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A new Oxfordian (Late Jurassic) Ammonite Assemblage from the Arimine Formation (Tetori Group) in the Arimine Area, southeastern Toyama Prefecture, northern Central Japan

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Abstract A rich new Jurassic ammonite assemblage was discovered from the Arimine area in the southeastern part of Toyama Prefecture. The assemblage is composed of *Phylloceras* (*Phylloceras*), *Ptychophylloceras*, *Holcophylloceras*, *Ochetoceras*, *Taramelliceras*, *Perisphinctes* (*Kranaosphinctes*), *Perisphinctes* (*Dichotomosphinctes*), and *Subdiscosphinctes* and is middle Oxfordian in age (Late Jurassic). This assemblage is correlated to the *Perisphinctes matsushimai* Assemblage Zone established in the Yambarazaka Formation distributed in the upper Kuzuryu area of the Hida Mountains. This zone has the widest geographical distribution of all the ammonite assemblage zones of the Tetori Group. It is known not only in the Hida Mountains but also in other regions of Japan, such as southern Kitakami, Yamizo and Kuga (Yamaguchi) regions. *Subdiscosphinctes* is represented by a new species, established on a well preserved huge adult shell and other immature specimens. Preservation of big ammonites like *Subdiscosphinctes* and *Perisphinctes* s.s. in the Arimine area suggests a particular depositional environment favorable for rapid burial of fragile ammonite shells, which is confined to some limited spots in this area in *P. matsusimai* Zone time.
Key words: ammonites, Jurassic, Oxfordian, Tetori Group, Arimine Formation, Hida

Introduction

The Tetori Group *sensu lato* is composed of the middle Jurassic - late Cretaceous clastic formations widely distributed in the Hida Mountains in northern Central Japan. It comprises half-dozen ammonite-bearing formations, which are distributed in more or less restricted areas, and are correlated to narrowly defined horizons of Middle Jurassic to Lower Cretaceous. The first known ammonite locality of the Tetori Group is in the upper reaches of the Kuzuryu River in the southeastern part of Fukui Prefecture, discovered already in the end of the 19th century. More localities have been added successively since then, and the faunal contents are accordingly increased by now. These added ammonite localities are, from west to east, Uchinami River area in the upper Kuzuryu River area in eastern Fukui Prefecture, Mitarai area in northern Gifu Prefecture, Furukawa area in northern central Gifu Prefecture, Kiritani area in south-central Toyama Prefecture, and Arimine area in southeastern Toyama Prefecture.

Some of the ammonites collected from these localities were systematically described and illustrated successively, but others were only cited in mostly stratigraphical reports. All the ammonite genera and species reported until 2008 from the Tetori Group are listed in Sato (2008). Among these, the Arimine Formation in the Arimine area was known to be ammonite-bearing

since the 1950's, but the rugged topography has much hindered geological exploration. Included ammonites were not systematically studied but were only cited by obscure names such as ammonites or Ataxioceratids in mainly stratigraphical reports. This ammonite-bearing formation was vaguely assigned to Late Jurassic. The repositories of these ammonites are not known, thus re-study of the cited ammonites is impossible at present.

Recently, better-preserved specimens of Perisphinctids were described and figured from the Higashi-Sakamori Valley of the Arimine area (Matsukawa *et al.*, 2008; Sato *et al.*, 2012). Staff members of the National Museum of Nature and Science organized a research project of detailed stratigraphical and paleontological research of the Arimine Formation, and succeeded to collect many better specimens of Jurassic ammonites, with the voluntary aids of the Tokai Fossil Society members. Most of the collected specimens belong to already known species from the Tetori Group, but some are new and offer important criteria for better understanding of the stratigraphy of the Tetori Group. Here we describe all the identified species. Some are new forms and present more information about the biodiversity of the Tetori Group. In this paper, Sato described the ammonites systematically, and Yamada stratigraphy. The assemblage of the ammonites is composed of 9 genera and 13 species.

Location and Stratigraphy

The Arimine Formation is a member of the Tetori Group and is distributed in the southeastern part of Toyama Prefecture (Fig. 1). Kawai (1955) first introduced the name of Arimine shale formation in his short report of the Tetori Group in this area. Later Maeda and Takenami (1957) established the stratigraphy of the Tetori Group in detail in this area, and reported the existence of ammonites in the Arimine shale formation. Kawai and Nozawa (1958) later revised the stratigraphy, subdividing the group of this area into Magawa, Arimine, Ihoridanitoge and Inotani Formations in ascending order. The former two formations are marine deposits while the latter two are fluvial.

(Note: Makawa is used for the geographical name in official and popular maps and documents, but Magawa has been used for the geological formation name since its foundation. We follow this usage in this paper.)

The stratigraphical relations between these formations are generally conformable, but the Ihoridanitoge lies on the deeply eroded surface of the Arimine or directly on the basement rocks elsewhere (Maeda and Takenami, 1957; Kawai and Nozawa, 1958; Toyama Prefecture, 1992). These formations are classified as members of the Tetori Group and this classification is currently used in general. Recently, Matsukawa *et al.* (2014) proposed a new name Jinzu Group for the Cretaceous sediments in this area, while they assigned the Jurassic sediments to the Tetori Group as before. However, their proposal needs further validation, thus we followed currently accepted stratigraphic scheme.

In the Arimine area fossils are known only from limited beds. The ammonoid specimens studied here were collected mostly from the exposures of the Arimine Formation in the Kamiuwabamidani Valley, a tributary of the Makawa River (Loc. AR0021 in Figs.1, 2). In this section along the Makawa River near the Kamiuwabamidani Valley, the Magawa Formation is in fault contact with the Ihoridanitoge Formation and its base is missing (Figs. 1, 2). It is, about 50 m thick, composed mainly of medium- to fine-grained brownish white sandstone and laminated black mudstone. A pebble conglomerate bed 50 cm thick marks the boundary between the Magawa and Arimine Formations (Fig. 2). The Arimine Formation is here ca. 125 m in thickness and composed of medium-grained grey sandstone with swaley or hummock cross-stratifications and bioturbated grey siltstone (Fig. 2). According to Takenami and Maeda (1959), the exposed Arimine Formation in this section is judged to correspond to the "lower part" of the Arimine Formation in the type section. The Ihoridanitoge

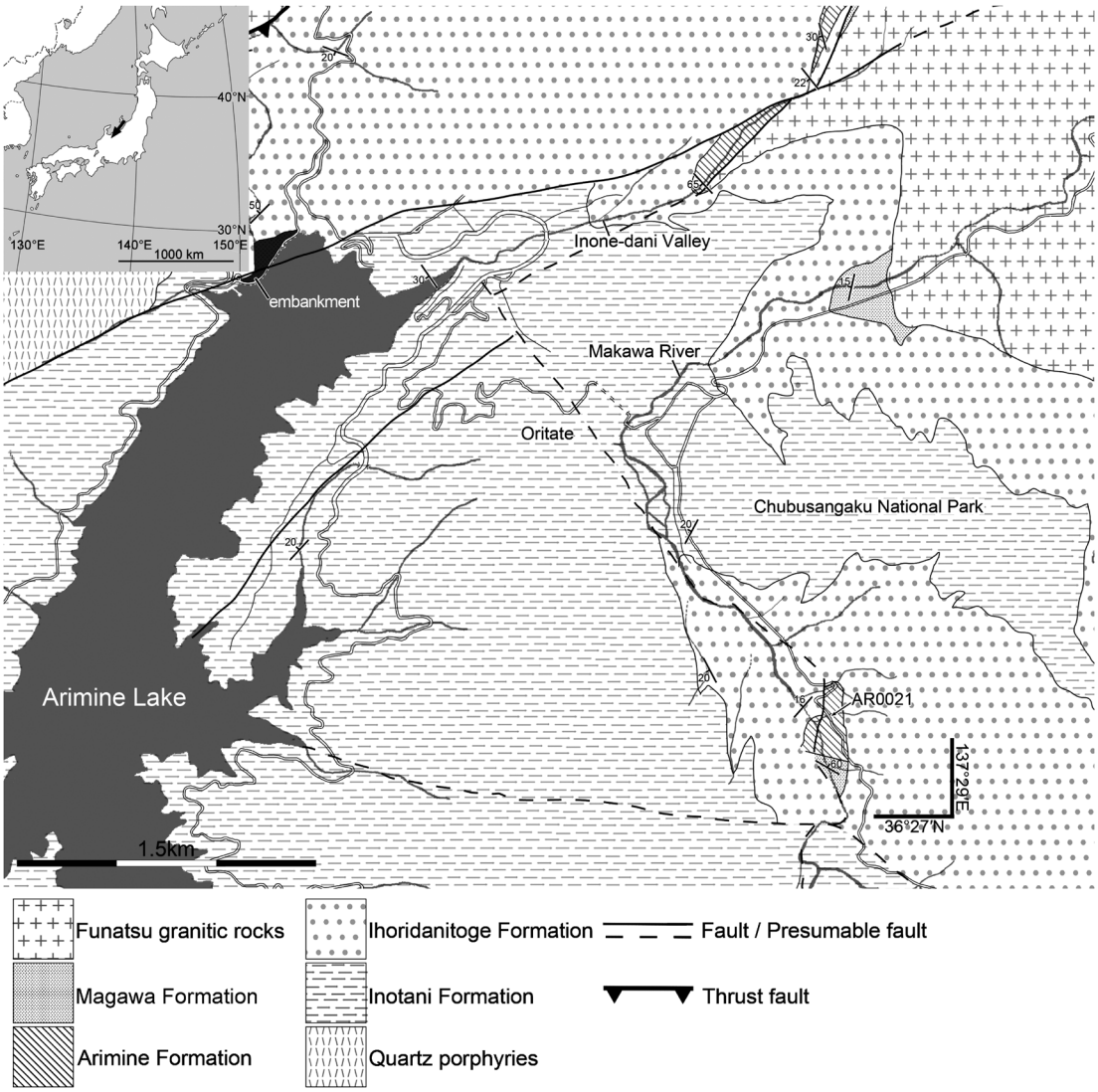


Fig. 1. Geologic sketch map of the Arimine area. Synthesized from the original data and partly adopted from Kawai and Nozawa (1958). AR0021 indicates the location of the Kami-uwabamidani Bridge over the Kami-uwabamidani Valley.

Formation is characterized by boulder-grained conglomerate. It is easily distinguishable by its coarse nature from the overlying Inotani Formation.

The siltstone of the Arimine Formation contains abundant molluscan fossils such as *Modiolus maedae* Hayami, *Pinna* sp. and *Tetorimya carinata* Hayami, and many of which retain their living position. The ammonoid specimens are collected from this siltstone. Shell fragments (*e.g. Myophorella* sp.) are scattered in the sandstone. Some specimens were collected from river floats of the Inone-dani Valley (Fig. 1) from the blackish grey siltstone with moderate lamination. Based on the color and lamination, these specimens seem to have been derived from the corresponding beds of the Arimine Formation.

Geological Age

There are several reports on ammonites from

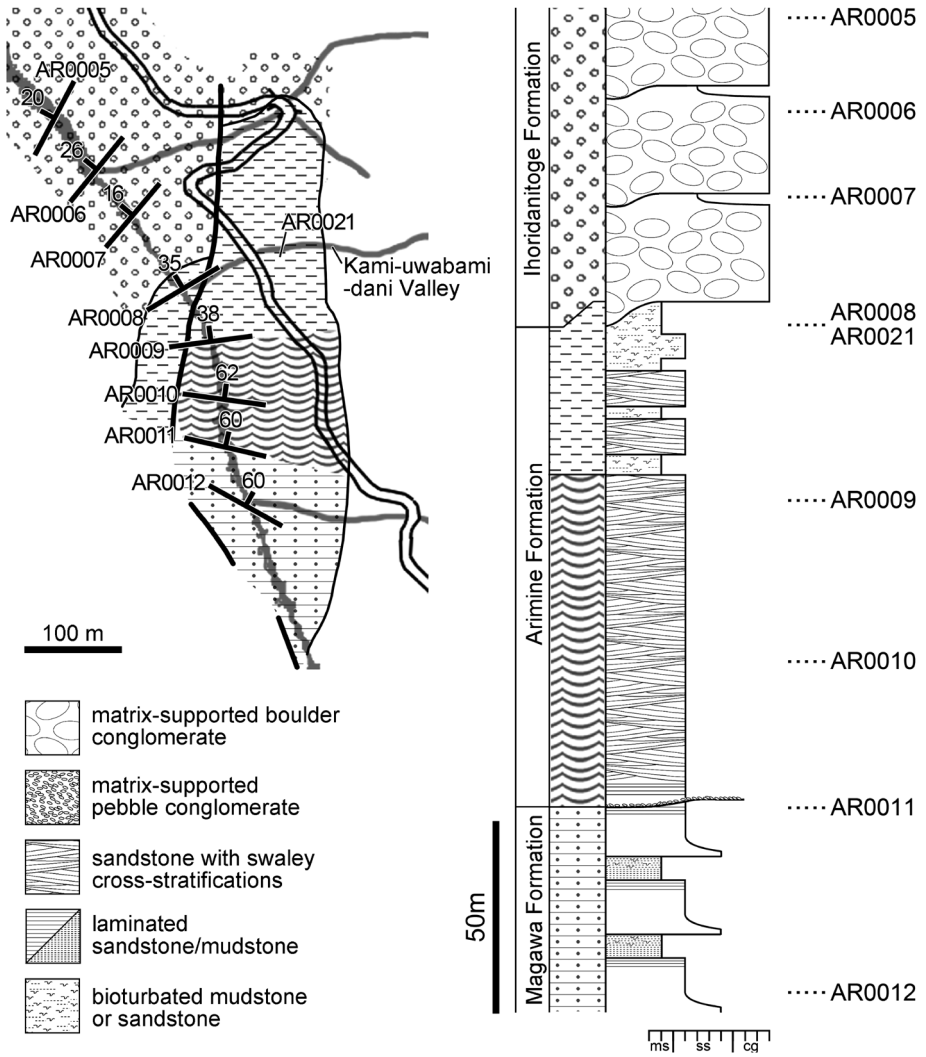


Fig. 2. Traverse map (left) of the Kami-uwabamidani Valley section and synthetic columnar section (right). Patterns of formations are used in common on both the geologic sketch map and the columnar section. Numbers (AR0005 and others) are sites of observation used also in common.

the Arimine Formation. Stratigraphically exact correlation among these ammonite-bearing horizons is difficult due to lack of key beds, but all are from the "lower part" of the Arimine Formation. Recently, Matsukawa *et al.* (2014) reports ammonites from the "upper part" of the Magawa Formation, but the horizon is almost the same as the ammonite-bearing horizon of this study.

Based on the fossils contained, the age of the Arimine Formation was judged to be Malm (used in the sense of Late Jurassic) by Maeda and Takenami (1957), middle Oxfordian by Matsukawa *et al.* (2008), middle Oxfordian to early Kimmeridgian by Sato *et al.* (2012) and early Oxfordian to early Kimmeridgian by Matsukawa *et al.* (2014). However, all these ages were based on solitary or poorly preserved ammonites in association with radiolarians or bivalves. The present ammonite assemblage includes numerous species of well-preserved ammonites and can offer more solid basis of dating. The age of the

assemblage is judged to be middle Oxfordian. In conclusion, the Arimine Formation, at least its ammonite-bearing lower part, is middle Oxfordian in age. The basis of the dating is given below.

The assemblage described herein comprises nine genera and subgenera such as *Holcophylloceras*, *Phylloceras* (*Phylloceras*), *Ptychophylloceras*, *Glochiceras*, *Ochetoceras*, *Taramelliceras*, *Perisphinctes* (*Kranaosphinctes*), *Perisphinctes* (*Dichotomosphinctes*), and *Subdiscosphinctes*. Of these, *Perisphinctes* (*Kranaosphinctes*) and *Perisphinctes* (*Dichotomosphinctes*) are essential elements of the *Perisphinctes matsushimai* Assemblage Zone, originally established in the Kuzuryu area (Sato and Westermann, 1992), which is correlated to late middle Oxfordian (Transversarium Zone) of Tethyan standard zonal scheme. *Perisphinctes* (*Kranaosphinctes*) is a genus widely distributed in the Submediterranean and Mediterranean regions and extends further East to reach Papua-New Guinea (peri-Gondowana continent). It is one of the index genera of the Zones of *Taramelliceras minax*, *Arisphinctes plicatilis* and *Gregoryceras transversarium* (Groupe français d'Etude du Jurassique, 1997) indicating lower and middle Oxfordian age. *Perisphinctes* (*Dichotomosphinctes*) ranges in early and middle Oxfordian in the Tethyan and Paleo-Pacific regions, including South America, according to Arkell *et al.* (1957). It occurs widely in the Tethys areas. In the Mediterranean region, this genus is a representative element of the middle Oxfordian (*Arisphinctes plicatilis* Zone and *Gregoryceras transversarium* Zone) of the Tethyan region (Groupe français d'Etude du Jurassique, 1997).

Besides these Perisphinctids, the present assemblage comprises Haploceratids such as *Glochiceras*, *Ochetoceras*, *Taramelliceras* and a new *Subdiscosphinctes* species. According to Arkell *et al.* (1957) the ranges of Halpoceratid genera are Oxfordian and Kimmeridgian. *Glochiceras* ranges from Oxfordian to Kimmeridgian in the Tethyan and paleo-Pacific realms. *Ochetoceras* occurs almost world-wide, mainly in the Tethys area, extending to Canada, Eastern Siberia and the Middle and South Americas, and ranges stratigraphically from lower Oxfordian to lower Kimmeridigian. Although the age of *Ochetoceras* varies following the areas, it is served as the index genus of the middle to upper parts of the middle Oxfordian (*Gregoryceras transversarium* Zone) and the upper Oxfordian (*Dichtomoceras bifurcatum* Zone to *Subnebrodites planula* Zone) of the Mediterranean and Submediterranean regions (Groupe français d'Etude du Jurassique, 1997). Unfortunately the present Arimine specimens can not be specifically determined (though compared to *O. irregulare*), so that the detailed age assignment is difficult, but the association with *Perisphinctes* (*Kranaosphinctes*), *P.* (*Dichotomosphinctes*) and *Ochetoceras* is strongly indicative of middle Oxfordian of the Tethyan biostratigraphical scheme. *Taramelliceras* is known to range in Oxfordian and Kimmeridgian according to Arkell *et al.* (1957). The Arimine *Subdiscosphinctes* is a new species, hence its age is not decided by itself, but the genus is hitherto known in Oxfordian and early Kimmeridgian (Hantzpergue, 1989). According to all these data, the age of the assemblage is most probably middle Oxfordian.

Correlation with other Japanese Jurassic formations

Perisphinctes matsushimai Assemblage Zone was first introduced as "Zone à *Kranaosphinctes matsushimai*" by Sato (1964, p. 888). It is characterized by an association of *Perisphinctes* (*Kranaosphinctes*) *matsushimai*, *P*. (*Dichotomosphinctes*) *kiritaniensis*, *Peltoceratoides* sp. Its type locality was defined to Yambara in the Kuzuryu area (southeastern Fukui Prefecture), and its type formation the Yambarazaka Formation of the Tetori Group. The index species, *P*. (*K*.) *matsushimai* occurs rather commonly in this area; for instance at Nagano (see Sato, 2008) and at Shimoyama (*e.g*. Toyama Palaeontological Research Club, 2007) both in this area.

Later the zone was redefined as an assemblage zone by Sato and Westermann (1991). Since then, other ammonite genera have been included in the assemblage. Sato (2008) summarized the composition of the zone: *Phylloceras* sp., *Holcophylloceras* sp., *Ptychophylloceras* sp., *Ochetoceras* sp., *Euaspidoceras* sp., in addition to the above three species. Now, in this paper, *Glochiceras*, *Taramelliceras* and *Subdiscosphinctes* are added. The distribution of the zone expanded outside the Kuzuryu area. It is now known from Kiritani in the upper reaches of the Joganji River (Sato, 1962), Arimine area (Matsukawa *et al.*, 2008 and this paper), Mashiko in the Yamizo Mountains (Suzuki and Sato, 1972), Ojika Peninsula (Fukada, 1950; Sato, 1962; Takahashi, 1969). If *Perisphinctes* (*Perisphinctes*) *ozikaensis* Fukada and its allies, indicating also middle Oxfordian age, is taken into account, the zone is distributed further outside; in Mone in the Karakuwa Peninsula (Kato *et al.*, 1977), Oginohama in the Ojika Peninsula (Fukada, 1950; Takahashi, 1969), the Kuga River area of the Yamaguchi Prefecture (Sato *et al.*, 1986) and Akka-Tanohata area of northern Kitakami (Suzuki *et al.*, 2007).

Therefore *Perisphinctes matsushimai* Assemblage Zone and contemporaneous Perisphinctid-bearing formations of middle Oxfordian age is one of the most extensively distributed ammonite zones of the Japanese Jurassic.

Presence of such huge ammonites as *Subdiscosphinctes* n.sp. (this paper), *Perisphinctes* s.s. sp. (Sato *et al.*, 2012) and "*P.* (*Kranaosphinctes*) *matsushimai*" (Matsukawa *et al.*, 2008) in the Arimine Formation suggests a special depositional environment which enabled the preservation of fragile shells. These big shells are easy to be broken after death, so that a combination of particular condition, such as a rapid burial in quiet sedimentary environment, probably without transportation for long distance and absence of scavengers, was required. Arimine is one of the locations realizing such conditions, among contemporaneous beds of the Tetori Group.

Systematic descriptions

Suprafamilial classification adapted from Arkell *et al.* (1957) and Donovan *et al.* (1981).

Abbreviations used in this paper: D for diameter, UD for umbilical diameter, UD/D for ratio of umbilical diameter to diameter, H for whorl height, W for whorl width. Measurements are in mm if not indicated. Number of ribs is indicated by number of primary ribs per whorl R1/W, and number of secondary ribs R2. For elements of suture-line, E for siphonal lobe, L1 for first lateral lobe, L2 for second lateral lobe, S1 for first lateral saddle, S2 for second lateral saddle, [m] for microconch, [M] for macroconch. NMNS stands for the the National Museum of Nature and Science.

Superfamily Phylloceratoidea Zittel, 1884

Family Phylloceratidae Zittel, 1884

Subfamily Phylloceratinae Zittel, 1884

Genus *Phylloceras* Suess, 1865

Subgenus *Phylloceras* Suess, 1865

Phylloceras* (*Phylloceras*)** cf. ***consanguineum Gemmellaro, 1876

Fig. 3

Material: A single internal mold NMNS PM23892, collected in the Kami-uwabamidani Valley, at a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Measurement: Taken at D = 92 mm, UD = ca 6 mm, UD/D = 0.06, H = 54 mm, W = ca 26 mm.

Description: Very involute oxycone (UD/D = ca 0.06), whorl section high oval, widest at outer one-third of flanks, venter rounded, umbilical wall steep, with rounded border; flanks covered by numerous folds (rounded ridge-like ribs) on inner half, and fine striae on outer, overlapping parts of folds and split at mid-flanks from folds. Both folds and striae lightly sinuous, gently prorsiradiate in ventro-lateral and ventral regions. Suture-lines partly visible and rounded folioles of Phylloceratid style confirmed.

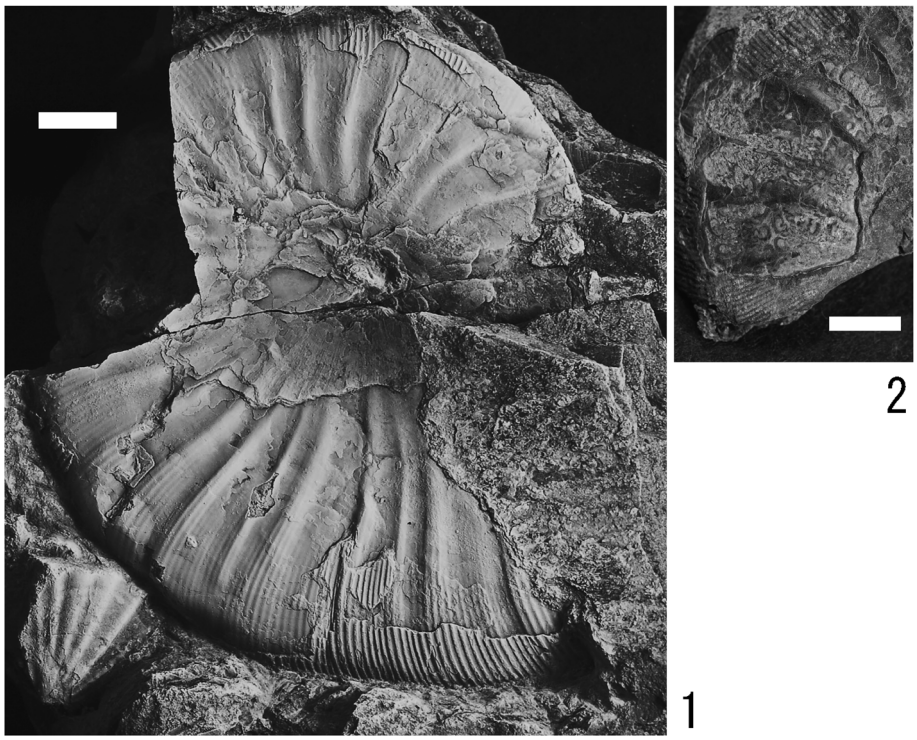


Fig. 3. *Phylloceras* (*Phylloceras*) cf. *consanguineum* Gemmellaro. NMNS PM23892. Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 1 cm. **1**, Lateral view of the inner mold; shell material partly preserved. **2**, Other side of the last preserved whorl, showing phylloid suture-lines.

Observation: A rather well preserved inner mold, with outer shell partly preserved, is available. The specimen is moderate in size (diameter about 10 cm). As shown by the round-topped suture-lines partly preserved on the inner mold of the last part of the phragmocone, it belongs undoubtedly to the group of *Phylloceras*. The ribbing, most characteristic of the specimen, is composed of narrow but frequent sinuous folds superposed by fine striae. Folds start near the umbilical margin; then inclined forward, soon back to rectiradiate and slightly swing forward on the ventro-lateral and ventral region. Finer secondary ribs are branched off from the folds forming bundles on the outer flanks. Suture-lines are partly visible on a part of the mold, uncovered by removal of a part of the outer shell on the left side of the shell (Fig. 3-2); the whole pattern is not visible, but *Phylloceras*-type rounded saddles are clearly seen.

Comparison and Affinity: The most remarkable characteristics of this species are numerous folds (plications) superposed by fine striae on the flanks. Among the species of *Phylloceras*, this type of ornamentation is rather rare, but seen in some late Jurassic forms, such as *Phylloceras* (*Phylloceras*) *consanguinum* Gemmellaro (1876, p. 160, pl. 1, fig. 2; refigured in Pavia and Cresta, 2002, fig. 2). Gemmellaro's specimen is not complete, but as far as examined on the figure, it is very close to the Arimine specimen. Similar species are reported from the Paleo-Pacific and Tethys provinces, namely from Northern Alaska (Imlay, 1981), California (Imlay and Jones, 1970), Mexico (Burckhardt, 1906), Spiti (Uhlig, 1903), and southern and eastern Europe (Gemmellaro, 1876, etc.).

This type of *Phylloceras* is also prolific in Cretaceous where various genera and subgenera are established; *Epiphylloceras* Collignon, 1956;

Neophylloceras Shimizu, 1934; *Euphylloceras* Druschchits, 1953; *Hypophylloceras* Salfeld, 1924 and so on. Some of them are quite similar in ornamentation to the Arimine form, but as the Arimine form occurs together with other Jurassic ammonites, these Cretaceous genera are difficult to be adopted.

Because the present specimen is not complete, the form is hardly identified with any of the above forms with certainty, and here it is described as a comparable species of *P.* (*P.*) *consanguineum*.

Formation and age: Arimine Formation of the Tetori Group. Most probably Oxfordian, as indicated by the associated fauna.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Subfamily Ptychophylloceratinae Collignon, 1956

Genus *Ptychophylloceras* Spath, 1927

Ptychophylloceras cf. ***euphyllum*** (Neumayr, 1871)

Fig. 4

Material: A rather well preserved inner mold of phragmocone and a part of living chamber NMNS PM23893, of which shell material partly preserved, collected in the Kami-uwabamidani Valley, at a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Measurement: Taken at D = 130 mm of NMNS PM23893 (along the long axis of the deformed elliptical shell), UD = 12 mm, UD/D = 0.09, H = 66 mm.

Description: Very involute platycone, umbilicus almost closed (UD/D = 0.09), umbilical wall steep with rounded border, whorl section probably compressed elliptical in shape, venter rounded, flanks slightly inflated at the middle, nearly smooth, except for the ventrol-lateral and ventral regions, provided with periodic narrow short labial folds accompanied with constrictions. Suture-lines of rounded foliole-bearing Phylloceratid type, with tetraphyllic first lateral saddle and triphyllic second lateral saddle.

Observation: The specimen at hand is deformed to elongate elliptical form in general outline, and also compressed laterally; the exact shape of shell is thus uncertain. The shell surface is a little deteriorated but the test is preserved locally. As in most of *Ptychophylloceras* species, the surface ornamentation is characterized by periodic folds resulted by thickening of test. On the inner mold these folds correspond to narrow constrictions, which are visible where the test is removed. Narrow but rounded labial folds on the shell surface are slightly sinuous, sprung from the umbilical margin, and cross the ventral region without modification. Suture-lines are only partly observable, where the test is dislodged. Siphonal lobe E is not seen. First lateral lobe L1 is stout, deeply incised with three well-developed sharply pointed lobules. First lateral saddle S1 is also wide and deeply incised, and split into four well developed folioles, equal in strength, thus tetraphyllic in appearance. Second lateral saddle S2 is much narrower than the first, and complexly incised with three or four branches.

Comparison and affinity: The general shape, characteristic suture-lines, regular labial folds on the flanks and venter of test, the specimen is judged to belong to *Ptychophylloceras* of Phylloceratidae. Species hitherto illustrated of the subgenus *Ptychophylloceras* look almost all alike, as characterized by their smooth shell surface, long or short narrow periodic folds on the surface of test and corresponding narrow constrictions on the inner mold. They are in fact difficult to distinguish from each other. One of the important features for specific identification is the way of subdivision of saddles, triphyllic and tetraphyllic. These terms are defined *e.g.* in Murphy and Rodda (2006), but it is not easy to distinguish one from another. Counting of number of branches seems somewhat arbitrary, as seen in their drawings (*loc. cit*., fig. 10, d, e) in which tri- and tetra-phyllic are not clearly distinguishable. Here it seems that the S1 can be tetraphyllic and

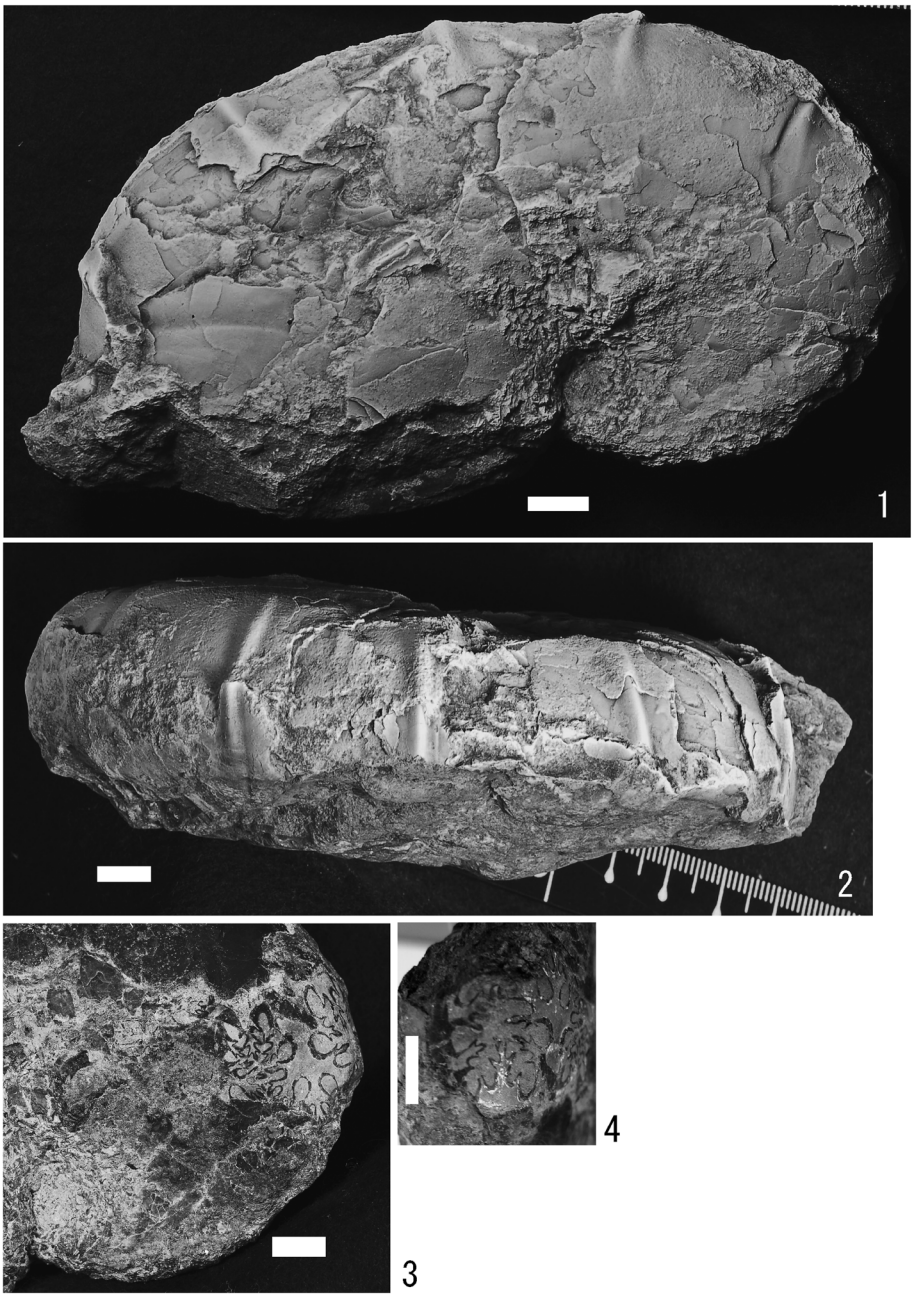


Fig. 4. *Ptychophylloceras* cf. *euphyllum* (Neumayr). NMNS PM23893, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 1 cm. **1**, Lateral view of the inner mold of the living chamber (partly destroyed). **2**, Ventral view of the living chamber. **3**, Lateral view of the last part of the living chamber, showing parts of the suture-lines, L1 and S2. **4**, Oblique view of the ventral region, showing S1.

S2 triphyllic at the diameter of about 6 cm; this drives us to place the specimen close to *Ptychophylloceras euphyllum* (Neumayr) (1871, p.325, pl. 16, fig. 7a, b). *P. euphyllum* is reported from southern Europe, Caucasus and Crimea.

There are other resembling species such as *Ptychophylloceras ptychoicum* (Quenstedt, 1847, p. 215, pl. 17, fig. 12); but it is claimed to have tetraphyllic saddles (Neumayr, 1871, pl. 16, fig. 10) which is different from ours.

Formation and age: Arimine Formation of the Tetori Group. Geologic age of *P. euphyllum* is Oxfordian in general, and this age is not contradictory to the age suggested by associated ammonites (middle Oxfordian).

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Subfamily Calliphylloceratinae Spath, 1927

Genus *Holcophylloceras* Spath, 1927

Holcophylloceras sp.

Fig. 5

Material: An internal mold NMNS PM23894, collected in the Kami-uwabamidani Valley, Arimine.

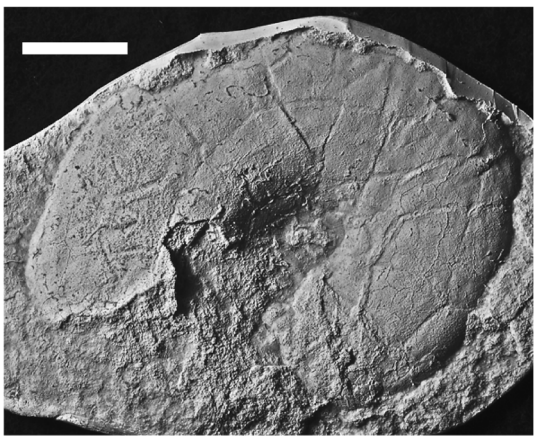


Fig. 5. *Holcophylloceras* sp., NMNS PM23894, float under the Kami-uwabamidani Bridge, Arimine. Lateral view of the rubber cast. Scale bar 1 cm.

Measurement: Taken at D = 49 mm of NMNS PM23894, UD = 4.5 mm, UD/D = 0.09, H = 25 mm.

Description: Very involute, slightly inflated laterally, venter sharply rounded, smooth sides and ventral region, fine sinuous constrictions.

Observation: The specimen in concern is an internal mold of probably immature whorls, thus very difficult to identify at specific level. The shell seems to be crushed by compression, as indicated by longitudinally running fractures; the original shape of the shell is judged to be very involute, with funnel-shaped narrow umbilicus. The umbilical wall is gently sloped gradually from the mid-flank, and inflated at the lower flanks. Periodical sinuous fine constrictions are on the smooth surface, forming double concave arcs which is characteristic of the genus.

Formation and age: Arimine Formation. In general, the genus ranges chronologically from Middle Jurassic to Lower Cretaceous, but in the present case, middle Oxfordian is probable from the accompanying species.

Occurrence: Kami-uwabamidani Valley, collected from a float under the Kami-uwabamidani Bridge.

Superfamily Haploceratacеae Zittel, 1884

Family Oppeliidae Douvillé, H., 1890

Genus *Glochiceras* Hyatt, 1900

Subgenus *Glochiceras* Hyatt, 1900

Glochiceras* (*Glochiceras*)** cf. ***nimbatum (Oppel), 1863 [m]

Fig. 6

Material: A small inner mold NMNS PM23895, collected in the Kami-uwabamidani Valley, Arimine.

Measurement: Taken at D = 11 mm of NMNS PM23895, UD = 2 mm, UD/D = 0.18, H = 5.5 mm.

Description: Small, involute shell. Whorl section high oval, flank gently inflated, thickest at mid-flank, venter probably rounded. Border of aperture biconcave, with prominent lateral lappets, and its outer arc broadly concave, bordered by shallow but distinct furrow parallel

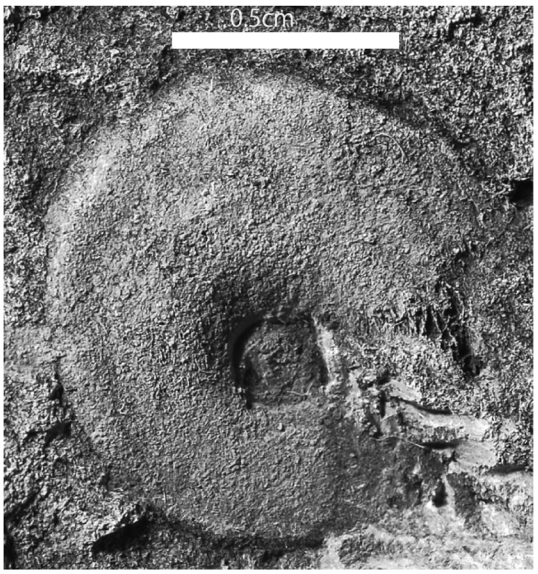


Fig. 6. *Glochiceras* (*Glochiceras*) cf. *nimbatus* (Oppel) [m]. NMNS PM23895, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 1 cm. Lateral view of a poorly preserved last whorl, showing the aperture.

to apertural margin, inner arc oblique to umbilical margin, bordered by narrow furrow. Lappet with long shank, but terminal part broken and unknown.

Observation: The specimen studied is a single inner mold impressed on silty mudstone, not perfectly preserved but general features well observable except for the tip of lappet. Whorls are flatly compressed, marked by a shallow spiral fracture. However, though it is tiny, characteristic features indicating the genus *Glochiceras* are ascertained. On the smooth surface, any ornamentation such as ribs or tubercles is not seen except for a shallow constriction at the end of phragmocone. At the aperture, a narrow, biconcave furrow runs parallel to the apertural margin. Lappets are destroyed but sharply pointed shank remains, indicating a long spatulate shape.

Comparison and affinity: Small, involute, smooth whorls with prominent lappets bounded by biconcave furrow at the base of lappets suggest that this specimen belongs to the genus *Glochiceras*. Its smooth whorls indicates that it is included in the subgenus *Glochiceras*. Among the species of this subgenus, *Glochiceras* (*Glochiceras*) *nimbatum* (Oppel, 1863, Pl. 52, fig. 5) looks very similar to the present form. Unfortunately the lappets and suture-lines are not completely preserved, it is impossible to identify specifically.

Wierzbowski *et al.* (2010) suggested the micro- and macroconch relation between *Glochiceras* and *Taramelliceras*, because the immature whorls closely resemble, and judged the former to be microconch (or male) and the latter macroconch (female). As always, because the correlation is difficult to prove, it is not adopted here, though it sounds plausible.

Formation and age: Arimine Formation. Oxfordian in age, as suggested by the ages of the hitherto known species of *Glochiceras* and associated *Taramelliceras* and *Ochetoceras*.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Subfamily Ochetoceratinae Spath, 1928

Genus *Ochetoceras* Haug 1885

Ochetoceras cf. ***irregulare*** Berckhemer and Hölder, 1959

Fig. 7

cf. *Ochetoceras irregulare* Berckhemer and Hölder, 1959, p. 99, pl. 23, figs. 118– 120, text-fig. 70.

Material: Three inner molds NMNS PM23896, 23897, 23898, collected in the Makawa and branch rivers.

Measruements: Taken at D = 52 mm of NMNS PM23896, UD = 52 mm, UD/D = 0.11, H = 27 mm; at D = 32 mm of NMNS PM23897, UD = 4 mm, UD/D = 0.13, H = 15 mm; at D = 22.5 mm of NMNS PM23898, UD = 2 mm, UD/D = 0.09, H = 13.5 mm.

Description: Flat discoidal shell, very involute, venter sharply rounded with denticulate or wavy median siphonal keel, flanks slightly

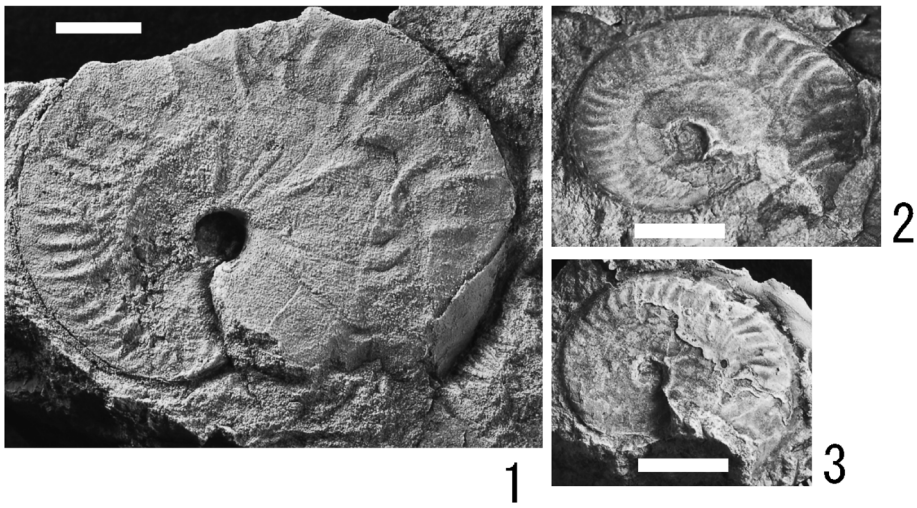


Fig. 7. *Ochetoceras* cf. *irregulare* Berckhemer and Hölder. Scale bar 1 cm. **1**, Lateral view of the adult whorl, NMNS PM23896, at the foot of the Kami-uwabamidani Bridge, Arimine. **2**, Lateral view of NMNS PM23897, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine; showing a shallow but clear lateral furrow. **3**, Lateral view of an imperfect specimen, NMNS PM23898, Kami-uwabamidani Valley, Arimine.

inflated but almost flat. Umbilicus small, deep with steep wall with rounded border. In the earlier stage flanks divided into two, outer and inner, parts by mid-flank spiral groove or faint fillet. Inner part with straight, prorsiradiate, spoke-like ribs or smooth. Outer part with falcate, fine ribs concave towards aperture and periodically stronger ribs parallel to the former on the last whorl. Suture-line unknown.

Observation: The ornamentation of this species changes following the growth stages. Innermost whorls are not observable, but in the whorls of the next stage flanks are clearly divided into inner and outer halves, bounded by a narrow but clear median spiral groove, as seen on a small specimen PM23897 (diameter about 32 mm) (Fig. 7-2). In this stage, the inner part of the flanks is almost smooth, devoid of ribs. The ornamentation changes then in the next stage, as seen on the specimen PM23896 (Fig. 7-1). Ribbing becomes prominent, distinctly bi-concave on the flanks. Median groove becomes shallower and replaced by faint fillet. On the outer flanks fine, regular ribs are thicker and irregularly replaced by thick folds. Then all fade out on the last part of the whorls, suggesting that the apertural region approaches. Though all the specimens are medium in size (maximum around 5 cm or more), the preserved specimens are, at least PM23896, adult, as shown by the modified apertural region. It seems that these are macroconchs, judged by the last part of the whorl preserved.

Still smaller specimens, less than about 3 cm in diameter, are also available. Most probably these specimens represent still earlier stage of development. These specimens are too poorly preserved, and difficult to identify with this species; they will be described below as *Ochetoceras* sp.

Comparisons and affinities: Though somewhat deformed and details are not observable, these specimens certainly belong to *Ochetoceras*. At the species level, it is comparable to *Ochetoceras irregulare* Berckhemer & Hölder (1959, p. 99, figs. 118–119). The holotype of this species is more sharply ribbed, but essential specific characters, such as irregularly spaced outer ribs,

are recognized in the present specimens. *Ochetoceras* was reported from the Kaizara Formation in the Kuzuryu River area. Half dozen specimens of *Ochetoceras* were illustrated by Shimonoya and Takahasi (1990, pl. 9, figs. 1–5; *O*. sp. A, *O*. sp. juv., *O*. sp. B). *O*. sp. B, refigured in other papers (*O*. sp., Fukui City Museum of Natural History, 1997, pl.II, fig. A; Hachiya and Mizuno, 2004, pl. 8, fig. 48), is a typical *canaliculatus* type form, having deep clear median groove which divides the flanks into outer and inner parts. Ribs on both parts are stout and strong, slightly curved, showing falciform biconcave style as whole. This is certainly not comparable to the present Arimine form. The present form is slightly different, as the ornamentation begins to disappear at the diameter of about 4 cm (outer ribs still persist), then all disappears on the last preserved whorls.

The Arimine species is thereby described as a comparable species of *irregulare*.

Geologic formation and age: Arimine Formation. Middle Oxfordian judged from the associated fauna.

Occurrence: Kami-uwabamidani Valley, Arimine area.

Ochetoceras sp.

Fig. 8

Materials: Three small inner molds, NMNS PM23899, 23900, 23901 (deformed, elliptical), collected in the Kami-uwabamidani Valley, Arimine.

Measurements: Taken at D = 22 mm of NMNS PM23899, UD = 2.5 mm, UD/D = 0.11, H = 12 mm; at 22.5 mm of NMNS PM23900, UD = 2 mm, UD/D = 0.09, H = 12 mm; at D = 32 mm of NMNS PM23901 along the long axis, UD = 3.5 mm, UD/D = 0.11, H = 17 mm, at D = ca 15 mm of NMNS PM23901 along the short axis, UD = 2 mm, UD/D = 0.13, H = 8 mm.

Description: Small, discoidal, very involute

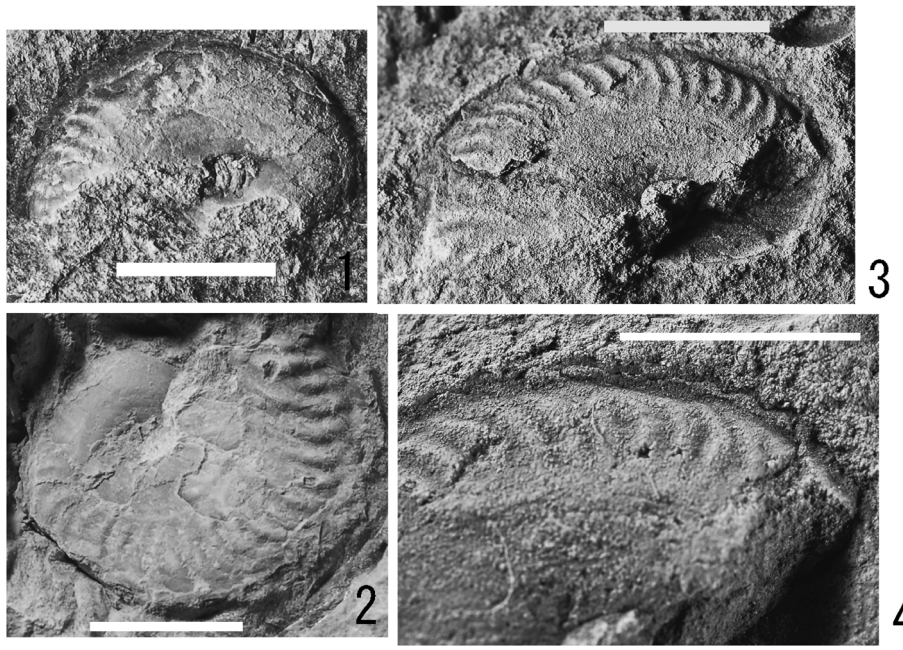


Fig. 8. *Ochetoceras* sp. Scale bar 1 cm. **1**, Lateral view of NMNS PM23899, Kami-uwabamidani Valley, 200 m upstream from the Bridge, Arimine; showing slightly inflated flank. **2**, Lateral view of NMNS PM23900, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **3**, Lateral view of an inner mold of a fragmentary whorl, NMNS PM23901, under the Kami-uwabamidani Bridge, Arimine. **4**, Enlarged view of the ventral part, showing a wavy keel, same specimen as above.

whorls with keeled venter. Ventral keel high, undulated. Flanks slightly inflated; ribs only on the outer flanks, short, concave; no ribs on the inner flanks. No suture-line visible.

Observation: Small, poorly preserved whorls. Partly preserved siphonal keel is observable on the specimen NMNS PM23901 (Figs. 8-3, 4) showing denticulation. Flanks are divided into outer and inner parts by the presence or absence of ribs. On the outer part, ribs are somewhat clearer, gently concave forward, with short intercalated ribs, while on the inner part no ribs of comarable strength but fine prorsiradiate striae are present.

Comparisons and affinities: It is not definite whether the specimens are adult or immature. However, as it is difficult to determine whether or not it belongs to *O*. cf. *irregulare* cited above, because of too poor preservation, then it is here treated as a separate, indeterminable species.

Formation and age: Arimine Formation, Oxfordian.

Occurrence: Kami-uwabamidani Valley, at the foot of the Bridge (PM23901) and a site 200 m upstream from the Kami-uwabamidani Bridge (PM23899 and 23900).

Subfamily Taramelliceratinae Spath, 1928

Genus *Taramelliceras* Del Campana, 1905

Taramelliceras cf. ***costatum*** (Quenstedt, 1849)

Fig. 9

cf. *Ammonites flexuosus costatus*, Quenstedt, 1849, pl. 9, fig. 4; Quenstedt, 1887, pl. 97, figs. 9, 10

cf. *Taramelliceras* (*Taramelliceras*) *costatum*, Hölder, 1955, p. 96, pl. 17, figs. 12, 14.

Material: Two incomplete, nearly adult whorls, NMNS PM23902 and 23903 collected in the Kami-uwabamidani Valley, at a site 200 m upstream from the Kami-uwabamidani Bridge.

Measurement: Taken at D = ca 62 mm of NMNS PM23902, UD = ca 7 mm, UD/D = ca 0.11, H = ca 33 mm; at D = 55 mm of NMNS PM23903, UD = 6 mm, UD/D = 0.11, H = 29 mm.

Description: Shell discoidal, very involute, high oval in section, venter rounded, flanks slightly swelled at the middle. Umbilicus very small. Ribbing prominent, bi-concave on the flanks, with pronounced sharp forward bend (knicks) at the middle flanks; ribbing changes rapidly from fine to strong at the diameter of about 3 cm, though general attitude unchanged; on the outer adult whorls, inner ribs on the inner half of flanks sharp, simple, slightly inclined forward, gently concave backwards; ribs on the outer half also sharp, largely concave forward, biplicate or with free ribs inserted; some ribs looped at the ventro-lateral tubercles. Three rows of tubercles observable, prominent at the ventro-lateral shoulders and on the middle venter, and less at the knick points of ribs. Suture-lines with well developed fitst lateral lobe L1 and second L2, symmetrical and deeply incised.

Observation: Available specimens are small in size, with no aperture preserved, but the living chamber is partly observable. Though the specimens are more or less flattened, the characteristic ornamentation of the *costatum* group of *Taramelliceras* is well preserved; sharp and fine ribbing on the inner whorls, becoming coarser at less than 30 mm in diameter, rather rapidly, as seen clearly on the specimen NMNS PM23903 (Fig. 9-4). Ribbing is biconcave as a whole with sharp angular bent at the middle flanks. Two rows of tiny tubercles are on the flanks, one at the knick points at the mid-flanks and another, somewhat bigger, at the ventro-lateral shoulder; tubercles are not on all the ribs, but periodically on each two or three ribs. On the specimen NMNS PM23902, a row of tiny siphonal tubercles is seen on partly preserved rounded venter. Loops of secondary ribs are formed at some of the ventral-lateral tubercles. Specimen NMNS PM23902 shows parts of the suture-line, which is characterized by stout, straight and deeply incised first lateral lobe L1 and second L2; the whole lines are unfortunately observable on any of the available specimens.

Comparison and affinity: The specimens described here belong to the genus *Taramelliceras* Del Campana, 1905, as indicated by characteris-

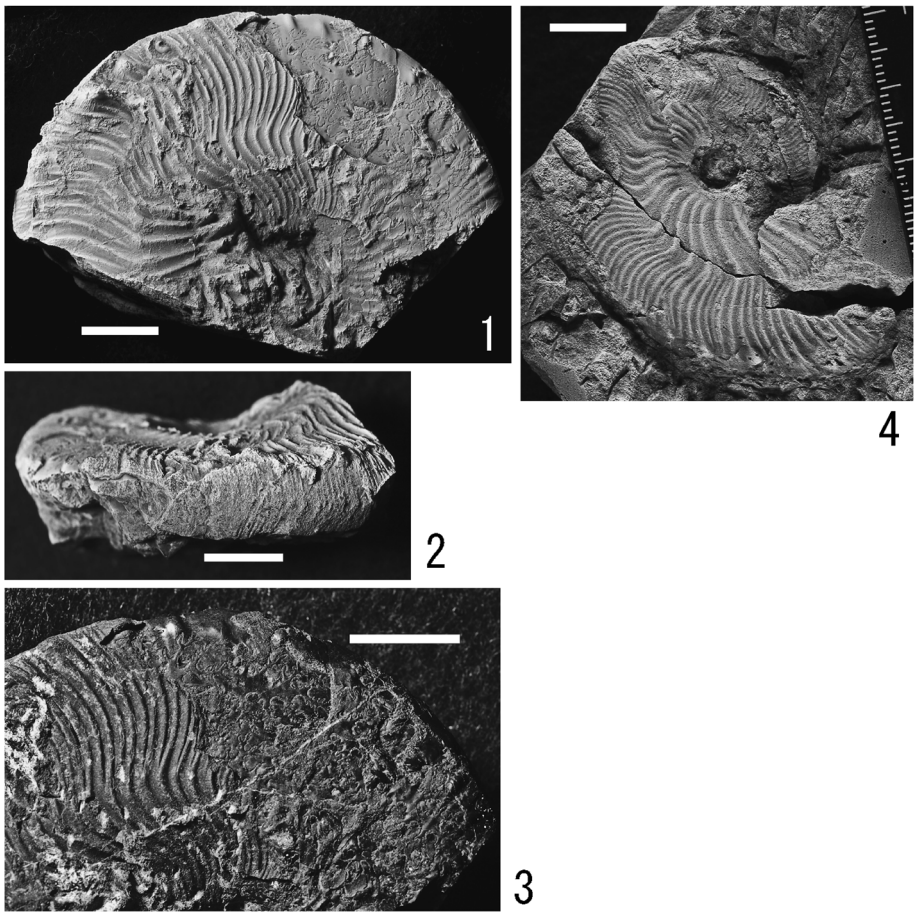


Fig. 9. *Taramelliceras* cf. *costatum* (Quenstedt). Scale bar 1 cm. **1**, Lateral view of the inner mold, NMNS PM23902, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge; showing a row of ventro-lateral tubercles. **2**, Ventral view of the same specimen, showing two rows of ventro-lateral tubercles and ribbed rounded venter between two rows of tubercles. **3**, Enlarged view of the last part of phragmocone, same specimen, showing parts of the suture-lines. **4**, Lateral view of NMNS PM23903, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge; showing finer ribbing on the inner whorls and coarser ribbing on the outer whorls, with prominent tubercles at the outer extremities of some outer ribs.

tic bi-concave ribbing with sharp bent at the mid-flanks, in particular. In addition, rows of rounded tubercles, looping of secondary ribs, rounded venter provided with a median row of small rounded tubercles support this identification. Suture-lines, though observable partly, provided with deeply incised L1 and L2, are affirmative for this identification.

Taramelliceras contains a variety of forms and classified into several groups by shell shapes and ornamentations. Hölder (1955) tried to formulate infra-generic classification, proposing six subgenera basically based on the types of ribbing and tuberculation. The main stock is represented by the group of *Taramellicrars trachinotum* (Oppel), characterized by smooth young stage which changes into the ribbed but not tuberculate intermediate stage and finally to strongly ornamented adult stage. He individualized a group of *Taramelliceras costatum*, based on *Ammonites flexuosus costatus* (Quenstedt, 1849). Later *Amm. flexuosus costatus* (Quenstedt, 1888,

tab. 97, figs. 9a, b, drawing) was designated lectotype by Hölder (1955, p. 96). The photo of the original specimen is shown on his plate 17, fig. 12, on which the real ribbing gives different impression from the above drawing, much more straight than that on the photograph. The Arimine specimens have more flexuous ribbing, which is seen for instance in Hölder's other specimen (pl. 17, fig. 14). *Amm*. *flexuosus* is described and illustrated from other places, *e.g*. Montagnes des Voirons, France (Favre, 1875, pl. 1, figs. 14 a, b), but it is difficult to identify perfectly with the Arimine form in view of much sharper and clearer ribbing at least on the living chamber. Spath (1927) illustrated many species belonging to *Taramelliceras* from Cutch, India. Among the illustrated species, *Taramelliceras jumarense* Spath (p. 143, pl. 17, figs. 4a, b) is somewhat similar in ribbing style, but is less sharp than the Arimine form, possibly because of poorer state of preservation, resulting from slight abrasion.

Among many *Taramelliceras* species described by Quereilhac (2009) from the Vienne region, West France, *T*. (*Taramelliceras*) *takowskii* morph *tarkowskii* [M] (Quereilhac, pl. 9, fig. 3) is morphologically close to the Arimine species, in view of sharply bent bi-concave ribs at the D = 50 mm stage. The ornamentation of this form seems to be smooth at earlier stage as seen on the other specimen (pl. 9, fig. 4).

From the Japanese Jurassic, a few *Taramelliceras* were hitherto described and illustrated from the Somanakamura Group in eastern Fukushima Prefecture; namely, *Taramelliceras* cf. *callicerum* from West of Yamashita (Sato 1962, pl. 10, fig.2), *Taramelliceras* sp. from Koike (Sato, 1962, pl. 3, fig.4), *Taramelliceras* sp. (Hachiya and Mizuno, 2004, pl. 8, fig.50-1, 2, 3) and *Taramelliceras* sp. (Sato and Misaki, 2010, fig.2). However, any of these is not comparable directly with the Arimine species, except Hachiya and Mizuno's *Taramelliceras* sp. which shows somewhat similar ribbing. All these are not well preserved, so that definite identifications are not possible.

Geological formation: Arimine Formation.

Geological age: *Taramelliceras* ranges from Callovian to Kimmeridgian, but the present form, comparable to *T*. *costatum*, is most probably a form of Oxfordian age. This age is not contradictory to the age of other ammonites.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream from the Kami-uwabamidani Bridge.

Taramelliceras sp.

Fig. 10

Materials: Four fragmentary specimens NMNS PM23904, 23905, 23906, 23907 collected in the Kami-uwabamidani Valley at a site 200 m upstream from the Bridge, Arimine.

Remarks: Specimens all fragmentary, but showing characteristic ornamentation of above described *Taramelliceras* cf. *costatum*. Because of the poor state of preservation, definite specific identification is impossible; it is here described as an unidentifiable species. An obliquely deformed specimen NMNS PM23905 is provided with a siphonal row of pronounced rounded tubercles, bordered by a ventro-lateral row of widely spaced strong rounded tubercles. PM23906 shows a row of siphonal tubercles. PM23907 is another specimen showing three rows of tiny tubercles on the ventral region.

Geologic formation and age: Arimine Formation, probably middle Oxfordian in age, suggested by the associated fauna.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Superfamily Perisphinctaceae Steinmann, 1890

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Perisphinctes* Waagen, 1869

Subgenus *Kranaosphinctes* Buckman 1921

Perisphinctes* (*Kranaosphinctes*) *matsushimai (Yokoyama, 1904) [M]

Figs. 11–13

Perisphinctes (*Procerites*) *Matsushimai (sic)* Yokoyama,

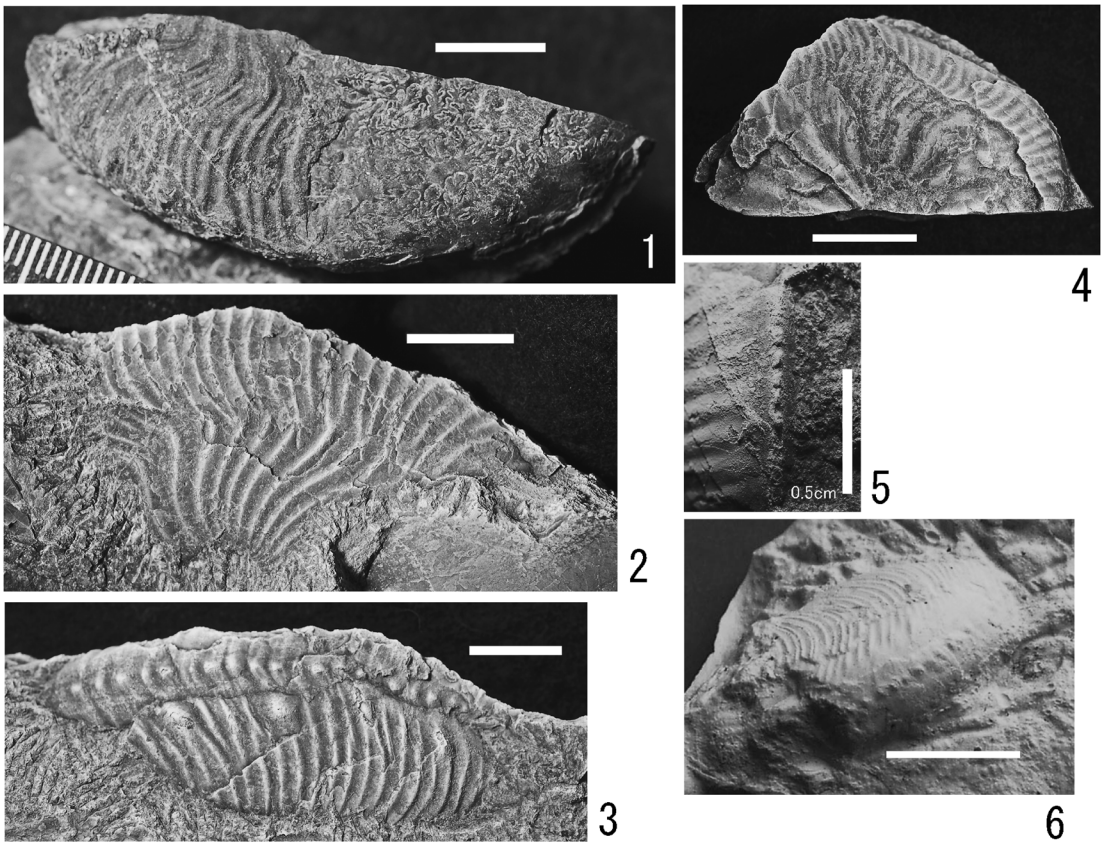


Fig. 10. *Taramelliceras* sp. Scale bar 1 cm, unless stated otherwise. **1**, Lateral view of a part of the phragmocone, NMNS PM23904, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine; showing the suture-lines. **2**, Lateral view of a fragment of phragmocone, NMNS PM23905, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **3**, Oblique view of the ventro-lateral shoulder, same specimen, showing a row of ventro-lateral tubercles. **4**, Lateral view of a fragmentary specimen, NMNS PM23906, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **5**, Ventral view of the same specimen, showing small tubercles on the keel. **6**, Oblique view, NMNS PM23907, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine; showing ventro-lateral region with a row of tiny tubercles.

1904, p. 3, pl. I, fig. 1 (holotype)

Kranaosphinctes matsushimai Yokoyama. Fukada,1949, p.24, pl. 5, fig. 5; Sato, 1962, p. 86, pl. II, figs. 4–8; pl. IX, fig. 7; Suzuki and Sato, 1972, p. 214, fig. 2; Shimonoya and Takahasi, 1990, pl. 24, figs. 2, 3, 4; pl. 25, figs. 1-4; pl. 26, figs. 1–3; Itoigawa Educational Committee, 1996, p. 57, photo 168; Fukui City Museum, 1997, pl. II-D; Hachiya and Mizuno, 2004, pl. 12, figs. 68 (1, 2).

Perisphinctes (*Kranaosphinctes*) cf. *matsuhsimai* Yokoyama, Takahashi,, 1969, p. 75, pl. 13, fig.3; pl. 14, fig.5

Perisphinctes (*Kranasophinctes*)? sp., Takahashi,, 1969, p. 76, pl. 12, fig. 2

Perisphinctes (*Kranaosphinctes*) *matsushimai* Yokoyama. Toyama Paleontological Research Club, 2007, p. 13 (12).

Materials: Ten specimens, NMNS PM23908, 23909, 23910, 23911, 23912, 23913, 23914, 23915, 23916, 23929, all immature whorls, collected from the Kami-uwabamidani Valley of the Makawa River, Arimine.

Measurements: See Table 1.

Description: Planulate, coiling evolute (UD/D about 0.5), with open umbilicus, overlapping only the ventral part of the preceding

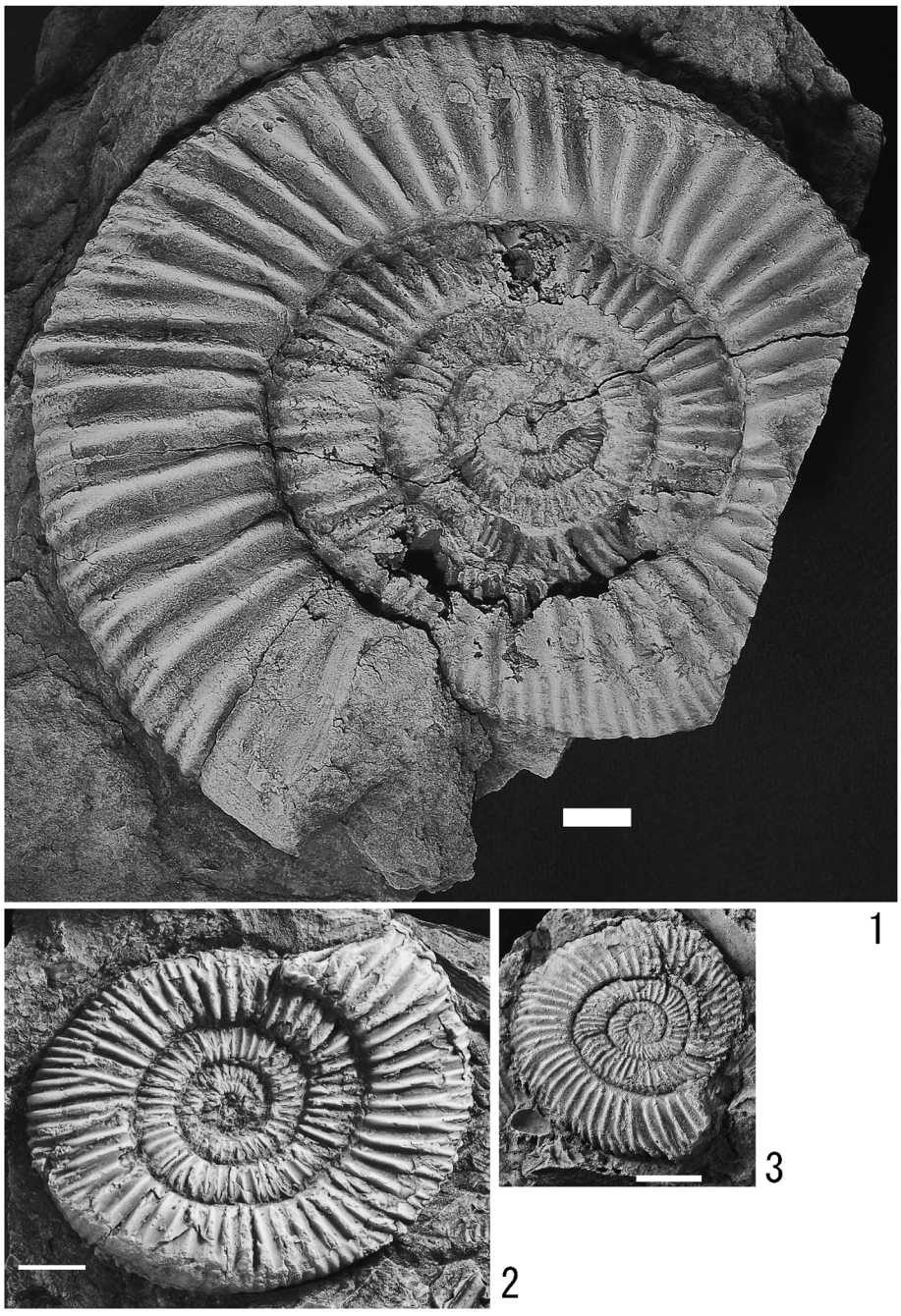


Fig. 11. *Perisphinctes* (*Kranaosphinctes) matsushimai* (Yokoyama), [M]. Scale bar 1 cm. **1**, Lateral view of an almost complete specimen, NMNS PM23908, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **2**, Lateral view of the phragmocone, NMNS PM23909, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **3**, Lateral view of an immature whorls, NMNS PM23910, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine; showing deep oblique constrictions..

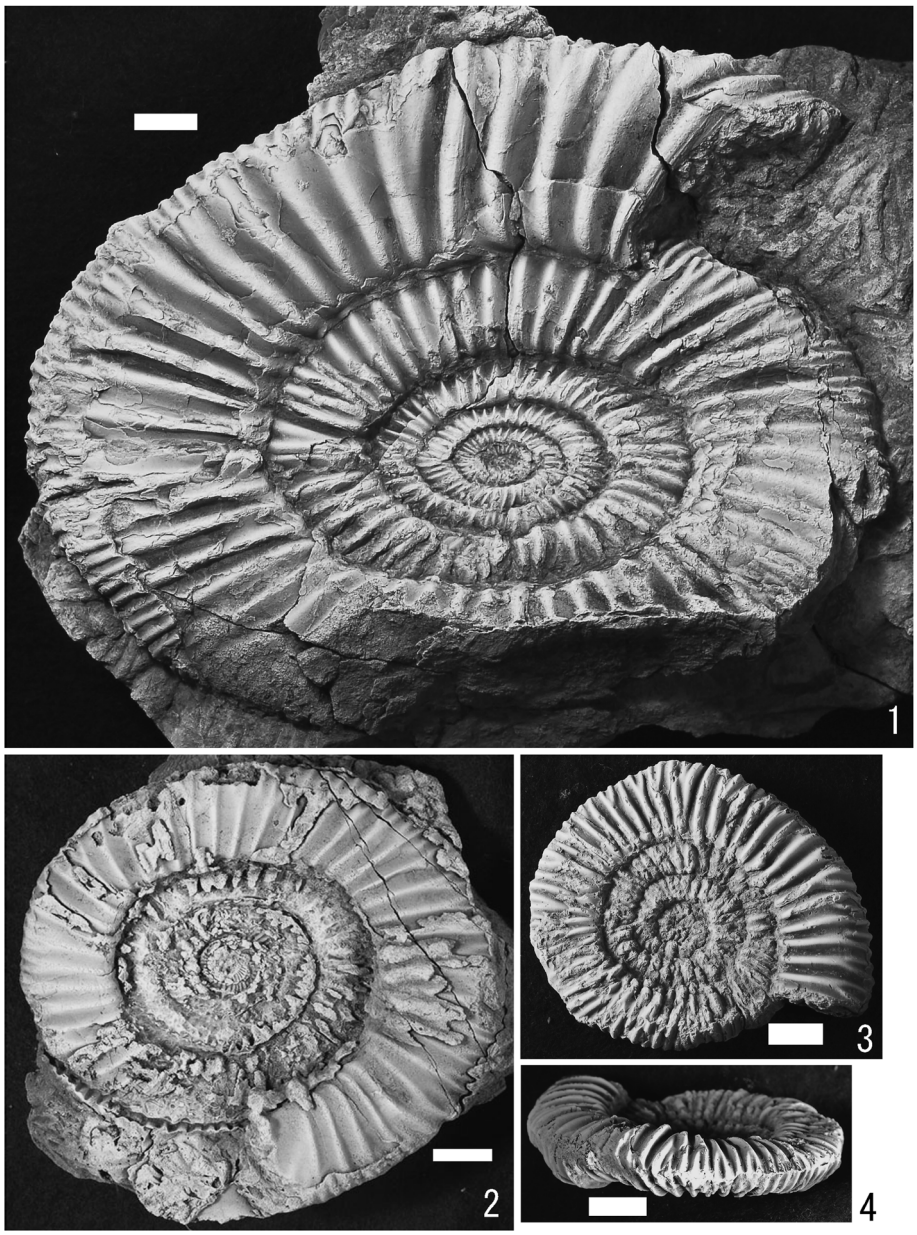


Fig. 12. *Perisphinctes* (*Kranaosphinctes) matsushimai* (Yokoyama), [M]. Scale bar 1 cm. **1**, Lateral view of an immature shell, NMNS PM23911, slightly deformed, aperture not preserved, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **2**, Lateral view of an almost complete specimen, NMNS PM23912, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine, with living chamber preserved; shell material partly preserved. **3**, Lateral view of an immature whorls, NMNS PM23913, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **4**, Ventral view of the same specimen, showing strongly ribbed ventral region.

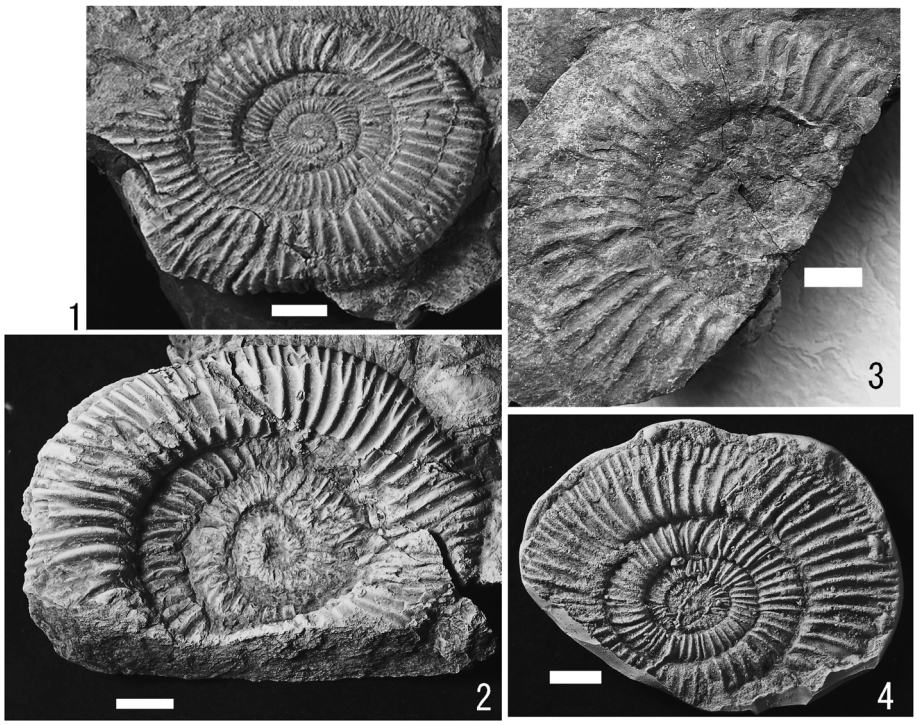


Fig. 13. *Perisphinctes* (*Kranaosphinctes*) *matsushimai* (Yokoyama), [M]. Scale bar 1 cm. **1**, Lateral view of an inner mold of immature shell, NMNS PM23914, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine, slightly deformed, showing regularly bifurcate ribbing. **2**, Lateral view of a phragmocone of slightly deformed shell, NMNS PM23915, Kami-uwabamidani Valley, 200 m upstream of the Kami-uwabamidani Bridge, Arimine. **3**, Lateral view of an inner mold, NMNS PM23916, Inone-dani, Arimine area. **4**, Lateral view of the silicon cast taken from the specimen PM23929, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine.

Table 1. Measurements (in mm) of herein described *Perisphinctes* (*Kranaosphinctes*) *matsushimai* (Yokoyama) [M] from the Arimine area.

Specimen no.	D	UD	UD/D	H	W
NMNS PM23908	122.5	64	0.52	35.5	ca 22
NMNS PM23909	69	34.5	0.50	6	—
NMNS PM23910	37	18	0.48	10	—
NMNS PM23911 (along the long axis)	125	60	0.48	31	ca 25
NMNS PM23911 (along the short axis)	ca 99	47	ca 0.47	36	—
NMNS PM23912	82	43	0.52	23	ca 16.5
NMNS PM23913	60	30	0.50	5	—
NMNS PM23914	ca 70	38	ca 0.54	—	—
NMNS PM23915	80	43	0.53	ca 23	—
NMNS PM23916	ca 65	30	ca 0.46	ca 21	—
NMNS PM23929	62	33.5	0.54	ca 14	—

whorls. Whorl shape and its ornamentation gradually change following growth. Whorl section compressed oval. In earliest stage, up to about 3 cm in diameter, ribbing fine, densely spaced, straight, slightly inclined forward. In intermediate stage, about 3 to 8 cm in diameter, primary ribs dense, radiate, sharp, bifurcated regularly. In adult stage, more than ca 8 cm in diameter, ribs

rounded, bi- or tri-furcated; free ribs intercalated. Constrictions narrow but deep, slightly oblique to ribbing, accompanying single ribs behind. Venter rounded, with no furrows or keels. Aperture simple, accompanying narrow smooth band. Living chamber about three fourths of whorl in length. Suture-lines with prominent, deep, well incised lobes.

Observation: All the studied specimens are not complete, representing either living chamber or phragmocone, except the specimen PM23908 (Fig. 11-1) which is nearly complete as shown by a smooth band before the aperture. Some other specimens, PM23908, 23911, 23912 for instance, are well preserved and reach the adult stage, though not complete. All show the gradual change of the whorl shape and ornamentation, indicating that the present form belongs to the subgenus *Kranaosphinctes* of the genus *Perisphinctes*, as supported by other features such as sharp, dense ribs, which are regularly bi- or tri-furcated at the ventro-lateral shoulder, by obliquely running deep constrictions, by long and deeply incised lateral lobes and so on. Many of the specimens at hand are inner mold impressed on the muddy matrix and more or less compressed by *post-mortem* compression, though most parts retain the original features.

Comparison and affinity: The Arimine specimens studied herein are judged to be conspecific with *P*. (*Procerites*) *Matshushimai* (*sic*) described and illustrated by Yokoyama (1904, p. 86, pl. I, fig. 1). This species was later reclassified as a species of *Kranaosphinctes* by Fukada (1949), and this generic assignment has been thereafter adopted by later authors. The holotype is slightly deformed and not completely preserved, but its size (about 12 cm in diameter) is comparable with the best preserved specimen (PM23908) of the present collection, which shows the part just behind the aperture. On this specimen, following characteristics are observable: the ribs on the living chamber count about 50, which falls in the supposed range of the rib number of the holotype; constrictions are also deep, slightly oblique forward in both holotype and the present specimen: ribbing on the living chamber, somewhat rounded and mostly tri-furcate, is as on the holotype. The whorl shape and ornamentation of this specimen changes gradually from the immature stage to the adult stage, one of the most important characteristics of the subgenus *Kranaosphinctes*, as discussed by Arkell (1935) and adopted by almost all later authors.

As pointed out repeatedly by various authors, *Perisphinctes* comprises a wide range of varieties, and many authors tried to split it into various subgenera. *Kranaosphinctes* is one of these subgenera, characterized by gradually changing ornamentation. *Per*. *matsushimai* belongs to this group of forms. All the specimens here described and illustrated are devoid of lappets, thus judged to be macroconchs.

Geologic formation and age: Arimine Formation. Middle Oxfordian.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream of the Kami-uwabamidani bridge.

Subgenus *Dichotomosphinctes* Buckman, 1926

Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis Sato, 1962 [m]

Figs. 14, 15

Dichotomosphinctes kiritaniensis (Naruse MS), Sato, 1962, p. 88–89, pl. VIII, figs. 1, 2, 6, 11; Shimonoya and Takahashi, 1990, p. 27, pl. 27, figs. 1–3; Itoigawa Educational Committee, 1996, p. 58, photos 171; Hachiya and Mizuno, 2004, p. 12, pl. 12, figs. 69-1, 2; Sato, 2008, p. 97, p. 100.

Perisphinctes (*Dichotomosphinctes*) *kiritaniensis*, Toyama Paleontological Research Club, 2007, p. 14, figs. 1–2.

Materials: Seven specimens collected from various localities of the Arimine area, NMNS PM23917 (compressed), 23918, 23919, 23920, 23921, 23922, 23923 (strongly deformed).

Measurements: See Table 2.

Description: Shell of moderate size, coiling involute (UD/D about 0.40), whorl section high ellipsoidal, umbilical border sharp but rounded, ventral region rounded, four to five deep oblique

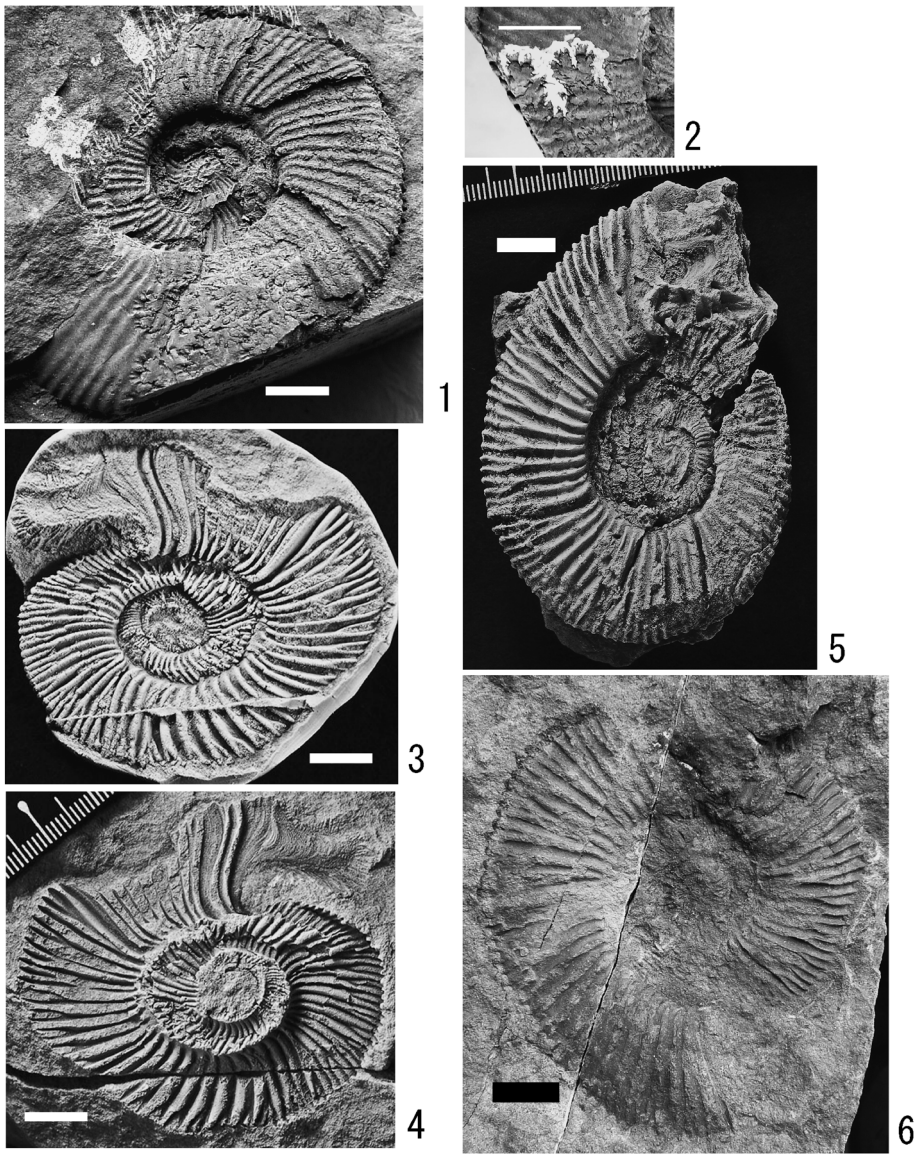


Fig. 14. *Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis* Sato [m]. Scale bar 1 cm. **1**, Lateral view of an inner mold, NMNS PM23917, right river bank at the foot of the Kami-uwabamidani Bridge, Arimine; showing suture-lines exposed at the terminal part of the phragmocone; the beginning part of the living chamber preserved. **2**, Enlarged view of the end of phragmocone of the same specimen, showing long L1 and a part of umbilical lobes. **3**, Lateral view of a rubber cast taken from the outer mold, NMNS PM23918 (collection unknown), Makawa Valley, Arimine, showing lateral lappets. **4**, Lateral view of the outer mold of the same specimen. **5**, Lateral view of a slightly deformed, adult specimen with lateral lappets, NMNS PM23919, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. **6**, Lateral view of the an inner mold, NMNS PM23920, right river bank at the foot of the Kami-uwabamidani Bridge, Arimine.

constrictions per whorl, cutting obliquely normal ribs; ribbing sharp, dense, rectiradiate, about 50 primary ribs on a whorl, regularly bifurcate at ventro-lateral shoulder but simple ribs intercalated rather frequently. Aperture accompanied with short, spatula-shaped lappets, after wide

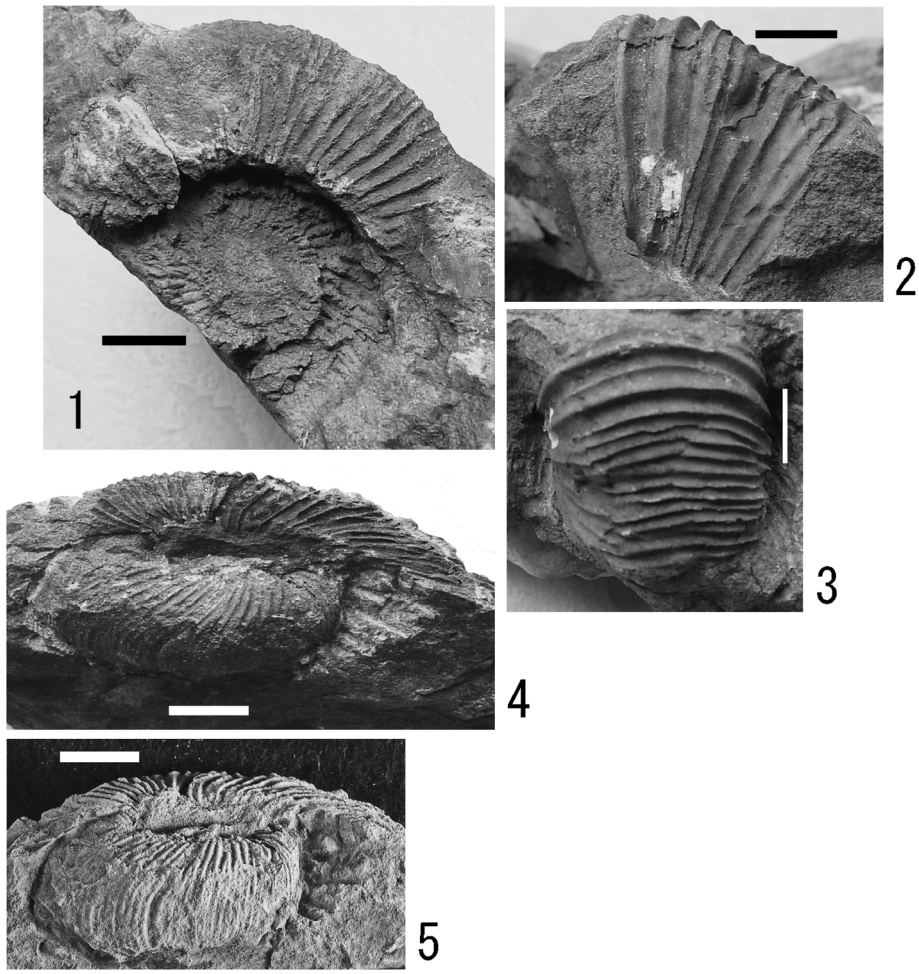


Fig. 15. *Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis* Sato [m]. Scale bar 1 cm. **1**, Lateral view of a part of the adult whorl with lappets preserved, NMNS PM23921, float under the Kami-uwabamidani Bridge. **2**, Lateral view of NMNS PM23922, Makawa main stream, showing the apertural part, bordered by a wide constriction with two strong simple ribs and a fine rib inside. **3**, Ventral view of the same specimen, showing finely ribbed ventral region, with wide constriction. **4**, Oblique view of deformed immature whorls, NMNS PM23923, float under the Kami-uwabamidani Bridge. **5**, Ventral view of the same specimen, showing regular ribbing with a narrow but deep constrictions.

Table 2. Measurements (in mm) of herein described *Perisphinctes* (*Dichotomosphinctes) kiritaniensis* Sato [m] from the Arimine area.

Specimen no.	D	UD	UD/D	H	W
NMNS PM23917	67	25	0.37	26	ca 6
NMNS PM23918	62	25	0.40	ca 23	—
NMNS PM23919 (along the long axis)	83	32.5	0.40	28	—
NMNS PM23919 (along the short axis)	58	23.5	0.41	20	—
NMNS PM23920	65.5	26	0.4	ca 25	—
NMNS PM23921	ca 50	—	—	—	—
NMNS PM23922	—	—	—	ca 29	ca 25
NMNS PM23923	ca 50	—	—	—	—

irregularly spaced strong ribs with deep constriction. Suture-lines typically Perisphinctoid, deeply incised, with long lobes and wide saddles; enveloping curve gradually declined toward umbilical suture; siphonal lobe E long, bipartite, first lateral saddle S1 wide, first lateral lobe L1 longer than others, second lateral saddle S2 wide and bipartite, accessory lobes gradually declined.

Observations: Available specimens are more or less deformed and flattened. The specimen NMNS PM23919 (Fig. 14-5) is almost completely preserved, about 80 mm in diameter (deformed, measured along the long axis of the ellipse), and shows essentially identical characters with the holotype of the species (Sato, 1962, pl. VIII, fig. 2), such as essentially unmodified ornamentation, sharp ribbing, regularly bifurcating primary ribs (with free inserted ribs on the living chamber), deep constrictions. This specimen is provided with prominent spatulate lateral lappets, which are not observable on the holotype. This corroborates the generic and subgeneric attribution of the species to *Perisphinctes* (*Dichotomosphinctes*).

Other specimens illustrated here show basically the same characteristics, though there are some differences of ribbing features and shape of lappets. The specimen NMNS PM23918 (Figs. 14-3, 4) is of moderate size (about 62 mm in diameter) and the last part of the living chamber is provided with somewhat longer lappets with deep wide constriction at the base, accompanied with strong, simple ribs.

Other specimens, NMNS PM23920 (Fig. 14-6), PM23921(Fig. 15-1), PM23923 (Figs. 15-4, 5) are more or less deformed, but the observable characters are all indicative of the species *kiritaniensis*. The specimen PM23922 (Figs. 15-2, 3) is a fragment of the apertural part of whorl, showing the extraordinary ribbing at the apertural border, similar to the specimen PM23918 (Figs. 14-3, 4).

Comparison and affinity: The holotype of this species was discovered from an isolated locality in Kiritani, about 30 km to the west of the present locality. It is an incomplete specimen, compressed and deformed to elliptical form, but shows diagnostic characters of *Dichotomosphinctes*, such as sharp and dense ribbing with acutely bifurcated ribs with frequently inserted simple ribs. The type species of this subgenus is *P*. (*D*.) *antecedens* (Salfeld, 1924), but the present species is more akin to the finely ribbed group of *P*. (*D*.) *elizabethae* (de Riaz, 1898), as discussed previously (Sato, 1962, p. 89). *P*. (*D*.) *elizabethae* described and illustrated by Enay (1966), Gygi (2001) and Pandey *et al.* (2012) are bigger in size, thereby not identifiable with the present species. In conclusion, the present Arimine specimens are identified to be *P*. (*D*.) *kiritaniensis*.

Remarks: As indicated by the presence of lappets (specimens NMNS PM23918 and 23919), the present species represents a microconch. Corresponding macroconch could be either *Perisphinctes* s. s. as suggested by Enay (1966), which is present in the Arimine area (Sato *et al.*, 2012), or *Kranaosphinctes*, rich in number in the present fauna. However, it is impossible to decide as usual.

Geological formation and age: Arimine Formation. Middle Oxfordian.

Occurrence: Makawa main stream (PM23921, 23923), its tributary Kami-uwabamidani (PM23917, 23919, 23920), and unidentified locality (PM23918), all in the Arimine area.

Perisphinctes (Dichotomosphintes) sp. [m]

Fig. 16

Material: A specimen of which the last whorl dislodged, NMNS PM23924.

Measurement: Taken at D = 62 mm (along long axis), UD = 25 mm, UD/D = 0.40, H = ca 23. D = ca 59 m along short axis.

Description: Shell of moderate size, coiling involute (UD/D about 0.40), whorl section high oval, three to four deep oblique constrictions per whorl, cutting obliquely normal ribs and accompanied with two ribs joined together at the umbilical margin; ribbing stout, dense, rectiradi-

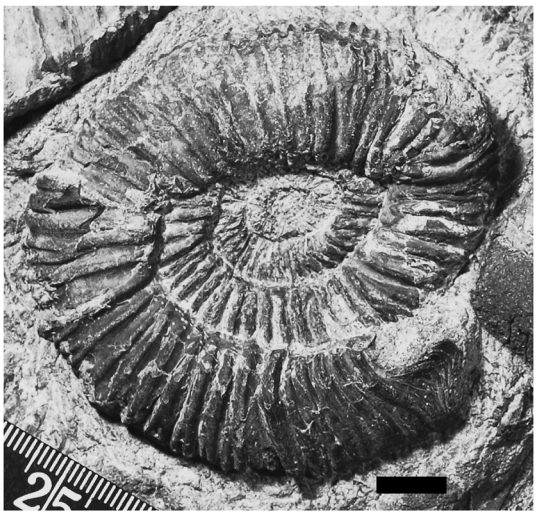


Fig. 16. *Perisphinctes* (*Dichotomosphinctes)* sp. [m]. Scale bar 1 cm. Lateral view of an inner mold, NMNS PM23924 from Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, obliquely deformed, showing the last preserved whorl displaced onto the inner whorls; lateral lappets preserved.

ate, about 40 primary ribs per whorl, mostly bifurcate at ventro-lateral shoulder but simple ribs intercalated rather frequently. Aperture accompanied with short, spatulate lappets, with crescentic growth lines. Suture-lines not clearly visible.

Observation: This is a deformed specimen, with the last part of phragmocone dislodged from the original position to overlap the inner whorls. The general feature of the shell is however well observable. Aperture with spatulate lappets. Ornamentation of the shell is relatively stouter than the previous species, though the basic characters are similar.

Comparison: Basic composition of the shell is similar to previously described *Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis*, except for much thicker and stouter ornamentation. Specific identification is difficult because of poor state of preservation and few number of available specimens, so that it is cited here as an undeterminable species of *P*. (*Dichotomosphinctes*).

Geologic formation and age: Arimine Formation, middle Oxfordian.

Occurrence: Kami-uwabamidani Valley, a site 200 m upstream of the Kami-uwabamidani Bridge, Arimine area.

Genus *Subdiscosphinctes* Malinowska, 1972

Subdiscosphinctes hachiyai sp. nov. [M]

Figs. 17–21

Lithacoceras nov. sp., Sato, 1962, p. 91, pl. IX, figs. 1a, b, c.
cf. *Lithacoceras onukii* Takahashi, 1969, p. 78, pl. 13, figs. 2, 4; pl. 14, fig. 4.

Material: Three specimens including an almost complete macroconch NMNS PM23925 and two immature whorls, PM23926 and 23927.

Type specimens: Holotype, NMNS PM 23925 (Figs. 17–19). Paratypes, immature whorls NMNS PM23926 and 23927 from the same locality as that of the holotype.

Derivation of the name: in honor of Mr. K. Hachiya, finder of the holotype and paratypes.

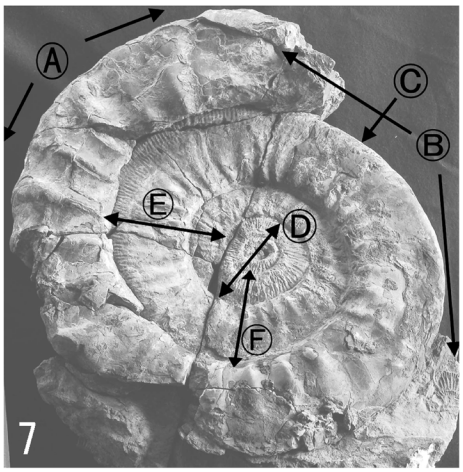
Measurements: See Table 3.

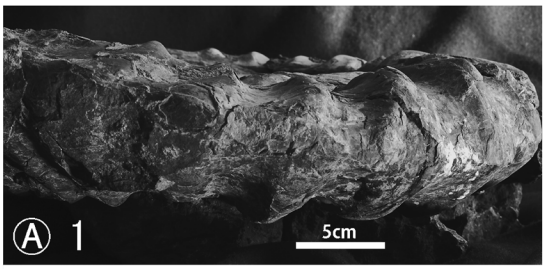
Diagnosis: Serpenticone of big size, developing in three successive growth stages, each having different whorl shape and ornamentation. First juvenile costate stage (less than about 15 cm in diameter) characterized by moderate coiling, whorls with sharp constrictions, dense, sharp ribbing, irregularly bifurcate at different levels of whorl flanks; second fasciculate ribbing stage (about 15–25 cm in diameter) characterized by whorls with deep oblique constrictions accompanied with irregular polygyrate ribs behind, high oval whorl section, ribbing composed of distant, coarse primary ribs, with tuberculate endings at the umbilical border and of fine, dense rectiradiate secondary ribs on the outer flanks, fasciculate at the middle of flank; third coarse ribbing stage (more than about 25 cm in diameter) characterized by evolute coiling, rounded quadrate whorls, coarse, distant, ridge-shaped ribbing. Suture lines of Perisphinctoid type, with deeply indented lobes and saddles.

Description: The species is a planulate evolute Perisphinctid, big in adult stage, reaching

Fig. 17. *Subdiscosphinctes hachiyai*, nov. [M]. Holotype, NMNS PM23925. Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 5 cm. Lateral view, showing three stages of development in one specimen (cf. Fig. 18).

Fig. 18. *Subdiscosphinctes hachiyai*, nov. [M]. Holotype NMNS PM23925. Scale bar 1 cm. except for 18-1 and 18-2 (5 cm.). Representative parts of developmental stages are shown separately. Locations of parts A–F (Fig. 18-1 to 18-6) are indicated in Fig. 18-7. **1**, Ventral view of the last part of the preserved whorl A, showing elevated rounded ridge-like ribs passing over the ventral region. **2**, Ventral view of the last part of the phragmocone B, showing suture-lines exposed on the inner mold, where the shell material is removed. **3**, Lateral view of the innermost preserved whorl D (1st stage), showing generally fine rectiradiate ribbing, bifurcated at various heights of flanks, including at the umbilical border; intercalatory simple ribs also present. **4**, Cross section across the last part of the phragmocone C. **5**, Lateral view of the whorls F of first and second stages, showing fine dense ribs of the first stage at right and swelled primary ribs and fasciculate secondaries of the second stage at left. **6**, Lateral view of the first and second stage whorls E. Fine, dense rectiradiate ribs of the first stage at right and swelled ridge-like primary ribs and exposed suture-lines of the second stage at left.





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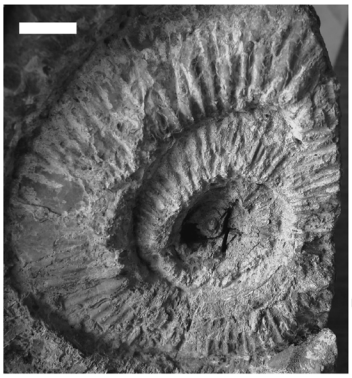

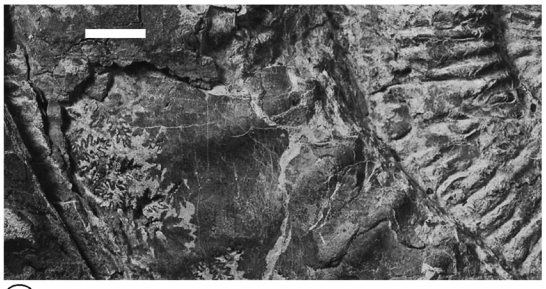

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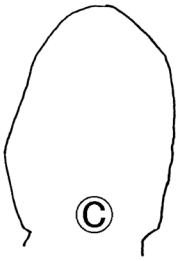

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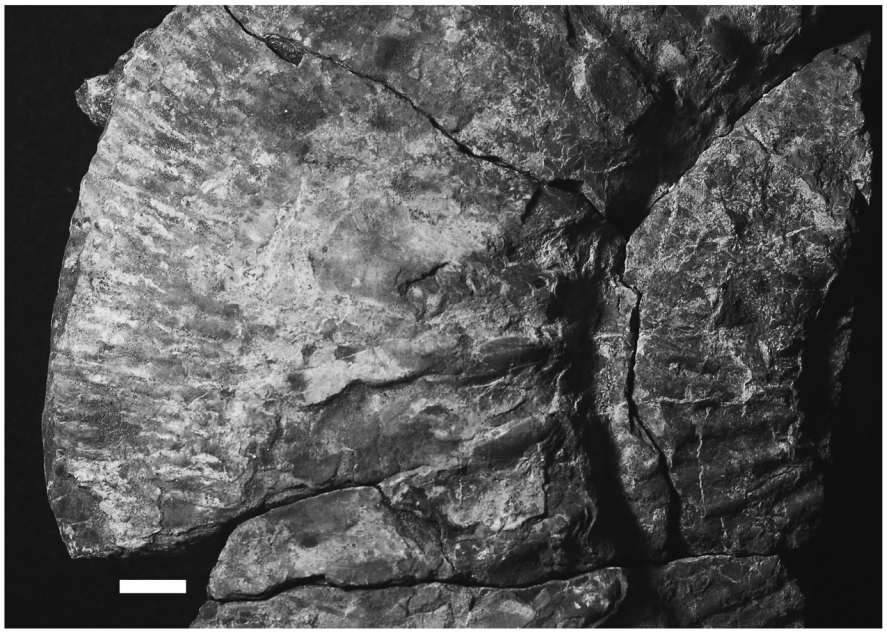

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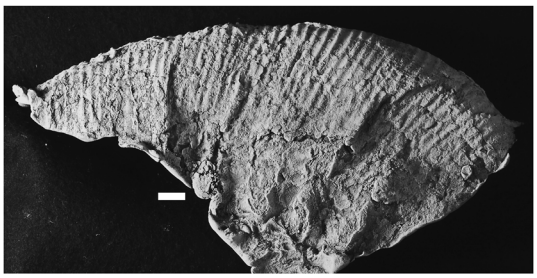

Fig. 19. *Subdiscosphinctes hachiyai* nov. [M]. Lateral view of the immature (second stage) whorl of the holotype, showing distant primary ribs and fasciculate secondary ribs. Rubber cast taken from the holotype. Scale bar 1 cm.

about 40 cm in diameter, developed through three morphologically different stages. The first stage is represented by moderately involute (UD/D about 0.4) whorls, with sharp, dense, rectiradiate and mostly bifurcate ribbing. The points of bifurcation is characteristically at various levels of flanks, including at the umbilical border. Simple ribs are often intercalated. Number of primary ribs per whorl is around 30. Sharp deep constrictions exist, slightly inclined forward, accompanied with irregular, trifurcate or polygyrate ribs behind. These characteristics are well represented in immature whorls of the holotype and paratypes (see for instance Figs. 18-3, 21-1).

The second stage is characterized by high, compressed, oval whorls, ornamented with fasciculate ribbing,without sharp point of bifurcation, forking from coarse, distant, rounded primary ribs, which are blunt, rounded at the top, terminating with markedly raised ridges at the umbilical region. Change of ribbing style occurs rather abruptly. Coiling is slightly more evolute than in the first stage (UD/D higher than 0.4). Within the umbilicus of the holotype, whorls of this stage is observable (see Fig. 17).

The third stage attains big size, and the whorls are more quadrate in section, and the coiling is distinctly evolute (UD/D more than 0.5); in this stage ribbing is composed only of distant, blunt ridges about 30 in number per whorl, without distinction of inner and outer ribs. Ventral region is almost smooth. Ridges pass the ventral region without furrow or keel. The general shape of the whorls of this stage reveals the adult whorls of *Perisphinctes* s.s. The last whorl of the holotype shows an example of this type of ribbing (see Fig. 18-1). Some fragments, dislocated from the holotype and discovered separately, show the same whorl shape. The whorl section is less compressed and short elliptical in shape (see Fig. 18-4). The change of the whorl shape and ornamentation occurs after a deep sharp constriction (see Fig. 17).

Apertural region is likely to be simple, without lappets. Suture-lines are of typical Perisphinctoid type, with long, deeply incised lobes and inclined enveloping curve.

Observation: The holotype is well preserved and all three growth stages are observable in one specimen. The whole shape is illustrated on Fig. 17. The first stage, represented here by the inner whorls D in Fig. 18-3 where characteristic fine, rectiradiate ribbing of the first stage is observable. Its position on the holotype is indicated by the same symbol D in Fig. 18-7, the second stage is here represented by the whorls F in Fig. 18-6 and Fig. 19, which show characteristic fasciculate ribbing of this stage; inner primary ribs are coarse and thick and less numerous compared to the that of the first stage. The last, senile stage is represented by the outermost whorl of the holotype (Fig. 17); coarse ridge-like swells in this stage is shown by the last part of the whorl A in Fig. 18-1, its position being indicated by A in Fig. 18-7. Though the apertural region is not completely preserved, the holotype seems to be adult, as suggested by its overall size and degeneration of ornaments. It should be considered to be a macroconch.

Paratypes are all incomplete (apertures lost), but relatively well preserved. Paratype NMNS PM23926 (Figs. 20) was collected from the same site as the holotype, and another PM23927 (Figs. 21) was discovered attached to the same slab of the holotype. Both specimens are judged to represent the first and the beginning part of the second stage of development, judged by the size

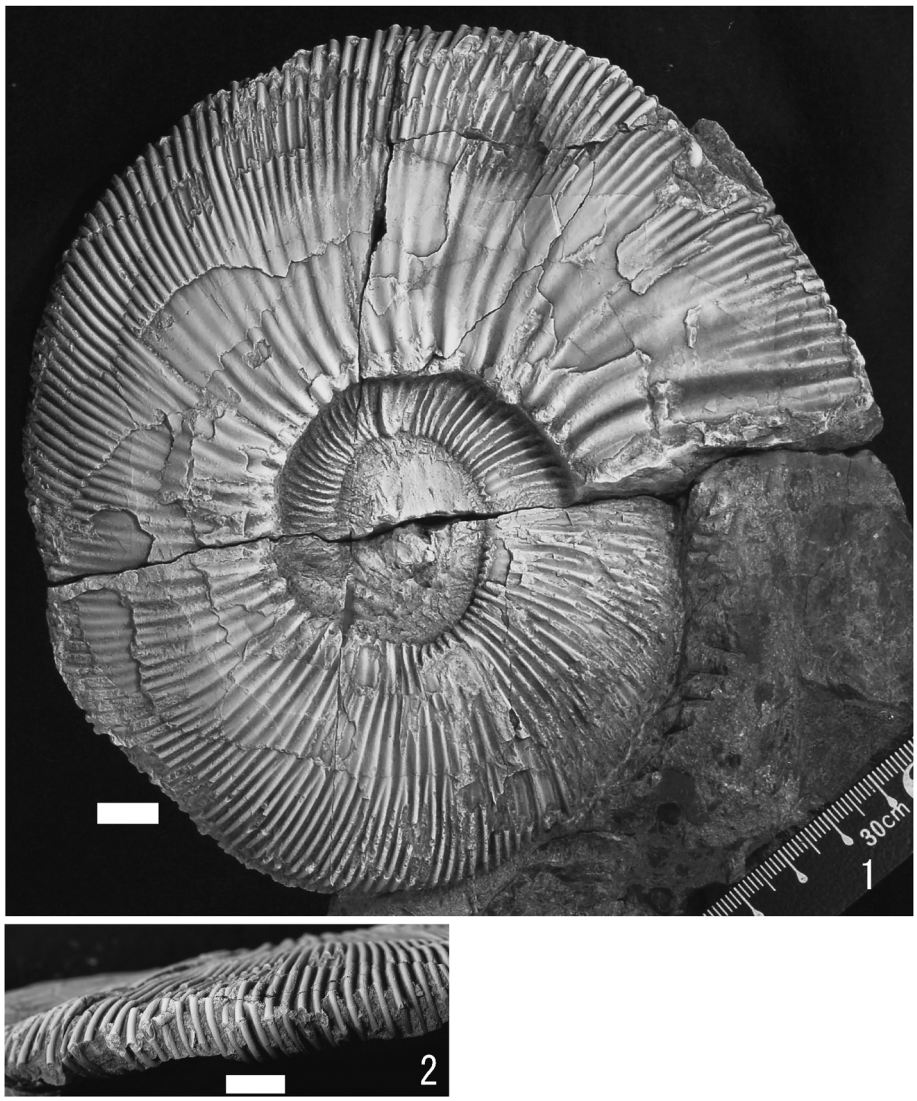

Fig. 20. *Subdiscosphinctes hachiyai* nov. [M]. Paratype, NMNS PM23926, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 1 cm. **1**, Lateral view, showing the second stage of development, with ribs bifurcated at various heights of flanks in the intermediate whorls, and swelled primaries and fasciculate or polygyrate secondaries in the outer whorl.. **2**, Ventral view of the last part of preserved whorl.

(about 15 cm in diameter) and ornamentation. Paratype PM23926 (Fig. 20) is strongly compressed, and superficially looks involute (UD/D about 0.34), but this could be resulted from flattening after burial. Both specimens show narrow but deep constrictions, oblique to the general ribbing, and accompanied with irregularly bifurcate ribs on the back side; this is especially well observable on the specimen PM23927 (Fig. 21). Ribbing on these specimens is characterized by polygyrate furcation, which takes place at various heights of the flanks. Some are bifurcated even near the umbilical border.

Comparison and Affinity: The biggest specimen, designated holotype of the species, superficially resembles *Perisphinctes* s. s. in Arkell's (1935) sense, but closer observation clarifies that it is different, by irregular ribbing

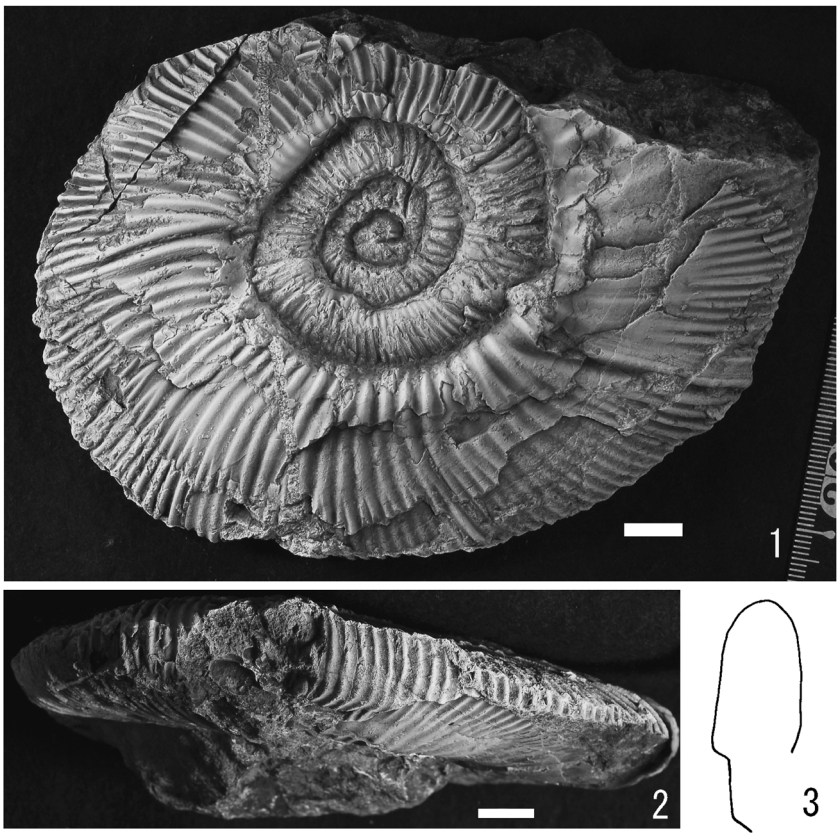

Fig. 21. *Subdiscosphinctes hachiyai* nov. [M]. Paratype, NMNS PM23927, Kami-uwabamidani Valley, 200 m upstream from the Kami-uwabamidani Bridge, Arimine. Scale bar 1 cm. **1**, Lateral view of the immature whorls (first stage and transient part to the second stage). **2**, Ventral view of the last part of the preserved whorl. **3**, Cross section at the last part of the preserved whorl.

Table 3. Measurements (in mm) of herein described *Subdiscosphinctes hachiyai* sp. nov. from the Arimine area.

Specimen no.	D	UD	UD/D	H	W	R1/W	R2
NMNS PM23925	401	222	0.55	88	—	29	—
NMNS PM23925	250	105	0.42	87	50	29	—
NMNS PM23925	120	50	0.42	31.5	—	ca 50	—
NMNS PM23925	ca 55	23	ca 0.42	—	—	ca 50	—
NMNS PM23926	143	49	0.34	52	—	55	—
NMNS PM23927	133	51	0.38	47	—	58	＞96

characterized by polygyrate and fasciculate furcation. In its first juvenile stage, ribbing is fine, dense rectiradate but is furcated at various levels of flanks, some are divided at the umbilical border, and others at the middle. Points of furcation are generally sharp but some are obscure. This stage changes over to the second stage characterized by fasciculate ribbing. In this stage, the primaries are generally blunt, rounded at the top, and divided into numerous finer secondaries at the middle of the flank. This stage passess to the last senile stage characterized by rounded high ridges, after a strong, sinuous constriction. These characteristics suggest that this is a species of *Subdiscosphinctes*.

Subdiscosphinctes was created by Malinowska

in 1972 as a subgenus of *Lithacoceras* Hyatt, with *Lithacoceras* (*Subdiscosphinctes*) *kreutzi* (Siemiradzki) as the type species. She placed it in the Prisphinctidae. In 1975, Brochwicz-Lewinski elevated its rank to a genus and subdivided into two subgenera; *Subdiscosphinctes* for microconches and *Aureimontanites* for macroconches. Later Hantzpergue (1989) ignored these subgenera and admitted only one genus, *Subdiscosphinctes*, including both micro- and macroconches within the genus. He retained the family Perisphinctidae Steinmann, 1890 for the genus. He thoroughly studied representative species of the genus, including *S. grandiplex* (Quenstet), *S. castroi* (Choffat) and *S. orbignyi* Hantzpergue, known from SW France and Portugal. He distinguished three developmental stages (initial, intermediate, and terminal) in *S. grandiplex*. The growth through successive developmental stages is the most important character of the genus, which is clearly recognized in the present species, as described above.

Until now, some 24 species attributed to *Subdiscosphinctes* are described and illustrated. Among these, *S. grandiplex* (Quenstedt) [M] (cf. Hantzpergue, 1989, pl. I, b) is closely akin to the Arimine species. The holotype of this species shows distinct three developmental stages and the last whorl attains almost as large as *S. hachiyai.* Hantzpergue figured also a smaller and regularly ribbed specimen on the same plate (Hantzpergue, 1989, pl. I, c) which was considered to be the microconch of the same species. It is not a complete specimen, but shows a short lappet on the mid-flank, limited by a deep straight constriction. But this type of forms is not confirmed in any of the Arimine collection. There is no other similar species of *Subdiscosphinctes*, as far as the authors could see on the published papers. Therefore the author decided to create a new species on the material available.

Fig. 22. *Subdiscosphinctes* sp. juv. Silicon cast of the inner mold NMNS PM23928, Arimine, detailed locality unknown. Lateral view of a part of the phragmocone, showing polygyrate fine ribs and constrictions. Scale bar 1 cm.

Lithacoceras nov. sp. illustrated in Sato (1962, pl. IX, figs. 1a–c) is an incomplete but rather well preserved specimen from Kiritani, which is an involute, constricted whorls characterized by fine, rectiradiate ribs, some of which are polygyrate. The primaries are somewhat coarse on the lower third of flanks. This is not distinguishable from the paratype PM23927, therefore it should be transferred to *Subdiscosphinctes.* Other species from the Jurassic of the Ojika Peninsula, described as *Lithococeras by* Takahashi (1969) is also similar in whorl shape and ornamentation to *Subdiscosphinctes*. They are possibly other representatives of this genus from Japan.

Occurrence: A shale lens of sandstone exposed in Kami-uwabami Valley, at a site 200 m upstream from the Kami-uwabamidani Bridge.

Geological Formation: Arimine Formation.

Geological age: The genus *Subdiscosphinctes* ranges from middle Oxfordian (Plicatilis Zone) to early Kimmeridgian (Cymodoce Zone) according to Hantzpergue (1989). In the case of the Arimine Formation, it is midde to late Oxfordian judged from the accompanied genera, such as *Ochetoceras* and *Taramelliceras*.

Subdiscosphinctes sp.

Fig. 22.

*Materia*l: A part of an immature whorl, NMNS PM23928, Arimine.

Measurements: Maximum length of the whorl = ca 60 mm, H = 28 mm.

Description: A framgent of septate whorl,

flatly compressed, with sharp narrow constriction accompanied with dichotomous rib behind; ribbing dense, rectiradiate, variously furcate, including polygyrate.

Remarks: This is a fragment of immature whorl, with poorly observable suture-lines. Its ribbing is characteristically of *Subdiscosphinctes* type; ribs are sharp, dense, rectiradiate, and furcation of various type, including simple bifurcation at the outer flanks, or near the umbilical border, or polygyrate. The ribbing resembles therefore that of the first stage of the *S. hachiyai* described above. As the specimen is too fragmentary, specific identification is impossible. It is therefore cited here as *Subdiscosphinctes* sp.

Geological Formation: Arimine Formation.

Geological age: Oxfordian as suggested by the range of the genus and associated fauna.

Occurrence: Arimine.

Conclusion

Newly collected ammonite fauna from the Arimine area includes following species: *Phylloceras* (*Phylloceras*) cf. *consanguineum*, *Ptychophylloceras* cf. *euphyllum*, *Holcophylloceras* sp., *Glochiceras* cf. *nimbatus*, *Ochetoceras* cf. *irregulare*, *O*. sp., *Taramelliceras* cf. *costatum*, *T*. sp., *Perisphinctes* (*Kranaosphinctes*) *matsushimai*, *Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis*, *P*. (*D*.) sp., *Subdiscosphinctes hachiyai* nov. and *S*. sp. Most of these species are already known in the Tetori Group, except for newly described *Subdiscosphinctes hachiyai.* It is characterized by the predominance of Perisphinctids and existence of Phylloceratids. This indicates that the fauna is of the Paleo-Pacific or Tethysian affinity. No boreal elements are included.

The above composition clearly indicates that the Arimine fauna takes part in *Perisphinctes matsushimai* Assemblage Zone established in the Kuzuryu area (Sato and Westermann, 1991). The geological age of the fauna is judged to be middle Oxfordian, as it was correlated in the type area. Though *Subdiscosphinctes* is known largely from Oxfordian to Kimmeridgian of Mediterranean region, the Arimine species should be of Oxfordian age judged by the associated ammonites.

Equivalents of *P. matsushimai* Assemblage Zone are known widely outside the Hida mountains, as *P*. (*Kranaosphinctes*) *matsuhimai*, *P*. (*Dichotomosphinctes*) *kiritaniensis*, and some Oppeliids are known in southern Kitakami (Ojika and Hashiura), eastern Abukuma (Soma and Minamisoma), the Yamizo moutains, Kuga area (Yamaguchi prefecture) and northern Kitakami. Therefore middle Oxfordian is the time of the most extensive marine spreading of Japanese Jurassic.

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