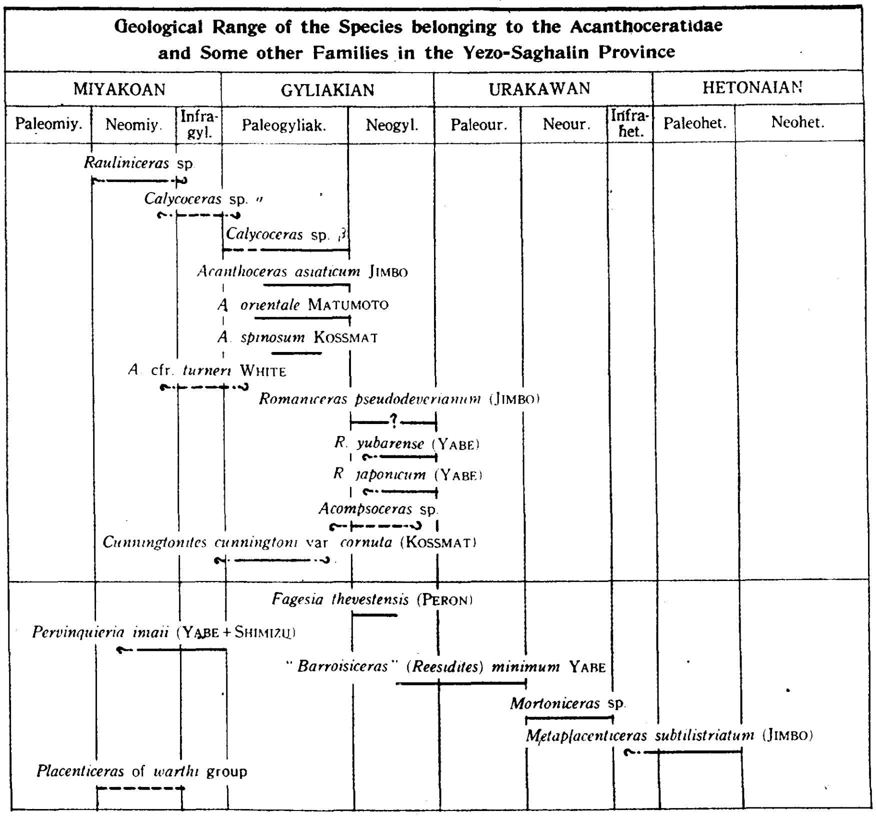
Geological Range of the Species belonging to the Acanthoceratidae and Some other Families in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Rauliniceras sp
Calycoceras sp. α
Calycoceras sp. β
Acanthoceras asiaticum JIMBO
A. orientale MATUMOTO
A. spinosum KOSSMAT
A. cfr. turneri WHITE
Romaniceras pseudodeverianum (JIMBO)
?
R. yubarense (YABE)
R. japonicum (YABE)
Acompsoceras sp.
Cunningtoniceras cunningtoni var cornuta (KOSSMAT)
Fagesia thevestensis (PERON)
Pervinquieria imaii (YABE + SHIMIZU)
"Barroisiceras" (Reesidites) minimum YABE
Mortoniceras sp.
Metaplacenticeras subtilistriatum (JIMBO)
Placenticeras of warthi group

Fig. 21

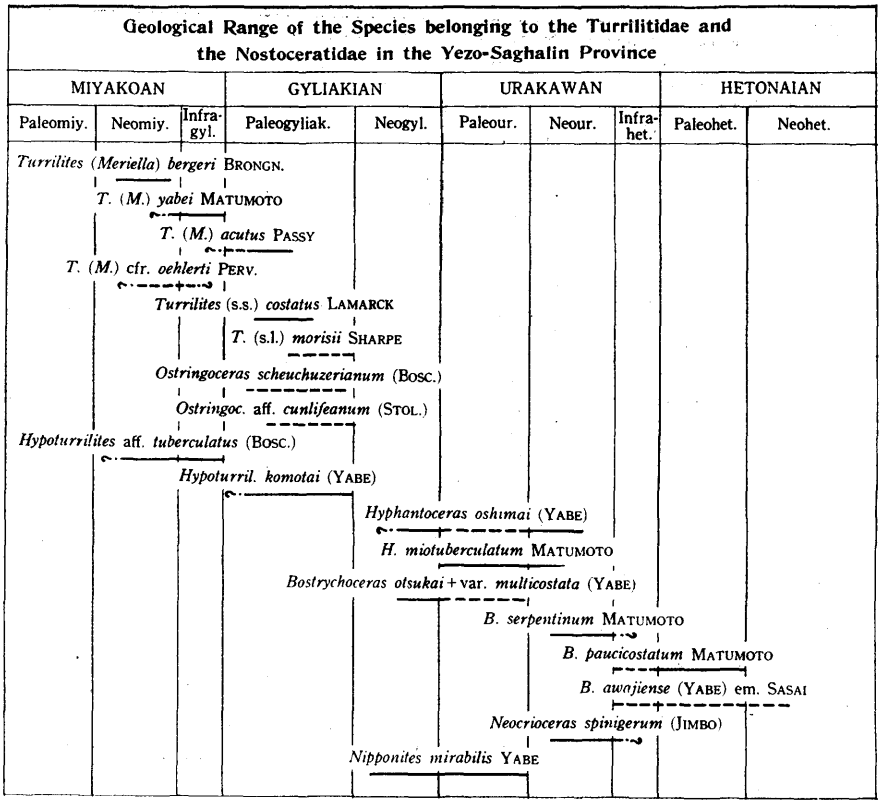
Geological Range of the Species belonging to the Turrilitidae and the Nostoceratidae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Turrilites (Meriella) bergeri BRONGN.
T. (M.) yabei MATUMOTO
T. (M.) acutus PASSY
T. (M.) cfr. oehlerti PERV.
Turrilites (s.s.) costatus LAMARCK
T. (s.l.) morisii SHARPE
Ostringoceras scheuchzerianum (BOSC.)
Ostringoc. aff. cunlifeanum (STOL.)
Hypoturrilites aff. tuberculatus (BOSC.)
Hypoturril. komotai (YABE)
Hyphantoceras oshimai (YABE)
H. miotuberculatum MATUMOTO
Bostrychoceras otsukai + var. multicostata (YABE)
B. serpentinum MATUMOTO
B. paucicostatum MATUMOTO
B. awajiense (YABE) em. SASAI
Neocrioceras spinigerum (JIMBO)
Nipponites mirabilis YABE

Fig. 22

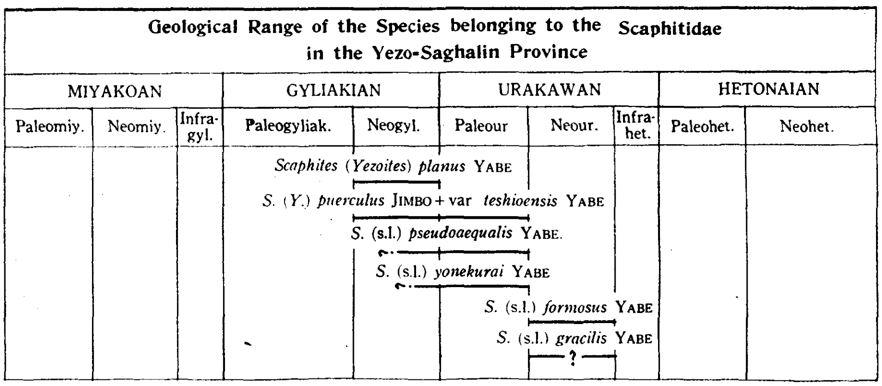
Geological Range of the Species belonging to the Scaphitidae in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour
Neour.
Infra-het.
Paleohet.
Neohet.
Scaphites (Yezoites) planus YABE
S. (Y.) puerculus JIMBO + var teshioensis YABE
S. (s.l.) pseudoaequalis YABE.
S. (s.l.) yonekurai YABE
S. (s.l.) formosus YABE
S. (s.l.) gracilis YABE
?

Fig. 23

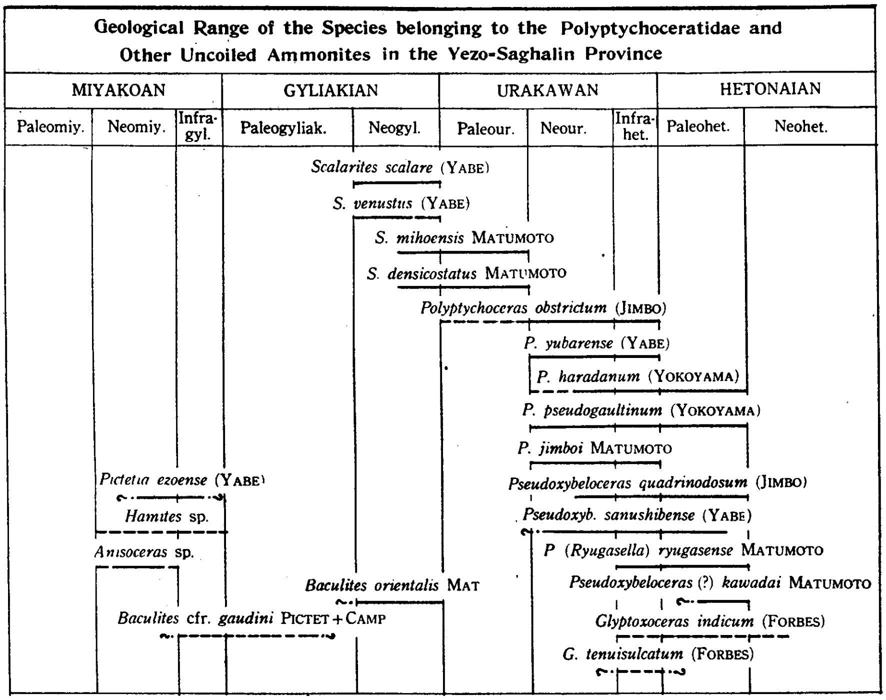
Geological Range of the Species belonging to the Polyptychoceratidae and Other Uncoiled Ammonites in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohet.
Scalarites scalare (YABE)
S. venustus (YABE)
S. mihoensis MATUMOTO
S. densicostatus MATUMOTO
Polyptychoceras obstrictum (JIMBO)
P. yubarense (YABE)
P. haradanum (YOKOYAMA)
P. pseudogaultinum (YOKOYAMA)
P. jimboi MATUMOTO
Pictetia ezoense (YABE)
Pseudoxybeloceras quadrinodosum (JIMBO)
Hamites sp.
Pseudoxyb. sanushibense (YABE)
Anisoceras sp.
P (Ryugasella) ryugasense MATUMOTO
Baculites orientalis MAT
Pseudoxybeloceras (?) kawadai MATUMOTO
Baculites cfr. gaudini PICTET + CAMP
Glyptoxoceras indicum (FORBES)
G. tenuisulcatum (FORBES)

Fig. 24

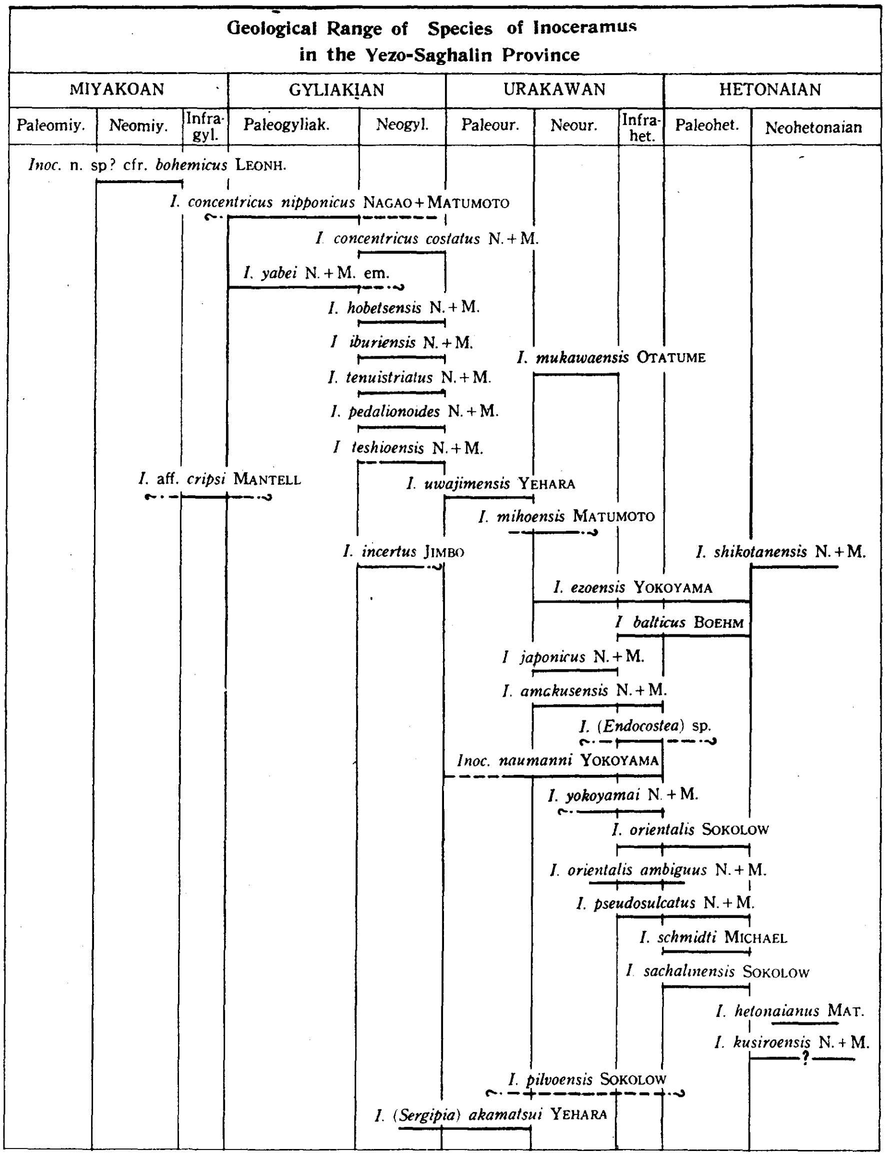
Geological Range of Species of Inoceramus
in the Yezo-Saghalin Province
MIYAKOAN
GYLIAKIAN
URAKAWAN
HETONAIAN
Paleomiy.
Neomiy.
Infra-gyl.
Paleogyliak.
Neogyl.
Paleour.
Neour.
Infra-het.
Paleohet.
Neohetonaian
Inoc. n. sp? cfr. bohemicus LEONH.
I. concentricus nipponicus NAGAO+MATUMOTO
I. concentricus costatus N.+M.
I. yabei N.+M. em.
I. hobetsensis N.+M.
I. iburiensis N.+M.
I. mukawaensis OTATUME
I. tenuistriatus N.+M.
I. pedalionoides N.+M.
I. teshioensis N.+M.
I. aff. cripsi MANTELL
I. uwajimensis YEHARA
I. mihoensis MATUMOTO
I. incertus JIMBO
I. shikotanensis N.+M.
I. ezoensis YOKOYAMA
I. balticus BOEHM
I. japonicus N.+M.
I. amakusensis N.+M.
I. (Endocostea) sp.
Inoc. naumanni YOKOYAMA
I. yokoyamai N.+M.
I. orientalis SOKOLOW
I. orientalis ambiguus N.+M.
I. pseudosulcatus N.+M.
I. schmidti MICHAEL
I. sachalinensis SOKOLOW
I. hetonaianus MAT.
I. kusiroensis N.+M.
I. pilvoensis SOKOLOW
I. (Sergipia) akamatsui YEHARA

Fig. 25

Chapter II

Chronologic Scale Applicable to the Cretaceous Deposits in the Meridional Zone of Hokkaidô and Karahuto

Division boundaries
System of classification
Nomenclature and definition of the units of the proposed chronologic classification
Note on further subdivisions

Division boundaries.——Based on the foregoing results of the investigation, it is possible to determine the chronologic scale by means of the life-period of species. Although the division boundaries may be drawn as one pleases, since it is desirable to do it

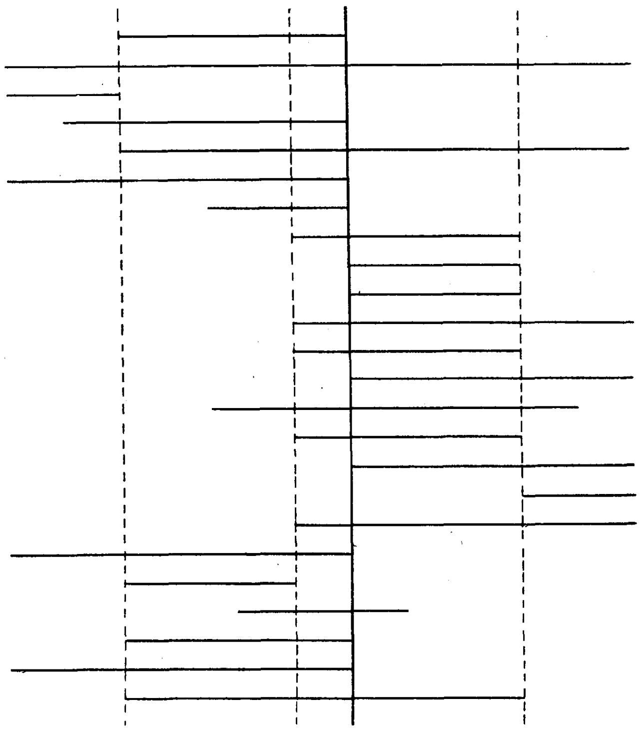

Fig. 26 A generalized illustration showing the time-ranges of various species. Vertical lines show the division boundaries.

so that the scale shall be practical and readily usuable, it is preferable, first of all, to set the boundary at the end-point of the range of the important species that occur in large numbers, with consequent wide horizontal distribution. Secondly, the boundary should be selected at the horizon where as many as possible of the end-points of the range are situated. Fortunately the material available satisfies these requirements. That is, a number of species often appear or disappear contemporaneously or, at any rate, almost contemporaneously, as will be seen from the preceding charts and a generalized illustration (Fig. 26)[1]. Consequently, we can define very clearly each chronologic division by means of the life-period of important species and the associated time-relation of many species. It was in this way that the boundaries of the divisions shown on the preceding charts were determined.

System of classification.——In the foregoing article we have determined the chronologic divisions and proposed a number of boundary-lines that are applicable to the fossiliferous Middle and Upper Cretaceous under consideration. We must next consider how we shall determine the order of magnitude of the scale, for which purpose we must establish a system of classification.

In connection with this problem, the following two principles should be considered: (1) The boundary of the major division must be established at that instant when a marked evolutional change in the organisms occurred, and the boundary of the minor division at that instant when the less marked change occurred. (2) It is preferable that the geochronologic division shall be adjusted so as to conform to an orderly system. Although for the chronologic classification we have a system of era-period-epoch-age that was established at one of the International Geological Congresses, this classification was defined as a chronologic scale corresponding to the formational system of "group"-system-series-stage, and, strictly speaking, the latter has been introduced as a term of stratigraphic division, not purely chronologic standpoint, but based on an empirical method.

My opinion is that the present advanced and progressive

[1] In this case, the phenomenon is not due to chronologic and ecologic conditions, nor is it a matter of pure accident, but solely evolutional, which fact, I think, is significant in connection with the problem of evolution and genetics.

science of geology needs a more orderly system of geochronology than that in vogue at present. According to the chronology by the physico-chemical method, a period in geology has in many cases an absolute value of nearly 30 million years or a multiple of it. That is, except for the periods of the Older Paleozoic, the estimates of which may be very vague, the duration of the Carboniferous, the Cretaceous, and the Tertiary periods are each twice the 30 million years, while each of the remaining periods is also 30 million years, whence it is preferable to define a period so that it shall have a constant value. Of course, there may be ambiguities in our knowledge in regard to absolute chronology, but the approximate and relative figures seem to be reliable. If a period is defined as a geochronolgic unit that has an absolute value of approximately 30 million years, the Cretaceous could be divided into two period, Paleocretaceous and Neocretaceous.(1)

As the next problem, I shall deal with the subdivision of a period into epochs. It is preferable in this case also to adopt a more uniform scale than heretofere. In other words, the number of epochs in each period ought to be constant.

The hitherto established major classification of a period (in a revised sense) is in many cases a threefold division, each of the three divisions being regarded as an epoch, examples of which are

Silurian:
- Early epoch, Valentian
- Mindle epoch, Wenlockian
- Late epoch, Ludlovian

Devonian:
- Early epoch, comprising the Gedinnian and Coblencian ages
- Middle epoch comprising the Eiferian and Givetian ages
- Late epoch comprising the Frasnian and Famennian ages

Upper Carboniferous:
- Early epoch, Waldenburgian or Namurian
- Middle epoch, Westphalian or Moscovian
- Late epoch, Stephanian or Uralian

Permian:
- Early epoch, Artinskian
- Middle epoch, Koungourian
- Late epoch, Kazanian

(1) So are the Carboniferous and the Tertiary. The former may be divided into the Mississippian and Carboniferous (s. str.) periods, while the latter may be divided into the Palaeogene and Neogene periods.

Triassic:	Early epoch, Scythic (Buntsandstein) Middle epoch, Anisic and Ladinic (Muschelkalk) Late epoch, Carnic and Noric (Keuper)
Jurassic:	Early epoch, Lias Middle epoch, Dogger Late epoch, Malm
Palaeogene:	Early epoch, Palaeocene Middle epoch, Eocene Late epoch, Oligocene
Neogene +:	Miocene Pliocene Pleistocene +

Then, is each of the Paleocretaceous Period and Neocretaceous Period divisible into three epochs? Fortunately, the answer from our material is yes. So far as the available material at hand is concerned, from the standpoint of the chronologic change of of organisms, we can divide the Neocretaceous into three epochs. In the upper Cretaceous invertebrates, in the province of Hokkaidô and Karahuto, at any rate, there are three instants when the evolutional change of organisms was relatively marked. They are (1) the first instant when the ammonoids of the Desmoceratidae and the Gaudryceratidae and true *Inoceramus* began to flourish, and many species newly appeared, (2) the second instant when many species of the first epoch disappeared and new forms appeared in large numbers, the latter being species that belong to the ammonite group of *Epigoniceras*, *Damesites*, the Pachydiscinae, the Polyptychoceratidae, etc, and *Inoceramus* of the equivalved form (i.e. *Equinoceramus* MATUMOTO MS.), and (3) the third instant, when many species that survived the second epoch disappeared and were replaced by new forms, which, in turn, were the last representatives of the Cretaceous invertebrates.

Obviously, the time when the change of organisms occur in a fairly marked manner is not, strictly speaking, an "instant", overlapping of the range from the old form to the new not being rare. But it was found that the coexistence of numerous old and new forms lasted for only a comparatively short period.(1) Following convention, the boundary of the species is determined at the

(1) The minor unit of chronologic scale is treated in the next paragraph and in the fourth article entitled "Note on further subdivisions".

point where the long or thick line is drawn in the preceding charts (Figs. 14–26), and a transitional sub-age established adjacent to it.

Although the question whether all these three epochs have the same time-length is at present difficult to answer, we can roughly estimate it from the thickness of the sediments, but it will have to be based on the assumption that the sediments accumulated with equal velocity under uniform conditions, and that the changes made in the thickness by later agencies was also uniform. Cases satisfying these conditions may be rare, but, as in those of the Ammonite Group or the Miho Group of the same lithologic characters, this was probably the case. For trial, the thickness of the sediments formed during the first epoch is compared with those formed during the second in the annexed Table.

TABLE VI

	Naibuti	Abesinai	Siyubari
First epoch	1000 m mudstone 100 m sandy mudstone 200 m ss. + shale	600 m + mudstone 400 m ss. + shale	1000 m mudstone 400 m ss. + sh.
Second epoch	1400 m+ mudstone	600 m + mudstone 250 m sandst.	1000 m ?+mudston

It will be seen that the differences between the two epochs is not great.

The next problem is the subdivision of an epoch into ages. In conformity with the principle of the biostratigraphic method adopted here, the age is a minor unit which is applicable to an area of small extent (at any rate, in one biogeographic province), and since the number of ages forming an epoch may differ with the particular province, an epoch in one place may be divided into two ages and that in another subdivided into three ages.

In our present case, each epoch has two ages, the boundary of which has been drawn in the preceding charts. The age is determined by the life-period of a characteristic species found in the province as well as by the coexistence there of several species. These, and still finer subdivisions, will be referred to later.

Nomenclature and definition of the units of the proposed chronologic classification.——For the nomenclature of the unit of chronologic classification under consideration, I prefer not to use the names of fossils (e.g. Pachydiscan, Acanthoceratan, etc.) for the following reasons: (1) The unit of the chronologic division treated here is not determined by the fauna itself nor by the life-period of a single characteristic species or genus. (2) If there is a characteristic species or genus, its geological range in a particular Japanese province may possibly differ from that in another province in another country. The Pachydiscan age, for example, of a Japanese region is not necessarily synchronous with the Pachydiscan age of Western Europe. (3) Strictly speaking, the chronologic scale adopted here is applicable only to the province of Hokkaidô and Karahuto, especially when a minor unit like age is concerned. A totally different scale may be necessary in another province. In sum, the scale has only local or provincial significance, although international correlation is not impossible between scales of widely separated areas.

For these reasons, a name carrying provincial significance is preferable. Conforming with this need, I propose here the following nomenclature for chronologic classification which is applicable to the fossiliferous Cretaceous deposits in the meridional zone running through Hokkaidô and Karahuto.

Late epoch of the Paleocretaceous Period:

Miyakoan epoch	**Paleomiyakoan age**
	Neomiyakoan ,,

Three epochs of the Neocretaceous Period:

Gyliakian epoch	**Paleogyliakian age**
	Neogyliakian ,,
Urakawan epoch	**Paleourakawan ,,**
	Neourakawan ,,
Hetonaian epoch	**Paleohetonaian ,,**
	Neohetonaian ,,

Although the names adopted here for the epochs, such as "Miyako", "Gyliak", "Urakawa", and "Hetonai", are stratigraphic names used by previous investigators, their meanings have been altered more or less to suit our purpose. A short account of the differences in meaning between the previous and the present definitions follows.

The following generalized divisions of the Cretaceous Period prevailing at present in Japan was proposed by Dr. H. YABE, in 1927.

The Ryoseki Epoch (Jurasso-Cretaceous of the Lowest Cretaceous according to European standard)
The Monobegawa Epoch (approximately the Lower Cretaceous according to European standard, the Wealden excluded.)
The Gyliak Epoch (approximately the Cenomanian-Turonaian according to European standard)
The Urakawa Epoch (approximately the Senonian, in the broad sense, according to European standard).

The principle of this classification depends on the history of the epeirogenic movement, the first and the third epochs being defined as epochs of emergence or marine regression, and the second and the fourth as epochs of submergence or marine transgression. Obviously, the assignation of a series to a corresponding epoch will depend largely on its fossil-contents, whence it follows that the proposed names are to be regarded as nomenclature of the purely chronologic classification, without any reference to associated geologic phenomena.

In the foregoing divisions, the Upper Cretaceous and the Lower Cretaceous each comprise two epochs, but, since in my new plan of classification, the Neocretaceous Period is divided into three epochs, it is necessary to modify the limitations of the two previous names and add one more new epoch. For the first epoch of my proposal the name *Gyliak* has been retained. In this case, its original meaning is therefore essentially unaltered, although some of the deposits formerly omitted from the Gyliak Series are now replaced in it. For the second epoch of my new classification, I shall use the name *Urakawan*(1), whence the upper half of

(1) Although this name comes from the Urakawa district, we find here not only deposits of the second epoch, but also those of the early half of the third epoch.

the old Urakawa Series will have to be called by another name. For this, I propose the name *Hetonaian*, because the fossiliferous deposits of this epoch are best exposed near Hetonai, as described in Part I. As the name of a formation, the *Hetonai Group* has already been in use by UWATOKO, OTATUME, and NAGAO[1] for the Hakobuti Group that is exposed near Hetonai, but since there is no reason for using two names for one and the same geologic formation, *Hetonai* is retained here as a chronologic name, using the word *Hakobuti* for the formation.[2]

Since, in contrast to the Upper Cretaceous, the Lower Cretaceous in Hokkaidô and Karahuto do not yield sufficient fossils to enable us to establish a standard chronologic scale, we still lack a thorough plan of Paleocretaceous chronology, only the upper epoch being determinable from biostratigraphic data of this region. For this epoch I intend to use the name *Miyakoan*. The Miyako Series was formerly proposed by Dr. YEHARA (1923, 1926) for the "Middle" Cretaceous deposits of Japan, with the "Lower Ammonite Beds" of Hokkaidô and the Cretaceous strata of Miyako (in the Kitakami Mountainland) as its typical representatives, so that I think it most appropriate to adopt this name with the necessary changes.

Although, chronologically, the Miyakoan epoch may be virtually equivalent to the upper half of the Monobegawa epoch, the question whether or not the former is applicable to the Cretaceous deposits of Southwest Japan must be left for the future to decide. I hope, however, that the Paleocretaceous Period in Japan may in future be divided into three epochs, early, middle, and late, and that the Miyakoan will be used for the late epoch (Cf. Part III, Chap. II).

In order to avoid confusion between the newly proposed age names and the previous names, I shall now present here again (not in tabular form) definitions of the proposed age names. Each unit of the chronologic division is fixed by the life-period of the species and their associations, both of which have been worked out from the fossil-contents of formations in the standard areas.

(1) UWATOKO, K. & K. OTATUME, 1933; NAGAO, T. & K. OTATUME, 1938.

(2) As will be discussed in Chap. V, the age of the Hakobuti Group does not necessarily coincide with the Hetonaian Epoch, that is to say, the Hakobuti Group does not coincide with the Hetonaian Series.

The analysis, which is based on our present state of knowledge, is obviously subject to changes in the future as the result of further studies. Furthermore, the proposed scale is a provincial time term applicable only to the Cretaceous deposits of the Yezo-Saghaline province (the meridional zone running through Hokkaidô and Karahuto). Should the terminology be extended for application also to deposits of other provinces, certain changes may have to be made in the present definitions. But even in these future studies, so far as the definition of chronologic terms is concerned, the basic facts mentioned here must form the foundation. Consequently, strata which are regarded as typical representatives of each age are enumerated together.

For convenience of description, in this definition the species of each age are classified under the following headings (Cf. Pig. 27):

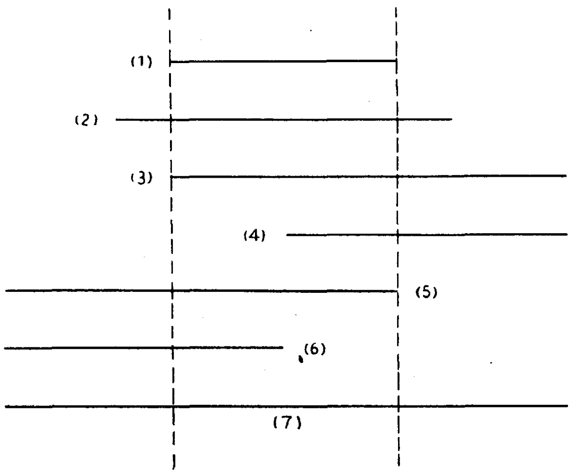

Fig. 27 (1) Characteristic species of the first category, (2) Characteristic species of the second category, (3) Appeared species, I, (4) Appeared species, II, 5 Species of last appearance, I, (6) Species of last appearance, II, (7) Species of long duration.

1. *Characteristic species of the first category* (I), species that are restricted to the particular age in question.

1′. *Species, presumably characteristic,* those presumed to be restricted to the age in question.

2. *Characteristic species of the second category* (II), species virtually restricted to the age in question, occuring both at slightly earlier and slightly later ages, but, nevertheless common to the age in question.

3. *Appeared species*, I, species that appear at the beginning of the age in question and range up considerably to the succeeding age.

4. *Appeared species*, II, species that appear in the middle of the age in question and range up considerably to the succeeding age.

5. *Species of last appearance*, I, species that appear before the age in question, exist during that age and disappear at its close.

6. *Species of last appearance*, II, species that exist before the age in question, remain in the age that follows it, but disappear in the middle of that age.

7. *Species of long duration:* Species that exist during the age in question but occur both earlier and later than that age, having a long time-range.

Miyakoan epoch: The latest of the three epochs in the Paleocretaceous Period.
In the present state of our knowledge its lower limit is indefinite. The following two ages and one sub-age are included in this epoch.

Paleomiyakoan age: The earlier half of the Miyakoan epoch. Many species of the so-called "*Orbitolina* limestone fauna" seem characteristic of this age, but the true time-range of the elements of the fauna has not yet been exactly determined. To the characteristic species of this age may belong most of the ammonite-species that were found in the Cretaceous deposits of the Miyako district on the eastern border of the Kitakami Mountainland, and described by S. SHIMIZU (1931), although they have not yet been detected in the Cretaceous deposits of Hokkaidô and Karahuto. Typical formations are the Cretaceous deposits of the Miyako district and subdivision Ic and its contiguous members of the Lower Ammonite Group of the Siyubari district.

Neomiyakoan age: The later half of the Miyakoan epoch. The characteristic species I are *Desmoceras latidorsatum* (MICHELIN) (presumably), *Turrilites* (*Meriella*) *bergeri* BRONGNIART, *Raulíniceras* sp. (presumably), *Placenticeras* sp. of *warthi* group (presumably), *Anisoceras* (s. s.) sp., and *Inoceramus* n. sp. aff. *bohemicus* LEONHARDT.

The characteristic species II are *Phylloceras* n. sp. aff. *tanit* PERVINQUIÈRE, *Tetragonites* cfr. *kiliani* (JACOB), *Parajaubertella kawakitana* MATUMOTO MS, *Desmoceras kossmati* MATUMOTO MS, *Hypoturrilites* aff. *tuberculatus* (BOSC), *Turrilites* (*Meriella*) *oehlerti* PERVINQUIÈRE (?), *Pictetia ezoense* (YABE), etc. The appeared species are *Baculites* cfr. *gaudini* PICTET & CAMPISCH, *Zelandites odiensis* (KOSSMAT), *Puzosia subcorbarica* YABE MS, *Pachydesmoceras denisoni* (STOLICZKA) (?), *Eogunnarites unicum* (YABE), *Pervinquieria imaii* (YABE & SHIMIZU), *Hamites* sp., etc.[1]

Typical formations of the Neomiyakoan age are the exposed part of the Lower Ammonite Group (Kv, Kv′) and part of the Kawakita Group below the middle of Formation Kx in the Naibuti-Aikawa district; upper part of the Lower Ammonite Group, comprizing member If, and the lower part of the Middle Ammonite Group (II a–II d) in the Siyubari district.

Infragyliakian sub-age: The latest sub-age of the Miyakoan epoch, presenting, in the assemblage of species, a feature apparently intermediate between the Miyakoan proper and the Gyliakian proper, in that the sub-age may be defined by coexistence of the following species: *Phylloceras* n. sp. aff. *tanit* PERVINQUIÈRE, *Tetragonites kiliani* (JACOB), *Pictetia ezoense* (YABE), *Parajaubertella kawakitana* MATUMOTO MS, *Desmoceras kossmati* MATUMOTO MS, *Hypoturrilites* aff. *tuberculatus* (BOSC.), *Pervinquieria imaii* (YABE & SHIMIZU) on the one hand, and *Tetragonites* n. sp. (?) (*T. tetragonus* MATUMOTO MS), *Anagaudryceras sacya* (FORBES), *Desmoceras* (*Pseudouhligella*) *japonica* YABE, *D.* (*P.*) *ezoana* MATUMOTO MS, *Jacobites* sp., *Calycoceras* sp. α, *Hamites* sp., etc., on the other.

The following species, which existed during this sub-age, appeared, or presumably did so, in the Neomiyakoan age and disappeared, or presumably did so, in the Paleogyliakian age: *Baculites* cfr. *gaudini* PICTET & CAMPISCH, *Zelandites odiensis*

[1] Whether *Anagaudryceras sacya* (FORBES) appeared already in the Neomiyakoan age (s. str.) in the Yezo-Saghalin province or whether it appeared after it cannot be definitely determined from our present data.

(KOSSMAT), *Puzosia subcorbarica* YABE MS, *Pachydesmoceras denisoni* (STOLICZKA), *Eogunnarites unicum* (YABE), *Acanthoceras* cfr. *turneri* (WHITE), *Turrilites* (*Meriella*) *yabei* MATUMOTO (= *T.* aff. *bergeri* YABE, 1904), *Inoceramus* aff. *cripsi* MANTELL, etc.

Typical strata referable to the Infragyliakian sub-stage are Formation Ky and probably the upper part of Form. Kx of the Kawakita Group, in the Naibuti district; Subdivision IIe and the lower half of subdivision IIf of the Middle Ammonite Group, in the Siyubari district; probably the top of the Lower Ammonite Group and the basal part of the Middle Ammonite Group (lower half of IIa) in the Abesinai district.

Gyliakian epoch: The earliest of the three epochs in the Neocretaceous Period.

This is characterized by the flourish of true *Inoceramus* (i.e. inequivalve or subequivalve *Inoceramus*), *Desmoceras* (*Paeudouhligella*) and *Tragodesmoceroides* of the Desmoceratinae, *Puzosia* (s.s.) and *Pachydesmoceras* of the Puzosinae, certain members of of the Kossmaticeratinae, the Acanthoceratidae, the Turrilitidae, and certain species of *Anagaudryceras*. Some elements of the Miyakoan epoch persist and some elements of the Urakawan epoch appear in this epoch. It comprises the following two ages.

Paleogyliakian age: The earlier half of the Gyliakian epoch.

Characteristic species I: *Phylloceras japonicum* MATUMOTO MS, *Ph. velledae* (MICHELIN) (?)[1], *Ph. ellipticum* KOSSMAT (?), *Gaudryceras subcostatum* MATUMOTO MS (?), *Puzosia nipponica* MATUMOTO MS, *Calycoceras* sp. β, *Acanthoceras asiaticum* (JIMBO), *A. orientale* MATUMOTO MS, *A. spinosum* KOSSMAT, *Cunningtonites cunningtoni* (SHARAE) var. *cornuta* (KOSSMAT), and *Turrilites* (s. s.) *costatus* LAMARCK.

Characteristic species II: *Tetragonites* n. sp.? (*T. tetragonus* MATUMOTO MS), *Anagaudryceras sacya* (FORBES) em., with varieties; *Anag. madraspatanum* (BLANFORD), *Desmoceras* (*Pseudouhligella*) *japonica* YABE, with varieties; *D.* (*P.*) *ezoana* MATUMOTO and its var. *poronaicum* YABE; *Jacobites* sp. (n. sp.?), *Neomadrasites* (?) *nipponicus* MATUMOTO MS, *Holcodiscoides papillatus* (STOLICZKA),

[1] Presumably characteristic species.

Turrilites (*Meriella*) *acutus* (PASSY), *T.* (s. 1.) cfr. *morisii* SHARPE, *Ostilingoceras* spp., *Hypoturrilites komotai* (YABE) (?), *Inoceramus concentricus nipponicus* NAGAO & MATUMOTO; *Inoc. yabei* NAGAO & MATUMOTO emend., etc. Appeared species II: *Zelandites mihoensis* MATUMOTO and *Baculites orientalis* MATUMOTO MS (aff. *baculoides* MANTELL).

Species of last appearance I: So far as the province under discussion is concerned, species belonging to general *Phylloceras* (s. str.) and *Tetragonites* (s. s.) disappear at the end of the age.

Species of last appearance II: *Baculites* cfr. *gaudini* PICTET & CAMPISCH, *Parajaubertella kawakitana* MATUMOTO[1], *Zelandites odiensis* (KOSSMAT), *Puzosia* (s. s.) *subcorbarica* YABE MS, *Pachydesmoceras denisoni* (STOLICZKA), *Eogunnarites unicum* (YABE), *Inoceramus* aff. *cripsi* MANTELL, etc.

Typical strata of the Paleogyliakian age are Formation Kz of the Kawakita Group and zone Miho in the lowest part of the Miho Group, in the Naibuti-Aikawa district; upper half of Formation IIa, the entire thickness of IIb, IIb–c, and IIc (δ) of the Middle Ammonite Group of the Abesinai district; middle part of the Middle Ammonite Group (i. e. Subdivisions IIg—IIm) in the Siyubari district. The larger part of the *Trigonia* Sandstone (except its uppermost part) along the Ikusyunbetu valley of the Isikari Coal-field will be added as a typical representative.

Neogyliakian age: The later half of the Gyliakian epoch.

The characteristic species I are *Tragodesmoceroides subcostatus* MATUMOTO MS, *Puzosia gaudama* (FORBES) var. *intermedia* KOSSMAT and var. *orientale* MATUMOTO MS, (presumable), *Pachydesmoceras pachydiscoides* MATUMOTO MS, *Fagesia thevestensis* PERON, *Romaniceras pseudodeverianum* (JIMBO) (?), *R. yubarense* (YABE MS), *R. japonicum* (YABE MS), *Scalarites scalare* (YABE) em., *S. venustum* (YABE), *Scaphites* (s. 1.) *planus* YABE, *Inoceramus tenuisulcatus* NAGAO & MATUMOTO, *Inoc. hobetsensis* N. & M., *Inoc. iburiensis* N. & M., *Inoc. teshioensis* N. & M., *Inoc. pedalionoides* N. & M., and *Inoc. incertus* JIMBO.

The characteristic species II are *Baculites orientalis* MATUMOTO MS (aff. *B. baculoides* MANTELL), *Parapuzosia* (*Mesopuzosia*) *yuba-*

(1) The main time-range of this species is in the Neomiyakoan age and in the Infragyliakian sub-age, persisting into the earlier half of the Paleogyliakian age.

rense (JIMBO) em., and *Anapuzosia* (*Jimboiceras*) *planulatiforme* (JIMBO).

Appeared species I are *Neophylloceras subramosum* SHIMIZU, *N. compressum* MATUMOTO MS, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO), *Anagaudryceras limatum* (YABE), *Gaudryceras denseplicatum* (JIMBO) and its var. *intermedia* (YABE), *Parapuzosia* (*Mesopuzosia*) *indopacifica* (KOSSMAT) em.,[1] *Nipponites mirabilis* YABE, *Scaphites* (*Yezoites*) *puerculus* JIMBO and var. *teshioensis* YABE.

Appeared species II are *Epigoniceras epigonus* (Kossmat) (?), "*Barroisiceras*" (*Reesidites* MS) *minimum* YABE MS, *Hyphantoceras oshimai* (YABE), *Bostrychoceras otsukai* (YABE), *Scalarites mihoensis* MATUMOTO MS, *S. densicostatus* MATUMOTO MS, *Scaphites* (s. l.) *pseudoaequalis* YABE, *S.* (s. l.) *yonekurai* YABE, *Kossmaticeras* (*Yokoyamaoceras*) *kotoi* (JIMBO), and *Inoceramus* (*Sergipia*) *akamatsui* YEHARA.

The species of last appearnace are *Zelandites mihoensis* MATUMOTO (?), *Anagaudryceras sacya* (FORBES) var. *plicatocostata* MATUMOTO[2], *Desmoceras* (*Pseudouhligella*) *ezoana* MATUMOTO MS, and *Inoceramus concentricus* var. *costatus* NAGAO & MATUMOTO.

Typical strata are part of the Miho Group, including zone Mh1, zone Mh2 and zone Mh3 in the Naibuti district; Formation IIc (*a*) and Saku Formation (IId) of the Abesinai district; most of the Saku Formation (IIn—IIs) of the Siyubari district.

Urakawa epoch: Middle epoch of the Neocretaceous Period. This is characterized by the flourish of *Inoceramus* of the *ezoensis* group and the appearance of *Inoceramus* of the *naumanni* group (inequivalved and subequivalveed forms of the genus being replaced by the equivalved form), and the rise of certain elements of the Desmoceratidae, such as genera *Damesites*, *Hauericeras*, *Parapuzosia*, and the subfamily Pachydiscinae, of *Polyptychoceras*, and of *Gaudryceras* (especially, the species *tenuiliratum*).

Paleourakawan age: Early age of the Urakawan epoch.

The characteeistic species I is *Inoceramus uwajimensis* YEHARA.

(1) Specimens doubtfully referred to this species occur in the upper part of the Paleogyliakian stage.

(2) So far as our present knowledge goes, the last representative of this form occurs in the lowest part of the Neogyliakian Series, evidently not coexisting with the earliest representative of *Anagaudryceras limatum* (YABE).

The characteristic species II are *Hyphantoceras miotuberculatum* MATUMOTO MS.

The appeared species I are *Gaudryceras tenuiliratum* YABE emend., *Damesites damesi* (JIMBO), *D. semicostatus* (YABE MS), *Hauericeras gardeni* (BAILEY) (?), *Parapuzosia (Mesopuzosia) ishikawai* (JIMBO) em. (?), *Anapachydiscus sutneri* (YOKOYAMA), *Anap. fascicostatus* (YABE), and *Polyptychoceras obstrictum* (JIMBO).

Appeared species II: *Inoceramus naumanni* YOKOYAMA, *Nowakites yokoyamai* (JIMBO) (?), *Damesites sugatus* (FORBES) (?), etc.

Species of last appearance I: *Anagaudryceras limatum* (YABE), *Parapuzosia (Mesopuzosia) indopacifica* (KOSSMAT) em., *Bostrychoceras otsukai* (YABE) (?), *Nipponites mirabilis* YABE, *Scalarites mihoensis* MATUMOTO MS, *S. densicostatus* MATUMOTO Ms. *Scaphites (Yezoites) puerculus* (JIMBO) and var. *teshioensis* YABE, *Scaph.* (s. l.) *yonekurai* YABE, and *Inoceramus (Sergipia) akamatsui* YEHARA. The species of last appearance II: "*Barroisiceras*" (*Reesidites* MS) *minimum* YABE MS (?).

The species of long duration: *Neophylloceras subramosum* SHIMIZU, *N. compressum* MATUMOTO MS, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO), *E. epigonum* (KOSSMAT), *Gaudryceras denseplicatum* (JIMBO) em., and *Hyphantoceras oshimai* (YABE).

The typical strata of the Paleourakawan age are zone Mh 4 of the Miho Group in the Naibuti district; Formation IIIa of the Upper Ammonite Group in the Abesinai district; and Subdivision IIIb of the Upper Ammonite Group in the Siyubari district.

Neourakawan age: Later main age of the Urakawan epoch. This term may be used in a broad sense to include the Infrahetonaian sub-age at its latest part, or may be used in a strict sense, excluding the Infrahetonaian sub-age. The characteristic species of the Urakawan age (s. l.) are *Anagaudryceras yokoyamai* (YABE) em., *Gaudryceras tenuiliratum* YABE var. *substriata* MATUMOTO, *Anapachydiscus yezoensis* (YABE MS) (?), *Menuites naibutiensis* MATUMOTO MS (?), *Parapuzosia (Mesopuzosia) japonica* (YABE MS), *P. (M.) comacana* MATUMOTO MS, *Kossmaticeras japonicum* (YABE MS) (?), *K. (Yokoyamaoceras) jimboi* (YABE MS), *Mortoniceras* spp., *Bostrychoceras serpentinum* MATUMOTO MS, *Neocrioceras spinigerum* (JIMBO), *Polyptychoceras yubarence* (YABE MS), *P. jimboi* MATUMOTO

MS, *Scaphites* (s. l.) *formosus* YABE, *Inoceramus japonicus* NAGAO & MATUMOTO, *Inoc. amakusensis* N. & M., *Inoc. yokoyamai* N. & M., and *Inoc. mukawaensis* OTATUME MS.

The characteristic species I of the early sub-stage of the Urakawan age (s. str.) are *Anapuzosia (Jimboiceras) mihoens* MATUMOTO MS, and *Inoceramus mihoensis* MATUMOTO MS.

The appeared species I of the Neourakawan age (s. s.)(1) are *Epigoniceras glabrum* var. *problematica* MATUMOTO MS, *Zelandites kawanoi* (JIMBO), *Polyptychoceras pseudogaultinum* (YOKOYAMA) em., *Polypt. haradanum* (YOKOYAMA) em., and *Inoceramus ezoensis* YOKOYAMA.

The appeared species II of the Neourakawan age (s. s.) are *Neophylloceras* aff. *hetonaiense* MATUMOTO MS, *Gaudryceras striatum* (JIMBO) var. *paucistrata* MATUMOTO, *Schlüteria diphylloida* (FORBES) em. (?), *Eupachydiscus haradai* (JIMBO) em., *Menuites* aff. *menu* (FORBES) *M. rotalinoides* (YABE), *Pseudoxybeloceras quadrinodosum* (JIMBO), *Paeudox. sanushibense* (YABE MS), etc.

The species of last appearance I of the Neourakawan ago (s. l.) are *Epigoniceras glabrum* (JIMBO) em., *Gaudryceras denseplicatum* (JIMBO) em., *G. tenuiliratum* YABE em., *Damesites damesi* (JIMBO) (?), *D. semicostatus* (YABE MS), *D. sugatus* (FORBES) em., *Anapachydiscus sutneri* (YOKOYAMA), *A. fascicostatus* (YABE), *Parapuzosia (Mesopuzosia) ishikawai* (JIMBO), (*Polyptychoceras obstrictum* (JIMBO), *Scurria cassidaria* (YOKOYAMA), and *Inoceramus naumanni* YOKOYAMA.

The species of last appearance II of the Neourakawan (s. s.) are *Nowakites yokoyamai* (JIMBO), and *Hyphantoceras oshimai* (YABE).

The species of long duration are *Neophylloceras subramosum* SHIMIZU, *N. compressum* MATUMOTO MS, *Puyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO) em., *Damesites damesi* (JIMBO) (?), and *Hauericeras gardeni* (BAILEY).

Typical formations of the Neourakawan age proper are zone Mh5 and zone Mh6 of the Miho Group in the Naibuti and its adjacent district; Formations IIIc and IIId and part of IIIb of the Upper Ammonite Group in the Abesinai district; upper half (Subdiv. IIIc and IIId) of the Upper Ammonite Group in the

(1) Species that disappear at the end of the Urakawan age (s. l.) (in the Infrahetonaian sub-age) are omitted here.

Siyubari-Hetonai district, and Subdivision Ur 1β of the Upper Ammonite Group in the Urakawa district.

Infrahetonaian sub-age: The latest sub-age of the Urakawan epoch, where a feature intermediate between the Urakawan proper and the Hetonaian proper is apparent in the assemblage of species. That is, the sub-age can be determined by the coexistence of the following species: "Characteristic species I" and "species of last appearance I" of the Neourakawan age (s. l.), just mentioned, on the one hand, and *Neophylloceras hetonaiense* MATUMOTO MS, *Epigoniceras popetense* (YABE) em., *Gaudryceras striatum* (JIMBO) (s. str.), *Schüteria diphylloida* (FORBES) (?), *Bostrychoceras* cfr. *awajiense* (YABE) em. SASAI, *B. paucicostatum* MATUMOTO MS, *Pseudoxybeloceras* (*Ryugasella*) *ryugasense* MATUMOTO MS, *Glyptoxoceras* cfr. *indicum* (FORBES), *Inoceramus orientalis* SOKOLOW (s. str.), *Inoc. pseudosulcatus* NAGAO & MATUMOTO, *Inoc. balticus* BÖHM, and *Patella* (s. l.) *gigantea* (SCHMIDT), on the other.

Besides these species, those that are almost restricted to this sub-age are *Anapachydiscus naumanni* (YOKOYAMA) and *Inoceramus orientalis* SOKOLOW var. *ambiguus* NAGAO & MATUMOTO.

The species of long duration and the appeared species enumerated in the definition of the Neourakawan age exist also in this sub-age.

The typical strata of the Infrahetonaian sub-age are zone Mh7 at the top of the Miho Group and zone Mh–Ry at the base of the Ryugase Group, in the Naibuti district; Basal Member of the Hakobuti Group (III–IVa) in the Hetonai district; Zone Ur 2 of the Upper Ammonite Group in the Abesinai district.

Hetonaian epoch: Last epoch of the Neocretaceous Period. This is characterized by the ammonite genera *Pachydiscus* s. str. (i.e. *gollevillensis-neubergicus* group) and *Canadoceras* (= "*Pseudopachydiscus*" YABE & SHIMIZU) and various specialized forms of the group of *Inoceramus naumanni.* The last representatives of the Phylloceratidae, the Tetragonitidae, the Gaudryceratidae, the Desmoceratinae, uncoiled ammonites, and the group of *Inoc. ezoensis* are all found in this epoch.

Paleohetonaian age: Early half of the Hetonaian epoch.

The characteristic species I are *Canadoceras kossmati* (YABE

MS) em., *Canadoc. multicostatum* MATUMOTO MS, *Pachydiscus* cfr. *wittekindi* (SCHLÜTER) (?), *Menuites ryugasense* MATUMOTO MS, *Inoceramus schmidti* MICHAEL, and *Inco. sachalinensis* SOKOLOW.

The characteristic species II[1] are *Gaudryceras striatum* (JIMBO), *G. crassicostatum* (JIMBO) (?), *Metaplacenticeras subtililobatum* (JIMBO) (?), *Bostrychoceras paucicostatum* MATUMOTO MS, *Pseudoxybeloceras* (*Ryugasella*) *ryugasense* MATUMOTO MS, *Pseudoxybeloceras* (?) *kawadai* MATUMOTO MS, *Inoceramus balticus* BÖHM (?), *Inoc. orientalis* SOKOLOW, and *Inoc. pseudosulcatus* NAGAO & MATUMOTO.

The appeared species I are *Anagaudryceras ryugasense* MATUMOTO MS.

Species that appeared either in or before the Infrahetonaian sub-age, ranged through the Paleohetonaian age, and continued to live in the succeeding Neohetonaian age are *Neophylloceras compressum* MATUMOTO MS, *N. hetonaiense* MATUMOTO MS, *Epigoniceras popetense* (YABE), and *Bostrychoceras awajiense* (YABE) em.

The species of last appearance I are *Neophylloceras aff. hetonaiense* MATUMOTO, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO) var. *problematica* MATUMOTO, *Gaudryceras striatum* (JIMBO) var. *paucistriata* MATUMOTO MS, *Zelandites kawanoi* (JIMBO), *Schlüteria diphylloida* (FORBES), *Hauericeras gardeni* (BAILEY), *Polyptychoceras pseudogaultinum* (YOKOYAMA) em., *P. haradanum* (YOKOYAMA) em., *Pseudoxybeloceras quadrinodosum* (JIMBO), *P. sanushibense* (YABE MS), and *Inoceramus ezoensis* YOKOYAMA.

The species of last appearance II (?) are *Neophylloceras subramosum* SHIMIZU, *Damesites damesi* (JIMBO) (?) *Eupachydiscus haradai* (JIMBO), *Menuites* aff. *menu* (FORBES), and *M. rotalinoides* (YABE).

The typical strata of the Paleohetonaian age are the lower part (Formation Ray and Form. Rby) of the Ryugase Group in the Naibuti and its contiguous district; the uppermost part of the Upper Ammonite Group (most of IIIe) and the exposed part of the Hakobuti Group in the Abeshinai district; Lower Sandstone (IVa) of the Hakobuti Group in the Hetonai district; and the Tinomigawa Formation (Subdivision Ur3—Ur7) of the Upper Ammonite Group in the Urakawa district.

[1] Most of these appear in the Infrahetonaian sub-age immediately preceding the Paleohetonaian age proper.

Neohetonaian age: Later half of the Hetonaian epoch.

The characteristic species are *Neophylloceras hetonaiense* var. *subtuberculata* MATUMOTO MS (?), *Epigoniceras popetense* var *frequence* MATUMOTO MS, *Zelandites varuna* (FORBES) var, *japonica* MATUMOTO, *Damesites hetonaiensis* (SAITO MS), *Hauericeras rembda* (FORBES), *Pachydiscus* (s. s.) *japonicus* (SAITO MS), *P. subcompressum* MATUMOTO MS, *P.* aff. *egertoni* (FORBES), *Canadoceras compressum* MATUMOTO MS (?), *Inoceramus shikotanensis* NAGAO & MATUMOTO, and *Inoc. hetonanus* MATUMOTO MS.

The spdcies of last appearance II are *Neophylloceras compressum* MATUMOTO MS, *N. hetonaiense* MATUMOTO MS, *Epigoniceras popetense* (YABE) em., *Anagaudryceras ryugasense* MATUMOTO MS, *Gaudryceras striatum* (JIMBO)[1], *Bostrychoceras awajiense* (YABE) em., and *Glyptoxoceras* cfr. *indicum* (FORBES). The typical strata are the upper half (Rfy, Rey, Rdy, and upper Rcy) of the Ryugase Group in the Naibuti district; Lower Sandy siltstone (IV b), Middle Sandstone (IV c), Upper Sandy siltstones (IV d), and Upper Sandstone (IV e) of the Hakobuti Group in the Hetonai-Noborikawa district.

N.B. So far as our available material goes, the uppermost part of the Neohetonaian stage is scanty of fossil-contents. Besides, the stratigraphic relation between the formations of the Hetonaian epoch and the Palaeogene is always an unconformity, although it is a parallel one, with the result that it is difficult to ascertain the detailed features of biologic life in the latest sub-age of the Hetonaian epoch.

Note on further subdivisions.—— As will be seen from the foregoing charts (Figs. 14–15), which are the summarized results of my present work, a large number of the species in the Cretaceous province of Hokkaidô and Karahuto have proved to possess a much longer time-range than the important species of Western and Middle Europe. The contrast is remarkable when our form is compared with the Jurassic and Middle Cretaceous Gault ammonites of Western Europe. Such contrast is often noticeable between a geosynclinal area near, or in, an oceanic body of water and the epicontinental marine area, the reason for which, in my opinion, is a debatable problem, although I shall not discuss it here.

(1) This species seems to disappear at the beginning of this age.

At any rate, although in our case, fine subdivision and a minute chronologic correlation are generally inapplicable, it is possible to a certain extent by noting the co-occurrence of many species. To illustrate, *Gaudryceras denseplicatum* (JIMBO), *Gaud. tenuiliratum* YABE and *Gaud. stratum* (JIMBO) have time-ranges of considerable length, their life-period extending over two or three ages. Nevertheless, a comparatively short period, namely, the latest sub-age of the Neourakawan age, can be determined by the co-occurrence of these three species. Since these fossils are very common members of our Cretaceous strata, their stratigraphic value is thus very high, notwithstanding the long time-range of each species. The same sub-age is recognizable by the co-relation of *Inoceramus naumanni* and *Inoc. orientalis*, or *Inoc. pseudosulcatus*. Other examples are not wanting. Thus we can recognize the Infragyliakian sub-age (or the latest sub-age of the Miyakoan), the three sub-ages (early, middle, and late) of the Paleogyliakian, the late sub-age of the Neogyliakian, the early and late sub-age of the Neourakawan (s. s.), and the Infrahetonaian sub-age (or the latest sub-age of the Urakawan epoch). These finer chronologic units can be dealt with, however, only when sufficient biostratigraphic data are available.

As to recognizing finer subdivisions, there are the fossil-zones, but as they are purely stratigraphic units, they will be dealt with in Chap. IV.

Chapter III

Correlation and Chronologic Classification of the Cretaceous Deposits in the Meridional Zone of Hokkaidô and Karahuto

Based on the chronologic scale established in the preceding chapter, we can correlate most of the Cretaceous formations exposed at numerous localities in the meridional zone running through Hokkaidô and Harahuto. The following system of chronologic classification is applicable to the Cretaceous rocks of this region:

Paleocretaceous System:

- **Pre-Miyakoan Series**
- **Miyakoan Series**
  - **Paleomiyakoan Stage**
  - **Neomiyakoan Stage, including the Infragyliakian Substage at its top**

Neocretaceous System:

- **Gyliakian Series**
  - **Paleogyliakian Stage**
    - **Lower substage**
    - **Middle substage**
    - **Upper substage**
  - **Neogyliakian Stage**
    - **Lower substage**
    - **Upper substage**
- **Urakawan Series**
  - **Paleourakawan Stage**
  - **Neourakawan Stage**
    - **Lower substage**
    - **Middle or main substage**
    - **Infrahetonaian Substage**
- **Hetonaian Series**
  - **Paleohetonaian Stage**
  - **Neohetonaian Stage**

The bases mentioned in the preceding articles have enabled us to correlate most of the formations in the standard localities and also, at the same time, to find the true time-range of the more important species. Thus we have referred these formations to the proper position in the proposed system of classification, although the ages of a few of the formations are uncertain.

From Table 5 in Chap. II, again, which gives a concise summary of this correlation, we have the following references:

Taking the formations of the Naibuti district, Kv : Miyakoan, Kx : Neomiyakoan, either its main part or the Infragyliakian

Substage, Ky : Infragyliakian, Kz : Paleogyliakian, Mho : Paleogyliakian, probably most of it, Mh 1 : lower part of Neogyliakian, Mh 2 and Mh 3 : Neogylian, Mh 4 : Paleourakawan, Mh 5 : lower substage of the Neourakawan, Mh 6 : most of the Neourakawan, Mh 7 and Mh–Ry : Infrahetonaian, Ray : Paleohetonaian, Rby : Paleohetonaian, Rcy : Neohetonaian, possibly inclusive of the uppermost Paleohetonaian, and Rdy : Neohetonaian.

Accordingly, the exposed part of the Lower Ammonite Group in this district belongs to the Miyakoan Series; the Kawakita Group (s. s.) is referred to the upper part of the Neomiyakoan Stage and the lower Part of the Paleogyliakian Stage; the Miho Group or the Ammonite Group ranges from the upper half of the Paleogyliakian Stage to the uppermost part of the Neourakawan Stage, and the Ryugase Group is largely the Hetonaian Series, although its basal member belongs to the Infrahetonaian Substage.

As to the Abesinai district, we have the following assignment. The middle fossiliferous part of the Lower Ammonite Group : Neomiyakoan, IIb : Paleogyliakian, the upper part of IIb being the middle substage of the Paleogyliakian, IIb–c and IIc (β): upper substage of the Paleogyliakian, IIc (δ): Paleogyliakian, IIc (α): lower substage of the Neogyliakian, IId: Neogyliakian, IIIa: Paleourakawan, IIId: most of the Neourakawan, IIIe: Paleohetonaian, probably inclusive of the Infrahetonaian Substage, and the exposed part of IV : Paleohetonaian.

Thus, most of the Middle Ammonite Group in the Abesinai district will be assigned to the Gyliakian Series, although we have no positive evidence for determining the age of the basal formation (IIa) of this group. It is possible that its lower part may range down to the Infragyliakian.

It should be noted that the Upper Ammonite Group in the district ranges up to the Paleohetonaian, although the larger part of it belongs to the Urakawan Series, with the result that the base of the Hakobuti Group in this district is not at the base of the Hetonaian Series. Although exact determination is not possible, most of the Lower Ammonite Group of this district may be assigned to the Miyakoan Series, while the Onisasi Group may belong to the Pre-Miyakoan, and probably older series.

In the Siyubari district, Subdivisions If, IIb, IIc, IId, and IIe will be referable to the Neomiyakoan, (of which IIe is possibly referable to the Infragyliakian); lower half of IIf : Infragoliakian, from the upper half of IIf to IIk : Paleogyliakian, IIn—IIs : Neogyliakian[1], IIIb : Paleourakawan, and IIId : most of the Neourakawan.

Thus the Middle Ammonite Group in the Siyubari district occupies not only the whole of the Gyliakian, but also a part of the Neomiyakoan, whereas, the main part of the Lower Ammonite Group is the Paleomiyakoan, although its uppermost member (If) belongs to the Neomiyakoan, while its lowest part is uncertain in age. The Onisasi Group in this district is presumably Premiyakoan.

From the definition of the Hetonaian and the Urakawan, all successions of the Hakobuti Group along the Mukawa near Hetonai, will be referred to the Hetonaian Series, except the basal member (III–IVa), which, in turn, will be assigned to the Infrahetonaian Substage. The Lower Sandstone (IVa) is the Paleohetonaian Stage and the succeeding formations the Neohetonaian Stage. This age determination is applicable to the Hakobuti Group of the Isikari coal-field, seeing that the strata are traceable from the Hetonai district to other areas in the field, so that the top of the Upper Ammonite Group in the Isikari coal-field is in the Neourakawan Stage, decidedly below the Hetonaian Series. On the other hand, the Upper Ammonite Group that is exposed near Urakawa extends upward to the Paleohetonaian, that is, Subdivisions Ur3 and Ur4 are of Paleohetonaian age, zone Ur2 is the Infrahetonaian Substage, Subdiv. Ur1β the Neourakawan Stage, and Subdiv. Ur1α the Paleourakawan Stage. Since Subdiv. Uro contains fossils of Neogyliakian age, the lower limit of the Upper Ammonite Group in this district exceeds the Urakawan Series.

Besides the standard localities just cited, there are a few areas that are fairly important for Cretaceous stratigraphy, as will be seen from the following.

One of these localities, the **Ikusyunbetu Valley** in the Isikari coal-field, which is one of the type localities of the Cretaceous deposits of Hokkaidô and Karahuto has been visited by a number

(1) Whether IIm belongs to the top of the Paleogyliakian or to the lowest Neogyliakian is uncertain, but in our present state of knowledge the former assignment seems the more justifiable.

of investigators[1]. Along this valley, the upper half (about 900 m) of the Lower Ammonite Group is typically exposed, yielding ammonites and other fossils. The important species are *Pictetia ezoense* (YABE), "*Lytoceras imperiale* YABE" (an ill-preserved adult specimen comparable to *Anagaudryceras sacya* (FORBES) em. or to *Parajaubertella kawakitana* MATUMOTO), *Puzosia subcorbarica* YABE MS, *Desmoceras* sp., and *Pervinquieria imaii* (YABE & SHIMIZU). The superjacent formation is the *Trigonia* Sandstone, 300–400 m thick, consisting mostly of greenish sandstones with intercalated layers of conglomerate in the upper part, and yielding at certain horizons, neritic molluscan shells. Of these, previous investigators have determined the following species: *Yoldia* sp a (ex. NAGAO), *Parallelodon* (*Nanonavis*) *sachalinensis* (SCHMIDT), *Cucullaea* aff. *truncata* GABB, *Glycimeris hokkaidoensis* YABE & NAGAO, *Pecten* (*Syncyclonema*) cfr. *obovatus* STOLICZKA, *Anomia linensis* WHITEAVES, *Trigonia hokkaidoana* YEHARA, *T. longiloba* JIMBO, *T. brevicula* YEHARA, *T. subovalis* JIMBO and var. *minor* YABE & NAGAO, *T.* cfr. *tryoniana* GABB, *T. ainuana* YABE & NAGAO, *Pinna* aff. *breveri* GABB, *Anthonya apicalis* NAGAO, *A. japonica* MATUMOTO, *Gervillia* (*Pseudoptera*) *acuticarinata* NAGAO, *Crenella gyliakiana* MATUMOTO, *Pseudasaphis japonica* MATUMOTO, "*Callista*" (*Pseudamiantis*) *crenulatus* MATUMOTO, "*Callista*" *pseudoplana* YABE & NAGAO, *Solemya angusticaudata* NAGAO, *Tabulostium callosum* STOLICZKA, *Glauconia* (*Gymnentome*) sp., *Pugnellus* (*Gymnarus*) *yabei* NAGAO, and *Trochus vestaloides* YABE & NAGAO. The occurrence of cephalopods and *Inoceramus* is rather sporadic. From the main part, *Desmoceras* (*Pseudouhligella*) *japonica* YABE, *Acanthoceras asiaticum* JIMBO, *Turrilites* (*Ostringoceras*) cfr. *cunlifeanus* STOLICZKA, *Hypoturrilites komotai* (YABE), *Inoceramus concentricus nipponicus* NAGAO & MATUMOTO, *I. yabei* NAGAO & MATUMOTO, etc., have been collected, and from the upper part, *Scaphites* (*Yezoites*) *planus* YABE, *Puzosia* ap., *Inoceramus concentricus costatus* NAGAO & MATUMOTO, *I.* cfr. *yabei* NAGAO & MATUMOTO, and *I. hobetsensis* NAGAO & MATUMOTO have been indentified.

The succeeding lower half of the Upper Ammonite Group is the so-called *Scaphites* Beds, the lower part of which consists of fine-sandy siltstones, which are noduliferous, and contain *Inoceramus*

(1) YABE, H. 1926, 1927; NAGAO, T., R. SAITO, and T. MATUMOTO 1938

hobetsensis NAGAO & MATUMOTO, *I. tenuistriatus* NAGAO & MATUMOTO, *I. concentricus nipponicus* NAGAO & MATUMOTO, *I. concentricus costatus* NAGAO & MATUMOTO, *I.* (*Sergipia*) *akamatsui* YEHARA, *I. incertus* JIMBO, *Anagaudryceras limatum* (YABE), *Baculites orientalis* MATUMOTO, *Scalarites scalare* (YABE), *Scaphites* spp., etc. The upper part of the *Scaphites* Beds is a mudstone with an intercalated glauconitic sandstone rich in *Inoceramus uwajimensis* YEHARA and *I.* (*Sergipia*) *akamatsui* YEHARA. The important ammonites are *Neophylloceras subramosum* SHIMIZU, *Anagaudryceras limatum* (YABE), *Gaudryceras denseplicatum* (JIMBO), *Kossmaticeras* sp., *Parapuzosia* sp., *Scaphites* spp., and "*Barroisiceras*" (*Reesidites*) *minimum* YABE MS.

What remains of the group is mudstones, with occasioanal intercalations of tuffaceous layers, containing abundant fossils of species common to the Neourakawan Stage.

The stratigraphic sequence and fossil-contents just described lead to the following conclusion regarding correlation. In the Ikusyunbetu district, the exposed part of the Lower Ammonite Group is Neomiyakoan (probably includes the Infragyliakian), most of the *Trigonia* Sandstone Paleogyliakian, the uppermost part of the same formation and the lower part of the Upper Ammonite Group Neogyliakian, and the larger part of the Upper Ammonite Group Urakawan, the zone of *Inoceramus uwajimensis* Paleourakawan, and the remainder Neourakawan.

Although about 20 km south of the preceding locality, near Yubari-mati, a centre of the Isikari coal-field, a similar stratigraphy is recognized, in this area, the Neogyliakian Stage is represented entirely by the upper half of the *Trigonia* Sandstone, which yields *Inoceramus hobetsensis* NAGAO & MATUMOTO, *I. teshioensis* NAGAO & MATUMOTO em., and *Scaphites* spp.

Besides the Naibuti district, the Cretaceous area, in which comparatively precise stratigraphic investigations have been made in Karahuto, is the **neighbourhood of Alexandrovsk,** in Russian Saghalin, and along the **valleys of the Keton, the Aton, and the Hoe,** in the northern part of the Japanese Karahuto. According to YABE & SHIMIZU (1924), the following sequence of strata is recognized in the former district.

Werblud Group

Lower Formation: Thin bedded alternations of sandstone and shale, with intercalated coal seams, containing plant remains, the so-called Gyliakian and Ainuan floras of KRYSHTOFOVICH.

Middle Formation: Sandstone containing marine molluscs.

Upper Formation: Conglomerate

(Relation not exactly known, the Werblud is presumably subjacent to the Cape de la Jonquière Group)

Cape de la Jonquière Group

Lower Formation: Thin bedded sandstone and shale in alternation, with intercalated coal seams containing plant remains, the so-called Orokian flora of KRYSHTOFOVICH.

Middle Formation: *Inoceramus schmidti* Beds, consisting of a lower thin shale, containing large nodules, a middle, thick greenish sandstone, and an upper sandy mudstone, containing large nodules of marl.

Upper Formations: Thin bedded sandstone and shale in alternation, with intercalated coal seams, containing plant remains. The assemblage of fossils is virtually the same as that of the lower formation.

Of the fossils from the middle sandstone of the Werblud Group, reported by YABE & NAGAO (1925), "*Inoceramus* cfr. *percostatus* MÜLLER", is *Inoc. hobetsensis* NAGAO & MATUMOTO, whence the formation should be assigned to the Neogyliakian, the group being probably largely Gyliakian, even should its lower part happen to represent the Neomiyakoan Stage. The fossil-contents of the middle formation of the Cape de la Jonquière Group are characterized by the presence of *Gaudryceras striatum* (JIMBO), *Canadoceras kossmati* (YABE MS), and other species of the same genus; *Eupachydiscus haradai* (JIMBO), "*Patella*" (s. 1) *gigantea* (SCHMIDT), *Inoceramus schmidti* MICHAEL, *Inoc. orientalis* SOKOLOW, and *Inoc. pseudosulcatus* NAGAO & MATUMOTO var. *elegans* SOKOLOW, all of which prove the age of the formation to be the Paleohetonaian.

The drainage areas of the Keton, the Aton, the Hoe, tributaries of the Horonai River, in the northern part of Japanese Karahuto, were investigated by S. OISHI and the writer (1937). The stratigraphic sequence there is summarized as follows:

———(Lower limit unknown, owing to faulting.)———

Division A. Andesitic tuffaceous sandstone prevailing, associated with conglomerate and shale. Very poor in macroscopic fossils.

Division B. Shale, with occasional intercalations of thin sandstone. Fossils rather scanty.

Division C. Sandstone containing marine fossils.

Division D.
- α. Mudstone, partly fine sandy, fossiliferous.
- β. Sandstone and conglomeratic sandstone, coaly shale.
- γ. Mudstone, very fossiliferous.

Green sandstone containing *Inoceramus schmidti* MICHAEL seems to follow Div. D, but the relation is not visible in the surveyed area.

The following is a revised list of the fossils yielded by each division. Div. A. (upper part): *Inoceramus* cfr. *concentricus costatus* NAGAO & MATUMOTO, or cfr. *yabei* NAGAO & MATUMOTO em.

Div. B: *Trigonia* cfr. *aniuana* YABE & NAGAO, *Inoceramus* cfr. *hobetsensis* NAGAO & MATUMOTO, and *Inoc.* sp. aff. *yabei* NAGAO & MATUMOTO.

Div. C: *Trigonia subovalis* JIMBO var. *minor* YABE & NAGAO, "*Callista*" *pseudoplana* YABE & NAGAO and var. *alata* YABE & NAGAO, *Ostrea* sp., *Inoceramus uwajimensis* YEHARA and var. *yeharai* NAGAO & MATUMOTO (abundant), and *Inoc.* cfr. *hobetsensis* NAGAO & MATUMOTO (very rare).

Div. Dα: *Nuculana* (*Ezonuculana*) *mactraeformis* NAGAO, *Inoceramus naumanni* YOKOYAMA, and *Gaudryceras denseplicatum* (JIMBO).

Div. Dβ: *Anomia* sp., *Ostrea* sp., *Inoceramus* sp. of *naumanni* group.

Div. Dγ: *Nuculana* (*Acila*) aff. *hokkaidoana* NAGAO, *Nuculana* (*Ezonuculana*) sp., *Pecten* (*Propeamusium*) *cowperi* WARING var. *yubarensis* YABE & NAGAO, *Inoceramus naumanni* YOKOYAMA, *Inoc. orientalis* SOKOLOW var. *ambiguus* NAGAO & MATUMOTO, *Inoc. pseudosulcatus* NAGAO & MATUMOTO, *Natica* (*Lunatina*) *ainuana alata* NAGAO, *Semifusus* (*Trochofusus*) *sachalinensis* NAGAO, *Pseudogaleodea tricarinata* NAGAO, *Scurria cassidaria* (YOKOYAMA), *Neophylloceras* sp., *Gaudryceras tenuiliratum* YABE, *G.* cfr. *striatum* (JIMBO), *Anagaudryceras yokoyamai* (YABE,) *Bostrychoceras* sp., *Polyptychoceras* sp., *Schlüteria* sp., *Parapuzosia ishikawai* (JIMBO), *Anapachydiscus naumanni* (YOKOYAMA), *Eupachydiscus haradai* (JIMBO), etc.

From these data, the following assignement is undoubted.

Div. A: Paleogyliakian and pre-Gyliakian, Div. B: Mainly Neogyliakian, Div. C: Paleourakawan, D γ being the Infrahetonaian Substage.

Although the other Cretaceous areas in the median zone of Karahuto have not yet been fully investigated, judging from reports of geologic reconnaissances at a number of detached localities, stratigraphic succession similar to that observed in the Naibuti-Aikawa district seems to be general throughout most of the Cretaceous area in South Karahuto.

Summarizing the foregoing, we get the correlation Table V, page 126. Thus the proposed chronologic scale has been shown to be applicable to the Cretaceous deposits of the meridional zone running through Hokkaidô and Karahuto, irrespective of local differences in their rock-facies. From this result, we see a general inconsistency in the chronologic classification of strata and stratigraphic division from the view-point of facies development, to which last we shall come back in Chap. V.

Chapter IV

Note on Fossil- Zones

An example of a fosil-zone in the Cretaceous deposits of Hokkaidô and Karahuto
Nature of fossil-zones
The values and limitations of fossil-zones as chronologic indicators
Fossil-zones and facies-fossils

An example of a fossil-zone in the Cretaceous deposits of Hokkaidô and Karahuto.——The unit of chronologic classification mentioned in the foregoing pages is a sort of biozone, if not identical with the biozone of NEUMAYR and WEDEKIND. It is defined, principally, by the life-period of a species and by a coexistent time-relation of more than one spedies within a geographical province. Apart from this classification, we recognize, actually, numerous fossil-zones in the Cretaceous deposits of Hokkaidô and Karahuto. The fossil-zone referred to here is OPPEL's zone, which is defined as a unit of strata with certain characteristic fossil-contents,[1] with more or less wide distribution. The following are examples.

Zone of *Inoceramus schmidti* and *Canadoceras kossmati*——represented by the *Inoceramus schmidti* beds of North Saghalin, zone Ray and its extension in South Karahuto, zone IIIe in the Abesinai district of northern Hokkaidô, Subdivision IVa in the Hetonai and adjacent districts in central Hokkaidô, and zone Ur3 and Ur4 of the Urakawa district in southern Hokkaidô. It is characterized by the associated occurrence in large numbers of *Inoceramus schmidti* MICHAEL, *Inoc. sachalinensis* SOKOLOW, *Inoc. pseudosulcatus* NAGAO & MATUMOTO, *Inoc. orientalis* SOKOLOW, *Epigoniceras popetense* (YABE) em., *Gaudryceras striatum* (JIMBO), *Schlüteria diphylloida* (FORBES), *Eupachydiscus haradai* (JIMBO) em., *Canadoceras kossmati* (YABE MS), *C. multicostatum* MATUMOTO MS, *Pseudoxybeloceras* (*Ryugasella*) *ryugasense* MATUMOTO MS, *Patella* (s. 1.) *gigantea* (SCHMIDT), etc.

(1) Contrary to usage, I refrain from using here the terms fauna and flora, because, as mentioned in the Introduction to Chapter I, the fossil-contents of a formation are not necessarily identical with the biota that prevailed during the age of that particular geologic formation.

The zone of *Inoceramus orientalis* **and** *Anapachydiscus naumanni* is represented by Division Dγ of the Keton-Aton-Hoe district, zone Mh7 and Mh–Ry and their extension in South Karahuto, the lowest part of IIIe in the Abeshinai district of northern Hokkaidô (?), member III–IVa at the basal part of the Hakobuti Group in the Hetonai district in south-central Hokkaidô, and by zone Ur2 of the Upper Ammonite Group in the Urakawa district, southern Hokkaidô. It is characterized by assemblage of the species *Inoceramus orientalis* SOKOLOW and var. *ambiguus* NAGAO & MATUMOTO, *Inoc. pseudosulcatus* NAGAO & MATUMOTO and var. *elegans* SOKOLOW, *Inoc. naumanni* YOKOYAMA, *Neophylloceras subramosum* SHIMIZU, *N. hetonaiense* MATUMOTO MS, *N. compressum* MATUMOTO MS, *Epigoniceras glabrum* (JIMBO), *E. popetense* (YABE) em., *Anagaudryceras yokoyamai* (YABE) em., *Gaudryceras striatum* (JIMBO) and var. *paucistriata* MATUMOTO MS, *G. tenuiliratum* (YABE) em., and var. *substriatata* MATUMOTO, *G. denseplicatum* (JIMBO), *Damesites damesi* (JIMBO), *Parapuzosia ishikawai* (JIMBO), *Hauericeras gardeni* (BAILEY), *Eupachydiscus haradai* (JIMBO) em., *Anapachydiscus naumanni* (YOKOYAMA), and other species that are also found in the subjacent zone.

Zone of *Inoceramus naumanni- Gaudryceras tenuiliratum-Eupachydiscus haradai.* This, a very prolific zone in Hokkaidô and Karahuto, is represented by zone Mh6 in South Karahuto, zone IIId in the Abesinai district of northern Hokkaidô, the very fossiliferous upper half of the Upper Ammonite Group in the Isikari coal-field of central Hokkaidô, and zone Ur1β of the Urakawa district of southern Hokkaidô. It contains numerous specimens of *Inoceramus naumanni* YOKOYAMA, *Inoc. yokoyamai* NAGAO & MATUMOTO, *Inoc. ezoensis* YOKOYAMA, *Inoc. japonicus* NAGAO & MATUMOTO, *Inoc. amakusensis* NAGAO & MATUMOTO, *Neophylloceras subramosum* SHIMIZU, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO), *Anagaudryceras yokoyamai* (YABE) em., *Gaudryceras tenuiliratum* YABE em., *G. denseplicatum* (JIMBO), *Polyptychoceras* spp., *Bostrychoceras serpentinum* MATUMOTO MS, *Damesites damesi* (JIMBO), *D. semicostatus* (YABE MS), *D. sugatus* (FORBES), *Hauericeras gardeni* (BAILEY), *Parapuzosia ishikawai* (JIMBO). *Anapachydiscus sutneri* (YOKOYAMA), *A. fascicostatus* (YABE), *Eupachydiscus haradai* (JIMBO), *Menuites* spp., *Scurria* *cassidaria* (YOKOYAMA), etc. Although this zone almost corresponds with what has been called the *Parapachydiscus* Beds, it is not identical with it.

The zone of *Inoceramus uwajimensis* is represented by Division C of the Keton-Aton-Hoe district, zone Mh 4 of the Naibuti district in South Karahuto, division IIIa of the Upper Ammonite Group of the Abesinai district, and the zone of *Inoc. uwajimensis-Gaudryceras limatum* of the Upper Ammonite Group of the Isikari coal-field, in Hakkaidô. In it, we find abundant *Inoceramus uwajimensis* YEHARA, associated with *Inoc.* (*Sergipia*) *akamatsui* YEHARA; *Anagaudryceras limatum* (YABE), *Scaphites puerculus* (JIMBO). *S. yonekurai* (YABE), *S. paeudoaequalis* (YABE), *Scalarites mihoensis* MATUMOTO MS, *Damesites damesi* (JIMBO), *D. semicostatus* (YABE MS), *Hyphantoceras oshimai* (YABE), *H. miotuberculatus* MATUMOTO MS, *Neophylloceras subramosum* SHIMIZU, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO), *Gaudryceras denseplicatum* (JIMBO), and *G. tenuiliratum* YABE em. *Anapachydiscus* spp., *Haueriċeras* sp., *Nipponites mirabilis* YABE, and *Inoc. naumanni* YOKOYAMA are sometimes found in this zone.

The zone of *Inoceramus hobetsensis* is represented by zones Mh 2 and Mh 3 of the Naibuti district, Saku Formation (IId) of the Abesinai district, Saku Formation (IIn–IIs) of the Siyubari district and its southern extension, the upper part of the *Trigonia* Sandstone and the lowest part of the Upper Ammonite Group in the Ikusyunbetu district, and the upper half of the *Trigonia* Sandstone near Yubari, Isikari coal-field. We find in it *Inoceramus hobetsensis* NAGAO & MATUMOTO, *Inoc. teshioensis* NAGAO & MATUMOTO em., and *Inoc. iburiensis* NAGAO & MATUMOTO. The associated fossils are *Inoc. tenuistriatus* NAGAO & MATUMOTO, *Inoc. concentricus costatus* NAGAO & MATUMOTO em., *Inoc. incertus* (JIMBO), *Inoc.* (*Sergipia*) *akamatsui* YEHARA, *Neophylloceras subramosum* SHIMIZU, *Phyllopachyceras ezoense* (YOKOYAMA), *Epigoniceras glabrum* (JIMBO), *Anagaudryceras limatum* (YABE), *Gaudryceras denseplicatum* (JIMBO), *Scaphites puerculus* (JIMBO), *S. planus* YABE, *S. pseudoaequalis* YABE, *S. yonekurai* YABE, *Scalarites* spp., *Nipponites mirabilis* YABE, *Tragodesmoceroides subcostatus* MATUMOTO, *Puzosia gaudama* (FORBES) var., *Parapuzosia indopacifica* (KOSSMAT), *P. yubarense*

(JIMBO) em., *Anapuzosia* (*Jimboiceras*) *planulatiforme* (JIMBO), *Romaniceras* spp., etc.

The zone of *Inoceramus concentricus nipponica-Desmoceras* (*Pseudouhligella*) *japonica* is represented by zones Mho, Kz-Mh, and Kz-1 of the Naibuti district, Division IIb of the Middle Ammonite Group of the Abesinai district, Division IIj–IIk of the Middle Ammonite Group of the Siyubari district, most of the *Trigonia* Sandstone in the Ikusyunbetu district, etc. It is characterized by the coëxistence of *Inoceramus concentricus nipponicus* NAGAO & MATUMOTO, *Inoc. yabei* NAGAO & MATUMOTO em., *Anagaudryceras sacya* (Forbes), *Desmoceras* (*Pseudouhligella*) *japonica* YABE, *D.* (*P.*) *ezoana* MATUMOTO, *P uzosia nipponica* MATUMOTO MS, while the occurrence of *Acanthoceras asiaticum* JIMBO, *A. orientalis* MATUMOTO MS, and *Turrilites costatus* LAMARCK is its outstanding feature.

The nature of fossil-zones.——Logically, there is no reason why a fossil-zone must represent a chronologic instant. The concept of fossil-zone is purely empirical; various zones having been established as the result of observation. But, as exemplified by the foregoing examples, a fossil-zone, in practice, virtually represents a chronologic instant. Tracing and correlating strata by means of fossil-zones have led us to a conclusion that is not inconsistent with the result of correlation based on the life-periods of species. The zone of *Inoceramus schmidti* consequently belongs to the Paleohetonaian stage, that of *Inoc. orientalis-Anapachydiscus naumanni* corresponds nearly to the Infrahetonaian substage, that of *Inoc. naumanni-Gaudryceras tenuiliratum-Eupachydiscus haradai* belongs to the Neourakawan stage, that of *Inoc. uwajimensis* almost corresponds to the Paleourakawan stage, that of *Inoc. hobetsensis* belongs largely to the Neogyliakian stage, while that of *Inoc. concentricus nipponicus-Desmoeeras* (*Pseudouhligella*) *japonica* is referable to the Paleogyliakian stage. It follows, therefore, that we must search more deeply into the intrinsic nature of fossil-zones and their real value in our studies.

A fossil-zone is one of the conditions that are related to the distribution of organic remains in sediments. A special case of these conditions gives us a fossil-zone. As already mentioned, the fossil-contents of strata is the final product of various processes, which may be grouped into three categories: (1) chronologic factor in relation to organisms, namely, evolution of organic life, (2) biologic (i.e. ecologic chorologic and other biologic) factors relating to organisms, and (3) the processes of sedimentation and fossilzation of organic remains. Accordingly, a fossil-zone must be the product of a special case of one of these three processes.

A fossil-zone, in order to be definite in vertical sequence, must first be characterized by a series of limited vertical ranges, that is to say, the evolution of the organisms must be rapid. This instant has been referred to by a number of biostratigraphers, and many of the hitherto adopted zone-fossils satisfy this condition. Typical examples are the graptolites and trilobites of the Palaeozoic and the ammonites of later Palaeozoic and Mesozic Eras. As additional examples, there are the corals, brachiopods, and fusulinids of the Palaeozoic, *Inoceramus* and echinoids of the Mesozoic, and *Nummulites* of the Palaeogene Tertiary. Actually, the zone-fossils in our present case are largely species of ammonites and *Inoceramus*, most of them showing remarkable evolutionary features.

Second, the fossils characterizing the zone must be represented by numerous specimens. The occurrence of a large number of specimens may, in reality, be a phenomenon arising from the conditions of sedimentation and fossilization of organic remains on the one hand, while it must represent a flourish of the organisms in question, or "an acme of the species" on the other. In the zone of *Inoceramus uwajimensis*, for example, the zone-fossil occurs always in great numbers, irrespective of differences in rock-facies. Since the difference in lithologic character certainly show considerable differences in the conditions of sedimentation and fossilization, the abundant occurrence of *Inoceramus uwajimensis* in this case may greatly depend on the flourishing condition of the species, which is an evolutional phenomenon.

Third, the characteristic fossil-content of a zone results from the assemblage of species. Assemblage of fossils is indeed the product of various conditions. Although it reflects, for example, a community of organisms during life, in the case of fossil-zones, it seems to represent to a great extent a chronologic instant in which numerous species coexisted. I have touched on this question on page 153 in the article entitled *Note on further subdivision*, giving several examples. Some of the species characterizing the zone have a fairly long time-range, but the co-relations of these long-ranged species point to a comparatively short age.

These are three features that form the special conditions in relation to the evolution of organic life that can produce a fossil-zone. In order that the zone may have a conspicuous horizontal distribution, irrespective of its lithologic character, the zone-species, during life, must not only have wide geographical distribution, but their remains must also be widely dispersed and deposited under conditions favourable for fossilization and preservation. Most of the ammonites and graptolites, which are important zone-fossils, satisfy these conditions. Ammonites of the thin-shelled variety that are so common in our Cretaceous deposits were certainly widely distributed during life, while after death their shells were dispersed necroplanktonically.

The values and limitations of fossil-zones as chronologic indicators.——From what has just been discussed regarding the intrinsic nature of fossil-zones, while on the one hand, we understand the theoretical reason why a fossil-zone can represent a chronologic instant, on the other hand, we become aware of its limitations, or the extent of its value, as a chronologic indicator. No matter how it may approximately reflect the chronologic instant, a fossil-zone is not perfectly identical with an exact chronologic unit of strata. Whereas the former is a quite concrete, tangible, actual unit of strata, the latter is an extracted one(1). As the factors that go to produce a fossil-zone are limited to a certain range, the extension of the zone itself is also limited both vertically and horizontally. It is, as one might say, a sort of lens. Indeed it can widely extend horizontally, regardless of certain differences in rock-facies, but not without restrictions. It may disappear when the rock-facies or sedimentary condition changes very markedly, or when the biostratigraphic province differes greatly from the original province. The zone of *Inoceramus uwajimensis*, for example, cannot be traced in the Cape de la Jonquière Group of the North Sagahlin, where deposits interfinger with plant beds, although it extends in the neritic sandstone as far north as the northernmost Japanese Karahuto. Most of the zones in our Creta-

(1) Biozones belong to the latter kind.

ceous do not continue to the Mediterranean or the European Cretaceous, although some of the species of our zones may be found also in provinces outside of Japan.

In the same way, the fossil-zones in the Cretaceous of Western Europe, for example, may be very useful for stratigraphic division and correlation of deposits in the same province, but their values are expected to diminish when it comes to international correlation.

A fossil-zone is determined empirically from concrete observation. We select the species that are apparently characteristic of the zone. We do not necessarily select them after we have extracted the life-period of the species and examined their chronologic instants. Sometimes, the selected assemblage of species may well represent a definite chronologic instant, but sometimes they may be inadequate for representing an exact chronologic instant, owing to the influence of conditional factors other than the chronologic factors relating to organisms. In the latter case, the zone may have a marked lenticular form and be oblique to the purely chronologic scale, an example of which is the so-called *Scaphites* Beds in the Cretaceous deposits of Hokkaidô. If the zone is defined by a species of *Scaphites*, the strata containing them are in places limited to the Neogyliakian, in another correspond to the Neogyliakian and Paleourakawan, and in another extend upward to the Neourakawan. (Detailed facts relating to this statement were already given in Part I, and Chap. I of Part II.) On the other hand, if the zone is defined by more numerous species and genera, (*Scaphites* being only a member among them), the zone can represent a more definite time-range. Examples are the zones of *Inoceramus hobetsensis* and *Inoc. uwajimensis*, defined in the preceding article. As to the so-called *Parapachydiscus* Beds and the *Mesopachydiscus* [= *Eupachydiscus*] *haradai* zone, we can make a similar statement. Obviously, too much stress should not be laid on the fossils that are named in denominating a zone. *Inoceramus naumanni* YOKOYAMA, for example, although very abundant in the zone of *Inoc. naumanni-Gaudryceras tenuilatum-Eupachydiscus haradai*, occurs also in the subjacent zone of *Inoc. uwajimensis* and the superjacent zone of *Inoc. orientalis;* in defining a zone, importance should rather be attached to the assemblage of species enumerated.

When a zone is determined by a world-wide species or genus, the horizontal distribution of the zone usually enlarges considerably, its lenticular shape in vertical dimensions possibly being very marked, with the result that we do not always succeed in coming to a conclusion regarding its world-wide correlation in a fine scale by utilizing this zone.

Fossil-zones and facies fossils.——A fossil zone must be descriminated from a fossiliferous bed. Although the former is a special case of the latter, the latter comprises also other cases, one of them being a fossil-bed that has been greatly affected by ecological conditions and environment of sedimentation——a great contrast to a fossil-zone that represents to a high degree the chronologic factor, although the two resemble each other, in their apparent features being sometioms scarcely distinguishable. Careful examination of the fossil occurrence and the fossil elements contained in the stratum usually enables us to distinguish the two cases. The criteria are: (1) Does the fossil belong to an organism that shows rapid evolutional changes? or is it a persistent form? (2) Can the fossil-species distribute itself widely or is it very restricted in its environmental conditions during life? (3) Is it possible for the organic remains to be widely dispersed, or not? (4) Is the fossil-bed traceable irrespective of differences in rock-facies? or is it traceable only in media of a certain lithologic character? Thus, the *Glycymeris* Bed in the *Trigonia* Sandstone of the Ikusynbetu district is a fossil-bed of facies nature. Another excellent example of a facies-fossil bed is the so-called Torinosu Limestone of our Mesozoic. Although it has a characteristic assemblage of fossil, its occurrence and the fossil elements contained do not agree with what is essential to a fossil-zone, but have distinctive features that serve as indicators of facies and environment. That the age of the Torinosu Limestone differs with place is proved by the ammonites that are sporadically found in the limestone, as well as by the stratigraphic facts.

In the same way what has been called a fossil-zone in the Tertiary deposits of Japan may often be a facies-fossil bed, not the treu fossil-zone.

Notwithstanding these distinctions, it is possible for the two kinds of fossiliferous strata to interchange, the distinctions not being absolute, but only relative. Furthermore, in a special case, a fossil-zone could have at the same time the nature of a facies-fossil bed. The graptolite zone of a graptolite facies and the trilobite zone of a shelly facies, being examples, which fact is not irrational, considering the nature of a fossiliferous bed (s. 1.).

Chapter V

Classification from the Standpoint of Facies-Development

A summarized stratigraphic classification of the Mesozoic in the meridional zone of Hokkaiddô and Karahuto
Note on the inconsistency between classification from the purely chronologic standpoint and that from the standpoint of facies.
Geologic meaning of the development of rock-facies in the Mesozic Yezo-Saghalin province, with a short note on the principle of stratigraphic classification from the standpoint of facies-development

A summarized stratigraphic classification of the Mesozoic in the meridional zone running through Hokkaidô and Karahuto.—— The Cretaceous deposits of the meridional zone of Hokkaidô and Karahuto are regarded as those of a continuous area of sedimentation, because the present distribution of strata is fairly continuous and the strata in the various localities are very similar in stratigraphic sequence, in rock-facies, and in fossil-contents. From observations of stratigraphic successions in individual localities in the area under consideration, we gain a generalized knowledge of the stratigraphy of the Cretaceous rocks. Obviously, a number of localities had to remain uninvestigated, while some of the Cretaceous rocks are far from our scope of inquiry, owing to deformations and denudations subsequent to their deposition, but the knowledge gained from studies of the following important districts will suffice to give a proper and general idea of the questions.

(1) Near Alexandrofsk, North Saghalin, (2)* the Keton-Aton-Hoe district, northern part of the backbone of the Japanese Karahuto and adjacent districts in the northwestern coastal region, (3)* the Naibuti district and adjacent areas in South Karahuto, (4) the Nisi-Notoro peninsula, southernmost part of Karahuto, (5)* the Abesinai district and the Mid-valley of the Tesio, northern central Hokkaidô, (6) the Obirasibetu district, northewestern part of Hokkaidô, (7)* the Isikari coal-field and the western part of the Yubari-range, central Hokkaidô, (8) the Hurano-Kanayama district, on the eastern side of the Yubari-range, central Hokkaidô, and (9)* the Urakawa district, southern central Hokkaidô.

* Districts starred were visited by the writer himself.

The major stratigraphic classification of the Mesozoic rocks in the main part of the meridional zone of Hokkaidô and Karahuto is summarized, as follows, in ascending order:

O. Onisasi Group

I. Lower Ammonite Group

II. (Tr). *Trigonia* Sandstone, II (Am) Middle Ammonite Group, II (Kw) Kawakita Group

III. Upper Ammonite Group

IV. Hakobuti Group

To the Cretaceous deposits of the marginal part of the area, represented by those now developed near Alexandrofsk, the following major classification is applicable:

X. Werblud Group

Y. Cape de la Jonquière Group

Corresponding to the local variations in the development of rock-facies, there are many formations and members of minor units, which will be included in some of the preceding major units. The classification may be schematically shown as in Fig. 28a. Definitions and concise explanations of each group follows.

O. The Onisasi Group (鬼刺層群)

A group of formations occupying the visible lowest part of the Mesozoic rocks in the area under consideration. It consists of greywackes derived from basic volcanic rocks, besides pyroclastic rocks, radiolarian cherts, shale, and sandstone. The thicknesses have not been exactly estimated, but they are very thick. Except of micro-organisms, fossils are scanty. A lens of organic limestone, however, is said to be intercalated in the group.

Typical localities are the Mid-valley of the Tesio and the Yubari mountain range, comprizing the upper valley of the Asibetu, the source of the Siyubari River, and the Tomitoi-Yamabe-Kanayama districts.

The name of the group, which is derived from the first locality (Onisasi river, a tributary of the Tesio), was first proposed by MORITA. In adopting MORITA's name with an extension of its original concept, I prefer to apply the group-name to what OTATUME recently called the *Schalstein Formation*, as well as OTATUME's Onisasi Formation. The reason is that the two have

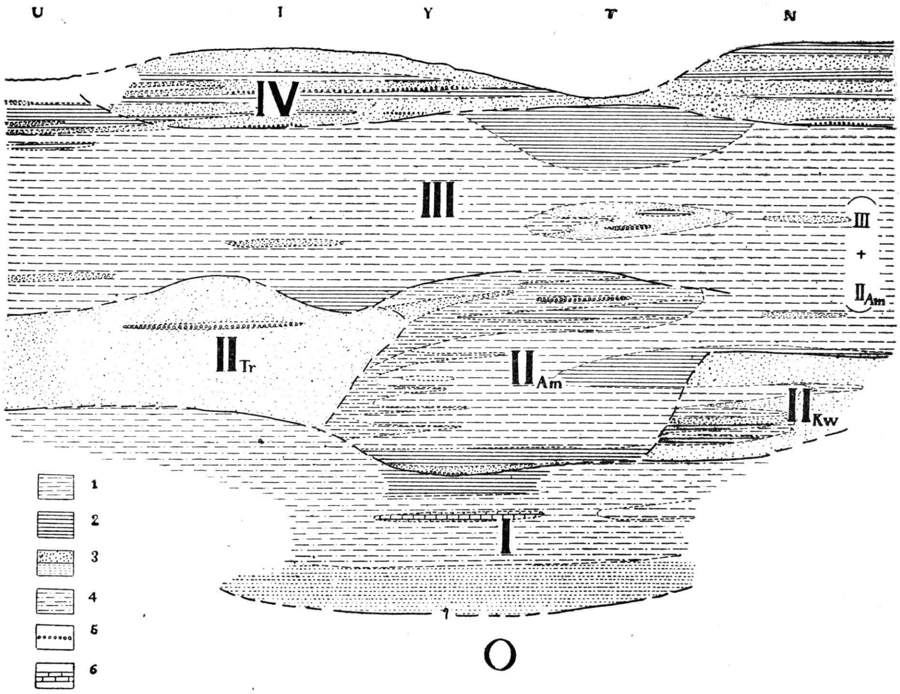

Fig. 28 a. Schematic illustration of the stratigraphic classification of the main part of the Cretaceous deposits of the Yezo-Saghalin province. a. Faciesstratigraphic classification. The thick line ist he boundary of major units (groups) and the fine line that of minor units, the fine broken line being that of formations, and the fine dotted line that of members. The thick broken line is a presumed boundary. 0. Onisasi Group, I. Lower Ammonite Group, II Am. Middle Ammonite Group, II Tr. *Trigonia* Sandstone, II Kw. Kawakita Group, III. Upper Ammonite Group, III+II Am. Miho Group, IV. Hakobuti Group (Ryugase Group) The predominant lithologic characters are shown by 1 (mudstones), 2 (fine-sandy mudstones), 3 (sandstones, either massive and heavy bedded, or frequently stratified), 4 (sandstone and shale in frequent alternation), 5 (conglomerates), and 6 (limestone). N,T, Y, I, and U are the approximate positions of the standard localities, the Naibuti district, the Abesinai district, and the Mid-valley of the Tesio, the Siyubari and its adjacent districts, the Isikari coalfield, and the Urakawa district.

much that is common in rock-facies[1], and the stratigraphic relation is very intimate.

(1) A green pyroclastic formation, or member, frequently interfingers in the cherty formation or member.

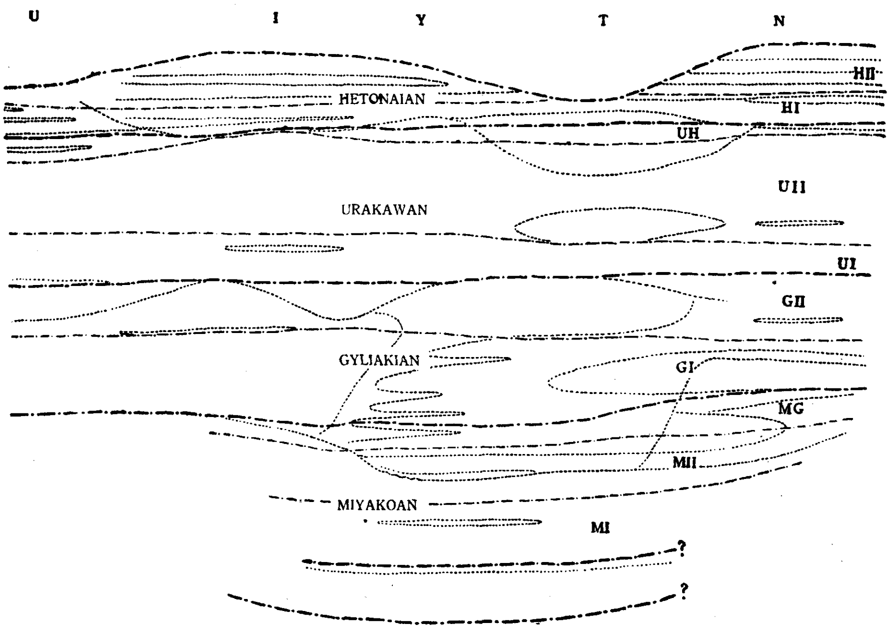

Fig. 28 b. Time-stratigraphic classification: Miyakoan comprising Paleomiyakoan (MI), Neomiyakoan (MII), and Infragyliakian (MG); Gyliakian comprising Paleogyliakian (GI), and Neogyliakian (GII); Urakawan comprising Paleourakawan (UI), Neourakawan s.s. (UII) and Infrahetonian (UH); Hetonaian comprising Paleohetonaian (HI) and Neohetonaian (HII). Dotted lines are the boundaries of facies-stratigraphic units, as illustrated in Fig. 28 a. showing, in some places, inconsistency between them and the chronologic boundaries.

Our present knowledge regarding this older part of the Mesozoic succession is insufficient; we must wait for future investigation[1].

Although, in lithologic character, Division A of the Keton-Aton-Hoe district resembles the Onisasi Group here defined, its stratigraphic position is below Division B, which will be assigned to a portion of the lower part of the Miho, or the Middle Ammonite Group. Moreover, its distributional area is too remote from the type locality of the Onisasi Group to enable us to examine the continuity of the two groups.

(1) While this paper, was in course of preparation, K. OTATUME published his precise observations of some of these older formations.

I. The Lower Ammonite Group (下部菊石層群)

This lies superjacent to the Onisasi Group, there being a conformable relation between the two, at any rate, in part.

The deposits are principally of flysch-type. Sometimes sandstone predominates and sometimes shale. Usually we find the lower part more frequently with sandstone, and even associated with a little conglomerate. Near the middle part, a member of organic limestone occurs. Except for this limestone, the group is generally poor in organic remains, although ammonites and other marine fossils are sporadically found. The sandstone of this group is usually quartzo-feldspathic, the material being probably derived from acidic rocks, acidic tuff and tuffite occurring in places.

Typical exposures are met with on the western and eastern sides of the Yubari mountain-range, along the Ikusyunbetu valley and the Ponhorokabetu in the Isikari coalfield, along the mid-valley of the Tesio, and in the Naibuti-Aikawa district. In the Siyubari district it attains a thickness of 1300 m.

The name Lower Ammonite Beds was proposed by H. YABE for that part of the group which is developed in province Isikari. I adopt here the name with an extension of its meaning, and with a redefinition. Strictly speaking, the name *Ammonite Group* is not appropriate, seeing that the group, which yields but few ammonites, differs considerably in rock-facies from the Middle and Upper Ammonite Groups.

II. The formations that lie on the Lower Ammonite Group show changes of rockfacies in places. The following three subgroups are discriminated. The exact relation between two of the three subgroups is not observable at present, there may have been a lateral and gradual change of facies.

II (Tr.) Trigonia Sandstone (三角貝砂岩): Greenish or grey sandstones predominate. Its typical part consists of a neritic sandstone, containing shallow sea fossils (*Trigonia* and other bivalves, gastropods, cephalopods, annelids, etc.). But in other parts, the sandstone is very poor in organic remains. Conglomerate and deposits of littoral origin occur in some parts, although in subordinate amount. Its thickness in the typical locality is about 500 m.

The type locality is the Ikusyunbetu valley in the Isikari coalfield, the formational name having been proposed by H. YABE. The subgroup is exposed at other localities in the same field, such as Yubari, Miruto, and Bibai. The sandstone and sandy shale in the lower part of the Cretaceous succession at Obirasibetu may belong to the same subgroup. In short, these localities represent the western part of the Cretaceous area under discussion.

II (Am). The Middle Ammonite Group (中部菊石層群): In the central or eastern part of the area, as for example, in the Abesinai district and in the Siyubari district, the Lower Ammonite Group is not succeeded by formations of sandy facies; we find instead a series of sedimentary rocks greatly resembling in lithologic character the Upper Ammonite Group. This is the Middle Ammonite Group. It consists largely of comparatively fine-grained sedimentary rocks, usually rich in calcareous concretions and fossils of ammonites and *Inoceramus*. Although it resembles the Upper Ammonite Group in rock-facies, it is more frequently intercalated by fine sandstone, being in some parts fine-sandy. In the upper part of the type localities we frequently meet with coarser sedimentaries. This part consists of alternations of mudstone, sandy mudstone, and sandstone, with a local conglomerate. It will be treated as a minor unit belonging to the group under consideration, and will be called the Saku Formation. Its rock-facies is intermediate between that of the typical part of the Middle Ammonite Group and the *Trigonia* Sandstone.

The thickness of the group at type sections is 1300 m (Abesinai) and 2800 m (Siyubari). The relation of the Middle Ammonite Group to the Lower Ammonite Group is a conformity in some places, but a disconformity in others.

II (Kw.) The Kawakita Group (emended) (川北層群): In the southern part of the Japanese Karahuto, as typically shown along the Naibuti valley, the Lower Ammonite Group is succeeded by a group of formations differing somewhat from the preceding two subgroups. The formations that consistute the group are those largely composed of sandstone, those chiefly composed of sandstone and shale in alternation, and those mainly composed of shale. Local disconformity and local conglomerate are discernible within the group. The fine-grained sedimentaries contain ammonites and other fossils.

The thickness of the group at type section is 1100–1200 m.

III. The Upper Ammonite Group (incl. the Miho Group) (上部菊石層群)

This group, lying conformably either on the *Trigonia* Sandstone or on the Middle Ammonite Group, consists of fine-grained sediments (chiefly mudstone) of a monotonous and homogeneous character, and containing abundant concretions and fossils of ammonites, *Inoceramus*, etc. Its rock-facies is what is called *Geodenterrains.*

The thickness in a typical area is about 1000 m. The group is typically developed in the Isikari coalfield, its distribution being very wide. Urakawa, Obirasibetu, Abesinai, and Soya are the districts in Hokkaidô besides the Isikari coalfield and its southern extension.

In Karahuto, as will be seen from the succession of the Naibuti district, although the Kawakita Group is overlain by a thick series of *Ammonite Group*, the upper half of which is undoubtedly a continuation of the Upper Ammonite Group in Hokkaidô, its lower half may be that of the upper part of the Middle Ammonite Group, the two parts being, however, quite identical in rock-facies and, forming, besides, a quite continuous series. For this whole succesion I have proposed the name *Miho Group* which, therefore, may also be called the Middle and Upper Ammonite Group.

The basal part of the Upper Ammonite Group in the Isikari coalfield is somewhat fine-sandy, a glauconitic sandstone occuring in its lower part. In the Urakawa district, a member consisting of the sandstone is foud in the lower part. The upper half of the group in this district is often somewhat sandy, members consisting of sandstone occuring at a number of horizons. For this part I propose the name *Tinomigawa Formation*, which shows a local variety of rock-facies within the Upper Ammonite Group. In the Abesinai district, the upper part of the group is very-fine-sandy mudstone, and the middle part frequently interfingered by greywacke-sandstone of either andesitic or basaltic origin, resulting in a local formation called the *Omagari Formation.*

In the northern part of the Japanese Karahuto, the Upper

Ammonite Group or the Miho Group, is interfingered by coarse-grained formations. To the latter belong Division C (*Inoceramus* Sandstone) and Div. Dβ (sandstone, shale, conglomerate, and coaly seams). Moreover, thin layers of sandstone frequently occur in the shale of Div. B.

IV. The Hakobuti Group (Ryugase Group, included) (函淵層群)

This is a group of formations which, occupying the uppermost part of the Cretaceous rocks in the area under consideration, lies conformably on the Upper Ammonite Group. Although conglomerate occurs in places, in the basal part there is no marked sedimentary break. The group is overlain by Tertiary formations, always with parallel unconformity. This epi-Cretaceous erosion is sometimes considerable, as shown in the succession of the Abesinai district.

This group consists of formations of sandstones of various grades of coarseness and that of fine-sandy siltstones, repeated a number of times. General coarseness of the sediments is a characteristic feature as compared with the Upper Ammonite Group, but the sediments are still of neritic environment, containing marine molluscs, although less abundantly in some formations. Littoral deposits and conglomerate occur only to a subordinate extent.

The type locality is the Isikari coalfield, good exposures being found along several valleys, such as the Mukawa (Hetonai), the Noborikawa, the Yubari, and others. The group, which was first recognized by H. IMAI, has been called the *Hakobuti Sandstone*. What UWATOKO and OTATUME called the Hetonai Group in the Hetonai district is a synonym for the Hakobuti Group.

The thickness of the group is estimated at 800 m at Hetonai and 450 m at Noborikawa.

This group is seen developed continuously to Karahuto, where andesitic greywacke of a green colour is the chief constituent in its coarse-grained formation. The name *Ryugase Group* is applicable to this group in Karahuto. (In which case, the Hakobuti Group, strictly speaking, is restricted to the group in its type locality.)

X, Y. The Werblud and Cape de la Jonquière Groups

Although these two groups, exposed near Alexandrofsk, North Saghalin, are stratigraphic units that differ in rock-facies from all the preceding groups, judging from their distribution, their fossil-contents, and the presence of intermediate rock-facies in the northern part of Japanese Karahuto (as described in the last paragraph of the Upper Ammonite Group). They may be regarded as continuations of the Cretaceous deposits in the main part of the Yezo-Sagahalin area of sedimentation. Probably, as OBRUTZEW and SHIMIZU have discussed already, they are marginal facies of the area of sedimentation, greatly affected by continental conditions.

The definition and subdivision of the two groups were given by H. YABE and S. SHIMIZU (1923). See citation in Chapter III, page 160.

A note on the inconsistency between classification from the purely chronologic standpoint and classification from the standpoint of facies-development.——The preceding stratigraphic division is a classification from the standpoint of facies-development. Although each unit of the classification is a continuous body of sedimentary rocks, its time-range is not necessarily constant at every section. That is, its lower or upper limit at one locality is not necessarily contemporaneous with that at another. This inconsistency, or obliqueness, between the chronologic scale and the division of rock-facies is clearly exemplified by the results of correlation given in Chapter III. (See also Fig. 28 b)

The boundary of the Hakobuti (or Ryugase) Group and the Upper Ammonite (or Miho) Group is found in the middle of the Infrahetonaian age in the Naibuti district, in the Paleohetonaian in the Abesinai district, and at the base of the Infrahetonaian (or at the top of the Neourakawan s.s.) in the Hetonai-Isikari district. Moreover, in the Urakawa district, the deposits of Paleohetonaian age are completely represented by the upper part of the Upper Ammonite Group.

The lower limit of the Upper Ammonite Group in the Abesinai district and in the Siyubari district lies at the boundary of the Urakawan epoch and the Gyliakian epoch. Although the same condition obtains near Yubari in the Isikari coalfield, along the section of the Ikusyunbetu in the same field the base of the group ranges downward to Neogyliakian age. In other words, the top of the *Torigonia* Sandstone at Ikusyunbetu is of different age from that at Yubari.

The boundary separating the *Trigonia* Sandstone from the Lower Ammonite Group in the Isikari coalfield is nearly at the boundary of the Gyliakian epoch and the Miyakoan epoch. The time-relation between the Middle Ammonite Group and the Lower Ammonite Group in the Abesinai district does not differ much from this, whereas, in the Siyubari district, the boundary between the two groups lies in the middle of the Miyakoan epoch. The top of the Lower Ammonite Group along the Naibuti Valley is of Neomiyakoan age (s. str.), since the formation in the middle part of the superjacent Kawakita Group is of Infragyliakian subage.

Thus, inconsistency between the chronologic scale and the division of rock-facies generally prevails in the Cretaceous deposits under consideration. The vertical change in rock-facies did not everywhere take place contemporaneously.

Geological meaning of the development of rock-facies in the Mesozoic Yezo-Saghalin Province, with a short note on the principle of stratigraphic classification from the standpoint of facies-development.——The preceding results of our study enable us to say that division of strata from a purely chronologic standpoint and that from the standpoint of facies-development belong to different forms of classification. The two must be separated.

The acustomary concept regarding the unit of stratigraphic division (since W. SMITH's time) is defined from both lithologic characters and fossil-contents. But the fossil-contents of a formation comprise factors of different kinds, e.g. those related to facies and those related to the chronologic instant. Since ascertaining the presence of the fossil-zone, the contradiction presented by the old stratigraphic unit came to be noticed, the zone having been traced quite independently of its lithologic characters. But, as discussed in Chapter IV, even the fossil-zone has not always a purely chronologic meaning.

We must abandon the old method of classification. I believe that it is preferable for the science of geology to establish two classifications of separate categories, one the classification from the chronologic standpoint and the other the stratigraphic division from the standpoint of facies-development. It is better to use only the terms of *system-series-stage* as those of chronologic units of strata, which are defined without regard to rock-facies, while another term should be introduced to suit the other system of classification, the unit of which classification may be defined as being a body of sedimentary rocks or sediments which is characterized by a certain *rock-facies.* Having a three dimensional magnitude, it was formed during a certain time-length of geological order. But, here, *rock-facies* means not only the features of sedimentational environment but the synthetic sum of all the characters of rocks, including mechnical composition, colour, textures, sedimentary structure, mineral composition, features of fossils as facies-indicator, variability and uniformity of lithologic characters, rate of accumulation of sediments, etc, all of which could indicate the geological conditions that prevailed during their formation.

I think it better to arrange the units of this classification with the following terminology[1].

Complex, Group, (Subgroup), Formation, Member

In arranging this system of classification, the following points must be considered: (1) the three-dimensional magnitude of each unit, (2) the magnitude of the time-length during which the unit formed, (3) the degree of similarities and differences in rock-facies, (4) mutual relation between units, (5) relation of the whole to part, and so on.

That classification based on rock-facies is often inconsistent with the chronologic division is no reason for holding that the former is meaningless in our study of stratigraphy. Considered from another angle of historical geology it is of utmost importance. It can well portray the geologic conditions and their evolution, each unit of the system of classification representing a certain geologic phenomena at each phase of that particular geologic evolution. It is one of the methods of historical geology, exactly as chronologic classification is only one of the methods in the same science. In order to exemplify this statement, I shall now attempt to describe the geologic meaning of the development of rock-facies in the Mesozoic Yezo-Saghalin province.

As stated in the first paragraph of this chapter, there is

(1) This is an extension of the so-called formational unit. Here the terminology of American stratigraphers is adopted with certain necessary emendations. American usage is unsatisfactory in that the terms that are arranged in a system are sometimes chronologic and at other times formational.

ample reason for regarding the Cretaceous deposits of the meridional zone of Hokkaidô and Karahuto as those having formed in a continuous area of sedimentation which, in turn, has been provisionally called the Yezo-Saghalin province. In this extensive area, sedimentation seems to have taken place even when it ceased in other regions, and the Cretaceous sediments accumulated almost continuously. Besides, these sediments are of more or less shallow sea origin, at any rate in its principal part, and have a considerable thickness. Thus the area in question is a sort of geosyncline to which the name **Yezo-Saghalin geosyncline** has been proposed(1).

It is possible to interpret the geologic conditions and their history, in and near the Yezo-Saghalin geosyncline from a study of the facies-development of the Mesozoic rocks in the meridional zone running through Hokkaidô and Karahuto.

We have at present no precise knowledge regarding the base of the geosyncline. The oldest preserved are the Onisasi Group, in which records may be found of the conditions that prevailed during the initial stage in the development of the orthogeosyncline. The predominance of basic pyroclastic matter and siliceous sedimentaries point to volcanic activity during this stage. Although radiolarian remains are common in the siliceous sedimentary rocks, we have nothing positive by which to determine whether it indicates an environment consisting of a deep submarine trough or some other environment.

Sooner of later, in the Paleocretaceous Period, the condition changed to that under which a flysch-type of deposition took place. The earlier half was under a very shallow water, where accumulation of sandstone predominated, and an organic limestone, having the character of reef-limestone, was formed. The material for deposit was brought from some acidic rocks, and intermittent volcanic activity occured.

This condition ceased somewhere in the middle of the Neomiyakoan age and elsewhere at the end of the same age. Towards, and in the Gyliakian epoch, the following three conditions affected the geosyncline.

(1) That in which deposition of neritic sandstone predominated.

(2) That in which thicker and finer sediments deposited, when conditions were generally more tranquil and monotonous, but later

(1) T. Matumoto 1940

(Neogyliakian) conditions changed to frequent depositions of coarser sediments of shallow seas.

(3) That in which interfingering of coarser deposits in fine sediments repeatedly occurred. In the coarse-grained formation occur local breaks of sedimentation, showing erosion on a minor scale.

Thus, contrary to customary belief, the Gyliakian epoch, or the Middle Cretaceous (including later Neomiyakoan) is not merely an epoch of emergence or marine regression, but that of some mobility. Namely, shallowing of the sea, and even upheaval and erosion took place somewhere, probably due to rise of mountains near the area of sedimentation, but more complete sinking and sedimentation continued in the core of the geosyncline, while even a renewed transgressive phase is found in connexion with the Lower Ammonite Group.

Sooner or later, the geosyncline was almost entirely subjected to an inundation phase, the maximum of which seems to have been in the Urakawan epoch. Fine-grained shallow sea sediments steadily continued to deposit without interruption, although certain variations in facies resulted from minor and local changes in geologic conditions. It should be remembered that this condition seems to be the sum total of results of both geosynclinal sinking and the epeirogenic subsidence of more extensive character, as I have fully discussed elsewhere (1940).

Towards the end of the Urakawa epoch or at some time in the Paleohetonaian age, a general shallowing of the sea occurred, and although even littoral conditions obtained in some places, there was no great sedimentational break. Since then, the geosyncline has been under that condition in which regressive coarse-grained formations and transgressive fine-grained formations alternated repeatedly. Nevertheless, the area of sedimentation was, under the environment of shallow seas, while the geosynclinal sinking was still going on. Volcanic activity and the presence of volcanoes near the area of sedimentation are indicated by the materials composing the sediments.

As has been confirmed by the investigations of geologists in Hokkaidô, retreat of the sea due to warping took place in the epi-Cretaceous epoch, although sedimentation kept on until the close of the Tertiary Period, at any rate, in a part of the area under consideration. But in the Neogene Period, the Yezo-Saghalin geosyncline was subjected to orogenic conditions at several phases.

We have not at present sufficient knowledge of the extent of the geosyncline and the siuation of other geotectonic units adjacent to it. The Cretaceous in North Saghalin, as described already, seems to show the marginal facies, and the lateral change in rock-facies during Middle Cretaceous seems to show the presence of a land on the western side.

Further studies in the stratigraphy of the Mesozoic of less fully explored areas may, in future, reveal a more accurate geologic history than I have here endeavoured to outline.

PART III

FURTHER PROBLEMS

Part III contains brief references to the problem that are intimately related to the subject dealt with in the preceding two parts. Since a complete solution of the problem demands still further investigations, only a few notes, suggestions, and preliminary observations are made here.

Chapter I

Notes on the Palaeontologic Material

In treating, in this memoir, the stratigraphy of the Cretaceous deposits in the meridional region of Hokkaidô and Karahuto, owing to their great importance from the standpoint of stratigrapy, much has depended on the molluscan remains, especially the cephalopoda and those of *Inoceramus*. Descriptions of the palaeontologic materials referred to in connection with the present study will be published on a future occasion in three separate papers entitled:

Studies on the Cretaceous Ammonites from Hokkaidô and Karahuto, Japan.

Further Studies on the Certaceous *Inoceramus* from Hokkaidô and Karahuto, Japan, being a supplement to *A Monograph of the Cretaceous Inoceramus of Japan.*

Short Contributions to the Cretaceous Palaeontology of Japan.

Although a number of valuable contributions have been made by previous investigators[1] to the palaeontology of molluscs, there still remain several forms undescribed, while, in some cases, a revised classification is necessary, for which reason it is my intention to fulfiill these requirements as far as possible in the three forthcoming papers just mentioned.

(1) J. BÖHM 1915, K. JIMBO 1894, R. MICHAEL 1899, T. NAGAO 1931 b, c, d, 1932 a, b, c, 1933, 1938, 1939, T. NAGAO & T. MATUMOTO 1939–1940, T. NAGAO & K. OTATUME 1938, T. NAGAO & R. SAITO 1934, F. B. SCHMIDT 1873. 1897, S. SHIMIZU 1926, 1929, 1931, 1932, 1933, 1935 a, b, H. YABE 1902, 1903–1904, 1909, 1910, H. YABE & NAGAO 1925, 1926, 1928, H. YABE & S. SHIMIZU 1921, 1924 a, 1925, 1926, S. YEHARA 1915, and M. YOKOYAMA 1890

Of palaeontologic material other than molluscs, we find foraminifera, corals, brachiopods, echinoids, annelids, crustaceans, fishes, reptiles, and plants, all of which have also been studied by numerous investigators[1]. Although, stratigraphically, many of these fossils are not so important as the molluscs, there is little doubt that further studies of them will contribute to the solution of the stratigraphic problems.

Mention, however, must be made of another palaeontologic problem. Although in the preceding chapters I have frequently referred to the *true range of species* and the *life-period of species*, there is a palaeontologic question requiring an answer on the life-period of species in connection with the problem of interspecific relations. Granted that we accept the theory of evolution of organic life, how does the old original species change to a new species? Leading students of palaeontology and biology are not in agreement regarding the process of evolution. According to one school (represented by DACQUE, BEURLEN, EFREMOV, SCHINDEWOLF, etc.), the species changes abruptly and discontinuously while, according to the other school (represented by BRINKMANN, ABEL, OSBORN, TRUEMAN, SWINNERTON, etc.), the species change gradually, admitting forms intermediate (Übergangformen) between any two species. If the latter be the case, there does not appear to be any sharp boundary of species when we trace the history of organisms chronologically, thus bringing us to the second question——how can we then define the life-period of a species? I have made attempts to answer these questions with the aid of the available materials at hand, with results as will be found in my paper in Japanese[2]. I shall give these results here in very concise form.

(1) The first requisite in solving the problem is, I think, a clear definition of *species*. Although various definitions have been proposed, my studies have led me to adopt what I think is the most

(1) S. ENDO 1025, K. FUJII 1910, K. FUJII & M. C. STOPES 1909, K. JIMBO 1894, A.N. KRYSHTOFOVICH 1917, 1918, T. NAGAO 1931, 1936, 1938, M. SIMAKURA & H. YABE 1901, 1902, H. YABE & S. HANZAWA 1926, H. YABE & T. NAGAO 1928, H. YABE & T. OBATA 1930, H. YABE & S. TOYAMA 1928, etc.

(2) 異種間の關係に就いての一研究——特に化石種の生存期間の問題に關聯して A study on the inter-specific relation, with special reference to the palaeontological question on the life-period of species (Journ. Geol. Society of Japan, vol. 47, no. 1, 1941)

satisfactory one, namely, that species is a fundamental concept of systematics (classification), which is an elementary branch of biology. In organic life there is an outstanding phenomenon from which the concept of species is derived. That is, there is a group of individuals that are able to reproduce in the natural state, and have, at the same time, more important morphological characters in common. This group of individuals is a *species*. The definition, however, subject to certain reservations, as stated in the Japanese text, which are omitted here. Largely from knowledge of comparative anatomy, it is poosible to recognize the species in the case of the palaeontologic material.

(2) With the term *species* clearly defined, its life-period in palaeontology is neither meaningless nor indeterminable.

(3) But no species is immutable; it changes as the result of external and internal causes. Between two species that may possibly be intimately related genetically, the following morphological relations hold:

a. Morphologically serial $\begin{cases} a1 \\ a2 \end{cases}$

b. Morphologically hyatal $\begin{cases} b1 \\ b2 \end{cases}$

Upon examining a large number of individuals belonging to a certain species, we find that not all of them are identical. This is variation in the true and broad sense. When numerous individuals of two resembling species are examined, in one case (a) the range of variation in the important characters (which represent the specific difference) in each species is found to connect or overlap, whereas, in the other case (b) we find no connecting point. In the former case a certain number of individuals is found to show characters intermediate between the typical forms of the two species. In the latter case (b) we find a larger or smaller gap in the morphological characters between the individuals of one species and those of another. Usually, a number of these characters serve for specific identity or distinction, and even in the morphologically serial case, an individual having intermediate features simultaneously in every one of these important characters is rather rare. This is case al. More often, a small group of individuals that may show intermediate features in one particular character does not always agree with another small group of individuals that may have intermediate features in another character, although the range of variation in the matter of each character connects the two species. This is case a2. In the morphologically hyatal case, discontinuity of variation is sometimes found to involve a few character (b1), and at other times involving a number of characters (b2), the degree of discontinuity varying. Moreover, that stage when the *new character* appears in ontogenetic growth varies with species and even with individuals.

The foregoing relations of different species are those as viewed morphologically, and not from purely genetical considerations, which is the reason for my introducing these terminologies.

(4) Careful scrutiny of the preceding results of my palaeontologic investigation from the standpoint of recent genetics, has failed to convince me that there is any inconsistency in the two branches of biology. The phenomena of variation expressed externally in the morphological characters of individuals vary when examined genetically. They are

A. Genetic variation (Mutation)
- A1. Gene mutation
- A2. Numerical change in the chromosomes
  - (a) Polyploidy n, 3n, 4n, ...
  - (b) Heteroploidy 2n+1, 2n−1
- A3. Chromosomal abberation
  Fragmentation, translocation, inversion, duplication, deficiency; Segmental interchange
- A4. Somatic mutation

B. Somatic variation (fluctuation or modification)

Should a change occur in an internal hereditary substance, the degree of that change presented externally on the phenotype varies, sometimes being almost unrecognizable, and at other times displaying *variety*, while at still other times the change is so great as to result almost in specific distinctions. Besides, somatic variation can modify the features, while genetic variation (mutation in the correct sense) is at present believed to be the internal factor that gives rise to evolution. For these reasons, in recognizing the presence of such morphological relations as have been described in the preceding paragraph between two species that are possibly intimate, genetically, I feel that my conclusions are in harmony with recent genetics.

(5) In applying the life-period of species to stratigraphy, it behooves us to give a clear definition of *species*, and elucidate its variations and relations (not merely comparaison) with resembling species through the phenomena of variation. Theoretically, it is possible for individuals having characters intermediate between them and another species to exist; as a matter of fact they are sometimes met with, but they should be included within one species, as a variety. Consequently, it is possible to describe definitely the life-period of a species even if there is an *intermediate form*. I make it a rule to note these points in describing palaeontologic material.

(6) The chronologic relation of two species, as here discussed, varies. The cases, as illustrated in Fig. 29, are (1) the life-period

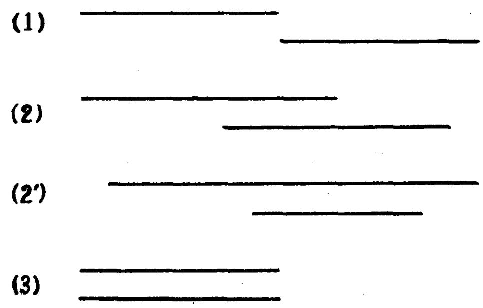

Fig. 29 Relations of the time-ranges of two species which are allied to each other: (1) successive, (2) overlapping, (2′) partly coexistent, (3) coextensive.

of the two species is successive, (2) the life-period of the two species overlaps (i.e. the species coexist during a part of the life-period of one or both species.), and (3) the life-period of the two species is coextensive.

(7) Accordingly, the succesive series of species can be applied to biostratigraphy as an indictor of successive time only in a special case. Biologically, the mutation idea of WAAGEN, which he defines from the stratigraphic, or chronologic standpoint, is not satisfactory. Generally, the change that brings about an evolutional change of organism is, in the sense of recent genetics, mutation. Although,

the mutant, in the genetical sense, can, it is true, appear successively from its original form, it can also, chronologically, overlap or be coextensive with the latter. The mutant is represented in the phenotype as a variety. Instead of the mutation of WAAGEN, biostratigraphers, in dealing with geological problems, should use the word variety in its biological sense.

Chapter II

Chronologic Scale Applicable to the Cretaceous Deposits of the Japanese Islands

A. REMARKS ON THE CORRELATION OF THE MIDDLE AND UPPER CRETACEOUS DEPOSITS OF JAPAN

Outside of the meridional zone of Hokkaidô and Karahuto, Cretaceous deposits are distributed over various localities in the Japanese Islands. Since it is my intention to deal with their stratigraphy in a comprehensive way in another paper, all I shall do here will be to touch on the matter of their correlation, following which I shall attempt to explain just how and why the new knowledge referred to in Part I, II of this paper is fundamental in constructing the Cretaceous stratigraphy of the regions concerned.

Although, with the exception of a part of the Lower Cretaceous of Southwestern Japan, the Cretaceous deposits under discussion consist largely of marine sediments, they are, in contrast with the Cretaceous of the meridional zone of Hokkaidô and Karahuto, usually poor in fossils, so that should there happen to be a prolific layer there, the occurrence could only be regarded as sporadic, with the chances that such a layer would be discontinuous either horizontally or vertically. Besides, in a number of areas, these Cretaceous deposits that we are now discussing show, in their rock facies as also in the succession of strata, various features that we do not find in the Cretaceous of Hokkaidô and Karahuto, with the result that in the case of some of the formations, at any rate, determination of their age seems a difficult task. Nevertheless, by availing ourselves of the new knowledge gained in regard to chronology as established on the basis of the Hokkaidô and Karahuto material, it is possible to correlate them with a fair degree of accuracy.

I shall now illustrate this statement with examples from the Upper and Middle Cretaceous strata. Much, of course, will have to remain for elucidation with the aid of further studies and additional fossil collections, both of which, unfortunately, are at present insufficient for many localities outside of Hokkaidô and Karahuto.

Before entering into a detailed discussion, a few general notes should be helpful.

(1) Since, as judged from data so far obtained, the marine Cretaceous of Japan belongs to one and the same biogeographic province, the life-period of a species for that region between Hokkaidô-Karahuto and other areas within the Japanese province may be regarded as being virtually the same, although there may have been subprovinces[1] in Japan, the time-range of a species in them not being always identical if not very different. This contingency should be borne in mind when correlating strata of different localities.

(2) With only a single species as basis, all that can be determined is the age in the chronologic unit that corresponds to the time-range of that species. Should, for example, *Gaudryceras tenuiliratum* YABE em. be found in a formation, it may safely be concluded that the formation belongs to the Urakawan Series, because this species is known to range throughout the entire Urakawan Epoch. We cannot decide from this single material alone whether the formation is Paleourakawan or Neourakawan, even if it did really belong to the Paleourakawan stage and does not extend upward to the Neourakawan. Should, however, a number of important species occur, more precise determination of age may be possible. Therefore, should, for example, *Scaphites* (*Yezoites*) *puerculus* (JIMBO), *Anagaudryceras limatum* (YABE), and *Damesites damesi* (JIMBO) happen to be found in addition to the solitary fossil, all doubts of the age of this solitary fossil would be dispelled, notwithstanding that the whole four species have a longer duration than this age (see charts, Part II).

(3) Fossils are not always found in abundance throughout the entire thickness of a formation. They often occur sporadically or in a few fossiliferous lenses of the formation. Is it impossible to determine from the "fragmentary" material the age of the entire formation instead of only that of the fossiliferous part? Hardly. We should first consider the magnitude of the geological scale. We should then remember the factors governing the occurrence of

[1] As shown by the uniformity of the Japanese Cretaceous fauna, the division into subprovinces was certainly not so large as in Recent times.

fossils. A fossil, it is true, may occur at a point or, at any rate, in a small part of the whole, compared with the entire formation, but this point must be regarded, logically, as the limit of a certain space of horizontal and vertical dimensions. Furthermore, methods other than the biostratigraphic are available so long as the limits of their application are not exceeded; they can fill the defficiencies in the biostratigraphic methods.

A. *Geological age of the Kuzi Group in the Kitakami Mountainland and the Hutaba Group in the Abukuma Mountainland.*——The Cretaceous deposits of the Kuzi district on the northeastern margin of the Kitakami Mountainland were investigated by Y. SASA (1932), who called them the Kuzi Group. From what we know of its stratigraphy we get the following abridgement, in ascending order:

Basement complex

~~~~~~~~~~ Great unconformity ~~~~~~~~~~

Kuzi Group
- Lower: Tamagawa Formation (Sandstone and conglomerate of the littoral origin.) 100–150 m. ※ *Ostrea* and plant remains.
- Middle: Kunitan Formation (Neritic sediments, chiefly composed of alternating sandstone and mudstone.) 200–150 m. ※ *Inoceramus japonicus* NAGAO & MATUMOTO, *Polytpychoceras* sp., *Gaudryceras denseplicatum* (JIMBO), *Mortoniceras amakusense* YABE & SHIMIZU.
- Upper: Kadonosawa Formation (Littoral or brackish sediments, mainly mudstone, shale, sandstone, and conglomerate in frequent alternation) 200–250 m. ※ Plant remains.

~~~~~~~~~~ Parallel unconformity ~~~~~~~~~~

Palaeogene

A similar narrow belt of Cretaceous strata is developed in the northern part of the Zyoban coal-field, Hutaba-gun, Hukusima Prefecture, along the eastern border of the Abukuma Mountainland ——the Hutaba Group that was investigated by S. TOKUNAGA and others. The stratigraphy is summarized as follows:

Basement complex

~~~~~~~~~~ Great unconformity ~~~~~~~~~~

Hutaba Group
- Lower Formation (sandy shale and sandstone, with conglomerates. Sediments of littoral or shallow sea origin) 270 m. ※ *Anagaudryceras limatum* (YABE), *Scaphites* (*Yezoites*) *puerculus* JIMBO var. *teshioensis* YABE, *Bostrychoceras indicum* (STOL.), *Yabeiceras* spp., *Inoceramus uwajimensis* YEHARA, and other molluscs and reptiles.
- Middle Formation (bluish mudstone with locally intercalated layers of coarse sandstone) 120 m, barren.
- Upper Formation (coarse sandstone and conglomerate with local intercalation of shale) 220 m, *Polyptychoceras* (?) sp.

~~~~~~~~~~ Parallel unconformity ~~~~~~~~~~

Palaeogene

Assuming the facts established in Part II as standard, we can clearly determine the age of the Kunitan Formation of the Kuzi Group to be Neourakawan, and that of the Lower Hutaba Formation to be the Paleourakawan. That the true range of species in the province under consideration is the same as that in the Yezo-Saghalin province is almost undoubted, because the former province is joined to the south of the latter, while the assemblage of fossils in no way contradicts this assumption.

But, is it possible to determine the age of the remaining formations that do not contain the necessary fossils? Since the environments of sedimentation of the Kunitan Formation differ from the two other formations in the Kuzi Group, there are two alternate contingencies, the one that the fossils in the Kunitan Formation may represent merely an apparent range of species, the superjacent and subjacent formations belonging also the Neo-urakawan Stage; the other that the Kunitan Formation may represent the main part of the Neourakawan, the Tamagawa formation being older than the Neourakawan and the Kadonosawa Formation being younger than the main part of the Neourakawan. The same may be said of the age of the formations of the Hutaba Group.

The Kitakami Mountainland and the Abukuma Mountainland are not only geographically adjacent, but have a like geologic history (especially since later Mesozoic), with the result that the correlation based on phases of crustal movement may be regarded as being applicable. With this assumption as basis, we may say that (1) Unconformities below the Kuzi Group and the Hutaba Group have one and the same meaning in geologic history. If the deposits in the two area are similarly located in the margin of the moutainland, deposition must have begun contemporaneously. (2) The three formations in each group represent phases in a cycle of sedimentation, whose phases do not always agree in age wherever found. But so far as the localities that occupy similar positions in the mountainland are concerned, we may conclude that they agree in time. (3) Had deposition occurred under similar conditions and along the course of a similar geologic history, the thickness of the sediments formed during an age may not vary much. We find that the thickness of the corresponding formations in the two groups under consideration do not differ greatly.

From these inferences we can accept the approximate correlation described below, although the boundaries of the formations may not be exactly contemporaneous.

Tamagawa Formation: Lower Hutaba Formation: Paleourakawan

Kunitan Formation: Middle Hutaba Formation: Neourakawan

Kadonosawa Formation: Upper Hutaba Formation.

Since the upper formation has not yielded available fossils from any of the two districts, its age is still uncertain. It may be uppermost Neourakawan (i.e. Infrahetonaian) or inclusive of Paleohetonaian. Considering that erosion took place at the beginning of the Palaeogene, the idea of the original presence of the Hetonaian sediments is justifiable.

The correlation mentioned above should be confirmed by further fossil collection.

B. *Izumi Sandstone Group in the Izumi Mountain-range and in the Island of Awazi.*——The Izumi Sandstone Group, a series of Cretaceous deposits, occupying a long belt along the Median Line of Southwest Japan, has been stratigraphically studied on the Island of Awazi, the locality most suitable for the purpose. According to SASAI (1936), who investigated the area, basing his study on the previous works of YABE (1915), Yehara (1921, 1925), and others, the following sequence is recognized:

Underlying: Granitic rocks

~~~~~~ Marked unconformity ~~~~~~

(1) Tui Basal Conglomerate, 200 m.
(2) Minato Shale (emend.) comprising the first fossil-zone, 500 m.
(3) Yoroizaki Sandstone with frequently intercalated shale, 1400 m.
(4) Siti Shale or the second fossil-zone.
(5) Kita-ama Sandstone, somewhat fossiliferous in the lower part, 3000 m.
(6) Nada Sandstone, and conglomerate, 1500 m.

The revised[1] list of the important fossils yielded from the formations is as follows:

1) This revision was made at the time when I had the opportunity of examining the collec tions of SASAI and others that are deposited in the Geological Institute of Tôkyô Imperial University.
~~~~~~

"*Arca*" *fibrosa d'Orbigny*	(2)
Cucullaea aff. *truncata* GABB	(2)
Parallelodon sachalinensis (SCHMIDT)	(2) (4)
Inoceramus aff. *balticus* BOEHM	(4) (5?)
Inoc. orientalis SOKOLOW	(2)
Inoc. shikotanensis NAGAO & MATUMOTO	(5)
Trigonia subovalis var. *minor* YABE & NAGAO	(4)
Bostrychoceras awajiense (YABE) em. SASAI	(2) (4?)
Pravitoceras sigmoidale YABE	(2)
"*Hamites*" sp.	(2)
Baculites cfr. *anceps* LAMARCK	(4)
B. cfr. *vagina* FORBES	(5)
Canadoceras cfr. *compressum* MATUMOTO MS	(2) (4)
Ananchytes ovatus (LESKE)	(2)
Linuparus japonicus NAGAO	(2)
Notidanus japonicus SASAI MS	(5)
Basilemys sp.,	
Zamiophyllum buchianum ETT.	(3) (5)
Cycadeoidea ezoana KRYSHT.	(6)

An outline of the same group in the Izumi Mountain-range has been given by T. KOBAYASHI (1931). It is as follows, in ascending order:

Underlying: Granite
~~~~~~ Marked unconformity ~~~~~~~~~~~~
(1) Kasayama Basal conglomerate (20–40 m) followed by a sandstone (50 m or so).
(2) Asenotani Shale, fossiliferous.
(3) Kinyuzi Sandstone and conglomerate.
(4) Warazuhata Shale and sandstone, yielding *Archaeozostrea*.
(5) Tuzurahara Sandstone and granule-conglomerate.

KOBAYASHI made a preliminary study of the marine fossils, mostly from the second formation; they are shown here with necessary emendations.

Nucula spp.
Cucullaea aff. *truncata* GABB
Cucullaea sp.
Trigonia subovalis JIMBO var. *minor* YABE & NAGAO
Astarte sp. aff. *A.* (*Dorzyia*) *striata* STOL.
Cyprina aff. *cuneata*
Siliqua sp.
Inoceramus sp. of *naumanni* group (cfr. *I. naumanni* YOKOYAMA or young shell of *I. orientalis ambiguus* NAGAO & MATUMOTO)
Pecten sp.
Scurria cassidaria (YOKOYAMA)
Natica sp.
~~~~~~

Neophylloceras sp. cfr. *N. compressum* MATUMOTO
Gaudryceras striatum (Jimbo) var. *paucistriata* MATUMOTO
Baculites sp.
Pachydiscus (s.s.) *kobayashii* (SHIMIZU)

Since the Izumi Sandstone Group in Awazi and in Izumi are not only contiguous, but also have the same stratigraphic succession, they can be correlated with each other, there being no doubt that the Asenotani Shale is equivalent to the Minato Shale.

Upon examining the fossils of the group, we find a few species that are entirely absent or rather rare in the Cretaceous deposits of Hokkaidô and Karahuto. For example, *Pravitoceras sigmoidale* YABE seems to be characteristic of Southwest Japan, while *Bostrychocecas awajiense* (YABE), which is very common in the Izumi Sandstone Group, is rather rare in Hokkaidô and Karahuto. Nevertheless, there are species that are widely distributed in Japan, so that differences in faunal province between the two areas, if any, cannot be marked, being merely a subprovincial difference.

Judging from the assemblage of fossils, especially the range of common species, the Minato-Asenotani Shale can possibly be referred to the Infrahetonaian substage of the Neourakawan Series, while the occurrence of *Inoceramus shikotanensis* NAGAO & MATUMOTO from the Kita-ama Sandstone indicates that the upper part of the group ranges up to the Neohetonaian. Further collection of fossils may confirm this conclusion.

As to the age of the basal conglomerate, we notice that it underlies directly the Minato-Asenotani Shale, its thickness being small considering the enormous thickness of the superjacent part, with the result that it may belong to the same series as the Minato Shale, or at most to the upper half of the Neourakawan. Of course, the base of the group may not everywhere be of the same age. As a matter of fact, we have evidence that in the western part of the Izumi Sandstone Belt (e. g. near Matuyama of Ehime Prefecture), it ranges further downward.

From this correlation we notice that the proper part of the Izumi Sandstone Group is younger than some of the Upper Cretaceous deposits in Southwest Japan (e.g. those of Amakusa, Onogawa in Kyūsyū, and Uwajima in Sikoku), which were once included in the "Izumi Sandstone Series" in the broad sense.

Another noteworthy fact is the tremendous thickness of the sediments that accumulated during only a comparatively short epoch.

C. *Cretaceous deposits of the Amakusa Islands, Kyūsyū.*——The Cretaceous deposits of the islands of Amakusa, which lies at the western end of the median zone of Kyūsyū, have been investigated by a number of geologists[1]. Their stratigraphy may be summarized as follows:

——— Lower limit unexposed ———

Gosyonoura Group

I. Lower Formation, 100–200 m.
  a. Coarse arkose, pebbly sandstone and conglomerate, rather massive and often cross-laminated; with intercalations of several lenticular layers of red siltstone or fine-sandstone.
  b. Mainly shallow sea sediments, consisting of very coarse to fine sandstone, conglomerate, and thin coaly shale; many richly fossiliferous layers included.

II. Middle Formation, 530 m.
  a. Coarse grained sediments, made up of sandstone and conglomerate, occasionally cross-laminated; pebbles well rounded.
  b. Very fine to medium grained sandstone, rather massive, bluish or greenish grey, containing *Trigonia*, *Callista*, ammonites, etc.
  c. Coarse sandstone predominating, *Trigonia* and gastropoda found seldom; partly pebble- and granule-conglomerates.
  d. Stratified sandstones, ranging from very coarse and conglomeratic rocks to very fine and silty ones, containing a few fossiliferous beds. A lenticular layer of red siltstone is rarely intercalated.
  e. Sandstone, rather massive, containing *Trigonia*, ammonoids, and other molluscan shells.

III. Upper Formation, 200 m.
  Deltaic deposits, mostly subaqaceous and partly subaerial, consisting of very coarse to very fine sandstone, silty rocks, cross-laminated conglomeratic sandstone and fanglomerate; many fossiliferous beds included. Several layers of red rocks are found in the lower part.

——— Partly lying conformably on the Gosyonoura Group ~~~ Partly lying unconformably on older complexes ~~~

Himenoura Group, 250–450 m.
  a. Basal conglomerate or arkose in the eastern part, basal sandstone in the western part, and beds transitional to the Gosyonoura Group in the southern part.
  b. Sandstone, bluish or greenish, rather massive, containing *Glycymeris* and *Inoceramus*.
  c. Rather massive sandy shale and shale, dark grey, fairly rich in fossils (ammonoids, *Inoceramus*, echinoids, etc.)
  d. Thin-bedded sandy shale with thin intercalated layers of sandstones; rarely fossiliferous.

1) YABE, H. 1901, 1902, 1909; YEHARA, S. 1929, 1922, 1923; NAGAO, T. 1922, 1930; YABE, H. and SHIMIZU, S. 1924, 1925; NOTOMI, S. 1930; MATUMOTO, T. 1938.

The following is a revised list of the important species of the richly fossiliferous Gosyonoura Group.

Desmoceras kossmati MATUMOTO	IIb, IIe (?)
D. (*Pseudouhligella*) *ezoana* MAT. and var. *poronaicum* YABE	IIe
Turrilites (*Meriella*) *oehlerti* PERVINQUIÈRE...	IIe
"*Anisoceras*" sp.	IIe
Baculites (*Lechites* ?) sp....	IIb
Astraea (s. l.) *kumasoana* MATUMOTO	III
Solarium sp. cfr. *S.* (*Nummocalcar*) *berthoni* PERVINQUIÈRE ...	IIb
Globularia (?) sp.	III
Pterodonta amaxensis MATUMOTO	III
Turritella sp. aff. *T. nodosa* ROEMER	IIe, III
T. sp. aff. *T. noeggerathiana* GOLDFUSS	IId, III
T. (*Zaria* ?) *goshorana* MATUMOTO...	III
Torcula (?) aff. *borei* BAILEY	IIa, IIb
Pyrgulifera (?) *japonica* MATUMOTO	Ib
Nerinea sp....	IIa
Vernedia (?) *uedai* MATUMOTO	III
"*Cerithium*" *pyramidaeforme* NAGAO	Ib, IIa–IIe, III
C. (*Exelissa* ?) cfr. *scalaroideum* FORBES	III
C. (*Fibula*) aff. *excavatum* PICTET & ROUX...	III
Cfr. "*Hemifusus*" *acuticostatus* STOLICZKA	III
Perissitys (?) sp....	IIa
Cucullaea ezoensis YABE & NAGAO var. *amakusensis* MAT. ...	IIa, IIb, IIe
Navicula sp.	IIa, IIb, IId, III
Glycymeris amakusensis NAGAO var. *solida* NAGAO	IIa, IIb, IIc, IIe
Inoceramus sp. aff. *I. anglicus* WOODS...	IIb
Ostrea (*Lopha*) aff. *semiplana* SOWERBY	IIb
Ostrea (?) sp. α (sp. nov. ?)	Ib
Ostrea sp. β	III
Trigonia pustulosa NAGAO	IIa, IIb, IIe (?)
T. hokkaidoana YEHARA	IIb, IIe
T. ogawai YEHARA	IIb, IIe
T. dilapsa YEHARA	IIa, IIb, IIe
T. sakakurai YEHARA	IIa, IIb, IIc, IIe, III
T. kikuchiana YOKOYAMA	IIa, IIb
Trigonioides kobayashii MATUMOTO	III
Anomia linensis WHITEAVES	Ib, IIa, IIb, IId, III
Septifer (?) sp. α aff. *S. lineatus* SOWERBY	Ia, III
Septifer (?) sp. β	IIe, III
Crenella gyliakiana MATUMOTO	IIe
Pholadomya sp....	IIb
Cercomya sp. aff. *C. arcuata* (FORBES)...	IIe
Anthonya japonica MATUMOTO	IIb
Veniella japonica NAGAO	Ib, IIa
Cyprina (?) sp. nov. ?	IIc, IId, III

Astarte (*Gouldia*) cfr. *trigonoides* STOLICZKA	IIa, IId, IIe, III
Crassatella (*Pachythaerus*) *nagaoi* MATUMOTO	IIb
"*Cyrena*" (aff. *Villorita*) sp.	Ib, IId, III
Pseudasaphis japonicus MATUMOTO	Ib, IId, IIe, III
Corbis (?) sp. α	IId, III
Corbis (?) sp. β	III
Protocardium aff. *hillanum* (Sowerby)	IIb, IId, III
"*Callista*" (*Pseudamiantis*) *crenulatus* MATUMOTO	IIb, IIe
Tellina (*Linearia*) sp.	IIb, IId
Leptosolen sp.	III
Siliqua (?) sp.	IId
Solen sp.	IIe
Aloidis sp. α	Ib, IIa, IIe, III
A. (*Caryocorbula*) *higoensis* MATUMOTO	IIa, IId, III

Among the invertebrates of the Himenoura Group we find

Nautilus (*Cymatoceras*) *pseudoatlas* YABE & SHIMIZU	IVc
Gaudryceras tenuiliratum YABE	IVb, IVc
G. denseplicatum (JIMBO)	IVb, IVc
Polyptychoceras haradanum (YOKOYAMA)	IVb, IVc
P. obstrictum (JIMBO)	IVc
Glyptoxoceras sp.	IVc
Eupachydiscus haradai (JIMBO)	IVc
Mortoniceras amakusense (YABE) em.	IVc
Scurria cassidaria (YOKOYAMA)	IVc
Nucula formosa NAGAO	IVc
N. (*Acila*) *hokkaidoana* NAGAO	IVc
Nuculana sp. nov.?	IVc
Glycymeris amakusensis NAGAO	IVb
Parallelodon sachalinensis (SCHMIDT)	IVc
Inoceramus amakusensis NAGAO & MATUMOTO	IVb, IVc
I. japonicus NAGAO & MATUMOTO forma α	IVc
Anomia sp.	IVc
Ostrea sp.	IVb
Spondylus sp.	IVb
Trigonia subovalis var. *minor* YABE & NAGAO	
Lucina (*Myrtea*) *ezoensis* NAGAO	
Solemya angusticaudata NAGAO	IVc
Cardita sp.	IVc

These lists generally suggest that there had been no difference in biogeographical province between Amakusa and Hokkaidô, although subprovincial differenciation may have existed, since they are considerably separated. If the range of a species in one area disagreed with that in the other area, it must be slight. Among the strata of the Gosyonoura Group, which on the whole, are deltaic deposits of neritic or littoral origin, Members IIb and IIe of the middle formation are of open-sea facies, yielding species that are commonly found in the Cretaceous of Hokkaidô and Karahuto. Of these, *Desmoceras kossmati* MATUMOTO and *D.* (*Pseudouhligella*) *ezoana* MATUMOTO, and its variety *poronaicum* YABE em., are worthy of special attention. From our chronologic scale established for the Yezo-Saghalin subprovince, the occurrence of these forms points to the age of the strata as being nearly the Infragyliakian subage, which conclusion is supported by the occurrence of *Turrilites* (*Meriella*) *oehlerti* PERVINQUIÈRE and *Baculites* sp., while the absence of *Acanthoceras* s.s. does not seem to nullify the conclusion, seeing that the genus is characteristic of the middle substage of the Paleogyliakian of Hokkaidô. The richly ornamented thick-shelled ammonites of the Paleomiyakoan Stage is at the same time also absent.

Turning our attention to molluscs other than ammonoids, we find that they are mostly those that are likely to be restricted to a certain kind of facies. As formations that have rock-facies similar to that of the Gosyonoura Group we can name the *Trigonia* Sandstone Group and the Hakobuti Group in Hokkaidô and the Miyako Group in the Kitakami Mountainland. We find that certain species occur only in one of these groups while others are found in more than one of them, notwithstanding the similarity in rock-facies among them. Should the true range be difficult to determine exactly, and should they be longer than that of ammonites and *Inoceramus*, this fact could be explained by a limitation to the life-period of the species under consideration. Consequently, when a sufficient number of species are treated, approximate correlation among these formations (of similar rock-facies) is possible from the assemblage of species. Upon comparing the fossil-contents of the Gosyonoura Group with those of other groups, as described in detail in my former paper (1938), we find that it greatly resembles those of the *Trigonia* Sandstone of Hokkaidô, which, in turn, is Gyliakian in age. In contrast to this, we find a dissimilarity between the present group and the Miyako Group of Paleomiyakoan age or the Hakobuti Group of principally the Hetonaian epoch.

These considerations lead to the conclusion that the middle formation of the group is largely referable to that stage ranging from the upper part of the Neomiyakoan to the lower part of the Paleogyliakian. The superjacent formation of the group belongs to the remaining part of the Gyliakian Series, since it underlies the Himenoura Group of the Urakawan epoch. On the other hand, the lower formation of the Gosyonoura Group is referable to the Neomiyakoan, although no conclusive evidence is found in its fossils.

Determination of the age of the Himenoura Group can be made without great difficulty, since it is of sedimentational conditions, similar to those of the Yezo-Saghalin Upper Cretaceous, and contains fossils of wider distribution. From the species contained in formations b and c, whose true range is represented in the standard localities of Hokkaidô and Karahuto, it may safely be concluded that the fossiliferous part of the Himenoura Group is the Neourakawan. The basal part of the group is most probably Paleourakawan. For determination of the age of the uppermost part, we must await further collections of fossils. The finer subdivision of the group into a number of fossil-zones, as made by S. SHIMIZU (1935), is not recognized in practice, his correlation being too artificial and academic.

B. NOTE ON THE LOWER CRETACEOUS STRATIGRAPHY OF JAPAN

As investigation of the regional stratigraphy is not yet completed, only preliminary notes and suggestions will be given here regarding the Lower Cretaceous stratigraphy of Japan. Compared with the Neocretaceous deposits, the Japanese Paleocretaceous deposits contains mostly poor biostratigraphic material, the reason for it being that, tectonically, they are in general highly disturbed, distributed over detached areas, their facies are irregular, both vertically and horizontally, and the fossils in them are not well preserved, which means that our chronologic classification and correlation are liable to be less accurate than if otherwise. Nevertheless, the general principles that have been our guide in working out the Upper and Middle Cretaceous stratigraphy are applicable also to the Lower Cretaceous strata, although it would have to be done on a somewhat rough scale.

Although the Paleocretaceous deposits are now distributed fragmentarily, they are mostly[1] the remnants of deposits that were originally more continuous and complete, so that by precisely investigating these remnants it will be possible to form a satisfactory plan of stratigraphic classification. Of the numerous detached areas, those that offer fairly sufficient data are the Yuasa district, Wakayama Prefecture, the Katuragawa-Nakagawa Basin of Tokusima Prefecture, and the Sakawa district, Kôti Prefecture, all belonging to the Outer Zone of Southwest Japan. Other localities in the same tectonic zone, and some localities in the Kwanto Mountainland and in the Kitakami Mountainland may furnish supplementary data. Stratigraphic investigations having recently been pushed forward in some of these localities, new interesting facts have been reported, resulting in our feeling keenly the necessity of fundamentally revising the previous classification of the Lower Cretaceous strata, and also that we must, in this case, distinguish the facies-stratigraphic classification from the time-stratigraphic classification.

The Lower Cretaceous deposits of Japan have been divided into two series, the Ryoseki and the Monobegawa. The former has been defined as deposits formed during the epoch of marine regression, and characterized by the so-called Ryoseki fauna and flora. It has come to be generally accepted that the Ryoseki epoch of regression is either earliest Cretaceous or Jurasso-Cretaceous, and was succeeded by an epoch of marine transgression, which in turn, forms the main part of the Lower Cretaceous. The Monobegawa Series has been defined as sediments that were formed during this epoch of marine transgression, thus containing the so-called Monobegawa fauna.

From my preliminary observations of the Cretaceous strata of the Yuasa district, Arita-gun, Wakayama Prefecture, the Lower Cretaceous strata are divisible into the following formations, in ascending order:

Underlying Palaeozoic Titibu Complex

~~~~~~ Marked unconformity ~~~~~~~~~~~~~~~~~~~~~~~~

Lower group of formations

Yuasa Formation emend. Basal conglomerates, with sandstone and shale, containing plant beds and shell beds.

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[1] Some of the continental deposits were formed in a separated area.
~~~~~~

Arita Formation. Fine sandy shale and shale, containing calcareous concretions and alternating sandstone and shale; *Trigonia*, ammonites and other marine fossils are found; Lenses of organic limestone are found in places. 200–300 m.

——— Disconformity ———————————

Upper group

Nisihiro Formation emend. Shallow water sediments, consisting of white arkosic sandstone of various thicknesses, sandstone and shale in alternation, shale, and conglomeratic rock; fossil beds of littoral and brackish origin, plant beds and coaly seams found. 400–450 m.

——— The Nisihiro Formation laterally changes its facies in the southern part of the district, being gradually replaced by ———

Izeki Formation emend. Sandstones of various thicknesses, conglomerates, dark grey shale, and shale and sandstone in frequent alternation, mostly of marine origin, *Inoceramus* and *Trigonia* being found, 450 m.

As a matter of fact, the so-called characteristic elements of the Ryoseki fauna and flora are found in the lowest formation, namely, the Yuasa Formation, although some species of the so-called Ryoseki type are also found in the Nisihiro Formation, which occupies a higher stratigraphic position —— a fact that may explain why the main part of the Nisihiro Formation was once referred to the Yuasa Formation of the Ryoseki Series, namely, owing to misinterpretation of its stratigraphy and its geologic structure. The elements of the so-called Monobegawa fauna, on the other hand, are most abundant in the Arita Formation, although some of them are found also in a certain part of the Yuasa Formation, as also in the Nisihiro-Izeki Formation.

After investigating the so-called Ryoseki and Monobegawa Series near Hanoura, Naka-gun, Tokusima Prefecture, K. SUZUKI recently (1941) divided the strata into the Komo Sandstone and conglomerate, the Hanoura Mudstone, the Motii Sandstone, and the Mukoyama Mudstone, in ascending order. An interesting fact pointed out by him is that the fossils of the so-called Ryoseki founa, containing *Polymesoda naumanni* (NEUMAYR) and other non-marine mulluscs, occur not only in the Komo Formation, but also in the Hanoura Formation, while those of the so-called Monobegawa fauna, consisting of *Trigonia pocilliformis* YOKOYAMA and other marine molluscs, are common not only in the Motii and Hanoura Formations, but also in the upper part of the Komo Formation, an intermingling of the Ryoseki fossils and the Monobegawa fossils being thus found in the Komo and Hanoura Formations.

The Paleocretaceous locality along the Ôhunato Bay, Kesen-gun, Iwate Prefecture, in the southern part of the Kitakami Mountalnland, was recently restudied by T. SEKI and R. IMAIZUMI (1941), who reported that the strata of the Lower Cretaceous, called the Ohunato Formation and the Suezaki Formation, yield marine molluscs of the Monobegawa type at various horizons, as also species of the Ryoseki flora, although sporadically. The authors maintained that the previous view to the effect that the lower part of the Ohunato Formation belongs to the Ryoseki Series and that the superjacent part belongs to the Monobegawa Series, is not tenable.

Data recently obtained, such as that just mentioned, enables us to state that the so-called Ryoseki fossils and the so-called Monobegawa fossils do not necessarily differ in age, the difference being rather in facies. Consequently, in my opinion, it is preferable to use the Ryoseki Group and the Monobegawa Group as major units of stratigraphic classification based on facies development, than to use them as those of time-stratigraphic classification[1].

In a chronologic classification of the Japanese Paleocretaceous we should proceed in the same way as that we have done in the case of the Neocretaceous. Definition of the division should be based on the time-range of species worked out from a number of standard localities. Compared with the Neocretaceous, however, the Palecretaceous localities provide us with less sufficient data for this purpose, with the result that divisions of the major scale alone can be defined. Together with the definition, its local correlation with the various localities should be made with the aid of all the methods available. In dealing with the problem of local correlation, the so-called Ryoseki flora and fauna and the Monobegawa fauna may be useful, according to the extent to which its

(1) A similar statement may hold in treating the other Mesozoic formations, such as the Torinosu Group, the Akigawa-Simantogawa Group, and the Terasoma Group, in Southwest Japan.

lithologic character is available, but as these represent to a high degree the conditional instead of the purely chronologic factors, their application should be carefully restricted. For chronologic purposes, ammonites and certain other fossils are useful. Although these available material may be obtained from only a part of the whole succession in a district, we may regard that part as representing the major unit, so far as the major classification is concerned.

As was discussed in Part II in connection with a fossil-zone and in Chapter III of this Part in connection with the problem of international correlation, to very finely subdivide the Japanese Paleocretaceous is, both in principle and practice, impossible even by means of ammonites, for which reason the details of previous work done on Japanese Lower Cretaceous "zoning" leaves us in considerable doubt.

In short, there is much to be done in future regarding the problem of chronologic classification. From what available material we have at hand, it is possible to state in a preliminary way the three-fold chronologic classification that is applicable to the Paleocretaceous deposits of Japan. The three divisions are as follows:

The Lower Series: Although somewhat indefinite in itself, this is to be established between the Middle Series of the Paleocretaceous and the Upper Jurassic, the latter two being comparatively well defined. No ammonite species has yet been found from formations below the Middle Series and above the Upper Jurassic Series, although they may be found in future. The species that enables us to distinguish this series from the Middle Series seem to be those belonging to the genus *Trigonia*, the assemblage of species *T. neumayri*, *T. naumanni* and *T. pocilliformis* indicating this epoch, while that of species *T. pocilliformis*, and *T. hokkaidoana*, and *T. kikuchiana* represents the Middle Epoch. The same genus, with certain other fossils, seems to be useful in distinguishing the series in consideration from the Upper Jurassic. Although most of the Ryoseki Group em. may belong to this Lower Series, whether or not the so-called fossils of the Ryoseki type, such as "*Cyrena*" *naumanni* and plants of Wealden type, have their true time-range restricted to this epoch is a question. The typical representative of the series is the socalled marine Ryoseki in the Tagano Basin, near Sakawa, Koti Prefecture.

The Middle Series. This seems to be clearly defined by ammonites belonging to the genera *Parahoplites* (*Pseudothurmannia*), *Pulchellia*, *Barremites*, *Crioceras*, *Australiceras*, *Shasticrioceras*, *Ancyloceras*, *Heteroceras*, and *Hamulia*, nearly all these ranging throughout the Barremian and the Hauterivian in Europe. The species of *Trigonia* just mentioned and many other molluscs, which have a long life-period, are found also in the superjacent series. The typical representatives of the Middle Series are the Arita Formation of the Yuasa district, Wakayama Prefecture, the Hanoura Formation of the Nakagawa-Katuragawa Valley, Tokusima Prefecture, and the Isido Formation of the Santyu Graben of the Kwanto Mountainland. The last mentioned, however, needs re-investigation.

The Upper Series. This is what has been defined in Part II as the Miyakoan, which includes the Paleomiyamoan and the Neomiyakoan Stages. The ammonoid genera *Hhpophylloceras*, *Salfeldiella*, *Parahoplites* (s.s.). *Cheloniceras*, *Ammonitoceras*, and *Douvilleiceras* characterize the Paleomiyakoan, whereas the Neomiyakoan is characterized by *Phylloceras* aff. *tanit* PERVINQUIÈRE, *Parajaubertella kawakitana* MATUMOTO MS, *Pictetia ezoense* (YABE), *Desmoceras latidorsatum* (MICHELIN), *D. kossmati* MATUMOTO, *Turrilites* (*Meriella*) *bergeri* BRONGNIART, *Beudanticeras shikokuensis* YABE & SHIMIZU, *Inflaticeras* sp., *Oxytropidoceras* sp., and other species already mentioned in Part II. Although species of *Australiceras* *Ancyloceras*, *Leptoceras*, *Parahoplites* (s. l.), *Acanthoplites*, and *Parahoplitoides* do range in the Middle and Upper Series, they may be useful in distinguishing the Neomiyakoan from the subjacent series.

Ryoseki and Monobegawa being now revised to stand for the names of facies-stratigraphic units, new names are necessary for the units of the time-stratigraphic division just mentioned. For the Upper Series, the Miyakoan has already been proposed, and for the Middle and Lower Series, I am inclined to propose the names *Aritagawan* and *Kotian*, respectively, for the reason that the typical representatives of the series are found in the localities bearing these names.

With this kind of definition as basis, and by correlating the various formations with the typical strata of each series, it is possible to obtain a summarized chronologic classification of the Paleocretaceous deposits of Japan.

Although a clear redefinition of the facies-stratigraphic units should be made after fully investigating the various localities, what we do know at present consist of the preliminary notion that the Ryoseki Group *emend.* is sediments of marine regression, characterized by limnic and paralic facies and by frequent occurrence of coarse-grained rocks, it being probably a product of synorogenesis during the crustal movement of the Ohga phase in Southwest and Northeast Japan, and that the Monobegawa Group *emend.* is a series of strata, mostly marine, that formed during the interval between the Ohga orogenic phase and the Sakawa orogenic phase on the Outer Side of Southwest Japan, the Kwanto Mountainland, and the Kitakami region.

Another important result that is expected from our recent investigations is that the Monobegawa Group represents two cycles of sedimentation, although the two may belong to one major cycle ——a conclusion supported by data obtained from the Yuasa and the Nakagawa-Katuragawa districts mentioned above, and also by those from the Monobegawa Valley and the Sakawa district, both in Koti Prefecture, and from the Yatusiro district in Kumamoto Prefecture——whence the group should be divided into two subgroups, the lower and the upper. These are to be regarded as effects of the crustal movement of Osima phase that occurred between the Ohga and the Sakawa phases. So intense was the orogenesis of the Osima phase in the Kitakami region that the Monobegawa Group proper is sharply separated from the Miyako Group, which, in turn, is approximately correlated in age with the Upper Monobegawa Subgroup of Southwest Japan, most of the two being referable to the Miyakoan Series. In certain other localities that have so far not been investigated sufficiently, the subdivision of the group into two subgroups has not yet been clearly confirmed.

Chapter III

Preliminary Note on the International Correlation

General remarks
Correlation of the Cretaceous deposits of Southern India with those of Japan
Note on the correlation of the European standard with the Japanese scale
Note on some of the Circum-Pacific Cretaceous deposits

General remarks.——Thus far, my endeavours have been to construct a stratigraphic scale that best applies to the Japanese Cretaceous deposits, quite independent of the so-called standard of other countries, but the time has come to take up the problem of international correlation. We must reexamine the Cretaceous stratigraphy of the Circum-Pacific and the Indian regions as compared with the Japanese scale, and also determine what correspondance there is in our scale and the so-called standard of Europe.

Important as these problems are, their final solution will require further time, for the following reasons: (1) Biostratigraphic investigation is still incomplete in some countries. Fossils are frequently collected unaccompanied with any precise stratigraphic field-work; sometimes succession of strata is reported unaccompanied with any accurate information regarding the palaeontological material. (2) Even in areas that are standard, the material from them is not always ideal for deducing the true geological range of genera and species. In matters of definition and nomenclature of divisions, investigators are not always agreed. (3) The palaeontologic study is more or less incomplete. Divergent opinions are frequently encountered regarding the classification and determination of fossils. Finally, as to the major part of the foreign material, I have not at present the opportunity of examining them, which is unfortunate.

Besides, the problem of international correlation is beset with difficulties radical in their nature. The period of existence of a species or a genus is not necessarily the same in the different biogeographic provinces. As a matter of fact, it is possible for the organisms to migrate in such a short time as to be neglegible, geologically speaking, which, of course, is only when conditions are favourable. In fact, owing to changes in palaeogeography and environments in the course of geologic history, the period of existence of species in the Japanese province, for example, sometimes differs from that of an Indian or European province. Another difficulty concerns the problem of so-called program-evolution. Evolution of organisms in one province can occur independently, although taking a parallel course with that in other provinces. This statement is based on actual examples. In this case, it is not necessary that the allied forms of two provinces shall coexist in strict chronologic sequence, should they represent the same phase in the course of evolution.

In these problems, attention should be paid to the biogeographic province, treating the palaeontologic materials under separate categories like the following, for example; (a) Cosmopolitan forms, (b) Pacific-Indian forms, (c) Northern Pacific forms which, not rarely occur in the Indian region, (d) Indian and Southern Pacific forms, which also occur in the northern Pacific region, although few, (e) Mediterranean forms, (f) Mid-European and Atlantic forms, and (g) Boreal forms. To each of them a separate meaning should attach, when, for example, a correlation is being made with India and Japan. Another point that will be of assistance in unravelling these problems to a certain extent is to take into consideration the association and the order of appearance or disappearance of many of the forms. Needless to add, it will facilitate matters if we correlate the larger units.

With these guiding principles in mind, it is possible to carry out to some extent, at any rate, the task of international correlation, even with material available at present, which may result in the gain of some important knowledge. The following few preliminary notes and suggestions, it is hoped, will be found helpful for future studies.

Correlation of the Cretaceous deposits of Southern India with those of Japan.——Of the typical Cretaceous localities in the Indo-Pacific Region, there is the Coromandel province, along the eastern coast of Southern India. Stratigraphic and palaeontologic investigations there have resulted in information that is fairly precise, so much so that upon them have depended, to a large extent, our studies of the Cretaceous sratigraphy of Japan. Since, from our own material, we have now concrete and accurate knowledge of the Japanese Cretaceous, I shall attempt, here, to reexamine the Indian material with the aid of these Japanese data. As judged from the palaeogeographic position of Southern India, correlation of Indian fauna with Japanese may lead to important knowledge in connexion with the stratigraphic problem of other Cretaceous areas in the Indian and Pacific Regions, as also in connexion with comparisons of the Japanese scale with the so-called standard scale of Western Europe.

In the Cretaceous area of Coromadel province, the Trichinopoly district has been studied the most closely. Summarizing what is found in the literatures of the subject, I have constructed the annexed Table (7), covering the stratigraphic sequence and the rock-facies of this district.

Another locality famous for its abundance of fossil is the Pondicherry district, where strata, corresponding approximately to the Ariyalur Group, are known to be exposed. The sequence of

TABLE 7

Stratigraphic sequence and rock-facies of the Cretaceous in the Trichinopoly district, compiled by T.M. 1942, (in ascending order; ⚒ indicates fossiliferous strata)

Basement Complex (Archaean gneiss and granite, plant-bearing older Mesozoic, etc.)	
~~ Unconformity ~~~	
I. Utatur (Ootatur) Group [Southern facies]	[Northern facies]
Muddy sediments from bottom to top. From the fossil-contents, the following subdivisions are discernible:	a. Lower formation (⚒): Marl and mudstone rich in ammonoids, Fossiliferous limestone is intercalated, and coral-limestone is developed in some basal parts.
a′. Lower div. (⚒) containing *Hamites, Pervinquieria*, etc.	—Gradual transition of lithic character—
b′. Middle div. (⚒) containing *Acanthoceras, Puzosia*, etc.	b. Middle formation (⚒): More sandy than in the lower formation, containing conglomerate in some parts; rich in fossils of *Acanthoceras*, and others.
	—Conformity—
c′. Uppermost div. (⚒) containing *Inoceramus problematicus*.	c. Upper formation (⚒): Hard sandstones containing calcareous concretions.

——— Slight unconformity ——————~~~~~~~~ Unconformity ~~~~~~~~~~~

II. Trichinopoly Group

Shallow-sea sediments, showing much irregularity in sedimentation and mode of occurrence of fossils.

a. Lower form. (⚒): Remains of bivalves and gastropods abundant, while those of ammonites (especially smooth-shelled forms) are rare. Basal part is the bed with bivalves.

b. Upper form. (⚒): Glauconitic mudstone, rich in ammonoid remains, predominant.

Strata thin out in the northern part. — Unconformity

— "Conformable", but precise information lacking. ———

III. Ariyalur Group

a. Lower formation (⚒): Sandstones, with frequent intercalations of calcareous sandstone and calcareous shale. Rich in fossils; ammonoids of the Desmoceratidae predominate; lytoceratids and aberrant forms less so.

b. Middle formation: Non-fossiliferous sandstones.

c. Uppermost bed (⚒): Sandy limestone or calcareous sandstone, containing fossils; ammonites absent, but *Nautilus* and other shells abound.

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strata and rock-facies, which differ somewhat from those of the Ariyalur Group, is shown in the annexed Table (8).

TABLE 8

Stratigraphic sequence of the Cretaceous of the Pondicherry district (in ascending order: ⚒ indicates fossiliferous strata)

Lower limit unexposed

a. Valudayur Formation

Lower part: Sandstone and sandy shale, with conglomerate; bare of fossils.

Upper part (⚒): Sandy shale rich in fossils. (*Glyptoxoceras* Beds)

b. *Trigonoarca* Beds (⚒)

Lower part: Sand and clay.

Upper part: Sandy clay.

c. *Nerinea* Beds (⚒)

Ammonite is absent; *Nautilus* and other shells found.

As will be seen from the foregoing Tables, the Cretaceous of Southern India yields, throughout its entire thickness, fossils from almost every formation. Seeing that there are vertical changes of rock-facies, the environments of sea, as well as the conditions of sedimentation, are inferred to have changed at different ages. A break is even found in the stratigraphic sequence which, upon examination, shows a few non-fossiliferous beds and sometimes irregularities in the mode of fossil-occurrence. In these circumstances, the true time-range of the species is not necessarily directly represented by this sequence of strata, the occurrence, in some cases, being either only an apparent or a partical vertical-range — a point that should not be lost sight of in dealing with the problem of international correlation.

Another fact to be noted is the horizontal change of rock-facies and the varying intensities in both conformity and unconformity with place. Consequently, the stratigraphic divisions enumerated are formational facies-stratigraphic units, which do not necessarily agree with the time-stratigraphic units.

The fossils yielded are largely molluscan remains, of which the ammonoids are indisputably the most useful for correlation (particularly international correlation). As for molluscs other than cephalopoda, (1) the geological range is usually long; (2) The geographical distribution is not so wide as in cephalopods; (3) The effects of local environment are great during life as well as after, the fossil-contents of a formation often depending much on the difference in facies rather than on difference in age; (4) Notwithstanding that our knowledge of Japanese Cretaceous molluscs other than cephalopods has advanced recently, accuracy in regard to their geological range is still lacking, except for a few genera like *Inoceramus*, for which reason it may be in order here to base our correlation mainly on ammonites.

The ammonoid fossils from the Cretaceous of Southern India were studied by FORBES (1845), BLANFORD (1862), STOLICZKA (1865, 1868) and KOSSMAT (1895, 1897), and their results published in a number of magnificient monographs. Since then, with advance in our knowledge of classification, these fossils from India also have to be revised. From the descriptions and illustrations in these monographs I have attempted to make what revision is possible, although there is nothing to excel a close examination of the actual specimens. Although I have consulted the opinions of modern investigators specializing in ammonites, the plan of classification is entirely my own. Revised lists of the ammonoid species from the Cretaceous of Southern India have thus been drawn up (see Table 9—18). In these Tables, the query (?) affixed to names in the left hand column means that reference of the species to the genus is doubtful. The star * in the next column indicates that the species is understood to occur in large numbers, the signs (+) or (−) mean that the species occur not only from the formation under consideration, but also from horizons higher or lower; while the query (?) in this column means that the occurrence is uncertain.

TABLE 9

Revised list of ammonoid species from the Lower Utatur Group

Phylloceras velledae MICH.	*	GI (−?)	
Ph. ellipticum KOSSMAT		GI (±?)	
Phyllopachyceras forbesianum (d'ORB.)	*(±?)		*Ph. ezoense* (GII—HI)
Pictetia mahadeva (STOL.)			*P. ezoense* (MII, MG±?)
Anagaudryceras sacya (FORBES)		MII (?), MG, GI	
Gaudryceras multiplexum (KOSSMAT)			*G. subcostatum* (GI ±?)
Anagaudryceras madraspatanum (STOL.)		MG (?), GI	
Anagaudryceras (?) *vertebratum* (KOSSMAT)			
Zelandites odiensis (KOSSMAT)		MII−GI	
Kossmatella (?) *marut* (STOL.)			
Tetragonites timotheanus (MAYOR)		(cf.) (MII)	gen. (MII−G)
Turrilites (*Meriella*) *bergeri* BRONG.	*	MII (±?)	
Turrilites (s. l.) *circumtaeniatus* KOSS.			
Hypoturrilites tuberculatus (BOSC.)		MII, MG	
H. (?) *spinosus* (KOSSMAT.)			
Anisoceras oldhamianum STOL.			gen. (MII)
Hamites armatus (SOW.)	*		gen. (MG, MII)
H. angulatus STOL.			
H. problematicus STOL.			
H. sp. aff. *meyrati* OOSTER			
Hamulina sublaevis STOL.			gen. ? (Mid. Paleocr.)

Diptychoceras forbesianus STOL.			
Baculites (?) sp. (="*Ptychoceras glaber* WHITEAVES")			
Baculites gaudini PICTET		(cf.) MG, GI	
B. cfr. baculoides LAM.			*B. orientalis* (GII)
Neoptychites xetra (STOL.)	(+)		
'*Placenticeras*' *warthi* KOSSMAT		(cf.) MII	
Pervinguieria inflata (SOW.)+var.	*		*P. imaii* (MII?, MG)
P. gracillina (KOSSM.)			gen. (MII?, MG)
P. propingua (STOL.)			”
P. utaturensis (STOL.)			”
Stoliczkaia dispar (D'ORB.)			gen.? (MII?, MG)
St. tetragona (NEUM.)			”
St. crotaloides (STOL.)			”
St. argonautiformis (STOL.)			”
'*Acanthoceras*' *bathyomphalum* KOSS.			
Holcodiscoides cliveanus (STOL.)			gen. (GI,—?)
H. moraviatoorensis (STOL.)			”
H. papillatus (STOL.)		GI (—?)	
Desmoceras latidorsatum (MICH.)	* (+)	MII (+?)	
Puzosia planulata (SOW.) var. *odiensis* KOSSMAT			*P. nipponica*
P. compressa KOSSMAT			*P. subcorbarica*
P. insculpta KOSSMAT	(?)		
P. (?) *bhima* (STOL.)			
Beudanticeras (?) *stoliczkai* (KOSS.)			gen. (MII)

TABLE 10
Revised list of ammonoid species from the Middle Utatur Group

Turrilites (s. s.) *costatus* LAMARCK	*	GI (main part)	
Ostringoceras cunliffeanum (STOL.)		(aff.) GI	
Neoptychites telinga (STOL.)			
N. xetra (STOL.)	(−)		
Acanthoceras turneri WHITE		(cf.) MG±?	
Ac. newboldi KOSSMAT	*		*Ac. orientale* (GI-mid and up.)
Ac. spinosum KOSSMAT	*	GI (middle part)	
Ac. planecosta KOSSMAT			gen. (mainly GI, rarely MG)
Ac. hunteri KOSSMAT			„ („)
Ac. cenomanense D'ARCH.			„ („)
Ac. (*Eucalycoceras*) *choffati* KOSS.			
Ac. (*E.*) *gothicum* KOSSMAT			
Ac. (*E.*) *harpax* (STOL.)	(+)		
Ac. (*E.*) *pentagonum* J. BROWNE & HILL			
Calycoceras naviculare (MANT.)	(+?)		gen. (MG, GI)
Romaniceras medlicottianum (STOL.)			gen. (GII)
Cunningtoniceras cunningtoni var. *cornuta* (KOSS.)		GI	
C. meridionale (STOL.)			gen. (GI)
C. aberrans (KOSSMAT)			„ („)
Pseudaspidoceras footeanum (STOL.)			gen. (?)
Ps. (?) *colerunense* (STOL.)	(+)		
Sharpeiceras laticlauium var. *indica*			
Mantelliceras mantelli (*Sow.*)			
M. vicinale (STOL.)	(+)		
M. (?) *discoidale* (KOSSM.)			
"*Acanthoceras*" *morpheus* (STOL.)			
Fagesia rudra (STOL.)	(?)		gen. (GII)
Desmoceras latidorsatum (MICH.)	* (−)	MII (+?)	
Puzosia planulata var. *odiensis* KOSSMAT	(+)		*P. nipponica* (GI)

TABLE 11

Revised list of ammonoid species from the Upper Utatur Group

Anagaudryceras (?) *revelatum* (STOL.)			gen. (MII ?, MG—H)
Tetragonites kingianus (KOSSMAT)			gen. (MII—G)
Calycoceras naviculare (MANT.)	(—), (?)		gen. (MG, GI)
Acanthoc. (*Eucalycoc.*) *harpax* (STOL.)	(—)		
Romaniceras ornatissimum (STOL.)			gen. (GI)
Pseudaspidoceras crassitestum (STOL.)			gen. (?)
Ps. (?) *colerunense* (STOL.)	(—)		
Mammites conciliatum (STOL.)			gen. ? (?)
Mantelliceras vicinale (STOL.)	(—)		
Fagesia superstes (KOSSMAT)	(?)		*F. thevestensis* (Low. GII)
Puzosia planulata var. *odiensis* (KOSS.)			*P. nipponica* (GI)

TABLE 12

Revised list of ammonoid species from the uncertain horizon of the Utatur Group

Phyllopachyceras improvisum (STOL.)			gen. (GII—HI)
Anagaudryceras (?) *involvulum* (STOL.)			gen. (MG—HII)
Ptychoceras tropicus KOSSMAT			
Baculites sp.			gen. (MG—HII)
Forbeciceras largilliertianum (D'ORB.)			
F. subobtectum (STOL.)			
Pervinquieria cerrupta (STOL.)			gen. (MG, MII ?)
Mantelliceras (?) *ushas* (STOL.)			
Scaphites similaris (STOL.)			gen. (GII—UII ?)
Sc. obliguus (SOW.)			„ („ „)
Sc. kingianus STOL.			„ („ „)
Pseudojacobites rotalinus (STOL.)			
Desmoceras inane (STOL.)			*D. kossmati* (MII, MG)
D. aff *inane* (STOL.)			*D. kossmati* (MII, MG)
Puzosia crebrisulcata KOSSM.			*P. subcorbarica* (MII—GI)
Desmoceras (?) *aliena* (STOL.)			
Pachydesmoceras denisoni (STOL.)		MII (?), GI	

TABLE 13

Revised list of ammonoid species from the Lower Trichinopoby Group

Baculites n. sp. aff. *bohemicus* FRITSCH			
Prionotropis serratocarinata (STOL.)			gen. (GII)
Scaphites n. sp. indet.			
Yokoyamaoceras (?) *paravati* (STOL.)			gen. (GII—UH)
Lewesiceras vaju (STOL.)			
Pseudojacobites (?) *anapadensis* (STOL.)	(?)		

TABLE 14

Revised list of ammonoid species from the Upper Trichinopoly Group

Gaudryceras varagurense KSSMAT			*G. denseplicatum* (GII—UH)
Anagaudryceras politissimum KOSS.			*A. limatum* (GII, UI)
Epigoniceras epigonum (KOSS.)		GII—UII	
Bostrychoceras indicum (STOL.)		UI	
Placenticeras tamulicum (BLANF.)			
Peroniceras dravidicum KOSS.	(+)		
Scaphites brahminicus STOL.	(?)		gen. (GII—UII)
Sc. (?) *andurensis* STOL.			
Sc. (?) *idoneus* STOL.			
Kossmaticeras theobaldianum (STOL.)	*		*K. japonicum* (U)
K. recurrens (KOSS.)			
K. bhavani (STOL.)	*		
K. (?) *buddhaicus* (KOSS.)			
Anapachydiscus kolutureusis (STOL.)			*A. sutneri, fascicostatum* (UI—UH)
A. (?) *cricki* (KOSS.)			
Damesites sugatus (FORBES)	* (+)	UII, UH, (−?)	
Parapuzosia indopacifica (KOSSMAT)		GII, UI	
Hauericeras gardeni (BAILY)	(?), +	UI (?), UII—UH	

TABLE 15

Revised list of ammonoid species from the uncertain horizon of the Trichinopoly Group

Kossmaticeras sparsicostatus (KOSSM.)			gen. (U)
K. pachystoma (KOSSM.)			gen.
Nowakites (?) *jimboi* (KOSSMAT)			gen. (U)
Puzosia gaudama (FORBES)		GII, var. (GII)	

TABLE 16

Revised list of the ammonoid species from the Ariyalur Group

Gaudryceras subtililineatum KOSS.			*G. striatum* var. *lata* (UH, HI, HII)
Glyptoxoceras tenuisulcatum (FORBES)	(?)	(cf.) (UH⊥?)	
Baculites vagina FORBES var.			
Muniericeras blanfordianum (STOL.)			
Pseudokossmaticeras pacificum (STOL.)			
Kossmaticeras theobaldianum (STOL.)	(?)		gen. (U)
K. bhavani (STOL.)	(?)		
Grossouvrites (?) *aemilianus* (STOL.)			
Gr. (?) *kandi* (STOL.)			
Gunnarites kalika (STOL.)			
Kossmaticeras (s. l.) *madrasinum* (STOL.)			
K. (s. l.) *karapadense* (KOSS.)			
Brahmaites brahma (FORBES)			gen. (?)
Pachydiscus egertoni (FORBES)		(af.) HII (−?)	
P. otacodensis (STOL.)	*		*E. haradai* (up. UII—HI)
Eupachydiscus grossouvrei (KOSS.)			*E. haradai* (up. UII—HI)
E. tweenianus (STOL.)			
E. (?) *ariyalurensis* (STOL.)	*		*A. subtililobatus* (HI?)
Anapachydiscus (?) *deccanensis* (STOL.)			
Schlüteria diphylloida (FORBES)		up. UII (?), UH, HI	
S. phyllimorpha (KOSSMAT)			
Damesites sugatus (FORBES)	*(−)	UI (?), UII, UH	
Hauericeras gardeni (BAILY)	(−?)	UI (?), UII—HI	
Peroniceras dravidicum KOSSMAT	(−)		

TABLE 17

Revised list of ammonoid species from the Valudayur Formation

Neophylloceeas nera (FORBES)			*N. compressum* (GII—HII)
N. decipiens (KOSSMAT)			
N. surya (FORBES)			*N. hetonaiense* (up. HII—HII)
Phyllopachyceras forbesianum (FORBES) ?			*P. ezoense* (GII—HI)
Gaudryceras kayei (FORBES)	*		*G. crassicostatum* (HII±?)
G. valudayurense (KOSS.)			*G. striatum* (up. UII—HI)
Zelandites varuna (FORBES)		var. (HII)	
Epigoniceras cala (FORBES)	*	UII+?	
Pseudophyllites indra (FORBES)	*(+)	?	
Glyptoxoceras indicum (FORBES)	*	(cf.) (UH—HII)	
G. subcompressum (FORBES)	*		gen. (UH—HII)
G. rugatum (FORBES)			„ („)
G. largesulcatum (FORBES)	*		„ („)
G. tenuisulcatum (FORBES)	*	(cf.) (UH±?)	
G. undulatum (FORBES)	*		gen. (UH—HII)
G. nereis (FORBES)			„ („)
Polyptychoceras sipho (FORBES)			*P. pseudogaultinum* (UII—HI)
Baculites teres (FORBES)			gen.
B. vagina (FORBES) + var.	*(+)		
Sphenodiscus siva (FORBES)			
Acanthoscaphites cunliffei (FORBES)			
A. (?) *pavana* (FORBES)			
Kossmaticeras (s. 1) *indicum* (FORBES)			
Kitchinites pondicherryanus (KOSS.)			
Brahmaites brahma (FORBES)	(+)		gen. (?)
B. bishnu (FORBES)			„ („)
Pachydiscus egertoni (FORBES)		(af.) (HII—?)	
P. ganesa (FORBES)			
P. sp. aff. *gollevillensis* (*d'*ORB)			*P. subcompressus* (HII)
P. crishna (FORBES)			
Menuites menu (FORBES)		(af.) (UII—HI)	
Schlüteria diphylloida (FORBES)		up. UII?, UH, HI	
Hauericeras rembda (FORBES)		HII (—?)	

TABLE 18

Revised list of ammonoid species from the *Trigonoarca* Bed

Pseudophyllites indra (FORBES)	(−)	?	
Baculites vagina (FORBES)	*(−)		gen.
Brahmaites brahma (FORBES)	(−)		gen. (?)
Pachydiscus compressus (SPATH)			*P. subcompressus* (HII)

The Cretaceous ammonoid fauna of Southern India contains a considerable number of species that are either identical to or greatly allied to that obtained from the Japanese Cretaceous. The geologic range of these identical species (including different varieties and comparable forms, as represented by *cf.* or *aff.*) in the Japanese province is shown in the third columns of the Tables, the allied species in Japan being inserted in the right hand (i. e. fourth) column, together with its geologic range. When there is neither an identical species nor an allied species, but the same genus, its occurrence in Japan is shown in the same column, with the abbrevation *gen.* affixed. The following abbreviations in the Table for the Japanese Cretaceous scale are used:

Low. Mid. Paleocr.		Lower and Middle Paleocretaceous	
MI	Paleomiyakoan	Miyakoan (M)	Upper Paleocretaceous
MII	Neomiyakoan (s. s.)		
MG	Infragyliakian		
GI	Paleogyliakian	Gyliakian (G)	Neocretaceous
GII	Neogyliakian		
UI	Paleourakawan	Urakawan (U)	
UII	Neourakawan (s. s.)		
UH	Infrahetonaian		
HI	Paleohetonaian	Hetonaian (H)	
HII	Neohetonaian		

The sign ? or −? in the third and fourth columns means that neither the upper nor lower limit of the range of the species is precisely known in Japan.

Ammonoid remains from the lower and middle formations of the Utatur Group are largely either Indo-Pacific elements or cosmopolitan forms. Of these, almost all the species that are either identical with or allied to those from the middle formation, occur as usual in the Paleogyliakian of Japan, although some of them range down to the Infragyliakian, while the species that are identical with or allied to those from the lower Utatur formation occur in Japan in the Infragyliakian and Neomiyakoan, some of them being restricted to the two divisions just named and others ranging up to the Paleogyliakian. Thus the middle formation of the Utatur Group is undoubtedly assignable to the main part of the Paleogyliakian, while the lower formation of the group goes lower than this, possibly ranging from the Neomiyakoan to lowest Paleogyliakian. Although a detailed and exact determination of the horizon within this range is impracticable, the lower formation certainly comprises the Infragyliakian.

What conflicts with the above conclusion is the occurrence of *Fagesia* and *Romaniceras* from the middle formation of the Utatur Group, because in Japan, the two genera are restricted to the Neogyliakian, although, in India, the genera occur also in the upper formation of the Utatur Group, represented, however, by different species. Setting *Fagesia* aside, information of the occurrence of which is doubtful, it may be in order to explain that *Romaniceras* appeared in the Indian province earlier than it did in the Japanese province, and with a longer life-period.

The upper formation of the Utatur Group does not provide sufficient material for exactly determining its age. From its stratigraphic position, wherein it overlies the middle Utatur formation mentioned above and underlies the upper Trichinopoly formation to be mentioned later, the possible range with which it may be correlated lies between uppermost Paleogyliakian and the base of the Urakawan. So far as the eleven species thus far described are concerned, they contain no species that are identical with the Japanese species. Taking the allied species into consideration, palaeontologic evidence is still insufficient for more exact determination of age. But the occurrence of *Fagesia* and *Romaniceras* seems to warrant our saying that the formation is correlated with the Neogyliakian, if it is not of that age itself.

Judging from the rock-facies of the Trichinopoly Group as well as from its stratigraphic relations to other groups, we can presume that the actual stratigraphic occurrence of a fossil in this group may represent only a partial time-range of the species. The upper formation of the group yields abundant ammonoid remains, forming a fossil-faunule, consisting largely of Indo-Pacific elements and Indo-Southern Pacific elements. Almost every species of Indo-Pacific type has its representative in Japan either as an identical form or as an allied form. Since the geologic range of these Japanese forms is (1) Neogyliakian + Paleourakawan, (2) Paleourakawan alone, and (3) Paleourakawan + Neourakawan(+), the upper formation of the Trichinipoly Group is largely referable to the Paleourakawan, some of the upper Trichinopoly species showing a partial range, while its longer true time-range is assumed to be represented in the Japanese material.

Contrary to the upper formation, the lower Trichinopoly formation yields a small number of ammonoid remains, from the stratigraphic position of which it is possible to determine its age to be older than Paleourakawan of the upper Trichinopoly formation, but younger than the Paleogyliakian of the middle Utatur formation. Evidences from the palaeontologic material do not nullify the conclusion that it is of Neogyliakian age.

Thus the Neogyliakian in our scale is represented in the Indian succession by the upper Utatur formation, lower Trichinopoly formation, and the unconformity between the two units. Accordingly we can confirm the observation of previous investigators that the unconformity between the Utatur Group and the Trichinopoly Group is only of slight significance in the southern facies. A possibility has, furthermore, arisen in that the uppermost part of the Utatur Group in the northern facies may be contemporaneous with the lowest part of the Trichinopoly Group in the southern facies. Since the latter is a bed containing bivalves, the data we have are insufficient to enable us to examine this possibility.

Of the strata of the Ariyalur Group the lower formation alone yields ammonoid fossils. This fossil-faunule is composed of the Indo-Southern Pacific elements, the Northern Pacific or Indo-Northern Pacific elements, and some Atlantic elements. The first is the most predominant, the second comprising less than half the number of species, of which, only the last three species of the Desmoceratidae are common in both India and Japan; the others being allied, but different, species, the material being therefore insufficient to enable exact correlation. Upon examining the geologic range of the species in Japan that are either identical with or allied to the Indian species, we find it in (1) Neourakawan+Infrahetonaian +Paleohetonaian, (2) Neourakawan+Infrahetonaian, and (3) in the Infrahetonaian+Paleohetonaian(+)[1]. Consequently, the age of the lower Ariyalur formation lies somewhere between Neourakawan and Paleohetonaian. Although further detailed and accurate determination is impracticable, that part which is near the boundary of the two ages, including the Infrahetonaian subage, seems the most probable. The remaining middle and upper formations of the Ariyalur Group may correspond approximately to the main part of the Hetonaian.

From the foregoing conclusion, a hiatus would be expected between the Trichinopoly Group and the Ariyalur Group, the two groups being said to be conformable. What supports this inference is the fact that the Trichinopoly Group gradually thins out in the northern part, with the Ariyalur Group, in an extreme case, overlying unconformably the Utatur Group.

Although the approximate correlation of the Cretaceous strata that is exposed in the Pondicherry district with the Ariyalur Group of the Trichinipoly district is, I think, correct, the question whether the age of the ammonite-rich Valudayur Formation is merely coincident with that of the lower Ariyalur Formation, or whether the two are somewhat displaced and overlapping has not yet been determined. The difference in fossil-contents may be due to differences in environment and in the conditions of sedimentation and fossilization, as suggested by the rock-facies, but this may be only a partial reason. For correlation with the Japanese scale, the Valudayur Formation does not offer sufficient material. Quite half of its ammonoid fossil-faunule is occupied by Indian elements, while in the remaining half, a few species are identical with the Japanese species, with others allied to Japanese forms. And evidence from these identical and allied species makes it possible that the formation under discussion extended over a wide time range with the contingency that the formation belongs to a certain part of the wide range covered by the Neourakawan and the whole of the Hetonaian. No finer determination than this is

(1) *Pachydiscus* aff. *egertoni* has been reported from the Neohetonaian of Hokkaidô, as a rare occurrence. Probably this Japanese occurrence indicates a part of the true range of the *Pachydiscus egertoni*-group.

possible. The fossil-contents of the superjacent *Trigonoarca* Beds are said to resemble those of the Valudayur Formation, but the number of ammonoid species diminishes considerably. The Neohetonaian age is suggested by *Pachydiscus compressus* (SPATH), which is closely allied to *P. subcompressus* MATUMOTO of Japan, but this evidence is not conclusive. In short, most of the Cretaceous strata that is exposed in the Pondicherry district is referable to the Hetonaian Series, and possibly to a part of Neourakawan.

Summarizing the foregoing discussions, we get the annexed Table of correlation:

TABLE 19

Utatur Group	Lower formation	≒ Infragyliakian (possibly extending to the lowest Paleogyliakian and a part of the Neomiyakoan)
	Middle formation	= Main part of the Paleogyliakian
	Upper formation	(Possibly inclusive of the uppermost Paleogyliakian) Neogyliakian
Trichinopoly Group	Lower formation	
	Upper formation	= Paleourakawan
		(Part of Neourakawan absent?)
Ariyalur Group	Lower formation	≒ Infrahetonaian (possibly extending to the lower Paleohetonaian and to the upper Neourakawan
	Middle formation	Main part of the Hetonaian
	Upper formation	

Cretaceous strata of the Pondicherry district ≒ Ariyalur Group
≒ Hetonaian and, possibly, a part of the Neourakawan (s. l.)

Note on correlation of the European standard with the Japanese scale.——The so-called standard scale of the Lower Cretaceous is based on the succession in Southern France, that of the Upper Cretaceous being based chiefly on the succession in Northern France and other localities in western Mid-Europe. The biostratigraphic material from these standard localities is not wide of the ideal, the true time-range of species and genera in the European region being fairly well represented by the actual occurrence of fossils in strata.

Nevertheless, careful examination shows that the material is not perfect. There is a local difference in the succession of fossils, some of the succession being only apparent. The stratigraphic occurrence of fossils in some cases represents a part of the true vertical range. Thus SPATH's splitting up of the Chalk and middle Cretaceous by species, for example, is only of local significance, if not imaginary——a drawback that may be negligible provided we deal with the problem of correlation in major units.

Even the major unit is, in some cases, under another difficulty, namely, that in regard to certain stages, their definitions or the determinations as to whether they belong in the upper or lower limit is not uniform among the different authors and countries. To illustrate, the problem of the Vraconnian has frequently been a subject of discussion in connexion with the boundary separating the Albian and Cenomanian. The boundary between the Campanian and Maestrichtian is in dispute between English, French, and German investigators.

A similar difficulty, but one that crops up more frequently, is the classification and definition of species.

Notwithstanding these vexatious questions, it is not impossible to correlate the European scale with the Japanese. An outline of how it could be done follows.

So far as the distribution of ammonites is concerned, the differences in the biogeographic provinces in the early Cretaceous diminish in the middle Cretaceous, whereas the differences again become quite marked in late Cretaceous. The Japanese scale can be correlated with the European scale *via* the Indian and Mediterranean (or the Tethys) provinces. The Indian province is intimately related to the Mediterranean, while the strata of the latter is correlated with fair ease with those of Mid-Europe. This, then, is the correlation of India with Japan, as mentioned in the preceding article.

Besides this side-by-side correlation, we can compare on a large scale the Indo-Pacific Region as a whole with the European-Atlantic Region. When we examine the genera or the groups of species which are very common in the Atlantic-European Region, we usually find no inconsistency between the order of their occurrence in the Indo-Pacific Region and their successive occurrence in the

European standard. For example, the Atlantic-European order *Beudanticeras* (1), *Inflaticeras* (2), *Acanthoceras, Turrilites* (s. str.) (3), *Romaniceras, Mammites, Prionotropis, Lewesiceras* (4), *Peroniceras, Barroisiceras, Gauthiericeras* (5), *Mortoniceras* (of the *texanum* group), *Placenticeras* (6), and *Pachydiscus* of the *neubergicus-gollevillensis* group (7) also obtains in the Indo-Pacific sequence. On the other hand, those which are common in the Indo-Pacific Region, sometimes occur again in the European-Atlantic Region. Their occurrence, however, in the European standard is somewhat sporadic or discontinuous, sometims showing lack of order compared with that in the Indo-Pacific sequence, examples of them being found in *Phylloceras, Neophylloceras, Phyllopachyceras, Epigoniceras, Anagaudryceras, Gaudryceras* (s. str.), *Zelandites, Bostrychoceras, Hyphantoceras, Puzosia, Parapuzosia, Pachydesmoceras, Hauericeras* (s. str.), *Kossmaticeras* (of the *theobaldianum* group), *Anapachydiscus, Menuites,* etc. These forms occur in Europe as

TABLE 20

Correlation between Southern India and the European standard

Utatur Group	Lower Formation	≒ Vraconnian (±x) (possibly extending from upper Albian to lowest Cenomanian)
	Middle Formation	= most of Cenomanian
	Upper Formation	≒ Turonian
Trichinopoly Group	Lower Formation	
	Upper Formation	= Coniacian
Ariyalur Group (≒Pondicherry Cretaceous)		≒ Upper Senonian (s. l.) + ? Danian

immigrants or erratics, where their stratigraphic range may often be partial, as compared with the entire range in the Indo-Pacific Region.

Bearing these general conditions in mind, we get the following approximate correlation (Table 20, 21):

TABLE 21

Correlation between European scale and Japanese scale

Neocomian (s. l.)	Berriasian	≒	Lower Series (Berriasian, Valangianian, part of Hauterivian)		Paleocretaceous
	Valangianian				
	Hauterivian				
	Barremian	≒	Middle Series (part of Hauterivian, Barremian)		
	Aptian	≒	Paleomiyakoan	Miyakoan	
	Albian	≒	Neomiyakoan (s. l.)		
	Cenomanian	≒	Paleogyliakian	Gyliakian	Neocretaceous
	Turonian	≒	Neogyliakian		
Senonian (s. l.)	Coniacian	≒	Paleourakawan	Urakawan	
	Santonian	≒	Neourakawan (s. s.) (Santonian, part of Campanian)		
	Campanian	≒	Infrahetonaian		
	Maestrichtian	≒	Paleohetonaian (part of Campanian, Maestrichtian, Danian)	Hetonaian	
	Danian		Neohetonaian		

From its nature, international correlation of minor units is, I think, impracticable[1]. A good example is the so-called Vraconnian problem. Although this substage was believed to be in the uppermost Albian, in Europe, it is difficult to say just where the boundary separating the Albian and Cenomanian is situated in the stratigraphic sequence of provinces like Southern India and Japan, which are so widely distant from Europe. The lower formation of the Utatur Group in India and the Japanese Infragyliakian substage suffer from this drawback. Their age may be near the boundary of the Albian and Cenomanian, but I hesitate to say whether they correspond to upper Albian, to lowest Cenomanian, or to that part lying between these two substages. We likewise meet with difficulties when we attempt to correlate in detail the finer divisions of Urakawan+Hetonaian with those of the Senonian

[1] Judging from the general principles govering the geologic and geographic distribution of organisms, I think it futile and meaningless to apply fine zonal correlations to areas in different biogeographic provinces. (See also Part II, Chapter V, Note on fossil-zone.)

(s. l.), except, however, the Paleourakawn and Coniacian which, in turn, approximately correspond with each other. Danian is another example. Although the uppermost part of the Japanese Cretaceous have no ammonites, we have no sufficient grounds on which to conclude that they are correlated with the Danian of Europe.

Against this correlation of Europe with the Indo-Pacific, just mentioned, there are a few fossils whose occurrence is questionable. The genera *Neoptychites*, *Pseudaspidoceras*, and *Fagesia*, although characteristic of the Turonian stage of the Mediterranean province, in India, occur in the middle and upper formations of the Utatur Group. The genus *Romaniceras* has also been reported from these two Indian formations, although in Europe it seems to be restricted to the Turonian and the Neogyliakian in Japan. *Peroniceras*, a characteristic genus of the Coniacian stage of the European-Atlantic region, is found in the approximately corresponding upper Trichinopoly formation, but KOSSMAT has reported the occurrence of the same genus (and also the same Trichinopoly species) from the Ariyalur Group[1]. This formation yields another questionable form——a species that has been assigned to the genus *Munier iceras*, which is also restricted to the Coniacian, according to the European standard. To answer these questions it is necessary to see the specimens and examine the strata of the various countries concerned, although we could mention here a number of possible interpretations.

Regarding the correlation concluded above, it must be added that there are provincial differences in the time-range and in the morphologic characters of some of the allied groups of Europe and Japan, as typical of which are certain subgroups of the genus *Inoceramus*. In Europe, *Inoceramus concentricus* PARKINSON is a characteristic species in the Albian age, while towards or in the succeeding Cenomanian age there occur *Inoc. tenuis* MANTELL, *Inoc. etheridgei* WOODS, and other species related to *Inoc. concentricus*. A similar, but independent evolutional history, is found in Japan, although its phase differs somewhat with the age. Namely, *Inoc. concentricus* PARKINSON occurs in our Paleogyliakian, which

(1) The Japanese Neourakawan species (*P. amakusense* YABE), which was assigned to *Peroniceras*, according to my examination of the original specimens, is an ill-preserved *Mortoniceras* (*M. amakusenes* (YABE 1903)=*M. fukazawai* YABE & SHIMIZU 1925).

is approximately equivalent to the European Cenomanian, although our species is represented by a variety (var. *nipponicus* NAGAO & MATUMOTO), while in the succeeding Neogyliakian, which is approximately equivalent to the European Turonian, appear forms that are related to it, such, for example, as *Inoc. concentricus* var. *costatus* NAGAO & MATUMOTO, and *Inoc. pedalionoides* NAGAO & MATUMOTO. Similar subparallelism is found in the group of *Inoc. naumanni* of Japan and the group of *Inoc. lingua* of Europe. What is, morphologically, the simplest form of the former group is *Inoc. naumanni* YOKOYAMA, which appears in the Paleo-urakawan age and ranges throughout the whole of the Neoura-kawan (s. l.). At the close of this (i. e. Infrahetonaian subage) or at the beginning of the succeeding Paleohetonaian age, there appear various forms, such, for example, as *Inoc. orientalis* SOKOLOW, *Inoc. pseudosulcatus* NAGAO & MATUMOTO, *Inoc. schmidti* MICHAEL, and *Inoc. sachalinensis* SOKOLOW, all of them being characterized by special ornamentations and other characters. These forms range throughout the whole of the Paleohetonaian. In Europe, *Inoc. lingua* GOLDFUSS is the species that is similar to, but different from our *Inoc. naumanni*. This species seems to have a long life-period, extending through almost the whole of the Senonian (s. l.). The variously ornamented forms that are presumed to be related to *Inoc. lingua* are *Inoc. patootentis* DE LORIOL, *Inoc. steenstrupi* DE LORIOL (= *Inoc. tuberculatus* WOODS), *Inoc. cardisoides* GOLDFUSS, etc. These species are known to occur in Santonian(1) and in lower Campanian. Since the Santonian and a part of the Campanian are approximately equivalent to our Neo-urakawan, we can again point to a general time-displacement in the phases of the courses of evolution between the subparallel groups under consideration. Facts of this kind are warnings against the danger of misusing the so-called allied or related forms of certain organic groups for the purpose of correlating strata between widely separated provinces.

In conclusion I will remark on the system of the European divisions. The unit in the divisions of the European Cretaceous is, I think, somewhat arbitary in its weight. This is clearly apparent when we compare the European scale with the Japanese

(1) An older occurrence has been reported from Germany.

scale. As has been discussed in detail in Part II, the scale for the Japanese Cretaceous is systematized, as far as it is possible to do so, with the result that a unit of scale has a constant value. Since the Senonian, for example, is correlated with our Urakawan *plus* a part of the Hetonaian, it has a weight of more than one epoch. The Turonian or the Cenomanian, in the meanwhile, has a weight of one age, because these two are approximately equivalent to our Paleogyliakian and Neogyliakian respectively. Thus it is necessary to reorganize the European scale, in attempting which, we become aware of the necessity of establishing some suitable terms for the name of the epoch or series. Being quite unfamiliar with the European materials, themselves, I shall here refrain from proposing such terms, merely calling the attention of foreign stratigraphers to the matter.

Note on some of the Circum-Pacific Cretaceous deposits.—— In regard to the Cretaceous stratigraphy of the Northern Pacific Region, I believe in the importance of the newly established knowledges of the Cretaceous of Japan. The late Dr. S. SHIMIZU once (1931) attempted to correlate the marine Lower Cretaceous deposits of Japan with those of California, where a concrete and precise stratigraphic investigation was made recently by F. M. ANDERSON. So far as the Lower Cretaceous is concerned, knowledge of the American side seems to be more complete at present than that of the Asiatic side, so that a reexamination is needed in connexion with the task of internationally correlating the Japanese Paleocretaceous, although it is not my intention to deal with it here. Since, judging from what data is available as the result of previous work, the Pacific coast of America in Neocretaceous Period was, palaeogeographically speaking, distinctly separated from the Atlantic and Gulf Regions, while it is intimately related to the Japanese province, the problem of international correlation regarding the Neocretaceous localities of the Pacific side of North America should be solved by comparing them with the standard of Japan, although our present knowledge of the stratigraphy and palaeontology of the Eastern Pacific is too incomplete to enable a definite conclusion being reached. To illustrate, the definition of the Chico Group, which is a widely used formational name for the Upper Cretaceous deposits of the Pacific coast of the U.S.A., is not only somewhat uncertain, but also has not been completely investigated, biostratigraphically (Cf. TAFF, HANNA, & CROSS, 1940). Furthermore, the Chico Group is, from its nature, clastic sediments of shallow seas, containing molluscan remains whose value is rather local, and is not so important for international correlation. As to the ammonoid remains, which are more useful for correlation purposes, we must await further information concerning their precise stratigraphic occurrence and up-to-date determinations of their genera and species.

Our knowledge of the stratigraphy of the Californian Neocretaceous deposits was recently revised, following the investigations of J. A. TAFF (1935) at Mount Diablo and vicinity. Quoting from TAFF's paper, the revised succession is as follows:

Underlying: Lower Cretaceous Shasta Series

——— Unconformity ———

Chico Group (7000 ft.) Arkose sandstone and sandy shale, with conglomerate at base.

——— Unconformity indicating regional uplift ———

Panoche Group (5000 ft.) Arkose sandstone, sandy and clay shale, conglomerate at and near base.

——— Unconformity? ———.

Moreno Group (7000 ft.) Blue and brown shales and sandstone. Massive buff and brown sandstone, with conglomerate or grit at base.

——— Unconformity indicating regional emergence, strong folding and extensive erosion ———

Overlying: Tertiary Martinez Group

The biostratigraphic data from this succession is not sufficient for establishing a standard of international correlation, from what we see by the facies of formation and by the presence of stratigraphic breaks. Determinations of the international age of these formations should be made by comparing them with the more complete and standard knowledge gained of the Japanese formations. But we have yet no precise information regarding the fossils of each group that are available for this comparison. Only the upper part of the Panoche Group is said to yield abundant ammonoid remains. ANDERSON and HANNA (1935) described the fossils from the Catarina Formation of Lower California (Mexico) which almost corresponds to the upper Panoche Group. The ammonoid species (three species of *Pachydiscus* s. s., aberrant forms belonging to *Bostrychoceras* and other genera) from this formation suggest the age as being a certain part of the uppermost Neo-urakawan and Hetonaian.

As to the Queen Charlotte Group and the Nanaimo Group of the Canadian Pacific coast, a reinvestigation is also needed in connexion with the necessity of a more precise knowledge of the stratigraphic occurrences and accurate palaeontologic determinations of their fossils.

International correlation of the Cretaceous deposits of the Southern Pacific Region may be facilitated by comparing them with the Indian scale on the one hand and with the Japanese scale on the other, while from the Japanese standpoint, some of the previous conclusions seem to need revision.

To illustrate, I shall refer to the Cretaceous of New Zealand. Describing the upper Cretaceous ammonites of New Zealand, MARSHALL (1926) correlated the fossiliferous deposits called the Batley Series with the Ariyalur Group of India and determined its age to be Senoian, although he stated that the series contains some "survivals of the Utatur species".

The Upper Cretaceous ammonid fossil-fauna of New Zealand is characteristic. Half of it consists of the Kossmaticeratidae; the other half, which consists of the Pacifico-Indian-Mediterranean elements, such as the Phylloceratidae, the Tetragonitidae, the Gaudryceratidae, and the Desmoceratidae, contains no Atlantic elements. Although an up-to-date determination of fossils is necessary also in the case of the New Zealand species, unfortunately we have no opportunity of examining the specimens, but owing to the precise descriptions of MARSHALL (1926) and WOODS (1917) it is possible to attempt the revision to some extent. Judging from my preliminary revision, this fossil-fauna contains long ranged genera such, for example, as *Phylloceras*, *Tetragonites* (s. l. including *Epigoniceras*), *Gaudryceras*, *Zelandites* and *Puzosia* (s. l. including *Parapuzosia*). Taking the Japanese and Indian scales into consideration as reference, the species belonging to these genera point to either Middle or Upper Cretaceous (s. s.). The latter Epoch (i. e. Urakawan and Hetonaian) may, in fact, be represented by a part of the Batley Series, as proved by the occurrence of *Pseudophyllites indra*, *Neophylloceras nera*, and others. Nevertheless, the generic determinations of some of the species that have been assigned by MARSHALL to the Upper Cretaceous (s. s.) genera, such as *Brahamites*, "*Parapachydiscus*" (i. e. *Pachydiscus* s. s. em.), *Hauericeras*, *Schlüteria*, and *Nowakites*, are doubtful. Furthermore, we find many forms that are either identical or are closely allied to species of the Japanese Gyliakian and Infragyliakian and of the Indian Utatur. They are *Anagaudryceras subsacya* (MARSHALL) (resembling the immature shall of *A. sacya* (FORBES)), *Jacobites* spp., *Maorites* spp., *Neomadrasites* spp., *Puzosia* (s. s.) *angusta* Marshall (resembling *P. compressa* KOSSMAT), *Pachydesmoceras* (?) *rogeri* (MARSHALL), and *Hypoturrilites circumtaeniatus* (KOSSMAT)[1].

From these facts I cannot disregard the high probability that the Middle Cretaceous (i. e. our Gyliakian and subjacent part) would also be found in New Zealand. Although, according to Marshall, the ammonoid fossil-fauna has only one horizon, I expect that the so-called Batley Series is composite and, chronologically, has a wider range[2]. However, I wish to reserve my final conclusion, as I have not yet had the opportunity of stratigraphically investigating the New Zealand field.

(1) "*Acanthoceras*" *ultimum* Marshall may not be the true *Acanthoceras* of Gyliakian age, and possibly may be one of the kossmaticeratids.

(2) From the study of molluscan remains, J. MARWICK (1933) expressed an opinion favourable to my conclusion.

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