

PALEOGENE ICHTHYOLITHS FROM THE SUBSTRATES OF FERROMANGANESE ENCRUSTATIONS AND NUCLEI OF THE MANGANESE NODULES FROM THE CENTRAL INDIAN OCEAN BASIN.

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ABSTRACT.

Ichthyoliths, the phosphatic microscopic skeletal debris of the fishes are found in the substrates and the nuclei of ferromanganese encrustations and the nodules, collected from the Central Indian Ocean Basin. About thirty subtypes of the ichthyoliths are identified and described in the coded descriptive system for the Ichthyoliths (Doyle and Riedel, 1979 a), followed by a brief description in words. The detailed study is in progress, but a tentative paleogene age can be assigned to the material studied.

INTRODUCTION

The Ichthyoliths are well studied microfossil group in various Deep Sea Drilling Project sites from the world oceans. Recent works of Dunsworth, Doyle and Riedel 1975; Edgerton, Doyle and Riedel 1977; Kaneps, Doyle and Riedel 1984 a, b, Doyle and Riedel 1985a, b have established biostratigraphic ranges of the Ichthyolith subtypes, which can be used for correlation of otherwise microfossiliferous tertiary sediments.

The ferromanganese encrustations and the nodules collected during various cruises for the survey of polymetallic nodules in the Central India Ocean Basin [fig. 1, table 1], when searched for the microfossil, yielded good number of ichthyoliths, the only microfossils in the nuclei of the encrustations and nodules. These nuclei are made up of burrowed and bored pelagic clays. The

present paper reports, the presence of the Ichthyoliths in the nuclei and substrates of ferromanganese nodules and encrustations and their geological age range.

MATERIAL AND METHOD.

The nuclei of the ferromanganese encrustations and nodules are chiefly of two kinds; either altered basalts or pelagic claystones and clayclasts. These clayclasts are the fragments of burrowed and bored hard grounds, with only phosphatic micro-fossils, the ichthyoliths. The nuclei were broken in to small pieces 0.5 cm., and tried for normal maceration procedure like dispersing in Sodium hexa meta phosphate and boiling in H₂O₂ for two hours. The material was sieved on 62 μ mesh and resulted in fragmentary fish micro-remains, which were picked by the brush and put on the glass slide and mounted in canada balsam. These fish micro-remains are studied under transmitted light microscope and are illustrated on x 63 magnification.

SYSTEMATIC DESCRIPTION

Ichthyoliths are recognised by decoding the coded descriptive system for the Ichthyoliths given by Doyle, Kennedy and Riedel 1974; Ramsey, Doyle and Riedel 1976; Doyle and Riedel 1979a, 1980, 1985a; Gottfried, Doyle and Riedel 1984 a and Tway, Doyle and Riedel 1985. These are described in the same system in the present work. For details of the coded descriptive system readers are requested to consult Doyle and Riedel 1979, and subsequent literature.

The following Ichthyolith subtypes are identified and described in coded as well as with a brief description of their characteristics and stratigraphic range.

Ichthyolith Subtypes.

Flexed triangle 115-118 DOYLE et al. 1979
(Plate II—10)

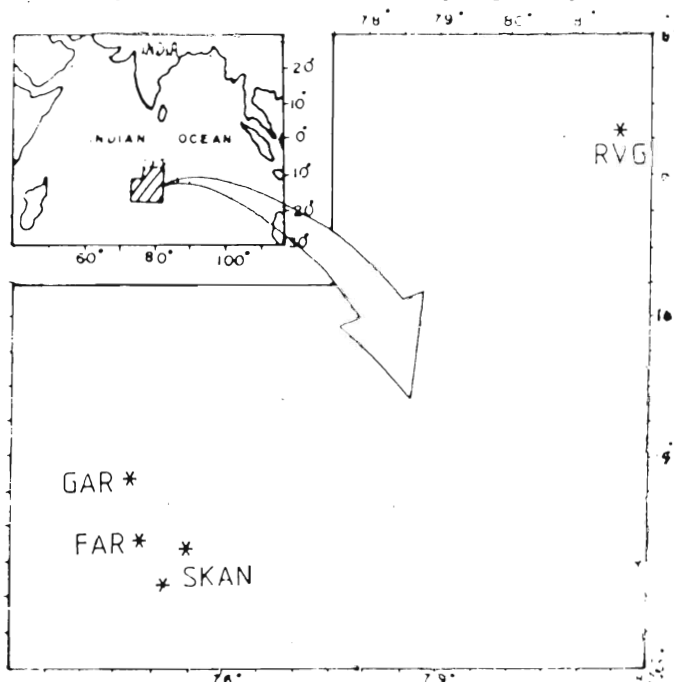


Fig 1. Location in the Central Indian Basin

a8/b1,5/c1/d1/e115-118/f26-36, Gottfried et al, 1984, pl.2, fig. 10.

Description: Triangular form with one margin having a prominent angular flexure and a transverse line. Base of inline or transverse line is at the same level as termination of the first flexure. Flexure angle 115-118. Apical angle 25-35.

Range: Late Oligocene-Quaternary

Triangle curved base. DOYLE et al. 1978.
(Plate II — 2)

a9/b1,5/c1/d1/e1,2/f4/g1/ho-5/12,3/J2,3/K3,7/mo.50-o.70/jo.50-0.70/nl.50-2.30/p1. 50-2.50/q0, 6,7/r0,1,3,4/s1/t1/z4/cc1/dd1/ee1/ff1/gg1/hho/jj1,2/kk1,2/mm1.0-1.5/nno. Gottfried et al, 1984b, pl. 2, fig. 3

Description: Triangular form with transverse line, lateral shadow between the inline and outline and straight margins. Inline is similar to outline with both the sides bowed in. Length/Width (hereafter; L/W) 1.5-2.30. Apex is sharp.

Range: Paleocene-Eocene.

Triangle pointed margin ends. DOYLE et al. 1974.
(Plate II — 14, 20)

a9/b1,5/c13/d13/e1/f4/g1/ho,5/i2/j2/k3,8/m/0.60/n2.00-3.00/p2.00-3.00/q0.30/r0, 3/s1,2/t4/z11/cc1/dd1/ee1/gg1/hh3.00/ii1/jj2/kk2/-mmo/nno. Gottfried et al. 1984b, pl.2, fig. 5

Description: Triangular form with prominent transverse line. Both margins have shallow simple angle at the bottom and lateral shadow are present. Margins are straight and bowed in. L/W 2.0-3.0. Both the bases between inline and outline are pointed. Apex is sharp.

Range: Late paleocene-Mid Miocene

Rectangular saw toothed. DOYLE et al. 1974. P, 845
(Plate II — 9)

a7/b1/c2/d3/e6. Gottfried et al. 1984b, pl. 2, fig. 6

Description: Outline is neither lanceolate nor triangular but rectangular. One edge acutely dentate, or undulating. Dentations are very close, broad, angular and regular in shape. Dendritic canals are present in dentations.

Range: Oligocene/Miocene-Quaternary.

Tanged triangle. GOTTFRIED et al, 1984a.
(Plate II — 19, 20)

a9/b1/c1/d1/e1/f4/g1/ho/i2/j2/k0,4.7/m0.55-1.00/n1.75-1.9/p0/q-10/r1/s1/t1. Gottfried et al. 1984b, pl. 2, fig. 2a,b

Description: Triangular form straight margins and a tanged base. Apex is sharp and pointed. L/W 1.75-1.9.

Range: Eocene to Oligocene/Miocene boundary.

Curved triangle pointed margins. DOYLE, et al
(Plate II — 7)

a9/b1,5/c1/d1/e1/f1,4.8/g1/ho,2,3,4,5/i2,6/j4/k4,8/m0.20-0.40/n1.0-2.0/p1.0-3.0/q0,2,3,4,5/r0,2/s1/t1/z11/cc1/dd1/ee1,2/ff1/gg n/hh1. 0-3.0/jj2/k2/mm0/nn0/nn0. Doyle et al. 1974, p.846, pl.1G, figs.3,4; p1.2j, fig. 1-3.

Description: Triangular form with one margin curved and sharply pointed, extending below the base of the inline. Curved margin has most of the curvature basally. Other margin is concave. Inline is parallel to the outline. L/W 1.00-2.00

Range: Upper Oligocene/Lr. Miocene-Quaternary.

Small triangle long striations. DUNSWORTH et al. 1975.
(Plate II — 12)

a9/b1,5/c1,13/d1/e1/f9,10 +13 +14/g1/h0,5/i2/j2/k0,3,5/m0.75-1.00/n1.1-2.40/p0/q2/r1/s1,t1/z2/cc1/dd1/ee1/ff1/gg1/hho/-jj4/kk3/mmo/nno. Dunsworth et al. p.857. pl.-1. fig. 13-14; emend. Kanepes et al, 1981.

Description: Triangular form with lateral shadow and characteristic subparallel striations extending into upper quarter of the tooth. Inline is either absent or lies at basal quarter with occasional, a shallow angle modifying the base of one margin. Apex is moderately pointed to blunt. L/W 1.3-2.0

Range: Oligocene/Miocene-Quaternary.

Narrow triangle cross hatchured DOYLE et al. 1974.
(Plate II — 6)

a9/b5/c1,4/d1/e1/f1,16,18/g1/h0/i2,7/j2/ko, 5, 8/mo/n>0.5/po/ qo/ ro/ s2/t1/z2/cc1,3/dd1/ee1/ff1/gg1/hh 3.00/jj2,4/kk2,3/mm1.70-4.50/nn0. Doyle et al, 1974, p.847, p1.2L, figs. 1-6.

Description: Narrow triangular form with straight or slightly curved transverse line, having a pattern of obliquely intersecting sets of lines, which varies from faint to sharp and clear in basal. In some cases a triangular projection in one margin may also be present. L/W 4.0-5.0

Range: Late Paleocene to Oligocene-Miocene boundary.

Triangle medium wing. (DOYLE et al.)
(Plate I — 2)

a9/b1/c6,7/d1/e1/f4+5/g1/h2,3,4,5/i2,3/j6/k8/m>0.40/n1.50-2.00/-p2.00-400/q1,9/r1/s1, 2/t1. Doyle et al, 1974. p.846. p1. 1KG, fig.6, p1.2J, fig. 8-10.

Description: Triangular form in which a shallow angle modifies one of the margin like a wing and the apex of the inline approaches in the upper 2/5th of the outline. L/W 1.5-2.0.

Range: Paleocene to Lr. Miocene?

Triangle short wing. DOYLE et al.
(Plate II — 13)

a9/b1/c5/d1/e1/f4+5/g1/h2,3,4,5/i2,3/j6/k8/m0.4/n1.5-2.0/p2.0-4.0/-q1,9/r1/s1,2/t1/ Doyle et al, 1974, p.846 Pl. 1G, fig. 5.

Description: Triangular form with shallow angle modifying one margin in the upper 1/5th of the margin. Apex of the inline is in the upper 2/5th of outline. L/W 1.5-2.0.

Range: Eocene-Early Miocene.

Triangle with triangular projection. (DOYLE et al)
(Plate I — 6, 9)

a9/b5/c1/d1/e1/f1.8/g1/ho/i2,7/ j2, 3/ko, 5,7//mo/n>1.00/-
po/qo/ro/s2/t1/z2/cc3/dd1/ee1/ff1/gg1/hh>3.00/jj2,4/kk3/mm1.-
40-4.50/nn0. Doyle *et al.*, 1974, p.887, pl.1H, fig. 16-19, pl.2k, fig. 17-21

Description: Narrow curved sharply pointed form with one triangular projection below a straight transverse line. Size of projection and it's location on the margin varies. Some time faint vertical/diagonal striations are present.
L/W 2.8-3 3.5

Range: Paleocene-Lr. Miocene.

Large fibrous triangle. TWAY *et al.*
(Plate I—18)

a9/b1/c1/d1/e1/f1/g4/h2,3,4/i2, 7,8/j2/k4,9/m0. 23-0.50/n1.-
67-2.36/p1.67-2.36/q9, 10/r1/s2/t1/zo. Tway *et al.*
1985, p. 308, pl.4, fig. 3a-d.

Description: Triangular form with prominent transverse line and branching canals within inline. Margins are straight. L/W 1.00-1.5. Apex is sharp and blunt. Transverse line is curved or straighter. Branching canals are within the inline.

Range: Eocene CP-13 to Oligocene CN-15

Triangle one canal above DOYLE *et al.*
(Plate I—12)

a9/b5/c1/d1/e1,2/f1,4/g1/ho/i2/j2/k7/m0.3-0.6/nl.0-1.8/P1.
3-2.3/q0/r0/s1/t1/z4/cc1/dd1/ee2/ff1/gg1/ho/jj2/kk2/mm1.2-1.8/nn0.
Doyle *et al.* 1974, p. 848, pl. II, fig. 15.

Description: Triangular form with prominent transverse line, straight margins and no branching canals within inline. Lateral shadow between inline and outline are present. Inline is markedly narrower than the outline. L/W 1.00-2.00. Apex is sharp and blunt. Branching canals are within the inline, well below the transverse line.

Range: Eocene-Mid Eocene

Narrow triangle sharply pointed. RAMSEY *et al.*
(Plate I—10)

a9/b1/c1/d1/e1/f8/g4/h2,3,4,5/i2,6/j2,3/k9/mo/n4.3-5.3/p0/-
q19/r1/s2/t1. Ramsey *et al.* 1976, p. 130, pl.2, fig.3-5

Description: Narrow triangular form without prominent transverse line. Longitudinal striations between inline and outline. Margins are straight. Inline is lower and same as outline and approaches to outline near the base. L/W 4.3-5.3.

Range: Jurassic-Oligocene.

Curved fibrous triangle. TWAY *et al.*
(Plate I—1, 13)

a9/b1/c14/d1/el/g4/h3,4,5/i2,3,4/j2,6,10/k5,8/mo/nl.20-1.80/po/q9,-
10/r1/s2/t1/zo. Tway *et al.*, 1985, p. 310, pl.5, fig. 4a-d.

Description: Large triangular form with pointed apex and terminal part of the first margin curved to form a hook. First margin is straight to convex and second straighter to concave. Inline is arcuate or similar to shape of outline.. Nature of tooth is fibrous. Base of the inline is irregularly jagged.

Range: Mid Eocene - Early Miocene.

Long triangle thin walls. (DUNSWORTH *et al.*)
(Plate I—10)

a9/ b5/c1/d1/e1/f1/g1/h0/i2,6/j2,3/k0,6,8/m0/n1.5-2.5/po/qo/-
ro/s2/t1/z2/ccl/dd1/ee1/ff3/gg1/hh 4.00/jj1,2,4/kk1,2,3/mm0/nn0.-
Dunsworth *et al.*, 1975, p.857, pl.1, figs 9, 10.

Description: Triangular form with prominent transverse line. Margins are straight. Inline absent and if present, similar to outline. Both sides of inline are constricted.

Range: Eocene-Lr. Miocene.

Prominence with wve line. DOYLE *et al.*
(Plate I—7)

a3.4/b1/cl,2,3/d3 [5+31]/e2/f2/gl+4+8/h2. Doyle *et al.* 1978, p.1.1, fig.1,4
Description: Polygonal to lanceolate form like a kite. A Y shaped fork at the end opposite the acute prominence and irregular network of lines. Legnth of acute prominence is greater than the base. Margins are smooth continuous to the sides of acute prominence or irregularly undulating or broken and sides of acute prominence are pronouncedly concave.

Range: Paleocene. [CP-16]

Fibrous triangle convex margins. TWAY *et al.*
(Plate I—5, 8)

a9/b1/c14/d1/e1/f4/g4/h3/i3/j3,4/k5/mo/nl.6-1.5/po/q9/r1/s1,2/t1/zo.-
Tway *et al.* 1985, p.310, pl.5, figs. 3a-d.

Description: Large fibrous triangular form with sharp apex. First margin is convex and terminal part curved upward to form hook. Inline is arcuate. Base of inline is irregularly jagged. L/W 1.16-1.5.

Range: Early Eocene [CP-11]—Late Miocene [CN-9]

Narrow triangle straight in base. (DOYLE *et al.*)
(Plate II—4)

a9/b1/c1/d1/e1/f1,4/g1/h2,3,4,5/i2,8/j2,4/k8/mo.2-0.4/n1.6-2.0/-
P1.5.3.0/q4,5,r1/s1,3/t1. Doyle *et al.*, 1974, p.846, pl.1F, figs. 4-6.

Description: Triangular form without transverse line. Margins are straight and their length is variable. Inline is same as the outline. L/W 1.6-2.0. Base within inline is an approximately straight line. Bases are smoothly rounded straight or curved inward. Apex is sharp and blunt.

Range: Paleocene-Quaternary.

Three peaks transverse lines. TWAY *et al.*
(Plate I—11)

a2/b2/c3/d1.00-1.40/el/f3/g1,2/h3/i1/j2+3/k2. Tway *et al.*, 1985, p.-
301, pl.1, fig. la-d.

Description: Lanceolate form with three sharp peaks and three parallel to subparallel lines. Median peak is larger than 1/3 time length of lateral peaks. Depression between the peaks are u/v shape. End opposite to peak end is undulating. L/W 1.00-138.

Range: Middle Miocene CN-71 to Quaternary.

Plain and lined lanceolate. DOYLE *et al.*
(Plate I—4)

a4/b1,2/c2/d1,2,4/.e2/f{2+3}/g1+2/h1/ Doyle *et al.* 1978, p.1.1, fig. 12-15

Description : Lanceolate form with parallel to subparallel lines within the outline. Hight of acute prominence is greater than the length of bases. Margins are smooth and continuous.

Range : Turonian (Cretaceous) — Mid Eocen

Narrow triangle ragged base. (DUNSWORTH *et al.*)
(Plate II—15)

a9/b1/c1/d1/e1/f1g1h3,4,5/j3,5/k9/mo.2-0.7/n>4.0/p>4.0/q9/r1/sl,3/t1. Dunsworth *et al.* 1975, p.1.1, fig.7,8.

Description : Very narrow tooth with concavely curved first margin shorter than the convexly curved second margin. Inline is approximately same as the outline but closely approaches the margin at the base. Base is broken and apex varies from blunt to pointed.

Range: Early Miocene/pliocene - Quaternary.

Flexed triangle asymmetric. DOYLE & RIEDELL.
(Plate II—8)

a8/b1,5/c1/d1/eo/f23-38/g2/h2. Doyle and Riedel, 1985, p. 357, p.1.1 fig. 1-5.

Description : Trinangular form with one margin modified by a prominent flexure. Flexure is sharply angled and the other near the base is smoothly curved. Base or transverse line is curved or a straighter line, terminating at margin at different levels. L/W 3.0.0

Range: Paleocene.

Triangle with base angle. (DUNSWORTH *et al.*)
(Plate II—17)

a9/b1,5/c9,13/d1/el/f4+8/g1/h0,4/i2/j2/k7,8/mo.2-0.6/nl.6-2.8/po/qo,2/-ro,1,2/s1/t1/z9/cc1/dd1/ee1/ff1/gg1/hho/j2/kk2/mmo/nno/.Dunswroth *et-al.* 1975,p.857,p.1.,fig.15,16.

Description : Triangular form with transverse line Straight margins are of unequal in length. Inline is same as the outline. Apex is sharp and blunt. Transverse line is simply curved, terminating at the margin at different level. L/W 1.6-2.2.8.

Range: Late Eocene Quaternary.

Triangle curved margin ends. (DOYLE & RIEDEL)
(Plate II—11)

a9/b1, 5/c1/d1/e1/f4+(1, 161/g1/ho, 5/i4/j4 k3, 8/m0.5-0.75/n l.6 1.8/p2.2-2.8/q0, 3,6/r0,4/sl,2/t1/z4/cc0/dd0 /ee0/ ff0/ gg0/ hh0/ jj2/k2/mm0/nn0. Doyle and Riedel, 1985, p. 359, pl. 3, figs 5.12.

Description: Triangular form with both margins basally curved and extended below base of inline. Inline is same as the outline, with sides bowed in. Base of inline smooth straight to curved line. Lateral shadows are present. L/W 1.6-1.8.

Range: Paleocene—Early Eocene.

Triangle double flex. DUNSWORTH, *et al.*
(Plate II—5)

a8/b1/c2/d2,3/e60-200/f20-35. Dunsworth *et-al.* 1975, emend. Doyle *et-al.* 1979a, p.71, pl.3, fig. 16-17

Description: Triangular form with both margins having a prominent flexure. Base of the inline is above the termination of the flexures. Flexure angle. 60-200. Apical angle 20-35.

Range: Mid. Eocene—Mid Miocene.

Triangle transverse line across. (DOYLE *et al.*)
(Plate II—16)

a9/b1,5/c1/d1/e1,2/f4/g1/h0,5/i4/j1/k3,8/m0.2-0.4/n1.5-2.5/p1.5-2.6/q6,7.8/r4/s1/t1/z4/cc1/dd1/ee2/ff1/gg1/hho/jj1,2,3/kk1,2,3/mm0/nn0. Doyle *et al.* 1979 a,p. 109, p.1.5, fig. 7,8.

Description: Triangular form with curved transverse line and a basal part having canals. Margins are basally convex and inwardly curved. Lateral shadow is distinct. Apex of inline to apex of outline ratio is 0.2-0.4 and L/W 1.5-2.5. Inline is parallel to outline and bowed inwardly. Canals are present but are not discriminating feature.

Range: Paleocene (CP-2) t Mid. Miocene. (CN-10)

Triangle crenulate. (DOYLE *et at.*)
(Plate I—15)

a9/b1, 5/c17/d1,18/e1,2/f1,4.8/g1/ho,2,3,4/i2,6/j2,3/ k8/ mo.1-0.4/n1.0-2.0/p1.0-2.0/q0,2,3,4,5/r0.1/s1,3/t1/z5/cc0/dd0/ee1,2/ff0/gg1/hh0/ jj0/kk0/mm0/nn0. Doyle *et-al.* 1979, p.848. Pl. 1j, fig. 2,3; 1974, p.165, p.1.5, fig. 10-11.

Description: Triangular form with prominent transverse line and margins are modified by crenate, saw toothed pattern on it's lower half. Branching canals may present in some specimen. Relative length of margins may be variable. Inline is same as outline. Apex is sharp and blunt. Transverse line is curved or straight. L/W 1.0-2.0

Range: Late Oligocene—Pliocene.

CONCLUSION.

Substrates and nuclei of ferromanganese encrustations and nodules are made up of otherwise unfossiliferous pelagic clays of paleogene age. Detailed study is in progress to split the various encrustations and nodules into paleogene Epochs.

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EXPLANATION OF PLATE

PLATE I

- 1, 13. *Curved fibrous triangle*. Tway et al 1985.
2. *Triangle medium wing*. Doyle et al 1974.
3. *Long triangle thin wall*. (Dunsworth et al)
4. *Triangle with canals*. Doyle et al 1974.
- 5, 8. *Fibrous triangle convex margins*. Tway et al 1985.
- 6, 9. *Triangle with triangular projecton*. Doyle et al 1974.
7. *Prominence with wye line*. Doyle et al 1978.
10. *Narrow triangle sharply pointed*. Doyle et al 1974.
11. *Three peaks transverse line*. Tway et al 1985.
12. *Triangle one canal above*. Doyle et al 1974.
14. *Plain and lined lanceolate*. Doyle et al 1978.
15. *Triangle crenulate*. [Doyle et al 1974.]

PLATE II

1. *Triangle Pointed margin ends*. [Doyle et al]
2. *Triangle curved base*. Doyle and Riedel, 1985.
3. *Triangle asymmetric*
4. *Narrow triangle straight inbase*. Doyle et al

5. *Triangle double flex*. Doyle et al
6. *Narrow Triangle cross hachtered*. Doyle et al
7. *Curved triangle pointed margins*. [Doyle et al]
8. *Flexed triangle asymmetric*. Doyle & Riedel
9. *Rectangular Saw-tooth*. Doyle et al.
10. *Flexed narrow triangle*. Group
11. *Triangle curved margin ends*. [Doyle and Riedel]
12. *Small triangle long striations*. Doyle et al
13. *Triangle short wing*. Doyle et al
14. *Triangle Pointed margin ends*. [Doyle et al]
15. *Narrow Triangle ragged base*. Doyle et al
16. *Triangle transverse line across*. Doyle et al
17. *Triangle with base angle*. Dunsworth et al
18. *Large fibrous triangle*. Tway et al 1985
20. *Triangle Pointed margin ends*. Doyle et al
- 19, 21. *Tanged Triangle*. Gottfried et al.

