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Fossil on the cover is the six leaves in a whorl of *Trizygia oblongifolia*  
(GERM. & KAULF.) ASAMA from the Maiya formation (*Parafusulina* zone),  
Maiya, N. E. Japan.

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657. ONTOGENIES OF THREE SPECIES OF SILICIFIED MIDDLE  
ORDOVICIAN TRILOBITES FROM VIRGINIA\*

CHUNG-HUNG HU

Department of Earth Sciences, Cheng Kung University, Taiwan

ヴァージニア州産オルドビス紀中期珪化三葉虫3種の個体発生: 本研究はヴァージニア州  
オルドビス中期 Edinburg 層産三葉虫の個体発生についての研究の一環をなすものである。  
今回は, *Dimeropyge virginensis* WHITTINGTON and EVITT, *Mesotaphraspis acris*, n.  
sp. および *Illaeus valvulus* RAYMOND の3種について記述した。第1の種に関する個体  
発生は不完全にしか判らなかつたが, 後2者についてはほぼ完全に解明された。また, 後2者  
の各種集団内には, それぞれ2つの形態を異にするグループが識別され, 雌雄異型現象による  
ものと解される。 胡 忠 恒

Introduction

The present report represents a part of studies of ontogenetic development of Middle Ordovician trilobites from the Edinburg Formation, Virginia (HU, 1971, 1974a, 1974b, 1975a, 1975b). Three species are described. They are *Dimeropyge virginensis* WHITTINGTON and EVITT, *Mesotaphraspis acris*, n. sp., and *Illaeus valvulus* RAYMOND. The earliest development of *D. virginensis* is incompletely known, and those of *M. acris* and *I. valvulus* are well. The ontogenetic development of trilobite is divided into anaprotaspid, metaprotaspid, paraprotaspid, early meraspid, and late meraspid stages as proposed earlier by the author (HU, 1964, 1971, 1974).

The studied specimens of *M. acris* and *I. valvulus* are represented by two different morphologic groups within each of these species populations. These bimodal phenomena are postulated as sexual

dimorphism. In the species *M. acris* the female pygidium possesses no axial tubercle, two complete pygidial segments, and a distinct marginal border, whereas the male pygidial axis is decorated by tubercles, three segments are present, and the margin is without a distinct border. The female form of *I. valvulus* has a rounded cranidium, forwardly located palpebral lobe, the pygidium is less convex, and semicircular in outline, and that of male cranidium is subquadrate, posteriorly located palpebral lobe, the pygidium is transverse trapezoidal and highly convex.

*Acknowledgements*—The writer wishes to thank to Dr. K.E. CASTER, University of Cincinnati, Ohio, for his supervision and kind reading over the present manuscript. Thanks are also due to Dr. F. RASSETTI, Università Degli Studi, Roma, for permission to study his excellent collections. The figured specimens are all deposited in the Geology Museum, University of Cincinnati, Ohio (U.C.G.M).

\* Received Sept. 16, 1975; read Jan. 31, 1976 at Narugo.

### Systematic description

Family Dimeropygidae WHITTINGTON  
and EVITT, 1953

Genus *Dimeropyge* ÖPIK, 1937

*Dimeropyge virginiensis* WHITTINGTON  
and EVITT, 1953

Pl. 26, Figs. 1-33; Text-fig. 1

*Dimeropyge virginiensis* WHITTINGTON and  
EVITT, 1953, p. 37, pl. 2 and 3, figs. 1-30;  
text-fig. 5-8.

*Remarks*—The present species is a common member within the studied materials. WHITTINGTON and EVITT (1953) gave a very detailed description of the species. However, the ontogenetic development was incompletely known by them. An associated hypostoma in the present material, which is characterized by its abundant granulation and thickness, seems to be correlated with the previously known cranidium, pygidium, and librigena of this species.

*Figured specimens*—Cranidia, U.C.G.M. 40422k-n; librigenae, U.C.G.M. 40422w-z; pygidia, U.C.G.M. 40422o-t, a'-d', f'; hypostomata, U.C.G.M. 40422u, v.

*Dimeropyge virginiensis* WHITTINGTON  
and EVITT, ontogeny

*Early protaspid stage* (Pl. 26, Fig. 1 and Text-fig. 1A)—Only a single skeleton of this stage has been recovered. It is pear-shaped, gently convex, with a granulated surface, and is about 0.35 mm in sagittal length; the posterior half of the skeleton is slightly broader than the anterior; the axial and the pleural lobes, cranidium and pygidium are all indistinctly separated; the ventral side of the skeleton

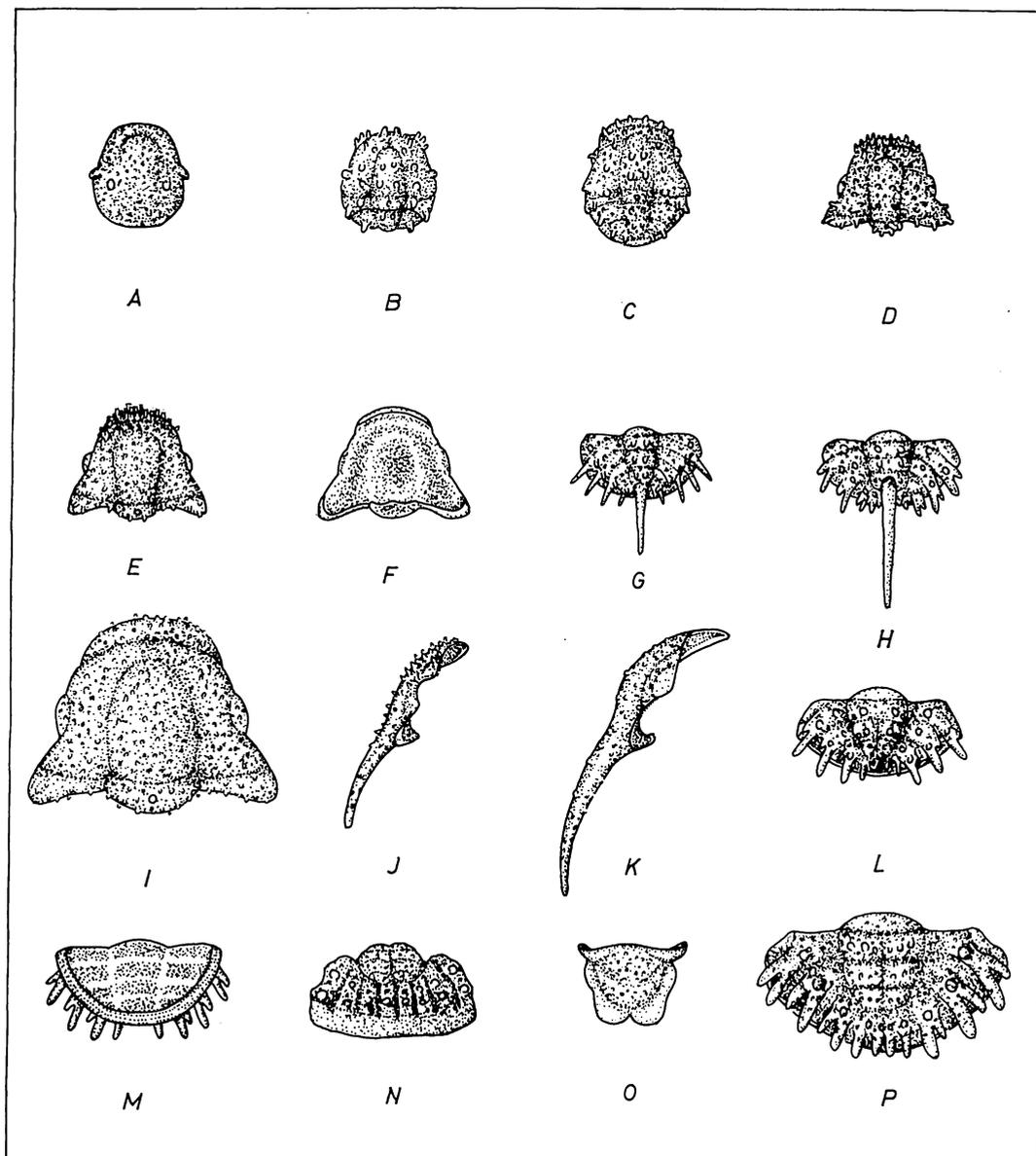
is smooth, with the anterior lateral margin curving slightly inward; the posterior margin is rounded, and surrounded by a narrow doublure.

The present specimen shows no any distinct structure which could assign to a certain specific growth stage. For the time being it is considered to belong to a protaspis.

*Paraprotaspid stage* (Pl. 26, Figs. 2-5, and Text-fig. 1B, C)—The skeleton is oval in outline, gently convex, about 0.4-0.7 mm in length (sag.); the axial and the pleural lobes are well differentiated by dorsal furrows; a small protopygidium appears behind of the large cranial shield; the glabella is conical, tapering slightly forward, and has the anterior margin arching slightly forward; no glabellar furrows are seen; the narrow, convex occipital ring is well set off by the occipital furrow and the posterior cranial suture; the lateral lobe of the fixigena is slightly narrower than the glabella, gently sloping downward from the dorsal furrow and with the anterolateral margin curved slightly inward; this suggests the position of the facial suture, and a portion of the librigena; the anterior border is indistinctly separated from the narrow preglabellar field. The protopygidium is semicircular in outline, convex and undifferentiated.

The surface of the skeleton is covered by both of fine and large granules; there are three pairs of large granules on the glabella, four pairs on the fixigenae, one to three on the pygidial axis, and a few pairs along the anterior border and the skeletal margins.

*Early meraspid stage* (Pl. 26, Figs. 6-8, 16-19 and Text-fig. 1D, G, H)—The trapezoidal cranidium is convex and has the anterior border arching slightly forward and with a deeply impressed frontal furrow; it is about 0.7-0.8 mm in length

Text-fig. 1. *Dimeropyge virginiensis* WHITTINGTON and EVITT.

A, an early protaspis,  $\times 43$ ; B, C, two paraprotaspides,  $\times 40$ ,  $\times 25$ ; D, early meraspid cranidium,  $\times 20$ ; E, a late meraspid cranidium,  $\times 15$ ; F, ventral view of an adult cranidium,  $\times 15$ ; G, H, two early meraspid pygidia,  $\times 25$ ,  $\times 15$ ; I, an adult cranidium,  $\times 13$ ; J, an immature librigena,  $\times 10$ ; K, librigena,  $\times 10$ ; L, a late meraspid pygidium,  $\times 15$ ; N, M, ventral and back views of a pygidium,  $\times 12$ ; O, hypostoma,  $\times 8$ ; P, a pygidium,  $\times 8$ . (All drawings were made from photographs.)

(sag.); the glabella is cylindrical, parallel-sided, convex, slightly higher than fixigena along the axial lobe, and the anterior margin is round; the glabellar furrow is unknown; the occipital ring is crescentic, convex, well differentiated by the occipital furrow, and a small median tubercle; the preglabellar field is gently convex, sloping downward from the anterior glabella, and is about one-half the length of the glabella (sag.); the convex anterior border is narrower than the preglabellar field, and well divided by the frontal furrow. The fixigena is convex, about the same width as the glabella between the palpebral lobe and the dorsal furrow; the small elevated palpebral lobe is well demarked by the palpebral furrow, and is situated in front of the mid-line of the glabella (sag.). The surface of the cranium is covered by both fine and large granules; the large granules are symmetrically disposed; three to four pairs of them are on the glabella, four pairs on the fixigena and posterior fixigenal borders. Both short and long spines are abundant or thickly on the anterior border from which they radiate; median furrow is poorly marked from the anterior glabellar margin to the frontal furrow.

The early meraspid pygidium is semi-circular in outline, convex, and the marginal border is nearly vertical; the conical axial lobe is tapering posteriorly and composed of three axial rings, one of which bears a slender medium-sized median spine; the pleural bands are well differentiated, but the intrapleural grooves are indistinct; each pygidial segment bears a pair of short spines. The surface is covered by fine granules; large paired pustules are present on both axial rings and the pygidial margin. The median pygidial spine has moved forward in correlation with the increase of pygidial segments from the proximal end.

*Late meraspid stage* (Pl. 26, Figs. 9-11, 20-22, 24 and Text-fig. 1L, J).—The cranium is trapezoidal in outline, elongate, highly convex, about 1.0-1.5mm in length (sag.); the dorsal furrow is deeply impressed; the glabella is expanded slightly forward, and without any recognizable glabellar furrow. The fixigena is convex, slopes downward, and is about one-third the width of the glabella; the posterior fixigenal border is well delimited by a deep furrow, convex, and of the same width as the occipital ring (tr.); the small and well defined palpebral lobe is located in front of the mid-line of the glabella; it is convex both vertically and laterally; the preglabellar field is convex, slopes downward from the anterior glabella; it is about one-third the length of the glabella, and well delimited by a broad frontal furrow; the convex anterior border arches strongly forward.

The librigena is narrowly elongate, convex, and with the ocular ring convex above the ocular platform; no distinct lateral border or border furrow is known; the anterolateral border is acuminate and narrower than the doublure; the posterior ocular platform is broad, gently convex at the genal angle, and has a short, broadly based genal spine. The ventral aspect of the librigenal doublure is narrow, but its posterior end extends broadly with a deeply marked notch at the genal angle. The hypostoma is generally hexagonal in outline, convex, well delimited by macular and marginal furrows; the narrow posterior border notches inward slightly.

The late meraspid pygidium is sub-semicircular in outline, convex, and divided into two segments and a terminal portion; the marginal border slopes nearly vertically from the marginal spine, and is distinctly delimited.

The skeletal surface is densely gran-

ular; there are short, radial spines are on the anterior border; the posterior half of the hypostoma is covered by fine granules and larger ones are scattered anteriorly.

The present stage differs from the early meraspis by its expanded glabella and the slightly flattened and transversal pygidium; it is differentiated from holaspis by its expanded glabella, distinctly marked librigenal border, hexagonal hypostoma, and the transversal pygidium; whereas the holaspis is oval, with distinctly divided librigenal border having a lateral embayment, the hypostoma has broader marginal border and a deep median notch, and the pygidium is subtriangular.

*Figured specimens*—Early protaspis, U.C.G.M. 40422; paraprotopaspides, U.C.G.M. 40422a-e; early meraspides, U.C.G.M. 40422d-g; late meraspides, U.C.G.M. 40422h, e', j'.

Genus *Mesotaphraspis* WHITTINGTON  
and EVITT, 1953

*Mesotaphraspis acris*, n. sp.

Pl. 27, Figs. 1-36; Text-fig. 2

*Diagnosis*—Cranidium trapezoidal, moderately convex; glabella conical, subtriangular, tapering rapidly forward, with the last glabellar furrows distinct; occipital ring crescentic, with the axis curving slightly anteriorly; preglabellar field more than one-half length of the glabella; anterior border convex, less narrower than the preglabellar field; fixigena gently convex, slightly narrower than the glabella. Librigena regular shaped, having a medium-sized genal spine. Hypostoma subquadrate, convex, with a distinctly depressed marginal furrow, three pairs of marginal spines and a

terminal portion; with or without inner marginal furrow or border; surface faintly granulated. Certain one thoracic segment occupied by a median spine, and tubercles along the pygidial axis.

*Description*—Cranidium is subquadrate to trapezoidal in outline, moderately convex, and with the dorsal furrow distinctly marked; the posterior pair of glabellar furrows is distinctly impressed and directed posteriorly from the mid-length of the glabella (tr.) to the occipital furrow; the anterior glabellar furrows are rather faint; the occipital ring is crescentic, convex, with the mid-line (sag.) curving slightly forward, and possessing a minute tubercle; the occipital furrow is well-developed, it arches forward to the mid-line, and deepens laterally to form a pair of elongate pits; the anterior brim is slightly narrower than the glabella (sag.), and well-delimited by a frontal furrow; the anterior border is narrow crescentic, convex, slightly narrower than the preglabellar field. Fixigena is gently convex, less than one-half the width of the glabella; the palpebral lobe is broad, without distinct palpebral furrow or ocular ridge, its maximum width is located behind of the mid-line of the glabella, and close to the posterior fixigena; the posterior fixigena is very narrow, possesses a broad, convex marginal border, and is slightly narrower than the occipital ring (tr.).

Librigeno-rostrum is regular tongue-shaped, convex, with the convex lateral border delimited by a lateral furrow and broad ocular platform; the lateral and the posterior genal furrows are connected at the genal angle, and thence extend into the genal spine for a short distance; the ocular ring is semicircular, located at the mid-line of the inner free margin at the facial suture. The hypostoma is generally subquadrate in outline, convex;

the median body is roundly triangular, convex, surrounded by deeply impressed marginal furrows; the posterior median area is U-shaped and convex; the lateral border is convex, less narrow than the posterior margin, and bearing two pairs of short spines at the mid-line of the hypostoma (tr.); the antero-lateral wings are short spines, tilted downward and directed antero-laterally from the front corners; the posterior border is convex, and has a pair of short broad lateral spines.

The subtriangular pygidium is convex; has the short broad axial lobe divided into two unequal sized rings and a small terminal portion by furrows; the pleural lobe is convex below the axis, and slopes downward around the lateral margin, and is divided into a pair of distinct intrapleural furrows and a pair of faint interpleural grooves; the narrow marginal border is convex and well delimited by an inner marginal furrow.

The exoskeletal surface is covered by faint granules, certain one thoracic segment possesses a long median spine, and the medium-sized tubercles-bearing along the pygidial axis.

*Remarks*—The present species is represented by two different pygidial types; in the first, the pygidial axis possesses no median tubercle, there are two complete segments, and a distinct marginal border; whereas in the other, the axial rings are decorated by tubercles, three segments are present, and the margin is without a distinct border. These differences are presumably sexual within the same species.

The present species is differentiated from *Mesotaphraspis parva* WHITTINGTON and EVITT, and *M. inornata* WHITTINGTON and EVITT (1953) by its slenderly conical glabella, broader preglabellar field, broader facial suture line (tr.), and the

slightly posteriorly directed fixigenal border. The pygidium is triangular, has three axial rings, with or without a marginal border, whereas in the other two species the pygidium is semicircular, without median axial tubercles.

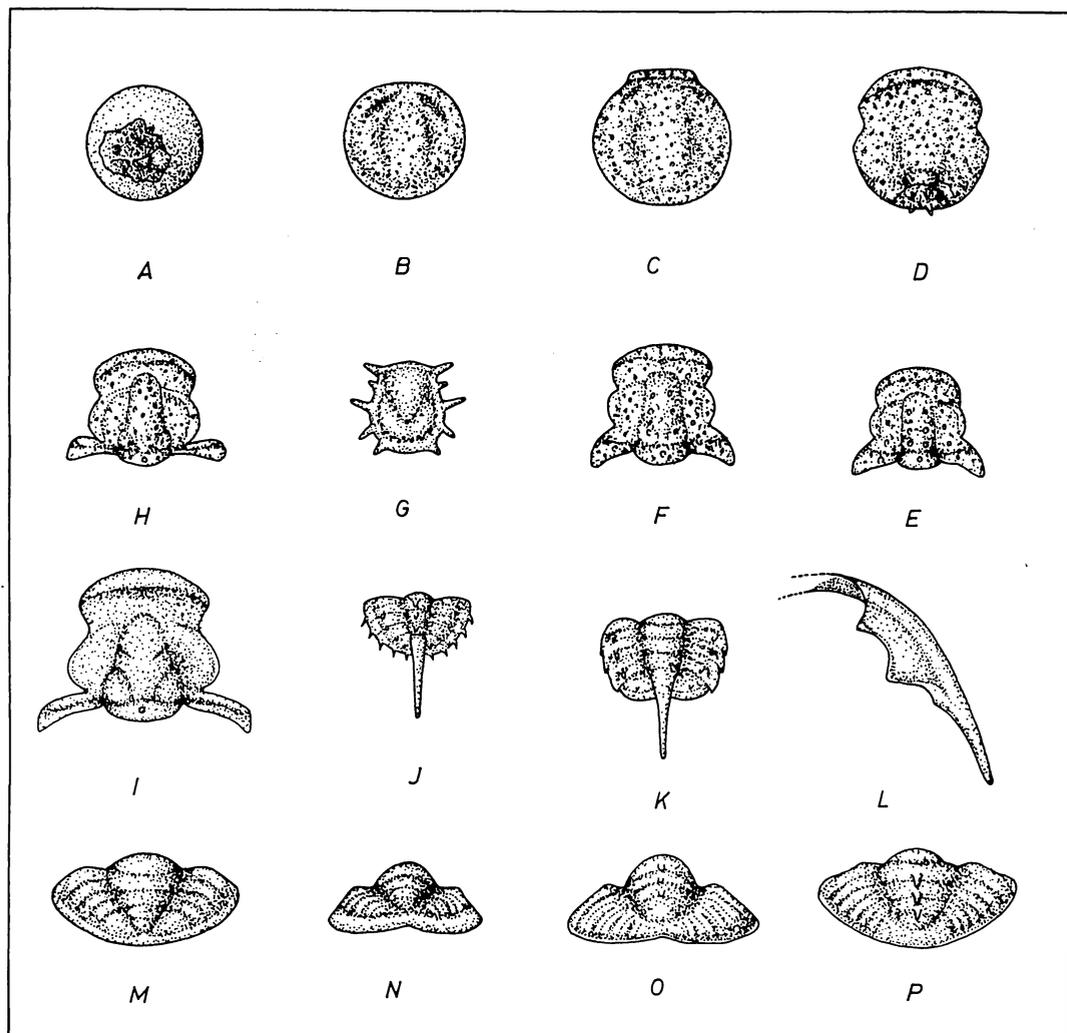
*Figured specimens*—Holotype, cranium, U. C. G. M. 40421r; paratypes, cranidia, U. C. G. M. 40421m, q, n; hypostoma, U. C. G. M. 40421p; pygidia, U. C. G. M. 40421o, 40421y ("female"), 40421d', c' ("male"); thoracic segment, U. C. G. M. 40421z.

*Mesotaphraspis acris*, n. sp.,  
ontogeny

*Problematica* (Pl. 27, Fig. 1, and Text-fig. 2A)—There is a spherical specimen in the collection about 0.30 mm in diameter, with broken surface, which shows an irregular hole; the inside of the hole contains certain unknown trilobitic (?) skeletal fragments; the outer surface of the specimen is smooth. It is postulated that this specimen is possibly an egg case, possibly of a trilobite larval integument, or perchance a single-chambered protaste.

*Anaprotaspid stage* (Pl. 27, Fig. 2, and Text-fig. 2)—The shield is round or slightly broader anteriorly, gently convex, about 0.33 mm in length (sag.); the dorsal surface shows few distinct characters except for a pair of elongate pits broadly marked on the anterior lateral margin; no axial furrow or marginal spine is known. The underside of the shield shows a rather narrow doublure around the posterior margin. The surface is granulated.

*Metaprotaspid stage* (Pl. 27, Figs. 3-5, and Text-fig. 2C)—The shield is round to subrounded, convex along the axis, but without distinct dorsal or axial fur-

Text-fig. 2. *Mesotaphraspis acris*, n. sp.

A, problematica,  $\times 50$ ; B, an anaprotaspis,  $\times 50$ ; C, a metaprotaspis,  $\times 40$ ; D, a paraprotaspis,  $\times 32$ ; E, an early meraspis cranidium,  $\times 23$ ; F, H, two late meraspis cranidia,  $\times 23$ ,  $\times 16$ ; G, a meraspis hypostoma,  $\times 20$ ; I, an holaspis cranidium,  $\times 12$ ; J, K, an early and a late meraspis pygidium,  $\times 20$ ,  $\times 30$ ; L, librigena,  $\times 5$ ; M, N, dorsal and back views of a "female" pygidium,  $\times 15$ ; O, P, baks and dorsal views of a "male" pygidium,  $\times 10$ . (All drawings were made from photographs.)

rows; it is about 0.35–0.52 mm in length (sag.); the anterior margin arches slightly forward but is nearly straight, and some specimens show a frontal furrow whereas

the other does not. The elongate frontal pits are deeply impressed at the antero-lateral margin; the narrow marginal border is nearly horizontal, faintly de-

pressed by the marginal furrow. The exoskeleton is granulated.

The present stage differs from the previous one in having the convex axis, closely located frontal pits, and the presence of the anterior border.

*Paraprotaspid stage* (Pl. 27, Fig. 10 and Text-fig. 2D)—The shield is subround, convex, about 0.6 mm long (sag.), composed of a large cranidium and a small protopygidium; the axial lobe is only visible near the occipital segment, otherwise, it is incomplete; the anterior border is convex and delimited by a broad conical frontal furrow, which is narrow crescentic, arching forward; the facial suture appears along the anterior lateral margin, that is short, narrow, convex forwardly from the anterior border to the mid-line of the shield (tr.). The proto-

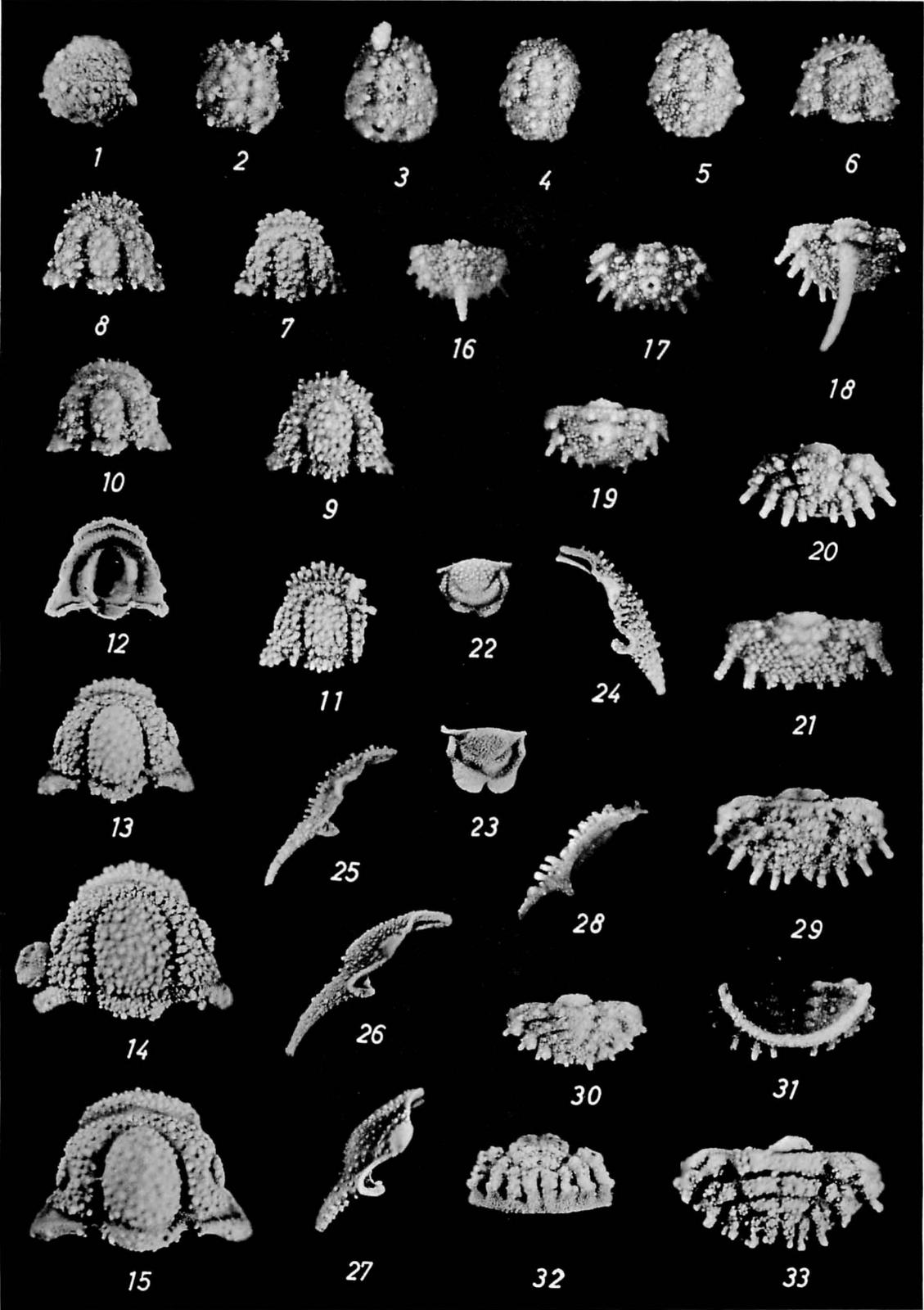
pygidium is rather small, lenticular, and without any distinct segmental furrow; the axis is gently elevated but has no defined dorsal furrow. The exoskeletal surface is marked by both faint and medium-sized granules.

*Early meraspid stage* (Pl. 27, Figs. 8, 9, 11, 12, 21, 23, 24, 26, 31 and Text-fig. 2E, F, J-K)—The cranidium is subquadrate or trapezoidal, narrow and long, convex, and about 0.6-0.8 mm in length (sag.); the dorsal furrow is faintly delimited; the glabella is cylindrical or slightly tapering forward, without distinct glabellar furrow, except for three to four pairs of rounded glabellar tubercles; the occipital ring is crescentic, convex, and well separated by the occipital ring and bears a minute median tubercle; the preglabellar field is about the same width as the

#### Explanation of Plate 26

Figs. 1-33. *Dimeropyge virginiensis* WHITTINGTON and EVITT

1. Dorsal view of an early protaspid shield.  $\times 43$ , U. C. G. M. 40422.
- 2-5. Dorsal views of four paraprotaspid shields; notice the cylindrical glabella. 2,  $\times 40$ , U. C. G. M. 40422a; 3,  $\times 25$ , U. C. G. M. 40422b; 4,  $\times 20$ , U. C. H. M. 40422c; 5,  $\times 18$ , U. C. G. M. 40422e.
- 6-8. Dorsal view of three early meraspid cranidia, showing the cylindrical glabella. 6,  $\times 20$ , U. C. G. M. 40422d; 7,  $\times 20$ , U. C. G. M. 40422f; 8,  $\times 20$ , U. C. G. M. 40422g.
- 9-11. Dorsal views of three late meraspid cranidia; notice the forwardly expanded glabella. 9,  $\times 15$ , U. C. G. M. 40422h; 10,  $\times 15$ , U. C. G. M. 40422e'; 11,  $\times 15$ , U. C. G. M. 40422j.
- 12-15. Ventral and dorsal views of four complete cranidia; notice the elongate-oval glabella. 12,  $\times 15$ , U. C. G. M. 40422k; 13,  $\times 16$ , U. C. G. M. 40422l; 14,  $\times 14$ , U. C. G. M. 40422m; 15,  $\times 13$ , U. C. G. M. 40422n.
- 16-21. Dorsal views of a growth series of pygidia; notice that the spinous segment progresses forward during the different growth stages. 16,  $\times 25$ , U. C. G. M. 40422o; 17,  $\times 14$ , U. C. G. M. 40422p; 18,  $\times 15$ , U. C. G. M. 40422q; 19,  $\times 14$ , U. C. G. M. 40422r; 20,  $\times 10$ , U. C. G. M. 40422s; 21,  $\times 15$ , U. C. G. M. 40422t.
- 22-23. A small and a medium sized hypostoma, showing the increasing abundance of granules.  $\times 10$ , U. C. G. M. 40422u;  $\times 8$ , U. C. G. M. 40422v.
- 24-28. A growth series of librigenae, showing the increase in width of the ocular platform, and the lateral border. 24,  $\times 15$ , U. C. G. M. 40422w; 25,  $\times 10$ , U. C. G. M. 40422x; 26,  $\times 10$ , U. C. G. M. 40422y; 27,  $\times 15$ , U. C. G. M. 40422z; 28, specimen missing.
- 29-33. Dorsal, ventral, and posterior views of five pygidia; notice the marginal spines and the vertically directed pygidial border. 29,  $\times 15$ , U. C. G. M. 40422a'; 30,  $\times 7$ , U. C. G. M. 40422b'; 31,  $\times 10$ , U. C. G. M. 40422c'; 32,  $\times 10$ , 40422d'; 33,  $\times 8$ , U. C. G. M. 40422f'.



anterior border or slightly wider, convex, downwardly sloping from the anterior glabellar margin, without any separation; the frontal furrow is broad and concave. Fixigena is about the same width as or slightly narrower than the glabella, convex, and slopes downward from the dorsal furrow; the narrow crescentic palpebral lobe is located on the mid-line of the cranium, well demarked by palpebral furrow, and convex; the posterior fixigena is triangular, has a well developed border furrow; the posterior fixigenal border is elevated from the border furrow, convex, and about the same width as the occipital ring. The early meraspid pygidium is often associated with two to three thoracic segments, a long median spine, convex, and the margin is spinose; the terminal portion of the axis is narrow and slopes downward.

The skeletal surface is covered by both fine and coarse granules; the pygidial axis is either with or without an axial node; a pair of coarse granules is present on the pleural region of each pygidial segment.

The distinct characteristics of the present stage are that the dorsal furrows are well demarked, glabella cylindrical, the palpebral lobe is located on the mid-line of the glabella, the pygidium is often associated by a few thoracic segments, and there is a median axial spine.

*Late meraspid stage* (Pl. 27, Figs. 6, 7, 13, 17, 22, 25, 32, 33 and Text-fig. 2G, I)—The cranium is subquadrate to trapezoidal in outline, convex, with well developed dorsal furrows, and about 0.7-1.0 mm in length (sag.); the glabella is slenderly conical, marked by three pairs of well-defined glabellar furrows; the last pair or the near occipital pair is deeper than the anterior ones, and acute; the occipital ring is crescent, convex, and

bears a minute median node; the preglabellar field is slightly narrower than one-half the length of the glabella (sag.), slopes gently downward, and has a longitudinal median notch; the anterior border is wider than the preglabellar field, convex above the broad frontal furrow, and arches forward. The fixigena is narrower than the glabella, convex below the glabella, and well delimited by the palpebral furrow; the palpebral lobe is sickle-shaped, elongate and its widest portion is located behind the mid-line of the cranium; the posterior fixigena is rather narrow, and well set off by the border furrow; the posterior fixigenal border is rather narrow, and well delimited by the border furrow; the posterior fixigenal border is narrower than the occipital ring. The anterior facial suture is divergent-convex, and the posterior one is laterally divergent and straight.

The hypostoma is subquadrate, slightly expanded posteriorly and convex; the median body is convex, triangular, and well surrounded by furrows; the broad posterior lobe is U-shaped, convex, and deeply defined by a marginal furrow; the marginal border is narrow and convex, and bears five pairs of marginal spines, of which the anterior and the third are subequal in size and larger than the rest.

The pygidium is semicircular or triangular in outline, convex, and composed of 2-4 pygidial segments and a terminal portion; the axial lobe is narrower than the pleuron, convex above the lateral lobe, and well divided into axial rings by furrows; the marginal border is narrow, with or without a distinct marginal furrow.

The surface of the skeleton is covered by both of fine and medium-sized granules; a few rounded pits are present along the median body furrow and the

marginal furrows; the pygidial axis may or may not have axial nodes.

The present stage differs from the early one in having a conical glabella, well differentiated posterior glabellar lobe, narrow posterior fixigena, and the large palpebral lobe situated behind of the mid-line of the cranidium. The pygidial axis is without an axial spine.

*Remarks*—The ontogenetic development of the present species resembles to that of *Dimeropyge virginiensis* WHITTINGTON and EVITT (1953), *Otarion trilobus* HU (1975), and *Phaseolops canus* HU (1971). The meraspides especially are almost indistinguishable. The protaspides of the present species is on the other hand, well differentiated by its roundness, convexity, and the ornamentation of the shield. This may indicate that they are derived from different ancestral stocks as suggested only in the young stage, but become similar latter due to convergent evolution and ecology, but ultimately emerging into characteristic and different adaptive forms reflected in the dissimilar epebic morphologies.

*Figured specimens*—Problematica, U.C.G.M. 40421; anaprotaspis, U.C.G.M. 40421a; metaprotaspides, U.C.G.M. 40421b-d; paraprotaspides, U.C.G.M. 40421i; early meraspides, U.C.G.M. 40421g, h, k, s, u, v, a'; late meraspides, U.C.G.M. 40421e, f, l, t, w, b', c'.

Family Illaenidae HAWLE  
and CORDA, 1847

Genus *Illaenus* DALMAN, 1827

*Illaenus valvulus* RAYMOND, 1925

Pl. 28, Figs. 1-40; Text-fig. 15

*Illaenus valvulus* RAYMOND, 1925, p. 106, pl. 4, figs. 13, 14.

*Diagnosis*—Cranidium subtrapezoidal, with rounded anterior margin, convex, and without distinct dorsal furrows; palpebral lobe small; palpebral furrow indistinct; glabellar furrow absent; palpebral lobe located extremely posteriorly; posterior fixigena very narrow, convex, underneath the palpebral lobe. Librigena subtriangular in outline, convex, without marginal furrow, lateral border, or genal spine; ocular ring located behind the genal angle. Rostrum transverse, pentagonal, convex, and the anterior margin swollen upward and pointed medially. Thoracic segment convex; axial lobe same width as pleuron; no half-ring furrow or interpleural furrow. Pygidium semicircular or trapezoidal in outline, convex, without axial or pleural furrows.

*Remarks*—The present species is very common in the studied materials; about a few hundred of both immature and mature forms have been selected from among isolated trilobite fragments. All show well its ontogenetic growth stages. The adult specimens fall into two morphologic groups, the first of which has strongly convex cranidium, posteriorly located palpebral lobes, and trapezoidal pygidium; and in the second, the cranidium is less convex, with forwardly located palpebral lobes, and semicircular pygidium. These bimodal traits are possibly the expression of the sexual dimorphism within the same genus and species population. The first group is more numerous and is postulated as male, the other as female.

Two rather well preserved specimens comprising a cranidium and a pygidium were reported from Holston, Catawaba Valley, north of Salem, Virginia by RAYMOND (1925). The cranidium is transverse trapezoidal; the pygidium is semi-oval in outline, and associated with a thoracic segment. The measurement of

the cranidium is 5 mm in length (sag.), and the pygidium 6 mm (sag.). They are similar both in morphology and occurrence to the present studied material.

*Illaeenus valvulus* RAYMOND, "male"

Pl. 28, Figs. 35, 36, 39, 40;  
Text-fig. 3K, L, S.

*Description*—Cranidium is subtrapezoidal in outline, very convex, smooth, without distinct dorsal and glabellar furrows except near the occipital ring which is slightly depressed laterally; no preglabellar field or anterior border are known; the anterior margin arches gently forward and is surrounded by a narrow, elevated ridge; the posterior fixigena is narrower than the occipital ring, being convex, and slopes downward from the glabella; the palpebral lobe is small, indistinctly separated by the palpebral lobe; it is convex laterally, and located far behind of the mid-line of the cranidium; the posterior fixigena is very narrow, convex, and directed laterally; it lies underneath the palpebral lobe. The subtriangular librigena is convex, without a lateral border or furrow; the anterior ocular platform is very broad; the ocular ring is located far posteriorly, and the posterior facial suture is underneath the ocular platform; the under side of the librigena is occupied by a broad doublure along the lateral margin; it is convex anteriorly, but depressed or concave posteriorly (Pl. 28, Fig. 10). The rostrum is transverse pentagonal, convex, and has the anterior margin swollen upward with the median margin slightly pointed forward; the lateral, or the connecting suture and the hypostomal suture are concave (horizontal). The thoracic segment is convex, without distinct ring-furrow or intrapleural furrow; the pleural

lobe is convex below the axis, and extended laterally from the dorsal furrow for a short distance and then directed posteriorly, and ends with a rounded pleural tip.

The pygidium is transverse trapezoidal in outline, highly convex, with indistinct dorsal and pleural furrows; the axis is convex above the pleural lobe; no axial ring is known; the posterior margin slopes downward from the mid-pleural region, and is without a marginal border or inner marginal furrow; ventrally the pygidium is surrounded by a broad doublure along the posterior margin, and its mid-terminal portion is pointed inward.

The skeletal surface is covered by faint pits.

*Illaeenus valvulus* RAYMOND, "female"

Pl. 27, Figs. 25-27, 30, 32-34, 37;  
Text-fig. 3M, R, Q.

*Comparison*—The supposed female form of the present species has a rounded cranidium; the palpebral lobes are narrower, smaller, and elongate, and located slightly forward; the pygidium is less convex and semicircular in outline; the skeletal surface is faintly granulated. It is less common than the "male". The sexual ratio is about 112.

*Figured specimens*—"Female" form: Cranidia, U.C.G.M. 40418v-x; librigenae, U.C.G.M. 40418o, p, s, u; pygidia, U.C.G.M. 40418a', d', c', e', h'; rostrum, U.C.G.M. 40418t. "Male" form: Cranidia, U.C.G.M. 40418j', k'; pygidia, U.C.G.M. 40418f', g'.

*Illaeenus valvulus* RAYMOND, ontogeny

*Anaprotaspis stage* (Pl. 28, Fig. 1 and Text-fig. 3A)—The shield is gently convex, about 0.35 mm in length (sag.), no axial and pleural lobes are separable, and

the dorsal furrows are indistinct; the axial region is slightly convex, and marked by a faint longitudinal furrow; neither marginal spine nor marginal border is observed. The surface is faintly granulated; the anterior margin is demarcated by a pair of distinct pits.

Only a single incomplete specimen is known of the present stage; it shows no distinct characteristics, except for a pair of frontal pits on the dorsal surface. This essentially growth form has been observed previously in several growth studies; e. g., *Norwoodella halli* RESSER (HU, 1963), *Coosella convexa* TASCH (HU, 1968), *Flexicalymene granulosa* (FOERSTE) and *Missisquoia cyclochila* (HU, 1971), etc.

*Metaprotaspis* stage (Pl. 28, Figs. 2-7, and Text-fig. 3B-D)—The shield is round or rounded oval in outline, convex, about 0.5-0.7 mm in length (sag.), with the axial and pleural lobes well defined by dorsal furrows; the axis is narrow fusiform, tapering both anteriorly and posteriorly from the mid-line (sag.); the frontal pits are distinctly demarcated, and are located behind of the anterolateral eye-ridges; the posterior end of the axis is indistinctly delimited by the dorsal furrows, roundly convex, and does not extend the full length of the shield; the pleural lobe is about the same width as the axis, convex, and sloping downward from the dorsal furrow; it has a rounded margin; the border furrow is absent. The protaspis librigeno-rostrum and the hypostoma

are fused as a single plate; the hypostomal portion is oblong and bears a few pairs of marginal spines; the median body is acute-triangular, conical, tapering backward, and well delimited by inner furrows; the posterior lobe is V-shaped, convex, and without a distinct marginal border; the librigenal portions are narrow, perrostraloid, and curving posterior laterally from the anterior hypostomal wings or rostrum.

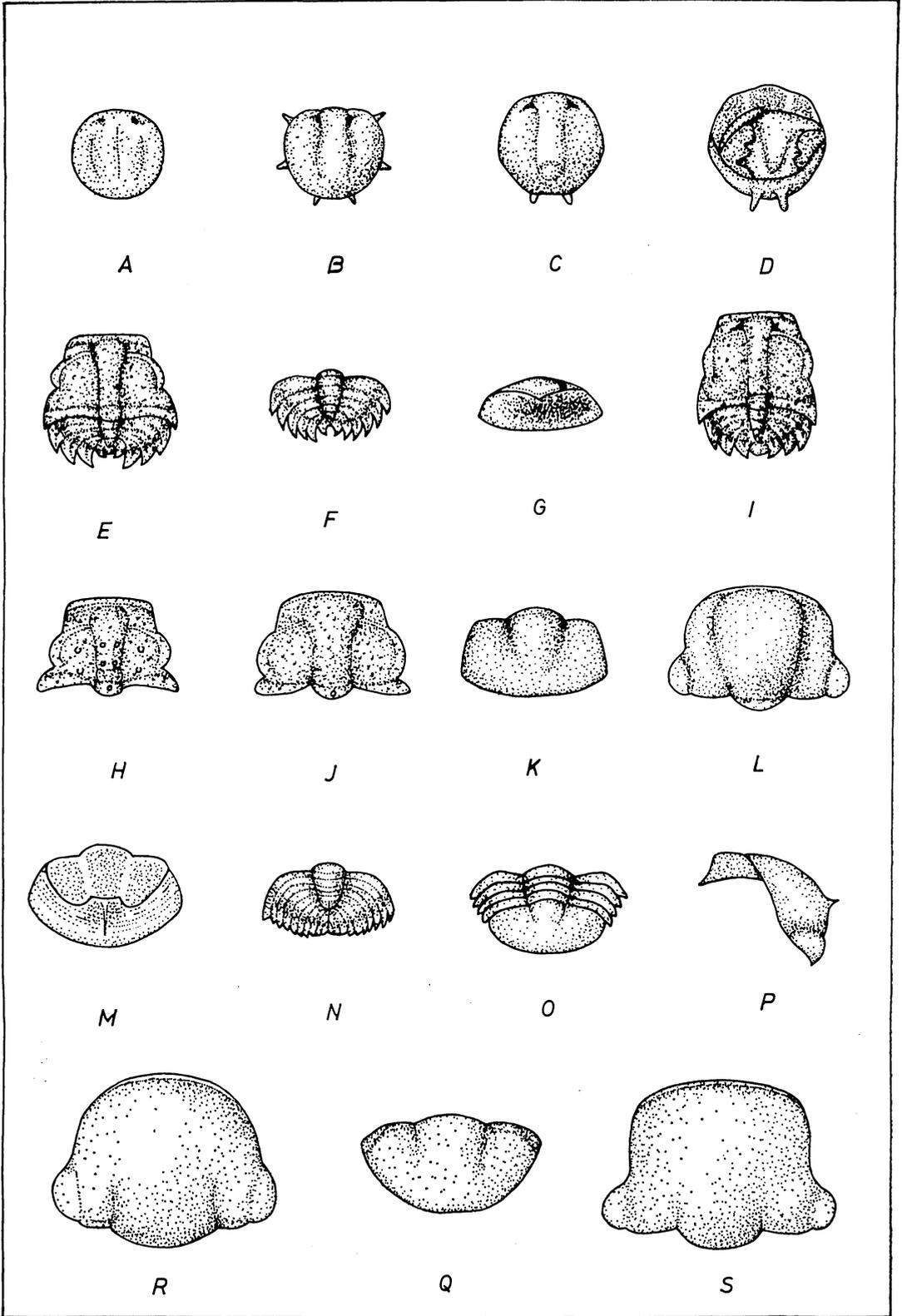
The surface of the shield is faintly granulated, and the ventral side of the shield has three pairs of marginal spines, of which the first pair extends from the anterolateral margin, the second is at the mid-line of the shield, and the third pair is on the marginal doublure, behind the axial lobe.

The present stage differs from the early one in having the axial and the pleural lobes well differentiated by the dorsal furrows.

*Paraprotaspis* stage (Pl. 28, Figs. 8, 9, 11, and Text-fig. 3E,I)—The shield is composed of a large cranidium and a small protopygidium, oval, convex, 0.7-1.0 mm in length (sag.); the glabella is cylindrical and the fixigenal lobes are well defined by a dorsal furrow; the glabella is expanded slightly forward, convex, and without distinct glabellar furrows; the occipital ring is convex and well demarcated by a furrow; the anterior border is narrow, elevated, and makes contact with the anterior margin of the glabella; no preglabellar field is known;

Text-fig. 3. *Illiaenus valvulus* RAYMOND.

A, anaprotaspis,  $\times 45$ ; B, C, D, dorsal and ventral views of two metaprotaspides,  $\times 30$ ,  $\times 27$ ; E, I, two paraprotaspides,  $\times 17$ ; F, N, two early meraspis pygidia,  $\times 12$ ; G, a rostrum,  $\times 2$ ; H, J, two early meraspis cranidia,  $\times 18$ ,  $\times 15$ ; K, a "male" pygidium,  $\times 7$ ; L, a late meraspis cranidium,  $\times 14$ ; M, Q, ventral and dorsal views of two "female" pygidia,  $\times 4$ ,  $\times 5$ ; O, a "female" cranidium,  $\times 5$ ; P, a small sized librigena,  $\times 5$ ; R, a "female" cranidium,  $\times 5$ ; S, a "male" cranidium,  $\times 4$ . (All drawings were made from photographs.)



the frontal pits are shallow and indistinct; the fixigena is convex at the same level as the glabella, and wider than the glabella; the narrow elongate palpebral lobes are well defined by furrow, crescentic, and its wider portion is situated on the mid-line of the glabella (tr.); the posterior fixigena is broad, convex, and slopes downwardly to the lateral margin; the narrow posterolateral border is convex, more than twice as wide as the occipital ring, and faintly delimited by a

furrow. The anterior facial suture is convergent, nearly straight, and the posterior one is slightly divergent-convex.

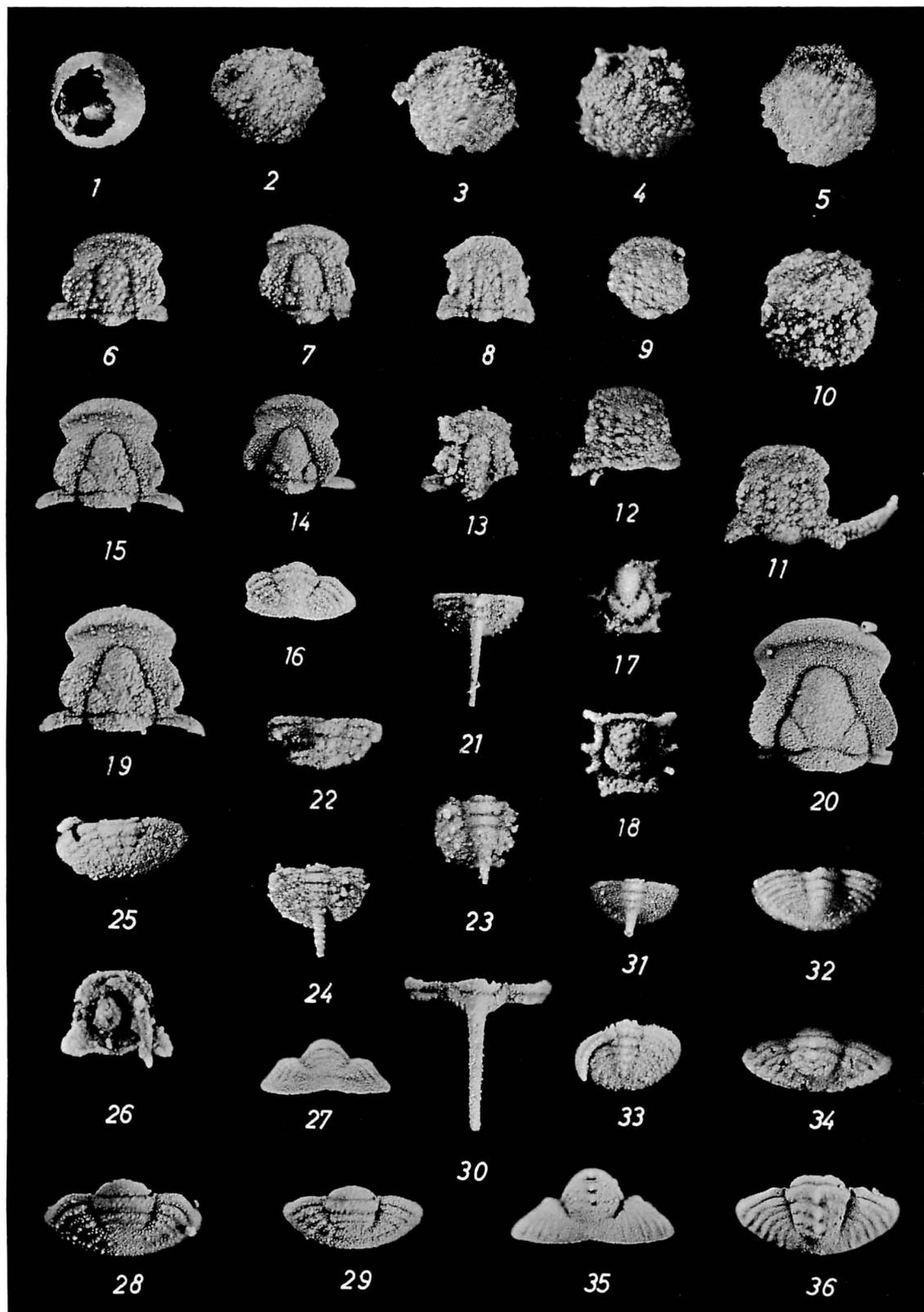
The protopygidium consists of two to three segments, convex; the axis is conical tapering posteriorly and divided into two axial and a terminal portions by distinct ring furrows; the pleural segment is extended laterally, horizontally, and deeply separated by intersegmental grooves; the three pairs of marginal spines are continuously directed posteriorly

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#### Explanation of Plate 27

Figs. 1-36. *Mesotaphraspis acris*, n. sp.

1. A problematium, showing the spherical ball and rounded internal hollow.  $\times 50$ , U.C.G.M. 40421.
2. An anaprotaspid shield, showing the elongate and deeply impressed anterior pits.  $\times 50$ , U.C.G.M. 40421a.
- 3-5. Three possible metaprotaspid shields. 3,  $\times 50$ , U.C.G.M. 40421b; 4,  $\times 50$ , U.C.G.M. 40421c; 5,  $\times 40$ , U.C.G.M. 40421d.
10. A paraprotaspid shield, showing the presence of the facial suture and the small protopygidium.  $\times 32$ , U.C.G.M. 40421i.
- 8, 9, 11, 12, 26. Four early meraspid cranidia; notice the cylindrical glabella and the palpebral lobes, situated on the mid-line of the cranium. 8,  $\times 23$ , U.C.G.M. 40421g; 9,  $\times 23$ , U.C.G.M. 40421h; 11,  $\times 23$ , U.C.G.M. 40421j; 12,  $\times 23$ , U.C.G.M. 40421k; 26, ventral view of figure 12, showing the hypostoma and librigena in place.
- 6, 7, 13. Three late meraspid cranidia, showing the conical glabella and the narrower posterior fixigena. 6,  $\times 23$ , U.C.G.M. 40421e; 7,  $\times 16$ , U.C.G.M. 40421f; 13,  $\times 15$ , U.C.G.M. 40421l.
- 14, 19, 20. Dorsal view of three holaspid cranidia. 14, paratype,  $\times 16$ , U.C.G.M. 40421m; 19, paratype,  $\times 15$ , U.C.G.M. 40421q; 20, holotype,  $\times 12$ , U.C.G.M. 40421r.
15. Dorsal view of a complete cranium;  $\times 11$ , U.C.G.M. 40421n.
16. Posterior oblique view of a small pygidium.  $\times 9$ , U.C.G.M. 40421o.
- 17, 18. Two problematic hypostomata, showing the well-preserved marginal spines. 18,  $\times 20$ , U.C.G.M. 40421p.
- 21, 23, 24, 31. Dorsal views of four early meraspid pygidia, each associated with two or three thoracic segments in front of the spiny one. 21,  $\times 20$ , U.C.G.M. 40421s; 23,  $\times 30$ , U.C.G.M. 40421u; 24,  $\times 15$ , U.C.G.M. 40421v; 31,  $\times 10$ , U.C.G.M. 40421a'.
- 22, 25, 32, 33. Dorsal views of four late meraspid pygidia; notice one or two rows of granules along the axial lobe. 22,  $\times 10$ , U.C.G.M. 40421t; 25,  $\times 10$ , U.C.G.M. 40421w; 32,  $\times 21$ , U.C.G.M. 40421b'; 33,  $\times 15$ , U.C.G.M. 40421c'.
- 27-29. Back and dorsal views of three female pygidia (paratype); notice the depression at the terminal portion. 27, 28,  $\times 15$ , U.C.G.M. 40421y; 29,  $\times 15$  (specimen missing).
30. A spiny thoracic segment;  $\times 10$ , U.C.G.M. 40421z.
- 34-36. Dorsal and posterior views of three male pygidia, a row of granules along the axis. 34,  $\times 10$ , U.C.G.M. 40421d'; 35, 36, paratype,  $\times 10$ , U.C.G.M. 40421e'.



from the pleural segments; there are flat, and shallowly depressed part around the inner margin; the skeletal surface is covered by faint granules.

*Early meraspid stage* (Pl. 28, Figs. 10, 12, 13, 23, 31 and Text-fig. 3F, H, J, N)—The cranidium is trapezoidal in outline, convex, about 0.8-1.0 mm long (sag.); the forwardly expanded glabella is deeply delimited by dorsal furrows; it is convex, and indistinctly demarked by glabellar furrows; the occipital ring is convex, and separated by a deep occipital furrow; the narrow anterior border is elevated, up-turned from the frontal furrow; it is horizontal and straight. The fixigena is strongly convex, elevated to about the same level as the glabella; encompassed by the palpebral and the posterior fixigenal furrow; the palpebral lobe is narrow, elongate, and elevated from the palpebral furrow; its anterior end is continuous with the ocular ridge, and ends at the posterolateral margin of the anterior glabella; the posterior fixigena is about twice as wide as the occipital ring, with the posterior border well delimited by a broad border furrow; the anterior fixigenal area is concave, and turned upward along the lateral free margin and the anterior border. The pygidium is semicircular in outline, convex, and consists of more than seven segments; the axis is conical, tapering posteriorly, and slender; the terminal portion slopes downward; the pleural lobe is more than twice as wide as the axis, convex below the axis, and slopes downward along the margin; each of the pleural segments ends in a pair of flat pleural spines, which are dericted posterolaterally or posteriorly, surrounding the terminal portion. The surface of the skeleton is covered by fine and coarse granules; the latter are fairly marked on the glabella and the fixigenae.

The present stage is characterized by the narrow palpebral lobes situated behind of the mid-line of the cranidium (tr.), the narrower fixigena, and the coarser granules. The pygidium increases in the number of the segments.

*Late meraspid stage* (Pl. 28, Figs. 17, 18, 24-26, 30, 32, 33, 35, 38 and Text-fig. 3L, O, P)—The cranidium is nearly of a regular trapezoidal outline, convex, about 1.2-1.5 mm in length (sag.); the glabella is strongly expanded forward, convex, delimited by an indistinct dorsal furrow, except these adjacent to the occipital; glabellar furrows are unknown; the narrow occipital ring is faintly delimited by a ring furrow; it is convex and arches posteriorly; the anterior margin makes a faint, elevated and horizontal ridge; the fixigena is broad at the palpebral lobes, convex, and faintly delimited by the palpebral furrow; the posterior fixigena constitutes the fixigenal border, which is vertical to its lateral end located underneath the palpebral lobe; the anterior fixigena is broad and concave.

The librigena is trapezoidal, convex, and without lateral border or the border furrow; the ocular platform is broad, with the ocular ring situated at the posterior margin; the genal spine is short and stout, and extends posterolaterally from the lateral margin.

The pygidium is semicircular in outline, convex, without a distinct dorsal furrow; the anterior margin of the pygidium is associated with one or few segments.

The specimens of the present stage might be segregated into two morphologic groups: The first group (Pl. 28, Figs. 25, 26, 30, 32, 33) having less convex cranidium, forwardly situated palpebral lobes, well defined fixigenal border, arched anterior margin, and a semicircular pygidium; the second (Pl. 28, Figs. 31, 35, 39, 40) has a highly convex

cranidium, posteriorly located palpebral lobes, incompletely developed posterior fixigenal border, and a subtrapezoidal pygidium. These differences within the same species population are interpreted as sexual differences as indicated above.

*Figured specimens* — Anaprotaspis, U.C.G.M. 40418; metaprotaspides, U.C.G.M. 40418a-d; paraprotaspides, U.C.G.M. 40418e-h; early meraspides, U.C.G.M.

40418i-m, y, z, b'; late meraspides, U.C.G.M. 40418n, i'.

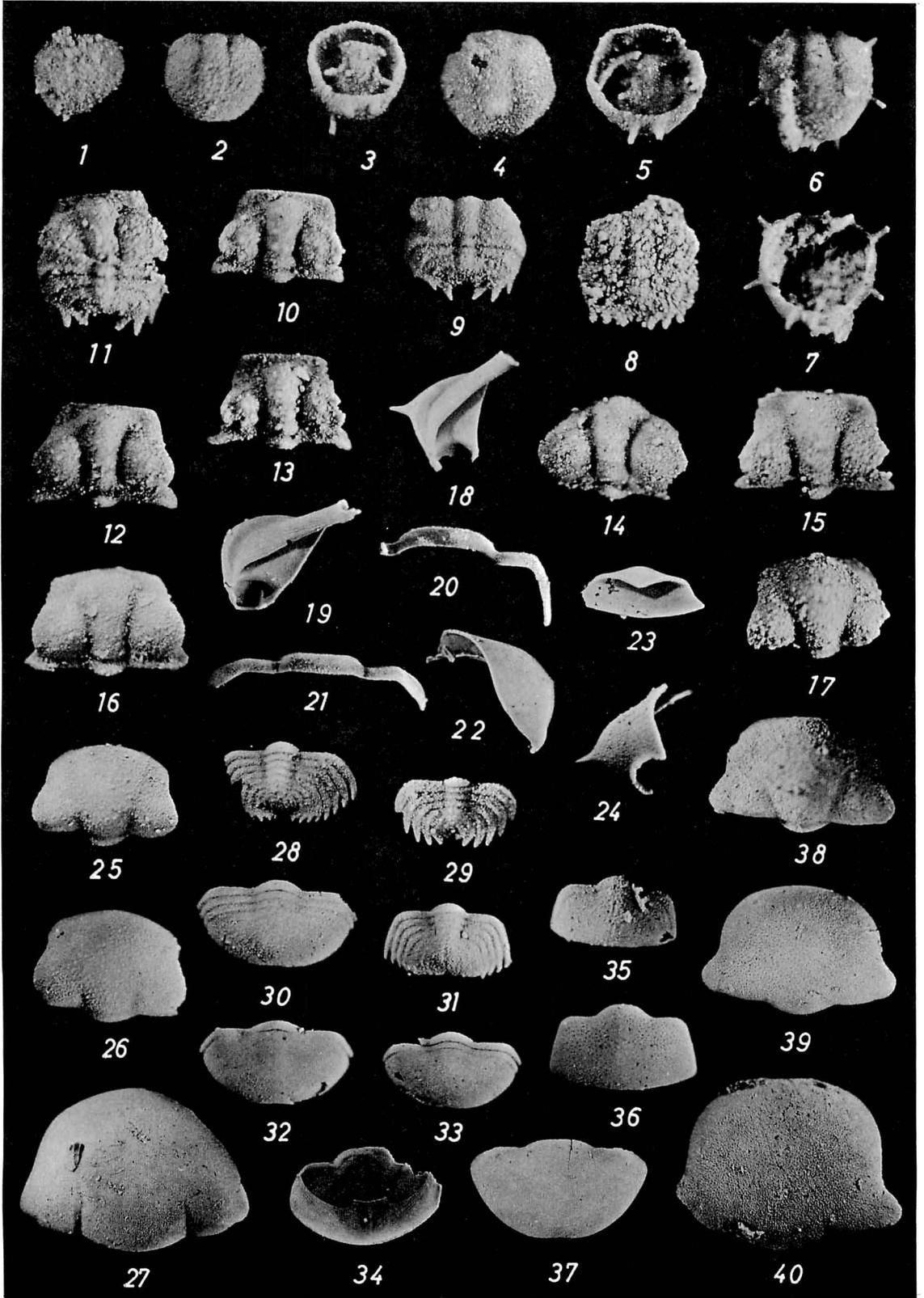
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### Explanation of Plate 28

Figs. 1-40. *Iliaenus valvulus* RAYMOND

1. Dorsal view of a broken anaprotaspid shield; notice the undifferentiated axial and pleural lobes.  $\times 45$ , U.C.G.M. 40418.
- 2-7. Dorsal and ventral views of a few metaprotaspid shields; notice the three pairs of marginal spines and librigeno-rostrum. 2,  $\times 30$ , U.C.G.M. 40418a; 3,  $\times 30$ , U.C.G.M. 40418b; 4, 5,  $\times 27$ , U.C.G.M. 40418c; 6, 7,  $\times 27$ , U.C.G.M. 40418d.
- 8, 9, 11. Dorsal views of three paraprotaspid shields; notice the appearance of the proto-pygidium. 8,  $\times 20$ , U.C.G.M. 40418e; 9,  $\times 17$ , U.C.G.M. 40418f; 11,  $\times 17$ , U.C.G.M. 40418h.
- 10, 12, 13-16. Dorsal views of six nearly complete early meraspid cranidia, showing the deep dorsal furrow and the anterior glabellar expanding. 10,  $\times 18$ , U.C.G.M. 40418g; 12,  $\times 18$ , U.C.G.M. 40418i; 13,  $\times 18$ , U.C.G.M. 40418j; 14,  $\times 17$ , U.C.G.M. 40418k; 15,  $\times 17$ , U.C.G.M. 40418l; 16,  $\times 15$ , U.C.G.M. 40418m.
- 17, 38. Dorsal views of two male forms of the late meraspid cranidia; notice the shallow dorsal furrow and the broad anterior glabella.  $\times 14$ , U.C.G.M. 40418n;  $\times 14$ , U.C.G.M. 40418i'.
- 18, 19. Ventral views of immature and mature librigenae; notice the doublure and the absence of the librigenal spine.  $\times 5$ , U.C.G.M. 40418o;  $\times 5$ , U.C.G.M. 40418p.
- 20, 21. Oblique and dorsal views of two thoracic segments.  $\times 4$ , U.C.G.M. 40418q;  $\times 7$ , U.C.G.M. 40418r.
23. A rostrum.  $\times 3$ , U.C.G.M. 40418t.
- 22, 24. Dorsal view of mature and immature librigenae; notice the absence of the librigenal spine.  $\times 5$ , U.C.G.M. 40418s;  $\times 14$ , U.C.G.M. 40418u.
- 25, 26. Dorsal view of two female forms of the late meraspid cranidia.  $\times 14$ , U.C.G.M. 40418v;  $\times 14$ , U.C.G.M. 40418w.
27. Dorsal view of a nearly complete female cranium.  $\times 5$ , U.C.G.M. 40418x.
- 28, 29, 31. Three early meraspid pygidia. 28,  $\times 12$ , U.C.G.M. 40418y; 29,  $\times 20$ , U.C.G.M. 40418z; 31,  $\times 12$ , U.C.G.M. 40418b'.
- 30, 33. Two female forms of the late meraspid pygidia.  $\times 10$ , U.C.G.M. 40418'a;  $\times 10$ , U.C.G.M. 40418d'.
- 32, 34, 37. Dorsal and ventral views of three female pygidia. 32,  $\times 7$ , U.C.G.M. 40418c'; 34,  $\times 4$ , U.C.G.M. 40418e'; 37,  $\times 5.5$ , U.C.G.M. 40418h'.
- 35, 36. Dorsal views of a small and a large sized pygidia.  $\times 10$ , U.C.G.M. 40418f';  $\times 7$ , U.C.G.M. 40418g'.
- 39, 40. Dorsal view of two male cranidia; notice the punctuated surface.  $\times 10$ , U.C.G.M. 40418j';  $\times 4$ , U.C.G.M. 40418k'.



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658. DISTRIBUTION AND BIOSTRATIGRAPHIC SIGNIFICANCE  
OF *DICTYOCHA SUBARCTIOS* (SILICOFLAGELLATE)  
IN THE NORTH PACIFIC\*

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*Dictyocha subarctios* (珪質鞭毛藻) の北太平洋海底堆積物中に於ける地理的並に地質的分布: 筆者により中部北太平洋の中緯度深海底堆積物より検出された *Dictyocha subarctios* (珪質鞭毛藻) に就て研究を続けた結果、此の種はベーリング海、日本海を含む中、高緯度地域の全北太平洋海底にのみ広く見出され、現生の *Distephanus octangulatus* の分布に似ている事が判明した。そして本種の地質的出現は鮮新—更新世の境界、即ち Matuyama 逆磁極期中の Olduvai 亜期で *Eucyrtidium matuyamai* (放散虫) と殆ど同時である。然してその絶滅は Brunhes 正磁極期と Matuyama 逆磁極期の境界よりは若く、0.6~0.65 m. y. と推定される。此の結果、環北太平洋地域殊に日本の更新世早期或はそれに対比される地層中、若しくは1977年に予定される国際深海掘削計画 (IPOD) 中、オホーック海より Kuril Arc にかけての深海底堆積物中に本種が見出されることが予測される。

林 信 一

**Introductory note**

The unexpected discovery of abundant Late Cenozoic silicoflagellate and ebridian skeletons from middle latitude deep-sea (piston) core sediments in the Central North Pacific (LING, 1970) led the present author to continuously investigate biostratigraphic occurrence of the group of siliceous microfossils mainly from the marine deposits. Two years later (LING, 1972) initial documentation of the geological distribution of these microfossils since Late Cretaceous time, based on samples mainly from deep-sea sediments, was completed. Material studied included the experimental Mohole drilling and the first three Legs of the Deep Sea Drilling

Project (DSDP). Since then the biostratigraphic utility of this once neglected group for both deep-sea sediments and land based sections has received ample demonstration from various parts of the world, particularly in the middle to high latitude region of both hemispheres.

A silicoflagellate species, *Dictyocha subarctios*, was proposed by the present author because of its ubiquitous limited occurrences in both time and space in the Central North Pacific sediments.

In this paper the author further discusses its distribution based on the observations from deep-sea sediments of the entire North Pacific together with results of magnetic measurements and radiolarian and diatom analyses undertaken for some of the cores.

\* Received Dec. 25, 1975; read Jan. 30, 1976 at Narugo.

### Material sources

Besides the previously reported North Pacific cores collected by the R/V THOMAS G. THOMPSON cruises 28 and 49 (abbreviated as TT 28, 49), the occurrence of the present species was already

reported from deep-sea sediments recovered during the Legs XIX (Sites 183-193) and XXI (Sites 299-302) of the DSDP (Ling, 1973, 1975). In addition, the following core sediments also contained the species:

Core	Latitude (North)	Longitude	Water depth (in m)
TT 3-8	47°07.1'	132°12.2'W	3,146
DSDP Site 173	39°57.71'	125°27.12'W	2,927
DSDP Site 178	56°57.38'	147°07.86'W	4,218
ARIES 49 G	36°26.0'	178°38.2'E	3,902

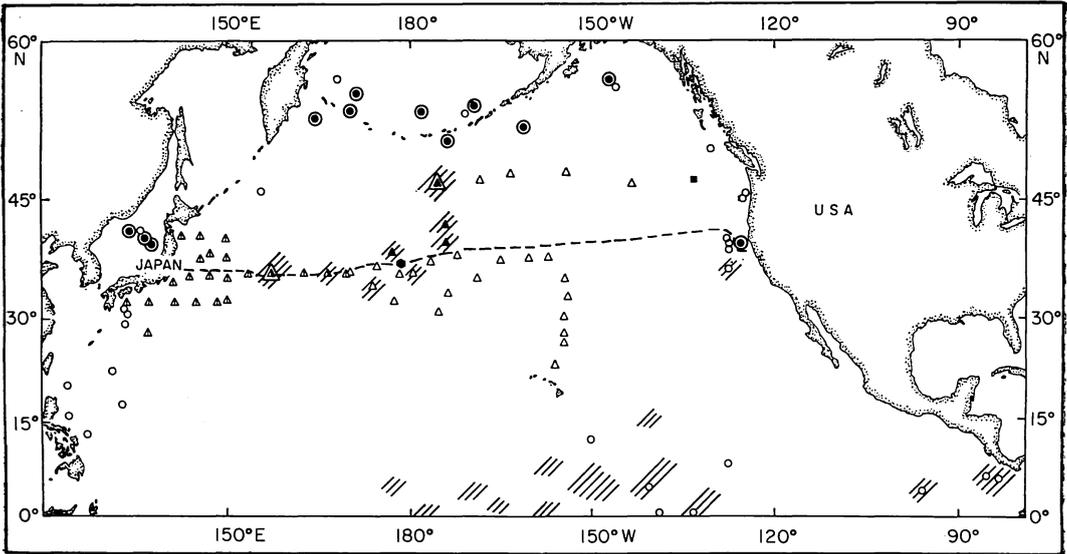
### Data

*Geographic distribution*—Sediment cores in which *Dictyochoa subarctios* was observed are shown in Text-fig. 1. It is readily apparent that its geographic distribution covers the entire North Pacific Ocean and its marginal seas including the Bering and Japan, but is limited to the middle to higher latitude region only. Its southern limit can be drawn approximately at the so-called "subarctic boundary" of the area (DODIMEAD *et al.*, 1936). A similar distributional pattern has been observed from surface sediments for a modern species, *Distephanus octangulatus* in the area (Text-fig. 2), inferring that this extinct species thrived under a similar physicochemical environment as its modern counterpart of the area. Because the occurrence of modern *Distephanus octangulatus* extends to the Sea of Okhotsk (LING, 1974), it will not be a surprise that *Dictyochoa subarctios* may be encountered in the sediments of the Okhotsk Sea when the D/V GLOMAR CHALLENGER drills the area in 1977 during the International Phase of Ocean Drilling (IPOD) of the Deep Sea Drilling Project.

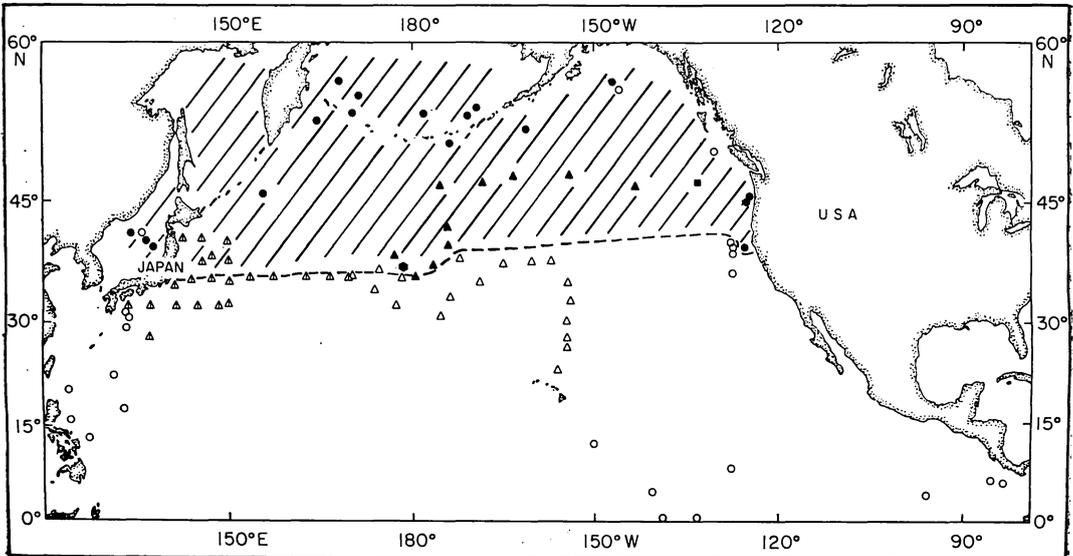
*Geologic ranges*—Among the previously studied piston cores from the Central

North Pacific, the initial appearance of *Dictyochoa subarctios* was observed only in the TT 28-24 and TT 49-4 sediments. The magnetic reversal history of the core recognized by KINOSHITA, HENSHAW and MERRILL extends downward to below the second normal event within the reversed epoch. Radiolarians recognized for the core sediments (Pl. 29, Text-fig. 3) agree with the above interpretation in that evolutionary appearance of *Eucyrtidium matuyamai* was observed. From the sediments collected during the two DSDP legs, the initial appearance of the species was always at or slightly after the Plio-Pleistocene boundary drawn by diatom analysis (KOIZUMI, 1973, 1975).

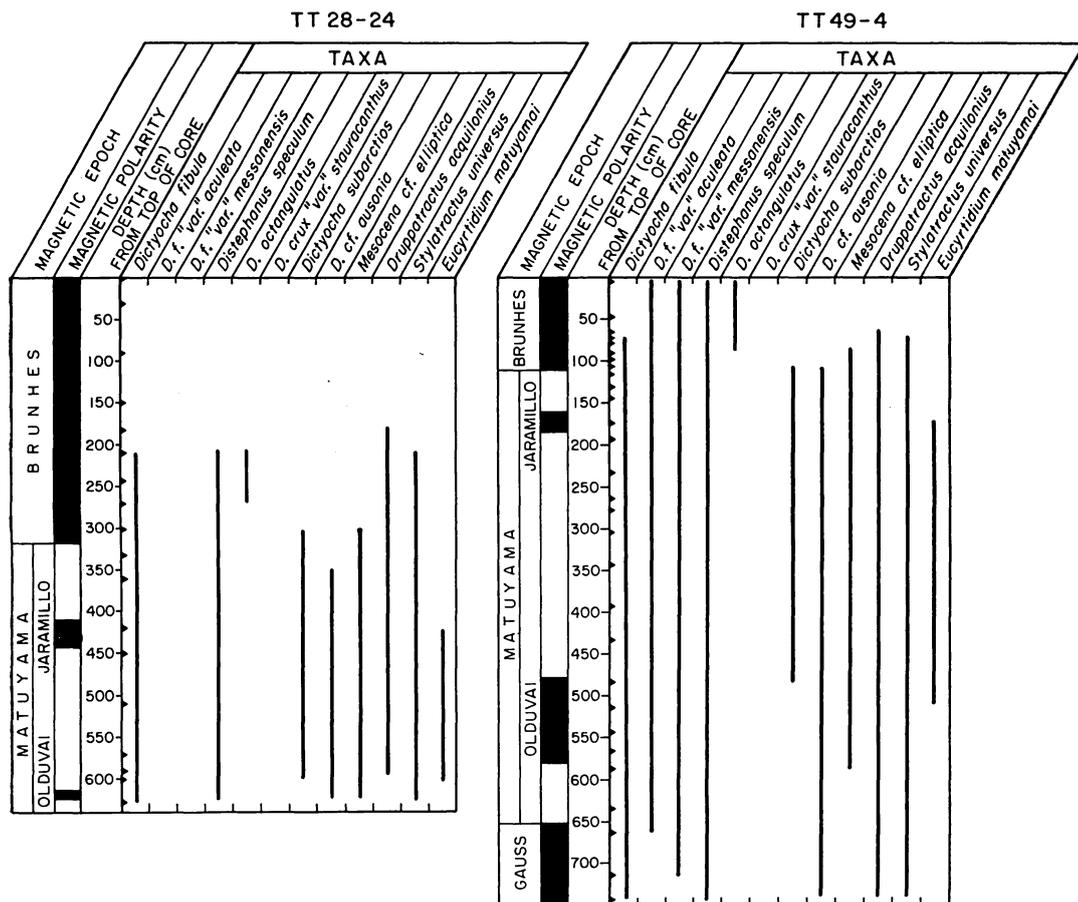
The upward extinction of *Dictyochoa subarctios* has been observed, on the contrary, in numerous cored sediments (see LING, 1970, text-fig. 4). The paleomagnetic analysis of the TT-cores indicates that this extinction level falls slightly above the Brunhes Normal and Matuyama Reversed epoch boundary. If the figure of .69 m.y. for this polarity boundary is accepted (COX, 1969), the age of the extinction of *Dictyochoa subarctios* falls within .60-.65 m.y. (Text-fig. 4). In constructing this figure, the assumption has been made that the sedi-



Text-fig. 1. Occurrence of *Dictyocha subarctios* (filled symbols) from deep sea sediments of the North Pacific Ocean and its marginal seas (data from LING, 1970, 1973, 1975, unpublished data). Symbols for core location;  $\square$ ,  $\triangle$ ,  $\Delta$ , R/V THOMAS G. THOMPSON cruise, 3, 28, 49 respectively;  $\circ$ , ARIES expedition (Scripps);  $\bigcirc$ , Deep Sea Drilling Project. Double symbol indicates cores in which the first appearance of the species was also observed. Occurrences of *Mesocena cf. elliptica* recognized in the sediment cores are shown by diagonal lines over the core location (data from JOUSÉ and MUKHINA, 1973, LING, unpublished data).



Text-fig. 2. Distribution of *Distephanus octangulatus* (filled symbols) from deep sea sediments of the North Pacific Ocean and its marginal seas (data from LING, 1970, 1973, 1974, 1975, unpublished data). For symbols for core locations, see Text-fig. 1.



Text-fig. 3. Distribution of silicoflagellates and radiolarians in the TT 28-24 and TT 49-4 sediment cores. Taxonomy of microfossils are according to HAYS (1970) and LING (1970).

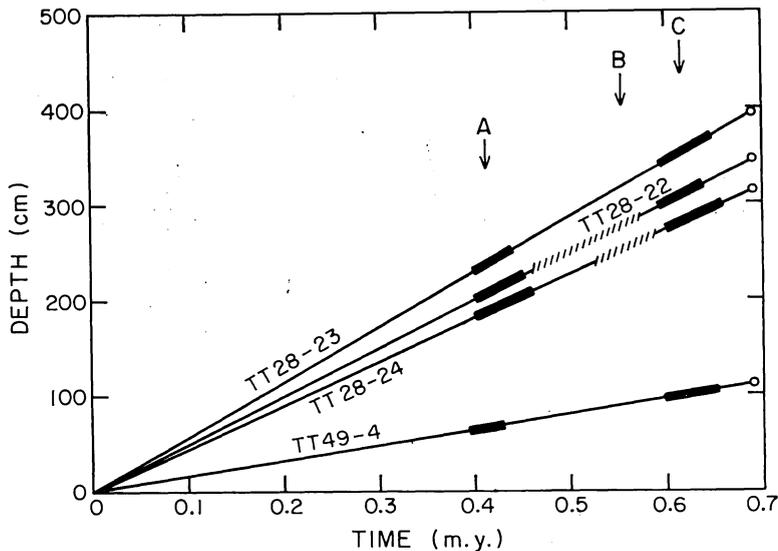
mentation rate has been constant within each core sediment at least for the last .70 m. y.

To test the above, the extinction level of a radiolarian species, *Stylatractus universus* HAYS, is plotted in the figure. It falls approximately at .40-.43 m. y., thus is in good agreement with the observation from the North Pacific by HAYS (1970). At the same time, the extinction level of a diatom species, *Nitzschia reinholdii* KANAYA, could be defined more precisely should more samples from these

sediment cores be examined closely for their diatom microflora.

The significance of this *Dictyocha subarctios* extinction level is further enhanced when it is recognized that this is the same level where another silicoflagellate species, *Mesocena cf. elliptica* becomes extinct in some cores.

As already discussed in detail, the Quaternary occurrence of *Mesocena cf. elliptica* has been restricted in the middle to low latitude areas (JOUSÉ and MUKHINA, 1973; LING, 1970, unpublished data)



Text-fig. 4. Time versus depth plots within Brunhes Normal Epoch for sediment cores from the North Pacific. The heavy black bar represents the limits within the extinction level of A, *Stylatractus universus* (radiolarian); B, *Nitzschia reinholdii* (diatom) (KOIZUMI, unpublished data); and C, *Dictyocha subarctios* (silicoflagellate) falls.

(see Text-fig. 1), therefore its extinction with *Dictyocha subarctios* in the middle latitude region serves as the bridge between the low and high latitudes of the North Pacific during the Pleistocene interval.

The above conclusion regarding the geologic range of *Dictyocha subarctios* would then lead to the following discussion. In hoping to establish nannoplankton stratigraphy of Japan, UCHIO (1974) examined a series of outcrop samples from the Sado Island in Niigata Prefecture of Honshu, Japan for silicoflagellate and coccolith assemblages, and reported the occurrence of specimens similar, if not identical, to the present species as *Dictyocha fibula* var. *subarctios* (LING) from the Pliocene Kawachi Formation, the lower part of the Sawane Formation (his samples nos. 48 and 56). To date this constitutes the only record for the

species from the land outcrops throughout the Circum-North Pacific region.

It is important to note here that in these two samples, UCHIO also recognized other silicoflagellate species including *Distephanus crux*, *Corbisema triacantha* whose last geologic appearances have been limited to the Miocene age. Therefore, re-examination of samples from the Sado Island for silicoflagellates together with similar studies for other groups of co-occurring microfossils will be necessary in order to ascertain the occurrence of this species from the Sado Island.

### Conclusion

1. *Dictyocha subarctios* is a silicoflagellate species, distributed widely in the middle to high latitude regions of the entire North Pacific and its marginal seas. Comparison of its distribution with that

of the modern silicoflagellate species, *Distephanus octangulatus*, suggests that it will be encountered in the sediments of the Sea of Okhotsk during IPOD drilling in 1977.

2. The geologic range of *Dictyocha subarctios* has been discussed. Its initial appearance generally corresponds with that of a radiolarian *Eucyrtidium matuyamai* approximately at Plio-Pleistocene boundary or Olduvai event of the Matuyama Reversal Epoch, while its extinction occurs at about .60-.65 m. y., which falls slightly above Brunhes Normal and Matuyama Reversal epoch boundary.

3. Finally, the present species has not been found inland of the Circum-North Pacific Ocean, except for the Sado Island, but its reported occurrence there deserves further clarification. Judging from accompanying microfossils, particularly radiolarians and diatoms, it is highly probable that it can be found in the Pleistocene deposits of Japan.

#### Acknowledgements

The author is indebted to Hajimu KINOSHITA of Tokyo University, Paul C. HENSHAW, and Ronald T. MERRILL of the University of Washington for their magnetic measurements of sediment cores, and to Itaru KOIZUMI of Osaka University for providing his unpublished data of diatom analysis. Samples taken by the R/V THOMAS G. THOMPSON were collected through the cooperation of the crews and scientists of the University of Washington under the financial support of the Office of Naval Research. Participation on the two cruises aboard the D/V GLOMAR CHALLENGER were made possible by the Deep Sea Drilling Project under the financial support of the National Science Foundation. The present author's re-

search has been supported by grants from the National Science Foundation, and the manuscript is completed under grant DES73-00489AI (formerly GA40142X). This is contribution No. 897 of the Department of Oceanography, University of Washington.

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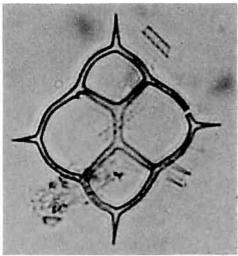
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#### Explanation of Plate 29

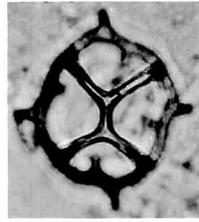
- Fig. 1. *Dictyocha fibula* EHRENBERG TT 49-3 PC, 80-38 cm, R-2 (C46/0), ×500.
- Fig. 2. *Dictyocha fibula* var. *aculeata* EHRENBERG TT 49-4 PC, 340-343 cm, L-2 (U49/2), ×500.
- Figs. 3, 4. *Dictyocha subarctios* LING TT 49-4 PC, 340-343 cm, L-2 (Y32/4), ×500. Different focus level.
- Fig. 5. *Distephanus speculum* EHRENBERG TT 49-22 AC, 0-3 cm, L-2 (T23/0), ×500.
- Figs. 6, 7. *Distephanus octangulatus* WAILES TT 49-21 PC, 30-33 cm, L-2 (N13/3), ×500. Different focus level.
- Fig. 8. *Mesocena* cf. *elliptica* EHRENBERG TT 49-2 PC, 50-53 cm, L-2 (Z13/2), ×500.
- Fig. 9. *Mesocena* cf. *elliptica* EHRENBERG TT 49-3 PC, 130-133 cm, L-2 (X12/1), ×500.
- Figs. 10, 11. *Drupptractus acquilonius* HAYS TT 3-8 GC, 224-227 cm, R-1 (X34/4), ×200.
- Figs. 12, 13. *Stylatractus universus* HAYS TT 49-4 PC, 340-343 cm, R-2 (S31/2), ×200.
- Figs. 14, 15. *Eucyrtidium matuyamai* HAYS TT 49-4 PC, 482-485 cm, R-1 (H16/3), ×200.



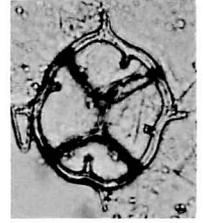
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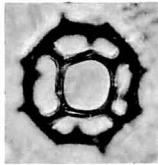
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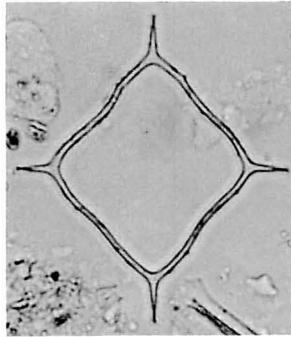
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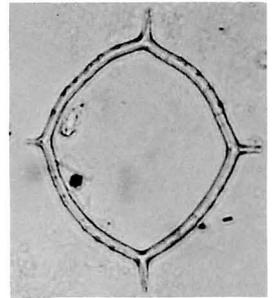
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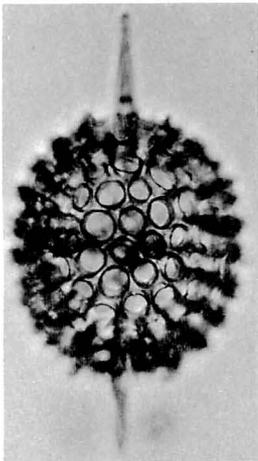
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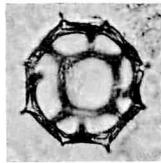
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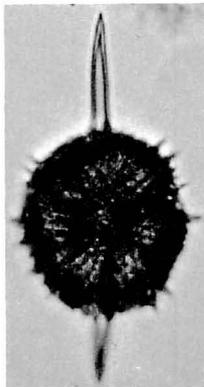
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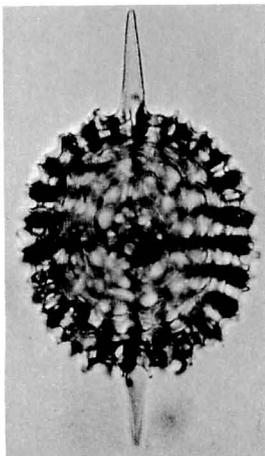
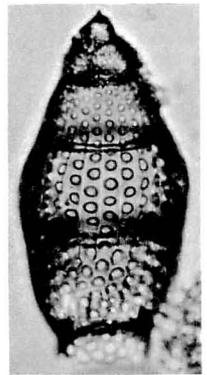


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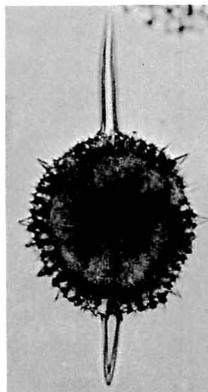


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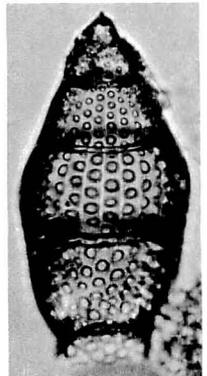


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13

15



659. THORIUM AND PROTACTINIUM ISOTOPES IN SOME  
PRESENT-DAY HERMATYPIC CORALS AND  
THEIR IMPLICATIONS TO DATING

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現生造礁性サンゴ中のトリウムおよびプロトアクチニウム同位体とそれらの年代測定への影響：四国室戸岬から New Britain 島にかけての太平洋西縁部に沿う9地域の現生造礁性サンゴを、U・Th および Pa 同位体組成と U の分布様式について検討した。その結果、ほとんどの試料で測定可能量の Th および Pa 同位体が検出された。また、南西諸島産化石試料中には、同地域の現生試料と同程度の  $^{232}\text{Th}$  が含まれていることから、少なくとも南西諸島産化石サンゴから  $^{230}\text{Th}$  および  $^{231}\text{Pa}$  放射年令を求める場合には、初生的な  $^{230}\text{Th}$  と  $^{231}\text{Pa}$  量を見積り、補正年令を求める必要がある。さらに、フィックション・トラック法で観察された U の不均一分布は、 $^{238}\text{U}$  量の部分的な差が最大 30% に達し、 $^{238}\text{U}$  最多部と最少部間で見かけの  $^{230}\text{Th}/^{231}\text{Pa}$  年令ともに、計数誤差以上の差を生ずる原因になる可能性もある。見かけの  $^{230}\text{Th}$  年令値の補正は、現生種の  $^{230}\text{Th}/^{232}\text{Th}$  放射能比が 1.4~3.0 と限られた範囲に入ることから、化石試料中の  $^{232}\text{Th}$  量が求まれば、近似的には可能である。ところが、今回得られた現生種の  $^{230}\text{Th}/^{232}\text{Th}$  比が、生息域の海水の同比より、見かけ上いく分高い事に注目しなければならない。このことは、各試料の分析された部位が数年~数十年以前に形成された部分であるため、試料採集時まで直接の親核種である  $^{234}\text{U}$  から成長した  $^{230}\text{Th}$  が、骨格分必当時の  $^{230}\text{Th}/^{232}\text{Th}$  比を、見かけ上増大させたためと説明される。結局、化石サンゴの見かけの  $^{230}\text{Th}$  年令の補正に用いる初期  $^{230}\text{Th}/^{232}\text{Th}$  比として、試料産出地付近の海水の  $^{230}\text{Th}/^{232}\text{Th}$  比を用いる事が、もっとも適切な方法といえる。本小論では、南西諸島化石サンゴに、与論島および徳之島の沿岸水の  $^{230}\text{Th}/^{232}\text{Th}$  比の平均値 (1.4) を初期  $^{230}\text{Th}/^{232}\text{Th}$  比として用い、補正  $^{230}\text{Th}$  年令を求めたところ、矛盾のない値を得ることが出来た。

大村明雄

### Introduction

Both the deficient  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  methods allow to extend the radiometric Pleistocene time scale back to about 250,000 years, and have greatly contributed to solve the Quaternary problems such as fluctuation of sea-level and tectonic movement (*e.g.* BROECKER *et al.*, 1968; MESOLELLA *et al.*, 1969; JAMES *et al.*, 1971; STEINEN *et al.*, 1973; VEEH and CHAPPELL, 1970; CHAPPELL, 1974a, 1974b;

KONISHI *et al.*, 1970, 1974). Yet there is still a room to reexamine rigorously the reliability of  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dates of hermatypic corals, which are accepted as the most favorable sample lacking the postmortem enrichment of secondary uranium like in molluscan shells.

There appears to be two ways that fossil corals give uncertain  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dates. The one is presence of the "initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ ", which were up-taken into the hard tissues together with uranium during fossils' lifetime. The premise to produce  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  coral ages is the sample in which these daugh-

\* Received Feb. 2, 1976; read Jan. 17, 1973 at Sendai.

ters are initially free. From fossil sample with the initial daughters, therefore, the precise death time of the coral cannot be estimated without a reasonable correction. Any uncorrected dates are regarded as the maximum ages.

Secondly, if the initial thorium and protactinium are distributed in no relation with uranium like at the two structural layers of molluscan shells (OMURA *et al.*, 1973), the heterogeneities in uranium distribution can complicate the picture to secure the reliable dating.

The purpose of this study is to make a close investigation on the amount of thorium and protactinium isotopes and the uranium distribution in present-day hermatypic corals as a basis to understand the extent of potential uncertainty of the observed  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dates from fossil corals. The analytical result of the present-day samples can be a direct estimate the undecayed amount of the initial daughters in fossil counterparts grown at the same geographic location, and also can provide the method to correct the apparent  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  coral dates. If the uranium concentration in a corallum systematically changes, furthermore, the intraskeletal variation of the apparent age obtained may be critically evaluated.

### Materials studied

All samples listed in Table 1 are hermatypic corals accompanied by symbiotic zooxanthellae, and most of them were collected alive in order to eliminate any possible postmortem alteration. They were collected from nine locations which extended from Shikoku (Southwest Japan) to New Britain Island along the western part of the Pacific Ocean. These samples are designated CAM-1, CYM-1, CTM-1, CNM-1 and so on, where "C",

indicates "coral"; "A", "Amami-oshima"; "Y", "Yoron-jima"; "T" "Taiwan (Formosa)"; "N", "New Britain Island"; and "M", "modern (present-day)", respectively.

The sea-water samples are coastal water collected from the locations without any distinct influx of land drainage. These samples, however, may not necessarily represent the life-long environment in which the sampled corals grew, because of the possible seasonal variation in local mixing. WY-1 and WY-2 were collected at Chichibina-banare ( $128^{\circ}24.2'E$ ,  $27^{\circ}02.8'N$ ) and south of Akazaki ( $128^{\circ}27.3'E$ ,  $27^{\circ}01.1'N$ ), Yoron-jima, respectively; WTK-1, at Hedono ( $128^{\circ}53.5'E$ ,  $27^{\circ}48.4'N$ ), Tokuno-shima.

### Experiments

*Sample preparation* Due to low concentration in sea-water, the analysis of uranium and thorium isotopes requires a large amount of sample water; 20l of sample water was used for the analysis of uranium and 360l for thorium, respectively. After filtered through a cotton gauze in field, suspensions coarser than  $0.54\mu$  in diameter were excluded with a millipore filter.

Carbonate samples for isotopic analysis by  $\alpha$ -spectrometry were prepared by the same manner as OMURA *et al.* (1973).

The sample for the fission track analysis was prepared separately depending upon the growth form of the corallum colony, whether branching or massive.

The massive colonial sample (CEM-1) was first embedded in an epoxy resin under vacuum. After solidifying of resin, the sample was trimmed to specific orientation and smoothed the surface by carborundum and chromium oxide powder on polished wheel. And then, it was given similar treatment as tridacnid

Table 1. List of the present-day coral samples.

Sample	Genus	Location	Collection date
CSM-1*	<i>Leptoria</i>	Drift on beach, Muroto-misaki, Shikoku	May 29, 1969
CSM-2*	<i>Favia</i>		
CCM-1**	<i>Favia</i>	Kominato, Chichi-jima, Ogasawara Islands	Jul., 1969
CCM-2**	<i>Acropora</i>	Drift on beach, Okumura, Chichi-jima	Jul., 1969
CHM-1**	<i>Pocillopora</i>	Oki-ko, Haha-jima, Ogasawara Islands	Jul., 1969
CAM-1**	<i>Goniastrea</i>	Dead sample, Saneku, Amami-o-shima, Ryukyu Islands	Aug., 1968
CEM-1	<i>Favia</i>	Kunigami-misaki, Okierabu-jima, Ryukyu Islands	Mar. 28, 1968
CEM-2	<i>Porites</i>		
CEM-3	<i>Favites</i>		
CEM-4	<i>Acropora</i>		
CEM-5	<i>Goniastrea</i>		
CEM-6	<i>Psammocora</i>		
CEM-7	<i>Acropora</i>		
CEM-8	<i>Acropora</i>		
CEM-9	<i>Stylophora</i>		
CYM-1	<i>Acropora</i>	N. of Chabana, Yoron-jima, Ryukyu Islands	Mar. 31, 1968
CYM-2	<i>Acropora</i>		
CYM-3	<i>Goniastrea</i>		
CYM-4	<i>Acropora</i>		
CYM-5	<i>Montipora</i>		
CYM-6	<i>Porites</i>		
CYM-7	<i>Goniastrea</i>		
CYM-8	<i>Acropora</i>		
COM-1*	<i>Hydnophora</i>	SW. coast of Kudaka-jima, Ryukyu Islands	Sept. 4, 1960
CTM-1***	<i>Turbinaria</i>	Suoa, Taiwan (Formosa)	Date unknown
CNM-1*	<i>Acropora</i>	Rabaul, New Britain Island	Feb. 26, 1971
CNM-2*	<i>Acropora</i>		
CNM-3*	<i>Pocillopora</i>		

\* collected by Dr. Kenji KONISHI, Depart. Earth Sci., Fac. Sci., Kanazawa Univ.

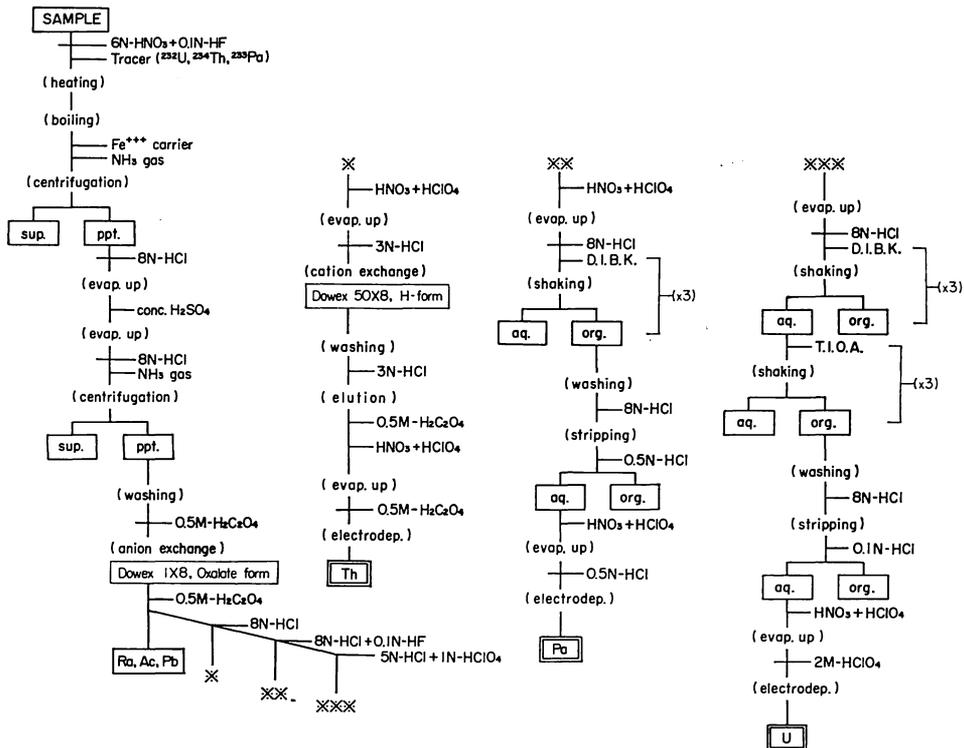
\*\* collected by Dr. Yasehide IWASAKI, Geological Institute, University of Tokyo.

\*\*\* collected by Dr. T. Y. H. MA of National Taiwan University.

sample (OMURA *et al.*, 1973).

The branching colony as CYM-8 sample was ground carefully with a file, after cleaning thoroughly. The powdered sample prepared was homogenized for grain

size, with sieving between 200 to 250 mesh (74 to 62  $\mu$ ) screens. The sample was uniformly poured on the muscovite detector placed at the bottom of the polyethylene tube. Both the sample pow-



Text-fig. 1. Analytical scheme of the carbonate samples.

der and muscovite detector were fixed with absorbent cotton and a lid of the tube. The reference powder sample with known concentration of uranium was used as the monitor to examine various factors when a uranium concentration was calculated from track density.

*α-spectrometry analysis*  $\alpha$ -spectrometry method was used the isotopic analysis of uranium, thorium and protactinium in carbonate samples and uranium and thorium in sea-water samples. In the present work, it was essentially important to separate each nuclide because of similarity in the energies of the alpha particles emitted by <sup>230</sup>Th (4.62 MeV, 4.68 MeV) and by <sup>234</sup>U (4.72 MeV, 4.77 MeV). The anion exchange technique established by SAKANOUÉ *et al.* (KOMURA and

SAKANOUÉ, 1967; SAKANOUÉ *et al.*, 1967) and partly modified by the author was successful for the separation of each nuclide. The electrodeposition technique was used to prepare the thin sources, which was also important to get a good peak resolution. The separation and purification procedures of each nuclide are schematically summarized in Text-figs. 1 and 2, in the case of carbonate and sea-water samples, respectively. For details of the actual procedures the papers by SAKANOUÉ *et al.* should be referred to.

*Fission track analysis* Only the procedures used in this study are briefly outlined below, as the principles of fission track analysis had been detailed already (*e.g.* LAHOUD *et al.*, 1966; SCHROEDER



Table 2. Analytical results of

Sample	Isotope content			
	<sup>238</sup> U (ppm)	<sup>232</sup> Th (ppm)	<sup>230</sup> Th (dmg)	<sup>231</sup> Pa (dmg)
C S M-1	2.45±0.10	0.120±0.005	0.0609±0.0020	<0.001
C S M-2	2.65±0.05	0.110±0.005	0.0521±0.0017	0.00501±0.00019
C C M-1	2.75±0.06	0.0511±0.0024	0.0214±0.0009	0.00409±0.00017
C C M-2	3.44±0.07	0.0632±0.0056	0.0249±0.0016	0.00198±0.00038
C H M-1	2.46±0.05	0.0609±0.0040	0.0242±0.0013	0.0140±0.0005
C A M-1	2.22±0.05	0.0275±0.0009	0.0229±0.0005	0.00908±0.00040
C E M-1	2.70±0.07	0.116±0.005	0.0788±0.0022	0.0168±0.0008
C E M-2	2.70±0.07	0.183±0.008	0.0716±0.0033	0.00858±0.00038
C E M-3	2.63±0.05	0.0903±0.0049	0.0517±0.0019	0.00594±0.00026
C E M-4	3.43±0.08	0.0321±0.0018	0.0187±0.0008	0.0113±0.0005
C E M-5	1.90±0.08	0.0517±0.0024	0.0187±0.0007	0.00809±0.00047
C E M-6	2.61±0.13	0.0323±0.0022	0.0215±0.0009	0.0143±0.0005
C E M-7	2.86±0.13	0.0675±0.0054	0.0270±0.0018	0.00700±0.00029
C E M-8	2.75±0.03	0.0386±0.0025	0.0131±0.0007	0.00287±0.00026
C E M-9	2.29±0.06	0.0149±0.0013	0.0149±0.0008	0.00460±0.00017
C Y M-1	2.75±0.06	0.0678±0.0033	0.0300±0.0014	0.00402±0.00017
C Y M-2a	2.82±0.14	0.0372±0.0021	0.0156±0.0007	0.00343±0.00015
C Y M-2b	3.61±0.10	0.0768±0.0040	0.0288±0.0012	0.00421±0.00024
C Y M-3	3.51±0.07	0.0442±0.0027	0.0196±0.0009	<0.001
C Y M-4	2.99±0.10	0.177±0.009	0.0723±0.0031	0.00142±0.00009
C Y M-5	3.02±0.06	0.0337±0.0021	0.0165±0.0007	0.00230±0.00013
C Y M-6	2.95±0.07	0.0608±0.0029	0.0224±0.0010	0.00141±0.00009
C Y M-7a	2.10±0.04	0.0143±0.0012	0.00700±0.00043	0.0108±0.0005
C Y M-7b	2.10±0.03	0.0119±0.0009	0.00550±0.00036	0.0111±0.0005
C Y M-7c	2.07±0.04	0.00960±0.00068	0.00451±0.00025	0.00850±0.00028
C Y M-7d	2.18±0.03	0.0101±0.0006	0.00384±0.00017	0.00810±0.00031
C Y M-7e	2.10±0.02	0.0102±0.0006	0.00486±0.00023	0.00820±0.00030
C Y M-7f	1.98±0.03	0.00882±0.00055	0.00412±0.00018	0.00730±0.00030
C O M-1	2.67±0.05	0.371±0.019	0.121±0.005	0.0238±0.0015
C T M-1	2.57±0.05	0.0432±0.0041	0.0235±0.0016	<0.001
C N M-1	2.72±0.08	0.109±0.006	0.0360±0.0016	<0.001
C N M-2	3.17±0.14	0.0387±0.0013	0.0125±0.0004	<0.001
C N M-3	3.32±0.08	0.0624±0.0037	0.0215±0.0013	<0.001

the present-day coral samples.

Activity ratio				Apparent age	
$^{234}\text{U}/^{238}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$	$^{230}\text{Th}/^{234}\text{U}$	$^{231}\text{Pa}/^{235}\text{U}$	$^{230}\text{Th}$ Age	$^{231}\text{Pa}$ Age
1.14±0.06	2.13±0.11	0.0296±0.0015	—	3,200±200	—
1.07±0.03	1.98±0.11	0.0251±0.0010	0.0560±0.0023	2,800±100	2,700±100
1.13±0.04	1.76±0.11	0.00938±0.00040	0.0440±0.0021	1,000±50	2,100±100
1.13±0.03	1.66±0.18	0.00873±0.00060	0.0170±0.0007	1,000±70	810±30
1.19±0.03	1.67±0.14	0.0113±0.0007	0.142±0.006	1,200±70	7,200±300
1.13±0.03	3.51±0.14	0.0124±0.0004	0.121±0.006	1,400±40	6,100±300
1.15±0.03	2.86±0.14	0.0346±0.0012	0.184±0.009	3,800±100	9,500±500
1.15±0.03	1.65±0.10	0.0313±0.0013	0.0941±0.0045	3,400±100	4,700±200
1.18±0.03	2.40±0.16	0.0227±0.0009	0.0669±0.0031	2,300±100	3,300±200
1.09±0.03	2.45±0.17	0.00680±0.00032	0.0973±0.0046	760±40	4,800±200
1.18±0.07	1.52±0.09	0.0113±0.0006	0.126±0.010	1,200±60	6,300±500
1.16±0.07	2.80±0.23	0.0112±0.0007	0.162±0.009	1,200±80	8,300±500
1.15±0.07	1.68±0.17	0.0128±0.0010	0.0723±0.0043	1,400±100	3,500±200
1.16±0.03	1.42±0.12	0.00556±0.00030	0.175±0.016	650±40	8,500±800
1.04±0.03	5.34±0.57	0.00850±0.00054	0.0593±0.0026	870±50	2,900±100
1.16±0.03	1.86±0.14	0.0128±0.0006	0.0433±0.0020	1,400±70	2,100±100
1.18±0.08	1.75±0.12	0.00754±0.00048	0.0359±0.0024	870±60	1,700±100
1.10±0.05	1.58±0.11	0.00988±0.00050	0.0345±0.0022	1,100±60	1,700±100
1.09±0.03	1.86±0.14	0.0070±0.0004	—	760±40	—
1.07±0.05	1.72±0.12	0.0307±0.0017	0.0141±0.0010	3,400±200	700±50
1.11±0.03	2.06±0.16	0.00673±0.00032	0.0225±0.0014	740±30	1,100±100
1.08±0.03	1.55±0.10	0.00961±0.00045	0.0141±0.0010	1,100±100	700±50
1.10±0.03	2.06±0.21	0.00412±0.00026	0.153±0.007	450±30	7,800±400
1.10±0.02	1.94±0.20	0.00324±0.00021	0.156±0.008	360±20	8,000±400
1.04±0.03	1.97±0.18	0.00286±0.00017	0.121±0.005	320±20	6,100±300
1.05±0.02	1.60±0.12	0.00229±0.00011	0.110±0.005	250±10	5,500±200
1.06±0.02	2.00±0.15	0.00298±0.00014	0.116±0.005	320±20	5,800±200
1.10±0.02	1.96±0.15	0.00257±0.00012	0.109±0.005	280±10	5,400±200
1.10±0.03	1.37±0.09	0.0563±0.0027	0.264±0.017	5,700±300	14,400±900
1.16±0.03	2.29±0.27	0.0107±0.0007	—	1,200±80	—
1.07±0.04	1.39±0.10	0.0167±0.0009	—	1,800±100	—
1.12±0.07	1.36±0.06	0.00480±0.00026	—	520±30	—
1.13±0.04	1.45±0.13	0.00779±0.00050	—	860±60	—

$^{234}\text{U}/^{238}\text{U}$  activity ratio in all samples ranges from several to less than twenty percent, which is close enough to the reported value of 1.15 from the present-day corals and oolites by THURBER (1962) and VEEH (1966). This anomaly in the uranium ratio prompted the possibility of an independent dating method, named either "uranium ratio method" or " $^{234}\text{U}$  method", which is based on the disintegration of the initial excess  $^{234}\text{U}$  in the sample. This method could be useful to cross-check the deficient  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dates, but any ages by this method appears to be less reliable. The measurement of  $^{234}\text{U}/^{238}\text{U}$  ratio is necessarily accompanied by the relatively large error as suggested from the gentle slope of the  $^{234}\text{U}$  decay curve, and the initial ratio ( $^{234}\text{U}/^{238}\text{U}$  activity ratio in the present-day samples) varies considerably among the individuals even in the same genera at the same habitat. Furthermore, even  $^{234}\text{U}/^{238}\text{U}$  ratio of three sea-water samples in the nearby region is not necessarily constant, though the  $^{234}\text{U}/^{238}\text{U}$  ratio is not unity and show that the activity of  $^{234}\text{U}$  is ten or more higher than that of  $^{238}\text{U}$  (Table 3).

It might be argumental if the concentrations of thorium and protactinium isotopes in the present-day samples are too low to be determined accurately because of the analytical method used here, but they can hardly be attributed to the analytical contamination as confirmed by

repeated blank tests, and can be accepted reliable (Table 2).

In addition to uranium isotopes, measurable amounts of  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  were detected together with  $^{232}\text{Th}$  in the most samples examined. It is clear that corals studied here have initially uptaken thorium and protactinium isotopes into their hard tissues from sea-water. In other words, most of the samples which must show zero year actually produce the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ages due to the presence of the initial thorium and protactinium isotopes. These observations probably reflect that the concentrations of thorium and protactinium isotopes are relatively high in sea-water at the sites where the present-day corals examined were collected. The analytical results of sea-water samples support at least the appreciably high concentration of thorium isotopes (Table 3).

Among the samples, the  $^{232}\text{Th}$  concentration ranges from  $1.7$  to  $6.0 \times 10^{-9}$  g/l, and the  $^{230}\text{Th}$  from  $1.3$  to  $4.0 \times 10^{-14}$  g/l. Comparing these data with those reported by the previous workers (*e.g.* MOORE and SACKETT, 1964), the observed concentrations of both  $^{232}\text{Th}$  and  $^{230}\text{Th}$  are taken as relatively higher level within the reasonable limit.

These important observation, coupled with that of the concentration of  $^{238}\text{U}$  (2 to 3.5 ppm) and thorium and protactinium isotopes (measurable amounts of both  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ ) in the present-day sam-

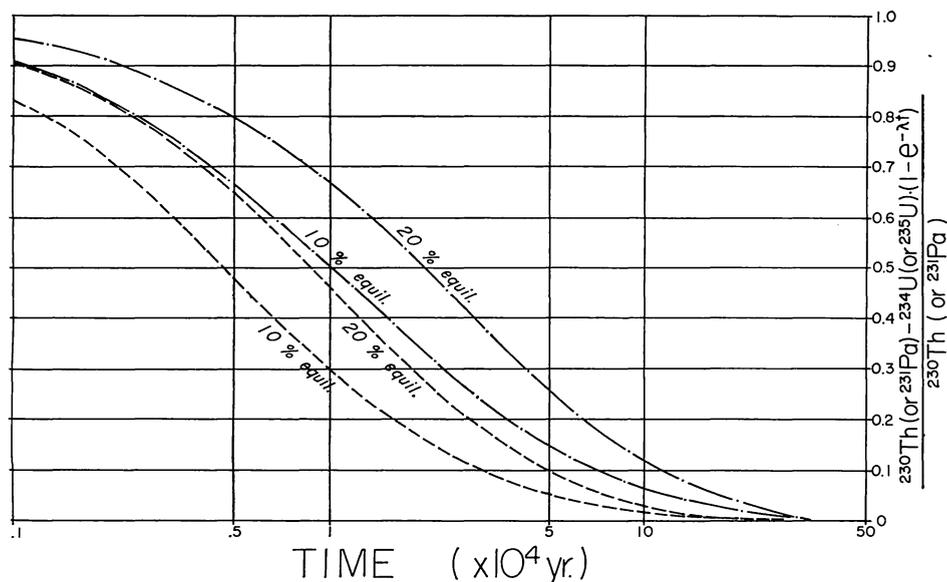
Table 3. Summary of  $\alpha$ -spectrometry analysis of the sea-water samples.

Sample	Isotope content			Activity ratio	
	$^{238}\text{U}$ ( $10^{-6}$ g/l)	$^{232}\text{Th}$ ( $10^{-9}$ g/l)	$^{230}\text{Th}$ ( $10^{-14}$ g/l)	$^{234}\text{U}/^{238}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$
WTK-1	$3.76 \pm 0.17$	$5.75 \pm 0.27$	$3.78 \pm 0.16$	$1.15 \pm 0.07$	$1.33 \pm 0.09$
WY-1	$3.54 \pm 0.21$	$5.47 \pm 0.25$	$3.41 \pm 0.14$	$1.11 \pm 0.09$	$1.26 \pm 0.08$
WY-2	$4.31 \pm 0.16$	$1.67 \pm 0.15$	$1.29 \pm 0.09$	$1.16 \pm 0.06$	$1.57 \pm 0.18$

ples examined, are suggestive of complicated conditions that render both the  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dating methods to apply to the fossil corals in the same region. The uncertainty associated with the "apparent ages" due to the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ , however, is so small that it can be masked with the statistical error and become negligible, in the case of fossils several tens of thousand years old. Within the order of several thousands years, on the contrary, any observed apparent ages may become a matter of serious consideration as discussed below.

Text-fig. 3 was prepared to visualize the effect of the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  upon the reliability of the apparent ages. Both the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  decrease with time, while the decay of uranium isotopes is to result in the accumulation of the radiogenic  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ , in turn. As a whole, both  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  are ex-

pected to increase with time. Text-fig. 3 shows the change of the ratio between the initial and total  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  with time. The values, 10% and 20% equil. are assigned not only as a matter of convenience, but 10% equil. for  $^{230}\text{Th}$  and 20% equil. for  $^{231}\text{Pa}$  may be regarded as the maximum values observed in the present-day corals of the Ryukyu Islands. If the initial amount of  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  were 20% equil., these nuclides would reach more than one-third of the total amounts after 10,000 years, but decrease significantly to approximately several percents beyond 100,000 years. In practice, however, only a few samples exceed 10% equil. in the total amounts of both  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ . In terms of percent equilibrium with respect to the parent nuclide,  $^{231}\text{Pa}$  seems to be contained more abundantly than  $^{230}\text{Th}$  in the present-day samples. Thus, the initial  $^{231}\text{Pa}$  appears to be more effective to deviate the ap-

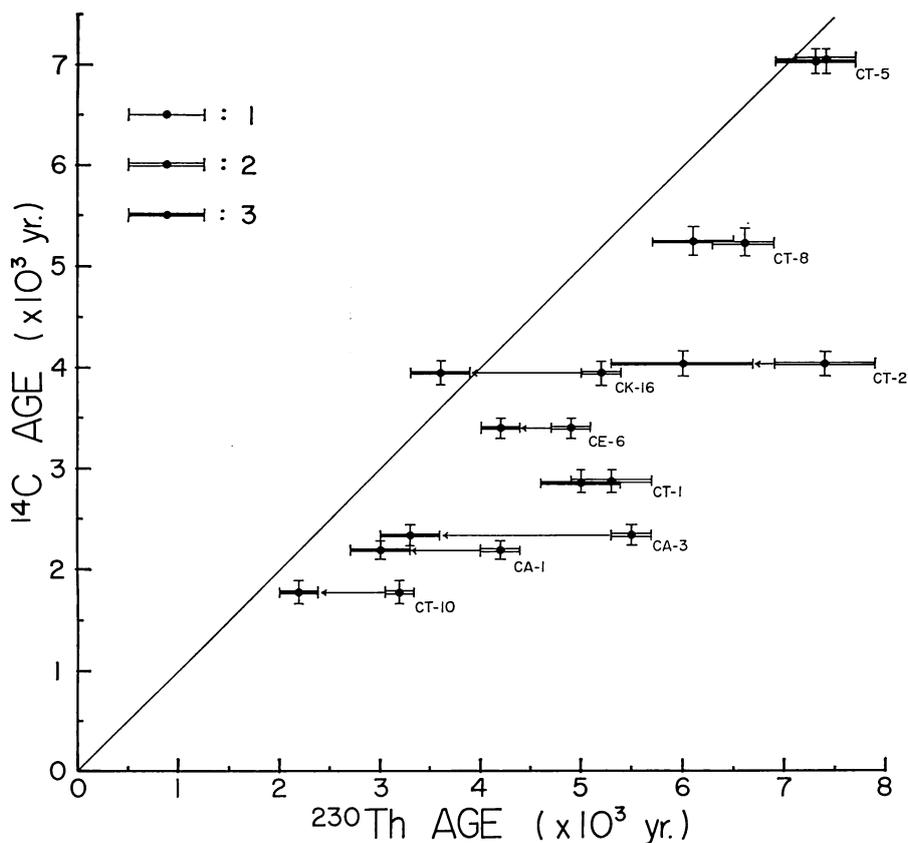


Text-fig. 3. Changes of the initial to total  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ratios with time. (The dashed and dotted curves represent the changes of the initial to total  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ratio, respectively.)

Table 4. Isotopic composition, apparent and corrected  $^{230}\text{Th}$  ages and conventional  $^{14}\text{C}$  age of some fossil coral samples.

Sample	Isotope content			Activity ratio			$^{230}\text{Th}$ age		$^{14}\text{C}$ age* (yr.)	Riken radiocarbon code*
	$^{238}\text{U}$ (ppm)	$^{232}\text{Th}$ (ppm)	$^{230}\text{Th}$ (dmg)	$^{234}\text{U}/^{238}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$	$^{230}\text{Th}/^{234}\text{U}$	Apparent age	Corrected age		
CA-1	2.43 $\pm 0.14$	0.0856 $\pm 0.0045$	0.0807 $\pm 0.0022$	1.10 $\pm 0.08$	3.97 $\pm 0.23$	0.0434 $\pm 0.0024$	4,200 $\pm 200$	3,000 $\pm 300$	2,190 $\pm 120$	N 546
CA-3	2.61 $\pm 0.07$	0.130 $\pm 0.007$	0.107 $\pm 0.003$	1.11 $\pm 0.04$	3.44 $\pm 0.21$	0.0502 $\pm 0.0020$	5,500 $\pm 200$	3,400 $\pm 300$	2,340 $\pm 115$	N 548
CK-16	3.28 $\pm 0.11$	0.118 $\pm 0.008$	0.124 $\pm 0.004$	1.11 $\pm 0.05$	4.42 $\pm 0.34$	0.0463 $\pm 0.0022$	5,200 $\pm 200$	3,600 $\pm 300$	3,950 $\pm 125$	N 549
CE-6	2.08 $\pm 0.04$	0.0416 $\pm 0.0025$	0.0802 $\pm 0.0019$	1.16 $\pm 0.03$	8.11 $\pm 0.50$	0.0454 $\pm 0.0015$	4,900 $\pm 200$	4,200 $\pm 200$	3,410 $\pm 125$	N 551
CT-1	2.48 $\pm 0.09$	0.0935 $\pm 0.0056$	0.0402 $\pm 0.0040$	1.11 $\pm 0.06$	9.76 $\pm 0.98$	0.0493 $\pm 0.0034$	5,300 $\pm 400$	5,000 $\pm 400$	2,880 $\pm 120$	N 407
CT-2	2.45 $\pm 0.04$	0.0625 $\pm 0.0088$	0.127 $\pm 0.010$	1.11 $\pm 0.03$	8.59 $\pm 0.14$	0.0639 $\pm 0.0053$	7,400 $\pm 500$	6,000 $\pm 700$	4,040 $\pm 120$	N 399
CT-5	2.57 $\pm 0.09$	0.0064 $\pm 0.0005$	0.145 $\pm 0.004$	1.12 $\pm 0.06$	94.8 $\pm 7.5$	0.0694 $\pm 0.0033$	7,400 $\pm 300$	7,300 $\pm 400$	7,050 $\pm 145$	N 402
CT-8	2.65 $\pm 0.06$	0.0275 $\pm 0.0030$	0.0935 $\pm 0.0056$	1.12 $\pm 0.06$	19.4 $\pm 2.1$	0.0590 $\pm 0.0030$	6,600 $\pm 300$	6,100 $\pm 400$	5,260 $\pm 140$	N 405
CT-10	2.89 $\pm 0.05$	0.0488 $\pm 0.0020$	0.0713 $\pm 0.0047$	1.16 $\pm 0.03$	6.15 $\pm 0.48$	0.0290 $\pm 0.0020$	3,200 $\pm 150$	2,200 $\pm 200$	1,780 $\pm 115$	N 447

\* Radiocarbon dates measured by Dr. and Mrs. T. HAMADA at Riken; they are "conventional  $^{14}\text{C}$  ages" based on half-life of 5,568 years.



Text-fig. 4. Comparison of the conventional  $^{14}\text{C}$  with the apparent and corrected  $^{230}\text{Th}$  ages of some fossil corals.

(1, conventional  $^{14}\text{C}$  age; 2, apparent  $^{230}\text{Th}$  age; 3, corrected  $^{230}\text{Th}$  age.)

parent age from the true age than the initial  $^{230}\text{Th}$ . But such a deviation in the apparent age will be relatively smaller in the  $^{231}\text{Pa}$  age than in the  $^{230}\text{Th}$  age for the same fossil sample, because of the shorter half-life of  $^{231}\text{Pa}$ .

It is always desirable, if not necessary, evaluate the reliability of a given radiometric date in comparison with that of an independent different radioactive series. Both apparent  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ages younger than 35,000 years B.P. can be cross-checked with the  $^{14}\text{C}$  ages. Although it is open to question whether

the conventional  $^{14}\text{C}$  ages represent true ages or not, the discrepancy between the  $^{14}\text{C}$  ages and the apparent  $^{230}\text{Th}$  ages, as seen in Text-fig. 4, may come at least partly from the presence of the initial thorium isotopes. If the apparent  $^{230}\text{Th}$  ages are to be regarded as the ambiguous ones, the next question will be how to reconcile the discordant ages with reasonable accuracy for the samples in which the initial  $^{230}\text{Th}$  is contained.

The apparent ages in the deficient  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  datings are the values calculated on the assumption that all of

$^{230}\text{Th}$  and  $^{231}\text{Pa}$  are originated from radioactive disintegration of each parent. If the remaining amounts of the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  in a fossil can be estimated, we can evaluate the amounts of the radiogenic  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  grown from their parents. Though difficult for  $^{231}\text{Pa}$ , it seems to be possible for  $^{230}\text{Th}$  to estimate the residual amounts of those initially incorporated.

The  $^{230}\text{Th}/^{232}\text{Th}$  ratios in Ryukyuan present-day corals are characterized by very limited ranges from 1.4 to 3.0 with a few marked exceptions (slightly higher than 2.0, on an average; Text-fig. 5). On the other hand, the decay of  $^{232}\text{Th}$  is so slow that the decrease in amount of the initial  $^{232}\text{Th}$  can be ignored for the time range of the deficient  $^{230}\text{Th}$  dating. If

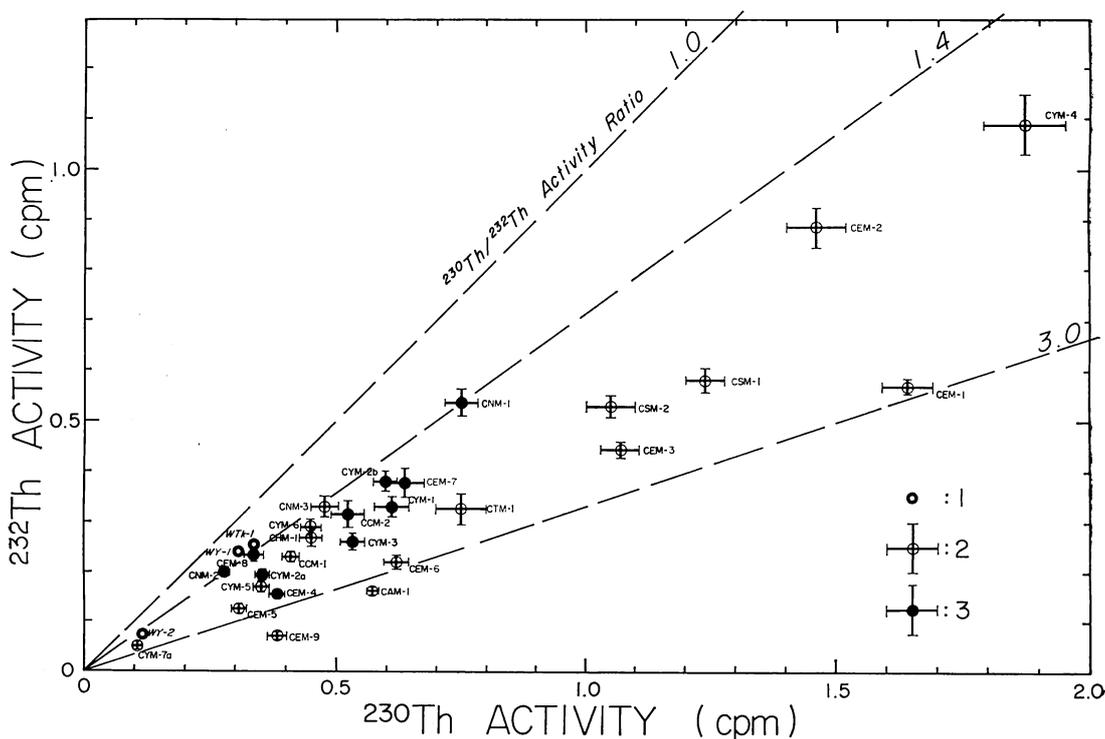
the assumption can be made that the initial  $^{230}\text{Th}/^{232}\text{Th}$  ratios in fossil remains had been the same degree of constancy as those in their present-day counterparts, the residual initial  $^{230}\text{Th}$  could be estimated by the equation from the  $^{232}\text{Th}$  concentration, as follows;

$$^{230}\text{Th}_{\text{initial}} = R \cdot ^{232}\text{Th} \cdot e^{-\lambda t} \dots \dots (1)$$

where  $\lambda$  is the decay constant of  $^{230}\text{Th}$ , and  $R$  is the initial  $^{230}\text{Th}/^{232}\text{Th}$  ratio and defined by the following equation;

$$R = \left( \frac{^{230}\text{Th}}{^{232}\text{Th}} \right)_{t=0} = \frac{^{230}\text{Th} - ^{234}\text{U} \cdot (1 - e^{-\lambda_{234}t})}{^{232}\text{Th} \cdot e^{-\lambda_{232}t}} \dots \dots (2)$$

where  $\lambda_{234}$  and  $\lambda_{232}$  are decay constant of  $^{234}\text{U}$  and  $^{232}\text{Th}$ , respectively. Then the radiogenic  $^{230}\text{Th}$  ( $^{230}\text{Th}_{\text{rad}}$ ) can be calcu-



Text-fig. 5.  $^{230}\text{Th}/^{232}\text{Th}$  activity ratios in sea-water and present-day coral samples.  
(1, sea-water samples; 2, massive colonial corals; 3, branching colonial corals.)

lated by the following equation;

$$^{230}\text{Th}_{\text{rad.}} = ^{230}\text{Th}_{\text{total}} - R \cdot ^{232}\text{Th} \cdot e^{-\lambda t} \dots (3)$$

If the uncertainty of an apparent  $^{230}\text{Th}$  age depends only on the amount of the initial  $^{230}\text{Th}$ , it can be satisfactorily solved by the proper estimation of the R value. The R values have been previously estimated from either the analytical data of sea-water or comparison between  $^{14}\text{C}$  and  $^{230}\text{Th}$  dates of fossil molluscs and corals (KAUFMAN and BROECKER, 1973; THURBER *et al.*, 1965; VALLENTINE and VEEH, 1969; VEEH and CHAPPELL, 1970; KAUFMAN *et al.*, 1971). In this study, this value was determined directly by analyses of present-day corals and sea-water where corals were sampled.

The average  $^{230}\text{Th}/^{232}\text{Th}$  ratio in the examined sea-water samples of the Ryukyu Islands is 1.4 (Table 4), whereas the present-day coral samples have a little higher ratio as described above. In the case of the present-day massive corals such as *Favia* and *Goniastrea*, the analyses were carried out at the inner portion of the corallum away from the surface where polyps were attached, in order to avoid the contamination of nuclides from soft tissue. If the sample was taken about 5 cm inside from the surface of a massive colony, *Favia*, it would represent an growth increment approximately about 10 years old, if a growth rate is accepted to be 0.5 cm/year (OMURA *et al.*, 1972). In this case, all  $^{230}\text{Th}$  in the portion analyzed may not be incorporated through secretion process of the skeleton, but might have grown in part from radioactive disintegration of  $^{234}\text{U}$  during the last ten years.

Then, the apparent increase of  $^{230}\text{Th}/^{232}\text{Th}$  ratio in "present-day coral" samples can be explained by assuming the initial isotopic composition as follows:

$$^{238}\text{U} = 2.7 \text{ ppm}$$

$$^{234}\text{U}/^{238}\text{U} = 1.15 \text{ A. R.}$$

$$^{232}\text{Th} = 0.05 \text{ ppm.}$$

These values are not absurd assumption but fair average among the present-day corals of the Ryukyu Islands. The results of the calculation are shown in Table 5 which lists data for growth ages versus apparent changes of the R value. After all, it seems acceptable to adopt the  $^{230}\text{Th}/^{232}\text{Th}$  ratio of the sea-water in habitat regardless of taxa of the organisms, as the R value.

Table 5. Apparent changes of R values (the initial  $^{230}\text{Th}/^{232}\text{Th}$  ratios) with growth ages.

Age (years old)	0	10	20	30	40	50
R	1.0	1.2	1.4	1.6	1.8	1.9
	1.5	1.5	1.9	2.1	2.3	2.4
	2.0	2.2	2.4	2.6	2.8	2.9

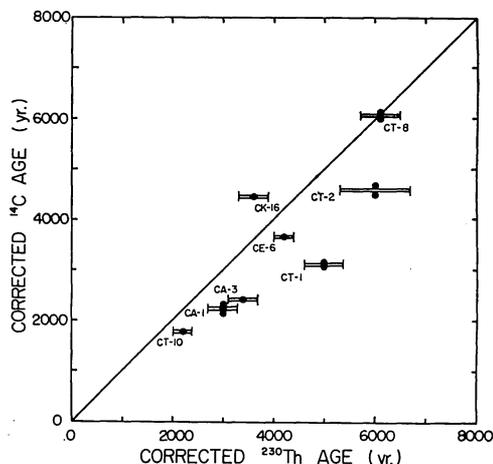
$^{231}\text{Pa}$  also is probably incorporated initially along with thorium isotopes. With our present knowledge, however, it is not possible to estimate the residual amounts of the initial  $^{231}\text{Pa}$  in fossil remains by any logical steps.

Thus, the corrected apparent  $^{230}\text{Th}$  ages, substituting 1.4 as the R value for equation (3), were compared again with the conventional  $^{14}\text{C}$  ages (Text-fig. 4). The discrepancies between the corrected  $^{230}\text{Th}$  and  $^{14}\text{C}$  ages undoubtedly become somewhat smaller, although they are not in entire agreement. These discrepancies between two dates may be attributable to the uncertainty inherent to the R value. However, there exists uncertainty for the conventional  $^{14}\text{C}$  ages.

The  $^{14}\text{C}$  age is conventionally computed, in principle, assuming that all the samples

initially contained the same  $^{14}\text{C}/^{12}\text{C}$  ratio. If this assumption was not accepted, the Conventional  $^{14}\text{C}$  age may not be relied upon. SUESS (1965, 1967, 1969) and KIGOSHI and HASEGAWA (1966) inferred from the discrepancy between dendrochronometric ages of wood samples and their  $^{14}\text{C}$  ages that  $^{14}\text{C}/^{12}\text{C}$  ratio, or  $^{14}\text{C}$  content in atmosphere has changed during the past 6,000 years. Additionally they proposed the correction curves for the conventional  $^{14}\text{C}$  ages.

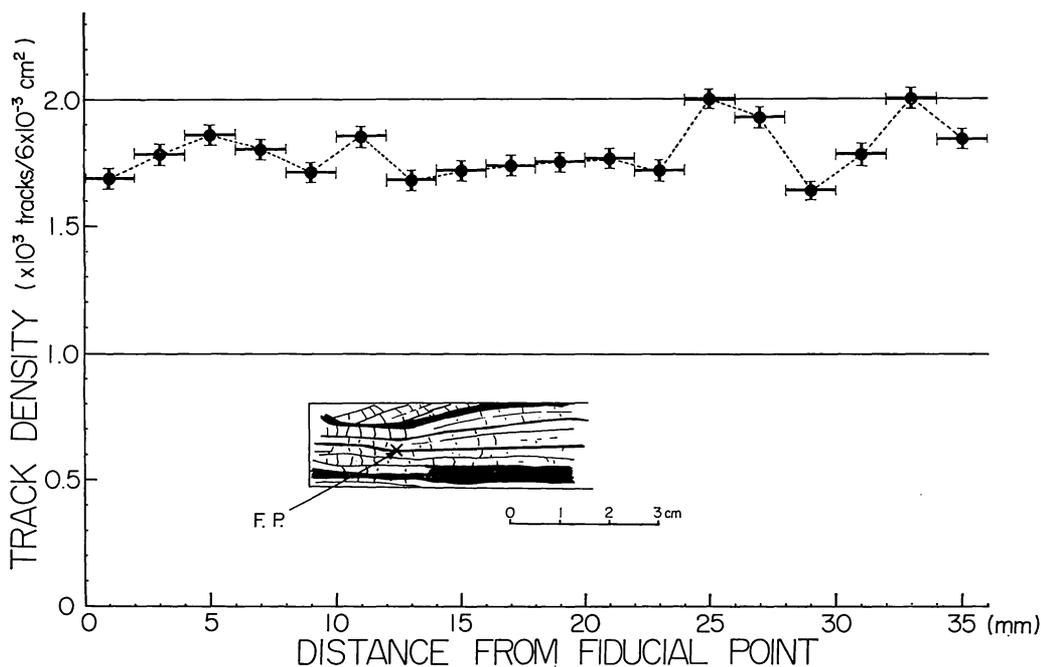
Text-fig. 6 compares the corrected  $^{230}\text{Th}$  age with the  $^{14}\text{C}$  age converted graphically with the correction curve of SUESS (1969). From the text-figure, it seems as if the discrepancies between two corrected dates reduce further smaller. If the correction of  $^{230}\text{Th}$  ages proposed here can be substantiated with future works, a similar correction curve of the conventional  $^{14}\text{C}$  ages may be ob-



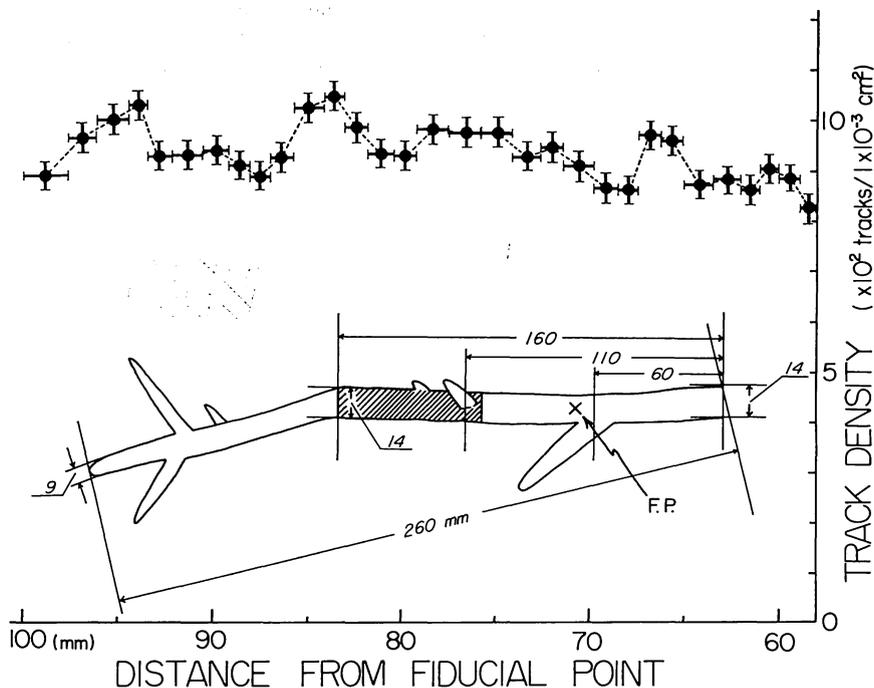
Text-fig. 6. Comparison between corrected  $^{230}\text{Th}$  and  $^{14}\text{C}$  dates.

tained beyond the dendrochronometric age, based on the  $^{230}\text{Th}$  ages of hermatypic corals.

The results of the fission track analysis



Text-fig. 7. Fission track counts measured along an axial line on a longitudinal section of CEM-1 specimen.



Text-fig. 8. Variation of track density in the axial growth direction of a branching coral (*Acropora* sp., CYM-8).

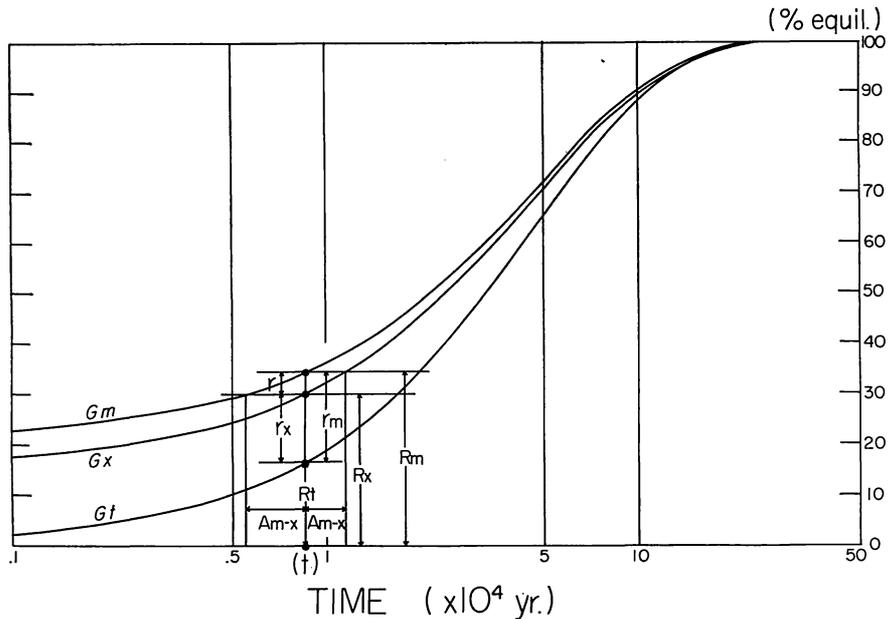
to examine the uranium distribution in coral skeletons are given in Text-figs. 7 and 8 where uranium distribution is expressed as the relative changes of track density.

Text-fig. 7 is the results obtained by counting the fission tracks along an axial line on a first-cycle septum in which no growth increments are recognized morphologically. Text-fig. 8 shows the uranium distribution in axial growth direction of a branching corallum (*Acropora* sp.). From these illustrations, it is clear that uranium distributes not necessarily in uniform but heterogeneously. The variation of the uranium concentration is estimated to be 30% at the maximum, although the much profound differences like those between two structural layers of tridacnid shells are not confirmed (OMURA *et al.*, 1973).

Assumed that both  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  are distributed homogeneously, in contrast to the heterogeneities of uranium, the difference in isotopic composition can be calculated by combining  $\alpha$ -spectrometry and fission track analyses for the three respective parts in which uranium isotopes are maximum, average and minimum in concentration. As to the analytical results of CEM-1 (Table 6), the following possibilities may be pointed out. If this sample had been well preserved as a closed system during its diagenetic history,  $^{231}\text{Pa}$  should grow from its parent  $^{235}\text{U}$  as shown in Text-fig. 9. The growth curve of  $^{230}\text{Th}$  might have the same pattern as that of  $^{231}\text{Pa}$ . The theoretical growth curve (Gt) estimated from the sample in which the initial  $^{231}\text{Pa}$  is free, also is shown together in text-figure. We notice readily by assuming the arbitrary

Table 6. Difference in isotopic composition among the various portions in a present-day coral sample ( $U_x$ , the maximum portion in uranium concentration;  $U_a$ , the average portion in uranium concentration;  $U_m$ , the minimum portion in uranium concentration).

	Activity (dmg)				Activity ratio		Apparent age (yr.)	
	$^{238}\text{U}$	$^{234}\text{U}$	$^{230}\text{Th}$	$^{231}\text{Pa}$	$^{230}\text{Th}/^{234}\text{U}$	$^{231}\text{Pa}/^{235}\text{U}$	$^{230}\text{Th}$ age	$^{231}\text{Pa}$ age
$U_x$	2.28	2.62	0.788	0.0168	0.0301	0.160	3,300	8,200
$U_a$	1.98	2.28			0.0346	0.184	3,800	9,500
$U_m$	1.72	1.98			0.0398	0.212	4,400	11,000



Text-fig. 9. Growth curve of  $^{231}\text{Pa}$  estimated in CEM-1 sample.

( $G_t$ , theoretical growth curve;  $G_m$ , growth curve estimated in the minimum part in uranium concentration;  $G_x$ , growth curve estimated in the maximum part in uranium concentration.)

time ( $t$ ) that the  $^{231}\text{Pa}/^{235}\text{U}$  ratio of CEM-1 is  $r_m$  or  $r_x$  higher than that of the ideal sample. Moreover, there should be the difference ( $r$ ) in  $^{231}\text{Pa}/^{235}\text{U}$  ratio, between the maximum and minimum parts of uranium isotopes in concentration. This  $r$  is responsible for the partial difference in apparent  $^{231}\text{Pa}$  age, which is

represented as  $A_{m-x}$  in Text-fig. 9. The decrease of  $r$  with time must be noted at this point. The relation between  $r$  and time can be seen also in Table 7 which shows the magnitude of  $A_{m-x}$  in various stages. Namely, the older the sample, the smaller the uncertainty due to heterogeneities in uranium distribution

Table 7. Changes of  $A_{m-x}$  values in various stages (see text for detailed discussion on  $A_{m-x}$  value).

Time (yr.)	$A_{m-x}$ (yr.)	
	$^{230}\text{Th}$ age	$^{231}\text{Pa}$ age
0	1,100	2,800
1,000	1,100	2,800
5,000	1,000	2,700
10,000	1,000	2,400
50,000	700	900
100,000	500	300

appears to be the general rule. After more than several tens of thousand years, this uncertainty in apparent ages of CEM-1 sample may become too small to be distinguished from the statistical error of counting. However, it is undoubtedly one of the unfavorable factors for reliable dating, if a sample is younger than 10,000 years old.

The above discussion may not fit in the reality, because we possess but very incomplete information on thorium and protactinium isotopes distribution in various present-day organisms. If  $^{232}\text{Th}$  microanalysis using fission tracks (HAIR *et al.*, 1971) be developed, we may be able to obtain the distribution patterns of  $^{232}\text{Th}$  in skeletal carbonates.

### Conclusion

The  $\alpha$ -spectrometry combined with fission track analysis was performed to get informations as to the concentrations and the activity ratios of uranium, thorium and protactinium isotopes in some present-day and fossil hermatypic corals, and to examine critically the effectiveness of the deficient  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dating methods.

The analysis of the sea-water samples from the Ryukyu Islands revealed that uranium was contained to the same extent as the sea-water in the other regions, while the concentrations of thorium isotopes were a little higher than those in the mid-oceanic region. These results vindicate that marine organisms are generally grown under the same environment with respect to uranium, but not necessarily so for thorium isotopes (and probably protactinium isotopes as well).

The  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  concentrations were not low enough to be neglected in the observed present-day corals. Because of such high  $^{230}\text{Th}/^{234}\text{U}$  and  $^{231}\text{Pa}/^{235}\text{U}$  ratios, the present-day coral samples examined had the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ages. From the presence of the equivalent amounts of  $^{232}\text{Th}$ , it may be inferred with certainty that the Ryukyuan fossil corals initially withheld similar  $^{230}\text{Th}/^{234}\text{U}$  ratio.

If it is a safe assumption that the fossils initially had the constant  $^{230}\text{Th}/^{232}\text{Th}$  ratio similar to the present-day counterparts in the same region, the residual amounts of the initial  $^{232}\text{Th}$  can be estimated by the following equation from the  $^{232}\text{Th}$  concentration:

$$^{230}\text{Th}_{\text{initial}} = R \cdot ^{232}\text{Th} \cdot e^{-\lambda t}$$

where  $\lambda$  is the decay constant of  $^{230}\text{Th}$ , and  $R$  is the initial  $^{230}\text{Th}/^{232}\text{Th}$  ratio. The uncertainty of an apparent  $^{230}\text{Th}$  age, due to the presence of the initial  $^{230}\text{Th}$ , can be satisfactorily solved by the proper estimation of the  $R$  value.

The present-day corals apparently had higher  $^{230}\text{Th}/^{232}\text{Th}$  ratio than the sea-water in their habitat. Accordingly, it could be questioned to adopt the  $^{230}\text{Th}/^{232}\text{Th}$  ratio of the present-day coral samples as the  $R$  value. The higher  $^{230}\text{Th}/^{232}\text{Th}$  in the present-day samples is accounted for by the growth rate of herma-

typic corals and the concentration of  $^{234}\text{U}$  enough to let the initial  $^{230}\text{Th}/^{232}\text{Th}$  ratio grow for several decades. After all, for the Ryukyuan fossil corals, it seems reasonable to use 1.4, an average  $^{230}\text{Th}/^{232}\text{Th}$  ratio of the coastal water in habitat, as R value.

In the Ryukyuan fossil corals in which the initial  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  are contained, the difference in distribution pattern between uranium isotopes and their daughter nuclides also become a troublesome problem. Although an extreme case comparable to the two structural layers of molluscan shell had not been confirmed, the differences in uranium concentration to attain 30% at the maximum were observed in axial growth direction of two scleractinian corallites. If the initial thorium and protactinium isotopes were distributed in no relation with uranium isotopes, the apparent  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  ages may be partially different, and the different growth curves of  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  must be used for dating.

The age ambiguity due to the initial daughters and the heterogeneities in uranium distribution must always be evaluated critically, but these factors may not cause any practical effect on dating the samples older than tens of thousand years.

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660. *Dictyozamites* AND SOME OTHER CYCADOPHYTES FROM  
THE EARLY LOWER CRETACEOUS OGUCHI FORMATION,  
THE ITOSHIRO GROUP, CENTRAL HONSHU, JAPAN\*

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下部白亜系下部石徹白層群尾口層の *Dictyozamites* およびその他のソテツ葉類：石川県石川郡白峰村および尾口村に分布する下部白亜系下部の石徹白層群尾口層（河合正虎，1961）から得られた植物化石のうち、ベネチテス目の *Dictyozamites* 6種（うち4種は新種）、新種1種を含む *Otozamites* 2種、ソテツ目の *Ctenis* 3種（うち1種は新種）、*Nilssonia* 1種、および種子シダ目の *Ctenozamites* sp. を記載した。以上のうち、*Nilssonia lobatidentata* は裂片に顕著な櫛歯状の鋸歯のある種で、このような鋸歯のある *Nilssonia* 葉は、シベリア植物地理区植物群に普遍的である。また、*Ctenis burejensis* は、同植物地理区の初期白亜紀植物群に普遍的な種で、これらはさきに記載報告した *Neozamites* や今後記載するシダ目および球果目に属する種の一部とともに、尾口植物群と同時代のシベリア植物地理区植物群との間の共通要素である。

尾口植物群はまた、質量ともに豊富な *Dictyozamites* によって特長づけられる。今般6種を記載するとともに、従来、世界各地から記載された種との比較を試みた。

尾口植物群のソテツ葉類 (cycadophytes) の組成は、ほぼ同時代と考えられる Wealden 型の領石植物群のそれとは明らかに異なり、両者の間には共通種は認められない。これに似た関係はシダ目や球果目の組成についても認められる。

したがって、以前から木村が繰り返し述べてきたように、尾口植物群は距離的に近い日本外帯の領石植物群や、同じく Wealden 型の南沿海州の初期白亜紀植物群よりは、距離的に遠い、アムール河、レナ河、コリマ河流域に知られているシベリア植物地理区初期白亜紀植物群に近縁である。

木村達明・関戸信次

**General remarks**

KIMURA (1975) subdivided the "Tetori Flora" into the Late Jurassic Kuzuryu, Early Neocomian Oguchi, Late Neocomian Akaiwa and Aptian Tamodani Floras based on the stratigraphical standpoint and their floristic characters. They are in the "Inner Zone Palaeofloristic Province" of Japan formerly proposed by KIMURA (1961, 1975) and KIMURA and SEKIDO

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(1963), and differ from the corresponding floras of Wealden-type in the "Outer Zone Palaeofloristic Province" of Japan in floristic character.

The rich Oguchi Flora derived from the Kuwashima (=Kuwajima) sandstone and shale alternation member and its equivalents, the Oguchi Formation (KAWAI, 1961), the Itoshiro Group, the Tetori Supergroup is the representative of "Tetori Flora" and has been studied by GEYLER (1877), YOKOYAMA (1889), YABE (1905, 1922, 1927), OISHI (1933, 1940, 1941), MATSUO and OMURA (1968), KIMURA

(1961, 1967) and KIMURA and SEKIDO (1963, 1965-1975).

The Oguchi Flora closely resembles the coeval Siberian floras in the "Siberian Palaeofloristic Area" proposed by VAKHRAMEEV (1964, 1966, 1970, 1971). Details of Oguchi Flora have been given by KIMURA (1975) and KIMURA and HIRATA (1975).

In this paper we describe six *Dictyozamites* species among which four are new to science, two *Otozamites* species of which one is new, two *Ctenis* species, one *Nilssonia* species and one *Ctenozamites* species, based on new specimens from the Oguchi Formation.

The discovery of *Ctenis burejensis* and *Nilssonia lobatidentata* with markedly dentate distal margin is noteworthy, because they are known to be of Siberian habitants.

The pteridosperms and cycadophytes from the Oguchi Formation now include ten genera and thirty species listed below but some of them are not yet described. Species with asterisk are described in the present paper.

#### Pteridosperms and Catoniales

\**Ctenozamites* sp.

\**Sagenopteris* sp. (MS)

#### Bennettitales

\**Otozamites endoi* KIMURA, 1961

?*O. klipsteinii* (DUNKER) SEWARD, 1895

\**O. pseudoanglica* KIMURA and SEKIDO, sp. nov.

\**Dictyozamites auriculatus* KIMURA and SEKIDO, sp. nov.

*D. falcatus* (MORRIS) OLDHAM, 1863

*D. grossinervis* YOKOYAMA, 1889

\**D. ishikawaensis* KIMURA and SEKIDO, sp. nov.

*D. kawasakii* TATEIWA, 1929

*D. imamurae* OISHI, 1936

*D. cfr. imamurae* OISHI, 1936

\**D. reniformis* OISHI, 1936

\**D. tetoriensis* KIMURA and SEKIDO, sp. nov.

\**D. yamazakii* KIMURA and SEKIDO, sp. nov.

*D. spp.* OISHI, 1936

?*Pterophyllum lyellianum* DUNKER, 1846

*P. spp.* (MS)

*Neozamites elongatus* KIMURA and SEKIDO, 1970

#### Cycadales

\**Ctenis burejensis* PRYNADA, 1934

\**C. cfr. formosa* VACHRAMEEV, 1961

*C. kaneharai* YOKOYAMA, 1906

*C. nipponica* KIMURA and SEKIDO, 1972

*Nilssoniocladus nipponensis*

(YOKOYAMA) KIMURA and SEKIDO,

1975 (leaf = *Nilssonia nipponensis*

YOKOYAMA, 1889)

*Nilssonia kotoi* (YOKOYAMA) OISHI, 1940

\**N. lobatidentata* VASSILEVSKAJA, 1972

*N. orientalis* HEER, 1878

*N. ozoana* YOKOYAMA, 1889

*Tetoria endoi* KIMURA and SEKIDO, 1974

In addition to the above, MATSUO and OMURA (1968) described *Taeniopteris vittata* BRONGNIART from Togadani now named *Nilssoniopteris vittata* (BRONGNIART) FLORIN.

In the coeval flora of the Ryoseki Formation in Kochi Prefecture, in the Outer Zone Palaeofloristic Province, the known cycadophytes are listed below (KIMURA and HIRATA 1975).

#### Bennettitales

*Otozamites klipsteinii* (DUNKER)

SEWARD, 1895

*Pterophyllum* spp.

*Ptilophyllum* ex gr. *pecten* (PHILLIPS)

MORRIS, 1841

*Zamiophyllum buchianum*

(ETTINGSHAUSEN) NATHORST, 1890

*Zamites tosanus* OISHI, 1940

*Cycadolepis oblongiformis* OISHI, 1940

#### Cycadales

*Nilssonia orientalis* HEER var. *minor*

FONTAINE, 1889

*N. schauburgensis* (DUNKER)  
NATHORST, 1890

*N. schauburgensis* (DUNKER) var.  
*parvula* YABE, 1913

In its cycadophytes, as well as in ferns, the Oguchi Flora is quite different from the coeval Ryoseki Flora (s. str.) and also from the floras of Upper Neocomian Lower Monobegawa and Aptian-Albian Upper Monobegawa Formations in Kochi Prefecture.

One of the characteristics of the Oguchi Flora is the rich representation of *Dictyozamites* with nine species and three or four other forms that may be distinct. Not one of these has so far been recorded in the floras of Outer Zone Palaeofloristic Province of Japan.

Unfortunately we could not study cuticles in the present work because the specimens available were all impressions without organic material.

Later a monograph of the Oguchi Flora will be contributed by us, based on the abundant materials accumulated for fifteen years.

#### Acknowledgement

Here we record our cordial thanks to Professor Emeritus Thomas M. HARRIS of the University of Reading for his critical reading this manuscript and for continuously receiving his valuable suggestions. We would also like to express our appreciation to Dr. V. A. VAKH-RAMEEV of Geological Institute of the Academy of Sciences of the USSR, who kindly gave us many valuable papers regarding palaeobotany.

Acknowledgement is extended to Miss Tamiko OHANA, a student of the Tokyo Gakugei University for her kind help of drawing the figures in the present work. The present paper would have been much

difficult to write without their generous contributions.

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#### Systematic description

##### Pteridospermales

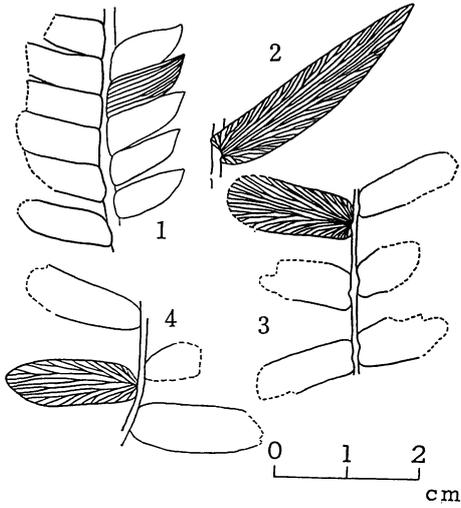
Genus *Ctenozamites* NATHORST, 1886: 122

*Ctenozamites* sp.

Pl. 31, Fig. 1; Text-fig. 1

*Description:* Two leaf-fragments on a small slab were obtained. Pl. 31, Fig. 1 (KU-Y0016) shows a part of a leaf fragment which is long and narrow, more than 6.5 cm long, nearly parallel-sided, 1 cm wide. Segments rhomboidal or triangular in outline, typically 0.5 cm long and 0.17 cm wide, set closely or slightly spaced, upper margin straight, lower margin convex with the broad curve to meet cuspidate or aristate apex, attached at a wide angle by their whole base to the upper surface of comparatively thick rachis, 3 mm across measured on impression. The bases of segments not contracted but somewhat decurrent. Nerves 5-7 in number at base, parallel each other, mostly simple, but sometimes forking; upper ones converging to the apex and lower ones ending in the apical basisopic margin as shown in Text-fig. 1.

*Remarks:* The fragments of this species do not show whether the leaf is bipinnate as in *Ctenozamites* or simply pinnate as in the older *Ptilozamites*, nor whether the main rachis forks. Accordingly we merely name it as *Ctenozamites* sp. provisionally. Had the acroscopic



Text-figs. 1-4.

1. *Ctenozamites* sp.; showing outline of segments or pinnae and venation (KU-Y0016). ( $\times 2$ )
2. *Otozamites endoi* KIMURA em. KIMURA and SEKIDO; showing outline of pinna and venation (KM-71006).
3. *Otozamites pseudoanglica* KIMURA and SEKIDO, sp. nov.; showing outline of pinnae and venation (KM-71003 Holotype).
4. *Otozamites pseudoanglica* KIMURA and SEKIDO, sp. nov.; (KM-71004).

segment margin been rounded, it would have resemble a *Ptilophyllum*.

*Occurrence*: Rare.

*Specimen*: KU-Y0016 (collected by Y. KANSHA from Kuwashima of the Oguchi Formation).

#### Bennettitales

Genus *Otozamites* BRAUN, 1842

*Otozamites endoi* KIMURA em.

KIMURA and SEKIDO, 1966

Pl. 31, Figs. 4, 5; Text-fig. 2

1961. *Otozamites endoi* KIMURA: p. 27, pl. 5, fig. 4; text-fig. 6. (Oguchi Formation).

1966. *Otozamites endoi* KIMURA em. KIMURA and SEKIDO: p. 2, pl. 1, figs. 1, 2; pl. 2, fig. 2. (Oguchi Formation).

*Description & remarks*: Pl. 31, Fig. 4 (KM-71006) is a new specimen in which pinna outline and venation are more clearly shown than those previously described. This specimen represents middle to upper part of a leaf and agrees with the emended diagnosis of KIMURA and SEKIDO.

Pl. 31, Fig. 5 enlarged shows an entire pinna and Text-fig. 2 shows its venation.

The form of this species has been compared with some similar ones, e. g., *Otozamites graphicus* (LECKENBY) and *O. lancifolius* OISHI by KIMURA (1961). *Otozamites pterophylloides* BRONGNIART (non YOKOYAMA) is also similar but differs in its pinnae which are straight, gradually narrowing to the acuminate apex and with a markedly auriculate acroscopic pinna base.

*Occurrence*: Common.

*Specimens*: KM-63004, KM-63005, KM-63006, KM-59001 (Holotype), KM-71006, KM-75052 and many leaf-fragments.

*Otozamites pseudoanglica* KIMURA and SEKIDO, sp. nov.

Pl. 30, Figs. 4, 5; Text-figs. 3, 4

*Diagnosis*: Leaf small, more than 4 cm long and about 3.2 cm wide, shape of whole leaf unknown, with tapering base. Pinnae remotely set, nearly perpendicular to the slender rachis, 1 mm thick. Apical pinna unusually set, being nearly parallel to the rachis and broader than the others. Pinnae elongate-obovate or elongate-oblong in outline with obtusely pointed apex, attached by the narrow area below the middle of pinna base; both auricles weakly developed. Nerves radiating from

the narrow area, branching at all levels, fairly crowded.

*Description:* Four leaf-fragments were obtained. Pl. 30, Fig. 4 (KM-71003) shows two leaves represented by under surface. They appear to converge towards a supposed common support point below. If so, the length of each leaf except the apical pinna might be estimated to be 7.5 cm right and 4.5 cm left respectively. Text-fig. 3 (KM-71003) shows the outline of pinnae and venation. Pl. 30, Fig. 5 (KM-71004) shows a similar leaf indicated by the under surface, of which pinnae are rather elongate-oblong in outline as shown in Text-fig. 4, 1.8 cm long and 0.6 cm wide, attached to the rachis in a similar way to the above.

*Comparison & remarks:* Though the specimens available are few and imperfect, they are distinguished specifically by their small size and narrow region of attachment just below the middle.

Had the attachment been in the middle they would have fitted the definition of *Zamites*. The upper auricle is developed feebly and the lower basal margin is even less expanded.

*Otozamites anglica* (SEWARD) HARRIS (1949, p. 275, text-figs. 1, 2; 1969, p. 39, pl. 1, fig. 5; text-fig. 17) looks rather similar but its pinnae are attached by the lower half of their bases. Its veins are much less crowded.

The present species named after the Yorkshire species.

*Occurrence:* Rare.

*Specimens:* KM-71003 (Holotype), KM-71004.

Genus *Dictyozamites* OLDHAM  
and MORRIS, 1863: 37

This genus was at first known from the Jurassic of India, then from Japan, Bornholm, Yorkshire, Nagdong, Ussuri and Primorye, Patagonia, Iran, Malaysia and recently from the Lena Basin. The geological distribution of this genus has interested many palaeobotanists (Text-fig. 33).

From Japan, five species, *D. falcatus*, *D. grossinervis*, *D. imamuræ*, *D. kawasakii* and *D. reniformis* and one unnamed form, *D. cfr. imamuræ* described from the Upper Jurassic Kiyosue Formation, Yamaguchi Prefecture and the Kuzuryu Group and mainly from the Oguchi Formation, Central Honshu.

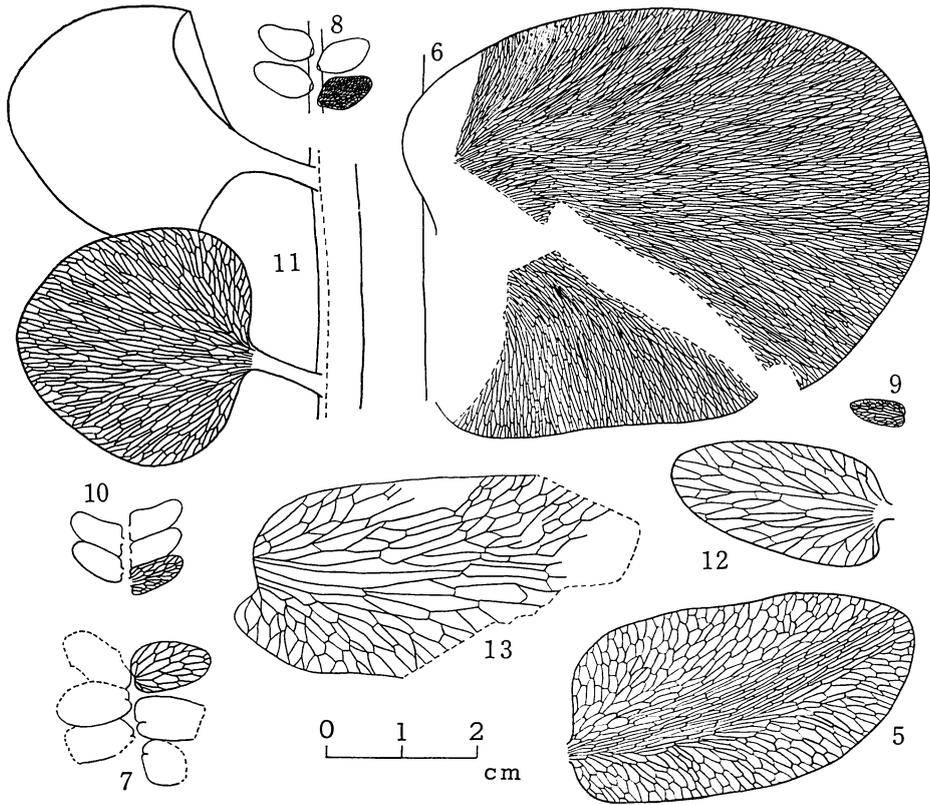
We now add four new species, *D. auriculatus*, *D. ishikawaensis*, *D. tetoriensis* and *D. yamazakii*, and one unnamed form, *D. sp.* from the Oguchi Formation at the upper course of the Mekkodani, a branch of Tetori River.

In addition there are *D. sp. A* and *D. sp. B* described by OISHI (1936) which may be distinct but are imperfectly known from poorly preserved specimens. So far as we know, *Dictyozamites* has now 25 species of which the oldest record is *D. crusinensis* KON'NO (1972) from the Upper Triassic of East Malaysia.

We offer a key to these 25 species on p. 296. It relates primarily to the Japanese species but with these we group similar looking leaves of other lands.

## Key on macroscopic form of typical specimens of leaves

- 1 [ -Pinna length up to twice its width ..... 2  
 [ -Pinna length exceeding twice its width ..... 5
- 2 [ -Pinna sessile (or stalk under 1 mm)..... 3  
 [ -Pinna stalk distinct, exceeding 1 mm ..... 4
- 3 [ -Pinna large, exceeding 4 cm long  
   *D. kawasakii* TATEIWA (Text-fig. 5)  
   *D. cordatus* (KRYSHTOFOVICH) PRYNADA (Text-fig. 6)  
   *D. crassinervis* MENÉNDEZ (Text-fig. 13)  
 [ -Pinna small, less than 3 cm long  
   *D. yamazakii* KIMURA and SEKIDO, sp. nov. (Text-fig. 7)  
   *D. indicus* FEISTMANTEL (Text-fig. 10)  
   *D. crusinensis* KON'NO (Text-fig. 8)  
   *D. minusculus* MENÉNDEZ (Text-fig. 9)
- 4 [ -Pinna circular, reaching 3.5 cm in diameter  
   *D. reniformis* OISHI (Text-fig. 11)  
 [ -Pinna oblong, less than 6 cm long  
   *D. grossinervis* YOKOYAMA (Text-fig. 12)
- 5 [ -Pinna length up to twice its width ..... 6  
 [ -Pinna length exceeding thrice its width ..... 7
- 6 [ -Pinna elongate-oblong or broadly lanceolate, less than 4 cm long  
   *D. ishikawaensis* KIMURA and SEKIDO, sp. nov. (Text-fig. 20)  
   *D. tateiwae* OISHI (Text-fig. 14)  
   *D. tetoriensis* KIMURA and SEKIDO, sp. nov. (Text-fig. 16)  
 [ -Pinna rectangular, less than 6 cm long  
   *D. imamurae* OISHI (Text-fig. 18)  
   *D. latifolius* MENÉNDEZ (Text-fig. 19)
- 7 [ -Pinna length up to four times its width ..... 8  
 [ -Pinna length exceeding four times its length..... 9
- 8 [ -Pinna base markedly auriculated  
   *D. johnstrupi* NATHORST (Text-fig. 27)  
 [ -Pinna base rounded or slightly auriculated  
   *D. falcatus* (MORRIS) OLDHAM (Text-figs. 23, 24, 25, 26?)  
   *D. areolatus* ARCHANGELSKY and BALDONI (Text-fig. 17)  
   *D. hawelli* SEWARD (Text-fig. 29)  
   *D. obliquus* SAMYLINA (Text-fig. 15)  
   *D. ussuriensis* KRYSHTOFOVICH (Text-fig. 30)
- 9 [ -Pinna base markedly auriculated  
   *D. auriculatus* KIMURA and SEKIDO, sp. nov. (Text-fig. 31)  
   *D. asseretoi* BARNARD (Text-fig. 32)  
 [ -Pinna width less than 2 mm  
   *D. bagjoriensis* JACOB (Text-fig. 22)  
   *D. hallei* SAHNI and RAO (Text-fig. 21)  
 [ -Pinna width exceeding 5 mm  
   *D. cazaubonii* ARCHANGELSKY and BALDONI (Text-fig. 28)



Text-figs. 5-13.

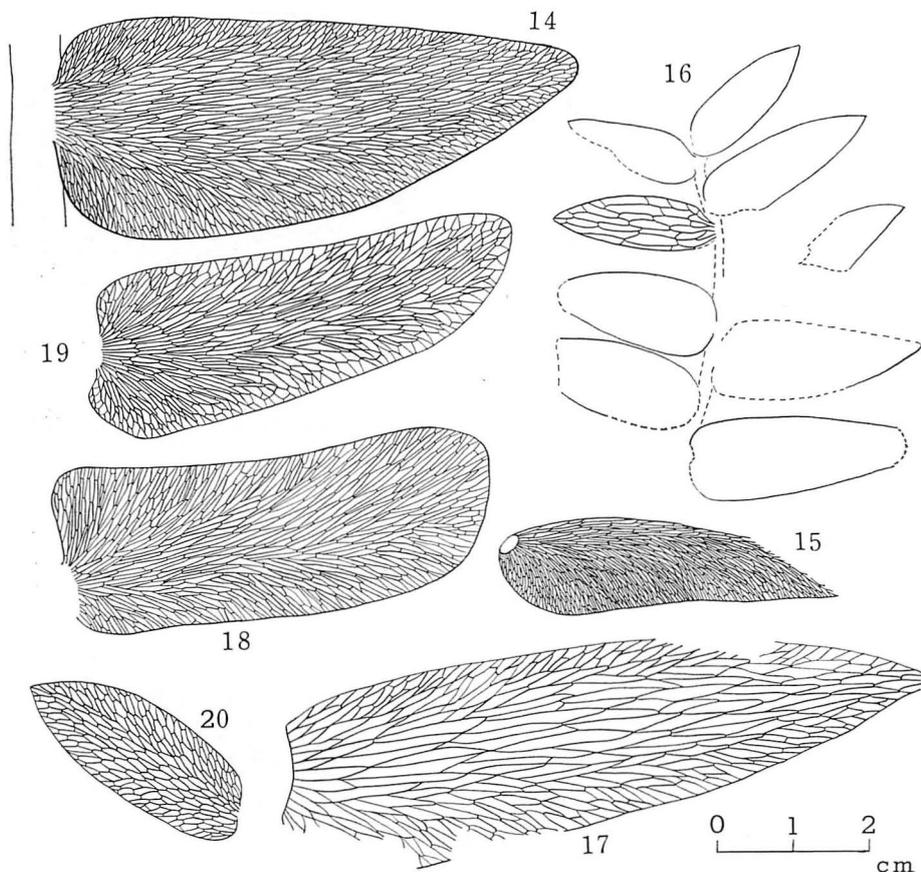
5. *Dictyozamites kawasakii* TATEIWA; after KIMURA, 1961, pl. 4, fig. 2 (KM-57001).
6. *D. cordatus* (KRYSHTOFOVICH) PRYNADA; after KRASSILOV, 1967, pl. 43, fig. 1.
7. *D. yamazakii* KIMURA and SEKIDO sp. nov.; drawn from Pl. 31, Fig. 3 of the present work (KM-61469).
8. *D. crusinensis* KON'NO; after KON'NO, 1972, text-fig. 4D.
9. *D. minusculus* MENÉNDEZ; after MENÉNDEZ, 1966, text-fig. 14.
10. *D. indicus* FEISTMANTEL; after FEISTMANTEL, 1879, pl. 3, fig. 3a.
11. *D. reniformis* OISHI; drawn from Pl. 32, Fig. 4 of the present work (KM-433-1).
12. *D. grossinervis* YOKOYAMA; after YOKOYAMA, 1889, pl. 7, fig. 10.
13. *D. crassinervis* MENÉNDEZ; after MENÉNDEZ, 1966, text-fig. 18.

*Dictyozamites auriculatus* KIMURA  
and SEKIDO, sp. nov.

Pl. 30, Figs. 1, 2; Text-fig. 31

*Diagnosis:* Leaf unknown in size. Pinnae set closely, alternate, long and narrow gradually tapering upwards (but

apex unknown), attached to the upper surface of a rachis up to 4 mm thick by the lower half of pinna base, acroscopic base free, markedly auriculate; auricle concealing the rachis and overlapping the lower pinna base on opposite side. Nerves consisting of 5-6 nearly longitudinal strong ones running from attach-



Text-figs. 14-20.

14. *Dictyozamites tateiwa* OISHI; after OISHI, 1936, pl. 9, fig. 3 and text-fig. 3.
15. *D. obliquus* SAMYLINA; after SAMYLINA, 1964, plate, figs. 10, 11.
16. *D. tetoriensis* KIMURA and SEKIDO sp. nov.; drawn from Pl. 31, Fig. 2 of the present work (KM-61468).
17. *D. areolatus* ARCHANGELSKY and BALDONI; after ARCHANGELSKY and BALDONI, 1972, pl. 1, fig. 4.
18. *D. imamurae* OISHI; after KIMURA, 1961, pl. 5, fig. 1 (KM-59811).
19. *D. latifolius* MENÉNDEZ; after MENÉNDEZ, 1966, text-fig. 21.
20. *D. ishikawaensis* KIMURA and SEKIDO, sp. nov.; drawn from Pl. 32, Fig. 3 of the present work (KM-63010).

ment to apical part along the median axis, and weaker ones curving out to margins, both forming reticular meshes; longitudinal meshes longer and narrower, typically  $0.8\text{ cm} \times 0.5\text{ mm}$ , marginal ones shorter and broader, typically  $0.5\text{ cm} \times$

$0.75\text{ mm}$ .

*Description:* Several fragments are collected, one of which is shown in Pl. 30, Fig. 1 (Holotype) (KM-61418). Pl. 30, Fig. 2 shows basal part of pinnae and Text-fig. 31 shows detailed venation.

*Comparison & remarks:* This species is characterized by the strongly auriculate acroscopic base, though the specimens at present available are only several number and not one shows the whole leaf or even the apex of a pinna.

Two species have similar large auricle. *Dictyozamites johnstrupi* from the Jurassic of Bornholm (MÖLLER, 1903, pl. 5, figs. 1, 1a) is distinguished by its shorter and falcate pinnae. *D. asseretoi* described by BARNARD (1965, pl. 99, figs. 3, 4; text-figs. 7A-C) from the Liassic of Northern Iran has different shaped auricles as shown in Text-fig. 32.

*Occurrence:* Not frequent.

*Specimens:* KM-61418 (Holotype), KM-71007, KM-61410, KM-75003, KM-75004.

*Dictyozamites ishikawaensis* KIMURA  
and SEKIDO, sp. nov.

Pl. 32, Figs. 1-3; Text-fig. 20

1966. *Dictyozamites* cfr. *imamurae* OISHI: KIMURA and SEKIDO, p. 4, pl. 2, fig. 2; text-fig. 3 (Mekko-dani, Oguchi Formation).

*Diagnosis:* Leaf length unknown, more than 17 cm long, 6 cm wide at the widest portion. Rachis up to 4 mm thick. Pinnae evenly pinnate, sessile, set closely, alternately attached at an angle of 70-90°. Pinnae nearly parallel-sided but increasing their width gradually towards the apical portion, then narrowing abruptly to meet at an angle of about 70° instead of gradually tapering; pinna base mostly contracted; both basal margins rounded, not prominently auriculated; typical pinnae, 3-3.5 cm long and 1.2-1.4 cm wide. Nerves dense, 18-20 per cm at the middle portion of pinna, divergent, ending at outer margin, anastomosing to form polygonal meshes; meshes in the median cen-

tral region being typically 4 mm long and 1 mm wide, becoming shorter and narrower towards the margin.

*Description:* Many new specimens were collected. Pl. 32, Fig. 1 (Holotype) (KM-63010) reinserted here from our previous paper (1966, pl. 2, fig. 2) representing the middle or upper part of a leaf, proves typical.

Pl. 32, Fig. 3 shows the outline of a typical pinna and Text-fig. 20 shows the detailed venation. Pl. 32, Fig. 2 (KM-690014) is a similar specimen to the holotype, clearly demonstrating the characteristic pinna form of this species.

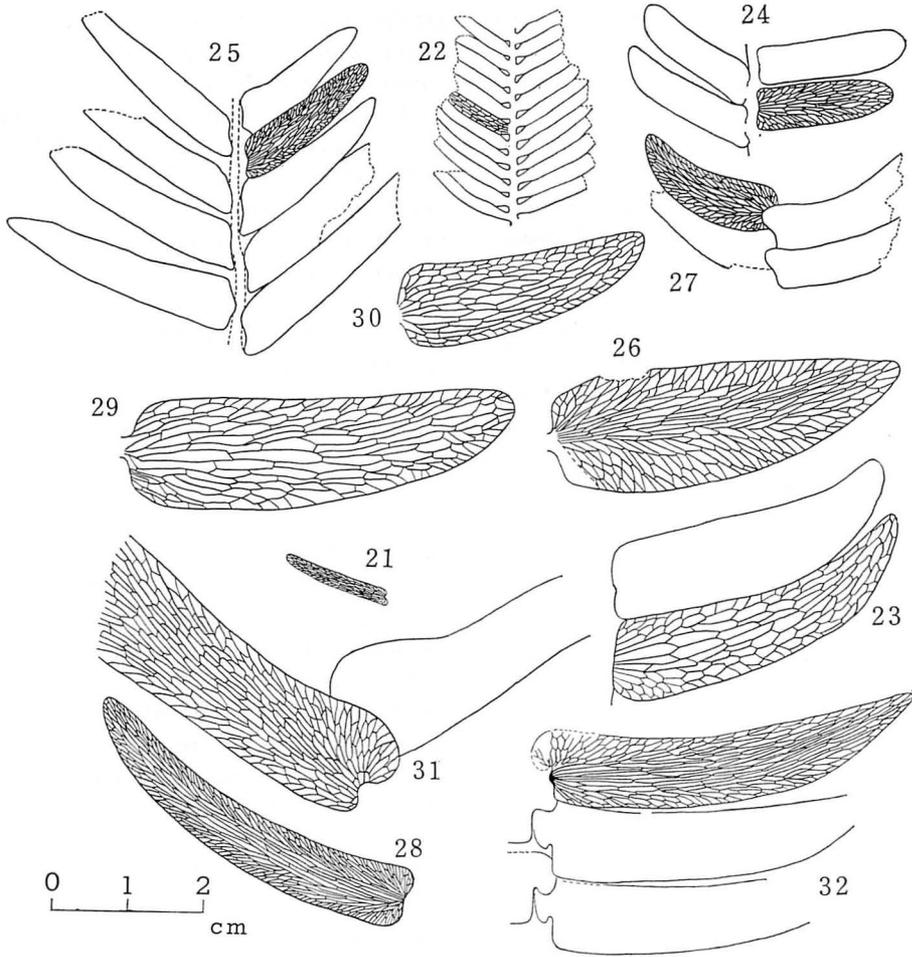
*Comparison & remarks:* *Dictyozamites ishikawaensis* is mainly characterized by its pinna form as typically shown in Pl. 32, Fig. 3 and Text-fig. 20. It is close in pinna form to *D. tateiwae* originally described by OISHI (1936, p. 28, pl. 9, fig. 3; text-fig. 3; 1940, p. 327) based on the Nagdong material, together with two specimens formerly regarded by YABE (1905, p. 11, pl. 2, figs. 6, 7; non figs. 2-5) as *D. falcatus* from the Nagdong Group.

*Dictyozamites ishikawaensis* differs from *D. tateiwae* which has elongate-triangular pinnae with a straight acroscopic margin and convex basisopic margin then abruptly curving upwards at the distal portion.

Some specimens from Ozo in the Oguchi Formation described by YOKOYAMA as *D. indicus* var. *distans* and later by OISHI (1936, p. 26; 1940, p. 325) as *D. falcatus* resemble both *D. tateiwae* or *D. ishikawaensis* but in our view do not agree fully with either *D. falcatus* or *D. indicus*.

*Occurrence:* Common.

*Specimens:* KM-63010 (Holotype), KM-690014, KM-434-1 and many leaf fragments.



Text-figs. 21-32.

21. *Dictyozamites hallei* SAHNI and RAO; after SAHNI and RAO, 1931, pl. 14, fig. 25.
22. *D. bagjoriensis* JACOB; after SITHOLEY, 1963, pl. 6, fig. 42.
23. *D. falcatus* (MORRIS); after OLDHAM and MORRIS, 1863, pl. 24, fig. 1a (regarded by OLDHAM and MORRIS as *Dictyopteris falcata*).
24. *D. falcatus* (MORRIS); *ibid.*, fig. 2a (regarded by OLDHAM and MORRIS as *Dictyopteris falcata* var. *obtusifolia*).
25. *D. falcatus* (MORRIS); after YABE, 1905, pl. 2, fig. 2.
26. *D. falcatus* (MORRIS)?; after YOKOYAMA, 1889, pl. 10, fig. 8 (regarded by YOKOYAMA as *D. indicus* var. *distans* and later by OISHI as *D. falcatus*; this specimen is similar in pinna form and venation to some of those regarded as *D. tateiwae* or *D. ishikawensis*, together with YOKOYAMA's fig. 8a).
27. *D. johnstrupi* NATHORST; after MÖLLER, 1903, pl. 5, fig. 2.
28. *D. cazaubonii* ARCHANGELSKY and BALDONI; after HALLE, 1913, pl. 5, figs. 29-33 (regarded by HALLE as *D. cfr. falcatus*); reconstructed by KIMURA and SEKIDO.
29. *D. hawelli* SEWARD; after SEWARD, 1917, fig. 609.
30. *D. ussuriensis* KRYSHTOFOVICH; after KRYSHTOFOVICH, 1957, fig. 303-4.
31. *D. auriculatus* KIMURA and SEKIDO, sp. nov.; drawn from Pl. 30, Fig. 1 of the present work (KM-61418).
32. *D. asseretoi* BARNARD; after BARNARD, 1965, text-fig. 74.



Text-fig. 33. Localities and occurrence of *Dictyozamites* species with works quoted.

1. Tierra del Fuego: *D. cazaubonii* (HALLE, 1912, 1913; ARCHANGELSKY and BALDONI, 1972).
2. Ticó and Baquero: *D. areolatus* (ARCHANGELSKY and BALDONI, 1972), *D. crassinervis* (MENÉNDEZ, 1966), *D. latifolius* (MENÉNDEZ, 1966; ARCHANGELSKY and BALDONI, 1972) and *D. minusculus* (MENÉNDEZ, 1966; ARCHANGELSKY and BALDONI, 1972).
3. Chubut: *D. cazaubonii* (CAZAUBON, 1947; ARCHANGELSKY and BALDONI, 1972).
4. Yorkshire: *D. hawelli* (SEWARD, 1903, 1917; THOMAS and BANCROFT, 1913; HARRIS, 1969).
5. Bornholm: *D. johnstrupi* (NATHORST, 1889, 1907; MÖLLER, 1903; FLORIN, 1933).
6. Dolud: *D. asseretoi* (BARNARD, 1965).
7. Madras coast, MURRERO and GORAPILLI: *D. falcatus* (FEISTMANTEL, 1877, 1879) and *D. indicus* (FEISTMANTEL, 1877, 1879).
8. Rajmahal Hills: *D. bagjoriensis* (JACOB, 1951), *D. falcatus* (SEWARD, 1903; BANCROFT, 1913; SAHNI and RAO, 1931) and *D. hallei* (non CAZAUBON) (SAHNI and RAO, 1931).
9. East Malaysia: *D. crusinensis* (KON'NO, 1972).
10. Lena Basin: *D. cordatus* (VAKHRAMEEV, 1970).
11. Central Sikhota-Alin: *D. obliquus* (SAMYLYNA, 1964).
12. Southern Primorye: *D. cordatus* (KRYSHTOFOVICH, 1929; KRYSHTOFOVICH and PRYNADA, 1932; PRYNADA, 1963; KRASSILOV, 1967), *D. falcatus* (KRASSILOV, 1967), *D. grossinervis* (KRASSILOV, 1967), *D. kawasakii* (KRASSILOV, 1967) and *D. ussuriensis* (KRYSHTOFOVICH, 1957; KRYSHTOFOVICH and PRYNADA, 1932).
13. Nagdong: *D. falcatus* (YABE, 1905 pars; OISHI, 1936, 1940), *D. kawasakii* (TATEIWA, 1929; OISHI, 1940) and *D. teteiwae* (YABE 1905 pars; OISHI, 1936, 1940).
14. Kiyosue: *D. falcatus* (OISHI, 1936, 1940), *D. kawasakii* (TAKAHASHI and NAITO, 1950) and *D. reniformis* (TAKAHASHI and NAITO, 1950).
15. Mochiana and Kizaki: *D. falcatus* (KIMURA, 1958, 1959).
16. Oguchi: *D. auriculatus* (present work), *D. falcatus* (YOKOYAMA, 1889; OISHI, 1936, 1940), *D. grossinervis* (YOKOYAMA, 1889), *D. imamuræ* (OISHI, 1936, 1940; KIMURA, 1961; KIMURA and SEKIDO, 1966), *D. ishikawaensis* (KIMURA, 1961; KIMURA and SEKIDO, 1966; present work), *D. kawasakii* (OISHI, 1940; KIMURA, 1961; KIMURA and SEKIDO, 1966, 1967), *D. reniformis* (OISHI, 1933, 1936, 1940; KIMURA, 1961; present work), *D. tetoriensis* (present work) and *D. yamazakii* (present work).

*Dictyozamites reniformis* OISHI, 1936

Pl. 32, Fig. 4; Text-fig. 11

1933. *Chiropteris?* sp. OISHI: p. 628 (name only, Yambara of the Oguchi Formation).
1936. *Dictyozamites reniformis* OISHI: p. 29, pl. 9, figs. 1, 1a (Yambara of the Oguchi Formation).
1940. *Dictyozamites reniformis* OISHI p. 327 (general remarks).
1950. *Dictyozamites kawasakii* TATEIWA: TAKAHASHI and NAITO, p. 188; text-fig. 2 (Kiyosue Formation).
1961. *Dictyozamites reniformis* OISHI: KIMURA, p. 25, text-figs. 3, 4 (Mekkodani of the Oguchi Formation).

*Description:* Several good new specimens were collected. Pl. 32, Fig. 4 (KM-433-1) is possibly the lower part of a leaf. Rachis stout, 5-6 mm thick. Pinnae with stalks about 1 cm long and 2 mm thick attached at 60-70° to upper part of rachis, distant but laminae of adjacent pinnae overlapping. Laminae reniform in outline, 2.8-3.2 cm in diameter, their upper surface convex, attached to the stalk below the middle of their bases, accordingly lamina is asymmetrical. Some of laminae as shown in Pl. 32, Fig. 4 appear to be circular in outline, because their basal angles are reflexed, especially so in acroscopic angle shown in Text-fig. 11.

The nerves radiate from the top of the stalk and anastomose to form fine meshes, filling over the lamina in almost equal at about 20 per cm in density. Text-fig. 11 drawn from Pl. 32, Fig. 4 shows the pinna form and the detailed venation.

*Remarks:* The present specimens agree with the original specimen of this species described by OISHI from Yambara of the Itsuki (or Ittsuki) Bed, the equivalent of the Oguchi Formation, except that their basal margins are less reniform.

TAKAHASHI and NAITO (1950, p. 188) combined *Dictyozamites kawasakii* and *D. reniformis* based on their material from the Kiyosue Formation, Yamaguchi Prefecture. The result of our observation of many specimens obtained from the Oguchi Formation, however, made us believe that *D. kawasakii* was distinct and text-fig. 2 (TAKAHASHI and NAITO) agreed well with the present specimens.

OISHI (1936) stated that "An isolated pinna may remind one strongly of *Chiropteris*. But, as the pinnate habit of the genus *Chiropteris* is not yet known, it is appropriate to use the generic name *Dictyozamites* for the present specimens." We agree.

*Occurrence:* Common.

*Specimens:* KM-433-1, KM-57003, KM-59010, KM-75001 and many pinna fragments.

*Dictyozamites tetoriensis* KIMURA and SEKIDO, sp. nov.

Pl. 31, Fig. 2; Text-fig. 16

*Diagnosis:* Leaf probably elongate, length unknown, more than 7 cm long and 5.5 cm wide at 5 cm below the apex. Rachis slender, bearing pinnae on its upper surface. Pinnae set closely, often overlapping, occasionally just separate, arising nearly perpendicularly, and still at a wide angle in the apical portion. Pinnae lanceolate, up to 3 cm long, 1.1 cm wide at the widest portion, narrowing gradually to an obtuse apex, attached by a small area on middle basal margin; basal margin retuse, neither basal angles expanded. Nerves distant, 5-7 in number at base, diverging and anastomosed to form polygonal meshes; meshes 0.5-0.8 cm long and 1-2 mm wide.

*Comparison & remarks:* One, in Pl. 31, Fig. 2 gives the main basis of the

diagnosis. *Dictyozamites tetoriensis* is distinguished from all species by the distant nerves arising from the small area at the pinna base. *Dictyozamites tateiwae* OISHI (1936, p. 28, pl. 9, fig. 3; text-fig. 3) is similar but has far more densely crowded nerves at about 20 per cm in density. *Dictyozamites tetoriensis* is named after the Tetori River.

*Occurrence*: Rare.

*Specimens*: KM-61468 (Holotype), KM-71008.

*Dictyozamites yamazakii* KIMURA

and SEKIDO, sp. nov.

Pl. 31, Fig. 3; Text-fig. 7

1967. *Dictyozamites* sp. (sp. nov. ?) KIMURA and SEKIDO: p. 417, pl. 3, fig. 1 (Mekko-dani of the Oguchi Formation).

*Diagnosis*: Leaf small, approximate dimensions 3 cm long and 2 cm wide, with very slender rachis, up to 1.5 mm wide. Pinnae delicate, alternate, set closely, oval with rounded apex, attached by the middle point of pinna base to the upper surface of the rachis, sessile. Nerves delicate, distant, about 10 per cm in density, radiating from the attachment, anastomosing to form polygonal meshes; meshes 0.3–0.5 cm long and 1–1.5 mm wide.

*Comparison & remarks*: Several fragments of the delicate leaf were obtained, one of which is enlarged and shown in Pl. 31, Fig. 3 (reinserted from pl. 3, fig. 1 of our previous paper) on which the above diagnosis is based. This species is distinguished from all others by its oval pinnae with distant nerves.

*Dictyozamites grossinervis* YOKOYAMA (1889, p. 56, pl. 7, fig. 10) from Kuwashima (formerly Shimamura) of the Oguchi Formation and recently by KRASSILOV (1967, p. 153, pl. 40, figs. 2–4; pl.

41, figs. 1–5; text-fig. 19a) from the Lower Cretaceous of Southern Primorye also has distant nerves, but differs in its larger and shortly stalked pinnae.

*Dictyozamites crusinensis* KON'NO (1972, p. 155, pl. 32, figs. 3, 4a; text-fig. 4D) from the Upper Triassic Bed of Sarawak, East Malaysia, is similar in pinna outline and size, but differs in its more crowded nerves.

*Dictyozamites yamazakii* is named in honour of Mr. K. YAMAZAKI, an instructor of the Komatsu City Girl's High School, who has cooperated with us in collecting fossil plants for fifteen years.

*Occurrence*: Rare.

*Specimens*: KM-65010 (Holotype) and several leaf-fragments.

*Dictyozamites* sp.

1961. *Otozamites* cfr. *beani* (LINDLEY and HUTTON) BRONGNIART: KIMURA, p. 27, text-fig. 5 (Mekko-dani of the Oguchi Formation).

1966. *Otozamites?* sp. KIMURA and SEKIDO: p. 3, pl. 2, fig. 3 (Mekko-dani).

*Remarks*: The two specimens cited above and some newly collected fragments all show nerve anastomosis and must be placed in *Dictyozamites*. But although we consider that their characters—a long leaf with round, overlapping and obliquely set pinnae distinguish them from any other Japanese species. We consider them insufficiently known for specific description. The most similar specimen is one illustrated by KRASSILOV (1967, pl. 42, fig. 1) from the Lower Cretaceous of Southern Primorye, under the name of *Dictyozamites cordatus* (KRYSHTOFOVICH) PRYNADA.

*Occurrence*: Occasional.

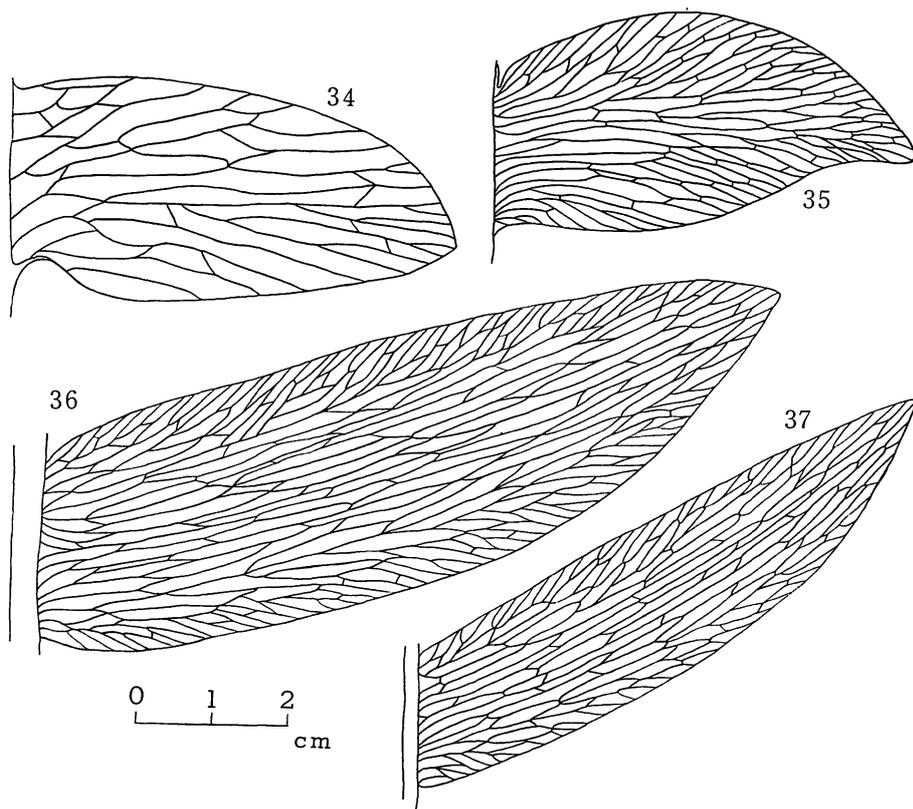
*Specimens*: KM-59005, KM-63007.

## Cycadales

Genus *Ctenis* LINDLEY and HUTTON,  
1834

In 1972, we described *Ctenis kaneharai* YOKOYAMA, *C. nipponica*, sp. nov. and *C. sp.* from the Oguchi Formation. We

now suspect that *Ctenis nipponica* may be the same as *C. kaneharai*, but better material is needed before we regard it as a synonym. Better material of *C. sp.* enables us to identify it as *C. burejensis* PRYNADA of the Lower Cretaceous of East Siberia. We also add *Ctenis* cfr. *formosa* VACHRMAEEV.



Text-figs. 34-37.

34. *Ctenis burejensis* PRYNADA; typical pinna reproduced from VAKHRAMEEV and DOLUDENKO, 1961, text-fig. 26.
35. *Ctenis burejensis* PRYNADA; typical pinna from the Oguchi Formation; present work (KM-71002).
36. *Ctenis nipponica* KIMURA and SEKIDO; reproduced from KM-57101 (KIMURA, 1961, pl. 6, fig. 2; KIMURA and SEKIDO, 1972, pl. 45, fig. 2).
37. *Ctenis nipponica* KIMURA and SEKIDO; reproduced from KM-61328 (KIMURA and SEKIDO, 1972, pl. 45, fig. 1).

Key to the Oguchi species of *Ctenis*

- 1 [Pinna length about twice its width ..... *C. burejensis*  
 [Pinna length more than twice its length ..... 2  
 2 [Pinna length up to four times its width ..... *C. nipponica*  
 [Pinna length exceeding four times its width ..... *C. kaneharai*  
*C. cfr. formosa* is too little known (in Japanese specimen) to be placed in a key.

*Ctenis burejensis* PRYNADA, 1934

Text-figs. 35, 38, 39

1934. *Ctenis burejensis* PRYNADA: in KRYSH-TOFOVICH and PRYNADA (1934), p. 70, fig. 25-2 (Lower Cretaceous of Ussuri).  
 1935. *Ctenis* sp. TOYAMA and OISHI: p. 66, pl. 4, fig. 1 (Jurasso-Cretaceous of Northeastern China).  
 1957. *Ctenis burejensis* PRYNADA: KRYSH-TOFOVICH, p. 287, fig. 268-1 (Lower Cretaceous of Ussuri).  
 1961. *Ctenis burejensis* PRYNADA: VAKH-RAMEEV and DOLUDENKO, p. 89, pl. 39, figs. 1, 2; pl. 40; text-fig. 26 (Jurasso-Cretaceous of Bureja Basin).  
 1963. *Ctenis burejensis* PRYNADA f. *typica* PRYNADA: SAMYLINA, p. 82, pl. 10, figs. 3-6; pl. 11; pl. 12, figs. 1-5 (Lower Cretaceous of Aldan).  
 1972. *Ctenis* sp. (n. sp. ?) KIMURA and SEKIDO: p. 365, pl. 44, fig. 3; pl. 45, fig. 3; text-fig. 2E (Mekgodani of the Oguchi Formation).  
 1974. *Ctenis* sp. cfr. *C. burejensis* PRYNADA: KIMURA and SEKIDO, pl. 1 (in association with *Tetoria endoi*, a cycad with bipinnate frond) (Mekgodani of the Oguchi Formation).

*Description:* Many new specimens were collected. Leaf in Japanese material probably large. Text-fig. 38 (KM-71002) shows a leaf fragment, more than 13 cm long and 11.5 cm wide. Rachis fairly slender, 4 mm thick measured at the broken proximal end, then narrowing gradually, 1.5 mm at the upper part, longitudinally striated, bearing pinnae laterally. Pinnae variable in shape, tri-

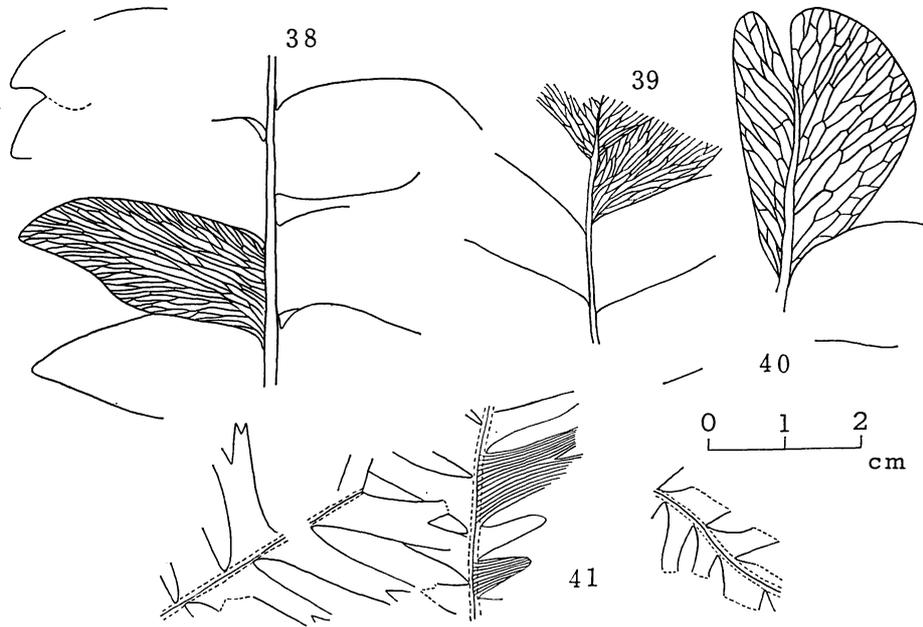
angular, elongate-oval or ovate, 7 cm × 2.6 cm, 4.4 cm × 2.5 cm to 3.5 cm × 2.5 cm, arising nearly perpendicularly in contact. Acroscopic margin strongly curving, mostly directed backwards at apex, and basisopic margin nearly straight, meeting at obtuse or blunt apex. Margins, constricted near the base, particularly the acroscopic one usually constricted basally, expansion follows inevitably. Nerves prominent, parallel at base then dichotomously forking and anastomosing to form elongate meshes, ending at the margin, often decurrent at base, about 8 per cm in density.

Judging from general appearance of pinnae and coarse nerves, Text-fig. 39 (D-17) is probably near a leaf apex. It was broken during collection.

The specimen (KM-61452) figured by KIMURA and SEKIDO (1974, pl. 1) and regarded as *Ctenis* sp. cfr. *C. burejensis*, associating with a large impression of bipinnate cycad, *Tetoria endoi*, is although its pinnae are remotely set, referable in general feature to this species.

The specimen (KM-61450) regarded as *Ctenis* sp. (n. sp.?) and figured by us (1972, p. 365, pl. 44, fig. 3; pl. 45, fig. 3; text-fig. 2E) is now also referable to this species, because its pinna outline is like that of the specimen shown in Text-fig. 38.

*Comparison & remarks:* It is difficult to distinguish externally the present specimens from the Siberian species *Ctenis burejensis* and its varieties (f. *typica* and f. *rarinervis*) of which pinna



Text-figs. 38-41.

38. *Ctenis burejensis* PRYNADA; middle part of a leaf (KM-71002).  
 39. *Ctenis burejensis* PRYNADA; apical part of a leaf (D-17).  
 40. *Ctenis* cfr. *formosa* VACHRAMEEV; showing a leaf apex in which the apical notch is reconstructed from the specimen shown in Pl. 30, Fig. 3 of the present work. ( $\times 1/2$ )  
 41. *Nilssonia lobatidentata* VASSILEVSKAJA; KM-75-309-1.

outline and coarse nerves are quite characteristic, though the present specimens have rather denser nerves than those of the Siberian ones.

As was stated before (KIMURA and SEKIDO, 1972, p. 365, text-fig. 2), *Ctenis auriculata* FONTAINE? and *Ctenis uwatoki* TOYAMA and OISHI resemble the present species. *Ctenis auriculata*? described by FONTAINE (in WARD, 1905, p. 117, pl. 29, fig. 1) from the Jurassic-Cretaceous of Oregon resembles the present species in its coarse nerves but differs in pinna outline. *Ctenis uwatoki* originally described by TOYAMA and OISHI (1935, p. 65, pl. 3, figs. 2, 3) from the Jurassic of Chalai-nor, North Hsingan,

Northeastern China and later described by SZE and XÜ (or HSÜ) (1954, p. 56, pl. 49, figs. 2, 3) from the same locality, resembles *C. burejensis* in pinna outline, but *C. uwatoki* showing small-sized lanceolate leaf-outline, 10.5 cm long and 4.5 cm wide at the middle widest portion, is different from *C. burejensis* having fairly large leaf as shown in Text-fig. 38.

*Ctenis* sp. described by TOYAMA and OISHI (1935, p. 66, pl. 4, fig. 1) is probably identical with the present species.

*Occurrence*: Common.

*Specimens*: KM-71002, KM-61452, KM-61450, D-17 (collected by Dr. A. ISHII, Tokyo Gakugei University) and many leaf-fragments.

*Ctenis* cfr. *formosa* VACHRAMEEV, 1961

Pl. 30, Fig. 3; Text-fig. 40

*Compare:*

1961. *Ctenis formosa* VACHRAMEEV: VAKHRAMEEV and DOLUDENKO, p. 91, pl. 41, figs. 1, 2; text-fig. 27 (Jurasso-Cretaceous of Bureja Basin).

*Remarks:* The only specimen is the fragment of a leaf apex and all its visible characters are displayed in our figures.

This specimen resembles closely that illustrated and described by VAKHRAMEEV and DOLUDENKO from the Jurasso-Cretaceous of Bureja Basin, under the new name of *Ctenis formosa*, though the Siberian specimen is more smaller in size than the present one.

We have nothing more to say about this specimen because leaf apices are very inconstant within a species of pinnate leaves.

In the drawing of *Ctenis yabei* from the Upper Triassic of Nariwa (OISHI, 1950, pl. 27, fig. 2), the leaf apex was wrongly reconstructed by OISHI as rounded without notch.

We here regard provisionally the present specimen as *Ctenis* cfr. *formosa*.

*Occurrence:* Rare.

*Specimen:* KM-71005.

Genus *Nilssonia* BRONGNIART, 1825

Isolated *Nilssonia* leaves are abundant in the Kuwashima sandstone and shale alternation member, Oguchi Formation from which *Nilssonia kotoi*, *N. nipponensis*, *N. orientalis* and *N. ozoana* have been known.

The leaf *Nilssonia nipponensis* has been found attached to a slender stem with spirally arranged dwarf shoots and the stem and leaves together have been named *Nilssoniocladus nipponensis* (KI-

MURA and SEKIDO, 1975, p. 113; in this paper we stated erroneously the specific suffix as *nipponense*). But the isolate leaf is correctly named *Nilssonia nipponensis*.

Recently we found in our collection three *Nilssonia* leaf-fragments with a markedly dentate distal margin from the Oguchi Formation and also from the Upper Neocomian Akaiwa Formation respectively. The specimens from the Akaiwa Formation will be shown in detail in our later paper.

*Nilssonia lobatidentata*

VASSILEVSKAJA, 1972

Text-fig. 41

1972. *Nilssonia lobatidentata* VASSILEVSKAJA: p. 322, pl. 74, figs. 1, 2 (Lower Cretaceous of the Lena Basin).

1963. *Nilssonia lobatidentata* VASSILEVSKAJA: VASSILEVSKAJA and PAVLOV, pl. 6, figs. 1-3 (Lower Cretaceous of the Lena Basin).

1970. *Nilssonia lobatidentata* VASSILEVSKAJA: ABRAMOVA, p. 45, pl. 4, figs. 2-5 (Lower Cretaceous of the Lena Basin).

*Description:* Text-fig. 41 (KM-75-309-1) shows three *Nilssonia* leaf fragments preserved on one slab. The leaf is possibly oblanceolate in outline, tapering gradually below. The lamina is divided into segments of very uneven width. They are commonly equal to length in the lower part as shown in Text-fig. 41, but longer than broad in the middle and upper part of leaf. The shape of the segments is very varied and the distal margin mostly irregularly dentate, often forked.

*Remarks:* The present specimens generally agree with those described as *Nilssonia lobatidentata* by VASSILEVSKAJA and ABRAMOVA from the Lower

Cretaceous of the Lena Basin.

*Nilssonia orskica* originally described by GENKINA (1963, p. 64, pl. 32, figs. 8, 9; pl. 33, figs. 1, 2) from the Middle Jurassic of Eastern Ural, is also with dentate distal margin, but *N. orskica* differs from the present species in that it has rectangular segments.

*Nilssonia prinadae* originally described by VAKHRAMEEV (VAKHRAMEEV and DOLUDENKO, 1961, p. 95, pl. 42, fig. 3; pl. 43, fig. 1) from the Jurassic-Cretaceous of the Bureja Basin, is rather similar to *N. lobatidentata*, but its distal margin is less strongly dentate.

*Nilssonia serrulata* originally described by OISHI (1940, p. 317, pl. 26, figs. 8, 8a) from the Lower Cretaceous Nagdong Group, Korea differs in lacking a dentate distal margin.

*Nilssonia magnifolia* SAMYLINA (1964, p. 73, pl. 13, figs. 1-3; pl. 15, figs. 1, 2; pl. 16, figs. 6, 7; pl. 17, fig. 1) from the Lower Cretaceous of the Kolyma Basin, is a much longer leaf, but the segments are often dentate or serrate.

Besides the above, *Nilssonia* leaves with more or less dentate margin are known as *Nilssonia denticulata* THOMAS (1911, p. 88, pl. 7, figs. 3-5) from the Jurassic of Kamenka and as *Nilssonia compta* (PHILLIPS) BRONN (see HARRIS, 1969). Unfortunately we could not com-

pare here *Nilssonia serrata* PRYNADA with the present one, because we have not acquainted its paper.

At any rate, these *Nilssonia* leaves with dentate distal margin are mostly of Siberian habitants. The new occurrence of this species and its allied form (to be described later on) with markedly dentate distal margin from the Oguchi Formation might be worth mentioning.

*Occurrence*: Rare (but fairly abundant in the Akaiwa Formation).

*Specimen*: KM-75-309-1.

#### Localities and material

Specimens with letters KM- in registered number were from the equivalent of the Kuwashima sandstone and shale alternation member, the Oguchi Formation, exposed at the upper course of Mekkodani, a branch of the Tetori River, Ozo, Oguchi-mura, Ishikawa-gun, Ishikawa Prefecture, and are deposited in the Komatsu City Museum, Komatsu, Ishikawa Prefecture.

A specimen with letter D- in registered number was collected by Dr. A. ISHII from the same locality as the above, and is deposited in Department of Astronomy and Earth Science, Tokyo Gakugei University.

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#### Explanation of Plate 30

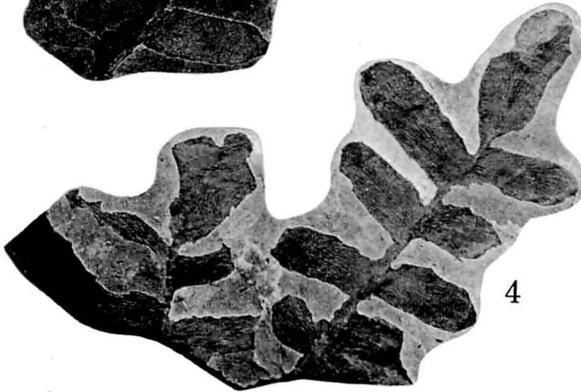
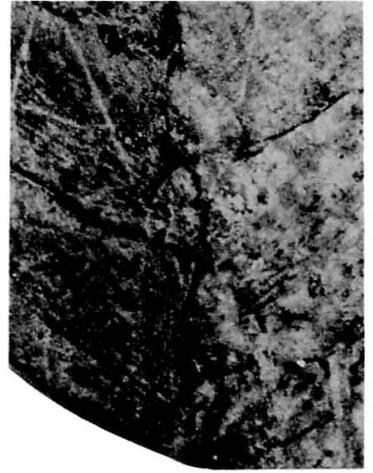
Figs. 1, 2. *Dictyozamites auriculatus* KIMURA and SEKIDO, sp. nov.

1. Showing markedly auriculated acroscopic basal angle (Holotype, KM-61418). Loc. Mekkodani. nat. size.
2. Showing pinna base enlarged from the Holotype.  $\times 2$ .

Fig. 3. *Ctenis* cfr. *formosa* VAKHRAMEEV; Showing two apical pinnae and two lateral ones incompletely preserved (KM-71005). Loc. Mekkodani.  $\times 0.8$ .

Figs. 4, 5. *Otozamites pseudoanglica* KIMURA and SEKIDO, sp. nov.

4. Showing two leaf-fragments which appear to converge towards a supposed common support below (Holotype, KM-71003). Loc. Mekkodani. nat. size.
5. Showing a similar leaf-fragment to the above (KM-71004). Loc. Mekkodani. nat. size.



A specimen with letters KU-Y in registered number was collected by Y. KANSHA from Kuwashima (a classical locality of the Oguchi Flora), Shiramine-mura, Ishikawa-gun, Ishikawa Prefecture, and is deposited in Department of Astronomy and Earth Sciences, Tokyo Gakugei University.

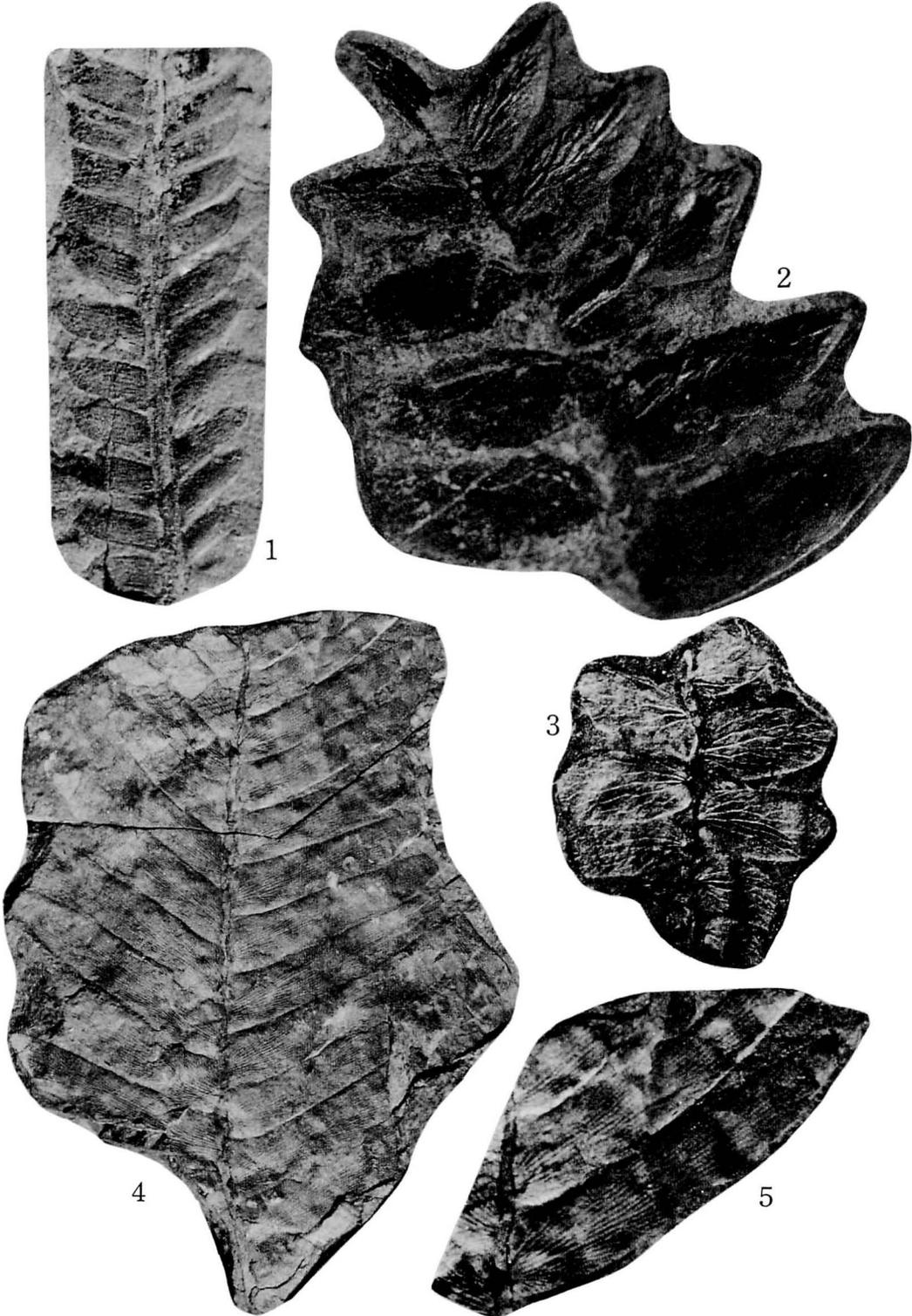
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### Explanation of Plate 31

- Fig. 1. *Ctenozamites* sp.; Showing outline of segments and comparatively thick rachis in lower surface view, both ends of the present leaf omitted here (KU-Y0016, collected by Y. KANSHA). Loc. Kuwashima.  $\times 3$ .
- Fig. 2. *Dictyozamites tetoriensis* KIMURA and SEKIDO, sp. nov.; (Holotype, KM-61468). Loc. Mekkodani.  $\times 1.5$ .
- Fig. 3. *Dictyozamites yamazakii* KIMURA and SEKIDO, sp. nov.; Reinserted from KIMURA and SEKIDO, 1967, pl. 3, fig. 1 enlarged (Holotype, KM-65010). Loc. Mekkodani.  $\times 2$ .
- Figs. 4,5. *Otozamites endoi* KIMURA, em. KIMURA and SEKIDO.
4. (KM-71006). Loc. Mekkodani. nat. size.
5. Showing pinna outline and venation enlarged from the above.  $\times 2$ .



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Akaiwa	赤 岩	Mekkodani	目 付 谷
Chalai-nor	扎 賚 諾 爾	Mochiana	持 穴
Hsingan	興 安	Nagdong (Naktong)	洛 東
Itoshiro	石 徹 白	Nariwa	成 羽
Kiyosue	清 末	Oguchi	尾 口
Kizaki	木 崎	Ryoseki	領 石
Komatsu	小 松	Tetori	手 取
Kuwashima (Kuwashima)	桑 島	Togadani	錫 ヶ 谷
Kuzuryu	九 頭 竜	Ushimaru	牛 丸

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#### Explanation of Plate 32

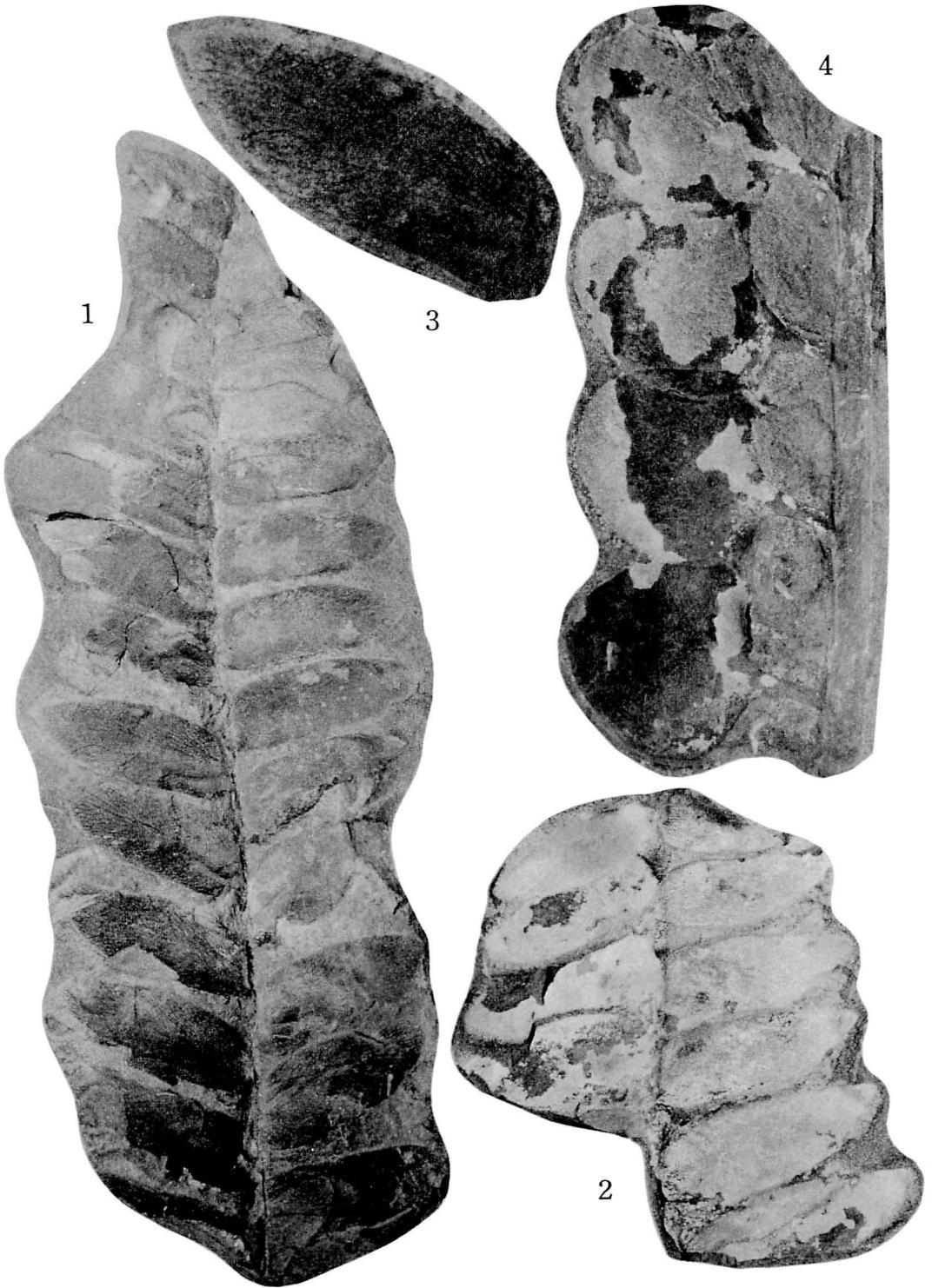
Figs. 1-3. *Dictyozamites ishikawaensis* KIMURA and SEKIDO, sp. nov.

1. Reinserted from KIMURA and SEKIDO, 1966, pl. 2, fig. 2 (Holotype, KM-63010). Loc. Mekkodani. nat. size.

2. Showing a middle portion of a leaf (KM-690014). Loc. Mekkodani. nat. size.

3. Showing a typical pinna enlarged from the Holotype.  $\times 2$ .

Fig. 4. *Dictyozamites reniformis* OISHI; (KM-433-1). Loc. Mekkodani. nat. size.



PROCEEDINGS OF THE PALAEOONTOLOGICAL SOCIETY  
OF JAPAN

日本古生物学会 1976 年度総会・年会は、1976 年 1 月 30 (金)・31 (土) 両日に東北大学川渡共同セミナーセンターにおいて開催された (参会者 51 名)。

海外学会出席報告

IGCP Project: Mid-Cretaceous Events, 1st Conference 報告 ..... 松本達郎  
UNESCO-IUGS による東南アジア地域科学誌編集者会議報告 ..... 浜田隆士  
化石サンゴ及びサンゴ礁に関する第 2 回国際シンポジウム報告 ..... 浜田隆士  
第 1 回底生有孔虫国際会議 (カナダ) 報告 ..... 的場保望  
IPOD Panel Meeting on Ocean Paleoenvironment (ラモント) 報告 ..... 高柳洋吉  
東南アジア地下資源会議 (インドネシア) 報告 ..... 菅野三郎  
第 12 回万国植物学会議 (レニングラード) 報告 ..... 浅間一男

個人講演

Fusulinids and geological structure of the Hakusan Limestone in Gifu Prefecture. .... T. CHISAKA & J. MATSUMURA  
南西諸島奄美大島名音層紡錘虫化石 (予報) ..... 石橋 毅  
Phylogenetic significance of the fusulinacean genus *Montiparus*, with several species of Japan ..... T. OZAWA  
Restudy of the Miocene planktonic Foraminifera from Shimoshiraiwa, Izu Peninsula, Japan. .... T. SAMATA & H. UJIE  
Distribution and biostratigraphic significance of *Dictyochoa subarctios* (silicoflagellate) in the North Pacific (代読) .. H. Y. LIN  
Planktonic foraminifera in the Lake Waco Formation (Eagle Ford Group), in central Texas, U. S. A. (代読) ..... K. KANAMORI  
Triassic coral fauna from Mt. Daifugen, Nara Prefecture, Southwest Japan ..... H. OKUDA & N. YAMAGIWA  
On the Permian bryozoa from the northern

part of Sainbeyli, Central Turkey ..... S. SAKAGAMI  
Colour patterns in some Cretaceous ammonites from Hokkaido ..... T. MATSUMOTO & H. HIRANO  
Barremian cephalopods from the Arita Formation ..... I. OBATA & Y. OGAWA  
Quantitative analysis on the problem of sexual dimorphism in *Scaphites* (Cretaceous ammonites) ..... K. TANABE  
Sexual dimorphism and transient polymorphism of *Gaudryceras denseplicatum*, a late Cretaceous ammonite. .... H. HIRANO  
On the internal structure of *Trigonioides* (s. s.) *paucisulcatus* ..... S.-Y. YANG  
日本産白亜紀二枚貝 *Neithea* の分類学的再検討 ..... 速水 格  
Preliminary report of the Upper Cretaceous mollusks from the Menabe area, Madagascar ..... Y. KANIE & I. OBATA  
“*Crassostrea*” *konbo* (上部白亜系産のかき) .. 鎮西清高  
Paleogene molluscan fauna from Plateau Series, Sarawak, Borneo ..... S. KANNO & D. TAN  
瀬戸川層群滝沢層の貝化石について ..... 岩崎泰颯・小野 進  
Introduction of Checklist and Bibliography of the Cenozoic Fossil Mollusca of Japan, 1950-1974 ..... K. MASUDA & H. NODA  
Miocene mollusca from Watari-machi, Miyagi Prefecture .. K. MASUDA & H. NODA  
大桑層の *Turritella* の系統について ..... 小高民夫・小笠原憲四郎  
鹿児島県燃島産 *Venus* (*Ventricoloidea*) *foveolata* SOWERBY ..... 松隈明彦  
現生キサゴ (*Umbonium costatum*) の分類学的再検討 ..... 小沢智生  
Checklist of Japanese Ostracoda ..... N. IKEYA, T. HANAI, K. ISHIZAKI & Y. SEKIGUCHI  
Taxonomic studies on some fossil and

- Recent *Balanus* in Japan ..T. YAMAGUCHI  
 岐阜県産シルル紀三葉虫群について .....  
 ..... 小林貞一・浜田隆士・TRGメンバー
- Devonian trilobites of Japan, in comparison  
 with Asian, Pacific and other faunas....  
 ..... T. KOBAYASHI & T. HAMADA
- Ontogenies of three species of silicified  
 Middle Ordovician trilobites of Virginia  
 (代読).....C.H. HU
- Mesozoic plants from the Daedong Group,  
 Korea (Part 2)....T. KIMURA & B.K. KIM  
 現生 *Spirodela polyrhiza* SCHEID の生態....  
 .....岡村長之助
- Manchuriophycus*→*Spirodela* from Sakari→  
 Recent *Spirodela polyrhiza* の系統研究....  
 .....岡村長之助
- Sinomegaceros yabei* (SHIKAMA) の骨格復原に  
 ついて .....長谷川善和・大塚裕之・小野慶一
- フタバスズキリュウの骨格復原について .....  
 .....長谷川善和・小島郁生

### 1975年度学術奨励金推薦文

木村達明君：日本の中生代フローラの研究

日本における中生代植物は産出が豊富で、その大要は戦前大石三郎によって記載報告され、中世代フローラ研究の基礎は確立された。

戦後大石の亡き後その研究を大きく発展させたのは木村君で、1952年群馬県北部利根川上流で岩室累層中に中生代植物化石を発見し、その採集に努力し、1959年にライアス植物群として発表した。同時に手取累層群と領石層群中の植物化石の採集とその研究を進め、それらの分布と層位学的位置とを明かにし、なお、両者の比較を試みた。

大石は日本の中生代植物群をその組成から古い方より *Dictyophyllum* Series, *Onychiopsis* Series, *Angiosperm* Series に3分し、*Onychiopsis* Series に属する手取植物群と領石植物群の組成の違いは時代の違いに原因するものであって、手取植物群は上部ジュラ紀、領石植物群は最下部白亜紀と考えた。これに対し木村君は両植物群ともその主要部は下部白亜紀の下部で同時異相とみ、両植物群の組成の違いは植物区による環境の違いによることを明かにした。またこれに先立って、日本においては中期ジュラ紀から前期白亜紀にわたって内帯・外帯・豊浦の3植物地理区が存在したことを明かにした。すなわち手取植物群は内帯植物地理区に、領石植物群は外帯植物地理区に属する。

バクラメフはユーラシア大陸においては中期ジュラ紀から前期白亜紀にかけて、北にシベリア植物地理区、南にインド・ヨーロッパ植物地理区を設定しているが、木村君は内帯区の手取植物群は温暖適湿下に生育したシベリア植物地理区の植物に比較され、また外帯の領石植物群は乾燥型のインド・ヨーロッパ植物地理区の *Wealdén* 植物群に近似であることを明かにした。すなわち手取植物群と領石植物群は同時異相の関係にあることを明かにした。

木村君の研究の主体は、下部白亜紀の植物群の層位的分布と植物地理学の問題にあったが、その研究は広く三畳紀から白亜紀に及び、また近年に至ってはチリ南部で後期白亜紀の植物群を発見し、朝鮮では大同植物群、高坊山植物群の植物化石を多数採集することに成功し、多くの新知見を得ている。このようにして中生代植物群の発見と採集、またその植物群の性格の解明に努力され古植物学の発展に大きく貢献した。よって日本古生物学会はここに学術奨励金を贈り、今後いっそうの発展を期待するものである。

## 1975年度日本古生物学会論文賞受賞者推薦文

梁 承榮君: Notes on the genus *Trigonioides* (Bivalvia). *Trans. Proc. Palaeont. Soc. Japan*, N.S. No. 95, pp. 359-408, 6 text-figs., pls. 54, 55, 1974.

*Trigonioides* 属は KOBAYASHI and SUZUKI により、1936年、韓国慶尚南道河東郡金南面水門洞より提唱された中生代の淡水産二枚貝であるが、その後、中国、日本、東南アジアおよびソビエト連邦からも広く報告され、1952年には Cox の *Trigonioididae* 科創設の基礎となった属である。

不幸にして、その模式標本は第二次大戦中に不明となったが、梁君は 1973年来日を期に、この重要な淡水産二枚貝の再検討に着手した。

梁君は、手はじめに模式産地周辺の地質層序を明らかにし、地層中の産状を詳細に観察して、保存良好な標本を多数採集し、再記載の資料とした。これらの標本の一部は将来 Holotype に代る標本として、この重要な属の展開に充分その責を果すものと考えられる。

標本の計測値と、詳細な観察、とくに二枚貝分類の基礎となる hinge area の構造をあますところなく記載し、本属の模式種 *Trigonioides kodairai* の実体を明らかにした。

二千数百語におよぶ本属の記載とディスカッションとは、古生物学、とくに分類学に志す学徒にとっては、一つの規範とも思われる。

このように梁君は、淡水産軟体動物の分類記載に秀でた論文を発表した。日本古生物学会は、ここに論文賞を贈る。

## ◎ TPPSJ, N.S. no. 100s 出版について

本年2月刊行予定の100s号は、都合によりおくれ、来る6月上旬に完成することになりました。出来次第配布いたします。会員の多くの方々から御撥金をいただきましたが、まだの方は何卒本書を御覧のうえ、御協力の程をお願い申し上げます。

100号記念事業計画委員会

## 日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS, NUMBER 21 を 1977 年度に刊行したく、その原稿を公募します。適当な原稿をお持ちの方は、次の事項に合わせて申込書を作成し、〒 812 福岡市東区箱崎町 九州大学理学部地質学教室気付、日本古生物学会特別号編集委員会（代表者 勘米良亀齡）宛に申し込んで下さい。

- (1) 古生物学に関する論文で、欧文の特別出版にふさわしい内容のもの。同一の大題目の下に数篇の論文を集めたもの（例えばシンポジウムの欧文論文集）でもよい。分量は従来発行の特別号に経費上ほぼ匹敵すること。学会以外からも経費が支出される見込のある場合には、その金額に応じて上記よりも分量が多くてよい。
- (2) 内容・文章ともに十分検討済の完成した原稿（または完成間近い原稿）で、印刷所に依頼して正確な見積りを算出できる状態にあること。なるべく原稿の写しを申込書とともに提出して下さい。（用済の上は返却致します）。
- (3) 申込用紙は自由ですが、次の事項を明記し、[ ] 内の注意を守って下さい。
  - (a) 申込者氏名；所属機関または連絡住所・電話番号。〔本会会員であること〕。
  - (b) 著者名；論文題目。〔和訳を付記すること〕。
  - (c) 研究内容の要旨。〔800～1,200 字程度、和文で可〕。
  - (d) 内容ならびに欧文が十分検討済であることの証明。〔校閲者の手紙の写しでもよい〕。
  - (e) 本文の頁数（刷上り見込頁数または原稿で欧文タイプ 25 行詰の場合の枚数 — ただし、ハイカーカエリート字体かを添記すること）；また本文中小活字（8 ポ組み）に指定すべき部分があるときは、そのおよその内訳（総頁に対するパーセント）；挿図・表の各々の数と刷上り所要頁数；写真図版の枚数。
  - (f) 他からの経費支出の見込の有無、その予算額、支出源。〔その見込の証明となる書類またはその写しを添えて下さい〕。〔1977 年度の文部省の刊行助成金を申請希望の場合も、その旨を上記の準じて添記して下さい〕。
  - (g) その他参考事項。原稿が未完成の場合には、申込時における進行状況ならびに完成確約年月日を必ず記して下さい。
- (4) 申込締切 1976 年 10 月 15 日（消印有効）。採否は 1977 年 1 月の評議員会で審議決定の上、申込者に回答の予定です。ただしその前または後に、申込者との細部の交渉を、編集委員から求めることがあるかもしれません。
- (5) 印刷予定論文が完全な場合には、決定後できるだけ早く印刷にとりかかる予定です。文部省の刊行助成金（「研究成果刊行費補助金」）を申請希望の場合には、学会から申請（例年は 11 月中旬中に申請締切）し、その採否・金額など決定後印刷にとりかかります。その場合は文部省との約束により、その年の秋（前例では 10 月 20 日）までに初校が全部出なければ、補助金の交付が中止されることになっています。
- (6) 特別号の投稿規定はとくにありません。会誌に準じ、前例を参考とし、不明の点は編集委員会に問い合わせて下さい。経費がかかるので、特別な場合を除き、別刷は作成せず、本刷 25 部を著者に無料進呈します。それ以上は購入（但し著者には割引）ということになります。いくつかの論文を集めて 1 冊にするときには、世話人の方から指示して、体裁上の不統一のないようにして下さい。印刷上の指示事項が記入できるよう、原稿の左右両側・上下に十分空白をとって、タイプで浄書して下さい。

例会等の通知

	開催地	開催日	講演申込締切日**
117回例会	広島大学	1976年6月27日*	1976年5月15日
118回例会	北海道大学	1976年10月4日	1976年8月4日
1977年総会・年会	東京学芸大学	1977年1月	1976年11月15日

\* N.S. No. 100 で 6月26日と公示しましたが、会場の都合により6月27日と訂正します。

\*\* 講演申込締切日は、開催予定日の2ヶ月前を原則とします。早目にお申込み下さい。

学会記事

- ◎ 1976年1月29日の評議員会において次の各君の入・退会が認められた。入会8名(岩尾雄四郎, 傍島竹史, 井上洋子, 大塚雅勇, 加瀬友喜, 永井節治, 林明, 村松二郎), 退会4名(黒田徳米, 冨澤恒雄, 片平忠実, 今井豊二), 逝去1名(Marshall KAY)。
- ◎ 同じく、次の5名の諸君が特別会員に推薦された。佐藤誠司, 大村明雄, 松丸國照, 粉川昭平, 尾上亨。
- ◎ 1975年末の会員数は次の通り。名譽会員6, 特別会員143, 普通会員304, 賛助会員10, 在外会員56, 合計519。
- ◎ 本年度より次のように幹事の交代・新任があった。庶務幹事: 岩崎泰頴君退任。行事幹事: 野田浩司君退任。特別号幹事: 柳田寿一君新任。退任された幹事諸君のこれまでの御尽力に感謝する。特に岩崎泰頴君は、1966年以来庶務幹事として学会の運営に努力された。
- ◎ 第10期古生物学研究連絡委員会は、日本古生物学会から選出の次の10君と、学会議会員大森昌衛君ならびに生物科学研連からの1名を加え、計12名で構成され、1月14日に第1回委員会を開催した。委員長松本達郎, 幹事花井哲郎, 浜田隆士。委員名(アルファベット順): 鎮西清高, 浜田隆士, 花井哲郎, 速水格, 菅野三郎, 小高民夫, 松本達郎, 大森昌衛, 高柳洋吉, 棚井敏雅, 氏家宏(生物研連からの1名)。
- ◎ 日本古生物学会より選出の第10期地質学研究連絡委員会委員には浜田隆士君がえらばれた。

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