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Cenomanian and Turonian Biostratigraphy of the Off-shore Facies of the Northern Pacific —An Example of the Oyubari Area, Central Hokkaido, Japan—†

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The Cenomanian and the Turonian faunas of the Oyubari area were described as a representative of the off-shore facies which compose the greater part of the Cretaceous System in Hokkaido, the northern main island of Japan.

A three-fold subdivision of the Cenomanian by inoceramid bivalves including East Siberian species, and a four-fold subdivision of the Turonian also by inoceramid species were described from the faunal point of view, with special attention to the boundary of these two stages.

In the Cenomanian stage, *Inoceramus concentricus nipponicus, I. concentricus costatus* and *I. corpulentus,* in ascending order, were recognised as zonal indices of the three subdivisions. The Turonian begins with the appearance of *Inoceramus labiatus, I.* aff. *saxonicus* and *Tragodesmoceroides subcostatus.* The lower part of the zone of *I. labiatus* is characterized by some species of *Mammites, Pseudaspidoceras, Kamerunoceras, Vascoceras* and *Fagesia*, which are of importance for the interregional correlation.

Key Words: Japan, Hokkaido, Oyubari, Off-shore facies, Black shale, *Inoceramus, Tragodesmoceroides, Mammites, Pseudaspidoceras, Vascoceras, Fagesia.*

1. Introduction

In Japan, the Cretaceous System has the largest area of distribution of the three Mesozoic systems. Its distribution, fauna and flora were described in detail by many authors (*e.g.*, MATSUMOTO, 1978)[1]. Among various areas of the marine Cretaceous of Japan, that of Hokkaido, the northern main island, yields numerous molluscan fossils in calcareous nodules, where shells are beautifully preserved,-even aragonitic shells are commonly preserved-, and shells are not deformed except parts of a body chamber.

The marine Cretaceous System of Hokkaido was deposited under the condition of so-called Arc-trench system, as explained by OKADA (1982)[2], and therefore the structure is very complicated in many places. Inter-areal correlation, however, is much advanced by industrial exploration of coal measures, and by studies of structural geology, palaeocurrent and key marker beds like dominant tuffs. The Cretaceous deposits in the central Hokkaido compose shallow-waters facies to the west, and off-shore facies to the east (*e.g.*, OBATA & FUTAKAMI, 1977[3]; HIRANO, 1982[4]). The Ikushumbetsu area which represents shallow facies has been intensively studied by MATSUMOTO (*e.g.*, 1965)[5]. Most of the Cretaceous system in the central Hokkaido, however, is off-shore sediments and therefore the Cretaceous of the Oyubari area (Fig. 1) is introduced as an example of the off-shore sediments. Furthermore, the occurrence of the five East Siberian species of Cenoma-

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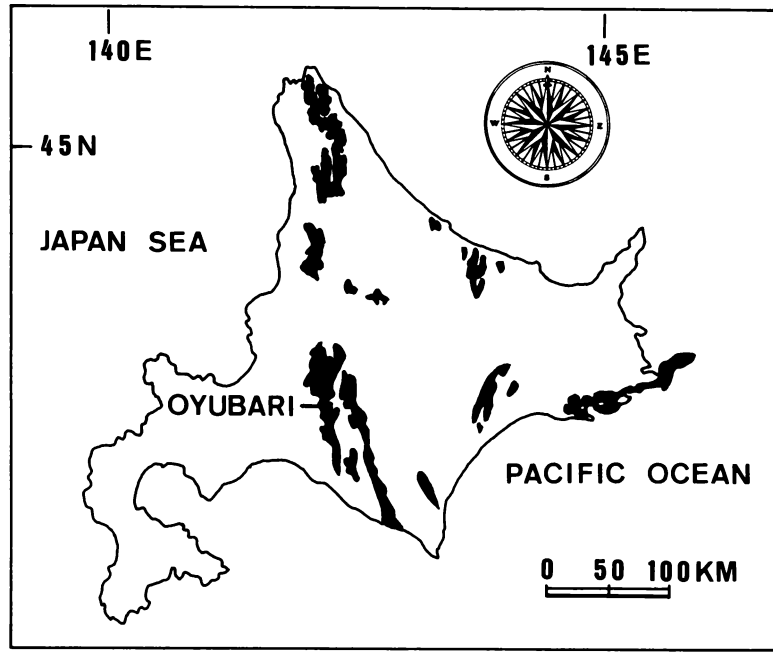

Fig. 1 Map showing the distribution of the Cretaceous sediments and the studied Oyubari area, Hokkaido.

nian *Inoceramus* in the Oyubari area is elucidated in this time. There are several ammonoid species common with Californian ones. Thus, this area can compete as one representative of the Upper Cretaceous of the Northwest Pacific.

In the Oyubari area, the Cretaceous is composed of flysch and off-shore black shale which range from the Albian to Santonian and deltaic sediments which range from the Campanian to Masstrichtian.

In this paper, the biostratigraphy of the Cenomanian and Turonian, of which exposures are best dissected by some valleys, is described with special reference to the boundary between these two stages.

Lithostratigraphy of the area was described in other papers (HIRANO *et al.*, 1977[6], 1980[7], 1981[8]; HIRANO, 1982[4]) and will be described in more detail in another paper. Here I introduce only a preliminary geological map and alphanumerical symbols of the twelve formations which range from the M1 to M5 and from the S1 to S4 of the Middle Yezo Group and from the U1 to U3 of the Upper Yezo Group. The macrofossils are mostly ammonoidea and inoceramid bivalves, and other groups are very rare, being omitted here.

2. Biostratigraphy of the Cenomanian

Eight surface sections were obtained along eight valleys in this area, which covers 15 km from north to south and 8 km from east to west. Unequivocal correlation of these eight sections can be established by means of remarkable tuff beds. Therefore I show range charts of ammonoid and inoceramid species against a composite section of this area (Figs. 6-9), with only one example of the surface section of the Hakkinzawa valley (Figs. 2-5) at first.

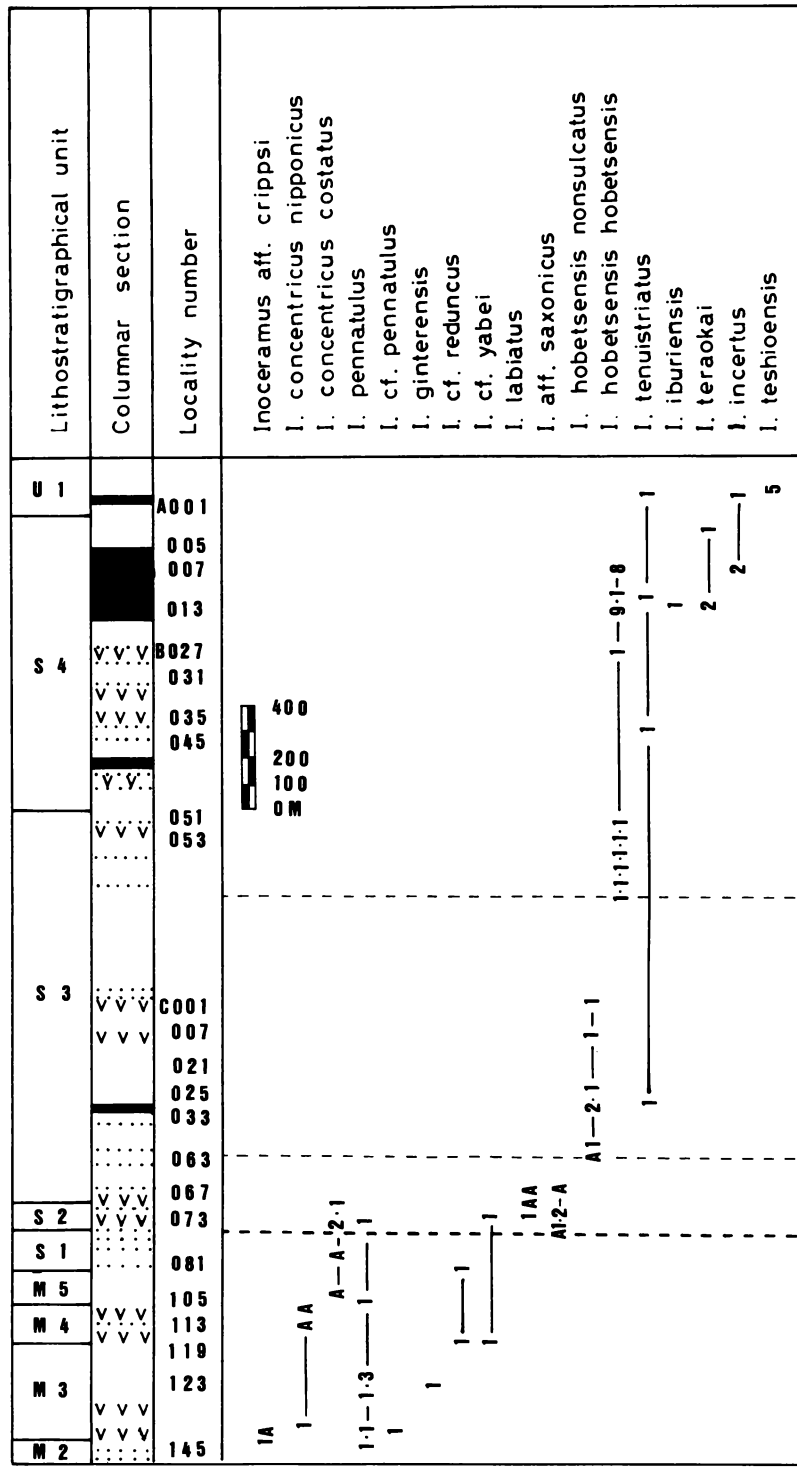

Fig. 2 Columnar section showing the lithology and the occurrence of inoceramid species obtained along the Hakkinzawa valley, in the central part of the Oyubari area. For the columnar section, black parts indicate a rhythmic alternation of sandstone and shale, dots indicate sandstone beds, v-marks indicate tuff beds and white parts indicate black shale. For the range chart, numbers indicate the number of specimens, (A) indicates that the occurrence was described by HIRANO *et al.* (1977), and (B) indicates that the occurrence was once described by MATSUMOTO or MATSUMOTO and his collegues.

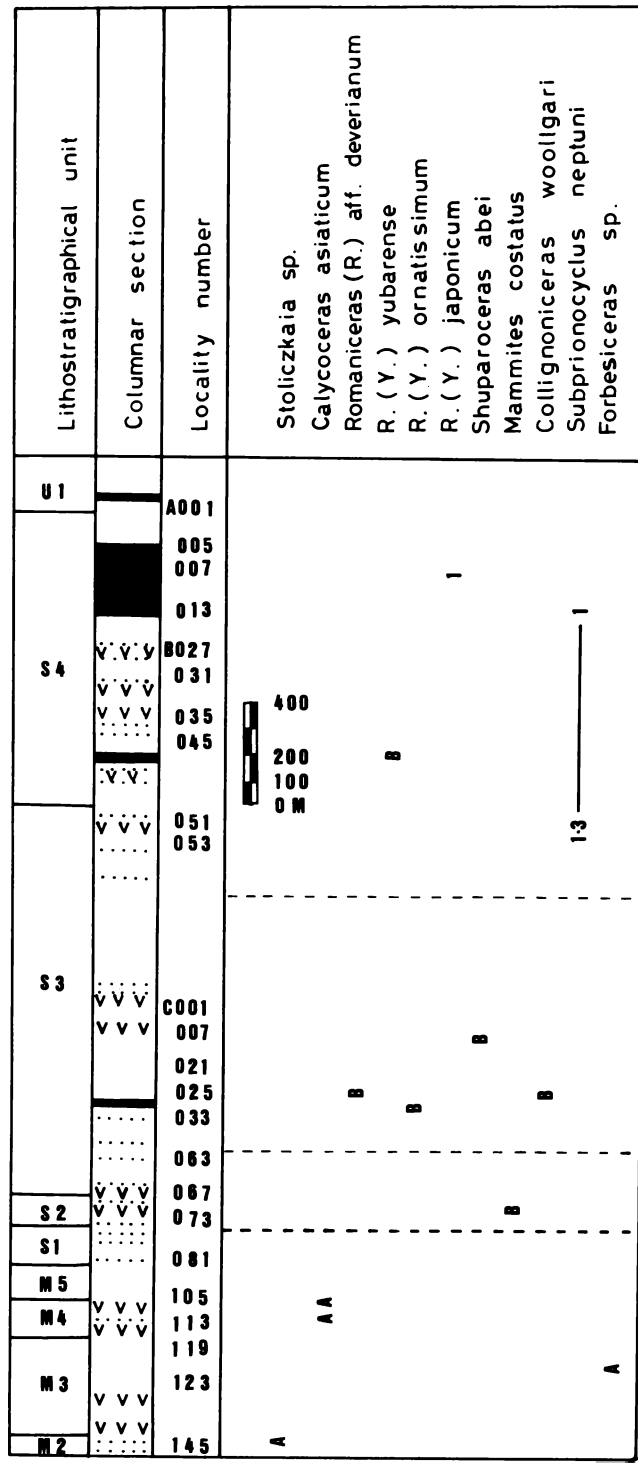

Fig. 3 Columnar section showing the lithology and the occurrence of Acanthoceratacean ammonites obtained along the Hakkinzawa valley, in the central part of the Oyubari area. Symbols are the same as in Fig. 2.

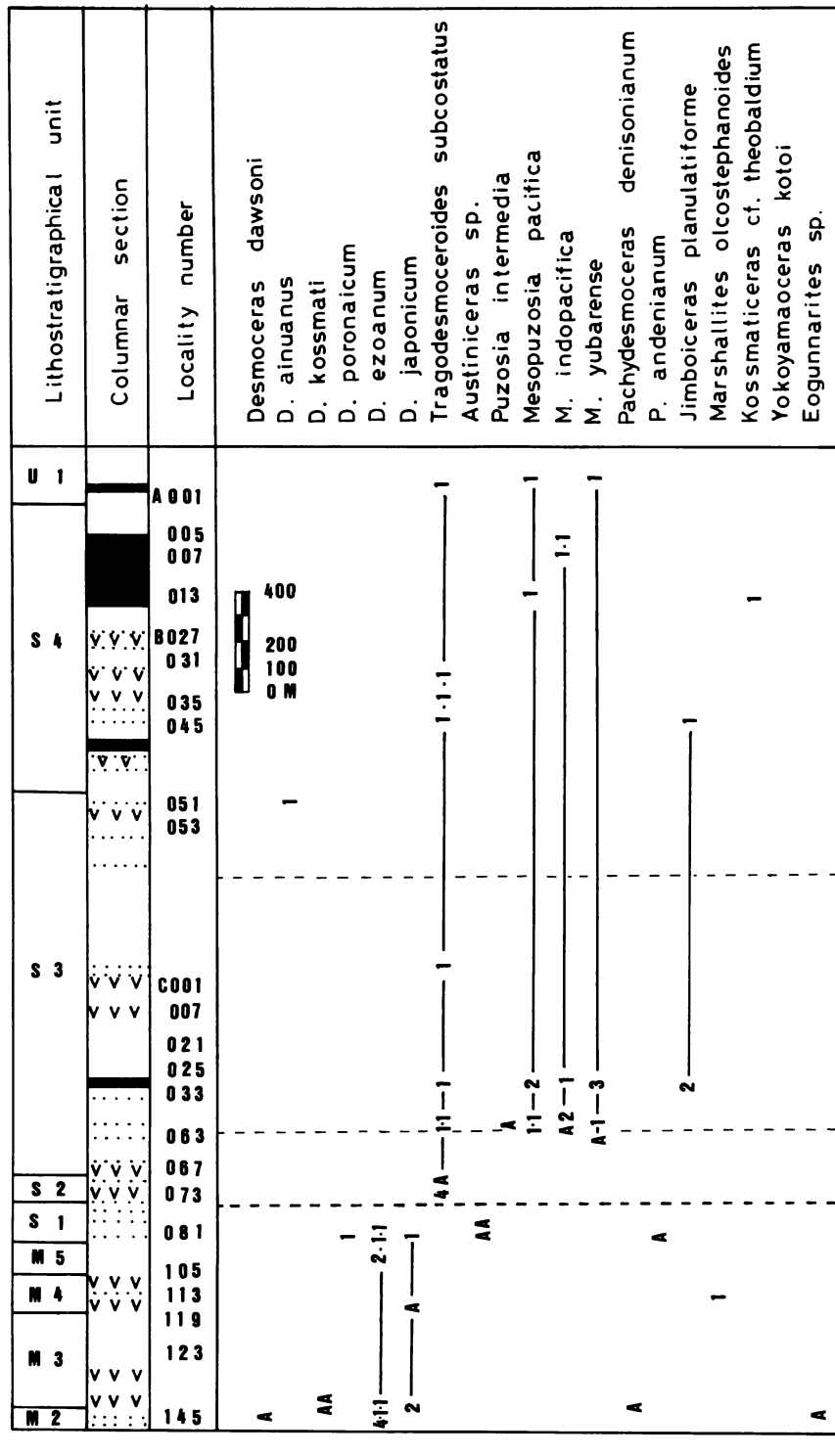

Fig. 4 Columnar section showing the lithology and the occurrence of Desmoceratacean ammonites obtained along the Hakkinzawa valley, in the central part of the Oyubari area. Symbols are the same as in Fig. 2.

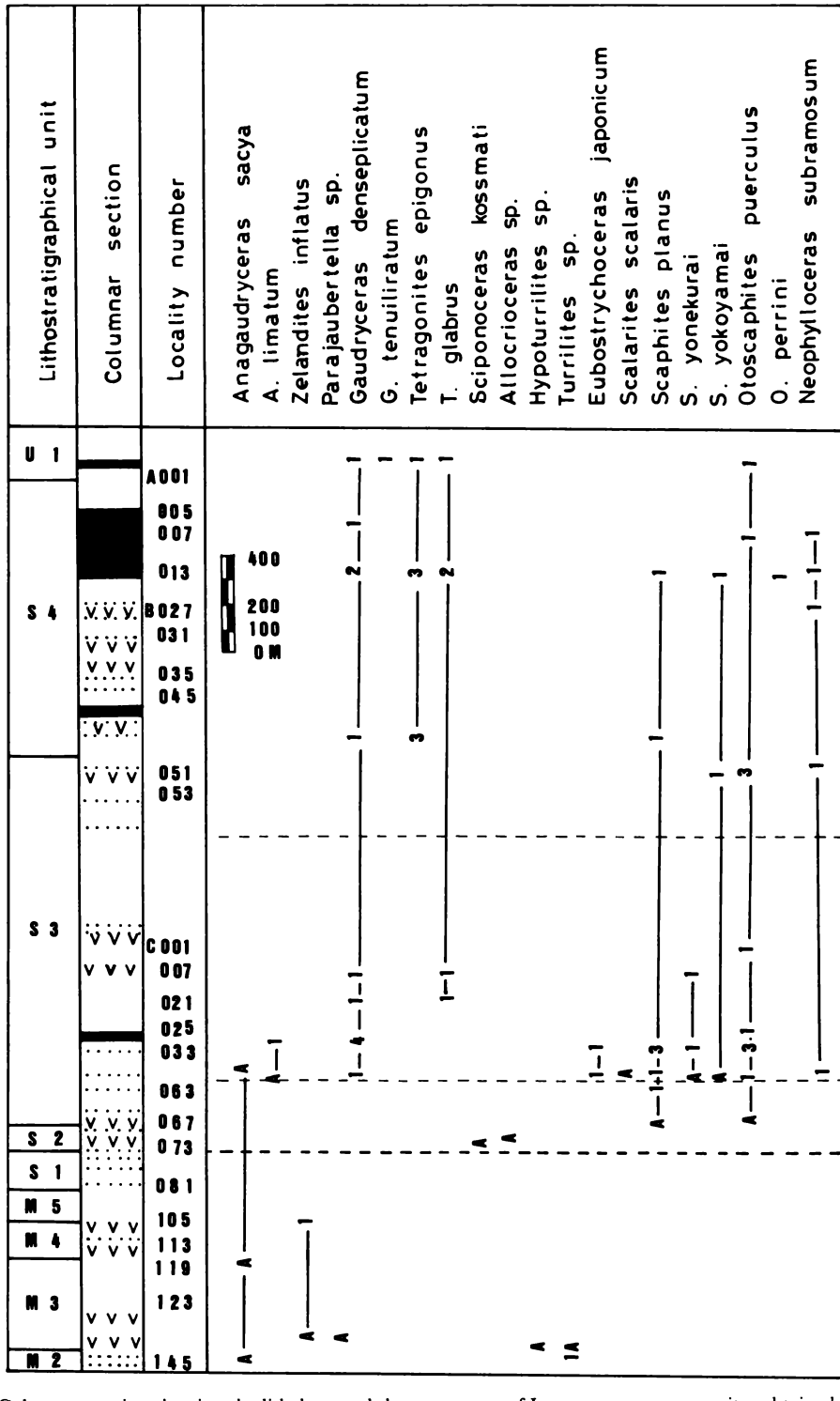

Fig. 5 Columnar section showing the lithology and the occurrence of Lytoceratacean ammonites obtained along the Hakkinzawa valley, in the central part of the Oyubari area. Symbols are the same as in Fig. 2.

2.1 Early Cenomanian

The lithostratigraphical unit of this age is represented by M3. The Cenomanian was hitherto divided into the lower Lower, upper Lower, Middle and Upper. In this classification the lower Lower Cenomanian is represented by a zone of *Inoceramus* aff. *crippsi* MANTELL, *Graysonites wooldridgei* YOUNG, *Sciponoceras matsumotoi* INOMA, and *Scaphites japonicus* INOMA. The upper Lower Cenomanian is represented by a zone of *Inoceramus nipponicus* NAGAO & MATSUMOTO, *Mantelliceras japonicus* MATSUMOTO, MURAMOTO & TAKAHASHI, *Sharpeiceras kongo* MATSUMOTO, MURAMOTO & TAKAHASHI, *Sciponoceras baculoide* (MANTELL) and *Hypoturrilites komotai* (YABE).

In the Oyubari area, however, *I.* aff. *crippsi* occurs only sparsely. Instead of the species, more common species, *Inoceramus concentricus nipponicus* characterizes the Lower Cenomanian (Fig. 2). Therefore the Lower Cenomanian is not subdivided into two parts in this paper, and *Inoceramus concentricus nipponicus* represents the Lower Cenomanian. In addition to these two inoceramid species, *Inoceramus pennatulus* PERGAMENT and *I.* sp. ex gr. *pennatulus* were obtained. In the ammonoid group, *Forbesiceras* sp., *Anagaudryceras sacya* (FORBES), *Zelandites inflatus* MATSUMOTO, *Parajaubertella* sp., *Hypoturrilites* sp., *Turrilites* sp., *Desmoceras* (*Pseudouhligella*) *ezoanum* MATSUMOTO and *D.* (*P.*) *japonicum* YABE were obtained (Figs. 7-9). *Mantelliceras* sp. was obtained from the Formation M2. The association of *Mantelliceras-Hypoturrilites-Forbesiceras* can be equated to the whole of the Lower Cenomanian of Le Mans section of JUIGNET(1977)[9].

2.2 Middle Cenomanian

The Middle Cenomanian of Japan has hitherto been defined by *Inoceramus yabei* NAGAO & MATSUMOTO, but this species is very rare in the area. Here I employed *Inoceramus concentricus costatus* NAGAO & MATSUMOTO as an alternative zonal index. The obtained fauna is, in addition to those two species, *Inoceramus concentricus nipponicus* NAGAO & MATSUMOTO, *Inoceramus pennatulus, I.* sp. ex gr. *pennatulus, I. ginterensis* PERGAMENT, *I. reduncus* PERGAMENT, *I. crippsi* (s.l.), *Desmoceras* (*Pseudouhligella*) *ezoanum, D.* (*P.*) *japonicum, Calycoceras asiaticum* (JIMBO), *Anagaudryceras sacya* and *Zelandites inflatus.* JUIGNET(1977)[9] mentioned that *Turrilites costatus* is the Middle Cenomanian species in the Le Mans area, France, but the genus *Turrilites* begins to occur from the top zone of the Lower Cenomanian, *Mantelliceras dixoni* assemblage zone. In U.K. and Northern France, *Turrilites costatus* forms the lowest zone of the three Middle Cenomanian zones (KENNEDY & HANCOCK, 1977)[10]. Near the top of the *I. concentricus costatus* zone *Calycoceras asiaticum* was obtained, and this is the first appearance of *Calycoceras* in the area. This horizon could equate with *Turrilites costatus* assemblage zone of the lower Middle Cenomanian in Le Mans.

2.3 Late Cenomanian

The lithostratigraphical units from upper M4 to lower S1 are recognized as this age. In the zonal framework hitherto established (*e.g.*, MATSUMOTO, 1978)[1], the Upper Cenomanian of Japan is represented by *Inoceramus pennatulus* zone below and *Mytiloides* sp. zone above, or *Eucalycoceras pentagonum* (JUKES-BROWNE) zone below and *Euomphaloceras septemseriatum* (CRAGIN) zone above.

The inoceramid species elucidated up to now are *Inoceramus concentricus costatus, I. pennatulus, I.* sp. ex gr. *pennatulus, I. ginterensis, I. corpulentus, I. reduncus, I. crippsi* (s.l.) and *I. yabei.* The first appearance of *Inoceramus corpulentus* from the middle part of M4 is designated as the base of a new "*Inoceramus corpulentus* zone" tentatively. The following ammonites have been identified in this zone: *Calycoceras asiaticum, C.* cf. *stoliczkai* COLLIGNON, *C. orientale* MATSUMOTO, SAITO & FUKADA, *Euomphaloceras* aff. *cunningtoni* (SHARPE), *Desmoceras* (*Pseudouhligella*) *ezoanum, D.* (*P.*) *japonicum,*

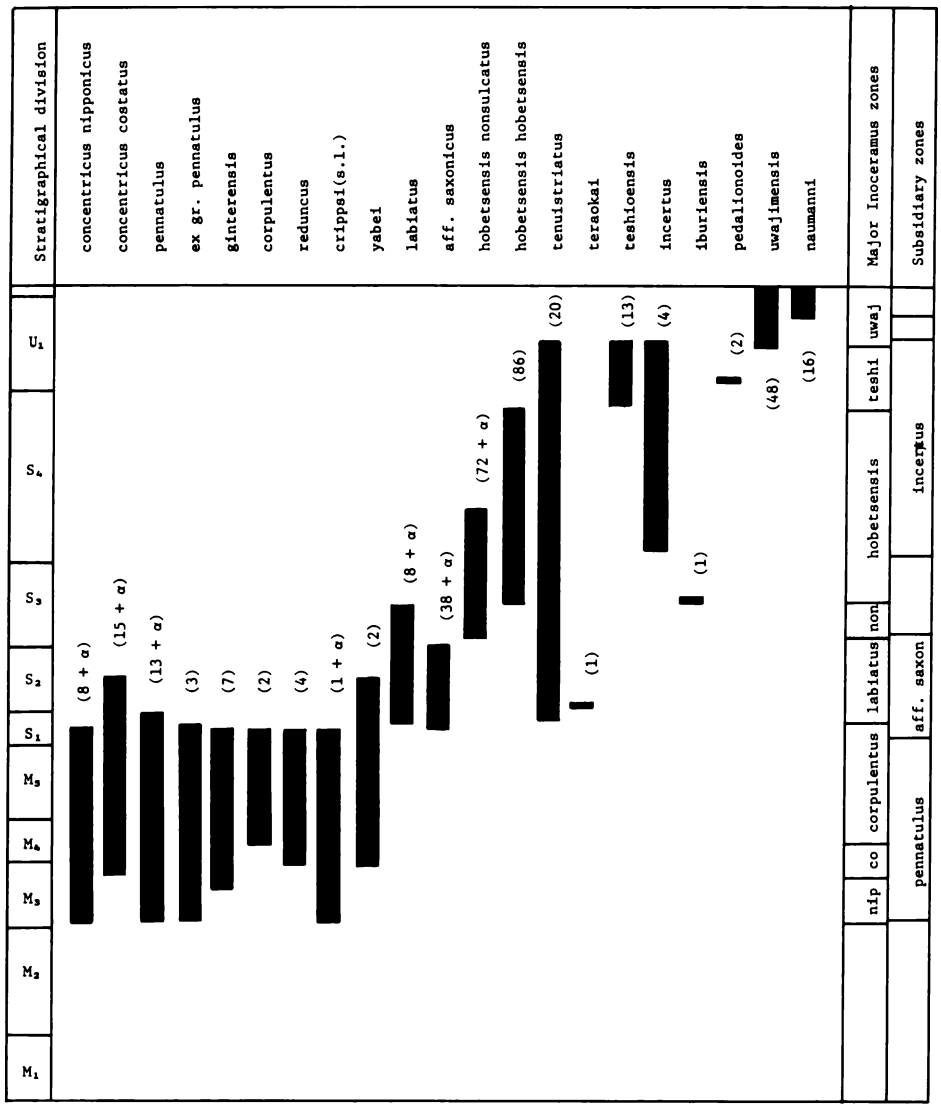

Fig. 6 Range chart of inoceramid species in the Oyubari area. Symbols are the same as in Fig. 2 (Read A for α). For the *Inoceramus* zones, nip: *I. concentricus nipponicus*, co: *I. concentricus costatus*, non: *I. hobetsensis nonsulcatus*, teshi: *I. teshioensis*, uwaj: *I. uwajimensis*, aff. saxon: *I.* aff. *saxonicus* and n: *I. naumanni*.

Pachydesmoceras andenianum, Marshallites olcostephanoides MATSUMOTO, *Anagaudryceras sacya, Zelandites inflatus, Turrilites costatus, T.* sp. and *Neophylloceras ramosum* (MEEK).

Three species of *Calycoceras* were obtained in this zone, of which fauna is in harmony with that of the Western European Upper Cenomanian (see KENNEDY & HANCOCK, 1977, p. 130-131, Fig. 1)[10].

3. Biostratigraphy of the Turonian

The Turonian of Japan has hitherto been divided into three, the Lower, Middle and Upper Turonian. In this paper, the Middle Turonian *Inoceramus hobetsensis* Zone is subdivided into two parts, *I.*

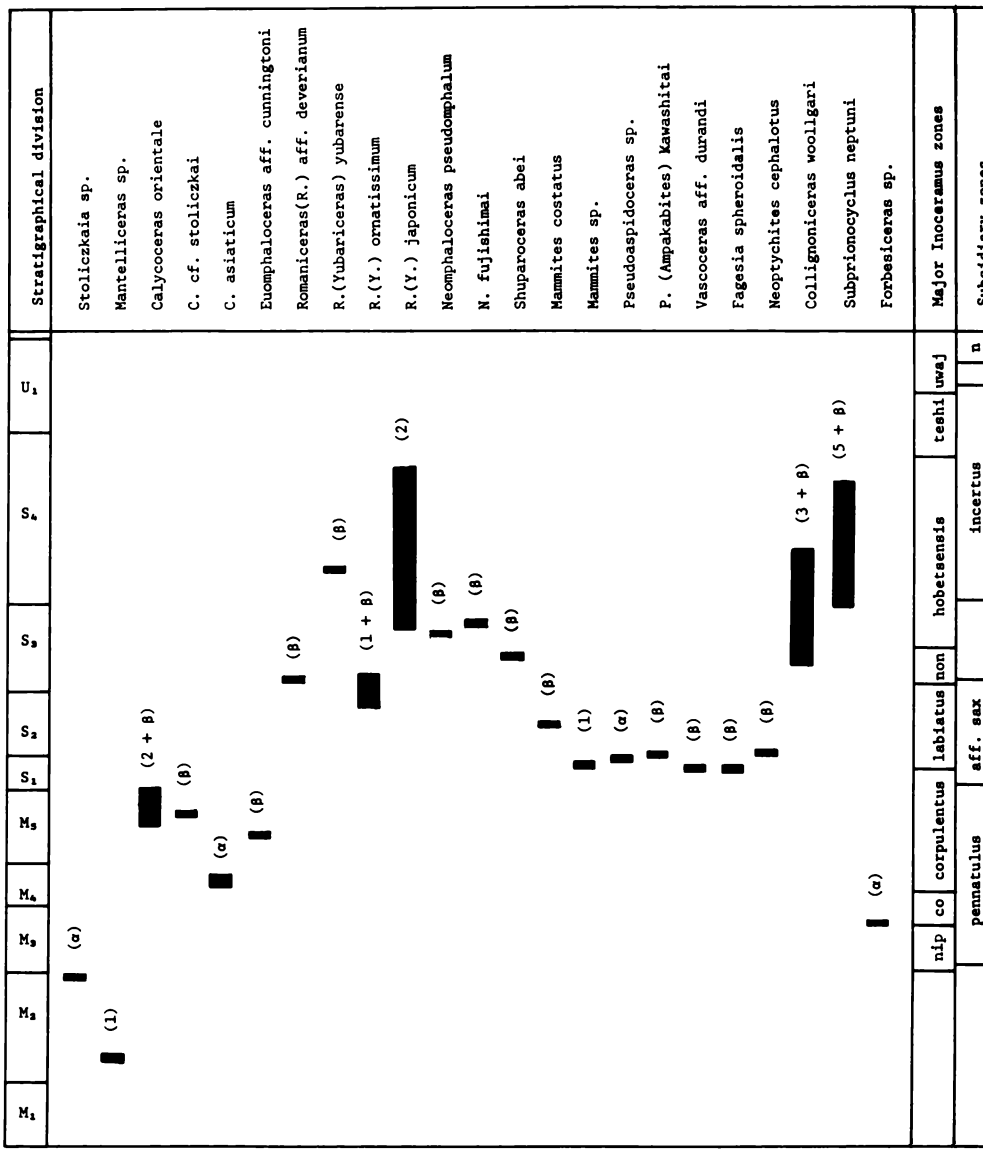

Fig. 7 Range chart of Acanthoceratacean and Hoplitacean ammonites in the Oyubari area. Symbols are the same as in Fig. 2. (Read B for β).

hobetsensis nonsulcatus Zone below and *I. hobetsensis hobetsensis* Zone above. Thus the Turonian is, in this paper, subdivided into the Lower, lower Middle, upper Middle and Upper.

3.1 Cenomanian/Turonian boundary and the Early Turonian

The Lower Turonian is lithostratigraphically represented by the units ranging from the upper S1 to lower S3. I adopt the zonal framework of MATSUMOTO (*e.g.*, 1978)[1] for this substage. This substage is defined by the zone of *Inoceramus labiatus* (SCHLOTHEIM)-*I.* aff. *saxonics* PETRASCHEK-*Fagesia thevestensis* PERON-*Mammites costatus* MATSUMOTO & KAWASHITA.

Inoceramus labiatus, I. aff. *saxonicus* and *Tragodesmoceroides subcostatus* MATSUMOTO begin to appear

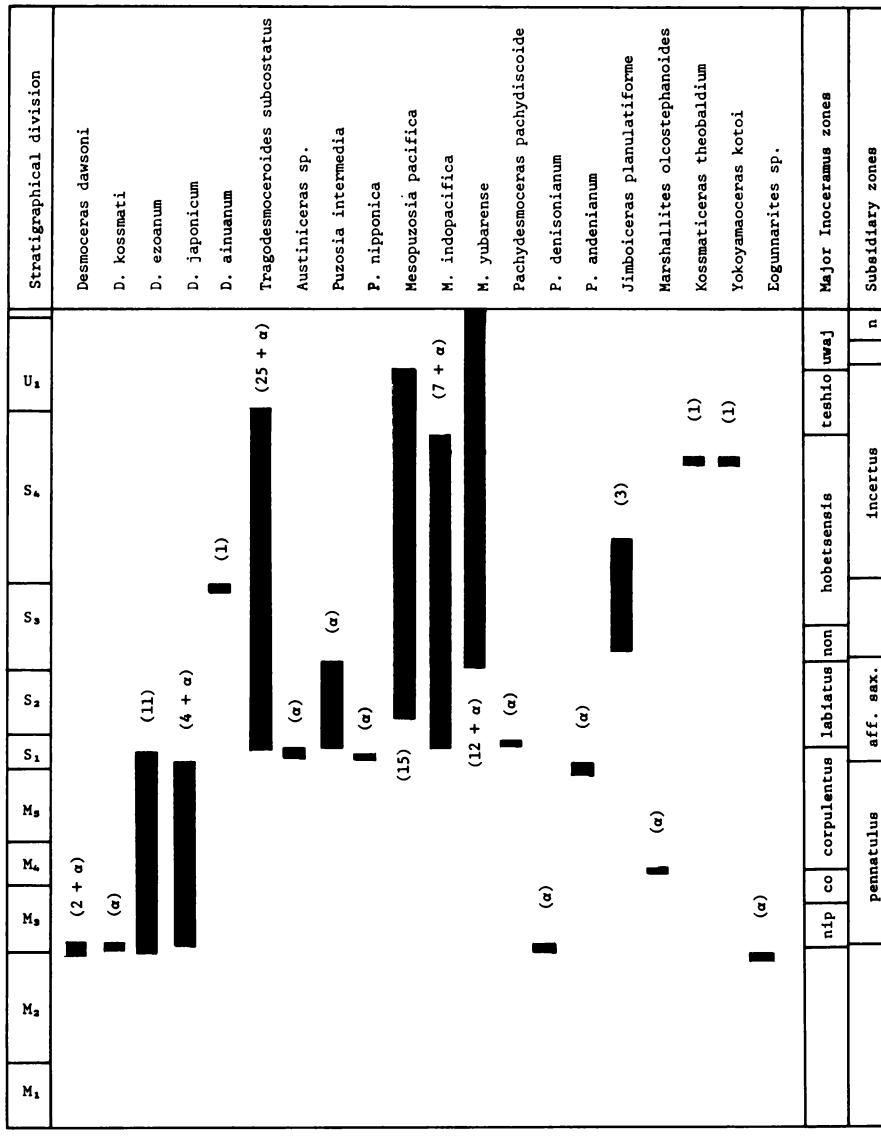

Fig. 8 Range chart of Desmoceratacean ammonites in the Oyubari area. Symbols are the same as in Figs. 2 & 6.

approximately coincidently. This phenomenon can be recognized throughout the Japanese Islands, and therefore the first appearance of one of these species, especially *I. labiatus* or *Tragodesmoceroides subcostatus,* is taken to define the basal part of the Lower Turonian. *Inoceramus concentricus costatus* which originated in the Cenomanian disappears within this substage. *Inoceramus tenuistriatus* NAGAO & MATSUMOTO and *I. teraokai* also appear and co-occur in this substage. The following ammonites were obtained: *Mammites* sp., *Pseudaspidoceras* sp., *Kamerunoceras* (*Ampakabites*) *kawashitai* MATSUMOTO & OBATA, *Vascoceras* aff. *durandi* (THOMAS & PERON), *Fagesia spheroidalis* PERVINQUIERE, *Neoptychites cephalotus* (COURTILLER), *Puzosia intermedia* KOSSMAT, *Mesopuzosia indopacifica* (KOSSMAT), *Pachydesmoceras pachydiscoide* MATSUMOTO, *Hyphantoceras* sp. and *Eubostrychoceras muramotoi* MATSUMOTO. It is convenient and in harmony with the fauna in Le Mans mentioned

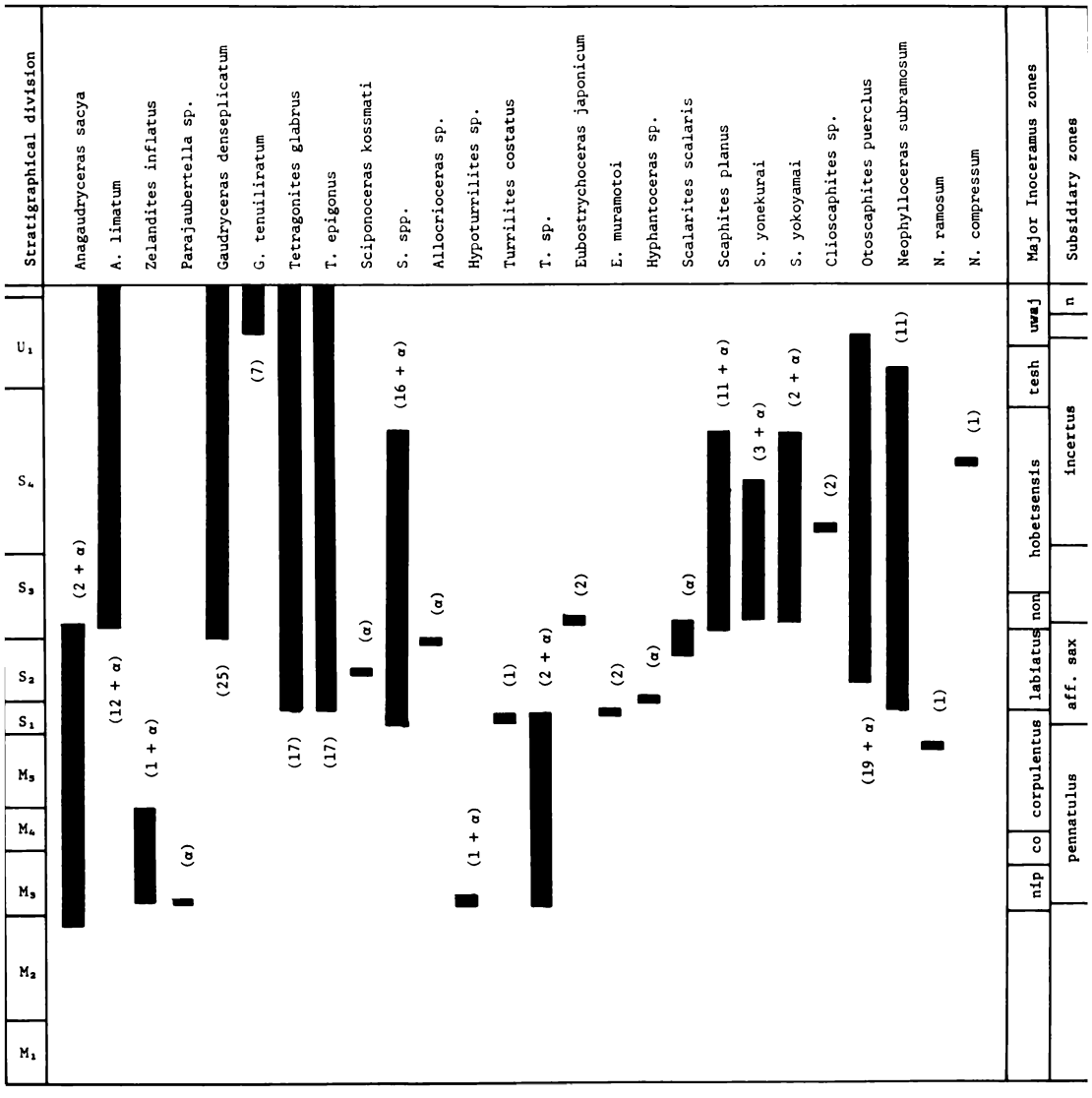

Fig. 9 Range chart of Lytoceratacean ammonites in the Oyubari area. Symbols are the same as in Figs. 2 & 6.

by JUIGNET(1977)[9] to define the basal part of the Lower Turonian with these inoceramid and ammonoid species mentioned above. In the Oyubari area, such ammonites as *Watinoceras* and *Neocardioceras* are unknown. If the definition of the Cenomanian/Turonian boundary proposed by WRIGHT & KENNEDY(1981)[11] is accepted, the boundary will be drawn at between the zones of *Inoceramus labiatus-I.* aff. *saxonicus* and *Mytiloides* sp. of TAKAYANAGI & MATSUMOTO(1981)[12]. In other words, the boundary at between *Euomphaloceras septemseriatum* and *Fagesia thevestensis* could equate with that proposed by WRIGHT & KENNEDY(1981)[11].

In addition to many species mentioned above, the following ammonoid species were obtained from the present zone of *Inoceramus labiatus: Romaniceras* (*Yubariceras*) *ornatissimum* (STOLICZKA), *Mesopuzosia pacifica* MATSUMOTO, *M. yubarense* (JIMBO), *Anagaudryceras sacya, Gaudryceras*

denseplicatum (JIMBO), *Tetragonies glabrus* (JIMBO), *T. epigonus* (KOSSMAT), *Sciponoceras kossmati* (NOWAK), *S.* spp., *Allocrioceras* sp., *Otoscaphites puerculus* (JIMBO) and *Neophylloceras subramosum* SHIMIZU.

3.2 Early Middle Turonian

This substage is lithostratigraphically represented by the middle part of S3, and equates with the lower part of the former zone of *Inoceramus hobetsensis-I. teraokai* MATSUMOTO & NODA. Adult shells of *Inoceramus hobetsensis hobetsensis* NAGAO & MATSUMOTO are much larger than those of *I. hobetsensis nonsulcatus* NAGAO & MATSUMOTO, and the appearance of the former is easily recognized in a field. Although the relation between these two subspecies is now the subject of biometrical analysis, it is practicable for the time being to divide the zone of *I. hobetsensis-I. teraokai* into two.

From the zone of *I. hobetsensis nonsulcatsus,* the lower Middle Turonian, *I. labiatus, I. tenuistriatus, Romaniceras* (*Yubariceras*) *deverianum* (d'ORBIGNY), *R.* (*Y.*) *ornatissimum, Sharpeiceras kongo* MATSUMOTO, MURAMOTO & TAKAHASHI, *Collignoniceras woollgari* (MANTELL), *Tragodesmoceroides subcostatus, Mesopuzosia pacifica, M. indopacifica, M. yubarense, Jimboiceras planulatiforme* (JIMBO), *Anagaudryceras sacya, A. limatum* (YABE), *Gaudryceras denseplicatum, Tetragonites glabrus, T. epigonus, Sciponoceras* sp., *Eubostrychoceras japonicum* MATSUMOTO, *Scalarites scalaris* (YABE), *Scaphites planus* (YABE), *S. yonekurai, S. yokoyamai* JIMBO, *Otoscaphite puerculus* and *Neophylloceras subramosum* were obtained.

The present zone could be correlated with the Middle Turonian of France (HANCOCK *et al.*, 1977[13]; HANCOCK & KENNEDY, 1981[14]) by the occurrence of some species of *Collignoniceras* like *C. woollgari* and of *R.* (*Y.*) *ornatissimum,* and also could be partly correlated with a part of the *Lata* zone of the British Middle Turonian of HANCOCK *et al.* (1977)[13].

3.3 Late Middle Turonian

The present substage is represented by the lithostratigraphical units which range from upper S3 to upper S4. It equates with the upper part of the former *Inoceramus hobetsensis - I. teraokai* Zone, i.e., zone of *I. hobetsensis hobetsensis*. The inoceramid fauna of this zone is as follows: *Inoceramus hobetsensis hobetsensis, I. hobetsensis nonsulcatus, I. tenuistriatus, I. incertus* JIMBO, *I. iburiensis* NAGAO & MATSUMOTO. The base of this zone is, of course, defined by the appearance of the characteristically large *I. hobetsensis hobetsensis.* The ammonoid fauna is as follows: *Romaniceras* (*Yubariceras*) *yubarense* MATSUMOTO, SAITO & FUKADA, *R.* (*Y.*) *japonicum* MATSUMOTO, SAITO & FUKADA, *Neomphaloceras pseudomphalum* (MATSUMOTO), *N. fujishimai* MATSUMOTO, *Collignoniceras woollgari, Subprionocyclus neptuni* GEINITZ, *Desmoceras ainuanus* MATSUMOTO, *Tragodesmoceroides subcostatus. Mesopuzosia pacifica, M. indopacifica, M. yubarense, Jimboiceras planulatiforme, Kossmaticeras theobaldium* STOLICZKA, *Yokoyamaoceras kotoi* JIMBO, *Anagaudryceras sacya, Gaudryceras denseplicatum, G.* sp., *Tetragonites glabrus, T. epigonus, Sciponoceras* sp., *Scaphites planus, S. yonekurai, S. yokoyamai, Clioscaphites* (?) sp., *Otoscaphites puerculus, O.* sp., *Neophylloceras subramosum* and *N. compressum.*

As shown by this fauna, the late Middle Turonian was the age of the highest diversity in ammonoid and inoceramid species.

Collignoniceras woollgari ranges from the zone of *I. hobetsensis nonsulcatus* to the lower half of the present zone, and *Subprionocyclus nuptuni* begins to occur within the middle part of the present zone. The assemblage of this zone is similar to Saumur and Bourre faunas at Le Mans mentioned by HANCOCK *et al.*(1977)[13], but the only species common to both areas is *Collignoniceras woollgari.* The present zone possibly equates to the upper part of the Middle Turonian to the lower part of the Upper

denseplicatum (JIMBO), *Tetragonies glabrus* (JIMBO), *T. epigonus* (KOSSMAT), *Sciponoceras kossmati* (NOWAK), *S.* spp., *Allocrioceras* sp., *Otoscaphites puerculus* (JIMBO) and *Neophylloceras subramosum* SHIMIZU.

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Collignoniceras woollgari ranges from the zone of *I. hobetsensis nonsulcatus* to the lower half of the present zone, and *Subprionocyclus nuptuni* begins to occur within the middle part of the present zone. The assemblage of this zone is similar to Saumur and Bourre faunas at Le Mans mentioned by HANCOCK *et al.*(1977)[13], but the only species common to both areas is *Collignoniceras woollgari.* The present zone possibly equates to the upper part of the Middle Turonian to the lower part of the Upper

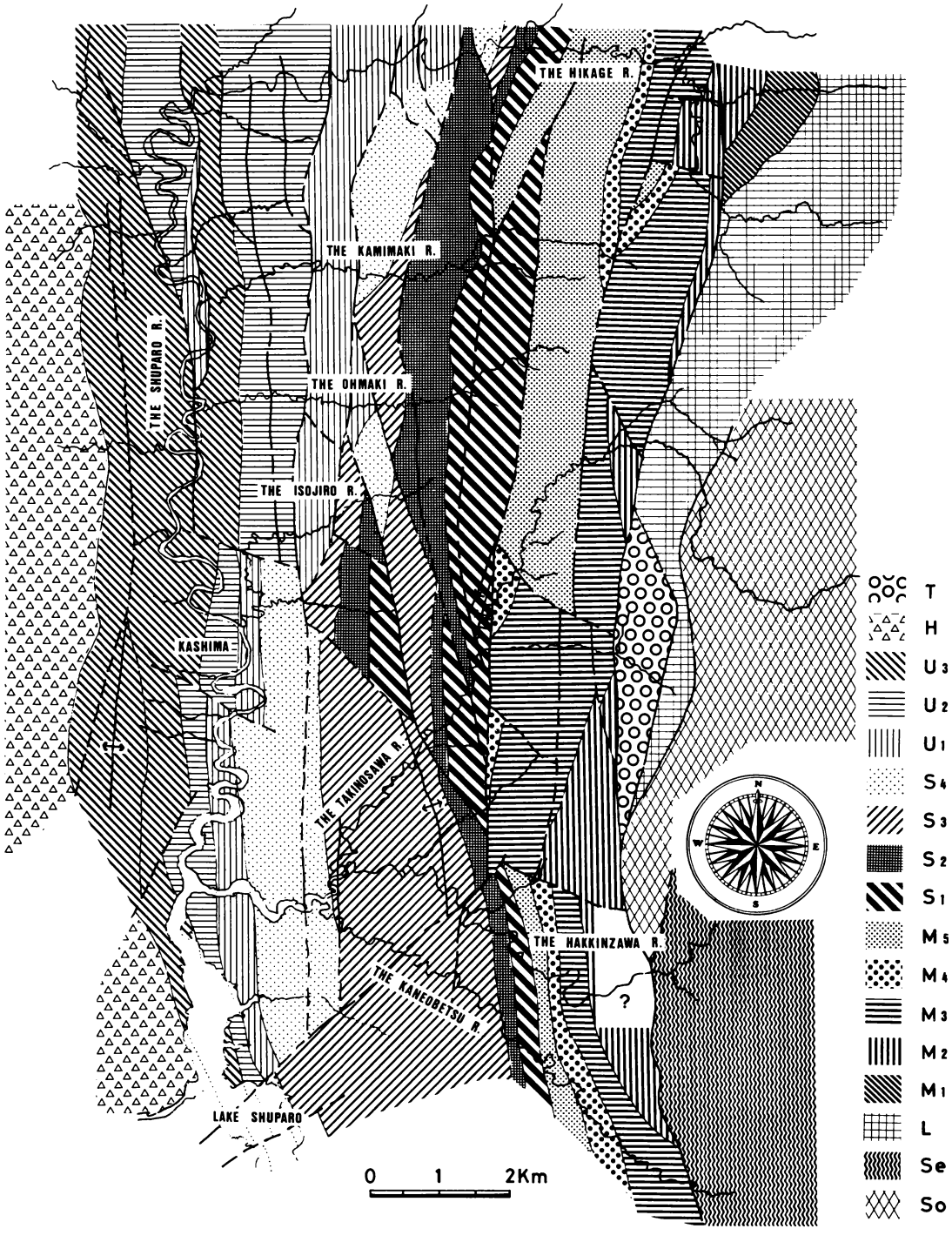

Fig. 10 Preliminary geological map of the Oyubari area. For abbreviations, So: the Sorachi Group, Se: Serpentinite and the Yubari-dake Metamorphic rocks, L: the Lower Yezo Group, M1-M5: the main part of the Middle Yezo Group, S1-S4: the upper part of the Middle Yezo Group (the Saku Facies), U1-U3: the Upper Yezo Group, H: the Hakobuchi Group, T: the Tertiary Itagakizawa Group.

Turonian of Le Mans.

3.4 Late Turonian

The Late Turonian has hitherto been called the zone of *Inoceramus teshioensis-I. incertus* (*e.g.*, TAKAYANAGI & MATSUMOTO, 1981)[12], and here it is lithostratigraphically represented by the units from the upper S4 to lower U1. In the Oyubari area, the sediments of this substage are under the main river, the Shuparo River and a lake of a dam, and therefore the available exposures are limited. Molluscan fossils obtained in this substage are as follows: *Inoceramus teshioensis* NAGAO & MATSUMOTO, *I. tenuistriatus, I. incertus* JIMBO, *I. pedalionoides* NAGAO & MATSUMOTO, *Tragodesmoceroides subcostatus, Mesopuzosia pacifica, M. yubarense, Anagaudryceras limatum, Gaudryceras denseplicatum, Tetragonites glabrus, T. epigonus, Otoscaphites puerculus* and *Neophylloceras subramosum.*

In do not show any detailed correlation of this zone with the European faunas here because the fauna in this area is poor as shown above.

The distribution of the Cenomanian and the Turonian in this area is preliminarily shown in Fig. 10.

4. Concluding Remarks

The following conclusions are obtained for the present investigation.

Japanese faunas of the Cenomanian and the Turonian are characterized by the dominant occurrence of Desmoceratacean, Tetragonitid and Turrilitacean ammonoids and inoceramid species.

Index species of the Cenomanian *Inoceramus* are partly modified by the more dominant occurrence of other species which are also common in the East Siberia. The Cenomanian four-fold subdivision established in the shallower facies are revised to the three-fold subdivision in this off-shore facies.

Some important Acanthoceratacean elements are sometimes obtained in addition to the predominant Pacific elements.

The boundary between the Cenomanian and the Turonian of Japan is characterized by *Mammites costatus, M.* sp., *Kamerunoceras* (*Ampakabites*) *kawashitai, Pseudaspidoceras* sp., *Vascoceras* aff. *durandi* and *Fagesia spheroidalis.* In the domestic practical point of view, the boundary is defined by the first appearacne of *Inoceramus labiatus, I.* aff. *saxonicus* and *Tragodesmoceroides subcostatus.*

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