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Eocene Coralline Algae from the Kuma Group in the Ishizuchi Range, Shikoku, Japan

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In the present article are given descriptions of some Eocene calcareous algae collected by Dr. Kozo Nagai of the Ehime University, from the Nimyo formation developed in Ishizuchi-yama and its environs, Ehime Prefecture. The calcareous sandstone of the Nimyo formation has yielded marine fossils of Mollusca, Bryozoa and Foraminifera etc. Recently from the discovery of *Discoyclina* and *Eofabiania* by Prof. Shoshiro Hanzawa of the Tohoku University, the Middle Eocene age of the Nimyo formation has been made clear.

Remains of calcareous algae are also abundant in the same calcareous sandstone, though they have not as yet been recorded, except for the occasional mention of calcareous algae by Dr. Nagai. The studied material contains representatives of the genera *Lithothamnium*, *Corallina*, *Arthrocardia* and *Jania* and the majority of the flora are those belonging to the genus *Corallina*.

The discriminated species are as follows :

Lithothamnium ishizuchiensis n. sp.

Corallina Johnsoni n. sp.

Corallina quadratica n. sp.

Corallina Nagaii n. sp.

Corallina sp. H.

Arthrocardia Varmai n. sp.

Ishizuchi Group	Omogo acidic rocks	Fine grained granite, Granodiorite.
	Saragamine volcanics	Sanukitic rocks, trachytoid andesite, biotite andesite, rhyolite.
	Kuromoritoge tuff and andesite	Rhombic pyroxene andesite, agglomerate, fine grained tuff, tuff breccia, tuffaceous sandstone.
	Takano tuff	Coarse grained tuff, agglomeratic tuff, fine grained tuff.
Unconformity		
Kuma Group	Myojin formation	Conglomerate, sandstone, shale, marl, tuffaceous shale.
	Nimyo formation	Conglomerate, sandstone, calcareous sandstone. With calcareous algae.
	Unconformity	
	Pre-Tertiary rocks	

Jania Hanzawai n. sp.

Jania elongata n. sp.

Jania sp. A.

Before going further, the writer expresses his thanks to Dr. Kozo Nagai who kindly submitted to him the collection of the fossil algae for study.

According to Dr. Nagai's recent conclusion, the Ishizuchiyama Tertiary may be divided in ascending order as shown above.

SYSTEMATIC DESCRIPTIONS

Tribe Lithothamninae

Genus *Lithothamnium* Philippi, 1837

Lithothamnium has a tissue formed of many layers of cells which normally are differentiated into a hypothallus and a perithallus. Commonly the hypothallus consists of curved rows of cells, but in a few species it has coaxial development similar to that common in the genus *Lithophyllum*. The conceptacles are characterized by many openings in the roof. *Lithothamnium* occurs abundantly in the Cenozoic limestones in Japan, but is represented by only a single Eocene species in the collection.

Lithothamnium ishizuchiensis Ishijima, n. sp.

Pl. 14, figs. 1, 2.

Thallus crust from which rise short stubby branches. Tissue shows strong saucer or lens-shaped growth zones. Hypothallus poorly developed, absent on some specimens, composed of cells $6.6\mu-8.3\mu$ by $3.3\mu-4.1\mu$. In branches, growth zones formed of slight curved rows of cells. Cells nearly square, measuring $6\mu-8\mu$ in length by $4\mu-6\mu$ in width. But cells show considerable range in size, both from one end of a row to middle, and from lower to upper layer in a zone.

Conceptacles numerous, flattened, distributed at or often near surface of branch. Conceptacle measurements listed below:

$83.3\mu \times 53\mu$

$100\mu \times 54\mu$

$108\mu \times 58\mu$

$140\mu \times 54\mu$

Remarks: This is the only branching Eocene *Lithothamnium* in the Ishizuchiyama collection. In general appearance and growth habit this species closely resembles *Lithothamnium marianae* described by Harlan Johnson from the upper Eocene of Saipan, but differs in cells dimensions and size of conceptacles.

Subfamily Corallinoideae (articulate corallines)

Genus *Corallina* Linnaeus, 1758

The diagnostic characters of the genus as noted by Harlan Johnson (1957):

The plants are clusters or tufts of segmented stems which branch at close intervals, ordinarily in a plane. Branching typically pinnate (dichotomous to trichotomous or

irregular). Perithallus weakly developed and inconspicuous, the greater part of the individual segment consisting of hypothallic tissue. Segments mainly clavate, flattened cylindrical, or flattened *Halimeda* like but varying widely in shape. Conceptacles lateral or terminal, commonly, not calcified; hence preserved in fossil materials.

Living *Corallina* occurs widely in the warm and temperate seas, where it is represented by many species and has been found as far north as latitude 70°C.

Fossil representatives are known from rocks as old as Eocene and the following species of *Corallina* are hitherto known from Japan :

Corallina elongata Ishijima

Miocene limestone of Kawaguchi formation (Ishijima, 1954, p. 64)

Corallina crassa Ishijima

Miocene limestone of the Misaka series (Ishijima, 1954, p. 65)

Corallina sp. C.

Miocene limestone of the Kawaguchi formation (Ishijima, 1954, p. 65)

Corallina sp. F.

Miocene limestone of the Oigawa formation (Ishijima, 1954, p. 65)

Corallina cfr. *officinalis* Linné

Miocene limestone of the Oigawa formation (Ishijima, 1954, p. 66)

Corallina? sp. B.

Eocene *Nummulites* limestone of Amakusa (Ishijima, 1954, p. 66)

Corallina sp. D.

Pliocene limestone of the Shirahama formation (Ishijima, 1954, p. 67)

Corallina sp. E.

Miocene limestone of the Oigawa formation (Ishijima, 1954, p. 67)

Corallina izuensis Ishijima

Pliocene limestone of the Shirahama formation (Ishijima, 1954, p. 68)

Corallina elliptica Ishijima

Miocene limestone of the Kawaguchi formation (Ishijima, 1932, p. 147)

Corallina typica Ishijima

Miocene limestone of the Kawaguchi formation (Ishijima, 1954, p. 70)

Corallina otukiensis Ishijima

Miocene limestone of the Kawaguchi formation (Ishijima, 1954, p. 71)

Corallina quadratica Ishijima, n. sp.

Pl. 14, figs. 4, 5.

Incomplete intergenicula long and relatively wide, measuring 0.65 mm in length and 0.26 mm in breadth. Intergenicula consist of hypothallic tissue with thick conspicuous perithallus. Hypothallic cells toward centers of tiers range from 16 μ to 24 μ in length, 4.1 μ to 6.6 μ in wide, averaging from 20 μ in length by 5.3 μ in wide.

Perithallic cells nearly square, measuring 5 μ –5.8 μ in length by 4.1 μ or so in width.

Remarks: This species differs considerably in shape of intergenicula, and the broad cortex from any previously described fossil form.

Corallina sp.

Pl. 14, fig. 3.

Form represented in Eocene limestones by many small intergenicula; most are quite incomplete. One fairly complete intergenicula measured 0.33 mm in length and 0.13 mm in breadth. Hypothallic cells of same specimens $22.8\ \mu$ in long and $2.5\ \mu$ wide. Perithallic cells nearly square, measuring $7\ \mu$ in length by $4\ \mu$ in width. Conceptacles and nodes not observed.

Remarks: The available material at hand is too imperfect for specific determination.

Corallina sp. H.

Pl. 14, figs. 9, 10.

Several badly worn intergenicula of articulated coralline algae were observed in the slides studied. Most of them can reasonably be assigned to the genus *Corallina*, but the material is too imperfect for specific determination.

Corallina Nagaii Ishijima, n. sp.

Pl. 15, figs. 1, 3-5, 8, 9.

A number of specimens of this species are in the collection; none of them are complete in both the upper and lower ends. One fairly complete intergenicula in Pl. 15, fig. 1 measured 2 mm in length and 0.2 mm in diameter. Intergenicula consist mainly of hypothallic tissue. Cells in center of tier $20.8\ \mu$ long and $6.6\ \mu$ wide. Perithallus but slightly developed, cells measuring $6.8\ \mu$ - $8.3\ \mu$ long and $4\ \mu$ - $4.6\ \mu$ wide. Measurements and other statistical data are given in the following table.

Measurements of six specimens of *Corallina Nagaii* n. sp.

Slide No.	Size of Segment		Hypothallic cells	
	Length	Width	Length	Width
114	$2.2\ \mu$	$0.2\ \mu$	$20.8\ \mu$	$6.6\ \mu$
"	$0.7\ "$	$0.2\ "$	16-20 "	4.6-6.6 "
"	$0.63\ "$		25-33 "	4.6-6.6 "
118	$0.66\ "$	0.18 - $0.2\ "$	23-25 "	$6.6\ "$
"	$0.7\ "$	$0.17\ "$	$16.6\ "$	$4.6\ "$

The variation shown is believed to be within that attributable to a single species, but differs from that of any described forms known to the author.

Corallina Johnsoni Ishijima, n. sp.

Pl. 15, figs. 6, 7.

Fronds consist of moderately wide, flattened, sharply tapering intergenicula. Each intergenicula consist mainly of tiers of hypothallic tissue. Marginal perithallus not defined. Hypothallic cells in center of tiers measure from 25 to $29\ \mu$ in length (average of about $27\ \mu$) by 2.9 to $4\ \mu$ in width and these cells are crowded and arranged compactly.

Remarks: This species in general appearance closely resembles *Corallina matansa*

Johnson recently described by Johnson from the Eocene Hagman formation of Saipan, but the present species differs considerably in having much smaller cells forming the hypothallus and in the lacking of cortex. The divergence of branches are probably pinnate, as can be seen from the branch embracements on the ends of the branches.

Genus *Jania* Lamouroux, 1812

The plants consist of masses of slender dichotomously branching fronds. Each frond is a series of slender intergenicula formed of tiers of hypothallic cells surrounded by a narrow perithallus that is characteristically restricted to a single layer of small rectangular cells. The hypothallic cells tend to be wider in proportion to length than in most genera of articulate corallines. In many instances, they are elongately wedge-shaped in section, and the successive tiers of cells tend to meet along irregular lines.

Living *Jania* occurs widely in the tropic and temperate seas, where it is represented by many species. Fossil representatives are known from rocks as old as Late Cretaceous and the following two species of *Jania* are known from Japan :

Jania Lemoni Ishijima

Miocene limestone of the Oigawa formation (Ishijima, 1932, p. 143)

Jania kuboensis Ishijima

Miocene limestone of Kawaguchi formation (Ishijima, 1954, p. 75)

Jania elongata Ishijima, n. sp.

Pl. 14, figs. 6, 7, 12.

Several fragments apparently belonging to the genus *Jania* were found in the collection.

A nearly complete intergenicula, small, very slender in shape, measuring 0.5 mm in length, 66 μ in breadth. Intergenicula consists mainly of tiers of hypothallic tissue with an inconspicuous perithallus ordinarily limited to one or two layers of small cells. Hypothallic cells in center of tiers measure from 28 to 33 μ in length with average of about 25 μ . Nodes and conceptacles are not preserved.

Fig. 12 in the Plate shows another complete upper terminal intergenicula, slender, gradually increasing in breadth from top to base.

Size of medullary cells are 29 μ to 40 μ in length with average of 25 μ . These are essentially of equal length except for the cells at the apical margin; tiers of hypothallic cells slightly curved. Perithallus is defined by only one layer of small cells.

Jania Hanzawai Ishijima, n. sp.

Pl. 15, fig. 2.

Nearly two complete intergeniculas, slender in shape, partly deformed at upper end, measuring 0.82 to 0.87 mm in length and 0.2 to 0.3 mm in breadth. Central strand consists principally of a medullary filament of nine rows of long, straight cells, measuring 28 to 28.5 μ in length and 10 μ in width. Cortical layer thin, apparently a single (or rarely two) layer of irregular cells and the boundary between it and medullary tissue is indistinct.

Node (genicula) measuring about 0.12 mm. in length but not preserved to show the

structure. Conceptacles unknown.

Remarks: The average cell size of *Jania Hanzawai* differs from any previously described Eocene or Miocene species for which cell dimensions are given.

Jania sp. A.

Pl. 14, fig. 8.

A nearly complete intergenicula is illustrated in Pl. 14, fig. 8, Intergenicula is very slender in shape, measuring at least 0.66 mm. in length and 0.12 mm. in breadth. The central strand consists of rectangular medullary cells, 14–16 μ in length and 8–10 μ in width. These are essentially of equal length except for the cells at both sides and each rows of cells are gently arched. Cortical layer consists of only one layer of cells.

Genus *Arthrocardia* Decaisne (emend. Areschoug)

Arthrocardia Varmai Ishijima, n. sp.

Pl. 14, fig. 11.

A nearly complete intergenicula; sub-cylindrical with angular corners or rectangular, more than 0.6 mm in length and 0.25 mm in breadth. Intergenicula consists mainly of tiers of hypothallic tissue with narrow marginal perithallus. Hypothallic rows nearly flat and its cells in center of tiers measure from 12 to 25 μ in length with average of about 18.5 μ .

Division between medullary hypothallus and cortical perithallus abrupt and clearly defined. Perithallus weakly developed but noticeable; its cells nearly square, measuring 4 μ or so on a side.

Remarks: The genus *Arthrocardia* has been allocated by Schmits and Hauptleish to the synonymy of the genus *Cheilosporum*. However, the four genera, *Arthrocardia*, *Cheilosporum*, *Corallina* and *Jania* are closely allied with one another. In all these four genera, the cells of the central strand are equal in size through the whole intergenicula. The intergenicula in *Arthrocardia* and *Cheilosporum* consist of a flat row of cells in the central strand. While in both *Jania* and *Corallina*, the rows of the cells in the central strand are not flat but slightly curved.

According to Wefer, *Cheilosporum* which is closely related to *Arthrocardia* is distinguished from the latter simply by the character of the position of the conceptacles. It however, is very difficult to detect this character in fossil forms. Although, it is somewhat doubtful whether the present specimen should be considered as belonging to the genus *Arthrocardia* or to *Corallina*, the writer here uses *Arthrocardia*, taking the general features of the intergenicula into consideration.

(The specimens described here are deposited in the Institute of Geology, Rikkyo University)

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PLATE 14

Figs. 1-2. *Lithothamnium ishizuchiensis* Ishijima, n. sp. ($\times 100$)

1. Section through a crust showing thin hypothallus at bases, and perithallus and three conceptacles with sporangia.

2. A slightly oblique section through a branch showing the strongly zoned tissue and several conceptacles with sporangia.

3. *Corallina* sp. G. ($\times 80$)

A segment showing medullary hypothallus and well-defined perithallus.

4-5. *Corallina quadratica* Ishijima, n. sp. ($\times 120$)

4. Partly oblique section of a segment showing medullary hypothallus and well developed perithallus.

5. Another example, partly oblique section.

6-7, 12. *Jania elongata* Ishijima, n. sp. ($\times 120$)

6. Badly frayed segment.

7. A nearly complete segment.

12. A terminal segment.

8. *Jania* sp. A.

9-10. *Corallina* sp. H. ($\times 120$)

11. *Arthrocardia Varmai* Ishijima, n. sp.

A nearly complete segment.

PLATE 15

Figs. 1, 3-5, 8-9. *Corallina Nagaii* Ishijima, n. sp. ($\times 120$)

1. A nearly complete slender segment.

3-5, 8-9. A portion of segment attributed to this species.

2. *Jania Hanzawai* Ishijima, n. sp. ($\times 120$)

Two well preserved segments.

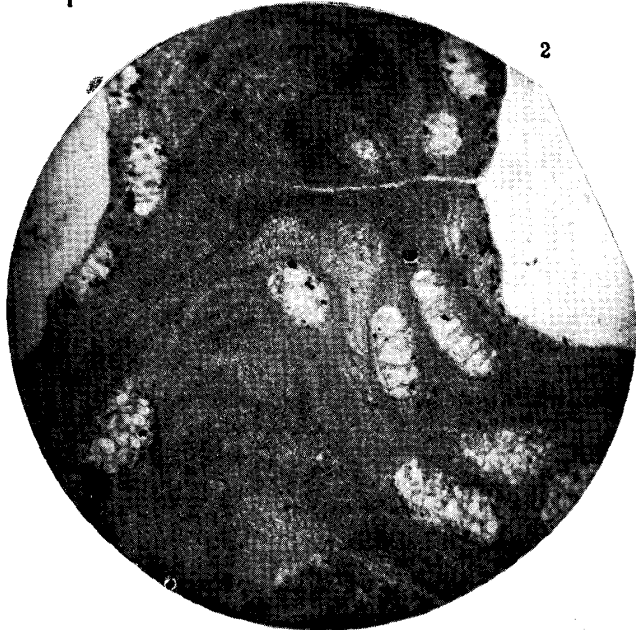
6-7. *Corallina Johnsoni* Ishijima, n. sp. ($\times 120$)

6. A segment probably from near bases of a frond.

7. A worn fragment showing a branch.



1



2

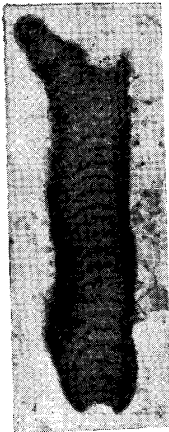
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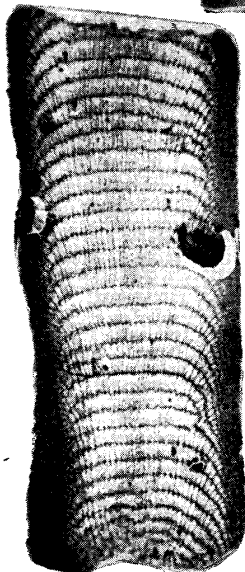
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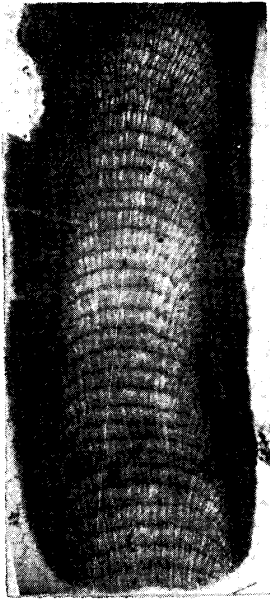
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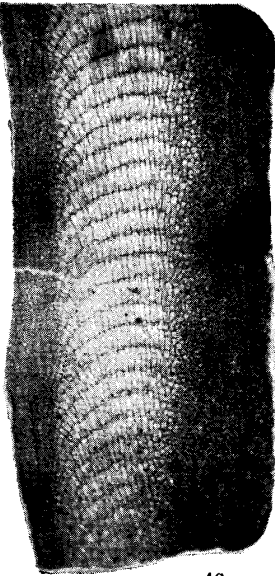
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