35. ICHTHYOLITHS FROM SOME NW PACIFIC SEDIMENTS, DSDP LEG 32

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INTRODUCTION

Recent investigations of the microscopic skeletal debris of fishes (Helms and Riedel, 1971; Doyle et al., in press) have indicated that these microfossils can be used for assigning approximate ages to otherwise unfossiliferous Cenozoic pelagic sediments. Therefore Carolyn Glockhoff took some samples for this purpose during Leg 32 of the Deep Sea Drilling Project. The samples that we report on are from the top two cores collected at Site 311 (28°07.46'N, 179°44.25'E, in 5775 m of water) and from the first core of Site 307 (28°35.26'N, 161°00.28'E, in 5696 m of water). At Site 311, which was continuously cored, calcareous nannofossils in Core 3 indicate an age of early late Oligocene. At Site 307, radiolarians in the first 9 cm of Core 1 are of Ouaternary age: the second core was cut 28 meters below the first, and the radiolarians indicate a Cretaceous age.

Table 1 lists the ichthyoliths found in Cores 311-1 and 311-2, with stratigraphic ranges as established mainly by Doyle et al. (in press). Some hitherto undescribed forms are also included, and their ranges determined in assemblages of known ages (Table 2). Many of these reference assemblages are the same as those used in the ichthyolith contributions to Volumes 7 and 26 of the DSDP Initial Reports, one notable omission being JYN V 10P at about 9 meters, which is now believed on the basis of its ichthyoliths to be not older than early Miocene, rather than late Eocene as originally supposed on the evidence of radiolarians (now believed to be reworked).

The system of describing and naming the ichthyoliths (Doyle et al. in press) requires modification and expansion to accommodate the new forms described here.

RESULTS

Table 1 gives the numbers of specimens found of stratigraphically significant specimens in samples from Site 311. Table 2 presents the data establishing the stratigraphic ranges of new forms. Reference samples (indicated by asterisks) not used by Helms and Riedel (1971) nor in the Leg 26 report are the following:

PAPA 120G, 160-168 cm, an SIO core from 20°56'N, 112°03'W, in 3379 meters of water. Radiolarians indicate a Quaternary age (Jean M. Westberg, personal communication).

BNFC 53P, 490-510 cm and 515-517 cm, an SIO core from 11°52'N, 110°0.0'W, in 3892 meters of water. Nannofossils indicate a late Pliocene age (D. Bukry, personal communication).

TRI 5P, 210-215 cm, an SIO core from 15°38'N, 112°57'W in 3929 meters of water. Radiolarians indicate

a Pliocene-Quaternary age (Jean M. Westberg, personal communication).

Age assignments for the following DSDP cores are discussed in the appropriate volumes of DSDP Initial Reports:

42-1-4 and 42-2-3 from 13°50.56'N, 140°11.31'W in 4844 meters of water, late Oligocene.

65.1-3, CC from 4°21.21'N, 176°59.16'E in 6130 meters of water, Eocene.

82A-2-3 from 02°35.48'N, 106°56.52'W in 3689 meters of water, Pliocene.

304-2, CC from 39°20.27'N, 155°04.19'E in 5630 meters of water, Pliocene.

310-10-6, 310-10, CC and 310-11-3 from 36°52.11'N, 176°54.09'E in 3516 meters of water; 310-10-6 and 310-10, CC middle Eocene, 310-11-3 early Eocene.

313-1-2, 4, 5, 6, CC from 21°10.52'N, 170°57.15'W in 3484 meters of water; 313-1-2, 4, 5 Pliocene-Quaternary, 313-1-6 and 313-1, CC late Miocene.

The assemblages from 311-1-1 and 311-1-2 are evidently late Miocene or younger, those from 311-1-3 and 311-1-4 are middle Miocene or younger, those from 311-1-5 through 311-2-2 at 40-42 cm are late Oligocene to early Miocene, and those from 311-2-2, 60-64 cm through 311-2-3, 50-54 cm are early Oligocene to early Miocene.

In addition to the samples from Site 311, three samples were examined from Site 307. The top two of these (307-1-1, 90-94 cm and 307-1-4, 50-54 cm) contained very few ichthyoliths, but a sample from 307-1, CC yielded several hundred specimens. The subtypes present in 307-1, CC, and the number of each, are as follows: Two curved triangles long base (1), Kite-shaped elongate prominence (?), Small triangle crenate margin (1), Triangle short wing (4), Triangle pointed margin ends (1), Asymmetrical peaks narrow depression (4), Triangle broad wing (1), Triangle medium wing (1), Triangle one canal above (1), Asymmetrical peak wide depression (1), Flexed triangle 115-118 (1), Triangle inline halfway (1), Triangle hooked margin (2), Triangle with parallel inline (?), Triangle with triangular projection (10), Triangle sigmoid (3), Triangle transverse line across (1), Flexed triangle shallow inbase (14), Triangle with canals (4), Short side peaks differentiated margin (1), Rhombus undulating margin (1), Rounded apex triangle (4), Curved triangle inline constricted (1), Small dendritic many radiating lines (20), Small dendritic few radiating lines (6), Large with numerous lines (12), Rectangular serially saw-toothed (3), Small circular center (2), Skewed four or five peaks (2), Narrow triangle ragged base (?). This assemblage indicates that 307-1, CC is late Oligocene to middle Miocene in age, evidently with some Eocene or older admixture.

Ranges of Subtypes	Quat. Plio. Mio. Olig. Eoc.									+	1													+				1	ľ		
Subty	les ^b	Small triangle crenate margin	Assymetrical peak narrow depression	Triangle medium wing	Flexed triangle 115-118	Wide triangle straight inbase	Long triangle thin wall	Trianlge with triangular projection	Triangle transverse line across	Flexed triangle shallow inbase	Wide triangle	Flexed triangle shallow inbase >120	Narrow triangle straight inbase	Triangle with canals	Triangle crenulate	Flexed triangle 102-112	Curved triangle pointed margin	Rounded apex triangle	Triangle crenulate with canals	Rectangular serially saw-toothed	Small dendritic few radiating lines	Flexed narrow triangle 120-128	Large with numerous lines	Skewed four or five peaks	Circular with line across	Small triangle long striations	Short triangle stepped margin	Large triangle saw-toothed margin	Two triangles	Elliptical with line across	Long triangle stepped margin
311-1-1, 40 311-1-2, 50 311-1-3, 40 311-1-4, 70 311-1-5, 40	⊢44 cm ⊦54 cm ⊦44 cm ⊦74 cm ⊦44 cm	1		1				2 1 1 2				2				3 1 1	1	1		3 2 3	2 1 1 3	2 1	2 3 1 3 3		3 2	?	1 2	1	1	4 6 2 3	2
311-2-1, 12 311-2-2, 40 311-2-2, 60 311-2-2, 14 311-2-3, 50	0-124 cm ⊦42 cm ⊦64 cm 0-142 cm ⊦54 cm	1 1 1 1	3 3 4 2 2	1	1	1	2 2 1 2	11 8 6 3 6	2	4 1 4 3	1 1	2 1 2 1	1	1 1 3	1		1	1	1		2 1			1							

 TABLE 1

 Distribution of Subtypes of Ichthyoliths in Site 311 (Numbers of Specimens Found)

^aThe following subtypes were looked for in these samples, but not found – Kite-shaped irregular network, Two curved triangles, Plain lanceolate, Triangle broad wing, Two curved triangles long base, Triangle short wing, Triangle pointed margin ends, Triangle one canal above, Triangle inline halfway, Triangle hooked margin, Triangle double flex, Triangle sigmoid, Triangle with base angle, Short kite-shaped, Three equal peaks flared base, Giant lanceolate, Kite-shaped longitudinal line, Rhombus smooth margin, Short side peaks differentiated margin, Triangle notched corner, Curved triangle inline constricted, Three similar peaks, Small dendritic many radiating lines, Tall median peak transverse lines, Small circular center, Narrow curved triangle, Stippled triangle, Skewed with transverse lines, Narrow triangle ragged base, Three tall peaks.

^bThe following samples proved to be unproductive of ichthyoliths, and thus could not be stratignathically interpreted – 311-1-6, 100-104 cm; 311-2-4, 90-94 cm; 311-2-5, 70-74 cm; 311-2-6, 70-74 cm.

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CHANGES TO THE DESCRIPTIVE SYSTEM

To accommodate the hitherto undescribed forms, the following modifications and additions are made to the descriptive system established in the Leg 26 report.

1) In Type a2 / b2, add the character k with the following states:

k. shape of peaks' apexes

1. neither of the following

- 2. sharp
- 3. blunt

- The definition of Type a7 / b1 is modified to accommodate forms with "two or more tooth-like projections"
- In Type a7 / b1, we do not use the character-state d.1, but add the following character-states:
 - d.4 short and stubby, without a flared base or two closely parallel basal lines

d.5 short and stubby, with a flared base

- d.6 short and stubby, with two closely parallel basal lines
- In Type a7 / b1, we do not use the character-states e.1, e.2 and e.3, but add the following character-states:
 - e.4 triangular, not markedly longer than broad

ICHTHYOLITHS

TABLE 2 Stratigraphic Distribution of Thirteen New Ichthyolith Subtypes

Ag	je	Samples	Small triangle crenate margin	Long triangle thin wall	Wide triangle	Triangle double flex	Triangle sigmoid	Triangle with base angle	Flexed triangle shallow inhase >120	Rectangular serially saw-toothed	Small triangle long striations	Stippled triangle	Large triangle saw-toothed margin	Narrow triangle ragged hase	Three tall peaks	Total number of a8.9 / bl.5
Conternation (JYN V 38PG, 98-101 cm *PAPA 120G, 160-168 cm PROA 128G, 67-70 cm PROA 174G, 120-131 cm *DSDP 313-12 5654 cm						2			1 3			5 ? 1		57 25 122 30
		*DSDP 313-1-4, 30-34 cm *DSDP 313-1-4, 90-93 cm *DSDP 313-1-4, 90-93 cm *DSDP 313-1-5, 40-43 cm *TRI 5P, 210-215 cm								1 2 1	1			2 ??		176 131 124 35
	relic	AMPH 30G, 90-93 cm AMPH 130G, 90-93 cm *BNFC 53P, 490-515 cm *BNFC 53P, 515-517 cm DODO 117P, 216-232 cm *DODO 117P, 216-232 cm						1		2	2			1 32 2		30 219 54 52
Dito		*DSDP 82A-2-3, 50-56 cm MSN 56P, 109-113 cm PROA 103P, 299-300 cm PROA 103P, 300-320 cm *DSDP 304-2, CC					1			2	3		1	1		25 129 64 358 62
	Late	*DSDP 313-1-6, 50-54 cm *DSDP 313-1, CC JYN 38P, 420-423 cm MSN 146P, 354-375 cm DSDP 15-6-3, 44-50 cm				1		1		4	1 7	1				143 190 24 315 129
liocene	Middle	DSDP 15-6-3, 65-69 cm DSDP 29B-3-2, 83-87 cm PROA 96P, 297-300 cm PROA 96P, 480-483 cm PROA 97P, 370-373 cm						1		1 2 1 1	1 2 1	2 3	1			165 143 135 105 192
W	Early	AMPH 109P, 325-328 cm DODO 37P, 356-370 cm DODO 37P, 490-500 cm DODO 38P, 132-152 cm DODO 38P, 430-450 cm DODO 38P, 410-450 cm			?		-	1 1 1		533	1 1 1	? 4	1	;		122 330 263 310 72
11	,11	DSDP 29B-4-3, 84-88 cm MSN 135P, 70-73 cm MSN 135P, 702-705 cm DSDP 75-1-2, 50-56 cm	?		2	1	1	1 1 1	6 1 2 2	1 3 3	1 1 1 3	7				357 170 342 200
77,	Late	DSDP 75-3-5, 40-45 cm DODO 111P, 112-128 cm DSDP 19-3-4, 40-44 cm *DSDP 42-1-4, 50-56 cm *DSDP 42-2-3, 50-56 cm		13	1	1	1	2 1 1	1	1						51 525 212 51 100
Oligocene		RIS 111P, 419-422 cm *DSDP 313-3-6, 130-134 cm *DSDP 313-4-6, 110-114 cm DSDP 14-5-4, 50-56 cm	1	1			1	2				1				291 60 31 51
	Late Earl	DSDP 14-9-2, 36-40 cm DSDP 75-9-1, 50-56 cm DSDP 119-16-2, 50-56 cm DODO 108P, 170-190 cm DSDP 19-5-6, 80-84 cm		1 2	1	ľ		1	1							51 55 647 54
Eocene	Middle	DSDP 19-7-4, 16-20 cm *DSDP 65, 1-3, CC DSDP 119-20-2, 30-34 cm *DSDP 310-10-6, 120-122 cm *DSDP 310-10, CC	2	?	1	2	3	1								126 2950 132 546 1122
	Early	LSDH 88P, 353-356 cm DODO 78P, 60-64 cm DODO 86P, 84-100 cm DSDP 119-24-3, 53-57 cm DSDP 119-24, CC *DSDP 310-11-3, 75-80 cm	8	4	2	1			1							61 261 72 190 57 300

e.5 triangular, markedly longer than broad

e.6 broad, angular, and regular in shape

e.8	broad,	rounded,	and	regular	in	shape	
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e.9 broad, rounded, and irregular in shape

e.7 broad, angular, and irregular in shape

- 5) In Type a9 / b1, we do not use the character-states c.2 and c.3, but add the following character-states:
 - c.15 crenate, saw-toothed, or some other incised pattern on upper half of margin. No lateral projection longer than 30μ
 - c.16 crenate, saw-toothed, or some other incised pattern on upper half of margin. At least one lateral projection longer than 30μ
 - c.17 crenate, saw-toothed, or some other incised pattern on lower half of margin. No lateral projection longer than 30μ
 - c.18 crenate, saw-toothed, or some other incised pattern on lower half of margin. At least one lateral projection longer than 30μ
- 6) In Type a9 / b1, we do not use the character-state f.2, but add the following character-states:
 - f.6 distinct striations radiating from apex of inline toward outline, or subparallel, and extending into the upper quarter of the outline
 - f.7 distinct striations radiating from apex of inline toward outline, or subparallel, but not extending into the upper quarter of the outline
- 7) In a9 / b1 / f4, a9 / b5 / i4, and a9 / b5 / u2, the use of the term "lateral shadow" needs clarification. Two kinds of difficulties have arisen in attempting to apply the description "lateral shadow" consistently. The first arises from an inadequacy of the original verbal definition, though the meaning should be clear from the accompanying sketch-a "lateral shadow" is not one which is most intensive at the margin and diminishing inward, as occurs in most ichthyoliths, but rather is a dark lateral zone separated from the edge by a narrow light zone. The second difficulty is more difficult to resolve, since with some microscopes and under some conditions of transmitted illumination, a lateral shadow cannot be seen in specimens in which it should be visible. The only solution to this dilemma is to move the specimen until its cross-section can be determined, in which a median, convex zone will be seen to separate two flattened lateral zones. Our reason for not requiring this as part of the routine examination is our desire to avoid threedimensional descriptors as far as possible.
- 8) In Type a9 / b1, we do not use the character-state h.1, but add the following character-states:
 - h.4 second margin 5%-15% longer than the first













- h.5 less than 5% difference between first and second margins
- 9) In Type a9 / b1, add the following character-state:
 - i.10 reverse sigmoid

Remarks: This term is used when a sigmoid margin of a tooth has the upper part convex outward.

- 10) In Type a9 / b1, we do not use the character-state k.2, but add the following character-states:
 - k.8 approximately parallel to outline, but not with sides bowed in or markedly acuminate, and not closely approaching the outline at the base



- k.9 approximately parallel to outline, not with sides bowed in or markedly acuminate, but closely approaching the outline at the base
- 11) In Type a9 / b5, we do not use the character-states c.2 and c.3, but add the following character-states (measured as in Type a9 / b1 / c15, 16, 17, 18):
 - c.14 crenate, saw-toothed, or some other incised pattern on upper half of margin. No lateral projection longer than 30μ
 - c.15 crenate, saw-toothed, or some other incised pattern on upper half of margin. At least one lateral projection longer than 30μ
 - c.16 crenate, saw-toothed, or some other incised pattern on lower half of margin. No lateral projection longer than 30μ
 - c.17 crenate, saw-toothed, or some other incised pattern on lower half of margin. At least one lateral projection longer than 30μ
- 12) In Type a9 / b5, we do not use the character-state i.2, but add the following character-states:
 - i.8 defined similarly to a9 / b1 / f6
 - i.9 defined similarly to a9 / b1 / f7
- 13) In Type a9 / b5, add the character-state:

j.4 stippling

14) In Type a9 / b5, add the character-state:

m.6 defined similarly to a9 / b1 / i10

15) In Type a9 / b5, add the character-state:

 o.9 simply curved line terminating at margins at different levels (length of margins above the transverse line differ by at least 5%)

- 16) In Type a9 / b5 add the character u with the following states:
 - u. Features between inline and outline below transverse line

- 1. none of the following
- 2. "lateral shadow"



- 3. distance between inline and outline less than 10μ at its maximum
- In Type a9 / b6 add the characters c, d, and e, with characterstates as follows:
 - c. Number of projections
 - Numbers. Not encoded
 - d. Shape of middle projection
 - 1. none of the following
 - 2. unmodified triangle
 - triangle modified by the lower parts of the sides being convexly curved



- distally truncate, straight or even a little depressed.
- e. Shape of inline of middle projection
 - 0. no inline within middle projection
 - 1. none of the following
 - 2. rounded, as in the diagrams

3. pointed, as in the diagrams

DESCRIPTIVE SECTION

a2 / b2 / c3 / d1 / e1 / f1 / g1 / h1 / i0 / j2 / k1, 3

Three tall peaks (Plate 1, Figures 1, 2)

Approximately elliptical, with three peaks; length $300-550\mu$, greater than width; not skewed. Median peak less than twice the length of lateral peaks; apexes of peaks usually blunt; depressions U-shaped. Range: two specimens found in one late Pliocene sample.

a7 / b1 / c2 / d3 / e6

Rectangular serially saw-toothed (Plate 1, Figure 3)

a7 / b1 / c2 / d3 / e3 (Rectangular saw-toothed), Doyle et al., in press, pl. 1D, fig. 3-8; pl. 2G, fig. 4-8 (in part).

Elongated rectangular form with broad, angular, regularly shaped projections closely spaced. Height $150-275\mu$.

Range: late Oligocene to Pliocene-Quaternary.

a8 / b1 / c2 / d2, 3 / e60-100 / f20-35

Triangle double flex (Plate 1, Figure 6)

Undescribed form, Dengler et al., in press, pl. 5, fig. 13. Triangles of narrow to medium width (apical angle 20°-35°) having two prominent flexures. Base of inline above termination of the flexures. Overall length 390-950µ, width 160-330µ.

Range: middle Eocene to middle Miocene.

$$\begin{array}{l} \textbf{a8 / b1,5 / c1 / d2,3 / e \geq 120 / f \leq 25} \\ Flexed \ triangle \ shallow \ inbase \ \geq 120 \\ (Plate \ 1, \ Figures \ 4, \ 5) \end{array}$$

Narrow triangles (apical angle ≤25°) having one prominent flexure with an angle greater than or equal to 120°. Base of inline (or transverse line) above the termination of the flexure. Overall length (above transverse line) 250-480µ, width 90-200µ.

Range: late Oligocene to early Miocene and one specimen found in late Eocene.

Undescribed form, Dengler et al., in press, pl. 5, fig. 12.

Wide triangle (length to width ratio <1) with convexly curved margin and rounded, blunt apex. Inline approximately parallel to outline, generally extending into upper half of outline, and with a straight or curved base. Overall length 100-350µ, width 200-450µ.

Range: early Eocene to early Miocene.

a9 | b1 | c1 | d1 | e1 | f1 | g1 | h2 | i6 | j3 | k2 | 1<0.5 | m>4 | n2 | ol / pl, Doyle et al., in press, pl. 4, fig. 1.

Narrow triangle (length to width ratio \geq 4) with convexly curved margin frequently longer than concavely curved margin. Inline approximately parallel to outline but closely approaching the outline basally. Overall length 230-450µ, width 50-120µ.

Range: Pliocene to Quaternary with two possible specimens in early Miocene.

$$\begin{array}{c} a9 \ / \ b1 \ / \ c1 \ / \ d1 \ / \ e1 \ / \ f1,3 \ / \ g1 \ / \ b5 \ / \\ i9 \ / \ j9 \ / \ k8 \ / \ l0.75-0.95 \ / \ m \geq 2.75 \ / \ n2 \ / \ o1 \ / \ p2 \\ + \ a9 \ / \ b5 \ / \ c1 \ / \ d1 \ / \ e1 \ / \ f1 \ / \ g1 \ / \ h1 \ / \ i1 \ / \ j1 \ / \ k9 \ / \ l9 \ / \\ m1,4 \ / \ n1,3 \ / \ o9 \ / \ p3 \ / \ q0.75-0.95 \ / \ r \geq 2.75 \ / \ s0 \ / \ t2 \ / \ u1 \\ Triangle \ sigmoid \end{array}$$

(Plate 1, Figures 11, 12; Plate 2, Figure 14)

Undescribed form, Dengler et al., in press, pl. 5, fig. 15, 16. Sigmoidally curved long triangle (length to width ratios above transverse line ≥ 2.75) with sharply pointed apex. Inline approximately parallel to outline, but with rounded apex. Overall length above transverse line 250-550µ, width 90-140µ.

Range: middle Eocene to early Miocene (and one specimen in Pliocene).

Triangle (range of length to width ratios 1.5-1.8) with straight margins, no lateral shadows, and striations extending from base into the upper quarter of the outline. Inline either absent or limited to bottom one-fourth of the outline. Rare specimens have a straight or slightly curved transverse line ending at the margins. Measurements above transverse line-length no greater than 150-300µ, width no greater than 80-200µ.

Range: early Miocene to Quaternary.

a9 / b1 / c1,15,(15+17) / d1 / e1,2 / f1 / g3 / h5 / i6,10 / j3 / k8 / 10.1-0.3 / m>2 / n2 / o1 / p1,2+ a9 / b5 / c1 / d1 / e1,2 / f1 / g1 / h1,2 / i1 / j4 k2 / l2 / m4,6 / n3 / o2,4 / p2,3 / q0 / r0 / s>2 / t2 / u1

Stippled triangle

(Plate 1, Figures 19-21)

a9 | b1 | c2,3 | d3 | e2 | f1 | g3 | h1 | i1 | j3 | k2 | 10.2 | m4,6 | n2 | o1 / pl. Doyle et al., in press, pl. 4, fig. 4.

Triangular form (length to width ratio greater than 2) with one margin concave or reverse sigmoid and generally modified by sawtoothed projections, the other convex. A straight or curved transverse line occasionally present near apex of the moderately or sharply pointed outline. Inline approximately parallel to outline, enclosing canals. Surface appears slightly stippled. Overall length 350-700µ, width 100-200µ.

Range: early to late Miocene.

Comment: The specimen illustrated by Doyle et al., in press, pl. 4, fig. 4, is the type specimen of this new subtype.

(Plate 1, Figures 15, 16)

cf. Fish tooth type D-4 Helms and Riedel, 1971, p. 1710, pl. 1, fig. 11. Triangular form with a shallow reflexed or simple angle in the bottom fifth of one margin, the other margin between 5% and 15% longer, a range of length to width ratios (above curved transverse line when present) of 1.6-2.8, "lateral shadows," and margins straight or almost so. Inline approximately parallel to outline or occasionally narrower and parallel sided, with its apex in the upper three-fifths of the outline. Striations radiate from apex of inline toward outline. Overall length 300-450µ, width 140-200µ.

Range: late Oligocene to Quaternary, with one specimen found in early Oligocene and one specimen in a reworked Eocene sample.

Small triangle crenate margin (Plate 2, Figures 4, 5)

a9 / b1 / c2,3 / d2,3 / e1 / f1 / g1 / h1 / i3 / j3 / k2 / l0.4-0.5 / m1-1.1 / n1 / o1 / p1 Doyle et al., in press, pl. 4, fig. 11, 13.

Wide triangle (range of length to width ratios 0.5-1.4) with both margins modified by crenate projections less than 30µ long. In some specimens, crenations limited to upper half of outline. Margins straight or convex. Inline approximately parallel to outline, occasionally enclosing canals, and extending into upper half of outline, but not into projections. Overall length 100-200µ, width 90-150µ.

Range: early Eocene to early Oligocene, with one possible specimen in early Miocene.

$$\begin{array}{c} a9\ /\ b5\ /\ c1\ /\ d1\ /\ e1\ /\ f1\ /\ g1\ /\ h1\ /\ i1\ /\ j1\ /\ k2,6\ /\\ l2,3\ /\ m2,4\ /\ m2,3\ /\ o2\ /\ p2,3,7\ /\ q0\ /\ r1.5-2.5\ /\ s\geq 4\ /\ t2\ /\ u3\end{array}$$

Long triangle thin wall (Plate 1, Figures 9, 10)

Undescribed form, Dengler et al., in press, pl. 5, fig. 14.

Long narrow triangle (length to width ratio below straight transverse line \geq 4), only a small part of the outline above transverse line. Margins either straight or curved. Inline below transverse line parallel to outline, and separated from it by no more than 10µ. Overall length 300-900µ, width 45-100µ.

Range: early Eocene to late Oligocene.

$$a9 / b6 / c \ge 4 / d4 / e0$$

Large triangle saw-toothed margin

(Plate 2, Figure 2)

a9 / b6 (Triangle saw-toothed margin) Doyle et al., in press, pl. 1J, fig. 4-6.

Roughly triangular to arcuate forms with dentate edge which is approximately paralleled by a distinct undulating line. Four or more projections, the shape of the middle projection distally truncate,

straight, or even a little depressed. The inline does not extend into the middle projection. Overall length approximately $90-310\mu$, width 230- 400μ .

Range: four specimens found in early Miocene to Pliocene.

Comment: The specimen illustrated by Doyle et al., in press, pl. 1J, fig. 5, is the type specimen of this new subtype.

LIST OF FORMS IDENTIFIED

Table 3 is a numerically arranged listing of the new subtypes described herein. Below is an alphabetically arranged list of the colloquial names of all of the new and previously described forms encountered, those not described by Doyle et al. (in press) being indicated by an asterisk.

Asymmetrical peak narrow depression Asymmetrical peak wide depression Circular with line across Curved triangle inline constricted Curved triangle pointed margin Elliptical with line across Flexed narrow triangle 120-128 Flexed triangle 102-112 Flexed triangle 115-118 Flexed triangle shallow inbase *Flexed triangle shallow inbase ≥ 120 Kite-shaped elongate prominence *Large triangle saw-toothed margin Large with numerous lines Long triangle stepped margin *Long triangle thin wall *Narrow triangle ragged base Narrow triangle straight inbase Plain lanceolate *Rectangular serially saw-toothed Rhombus undulating margin Rounded apex triangle Short side peaks differentiated margin Short triangle stepped margin Skewed four or five peaks Small circular center Small dendritic few radiating lines Small dendritic many radiating lines *Small triangle crenate margin *Small triangle long striations *Stippled triangle *Three tall peaks

Triangle broad wing Triangle crenulate Triangle crenulate with canals *Triangle double flex Triangle hooked margin Triangle inline halfway Triangle medium wing Triangle one canal above Triangle pointed margin ends Triangle short wing *Triangle sigmoid Triangle transverse line across *Triangle with base angle Triangle with canals Triangle with parallel inline Triangle with triangular projection Two triangles *Wide triangle Wide triangle straight inbase

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REFERENCES

- Dengler, A. T., Doyle, P. S., and Riedel, W. R., in press. Ichthyoliths in some samples from the Philippine Sea, Deep Sea Drilling Project Leg 31. In Ingle, J. C. and Karig, D. E., et al., Initial Reports of the Deep Sea Drilling Project, Volume 31: Washington (U.S. Government Printing Office).
- Doyle, P. S., Kennedy, G. G., and Riedel, W. R., in press. Stratignathy. *In* Davies, T. A., Luyendyk, B. P., et al., Initial Reports of the Deep Sea Drilling Project, Volume 26: Washington (U.S. Government Printing Office).
 Helms, P. B. and Riedel, W. R., 1971. Skeletal debris of fishes.
- Helms, P. B. and Riedel, W. R., 1971. Skeletal debris of fishes. In Winterer, E. L., et al., Initial Reports of the Deep Sea Drilling Project, Volume 7: Washington (U.S. Government Printing Office), p. 1709-1720.

FABLE	3
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Numerically Arranged Name Descriptions, With Equivalent Colloquial Names, of Subtypes Described in This Chapter

								N	ame I	escrip	tions								_		Colloquial Names	
8	b	c	d	c	f	g	h	i	j	k	1	m	n	0	р	q	r	\$	t	u		
2	2	3	1	1	1	1	1	0	2	1.3											Three tall peaks	
7	1	2	3	6	_																Rectangular serially saw-toothed	
8	1	2	2.3	60-100	20-35	-	-													-	Triangle double flex	
8	1.5	1	2,3	>120	≤25				-				_							-	Flexed triangle shallow inbase >120	
9	1	1	1	1	1	1	3.4.5	3	3	8	0.2-0.8	<1	4-8	1	3						Wide triangle	
9	1	1	1	1	1	1	3,4,5	6	3	9	0.2-0.7	>4	1	1	3					-	Narrow triangle ragged base	
9	1	1	1	1	1,3	1	5	9	9	8	0.75-0.95	≥2.75	2	1	2				. U		Triangle sigmoid	
9	5	1	1	1	1	1	1	1	1	9	9	1.4	1,3	9	3	0.75-0.95	≥2.75	0	2	1		
9	5		1	1	6	1	5	2	2	0,5	0-0.75	1.5-1.8	2	1 2	0,6	0-0.75	1.5-1.8	0	1	1	Small triangle long striations	
9	1	1,15(15+17)	1	1,3	1	3	5	6,10	3	8	0.1-0.3	>2	2	1	1.2	0	0	>2	,	1	Stippled triangle	
9	5	0.12	1	1,2	4+16 21	+	1,2	2	2	7.0	0206	16.28	2	1.7	1				-	+		
9	5	8.12	1	1	4+(0,7)	i	1	2+4	ĩ	2	2	2	2	9	3.8	0.2-0.6	1.6-2.8	0	1	1	Triangle with base angle	
9	T	15,17	15.17	1.2	1	i	5	2.3	2.3	9	0.25-0.5	0.5-1.4	1	1	1					-	Small triangle crenate margin	
9	5	1	1	1	1	1	1	1	1	2.6	2.3	2,4	2,3	2	2,3.7	0	1.5-2.5	>4	2	3	Long triangle thin wall	
9	6	>4	4	0		-	1			-10										1	Large triangle saw-toothed margin	

PLATES

In the explanations to the figures, the sample numbers and slide designations (in the form "S1.4", etc.) indicate preparations in our collection at Scripps Institution of Oceanography, and designations in the form "R45/1" indicate England Finder positions of the illustrated specimens on the slides.

PLATE 1

	All figures are magnified $110 \times$.
Figures 1, 2	 a2 / b2 / c3 / dl / el / fl / gl / hl / i0 / j2 / kl,3. Three tall peaks. 1. BNFC 53P, 515-517 cm, S1.1, M29/1. 2. RIS 8P, 650-655 cm, Cse.1, H21/0, type specimen.
Figure 3	a7 / b1 / c2 / d3 / e6. Rectangular serially saw-toothed. AMPH 98P, 500-503 cm, S1.A, L35/2, type specimen.
Figures 4, 5	a8 / b1,5 / c1 / d2,3 / $e \ge 120$ / $f \le 25$. Flexed triangle shallow inbase ≥ 120 . 4. 19-3-4, 40-44 cm, S1.4, J37/4, type specimen. 5. MSN 135P, 702-705 cm, S1.D, D40/4.
Figure 6	a8 / b1 / c2 / d2,3 / e60-100 / f20-35. Triangle double flex. 65.1-3, CC, S1.15, H43/0, type specimen.
Figures 7, 8	a9 / b1 / c1 / d1 / e1 / f1 / g1 / h3,4,5 / i6 / j3 / k9 / l0.2-0.7 / m≥4 / n1 / o1 / p3. Narrow triangle ragged base. 7. AMPH 130G, 90-93 cm, S1.A, N37/1. 8. BNFC 53P, 490-510 cm, S1.1, M37/1, type specimen.
Figures 9, 10	a9 / b5 / c1 / d1 / e1 / f1 / g1 / h1 / i1 / j1 / k2,6 / l2,3 / m2,4 / n2,3 / o2 / p2,3,7 / q0 / r1.5-2.5 / $s \ge 4$ / t2 / u3. Long triangle thin wall. 9. DODO 111P, 112-128 cm, S1.6, C43/1. 10. 311-2-2, 40-42 cm, S1.2, J23/1, type specimen.
Figures 11, 12	a9 / b1 / c1 / d1 / e1 / f1,3 / g1 / h5 / i9 / j9 / k8 / l0.75-0.95 / $m \ge 2.75$ / n2 / o1 / p2 + a9 / b5 / c1 / d1 / e1 / f1 / g1 / h1 / i1 / j1 / k9 / l9 / m1,4 / n1,3 / o9 / p3 / q0.75-0.95 / $r \ge 2.75$ / s0 / t2 / u1. Triangle sigmoid. 11. 65.1-3, CC, S1.9, N21/2, type specimen. 12. DODO 30P, 534-544 cm, S1.1, F30/0.
Figures 13, 14	$\begin{array}{l} a9 \ / \ b1 \ / \ c1 \ / \ d1 \ / \ e1 \ / \ f6 \ / \ g1 \ / \ h5 \ / \ i2 \ / \ j2 \ / \ k0.5 \ / \ l0.75-1 \ / \ m1.5-\\ 1.8 \ / \ n2 \ / \ o1 \ / \ p1 \ + \\ a9 \ / \ b5 \ / \ c1 \ / \ d1 \ / \ e1 \ / \ f1 \ / \ g1 \ / \ h1 \ / \ i8 \ / \ j1 \ / \ k2 \ / \ l2 \ / \ m2 \ / \ n2 \ / \ o2 \ / \\ p0,6 \ / \ q0.75-1 \ / \ r1.5-1.8 \ / \ s0 \ / \ t1 \ / \ u1.\\ Small \ triangle \ long \ striations.\\ 13. \ AMPH \ 109P, \ 325-328 \ cm, \ S1.B, \ N32/1, \ type \ specimen.\\ 14. \ MSN \ 135P, \ 70-73 \ cm, \ S1.B, \ N53/4.\\ \end{array}$
Figures 15, 16	a9 / b1 / c9,13 / d1 / e1 / f4+(6,7) / g1 / h4 / i2 / j2 / k7,8 / l0.2-0.6 / m1.6-2.8 / n2 / o1,2 / p1 + a9 / b5 / c8,12 / d1 / e1 / f1 / g1 / h1 / i2+4 / j1 / k2 / l2 / m2 / n2 / o9 / p3,8 / q0.2-0.6 / r1.6-2.8 / s0 / t1 / u1. Triangle with base angle. 15. 15-6-3, 44-50 cm, S1.2, E35/1. 16. LSDH 96P, 400-411 cm, S1.4, J44/2, type specimen.
Figures 17, 18	a9 / b1 / c1 / d1 / e1 / f1 / g1 / h3,4,5 / i3 / j3 / k8 / l0.2-0.8 / m<1 / n4-8 / o1 / p3. Wide triangle. 17. MSN 135P, 702-705 cm, S1.A, E55/1, type specimen. 18. 65.1-3, CC, S1.20, F29/0.
Figures 19-21	a9 b1 c1,15,(15+17) d1 e1,2 f1 g3 h5 i6,10 j3 k8 l0.1-0.3 $m>2$ n2 o1 p1,2 + a9 b5 c1 d1 e1,2 f1 g1 h1,2 i1 j4 k2 l2 m4,6 n3 o2,4 p2,3 q0 r0 $s>2$ t2 u1. Stippled triangle. 19. DODO 37P, 356-370 cm, S1.2, M44/2. 20. MSN 135P, 70-73 cm, S1.B, M33/4. 21. Same sample, S1.A, X29/2.
Figure 22	Undescribed form, 42-1-4, 50-56 cm, S1.1, K36/2.

PLATE 1



PLATE 2

	All figures are magnified $110 \times$.
Figure 1	Undescribed form. 311-2-2, 140-142 cm, S1.3, T23/4.
Figure 2	$a9 / b6 / c \ge 4 / d4 / e0.$ Large triangle saw-toothed margin. PROA 103P, 300-320 cm, S1.5, G23/4.
Figure 3	Undescribed form. MSN 7P, 850-860 cm, S1.16, K18/3.
Figures 4, 5	a9 / b1 / c15,17 / d15,17 / e1,2 / f1 / g1 / h5 / i2,3 / j2,3 / k9 / l0.25-0.5 / m0.5-1.4 / n1 / o1 / p1. Small triangle crenate margin. 4. MSN 7P, 850-860 cm, S1.6, M18/0, type specimen. 5. 65.1-3-CC, S1.17, R34/0.
Figures 6, 7	Undescribed forms. 6. MSN 7P, 850-860 cm, S1.19, W18/2. 7. 311-2-2, 40-42 cm, S1.3, J18/4.
Ass	semblage from 307-1-CC (Figures 8-20)
Figures 8-10	 Undescribed forms. 8. S1.4 P33/2. 9. S1.5, F24/1. A form similar to Doyle et al., 1974, pl. 5, fig. 7. 10. S1.5, H18/0.
Figure 11	a7 / b6 / c2; Asymmetrical two peaks depression, Doyle et al., 1974. S1.2, P41/2.
Figure 12	a5,6 / b3 / c1 / d3 / e1. Small circular center, Doyle et al., 1974. S1.3, U35/1.
Figure 13	Undescribed form. S1.1, R25/0.
Figure 14	$a9 / b1 / c1 / d1 / e1 / f1,3 / g1 / h5 / i9 / j9 / k8 / l0.75-0.95 / m \ge 2.75 / n2 / o1 / p2 a9 / b5 / c1 / d2 / e1 / f1 / g1 / h1 / i1 / j1 / k9 / l9 / m1,4 / n1,3 / o9 / p3 / q0.75-0.95 / r \ge 2.75 / s0 / t2 / u1. Triangle sigmoid. S1.1, T24/0.$
Figures 15, 16	Undescribed forms. 15. S1.1, U21/0. 16. S1.1, M19/0.
Figure 17	a9 / b1 / c6 / d1 / e1 / f1,5 / g1 / h1,3 / i2 / j2,6 / k2 / $l>0.25 / m<1.4 / n1 / o1 / p1,2.Triangle broad wing, Doyle et al., 1974.S1.3, P40/0.$
Figure 18	a9 / b1 / c1 / d1 / e1 / f1 / g1 / h1,2,3 / i2,3 / j2,3 / k2 / l0.25-0.45 / m1-1.5 / n4,5 / o1 / p3. Wide triangle straight inbase, Doyle et al., 1974. S1.2, D32/3.
Figures 19, 20	 Undescribed forms. 19. S1.2, N15/1. A form similar to Doyle et al., 1974, pl. 5, figs. 18, 24, 25, seen also in Late Cretaceous assemblages from the Caribbean (DSDP Leg 15). 20. S1.1, L41/2.

ICHTHYOLITHS

PLATE 2

































