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Zonation of the Upper Cretaceous in Japan*

By

Tatsuro MATSUMOTO

Abstract

A scheme of the zoning which is best applicable to the Upper Cretaceous in Japan and adjacent areas is tabulated, with zonal indices and ranges of principal associated species. The indices are species of Inocerami and ammonites of the superfamily Desmocerataceae. They are mostly particular to the Japanese province, so that the scheme is entirely different from the well known ones in Western Countries. World-wide correlation is, however, attempted as far as possible from the careful considerations of genera and species-groups that are common to Japanese and extra-Japanese provinces. A tentative result of the approximate correlation is presented, but several questions remain, especially about the exact position of the boundaries between stages. The Japanese sequence will throw much new light on the Upper Cretaceous sequence in the vast Indo-Pacific area.

Foreword

At the XXth International Geological Congress, September 1956, I read a paper entitled "Zoning of the Upper Cretaceous in Japan and adjacent areas, with special reference to world-wide correlation". The paper should have been published immediately after the Congress, but the publication has been delayed for some reason. This seems to give inconvenience for the students, at home and abroad, working in the Cretaceous stratigraphy and palaeontology. I myself have to refer the results of my own previous work.

In the meanwhile, I had an opportunity of visiting the United States as a Fulbright Fellow of 1957-1958. I was benefited on that occasion by new acquisitions concerning the subject. In addition a considerable number of important papers has been added to the literature, since I prepared my previous manuscript. I also have continued stratigraphical and palaeontological studies of the Japanese Cretaceous, resulting in still more refinement of the scheme as compared with that of 1956.

This paper summarizes concisely the present knowledge about the zonation of the Upper Cretaceous in Japan and its bearing on the world-wide correlation. The writing principally follows that read at the Congress, but is modified in many places with new additions and necessary revisions.

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Introduction

Generally speaking the Mesozoic strata in Japan and adjacent areas are tectonically much disturbed and not so fossiliferous as in the standard areas in Europe. Fifty years ago or more our predecessors, M. YOKOYAMA (1890, 1904), K. JIMBO (1894), H. YABE (1903–4, 1909, 1910), etc., have made great efforts to contribute from the Japanese material to Mesozoic biostratigraphy of the world. These pioneer works should be highly appreciated, notwithstanding the fact that the subdivisions at those dates are much broader than the then already well divided Mesozoic sequence in certain areas of Western Europe.

Since then a great deal of work has been done, both from stratigraphical and paleontological sides, on the Mesozoic of Japan and adjacent areas. Among several major subjects of international importance, the development of the non-marine faunas and floras in the Mesozoic of Eastern Asia has been clarified to a considerable extent. Another contribution may be the zoning of the Upper Cretaceous, which has been much studied since Dr. YABE's classification in central Hokkaido (YABE, 1909, 1927).

Dr. S. SHIMIZU (1935) once presented a scheme of subdivisions of the Upper Cretaceous of Japan, but did not complete a monographic work. The zones proposed by him looked nearly as fine as the then known European ones, but actually in many cases they do not accord with the facts obtained by subsequent field works. Without detailed description of the stratigraphic sequence in each area and without paleontological monographs of the contained fossils, we cannot evaluate properly the proposed zones. On the other hand active geologists and palaeontologists in Hokkaido, such as the late Professor T. NAGAO, R. SAITO, K. OTATUME and others, had been accumulating reliable material for accurate zoning and correlation, but for various reasons their works have not been completed. At first in cooperation with them and then independently I have devoted myself for these twenty years to stratigraphical and palaeontological studies on the Cretaceous System of the Japanese Islands. Recently many active geologists have joined with me, with the resulting publication of a compiled book entitled *The Cretaceous System in the Japanese Islands.* In that book I have presented my scheme of zoning that is best applicable in the fossiliferous Upper Cretaceous of South Saghalien, Hokkaido and several areas in Honshu, Shikoku and Kyushu. In an appendix to the same book and in other papers which have been subsequently published or are now under preparation, I am describing our Cretaceous ammonites and Inocerami, both of which are the principal members in the proposed zones.

As set out below the proposed zones, with some recent revision, are special to the Japanese province and never can be regarded as direct extensions of those in the well known areas in Europe and North America. However world-wide correlation is, none the less, important. Owing to the kind help of my friends in Great Britain, France, Germany, the United States, Canada and other countries and also to the cooperation of my Japanese friends our available material for international correlation has accumulated to a considerable extent. I offer here an outline of our present knowledge and endeavour to advance as far as possible the problem of world-wide correlation.

Proposed Zones of the Upper Cretaceous in Japan and Adjacent Areas

Material for zonal subdivision.—As have been known since the papers of YOKOYAMA, JIMBO and YABE, the Upper Cretaceous strata in Japan and adjacent areas are fairly fossiliferous. But they are not necessarily favourable for zonal subdivision. The strata are products of fairly rapid sedimentation supplied with a large amount of terrigenous matters. In Hokkaido and Saghalien, the celebrated fossiliferous province, the Mesozoic deposition is rather of geosynclinal nature and the Upper Cretaceous is largely composed of mudstones rich in calcareous nodules with subordinate sandstones, fine-sandy siltstones, a few conglomerates and some tuffs (see FUJII, 1958). The strata are intensely folded, faulted and locally overturned. Fossils are only well preserved where they occur in compact, calcareous nodules.

Under these circumstances accurate zoning cannot be done without laborious and patient field work. Observation of the sequence along a single route is not sufficient for establishment of zones. Fossiliferous strata are well exposed along valleys, which are, however, often developed deep in the mountainous areas. A number of valleys has been examined again and again to establish and trace the proposed zones.

The standard or type areas are the Naibuchi Valley in South Saghalien, the Abeshinai Valley and adjacent Saku area in Teshio Province in north Hokkaido, the Ikushumbetsu and Yubari (Shiyubari) Valleys in central Hokkaido, Hobets (Popets) and Mukawa Valleys in Iburi Province in south-central Hokkaido and the coastal area of Urakawa in Hidaka Province in south Hokkaido.

The stratigraphic sequences of the Cretaceous deposits in these type areas have been described in my 1942–43 and other papers, also concisely presented on plates 4, 5 and 6 of *The Cretaceous System of the Japanese Islands* (MATSUMOTO [Editor], 1954) and schematically summarized in plates 2 and text-fig. 5 of the last mentioned book.

Among a number of contributions in the subsequent work, that of K. TANAKA, of the Geological Survey of Japan, (*in* TSUSHIMA *et al.*, 1958) to the stratigraphic succession along the Obirashibetu [= Opiraushibets] Valley, Teshio province, in the northeastern part of central Hokkaido, is important. This area includes classical localities of JIMBO (1894) and YABE (1903–4, 1909, 1910). I myself have joined TANAKA in identifying some of the fossils in his collection. A summary of his results is in a columnar section (TSUSHIMA *et al.*, 1958, fig. 1). Koji KINOSHITA and his associates of the Japan Petroleum Exploration Company, are accumulating fairly large collections from various Cretaceous areas in Hokkaido, with renewed stratigraphic observations. I had an opportunity of studying their collections.

Being frequently assisted by Messrs. T. and K. MURAMOTO, T. ÔMORI and M. KIKUCHI, I have recently obtained more and better specimens from the classical area of the Ikushumbets Valley and vicinities. The details of the stratigraphic succession there should be described separately. In this paper the important results are condensed in a columnar section of Plate 7.

Even in Hokkaido and Saghalien local stratigraphic ranges of the species may vary to some extent among various areas, depending on local ecological and sedimentary conditions. The apparent ranges must be distinguished from the true ranges by careful observations. Thus Plate 6 shows the most reasonable conclusion of the local correlation among different section. The true ranges of the selected species are shown in Plate 8.

Outside Hokkaido and Saghalien the Upper Cretaceous deposits distribute at irregular intervals in Honshu (i.e. the main island of Japan), Shikoku and Kyushu. They are rather heterogeneous or often unequal in their lithologic constituents, stratigraphic sequence, thickness, mode of occurrence of fossils and intensity of structural deformation among different areas. In some favourable cases, however, the zones that have been established in Hokkaido and South Saghalien are clearly recognized and thus the proposed zones are principally applicable all over the Japanese Islands.

Another fact which should be remarked is that the faunal province of Japan and adjacent areas is entirely different and much separated from that of Western Europe and other well zoned areas. In other words the genera and species which define each zone of our province are mostly Indo-Pacific elements and different from the zonal indices in Western Europe or in the Gulf Coast—Western Interior of America. Furthermore our species have relatively long ranges as compared with the highly ornamented forms in epicontinental areas. Notwithstanding these unfavour able conditions zoning is possible and has actually been established to some extent. Moreover finer subdivision into subzones or supplemental local zonules seems possible in certain areas. For the latter case we select relatively well ornamented elements which are, at least as genera or species-groups, mostly cosmopolitan, being common to both Japanese and European or other distant provinces. These latter elements, though not necessarily abundant in the circum-Pacific region, being sometimes immigrants, are very useful for correlating the Cretaceous deposits between different faunal provinces, while the former elements will become increasingly important as zonal indices in the Indo-Pacific region, and thus the Japanese material

AREAS \ STAGES	APTIAN	ALBIAN	CENOMANIAN	CENOMANIAN	TURONIAN	CONIACIAN	SANTONIAN	CAMPANIAN	CAMPANIAN	MAESTRICHTIAN
	LOWER MIYAKOAN	UPPER MIYAKOAN	INFRAGYLIAK.	LOWER GYLIAKIAN	UPPER GYLIAKIAN	LOWER URAKAWAN	UPPER URAKAWAN	INFRAHETONAI.	LOWER HETONAIAN	UPPER HETONAIAN
	$K3_\alpha$	$K3_\beta$	$K3_\gamma$	$K4_\alpha$	$K4_\beta$	$K5_\alpha$	$K5_\beta$	$K5_\gamma$	$K6_\alpha$	$K6_\beta$
NAIBUCHI VALLEY	UNEXPOSED	Kv, Kw	Kx, Ky	Kz, Mho	Mh_1, Mh_2, Mh_3	Mh_4, Mh_5	Mh_6	Mh_7, Mh Ry	Ray, Rby	Rcy, Rdy, Rey, Rfy
		KAWAKITA SUBGROUP	KAWAKITA SUBGROUP	KAWAKITA SUBGROUP / MIHO GROUP	MIHO GROUP	MIHO GROUP	MIHO GROUP	MIHO GROUP / RYUGASE GROUP	RYUGASE GROUP	RYUGASE GROUP
ABESHINAI–SAKU AREA	Ia, Ib	Ic, Id, Ie, If, Ig	IIa	IIb, IIb-c, IIc	IId	IIIa	IIIb, IIIc, IIId	IIIe	IIIe, IV	
	LOWER YEZO GROUP	MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	SAKU FORMATION	UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	HAKOBUCHI GROUP	
OPIRASHIBETS–TAPPU AREA		Ma, Mb	Mc, Md	Me, Mf, Mg	Mh, Mi–Mk, Ml–Mq	Ua, Ub, Uc	Ud, Ue, Uf, Ug	Uh	Ui, Uj, Uk	
		(LOWEST PART)	(MAIN PART)	(MAIN PART)	(MAIN PART) (UPPM.)	(MAIN PART)	(MAIN PART)	(UPPERMOST PART)	(UPPERMOST PART)	
		MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	
IKUSHUMBETS VALLEY	UNEXPOSED	I	I, IIa	IIb, IIc	IId, IIIa	IIIb, IIIc	IIId1, IIId2		IV	
		MIDDLE YEZO GROUP	MIDDLE YEZO GROUP / MIKASA FORMATION	MIKASA FORMATION	MIKASA FORMATION	UPPER YEZO GROUP	UPPER YEZO GROUP		HAKOBUCHI GROUP	
SHIYUBARI VALLEY	Ia – Id	If, IIa – IId	IIe, IIf	IIg–IIi, IIj–IIk	IIm, IIn, IIs	IIIa, IIIb, IIIc	IIId	IV	IV	
	LOWER YEZO GROUP	LOWER YEZO GROUP / MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	MIDDLE YEZO GROUP	SAKU FORMATION	UPPER YEZO GROUP	UPPER YEZO GROUP	HAKOBUCHI GROUP	HAKOBUCHI GROUP	
HETONAI (TOMIUCHI) AREA							III	III – IVa	IVa	IVb, IVc, IVd, IVe
						UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	HAKOBUCHI GROUP	HAKOBUCHI GROUP
URAKAWA AREA					Uro	Ur_1	Ur_1	Ur_2	$Ur_{3\cdot4\cdot5\cdot6\cdot7}$	
			MIKASA – SAKU EQUIVALENT	MIKASA – SAKU EQUIVALENT	UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	UPPER YEZO GROUP	CHINOMIGAWA FORM.	

Plate 6. Correlation of the subdivisions between type sections in Hokkaido and South Saghalien.

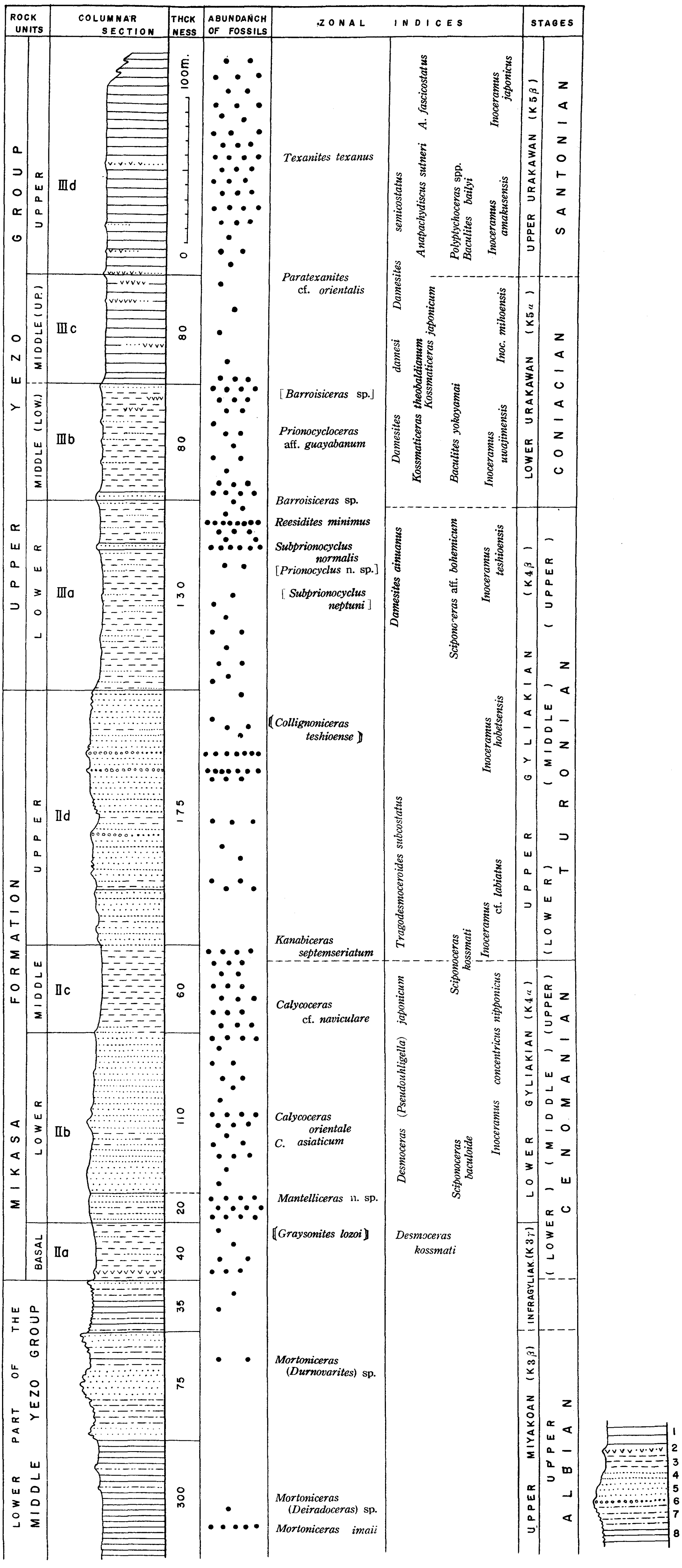


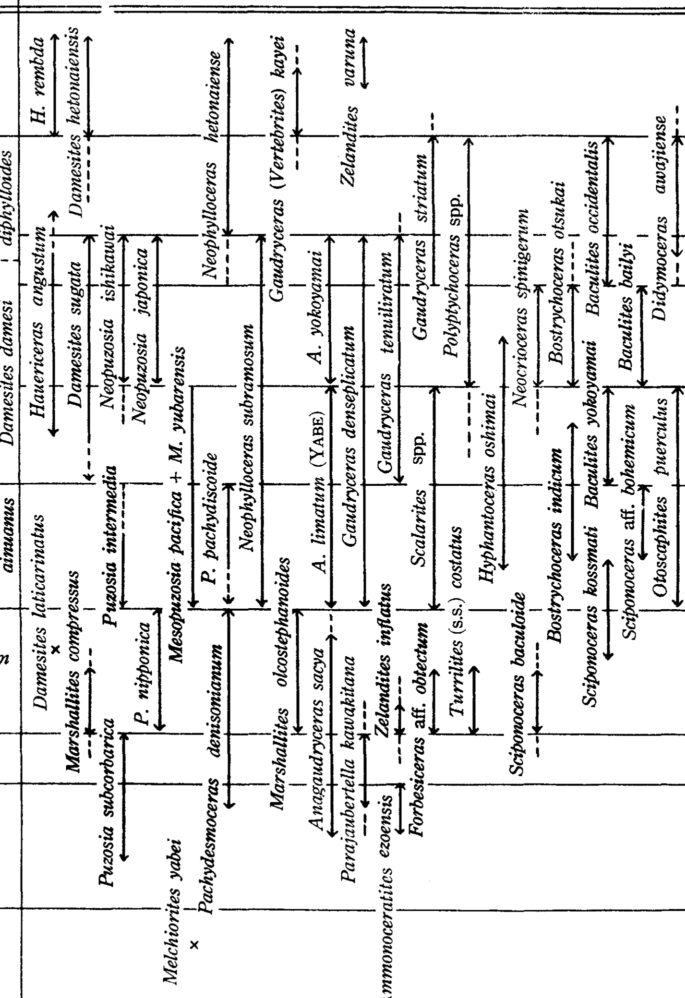
Plate 7. Stratigraphic section along the Ikushumbets Valley (on the eastern wing), central Hokkaido.

Species in square brackets, occur in the neighbouring areas; those in double brackets are doubtfully recorded as occurring in this area.

Lithology in the columnar section; 1: mudstone, 2: tuff and tuffaceous sandstone, 3: fine-sandy siltstone, 4: silty fine-sandstone, 5: sandstone (medium to coarse-grained), 6: conglomerate and very coarse-sandstone, 7: alternating shale and sandstone, 8: shale (frequently laminated).

Series			Stages or substages	Zonal indices: *Inoceramus*	Zonal indices: Ammonites	Subzonal indices: Relatively short-ranged forms	Correlation with the International scale	
HETONAIAN	K 6	β	Upper Hetonaian	*I. hetonaianus* + *I.* (?) *awajiensis* *I. shikotanensis*	*Pachydiscus subcompressus* + *Pach.* (*Neodesmoc.*) *japonicus*	[*Kitchinites* sp., *Brahmaites saghalinensis*] *Patagiosites compressus*	Maestrichtian (s.l.)	UPPER CRETACEOUS
		α	Lower Hetonaian	*I. schmidti*; *I. balticus*	*Canadoceras kossmati*; *Desmophyllites diphylloides*	*Metaplacenticeras subtilistriatum* [*Natalites* sp.]	Campanian — SENONIAN (s.s.)	
URAKAWAN	K 5	γ	Infra-hetonaian	*I. orientalis*; *Inoc. naumanni*; + *I. ezoensis*	*A.* (*Neopachydiscus*) *naumanni*; *Eupachydiscus haradai*			
		β	Upper Urakawan	*I. japonicus* *I. amakusensis*	*Anapachydiscus sutneri* + *A. fascicostatus*; *Damesites damesi*	*Submortoniceras* (?) sp. *Texanites texanus, etc.* *Protexanites fukazawai, etc.*	Santonian	
		α	Lower Urakawan	*I. mihoensis* *I. uwajimensis*; *I.* (*Sergipia*) *akamatsui*	*Kossmaticeras theobaldianum*; *Yokoyamaoceras kotoi.*	*Paratexanites orientalis* *Peroniceras* aff. *platicostatum* *Prionocycloceras* aff. *guayabanum* *Barroisiceras* sp.	Coniacian	
GYLIAKIAN	K 4	β	Upper Gyliakian	*I. teshioensis* *I. hobetsensis* *I.* cf. *labiatus*; *I. incertus*	*Tragodesmoceroides subcostatus* + *Scaphites planus*; *Damesites ainuanus*	*Reesidites minimus* *Subprionocyclus normalis* *Subprionocyclus neptuni* *Collignoniceras teshioense* — *Romaniceras* spp.; *Yubariceras* spp. *Kanabiceras septemseriatum* — *Fagesia thevestensis*	Turonian	
		α	Lower Gyliakian	*I. concentricus nipponicus* + *I. yabei*	*Desmoceras* (*Pseudouhligella*) *japonicum* + *D.* (*P.*) *ezoanum*	*Calycoceras* cf. *naviculare* *Calycoceras stoliczkai* *Calycoceras orientale*, *C. asiaticum*, *C. spinosum* *Mantelliceras* n. sp.	Cenomanian	
MIYAKOAN	K 3	γ	Infra-gyliakian	*I.* aff. *crippsi*	*Desmoceras kossmati*	[*Graysonites lozoi*] *Stoliczkaia* spp.		
		β	Upper Miyakoan	*I.* aff. *bohemicus*	*Desmoceras latidorsatum*	*Mortoniceras* (*Durnovarites*) sp. *Mort.* (*Deiradoceras*) sp. *Hoplites* aff. *dentatus*	Albian	Lower Cretaceous
		α	Lower Miyakoan		*Cheloniceras subcornuelianum* + *Colombiceras* sp.	*Diadochoceras nodosocostatiforme* *Parahoplites yaegashii*	Aptian	
	K 2 K 1						NEOCOMIAN	

Selected species other than zonal indices — Relatively long-ranged forms



× Sporadic occurrence

[ ] Those in square brackets are of isolated or doubtful occurrence

Plate 8. Upper Cretaceous zones in Japan and adjacent areas.

will take the key part in world-wide correlation. There are some endemic elements which afford difficulties for international correlation, even if they are available as zonal indices within the Japanese province.

Upper Cretaceous zones in tabular form, with some explanatory notes.—The annexed chart (Plate 8) shows the scheme of the Upper Cretaceous zones established in Hokkaido and Saghalien. It is not much different from the table which I proposed in 1954 (Table I facing p. 4 in T. M. [Editor] 1954) but is somewhat amended from the additional facts obtained in subsequent studies as briefly explained above.

As the name fossils of the zones I have selected most characteristic species of both ammonite and Inocerami. The ammonites are those of the superfamily Desmocerataceae, especially the families Desmoceratidae (*s. s.*) and Pachydiscidae, with a few Kossmaticeratids. Sometimes a zonal-index exceeds in stratigraphic range beyond the designated zone, which is to be defined by the assemblage of species. The commonly associated species are given in the adjacent column with their known ranges. They are other members of Desmocerataceae, Phylloceratidae, Tetragonitidae and certain heteromorpha. Although they have relatively long stratigraphical ranges, they are by no means useless, for they occur fairly abundantly and the assemblage of several coexisting species can define a particular zone.

In the next column on the right side I put selected species that are relatively well ornamented and short-ranging. Some of them occur rather sporadically, but some others are fairly common, forming subzones or local zonules. *Reesidites minimus* (YABE MS.) (HAYASAKA and FUKADA), for instance, occurs abundantly in a certain limited thickness of strata in central Hokkaido, forming a zonule, and is found rather sporadically in other areas. Similarly *Metaplacenticeras subtilistriatum* (JIMBO) defines a local zonule in the Abeshinai Valley and adjacent area at a higher horizon.

Apart from ammonites and Inocerami there are a few other species which are characteristic of certain zones. *Scuria* (?) *cassidaria* (YOKOYAMA), for instance, is very common in the zone of *Inoceramus naumanni*, while *Pattella* (?) *gigantea* (SCHMIDT) characteristically occurs in the superjacent zone of *Inoceramus schmidti*. Smaller foraminiferas do occur in our Cretaceous as have recently been reported by K. ASANO (1950 a, b). The study is now being succeeded by Y. TAKAYANAGI. As in the Chalk of Northwest Europe species of belemnites, echinoids, crinoids and brachiopods might be available for zonal subdivision of our Cretaceous, but they have not yet been so well described and actually do not occur so abundantly. Anyhow these sorts of fossils await further studies.

Certain particular species, e.g. *Linuparus japonicus* NAGAO, a crustacean, and *Holcolepis delicatostriatus* YABE and OBATA, a fish, are apparently characteristic of a definite bed (within the zone of *Inoceramus teshioensis-tenuistriatus* in Hokkaido), but their true range is not precisely known. Their occurrence in a particular bed may, however, depends much on environmental conditions, as in the case of trigonians, ostreids, glycymerids, etc., that are embedded in some particular sandy rocks. They may be, however, of some importance for correlation within the Japanese province, as is now being exemplified by KOBAYASHI (1957), KOBAYASHI and AMANO (1955), KOBAYASHI and NAKANO (1957, 1958) and NAKANO (1957, 1958 a, b). Among the plant remains, that are sometimes intermingled with marine fossils, *Cycadeoidea* seems to be of use to a certain extent for correlating the higher part of our Upper Cretaceous.

The zones here tabulated are recognized successively in a continuous series of Cretaceous strata in Hokkaido and South Saghalien. The Lower Cretaceous in that area, except for its upper part, is generally poor in fossils, so that zoning is impossible. The table comprises the upper portion of the Lower Cretaceous to indicate the position of the boundary between Upper and Lower Cretaceous Subsystems.

In the areas outside Hokkaido and Saghalien the Cretaceous formations are distributed relatively discontinuously, very variable in both lithologic and biological facies and often interrupted by disconformities and unconformities. Nevertheless some of the zones are well traced throughout the long Japanese Islands. For instance, the zone of *Inoceramus uwajimensis* YEHARA, which is defined in Hokkaido and Saghalien, is recognized in the Lower Futaba formation of Northeast Honshu, the Goryo formation of Southwest Honshu, the Furushiroyama shale (Uwajima group) of Shikoku and the Upper Onogawa group of Kyushu. Similarly the zone of *Inoceramus hobetsensis* is traceable from Saghalien to Kyushu and the zone of *Inoceramus amakusensis-japonicus* is found in Northeast Honshu, Southwest Honshu, Shikoku and Kyushu. The zones which are defined by the successive occurrence of *Inoceramus naumanni*, *I. orientalis* and *I. schmidti*, the group apparently characteristic of the northern area of the Japanese province, have now proved to extend to Southwest Japan. The highest zone, *Inoceramus hetonaianus-Pachydiscus subcompressus* is not only recognized in Hokkaido and South Saghalien but also found in the uppermost fossiliferous bed of the thick Izumi group in Southwest Japan. In the subjacent part of the Izumi group there is *Inoceramus shikotanensis*, whose original type locality is in the Island of Shikotan, off the eastern end of the main island of Hokkaido. Thus, so far as conditions are favourable, nearly all the zones are traceable throughout the marine Upper Cretaceous parts of the Japanese Islands and adjacent areas. They are of great use for correlating formations among various areas within the Japanese province (in the palaeogeographical sense). The fine tracing of the zones irrespective of lithological changes has been illustrated on previous occasions, with consequent proposals for dual stratigraphic classification (T. M. 1942-43; T. M. [Editor] 1954).

World-wide correlation

General remarks.—The above explained zones have been established on the fossiliferous Cretaceous in Hokkaido and Saghalien and are best available for correlating formations within Japan and neighbouring areas. They may be considered as entirely unfamiliar to geologists working in Western countries.

There are relatively well established Upper Cretaceous zones in British Isles (cited by C.W. and E.V. WRIGHT, 1951), France (compiled by HAUG, 1912, based on the works of DE GROSSOUVRE, 1901 and JACOB, 1907; reproduced with slight modification by COLLIGNON, 1954), Germany and adjacent areas (SCHLÜTER, 1861–67; JELETZKY, 1951, 1958), Madagascar (BESAIRIE, 1936 and COLLIGNON, 1954), Nigeria and the Cameroons (REYMENT, 1956), Gulf Coast of North America (STEPHENSON *et al.*, 1942), and Western Interior of the United States (COBBAN and REESIDE, 1952; COBBAN, 1958 b). It should be noted that the zones proposed in the various areas are defined by particular assemblages of species which belong to faunas more or less dissimilar in different provinces.

The difference is particularly great, when we compare the zones of the Japanese province with those of the above mentioned areas. On account of this fact it is rather difficult to assign at once formations in Japan to any of the stages in the international scale. Therefore series names are temporarily used which are particular to the Japanese province. Thus our Upper Cretaceous has been divided into three series, Gyliakian, Urakawan and Hetonaian in ascending order and each of them is again bi- or tripartite (see T.M. 1942–43). For convenience sake we sometimes use simpler nomenclature, K4α, K4β, K5α, K5β, K5γ, K6α and K6β (while K1, K2, and K3, except K3γ, belong to Lower Cretaceous) (see T.M. [Editor], 1954). The reference to this Japanese scale of the proposed zones is shown in the left column of the table.

Although endemic species are numerous in each faunal province, there are of course certain widely distributed species that are common to several provinces. It may be difficult to establish a scheme of zones which are applicable extensively to all parts of the world. I doubt whether the generalized scheme of ammonite zones and subzones proposed by SPATH (1926) (and later adopted by MULLER and SCHENCK, 1943) is really applicable to a world-wide extent and in such fine scale. Certain species can and actually do show different stratigraphical ranges among the separated areas.

Now the vast region of the Pacific and Indian Oceans may have constituted a major biogeographical realm in the great marine transgression of the late Cretaceous. In fact we already know of marked similarity between the Upper Cretaceous faunas of the Japanese province and the Pacific side of North America and again, between those of Japan and South India. Some relation with the Late Cretaceous faunas of

Japan may be sought in those of New Zealand, Chile, Patagonia and Antarctica, all areas bordering the Southern Pacific. There was less frequent and temporary connection with the Western Interior of the United States or with the Gulf Coastal or Mexican provinces.

The Cretaceous faunas of South India have long been studied (FORBES, 1846; STOLICZKA and BLANFORD, 1861–66; STOLICZKA 1867–68; 1870–71; KOSSMAT, 1895–98), but is now awaiting modern zoning. Up to date zonation has recently been established by COLLIGNON (1954b) in the Upper Cretaceous of Madagascar, where the faunas have some features in common with those of India and Japan. Furthermore the Indian and Malgash faunas have some relation to the Mediterranean and West European ones on one hand and more intimate connection with those of South Africa, Australia, New Zealand, Antarctica and South America on the other. Thus we shall be able to advance correlation step by step from the better connected areas to the remotest parts of the world. While modern zonation is wanted in many parts of the circum-Pacific region, the proposed scheme of zones in Japan and adjacent areas will throw a new light on the succession and correlation of the Upper Cretaceous in the Indo-Pacific realm.

Turning to the Japanese material I give here concise remarks on the principal species and genera from the standpoint of world-wide correlation.

Successive occurrence of the species belonging to Acanthocerataceae and Hoplitaceae.—The species of Acanthocerataceae and Hoplitaceae are the most important groups for world-wide correlation of the Cretaceous in zonal scale. In the Cretaceous of Japan and adjacent areas several representatives of the superfamilies do occur, but their occurrence is rather sporadic, except in several cases in which the subzones or zonules are defined by local abundance. Their stratigraphic sequence in our province is not complete, but is generally in harmony with that in the well studied standard areas of Europe and America.

(1) *Mortoniceras imaii* (YABE and SHIMIZU) has been represented by many immature specimens. Therefore to which of the subgenera it belongs is not clear. Anyhow the species has been reported from many localities, indicating the Upper Albian age. Recently ÔMORI and I have obtained a probably adult and another middle aged whorls of *Mortoniceras* (*Deiradoceras*) sp., from a locality on the Ikushumbets River close to that of *M. imaii*. From another locality, somewhat higher than *M.* (*Deiradoceras*) sp., MURAMOTO and I have obtained another example of *Mortoniceras* sp., probably to be referred to *M.* (*Durnovarites*). The discovery of these two species throws a light in determining the upper limit of the Lower Cretaceous in our succession, since *M.* (*Deiradoceras*) indicates in Western Europe Lower Upper Albian and *M.* (*Durnovarites*) Upper Upper Albian.

(2) *Mantelliceras martimpreyi*, which is said to define the basal zone of the

Cenomanian in Europe and North Africa, is undiscovered in Japan. The Infragyliakian, i.e. the Uppermost Miyakoan [K3γ], has been set forth as an intermediate substage between undoubted Lower and Upper Cretaceous, although the boundary was provisionally placed at the upper limit of the Infragyliakian in my previous papers (1942–43; 1954 in MATSUMOTO [Editor]). This part can be defined as the zone of *Desmoceras kossmati*, but *D. kossmati* itself occasionally exceeds in range beyond the limit of the zone.

Among the species occurring in the zone of *D. kossmati* those belonging to *Stoliczkaia* and *Graysonites* should be discussed here. The former have been recently obtained and provided me for study by Mr. K. TANAKA, Professor W. HASHIMOTO, and his student, Mr. INOMA, from the Shumarinai area adjacent to the Opirashibets Valley, Hokkaido and by Mr. AMANO, from the probable extension of the same zone in the Goshora group of Koshiki Islet, off the west coast of Kyushu. The species of *Stoliczkaia* are more than one but unfortunately represented by immature specimens, some of which have peripheral tubercles. Although the zone of *Stoliczkaia dispar* defines the uppermost part of the Albian in Europe, certain species of *Stoliczkaia* do occur in the Lower Cenomanian. There seems to be no remarkable distinction between the Upper Albian and Lower Cenomanian species of *Stoliczkaia.* In other words by the species of *Stoliczkaia* alone the boundary of Lower and Upper Cretaceous cannot be well defined especially in a region far from Europe.

Graysonites indicates Lower Lower Cenomanian in Texas, as recorded by YOUNG (1958). The specimens from the Goshora group, which Mr. AMANO provided me for study, are to be referred to *G. lozoi* YOUNG.* The two fragmentary whorls, which I once (1942–43) listed as *Acanthoceras* cf. *turneri* (WHITE), from bed IIf of the Shiyubari Valley, Hokkaido, may be comparable with *Graysonites* sp. I have recognized *Graysonites wooldridgei* YOUNG in Mr. M.V. KIRK's collection from the probable Lower Cenomanian of California. Some of the species which were once referred to *Submantelliceras* in several parts of the world could be immature *Graysonites.* Thus the genus is becoming important as a widespread indicator of the Lower Lower Cenomanian. From this ground I am now inclined to conclude that our Infragyliakian, the zone of *D. kossmati*, can more probably be assigned to the Lower Lower Cenomanian than to the Upper Upper Albian.

(3) Several species of *Mantelliceras* have recently been discovered (but not yet fully described) at a limited lower portion of *Desmoceras* (*Pseudouhligella*) *japonicum* zone (K4α) in Hokkaido. They are associated with the longer ranging *Hypoturrilites* cf. *tuberculatus* (BOSC), *Ostlingoceras* sp. nov. (?) (related to *O. puzosiforme* SPATH), *Zelandites inflatus* MATSUMOTO, *Sciponoceras baculoide* (MANTELL) etc. [see

* P.S. (August, 1959) I have quite recently identified *G.* cf. *lozoi* in INOMA's additional collection from the zone of *Desmoceras kossmati* of the Shumarinai area, Hokkaido.

(55)]. *Mantelliceras* sp. is known furthermore in the Monobegawa Valley and Miyanohara sandstone of Shikoku.

(4) *Calycoceras asiaticum* (JIMBO), *C. spinosum* (KOSSMAT) and *C. orientale* MATSUMOTO, SAITO and FUKADA, which are more or less allied to the better known *Calycoceras newboldi* (KOSSMAT), are not rare in the middle part of the zone of *D.* (*P.*) *japonicum.* The *newboldi* group is indeed widespread in the Indo-Pacific, Mediterranean and West European regions, in the Middle Cenomanian to Lower Upper Cenomanian.

(5) *Schloenbachia varians* and other allied species, which are very abundant and regarded as zonal indices in the Lower Cenomanian of Europe and related areas, are quite rare in the Japanese province. *Forbesiceras* sp.* which is closely related to *F. obtectum* (SHARPE) from the zone of *Sch. varians,* is occasionally found in our Lower Gyliakian (K4a).

(6) *Calycoceras* cf. *stoliczkai* COLLIGNON (MATSUMOTO *et al.,* 1957, p. 20, pl. 6, fig. 2) occurs in bed IIj of the Shiyubari Valley, middle part of the Lower Gyliakian. This species is known in India, Madagascar, Portugal and California.

Calycoceras cf. *naviculare* (MANTELL) has been recently discovered in the lower part of the middle member of the Mikasa formation of the Ikushumbets Valley, i.e. upper part of the Lower Gyliakian. This species is world-wide in the Upper Cenomanian. *Calycoceras obrieni* YOUNG, 1957, from Arizona, is, in my opinion, identical with *C. naviculare* (MANTELL).

Relatively compressed species of *Calycoceras,* related to *C. gentoni* (BRONGNIART) and to *C. jeanneti* COLLIGNON, occasionally occur in our upper Lower Gyliakian (see MATSUMOTO *et al.,* 1957, p. 20, 21). Probably from the same unit came *Eucalycoceras* sp. and *Protacanthoceras* sp., although they are rare and represented by imperfect specimens.

Acanthoceras of *rhotomagense* group is rare, if not absent, in Japan. A specimen which can be called *Acanthoceras* aff. *evolutum* SPATH came from the upper Lower Gyliakian. Several examples comparable with *Euomphaloceras euomphalum* (SHARPE) have been obtained from the middle Lower Gyliakian. *Acanthoceras* (*s.s.*), including the horned species, and *Euomphaloceras* are world-wide, being rather common in the upper half of the Cenomanian, or in the Middle to Upper Cenomanian.

(7) The uppermost Cenomanian Acanthoceratids, such as the aberrant *Dunveganoceras,* have not yet been discovered in our province. *Dunveganoceras* is characteristic of the Western Interior province of North America, but seems to occur also in Texas, because *Acanthoceras validum* MOREMAN (1942, p. 203, pl. 32, fig. 1; text-fig. 2) is, in my opinion, an example of *Dunveganoceras.* Therefore it is not surprising to find a representative in Europe (see WRIGHT and WRIGHT, 1951, p. 29). We should

* In addition to several fragmentary specimens in our collection Dr. R. SAITO has provided me with a well preserved adult shell.

search for it in the Japanese province too, so that the top of the Cenomanian in our succession may be more clearly defined. Similarly *Utaturiceras* and *Metoicoceras* have not yet been discovered in Japan, except a few small specimens, which possibly can be regarded as an inner whorl of *Metoicoceras*, from the bed with *Kanabiceras* in the Ikushumbets Valley.

(8) I have recently discovered *Kanabiceras septemseriatum* (CRAGIN) at the top of the middle member of the Mikasa formation in the section of the Ikushumbets River. Whether this indicates the uppermost Cenomanian or the basal Turonian may be debatable. In our case the species is associated with *Allocrioceras* sp., *Sciponoceras kossmati* (NOWAK), and *Inoceramus* cf. *labiatus* SCHLOTHEIM. Therefore I am inclined to put the bed with *Kanabiceras septemseriatum* in the Ikushumbets Valley at the base of the Turonian. Anyhow, it represents the basal part of our Upper Gyliakian. *K. septemseriatum* (CRAGIN) occurs characteristically in the Britton member of Eagle Ford shale of Texas and the Greenhorn limestone of the Western Interior. There are several examples in California, where the species is associated with *Inoceramus labiatus* and *Sciponoceras kossmati.* Thus this species is becoming important as a world-wide zonal index.

(9) *Fagesia thevestensis* (PERON) [= *F. kotoi* (YABE)] and *Pseudaspidoceras sorachiense* MATSUMOTO and HASHIMOTO occur, though very rarely, at a horizon somewhat below the beds with abundant *Inoceramus hobetsensis*, or, in other words, in the lower portion of the Upper Gyliakian (K4β) in Hokkaido.

(10) Several species of *Romaniceras*, including *R. pseudodeverianum* (JIMBO), *R.* aff. *uchauxiense* COLLIGNON (already described by MATSUMOTO *et al.*, 1957) and *R. deverioide* (DE GROSSOUVRE) (recently collected and supplied me for study by Professor HASHIMOTO from Hobets [Popets], Hokkaido), are known to occur in the Upper Gyliakian (K4β). The specimens in older collections were obtained from the pebbles or rolled blocks, so that their original horizons cannot be exactly determined, but those in recent collections rather indicate their predominance in the zone of *Inoceramus hobetsensis* - *I. teshioensis*, the middle to upper part of the Upper Gyliakian.

The genus *Romaniceras* is world-wide in the Turonian, but seems to extend downwards. Certain species of it may prove to be good zonal indices. As a remarkable example can be reckoned *R. deverioide* (DE GROSSOUVRE) occuring in the Middle Turonian of France, Syria, Madagascar, Texas, California and Japan. (See MATSUMOTO, 1959 c for the American representatives of *R. deverioide* (DE GROSSOUVRE) [= *R. loboense* ADKINS].)

Yubariceras is contemporary and parallel with *Romaniceras*. It is not necessary particular to the Japanese province, since representatives are known in Mexico, India and France (?) (see MATSUMOTO *et al.*, 1957, p. 27).

(11) *Collignoniceras woollgari* (MANTELL) is another widespread index of the Middle

Turonian. It occurs not only in Western Europe but also in the Western Interior and Gulf Coast of North America. Furthermore its probable representative is recognized in California. *Collignoniceras teshioensis* (YABE and SHIMIZU) (1925, p. 134 [10], pl. 31 [2], fig. 10; pl. 33 [4], figs. 6–10), from Hokkaido is very closely allied to, if not quite identical with, *C. woollgari* (MANTELL). Its original types came from the pebbles of the Opirashibets River, and TANAKA has recently obtained *Collignoniceras* sp. from bed Mn, middle part of Upper Gyliakian, in the same general area. Another example of *Collignoniceras* sp. is in MURAMOTO's recent collection from a drift probably derived from the upper member of the Mikasa formation in the type section along the creek of the Ikushumbets.

(12) *Subprionocyclus* SHIMIZU, which has been redefined by WRIGHT and MATSUMOTO (1954), shows world-wide distribution in the Upper Turonian. *S. neptuni* (GEINITZ) and then *S. normalis* (ANDERSON) occur in the zone of *Inoceramus teshioensis*, the upper part of Upper Gyliakian. This is in harmony with the occurrence of the two species in California. In both areas the two species are often associated with *Sciponoceras* aff. *bohemicum* (FRITSCH) (see MATSUMOTO, 1959 b, p. 109, pl. 30, figs. 2 a–c, 3 a, b; pl. 31, fig. 4; text-figs. 7 a, b, 8–11).

Prionocyclus n. sp. α of relatively compressed type, which is allied to *P. macombi* MEEK from the Upper Turonian of the Western Interior, occurs at Pombets (near Ikushumbets) in the zone of *Inoceramus teshioensis*. From the same locality came another new species β that resembles *Prionocyclus reesidei* SIDWELL (1932) from the Upper Turonian of the Western Interior.

(13) *Reesidites minimus* (YABE MS.) (HAYASAKA and FUKADA) forms, together with other associated species, a definite subzone at the top of the Upper Gyliakian (K4β), in the zone of *Inoceramus teshioensis*. *Reesidites* resembles *Barroisiceras* GROSSOUVRE (redefined by BASSE, 1947) in the outer whorl, but its inner whorl indicates the intimate connection with *Subprionocyclus*, as WRIGHT and MATSUMOTO (1954, p. 130) have remarked. Therefore it can be regarded as representing the intermediate stage between *Subprionocyclus* and *Barroisiceras*, but *Barroisiceras* itself might have derived directly from *Subprionocyclus* and *Reesidites* might be a localized offshoot. While *Subprionocyclus* and *Barroisiceras* are world-wide in the Upper Turonian and in the Coniacian respectively, *Reesidites* does not seem to be so widespread. The latter, however, has recently been recognized by REYMENT in Columbia, South America, being represented by *R. subtuberculatus* (GERHARDT) (1897, p. 156, pl. 3, fig. 12) (REYMENT, 1958, p. 10, pl. 1, figs. 4, 5; pl. 2, figs. 1 a, b, 2; text-fig. 4 a; p. 11, pl. 2, fig. 3; text-fig. 3 b), and also by C. W. WRIGHT (personal communication) in the collections of University of California from Columbia. REYMENT assigned the beds with *R. subtuberculatus* in Columbia to Coniacian. As regards the subzone of *R. minimus* in Hokkaido I hesitate to put it at the base of Coniacian, but consider that it is more possibly correlated with the uppermost

Turonian. The reasons are the Coniacian assemblage of species in the superjacent beds [see (14)] and the Turonian aspect in the assemblage of species of the subzone [see (56) and (61)].

(14) Undoubted examples of *Barroisiceras* (*s. s.*) do occur, though very rarely in Japan. One at a locality on the main river of Ikushumbets came from a level immediately above the bed of *Reesidites minimus*. This critical locality has submerged under the artificial lake of the Katsurazawa dam since October 1957. Another near Pombets on the western wing of the Ikushumbets anticline is evidently in the zone of *Inoceramus uwajimensis*.

In addition, *Prionocycloceras* sp., a close ally of *P. guayabanum* (STEINMANN), *Gauthiericeras* of *aberlei* group, *Peroniceras ninakawai* YABE and SHIMIZU and *Peroniceras* n. sp. of *platicostatum-dravidicum* group occur in the zone of *Inoceramus uwajimensis*, i.e. the main part of the Lower Urakawan (K5α). The assemblage of these species altogether indicates the Coniacian age of the *uwajimensis* zone.

Yabeiceras orientale TOKUNAGA and SHIMIZU, another member of the Peroniceratinae, is particular to the zone of *I. uwajimensis* in northeast Honshu (Lower Futaba formation) and Hokkaido. The genus *Yabeiceras* seems, however, to be endemic, because it has not yet been reported outside Japan since it was errected by TOKUNAGA and SHIMIZU (1926).

(15) From the subzone of *Inoceramus mihoensis*, which is situated in the intermediate part between the more clearly defined zones of *I. uwajimensis* and *I. amakusensis-naumanni*, there is no clear information of the occurrence of any good representatives of Peroniceratids. The only possible member is *Paratexanites orientalis* (YABE), but the type specimen actually came from a pebble in the Sanushibe river, Iburi Province, where the geological structure is much complicated. There is thus no reliable evidence to decide whether the *mihoensis* subzone belongs to Upper Coniacian or it belongs to Lowest Santonian. [See also (55), (65) and (66).] In the Ikushumbets Valley *P.* cf. *orientalis* occurs in the *mihoensis* zone.

(16) *Protexanites fukazawai* (YABE and SHIMIZU) [= ? *P. amakusensis* (YABE)], *Protexanites nomii* YABE, *Texanites texanus* (ROMER), *T.* cf. *oliveti* (BLANCKENHORN), and *T. kawasakii* (KAWADA) are found in the zone of *Inoceramus amakusensis-japonicus*, i.e. in the main part of Upper Urakawan (K5β). Therefore the zone is most reasonably assigned to the principal part of the Santonian.

According to YOUNG's recent study (personal communication) several species of *Texanites* are distinguished as forming subzones in the middle to upper part of the Austin Chalk in Texas. The lowest of them occurs in the zone of *Inoceramus undulatoplicatus*, which he considers as the uppermost Coniacian but could be the basal Santonian. COBBAN showed me an interesting faunule from western Texas (loc. USGS. 1467) which consists of *Texanites* cf. *oliveti* BLANKENHORN, *Stantonoceras* *guadeloupae* (RÖMER), *Baculites asper* MORTON, *Baculites* cf. *bailyi* WOODS, *Clioscaphites vermiformis* (MEEK and HAYDEN), *Inoceramus* sp. of *expansus-ezoensis* type and *Exogyra* sp. This can well be a key point for interregional correlation between Indo-Pacific, Gulf Coastal and Western Interior provinces. In Madagascar species of *Texanites* have been reported by COLLIGNON from both the Lower and Upper Santonian. Thus in our present knowledge it cannot be generally concluded that *Texanites* and *Stantonoceras* characterize Lower and Upper Santonian respectively, even if they actually do so in a certain limited area.

(17) Anyhow such Placenticeratids as *Stantonoceras* and *Diplacmoceras* have not yet been found in the Japanese province. In stead we have *Metaplacenticeras subtilistriatum* (JIMBO), which defines a local zonule in the upper part of the Lower Hetonaian (K6α), above the prolific part of the zone of *Inoceramus schmidti*. The occurrence of *Metaplacenticeras* in California is in harmony with ours. *Metaplacenticeras besairiei* COLLIGNON (*in* BESAIRIE, 1936, p. 200, pl. 21, figs. 21, 22), from the Upper Turonian of Antantiloky, Madagascar, is entirely different from the species from Japan and California. It may not belong to *Metaplacenticeras*.

(18) *Submortoniceras, Delawarella* and *Menabites,* with subgenera, have been regarded as Campanian representatives of Texanitinae. *Submortoniceras chicoense* (TRASK), for instance, is a good representative in the Campanian of California. This species has not yet been found in Japan. but in our K5β, Santonian, there is an example which is rather transitional between *Texanites* and *Submortoniceras*. A spinose *Menabites* occurs in our K5β as in the Santonian of Taxas (personal information from YOUNG).

Pseudoschloenbachia and *Hoplitoplacenticeras* have not been found in Japan, although a few representative are known on the West Coast of North America. *Pseudobarroisiceras nagaoi* SHIMIZU from Hokkaido is doubtful in its systematic and stratigraphic positions. I know an isolated occurrence of *Diaziceras tissotiaeforme* (SPATH) in the probable Urakawan (K5) in South Saghalien. Thus we have poor representatives of the well known zonal indices of the Campanian. Likewise a Maestrichtian indicator, *Sphenodiscus*, has not yet been discovered in Japan.

Succession of ammonites belonging to Desmocerataceae.—Generally speaking ammonites belonging to Desmocerataceae show universal distribution, being more common in the Indo-Pacific region, but have relatively longer vertical range than those belonging to Acanthocerataceae and Hoplitaceae. Certain genera (e.g. *Desmoceras, Puzosia, Damesites,* etc.) have very wide stratigraphical ranges, covering more than two stages or several zones. Nevertheless certain species can define a particular zone within the Japanese province on account of their abundance and characteristic assemblage. How far such zones can be traced in the Indo-Pacific realm is a question to be examined in future, but some of them are proved to have fairly wide extension.

(19) *Desmoceras latidorsatum* (MICHELIN) is a widespread species and reported mainly from Albian but sometimes from Cenomanian. In our province it is confined to Neomiyakoan (K3β, i.e. probable Albian) and is succeeded upwards by another species.

(20) *Desmoceras kossmati* MATSUMOTO is common in the Infragyliakian (K3γ), forming the lowest zone of our Upper Cretaceous together with other associated species [see (2)], but extends upwards and downwards to some extent. The same species has been known in the lowest part of the Ootatoor group of India (MATSUMOTO, 1954 a, p. 251) and also recently recognized in California (MATSUMOTO, 1959 c).

(21) *Pseudouhligella*, a subgenus of *Desmoceras*, is characteristic of our Lower Gyliakian (K4α), forming a broad zone defined by *D.* (*P.*) *japonicum* YABE *plus D.* (*P.*) *ezoanum* MATSUMOTO.

This zone has proved to extend to southeast Alaska (see MATSUMOTO, 1959 a). In Oregon and California *D.* (*P.*) *japonicum* is rare, if not absent, but *D.* (*P.*) *poronaicum* is occasionally found. A more remarkable representative of *Pseudouhligella* on the West Coast of North America is *D.* (*P.*) *dawsoni* WHITEAVES, occurring not only in British Columbia but also in southeast Alaska and California. It is common in the Upper Albian (the beds with *Mortoniceras*).

Examples of *D.* (*Pseudouhligella*) outside the Northern Pacific are *D.* (*P.*) *calabarense* REYMENT, 1957 from the Lower Cenomanian zone of *Euhystrichoceras occidentale* in Nigeria and *D.* (*P.*) *elgini* YOUNG, 1958 from the Lower Cenomanian in Trans-Pecos Texas.

In the zone of *D.* (*P.*) *japonicum* a rare species of *Damesites*, *D. laticarinatus* SAITO and MATSUMOTO, 1956, appears. That species resembles a form obtained from the Upper Cenomanian in the Western Interior of the United States (according to a kind information from Dr. COBBAN).

(22) The superjacent part, Upper Gyliakian (K4β) is characterized by *Tragodesmoceroides subcostatus* MATSUMOTO. In its upper part there is *Damesites ainuanus* MATSUMOTO, a probable predecessor of *D. sugata* (FORBES). The two species are particular to our province in the present state of knowledge.

(23) The three well defined species of *Damesites*, *D. sugata* (FORBES), *D. damesi* (JIMBO) and *D. semicostatus* (YABE MS.) MATSUMOTO, range through the whole Urakawan series (K5$\alpha-\gamma$), although locally abundant in some particular parts. The first species is known in India and Southeast and North Africa, but is too long ranging for zonal correlation. The second species, as represented by *D. damesi intermedius* MATSUMOTO, occasionally occurs in the probable Coniacian in California.

(24) *Desmophyllites diphylloides* (FORBES) is characteristic of the zone of *Inoceramus*

schmidti-Canadoceras kossmati, Lower Hetonaian (K6α). The species is known to occur in India (Arrialoor group), South Africa, Tunisia, New Zealand, British Columbia, California and probably also France (see the synonymy listed by T.M. and I. OBATA 1955 and by MATSUMOTO, 1959 c), suggesting a world-wide distribution in Campanian (and also Lower Maestrichtian ?). In Europe and Madagascar *D. larteti* (SEUNES) is known in the nearly corresponding and also higher zones.

(25) *Damesites hetonaiensis* MATSUMOTO characterizes the zone of *Inoceramus shikotanensis*, lower part of Upper Hetonaian (K6β). It is the last representative of the genus, with weakening of the keel and the subcostae. A Californian example, *Neokotoceras fresnoense* ANDERSON (1958, p. 218, pl. 57, figs. 1–5), can only be subspecifically separable from the Japanese form of *D. hetonaiensis* and should be called *D. hetonaiensis fresnoensis* (ANDERSON). In both Japan and California the associated species indicate the age of *D. hetonaiensis* near the boundary of Campanian and Maestrichtian, if not definitely Lower Maestrichtian. As has been pointed out by MATSUMOTO and OBATA (1955, p. 131), there is a possibly identical or allied form in the Upper Senonian of Madagascar.

(26) *Hauericeras* (*Gardeniceras*) *gardeni* (BAILY) is associated with *Texanites soutoni* (BAILY), *T. stangeri* (BAILY) and *Pseudoschloenbachia umbulazi* (BAILY) in Southeast Africa. A Santonian age is thus suggested by this assemblage. As has recently been remarked (MATSUMOTO and OBATA 1955, p. 137), what has been called as *H. gardeni* in the Japanese province and also in India and British Columbia is an allied but different species, *H.* (*G.*) *angustum* YABE. *H. mickeyi* ANDERSON (1958, p. 219, pl. 47, fig. 2, 2 a) is nothing but an example of *H. angustum* YABE, as I discuss in another paper (MATSUMOTO, 1959 c). This species is rather abundant in the zone of *Inoceramus amakusensis-japonicus* or *I. naumanni*, in the main part of Upper Urakawan (K5β), but ranges somewhat upwards and probably also downward. Therefore I do not think that species of *Hauericeras* can define a narrow zone.

(27) *H.* (*G.*) *angustum* is replaced by *H.* (*G.*) *rembda* (FORBES) in a higher zone of our Upper Hetonaian (K6β). The latter species came from the Valudayur beds of India and the closely allied *H.* (*G.*) *fayoli* GROSSOUVRE from the Maestrichtian *neubergicus* zone of France.

(28) The genera belonging to Puzosiinae mostly have long vertical ranges, as have been tabulated in my recent paper (MATSUMOTO, 1954 b), so that they have little value for narrow zonal correlation. However, some species may be valuable for indicating relatively broad zones, if they are carefully considered as associates with other more characteristic species. The examples are as follows [(29)-(33)].

(29) *Puzosia nipponica* MATSUMOTO in the zone of *Desmoceras* (*Pseudouhligella*) *japonicum*, or Lower Gyliakian, closely resembles *P. odiensis* KOSSMAT from the Ootatoor group of India and *P. subplanulata* (SCHLÜTER) from the Cenomanian of Europe.

(30) *Puzosia intermedia orientalis* MATSUMOTO [= *P. gaudama pars.*] occurs in the lower part of Upper Gyliakian. It occurs also in California (Lower Turonian) (see MATSUMOTO, 1959 c) and is known, though subspecifically distinguished, in the Trichinopoly group of India and the Lower Turonian of Portugal (see MATSUMOTO, 1954 b, p. 75). Furthermore *Puzosia mülleri* GROSSOUVRE from the Upper Turonian of Europe is closely allied to *P. intermedia* as I have remarked (MATSUMOTO, 1954 b, p. 76).

(31) *Mesopuzosia pacifica* MATSUMOTO is common in Japan, occurring, in both the Upper Gyliakian (K4β) and the Lower Urakawan (K5α). I have identified a few examples of it from the Turonian of California. *M. indopacifica* (KOSSMAT) is rather rare in Japan and California, but may occur more frequently in India and Madagascar. Its geological range is nearly the same as *M. pacifica*. *M. yubarensis* (JIMBO) is as abundant as *M. pacifica*, but is known only in Japan, being common in and near the zone of *Inoceramus mihoensis*.

(32) *Neopuzosia japonica* (SPATH) and *N. ishikawai* (JIMBO) are very common in the zone of *Inoceramus naumanni*, Upper Urakawan (K5β+K5γ), but their occurrence outside Japan has not yet been ascertained. Only a possibly comparable form is known in Rumania.

(33) *Kitchinites* is not rare in the probable Upper Senonian of India, Western Australia, New Zealand, Chile and Angola (?). I know a species (probably n. sp.) of the same genus probably derived from the zone of *Pachydiscus subcompressus* in South Saghalien. In my opinion the genus is a specialized end member of Puzosiinae. Accordingly, if the species are better sorted and if the strata are much more subdivided than at present, they might be useful for correlating zones of Upper Senonian in the Indo-Pacific areas.

(34) Our knowledge of the evolutionary history of Kossmaticeratidae has been fundamentally altered from the material of Hokkaido (see MATSUMOTO, 1955 b, 1956 a). The family comprises two subfamilies of different epochs. The earlier group, Marshallitinae, are represented by *Marshallites* and *Eogunnarites*, both of which range from the Upper Albian to the Upper Cenomanian, distributing in Japan, Saghalien, Alaska, British Columbia and California around the northern Pacific; several identical species are being found all through these areas. The subfamily furthermore contains several specialized genera, such as *Eomadrasites*, *Mikasaites* and *Maccarthyites*, that could become good indices of narrow subzones within the Cenomanian. Their representatives are, however, rather rare according to our present knowledge. *Holcodiscoides* and *Wellmanites* are known in southern India and New Zealand respectively. They likewise belong to Marshallitinae and their evaluation for interregional correlation must owe to further careful collecting too.

(35) Among the later subfamily Kossmaticeratinae, *Kossmaticeras* of *theobaldianum* group has recently proved to be a good indicator of Lower Senonian (especially

Coniacian) in the Indo-Pacific realm (COLLIGNON, 1954; T. MATSUMOTO, 1955 b, 1959 c), although the genus appears in the latest Turonian and persists into Santonian. In Japan the genus is accompanied by *Yokoyamaoceras*, the bi- or trituberculate offshoot of *Kossmaticeras*.

The zone of *K. theobaldianum* in SPATH's 1926 scheme (and MULLER and SCHENCK's 1943 scheme) was entirely misplaced at a too high horizon. SPATH depended on "*K. theobaldianum*" of PAULCKE (1907), which came near the bed with *Hoplitoplacenticeras* spp. in Patagonia. This has been revised as *Neograhamites* (?) *paulcki* MATSUMOTO (1955 b, p. 144, 149). *Neograhamites* is characteristic of the Upper Campanian in Grahamland (SPATH, 1953).

(36) Variously specialized members of Kossmaticeratinae are distributed principally in the southern province, including South India, New Zealand, Antarctica, Chile, South Africa and Madagascar. However they have not been properly evaluated for zonal correlation, since the Upper Cretaceous rocks in these areas, except in Madagascar, are not finely subdivided. From the Madagascar material COLLIGNON (1954) placed the zone of *Maorites aemilii* in the lower part of the Campanian and listed several species of *Brahmaites* and *Pseudokossmaticeras* in the zone of *Pachydiscus neubergicus* of Lower Maestrichtian. In Japan and adjoining areas the "Upper Senonian" members of Kossmaticeratinae are very rare, probably for some palaeogeographical reason. *Brahmaites* has been reported by YABE and SHIMIZU (1924), but unfortunately its stratigraphic position is uncertain. From the zone of *Inoceramus schmidti*, Lower Hetonaian, at Toyajo in Southwest Japan an imperfect specimen of *Natalites* [= *Kaiparaites* MATSUMOTO, 1955] (?) was found.

(37) Members of Pachydiscidae are fairly useful for zonal correlation. Curiously *Lewesiceras*, the Turonian representative of the family, has not yet been discovered in the Japanese province. The genus ranges up to Lower Coniacian, as clearly illustrated by COLLIGNON (1952) with the material from Madagascar. I regard '*Lewesiceras*' *jimboi* (KOSSMAT) as an example of *Nowakites*. That species is known from the Trichinopoly group of India and from the Santonian of Madagascar. *Pseudojacobites*, a probable offshoot from *Lewesiceras* with acquisition of trituberculation, seems similarly characteristic of the Turonian, for it occurs in Chalk Rock of England (type-species), the "uppermost Turonian" of Madagascar [*P. masiaposense* (COLLIGNON) and *P. rotalinus* (KOSSMAT)] and the Trichinopoly group ("probably its lower part") [*P. anapadense* (KOSSMAT)] and also Ootatoor group [*P. rotalinus* (STOLICZKA)] of India. The genus may range from bottom to top of Turonian (or further up to Lower Coniacian), as *Lewesiceras* does. Again no Japanese examples of the genus have been found.

(38) Species of *Anapachydiscus* have fairly long ranges and at present cannot be said to be taxonomically well sorted. Therefore they must be carefully treated for zonal correlation. In Hokkaido and Saghalien *A. fascicostatus* (YABE), *A. sutneri*

(YOKOYAMA) and *A. deccanensis yezoensis* MATSUMOTO are characteristic of the Upper Urakawan, constituting zonal indices together with *Inoceramus naumanni*, *I. amakusensis* and *I. japonicus*. Some of them persist into the superjacent zone of *Inoceramus orientalis*, but in the latter zone *Anapachydiscus* (*Neopachydiscus*) *naumanni* (YOKOYAMA) is more characteristic.

A form which was temporarily treated as a variety (*californica*) of the first species by YABE (*in* YABE and SHIMIZU, 1921, p. 58 [6], pl. 8 [1], fig. 4; text-fig. 5) has now proved to be distinct from *A. fascicostatus* (YABE). It should be called *A. californicus* (YABE) and occurs in the higher part (probably Campanian) of the section in California (see MATSUMOTO, 1959 c).

The second species is known from "the basal Campanian" of Madagascar (COLLIGNON, 1952) and the third species, though subspecifically distinguished, in the zone of *A. deccanensis* at "the horizon between Lower and Middle Campanian" in Madagascar (COLLIGNON, 1952, 1954) and in the Arrialoor group of South India. Thus the genus seems to appear relatively earlier in the Japanese province than in other regions.

Anapachydiscus subtililobatus (JIMBO), from our Lower Hetonaian (K6*a*), *A. arrialoorensis* (STOLICZKA), from the Arrialoor group of India, Middle Campanian of Madagascar, and the upper part of the Upper Yezo group at Urakawan in Hokkaido (YOKOYAMA, 1890) and *A. peninsularis* ANDERSON and HANNA, from the Catarina formation of Baja California, are closely related to one another. They are less inflated, more strongly ribbed, and geologically younger than the type-species, *A. fascicostatus* (YABE). In other words they are somewhat related to *Pachydiscus colligatus* (BINKHORST), from the Maestrichtian in Europe. Similarly *A. franciscae* COLLIGNON, from the basal Campanian of Madagascar, considerably deviates from *A. fascicostatus*, being fairly similar to such species as *Pachydiscus buckhami* USHER (1952, emend MATSUMOTO, 1959 c), from the Lower Campanian of British Columbia and California. Thus there are in the Campanian several species which are rather transitional from *Anapachydiscus* to *Pachydiscus*. *A. californicus*, mentioned above, and *A.* (?) *dülmenensis* (SCHLÜTER), from the Campanian of Europe, are also other examples of such a group. Dr. COBBAN kindly showed me two species of *Anapachydiscus* of the *arrialoorensis* group from the lower-middle part of the Pierre shale of the Western Interior of the United States.

(39) *Anapachydiscus* (*Neopachydiscus*) is a lateral offshoot and should be noted as a possible zonal index in the Campanian because of its wide distribution. To the same subgenus I refer *Pachydiscus patagonicus* PAULCKE from Patagonia and *P. sphaeroidalis* COLLIGNON from the Campanian of Madagascar. They were grouped, together with several other species of southern hemisphere, in *Hoepenites*. But this should be synonymized with *Neopachydiscus*, since *P. patagonicus* (type of *Hoepenites*) is closely allied to *A.* (*N.*) *naumanni*. Anyhow the Patagonian species was recorded

from a locality not far from the zone of *Hoplitoplacenticeras* spp. *Pachydiscus steinmanni* PAULCKE, one of the associated species, is in my opinion an example of *Anapachydiscus* (*s. s.*) in South America.

COLLIGNON included *Pachydiscus umtafunensis* SPATH, *P. simplex* HOEPEN and *P. antecursor* HOEPEN in his *Hoepenites*, but these Pondoland species are fairly peculiar in their relatively evolute whorls, subcircular whorl-sections and weak ornaments. Similar form has quite recently been discovered (but not yet illustrated) from the zone of *Inoceramus uwajimensis-Kossmaticeras theobaldianum* in Hokkaido. They may require a new generic name and zonal collection of fossils in Pondoland would furnish better evidence of correlation.

(40) *Eupachydiscus haradai* (JIMBO) is characteristic of the upper part of Upper Urakawan (K5β) and also Infrahetonaian (K5γ), approximately Upper Santonian to Lower Campanian, in our province. The same species, including a slightly younger (?) subspecies, is known in the Nanaimo group of British Columbia, probably Campanian of California, and Lower Campanian of Madagascar.

The type-species of *Eupachydiscus*, *E. isulensis* (REDTENBACHER) occurs, according to BRINKMANN (1935), in the Upper Coniacian and the Lower Santonian of the Alpine Gosau beds. The Alpine representative seems to me to be allied to *Eupachydiscus teshioensis* (JIMBO) from Hokkaido. It is interesting to note that there is *Eupachydiscus* aff. *teshioensis* in the probable Upper Coniacian of California (MATSUMOTO, 1959 c). According to COLLIGNON (1952, 1954) *E. isculensis* occurs in the Upper Santonian and Lower Campanian of Western Europe, Madagascar, and Zululand, being, therefore, nearly contemporary with *E. haradai.*

Other species of *Eupachydiscus* are known in Madagascar as coming from the Upper Santonian and the Lower or Middle Campanian. In addition to the above-mentioned species there are several species of *Eupachydiscus* in the Campanian. *E. grossouvrei* (KOSSMAT), from the Arriyaloor group of India and Madagascar, *E. levyi* GROSSOUVRE, from Europe and Madagascar, and *E. lamberti* COLLIGNON, from Madagascar, are the examples. Their representatives have not yet been found in Japan, but the species allied to the last two are known in California (see MATSUMOTO, 1959 c).

(41) *Canadoceras* is another important member of Pachydiscidae with increasingly recognized wide distribution. Its stratigraphical range in the type locality (Nanaimo group of Vancouver Island, British Columbia) is fairly long, extending from "Lower to Upper Campanian" in USHER's correlation (1952). In Hokkaido and Saghalien it is characteristic of the zone of *Inoceramus schmidti* of the Lower Hetonaian, being represented by *C. yokoyamai* (JIMBO), *C. kossmati* (YABE MS.) MATSUMOTO, *C. multicostatum* MATSUMOTO and *C. mysticum* MATSUMOTO. The first species appears slightly earlier than the second at least in some sections. In California I have recognized *C. yokoyamai*, *C. newberryanum* and *C. mysticum* occurring in the Cam-

panian. Here again the first species appears earlier than the second. In Madagascar three species of *Canadoceras* have been described in "Middle-Upper Campanian" (i.e. COLLIGNON's zone of *Eupachydiscus levyi*). Thus the genus occurs at corresponding horizons in the Japanese and Madagascar provinces, although it is represented by different species. In Europe no species has been assigned to *Canadoceras*, but there are certain possible members (e.g. *Ammonites draschei* REDTENBACHER from Gosau). Taking into consideration the common occurrence of *Nowakites* in Europe and other areas, *Canadoceras*, as its probable descendant, could be expected to be found in these areas. (See also the next paragraph).

(42) *Patagiosites* is, in my opinion, a derivative of *Canadoceras* with weakening of the ornaments. What I have described as *Canadoceras compressum* MATSUMOTO (*in* T.M. [Editor], 1954) is in our present knowledge better transferred to *Patagiosites*. It came from the zone of *Inoceramus shikotanensis* in the lower part of Upper Hetonaian. *P. arbucklensis* (ANDERSON) (emend MATSUMOTO, 1959 c) is a Californian example. It is regarded as Campanian, because it is associated with *Inoceramus schmidti*. The genus is not rare in the Upper Campanian to Maestrichtian of Northwest Europe, being represented by *P. patagiosus* (SCHLÜTER), type-species, *P. griffithii* (SHARPE) and *P. stobaei* (NILSSON). Its widespread distribution is suggested furthermore by *P. amarus* (PAULCKE) from Patagonia, which, however, is rather intermediate between *Canadoceras* and *Patagiosites*.

(43) *Pachydiscus* in the strict sense, namely the *P. neubergicus-gollevillensis* group, has a world-wide distribution. In the Japanese province *P. subcompressus* MATSUMOTO, which is closely allied to *P. compressus* (SPATH) from the probable Maestrichtian of India and Madagascar and *P. gollevillensis* (D'ORBIGNY) from the Maestrichtian of Europe, occurs commonly in the Upper Hetonaian, but begins to appear in the upper Lower Hetonaian, higher part of the Campanian. The occurrence of the same species and *P. egertoni* (FORBES) in California is correlatable with that in Japan and Saghalien.

(44) Since the so-called *Pachydiscus* have not yet been completely sorted, still including the subgroup which seems intermediate between *Anapachydiscus* and typical *Pachydiscus*, and since the question of the boundary between Campanian and Maestrichtian has not yet been clearly settled even in the type area of Western Europe, the range of the genus is somewhat indefinite in its lower limit. *P. kobayashii* (SHIMIZU 1935) [= *P.* aff. *egertoni* KOBAYASHI, 1931] (see MATSUMOTO, 1936, p. 262, pl. 30, fig. 1; pl. 31, fig. 1) from the shale member just above the basal conglomerate of Izumi group, the probable Lower Hetonaian or Infrahetonaian in Southwest Japan, much resembles *Pachydiscus preegertoni* COLLIGNON (1952) from the Middle Campanian of Madagascar.

(45) *Neodesmoceras*, which has been regarded as a subgenus of *Pachydiscus* by MATSUMOTO and SAITO (1954), seems to be an index of the Maestrichtian. The type

species, *P.* (*N.*) *japonicus* MATSUMOTO, occurs in the Upper Hetonaian, both the zones of *Inoceramus hetonaianus* and *I. shikotanensis*, of Hokkaido. Closely allied species are known in the Upper Senonian of Lower California [*P.* (*N.*) *catarinae* (ANDERSON and HANNA)] and in the Lower Maestrichtian of Madagascar [*P.* (*N.*) *mokotibense* COLLIGNON]. As I have already mentioned (1954 b, p. 82), "*Parapuzosia*" *icenica* (SHARPE) from the "Upper Mucronata Subzone" of the English Chalk is, in my opinion, an example of *Neodesmoceras*. The better known *Pachydiscus ootacodensis* (STOLICZKA) from the Arrialoor group of India and upper Lambert formation of Vancouver Island and *P. neevesi* WHITEAVES from the Nanaimo group of Vancouver Island and Campanian of California are somewhat intermediate between *Pachydiscus* (*s. s.*) and *Neodesmoceras*. Such examples seem to be found furthermore in Brazil.

(46) As has been recently demonstrated, (MATSUMOTO, 1955 c), *Menuites* has a long range like its probable ancestor *Anapachydiscus*. Among five species in Hokkaido and Saghalien three are from the Upper Urakawan (K5β), one from the Uppermost Urakawan (K5γ) and another from Upper Hetonaian (K6β). The relatively limited occurrence of the genus in the Upper Senonian of Europe, Tunisia, Madagascar, India, California and the Western Interior province means a partial or provincial range.

Urakawites, *Teshioites* and *Pseudomenuites* have recently been separated from *Menuites* (MATSUMOTO, 1955 c). The type-species and other examples of the first and second genera occur in the Lower Hetonaian of the Japanese province, while those of the third in the Upper Senonian (*s. l.*) of Europe and (?) India. Other members of *Urakawites* are found in the Nanaimo group of Vancouver Island and doubtfully in Europe and Africa. There is an example of *Teshioites* from France. The facts suggest the fairly wide distribution of these bituberculate Pachydiscids, so that they may become more useful for international correlation, if more examples are supplied by further collection.

Succession of some other ammonoid species.—Species belonging to Phylloceratida and Lytoceratida are generally persistent and mostly inadequate for zonal correlation. Nevertheless remarks should be given on certain forms, because their succession seems to have been misunderstood and because well sorted material can sometimes be properly used for correlation on a broader scale.

(47) Successive occurrence of the species of *Anagaudryceras* and *Gaudryceras* in the Cretaceous of the Japanese province is clearly recognized from both stratigraphical and palaeontological grounds. The succession as shown in the range chart of Plate 8 is available for correlating strata within the Japanese province and may become a reliable basis for sorting various forms in the extra-Japanese areas. *Anagaudryceras sacya* (FORBES) [= *Ammonites budha* FORBES] is distributed

extensively in the Indo-Pacific and Mediterranean province, but it ranges from Middle Albian to Upper Cenomanian, so that it is only useful for correlation in a broad scale. *A. yamashitai* (YABE) is a rare species which is allied to the nearly contemporary *A. yokoyamai* (YABE). I have recently discovered an example of it from the probable Santonian of California. It resembles *A. politissimum* (KOSSMAT) which occurs in the Upper Trichinopoly group of southern India. COLLIGNON (1956) reported the same species from the Lower Maestrichtian of Madagascar. This is unusually high, but the species may have persisted in that part of the world. From the same Lower Maestrichtian of Madagascar came another species *A. mikobokense* COLLIGNON. I have identified the same species in a faunule near the Campanian-Maestrichtian boundary in California.

Without examining the changes of characters with growth up to the adult, we cannot identify accurately the species of *Gaudryceras*, while many forms are too poorly described for that requirement. *Gaudryceras mite* (HAUER) from the Santonian (*Texanites* bearing bed) of E. Alps, France, Carpathia (?) and other areas, *G. glaneggense* (REDTENBACHER) from Gosau (E. Alps) and Carpathia (?), *G. varagurense* KOSSMAT from the Upper Trichinopoly group (India), Senonian of Madagascar and Patagonia (?) and *G. denmanense* (WHITEAVES) from the Nanaimo group (Vancouver Island) are more or less allied to one another, being closely related to *G. denseplicatum* (JIMBO) and *G. tenuiliratum* YABE, especially *G. denseplicatum intermedium* from our Urakawan (K5). Recently *G. denseplicatum* itself has been described from the Coniacian of Madagascar (COLLIGNON, 1956) and the Turonian of California (ANDERSON, 1958, revised by MATSUMOTO, 1959 c). *G. varicostatum* v. HOEPEN from the Senonian of Pondoland and the Santonian of Madagascar is very close to the inner whorl of *G. tenuiliratum ornatum* YABE from the upper part of K5 and lower part of K6 (zones of *Eupachydiscus haradai* and *Canadoceras kossmati*). Similarly *G. tenuilineatum* v. HOEPEN from the Upper Senonian of Pondoland seems to be an immature *G. striatum* (JIMBO) from $K5\gamma - K6\alpha$. Comprehensive and careful revision with a resulting monographical work is necessary for clearing up the subject.

Gaudryceras (*Vertebrites*) *kayei* (FORBES) is widespread in the Indo-Pacific and also Mediterranean regions. Its type locality is in the Valudayur beds of southern India. In the recent collections of Mr. S. YOSHIDA, Professor W. HASHIMOTO and myself, from eastern Hokkaido, and Dr. ICHIKAWA and Mr. MAEDA, from the upper part of the Izumi group, I have recognized the Japanese representatives of the same species. Californian examples have been recently added (MATSUMOTO, 1959 c). So far as the available evidence is concerned, *G.* (*V.*) *kayei* is most reasonably regarded as an index of Lower Maestrichtian, but could range slightly upward or downward beyond the boundary.

Species of *Zelandites* may be of some use for interregional correlation. *Z. varuna* (FORBES), for instance, occurs in both southern India and Japan, again probably indicating Lower Maestrichtian. Similarly *Z. odiensis* (KOSSMAT) occurs in both countries of Asia near the Albian-Cenomanian boundary. Recently I have noticed the common occurrence of *Z. inflatus* MATSUMOTO (1959 a) in the Cenomanian (probably Lower Cenomanian) between Hokkaido and southeast Alaska.

(48) Species of Tetragonitinae are very long ranging and of limited use for zonal correlation. Genus *Tetragonites* has now proved to range from the Albian to the Maestrichtian. Among several Japanese species *Tetragonites glabrus* (JIMBO) is most abundant, but persistent (K4β—K5γ). The same species occurs in California, but is known only in the Turonian part of the thick section. *T. beantalyensis* COLLIGNON and *T. embergeri* COLLIGNON, from the Coniacian of Madagascar, are closely allied to *T. glabrus*. In the Japanese province *T. epigonus* KOSSMAT is as long ranging as *T. glabrus*, but in southern India it came from the Upper Trichinopoly group and in Madagascar from the Santonian (COLLIGNON, 1956). *Tetragonites glabrus problematicus* MATSUMOTO, which ranges from the Upper Urakawan (K5β) to the Lower Hetonaian (K6α) in Japan and is known in the basal Campanian in Madagascar, is a passage form to *Tetragonites popetensis* (YABE). The latter species ranges from the Infrahetonaian (K5γ) to the Upper Hetonaian (K6α) in Japan and occurs also in the Upper Campanian to the Lower Maestrichtian (?) of California.

Lytoceras (*Tetragonites*) *kingianum* KOSSMAT var. *involutior* PAULCKE, 1907, from the Campanian of Patagonia, which should be specifically separated from the species from the Ootatoor group of India, is very similar to *T. popetensis*, but seems to have no constrictions.

Tetragonites (*Saghalinites*) *cala* (FORBES) originally came from the Valudayur beds (probable Maestrichtian) of southern India. *T.* (*S.*) cf. *cala* was described by YABE (1915) from Toyajo (i.e. K6α) in Southwest Japan and *T.* (*S.*) aff. *cala* by WOODS (1906) from the Campanian (?) of Pondoland. In the latter area and in Madagascar *T.* (*S.*) *nuperus* VAN HOEPEN has been described. According to COLLIGNON (1956) this species occurs in the Santonian and the Lower Campanian. He remarked that *T.* (*S.*) cf. *cala* from Toyajo is better ascribed to *T.* (*S.*) *nuperus*. I know a few Santonian examples of *T.* (*Saghalinites*), from the Upper Urakawan (Santonian) of Hokkaido, which are closely allied to, but not quite identical with, *T.* (*S.*) *nuperus*.

(49) A careful work is needed on the taxonomy and dating of the heteromorpha. As an illustration a short remark is given here on *Hyphantoceras*. In Europe *H. reussianum* (D'ORBIGNY) occurs rather characteristically in the Upper Turonian, forming a subzone. In Japan a closely allied species, *H. oshimai* (YABE) emend ranges from K4β to early K5β and another allied species, *H. venustum* (YABE) (*s. s.*, i.e. a form represented by YABE 1904, pl. 5, fig. 1, non pl. 3, fig. 4), comes from K5β. Such a long range of the *reussianum* group as revealed in the Japanese succession warns us against too much reliance on the *reussianum* group as a world-wide index of Upper Turonian.

(50) Another example is found in *Bostrychoceras*. *B. polyplocum* (RÖMER) has been regarded as an index of Upper Campanian (or Lower Maestrichtian according to the boundary definition of some authors) in the European succession. An allied species, *B. otsukai* (YABE) occurs, however, in the Santonian and subjacent part in Hokkaido. *B.* aff. *otsukai* has been recently recognized in the Santonian in California (MATSUMOTO, 1959 c). *B. woodsi* (KITCHIN) occurs in the Upper Turonian of England, while the closely allied *B. indicum* (KOSSMAT) comes from the Upper Trichinopoly group of India. A probably identical species is found in our zones of *Inoceramus teshioensis* (i.e. upper K4β) and *Inoceramus uwajimensis* (K5α).

(51) *Didymoceras* has proved to be a world-wide Campanian index. It is most abundant in the Campanian of the Western Interior province, being represented by a succession of several species in the Pierre shale as will be soon published by COBBAN and SCOTT. *Heteroceras hornbyense* WHITEAVES is in my opinion a representative of *Didymoceras* on the West Coast of North America, although it may be transitional between *Didymoceras* and *Nostoceras*. It is very closely allied to *Didymoceras awajiense* (YABE), which occurs in the Lower Hetonaian (K6α) in Southwest Japan and also in Northeast Japan (SAITO, 1958–59, with emendation).

Nostoceras (*s. s.*) is known in the probable Maestrichtian of the Gulf Coast of North America and Africa, but its typical representatives have not yet been confirmed to occur in Japan. Other specialized members of Nostoceratidae seem to have rather limited distribution. *Nostoceras* (*Anaklinoceras*) and *Axonoceras* are known in the Gulf Coast and west Africa, while *Nipponites* is particular to the Japanese province, except for a very doubtful form from Africa. In Japan and Saghalien *Nipponites mirabilis* YABE is not rare in upper K4β and K5α. There is another, new, peculiar ammonites, *Nipponites*-like form with quadrituberculate flares, in the subzone of *Reesidites minimus*, awaiting full description.

Neocrioceras spinigerum (JIMBO) is a probable derivative from *Hyphantoceras* of the *venustum* group and occurs in K5β of Hokkaido and Saghalien. As there are European and African representatives, a wider distribution of the genus may be expected.

(52) *Pseudoxybeloceras* is better ascribed to the family Nostoceratidae because of its close relationship with *Neocrioceras*. It occurs in Japan, California, New Zealand, and South Africa. It is long ranging in Japan, but is more common in the Campanian in various areas.

Oxybeloceras may be parallel to *Pseudoxybeloceras*. It occurs, according to COBBAN (personal information), in the Campanian of the Gulf Coast and the Western Interior provinces. In the Maestrichtian, i.e. the Navarro group and its equivalents, *Solenoceras*, with constrictions, takes the place of *Oxybeloceras*. The two genera are not confined to this part of the world. For instance, there are some examples of *Solenoceras* in California and Baja California (see MATSUMOTO, 1959 c). A probable example of *Oxybeloceras* has recently been obtained, though not fully described, by Mr. Keisaku TANAKA, from the Toyajo formation (K6α) in Southwest Japan.

(53) *Scalarites* is probably a derivative of *Hyphantoceras* and gives rise to several genera of Diplomoceratidae. It occurs in K4β (Turonian) and K5α (Coniacian) of Japan and Saghalien. In the Urakawan (K5$\alpha-\gamma$) of the same area *Polyptychoceras*, with subgenera *Polyptychoceras* (*s. s.*) and *Subptychoceras*, occurs in abundance. These genera are very rare, if not absent, on the West Coast of North America and other regions.

Pravitoceras is another endemic genus of Japan. Its type-species, *P. sigmoidale* YABE, which is presumably related to *Diplomoceras* as WRIGHT has suggested me, comes from K6α together with *Didymoceras awajiense* in Southwest Japan.

Ryugasella has proved to be more widespread. Its type-species, *R. ryugasensis* WRIGHT and MATSUMOTO occurs not only in the Campanian (K6α) of Hokkaido and Saghalien but also in the Campanian of California, Sucia Island and also (?) Graham Land.

Glyptoxoceras and *Diplomoceras* are world-wide in the Campanian and Maestrichtian, but their examples occur rather sparsely in the Japanese province.

(54) *Turrilites* (*s. s.*) of *costatum* group is world-wide but relatively long-ranged in the Cenomanian. In Hokkaido and Saghalien *T. costatus* LAMARCK, *T. acutus* PASSY [= *T. wiestii* SHARPE] and *T.* (*Euturrilites*) *scheuchzerianus* BOSC are occasionally found in the zone of *Desmoceras japonicum* (K4α), sometimes associated with *Calycoceras* of *asiaticum-newboldi* group and also with *Mantelliceras* spp.

(55) In the subzone of *Mantelliceras* spp. at Ikushumbets there is a form of *Ostlingoceras* which is somewhat intermediate between *O. puzosianum* (D'ORBIGNY) (of *dispar* zone) and *O. bechei* (SHARPE) (of Lower Cenomanian) in the early whorls and is closely allied to "*O. puzosiforme* SPATH" (of Lower Cenomanian) in the last whorl. In the same subzone and also subjacent part MURAMOTO and I found many specimens of *Hypoturrilites tuberculatus* (BOSC). The stratigraphic relationship of this species with an isolated holotype of *H. komotai* (YABE) is not clear. These specialized species could be regarded as indicating Lower Cenomanian but their precise dating in separated provinces await further research.

(56) Scaphitidae appear in the Albian and persist into the Maestrichtian. The occurrences of its numerous species are dissimilar among different provinces, although they often defines subzones or zonules in the respective areas. In Britain, for example, SPATH (1937) has reported a series of species from the bottom to the top of the Upper Albian, followed by Cenomanian *S. equalis* SOWERBY and *S. obliqus* SOWERBY. In the *planus* zone at the top of the Turonian *S. geinitzi* (D'ORBIGNY) is described as occurring fairly abundantly but the species appears in the *lata* zone and persists into the *cortestudinarium* zone. Furthermore, *S. binodus* RÖMER and

S. inflatus RÖMER occur in the *lingua* zone (Campanian) of Northwest Europe. *Hoploscaphites constrictus* (J. SOWERBY) is characteristic of the Maestrichtian in Europe. In the Western Interior of the United States COBBAN (1951) and COBBAN and REESIDE (1952) have tabulated a number of successive species belonging to *Scaphites, Pteroscaphites, Clioscaphites, Desmoscaphites, Acanthoscaphites, Discoscaphites* and *Hoploscaphites* from Turonian to Maestrichtian.

In South Saghalien, Hokkaido and Honshu *Scaphites* and *Otoscaphites* are fairly common in K4β and K5α, but their species do not seem to define zones so finely as in North America. Cenomanian representatives of *Scaphites* are rare, if not absent, in Japan. I agree with WRIGHT (1953) in regarding *S. planus* YABE as a representative of true *Scaphites* in the Japanese province, rejecting *Yezoites*. That species seems to be restricted in the Upper Gyliakian (K4β), while *S. pseudoaequalis* YABE and *S. yonekurai* YABE are not uncommon in both zones of *Inoceramus hobetsensis* (K4β) and *Inoceramus uwajimensis* (K5α). There is *S. formosus* YABE in K5β*. *Otoscaphites puerculus* (JIMBO), *O. perrini* (ANDERSON), and other related forms are found in the *uwajimensis* zone but extend down to the *hobetsensis* zone. The second species is known in the probable Turonian in California, while the type-species of *Otoscaphites* [*O. bladenensis* (SCHLÜTER)] came from the "Scaphitenpläner" (Turonian) in Germany. A form which is fairly similar to *Clioscaphites novimexicanus* (REESIDE) has recently been discovered in the *uwajimensis* and *mihoensis* zones. In spite of the almost universal abundance of members of the Scaphitidae in the Campanian and Maestrichtian, no species of *Scaphites, Discoscaphites* and *Hoploscaphites* have been found in our Hetonaian (K6$\alpha+\beta$). The absence of *Hoploscaphites constrictus, Discoscaphites conradi,* or their allies and also that of *Sphenodiscus* species in the Japanese province unfortunately give some ambiguity in identifying the Maestrichtian in the rock succession. The same statement can be applied to the West Coast of North America. In that region species of *Scaphites* and *Otoscaphites,* which are closely allied to and sometimes identical with the Japanese ones, occur in the Turonian and probably also in the Coniacian.

Several species of Scaphitids have been described from the Ootatoor and Trichinopoly groups of India, but they await further taxonomic sorting and geological dating. *Indoscaphites cunliffei* (FORBES) occurs in the Valudayur beds.

To sum up, as has been pointed out by COBBAN, provincial developments of the family in the independent areas are apparent especially from Turonian onwards, although migration may have taken place at certain epochs. Therefore the reliability of the species of Scaphitidae for world-wide correlation is still doubtful and further comparative studies among separated provinces are needed.

(57) COBBAN (1951, 1958 a, b) has recently presented an admirably fine scheme of

* The age of *S. formosus* YABE and other Japanese species was erroneously written as Cenomanian in REESIDE's list (1927).

zones in the Upper Cretaceous of the Western Interior province. The zonal indices in the upper half of the sequence are mostly species of *Baculites.* How far the zones or subzones defined by COBBAN can be extended beyond the Western Interior province is not necessarily known. For the evaluation of species of Baculitidae for zonal correlation of universal scale more studies on various regions are needed.

I have attempted to sort a large number of specimens of Baculitidae from California and adjacent areas. The result (MATSUMOTO, 1959 b) is rather promising for the zonation of the Upper Cretaceous in this region and also for the world-wide correlation.

In the Cretaceous of Japan there is a considerable number of baculitid species, which are now being studied by OBATA and MATSUMOTO. Our preliminary result is again promising. Most of the species from Japan and California are Indo-Pacific, some are cosmopolitan, and only a few are endemic according to the present knowledge. The examples of the cosmopolites are *Sciponoceras bohemicum* (FRITSCH) in the Upper Turonian and *Baculites anceps* (LAMARCK) near the boundary of Campanian and Maestrichtian. As I have discussed (MATSUMOTO, 1959 b), there is a possibility of the subspecific difference between the representatives of the Northern Pacific region and Western Europe. This does not, however, necessarily mean geographic subspecies but more probably implies a slight difference in geological age. The examples of the Indo-Pacific elements are *Sciponoceras kossmati* (NOWAK) in the Lower Turonian, *Baculites yokoyamai* TOKUNAGA and SHIMIZU [= ? *B. besairiei* COLLIGNON], *B. boulei* COLLIGNON and *B. capensis* WOODS in the Lower Senonian, *B. bailyi* WOODS in the Santonian, and *Eubaculites ootacodensis* (STOLICZKA) in the Lower Maestrichtian. The last species, however, has not yet been discovered in Japan. *Baculites chicoensis* TRASK seems to be particular to the Lower (to Middle?) Campanian of California, while another peculiar species, which is probably new, occurs in the zone of *Inoceramus schmidti* [K6α], middle to upper part of the Campanian, in Japan. *Baculites occidentalis* MEEK, which is transitional to *Eubaculites,* occurs in the Nanaimo group of British Columbia, the Upper Campanian of California and Baja California, and also in K6α of Japan.

(58) While *Hypophylloceras* occurs in the Lower Cretaceous, *Neophylloceras* is common in the Upper Cretaceous. It is not certain whether this replacement took place simultaneously or at different times in various parts of the world. A world-wide species, *Neophylloceras seresitense* (PERVINQUIÈRE), which can be regarded as intermediate between the two genera, occurs in both the Upper Albian and the Cenomanian.

Because of faintly manifested specific characters of the phylloceratids it is often difficult to determine identity or distinctness of the forms which have various names in different countries. One of the examples is the relationship between *N. ramosum* (MEEK) and *N. compressum* MATSUMOTO. The two nominal species have now proved to be identical (see MATSUMOTO, 1959 c). At the same time it becomes evident that *N. ramosum* (MEEK) emend. is long-ranging, from Turonian to Upper Campanian, on both sides of the Pacific Ocean. Similarly the distinctness or identity of *Phyllopachyceras forbesianum* (D'ORBIGNY) and *P. ezoense* (YOKOYAMA) should be carefully studied. The extensive distribution of *Neophylloceras hetonaiense* MATSUMOTO in the Campanian and Maestrichtian (K5γ—K6β) has been suggested by its occurrence, outside Japan, in Graham Land and in the Moreno shale of California. Its relationship with certain African or Madagascar species should be examined too.

Although the species of the phylloceratids may be widespread, many of them are persistent. Therefore, without knowing the associated species, we cannot tell a definite geological age. There may be exceptions in a special case. For instance, so far as I know, a tuberculate variety of *Neophylloceras hetonaiense* occurs in the highest ammonite-bearing beds, probably Maestrichtian, of the successions in both Japan and California.

"*Phylloceras*" *japonicum* MATSUMOTO seems to be referred to *Partschiceras* (see MATSUMOTO, 1959 a). It occurs in the Cenomanian of Hokkaido and Alaska, while the genus *Partschiceras* has been known in the Jurassic and the Neocomian. Therefore it may represent a relict in the Northern Pacific region.

Succession of the species of Inocerami.—Generally speaking fossils of Inocerami* occur very commonly in the Cretaceous of various parts of the world. There is, however, much to be done as to their taxonomy and dating. In a few areas, e.g. England and Germany, they are relatively well classified and their succession has been considerably clarified. In Japan and adjacent areas they occur in abundance in the Upper Cretaceous and have been monographed by NAGAO and MATSUMOTO (1939–40). The classification presented in that monograph is essentially applicable at present, although some supplemental work is needed. In addition to the monograph there has been much advance in the knowledge of the stratigraphic succession of our Inocerami. Thus we have established a scheme of zones defined by species of *Inoceramus*, as tabulated above, and can precisely correlate strata throughout the Japanese Islands by means of the zones of Inocerami. It is, however, fairly difficult to determine, without seeing specimens, the identity and affinity of foreign species, and accordingly, to reach reasonable conclusions on international correlation. Fortunately I had an opportunity of studying specimens at the British Museum (Natural History), the Sedgwick Museum in England, and many institutions in the United States so that I can give some remarks on the Japanese forms in comparison with the European and American ones. As to the species of other areas I can say little at

* This might be ranked as a family and could be classified into a number of genera as HEINTZ has proposed. In this paper the comprehensive name *Inoceramus* is used for the time being and I refer to species-groups instead of questionable "genera".

present, but a glance at the New Zealand specimens, which Dr. WELLMAN exhibited at the Cretaceous Symposium in Mexico, has impressed me the fact of intimate alliance between the species of Northern and Southern Pacific.

(59) *Inoceramus concentricus* PARKINSON is characteristic of Albian in Europe and other areas. In our province *I. concentricus nipponicus* NAGAO and MATSUMOTO is very common in the Lower Gyliakian (K4α) together with *Calycoceras* of *newboldi* group and *Desmoceras* (*Pseudouhligella*) *japonicum*. The subspecific separation is justified from both morphological and geological grounds. The evidently delayed occurrence in Japan as compared with Europe may suggest provincial development.

(60) *Inoceramus tenuistriatus* NAGAO and MATSUMOTO from K4β (Turonian) is somewhat allied to *I. tenuis* MANTELL and more closely so to *I. etheridgei* WOODS from the Lower Chalk. The morphological difference is so slight that subspecific separation might be preferable, but *I. tenuistriatus* is evidently smaller than the European species and has slightly elevated concentric rings. Again the delayed occurrence in the Japanese province is evident.

(61) *Inoceramus teshioensis* NAGAO and MATSUMOTO (K4β) is a probable descendant from *I. tenuistriatus* and is relatively common in the upper part of K4β. I have recognized a remarkable resemblance between certain specimens of our *I. teshioensis* from our province, *I. costellatus* WOODS, from the Chalk Rock (Upper Turonian) of England, and *I. perplexus* WHITFIELD, from the zone of *Prionocyclus wyomingensis* in the Western Interior of the United States, so that specific identity might be suggested. Anyhow the three forms are harmonious in geological occurrence.

(62) As has already been remarked by NAGAO and MATSUMOTO (1939), *Inoceramus hobetsensis* and *I. iburiensis* of Upper Gyliakian (K4β) are evidently similar to *I. lamarcki* PARKINSON and its allies. In the Japanese material there is a passage form from *I. concentricus costatus* to *I. hobetsensis nonsulcatus*. From this and the corresponding facts found in the European material, it seems to me better to regard the *lamarcki* group as a derivative from the *concentricus* group rather than from the *anglicus-crippsi* series. The developments may have been provincial and parallel between Japan and Europe, so that some disharmony may be found as to the geological ranges of the species concerned. Nevertheless it should be noted that a certain form which is illustrated under the name of *I. lamarcki* (or *I. cuvieri* or *I. brongniarti*) and common in the Middle Turonian of England, France and Germany is very similar to, but distinguishable from, our *I. hobetsensis*.

I have recognized several specimens from Alaska and California which are comparable with *Inoceramus hobetsensis*, and furthermore a closely resembling species from the Middle Turonian zone of *Collignoniceras woollgari*-*Inoceramus fragilis* in the Western Interior. Incidentally *I. fragilis* HALL and MEEK is indistinguishable from an immature *I. cuvieri* SOWERBY.

In North America there is no true representative of *I. lamarcki* PARKINSON which can be exactly identified with the types in Europe. *I. flaccidus* WHITE, from the zone of *Collignoniceras hyatti* in the Western Interior province, is evidently a member of the group of *I. lamarcki*. *I. iburiensis* NAGAO and MATSUMOTO, from middle to upper K4β of the Japanese province, is very similar to *I. flaccidus*.

(63) *Inoceramus labiatus* (SCHLOTHEIM) is a world-wide zonal index of the Lower Turonian. It is, however, very rare in Japan. I have recently obtained its probable examples from a bed with *Kanabiceras septemseriatum* and *Sciponoceras kossmati* in the Ikushumbets Valley, Hokkaido. The same species occurs fairly commonly in California. It is associated with *K. septemseriatum* at one of the Californian localities.

Inoceramus incertus JIMBO from our Upper Gyliakian (K4β) (rather common in its upper part) is somewhat related to *I. labiatus* but much more akin to *I. latus* SOWERBY. Upon examining British specimens I am inclined to consider *I. crippsi* MANTELL (*s. s.*) → *I. crippsi reachensis* ETHERIDGE → *I. latus* as a reasonable and natural series, admitting the long range of *I. latus* from Lower to Upper Turonian. In my opinion *I. labiatus* is a somewhat specialized offshoot from this lineage.

(64) *Inoceramus uwajimensis* YEHARA is a widespread index of the Lower Urakawan (K5α) throughout the Japanese Islands. It is furthermore found in Alaska and California. It is very similar to *I. kleini* MÜLLER from the Emscherian of Germany and also to *I. stantoni* SOKOLOW [= *I. acuteplicatus* STANTON] from the Coniacian of the Western Interior province. In my opinion these species are probably derived from *I. teshioensis-costellatus-perplexus*. Dr. COBBAN showed me an interesting form which has radial riblets in addition to the normal form of *I. stantoni* and came from the upper part of the Coniacian together with *Protexanites* sp. and *Scaphites binneyi*. As NAGAO and MATSUMOTO (1939, p. 289) have already described, faint divergent ribs are developed in certain Japanese specimens which otherwise are indistinguishable from normal form of *I. uwajimensis*. *Inoceramus gürichi* HEINTZ, from the Lower Senonian of Germany, has more distinct and numerous, radial riblets.

(65) *Inoceramus mihoensis* MATSUMOTO forms a subzone between the prolific part of the zone of *I. uwajimensis* and the zone of *I. amakusensis*, as can be observed in the succession of the Naibuchi Valley in South Saghalien and that of the Ikushumbets Valley in Hokkaido. The subzone can be conventionally included in the upper part of the Lower Urakawan (K5α), but TANAKA (1958) has shown that in the succession of the Opirashibets River *I. mihoensis* persists into the zone of *I. amakusensis*, Upper Urakawan (K5β).

I. mihoensis itself is, as I (1957) have recently discussed, evidently related to a certain form of *I. inconstans* WOODS. That European species may be too broadly defined and too long-ranging for accurate comparison with others, but some of its syntypes are very closely allied to *I. deformis* MEEK, from the Coniacian of the Western Interior and Gulf Coastal provinces.

(66) *Inoceramus mukawaensis* NAGAO and MATSUMOTO, that occurs sporadically in the subzone of *I. mihoensis* and superjacent part, is very similar to, or possibly identical with, *I. cordiformis* SOWERBY, a Lower to Middle Santonian species. I have recently recognized unmistakable examples of *I. cordiformis* in the collection of Dr. POPENOE from the lower part of Member V, probably Lower Santonian, of the Redding area, California. An allied form is in the collection of Dr. COBBAN from his zone of *Clioscaphites vermiformis*, Lower Santonian, in the Western Interior province. *I. gilberti* WHITE is another allied species but comes from the uppermost Turonian to the Lower Coniacian of the Western Interior.

(67) *Inoceramus amakusensis* NAGAO and MATSUMOTO, an index of Upper Urakawan (K5β) proper, is probably developed from *I. mihoensis*. It is fairly similar but probably parallel to the "flat variety" of *I. inconstans* in the Santonian. The latter apparently resembles *I. ezoensis* YOKOYAMA, another Upper Urakawan (K5$\beta+\gamma$) species. Outside Europe *I. expansus* BAILY from the probable Santonian of South Africa (where *Texanites* occurs) is an ally of this group. On examining the original specimens of that African species at the British Museum (Nat. Hist.), I noticed that *I. expansus* is almost indistinguishable from *I. ezoensis*. BAILY mentioned the similarity of *I. expansus* to *I. latus*, while NAGAO and MATSUMOTO remarked the intimate relation between *I. ezoensis* and *I. incertus*. Taking into consideration the close affinity (or possible identity) of *I. incertus* and *I. latus* (see 63), *I. ezoensis* is possibly identical with *I. expansus*.

(68) Another case of possible identity is the close resemblance between *I. japonicus* NAGAO and MATSUMOTO from our Upper Urakawan and the world-wide *I. undulatoplicatus* RÖMER. STEPHENSON (1950) has already pointed out the fact from his direct comparison of Japanese and American specimens. I myself have compared our form with the British and Texas ones. Moreover I have found at the Sedgwick Museum a plaster cast of a large specimen from the Umzamba River mouth, South Africa, which is again indistinguishable from our large form of *I. japonicus*. In my opinion *I. japonicus* is derived from, or has a common ancestor with, *I. ezoensis*. Similarly that African form must have intimate relation with *I. expansus*. Anyhow this sort of characteristic form is a world-wide index of the Santonian. While *I. undulatoplicatus* is considered to characterize the Lower Santonian (? plus Upper Coniacian) in Europe and America, *I. japonicus* is rather abundant in the upper part of K5β.

(69) *Inoceramus balticus* BÖHM is widespread in the Upper Senonian. It is regarded as a descendant from *I. inconstans*. In spite of the absence of typical *I. inconstans* in Japan, *I. balticus* is found in the Lower Hetonaian equivalent (K6α) of Southwest

Japan. *I. subundatus* MEEK from the Campanian on the West Coast of North America is very similar to or possibly identical with *I. balticus.*

(70) *Inoceramus naumanni* YOKOYAMA and its variously ornamented descendants, *I. orientalis* SOKOLOW, *I. schmidti* MICHAEL, *I. sachalinensis* SOKOLOW and *I. pseudosulcatus* NAGAO and MATSUMOTO, are characteristic of the Japanese province and adjacent areas. Identical or allied forms are found in other parts around the North Pacific, such as Alaska, British Columbia and California, but no correspondants have been described in Europe and other well known areas. The similarity to *I. lobatus* GOLDFUSS and its derivatives is only superficial and cannot necessarily mean contemporaneity. The resemblance of the ornament between *I. schmidti* and *I. undulatoplicatus* (or *I. japonicus*) is again entirely homoeomorphic. Geologically *I. schmidti* (an index of K6α) is evidently later than *I. japonicus* (an index of K5β).

(71) *Inoceramus shikotanensis* NAGAO and MATSUMOTO is characteristic of the lower part of K6β. It may be a specialized derivative from *I. balticus. I. pacificus* ANDERSON and HANNA, 1935 (*non* WOODS, 1917), from the Rosario formation of Baja California, is probably identical with *I. shikotanensis.* I have recognized in Dr. COBBAN's collection from his zone of *Baculites baculus*, Lower Maestrichtian, of the Western Interior province, a species of *Inoceramus* which is remarkably similar to our *I. shikotanensis.*

(72) As to other species in K6β, such as *I. kusiroensis* NAGAO and MATSUMOTO, *I. hetonaianus* MATSUMOTO and *I.* (?) *awajiensis* MATSUMOTO, I do not know any European allies. The last two species occur in the upper part of the Upper Hetonaian in both Hokkaido and Southwest Japan. It cannot be overlooked that *I.* (?) *awajiensis* is somewhat similar to *I.* (?) *fibrosus* (MEEK and HAYDEN) from the Maestrichtian Fox Hills sandstone of the Western Interior province.

(73) The systematic position of *Inoceramus* (*Sergipia*?) *akamatsui* YEHARA is still doubtful. Its resemblance to *Sergipia posidomyaformis* MAURY from the Maestrichtian of Brazil is rather curious. Our species is very common in the zone of *Inoceramus teshioensis* and *I. uwajimensis.* A related form has been reported (BÖSE, 1923) from presumed Coniacian or Upper Turonian of Mexico.

Concluding Remarks.—As a conclusion from the above considerations [(1)—(73)] the following approximate correlation can be made between the Japanese and international scales.

Japanese scale	International scale
Upper Miyakoan [K3β]	Albian
Infragyliakian [K3γ]	Lower Lower Cenomanian
Lower Gyliakian [K4α]	Cenomanian (main part)
Upper Gyliakian [K4β]	Turonian

Lower Urakawan [K5α]	Coniacian
Upper Urakawan [K5β]	Santonian
Infrahetonaian [K5γ]	Lower Campanian
Lower Hetonaian [K6α]	Middle to Upper Campanian
Upper Hetonaian [K6β]	Maestrichtian

Recent acquisitions have enabled us to correlate more precisely than on previous occasions (e.g. MATSUMOTO, 1943; 1954) the Japanese scale with the international one. Yet the exact dating of the boundary of adjoining units in the Japanese province in terms of the international scale is in some cases still difficult. For example, the very point of the Albian-Cenomanian boundary is often hardly fixed in the Japanese succession, although the zone of *Desmoceras kossmati* includes, if it is not wholly referable to, the Lower Lower Cenomanian [(1), (2), (3), (20), (54), (55)].

The subzone of ***Kanabiceras septemseriatum***, the lowest part of our K4β, is probably assigned to the basal Turonian [(8), (57), (63)], but we are not successful in obtaining good indices of the uppermost Cenomanian [(7)]. Similarly the subzone of ***Reesidites minimus***, the highest part of our K4β, is probably, but not conclusively, referred to the uppermost Turonian [(12), (13), (14), (57), (61), (64)].

The subzone of ***Inoceramus mihoensis*** in the higher part of K5α is only provisionally, but not with certainty, assigned to the Upper Coniacian; it may possibly represent the Lower Santonian as well [(56), (65), (66), (67)]. The position of the Santonian-Campanian boundary in our sequence is again provisionally placed at the boundary of K5β and K5γ [(16), (17), (18), (24), (26), (36), (38), (39), (40), (41), (48), (51), (57), (58), (68), (69), (70)]. Similarly that of the Campanian-Maestrichtian boundary is only approximately determined at the boundary of K6α and K6β [(18), (24), (25), (27), (33), (36), (42), (43), (45), (46), (47), (48), (50), (51), (52), (53), (56), (57), (58), (71), (72)].

The upper limit of the Maestrichtian in our Cretaceous has not been clearly determined, because no reliable fossils have been found in the uppermost K6β. There is always an unconformity between the Cretaceous and Tertiary formations, although its time interval may vary by places.

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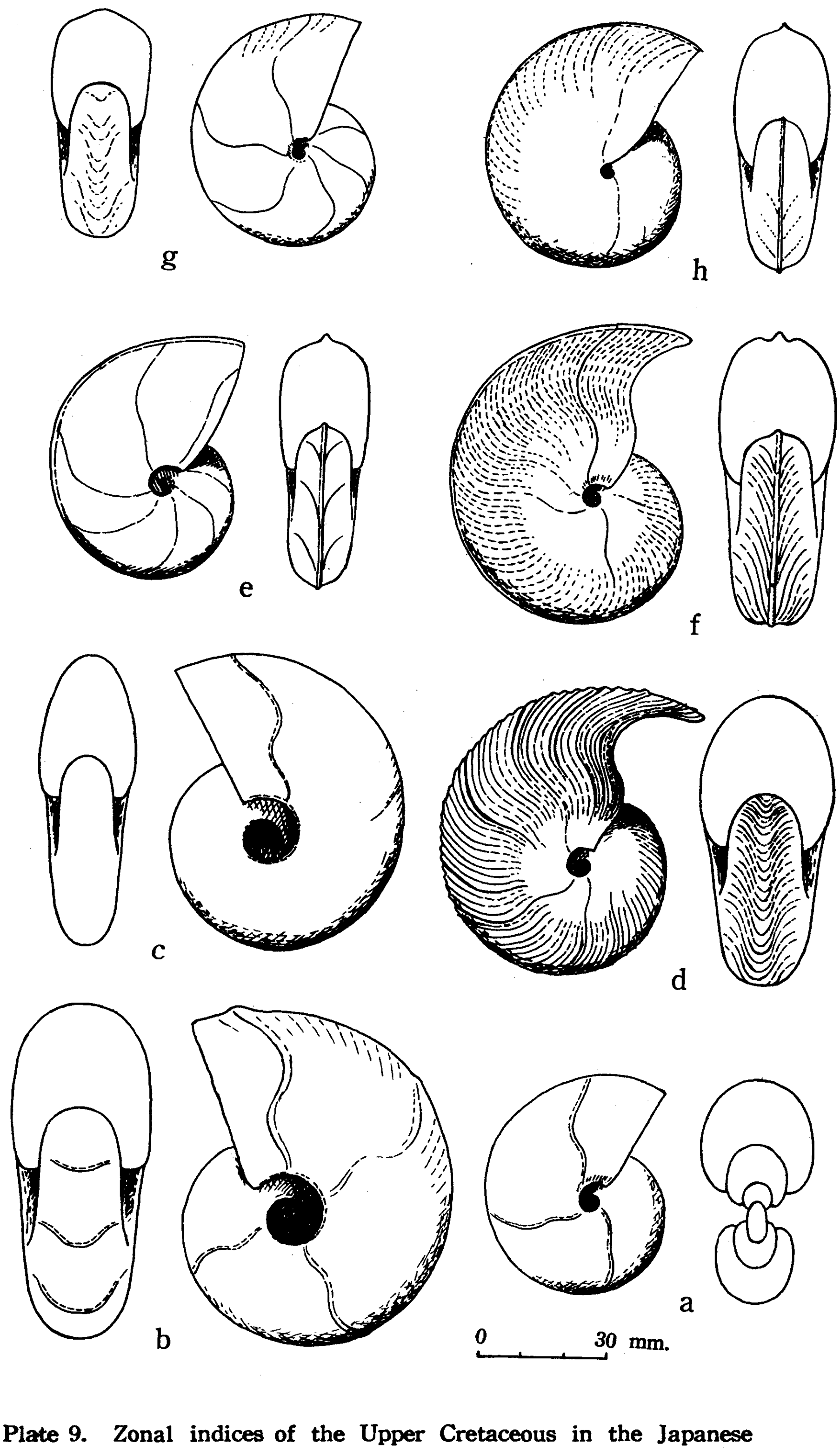

Plate 9. Zonal indices of the Upper Cretaceous in the Japanese province: Desmoceratidae.

a. *Desmoceras kossmati* MATSUMOTO, Infragyliakian (K3γ); b. *Desmoceras* (*Pseudouhligella*) *japonicum* YABE, Lower Gyliakian (K4α); c. *D.* (*P.*) *ezoanum* MATSUMOTO, K4α: d. *Tragodesmoceroides subcostatus* MATSUMOTO, Upper Gyliakian (K4β); e. *Damesites sugata* (FORBES), Urakawan (K5α+K5β+K5γ); f. *Damesites damesi* (JIMBO), (K5α+K5β+K5γ); g. *Desmophyllites diphylloides* (FORBES), Infrahetonaian-Lower Hetonaian (K5γ+K6α); *Damesites hetonaiensis* MATSUMOTO, Upper Hetonaian (K6β).

The figures in Plates 9-11 are drawn from the synthetic observation of several specimens, including the holotype, lectotype or syntypes. T. MATSUMOTO *del.*

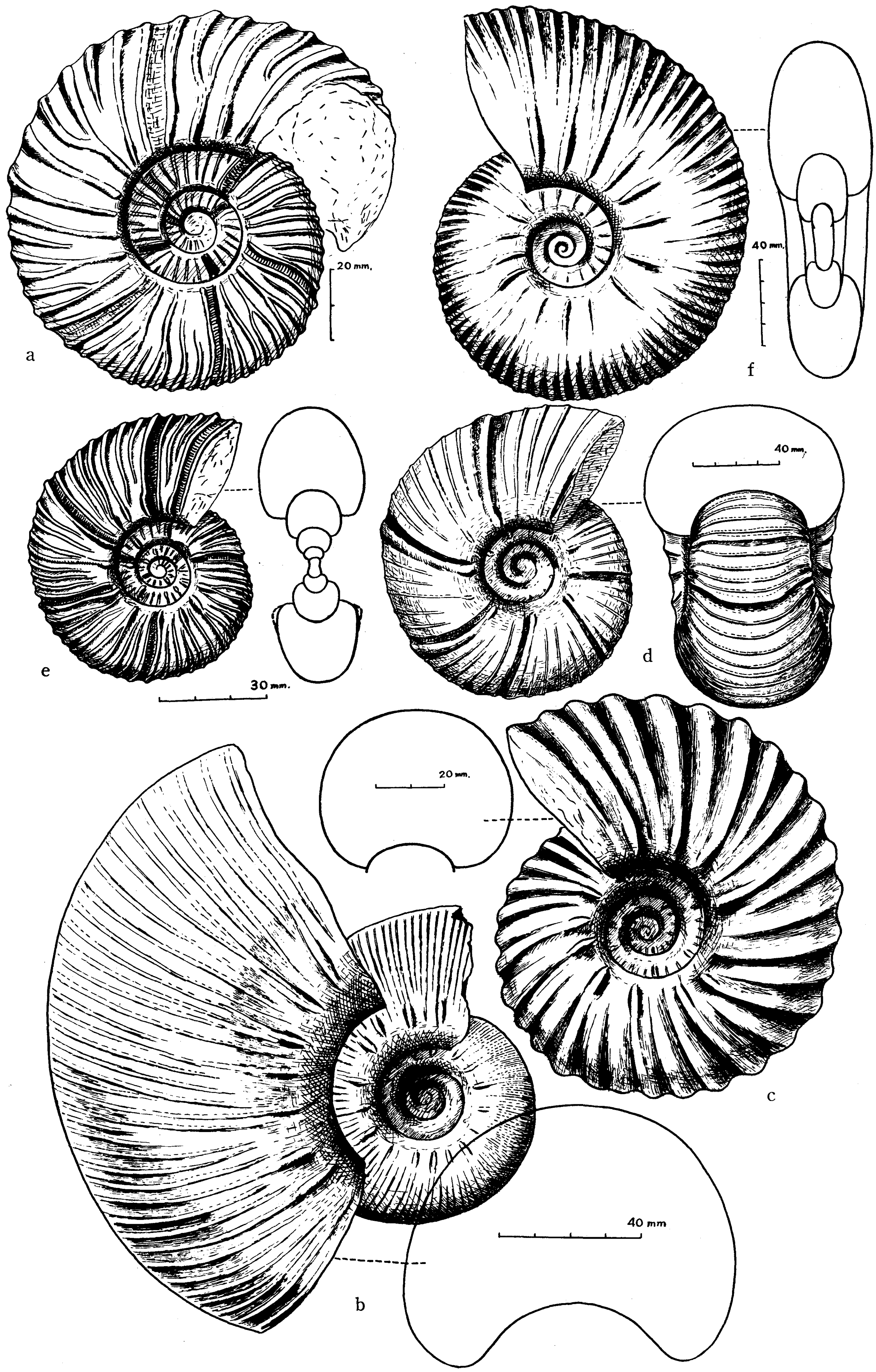

Plate 10. Zonal indices of the Upper Cretaceous in the Japanese province: Pachydiscidae and Kossmaticeratidae.

a. *Kossmaticeras theobaldianum paucicostatum* MATSUMOTO, Lower Urakawan (K5α): b. *Anapachydiscus fascicostatus* (YABE), Upper Urakawan (K5β+K5γ); c. *Eupachydiscus haradai* (JIMBO), Upper Urakawan (late K5β+K5γ); d. *Anapachydiscus* (*Neopachydiscus*) *naumanni* (YOKOYAMA), Uppermost Urakawan or Infrahetonaian (K5γ); e. *Canadoceras kossmati* (YABE MS.) MATSUMOTO, Lower Hetonaian (K6α); f. *Pachydiscus subcompressum* MATSUMOTO, Upper Lower Hetonaian-Upper Hetonaian (late K6α+K6β).

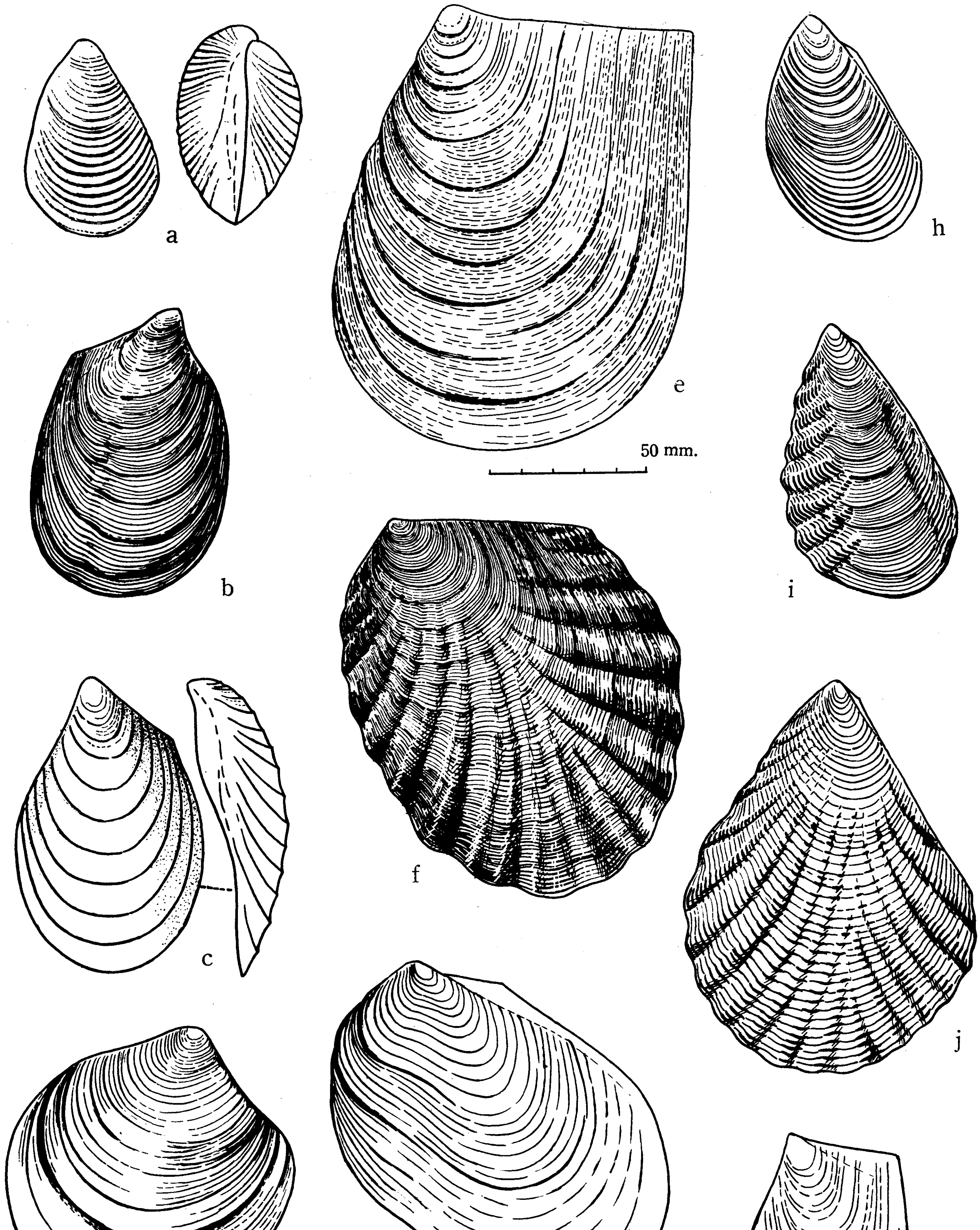

Plate 11. Zonal indices of the Upper Cretaceous in the Japanese province: Inocerami.
a. ***Inoceramus concentricus nipponicus*** **Nagao and Matsumoto, Lower Gyliakian (K4α); b. *I. hobetsensis* Nagao and Matsumoto, Upper Gyliakian (K4β); c. *I uwajimensis* Yehara, Lower Urakawan (K5α); d. *I. mihoensis* Matsumoto, transitional part from Lower to Upper Urakawan (K5$\alpha-\beta$); e. *I amakusensis* Nagao and Matsumoto, Upper Urakawan (K5β); common in its lower part; f. *I. japonicus* Nagao and Matsumoto, Upper Urakawan (K5β); g. *I. shikotanensis* Nagao and Matsumoto, Lower Upper Hetonaian (early K6β); h. *I. naumanni* Yokoyama, Urakawan (K5α+K5β+K5γ); i. *I. orientalis* Sokolow, mainly Uppermost Urakawan and partly Lower Hetonaian (K5γ+K6α); j. *I. schmidti* Michael, Lower Hetonaian (K6α); k. *I. hetonaianus* Matsumoto, Upper Upper Hetonaian (late K6β).**