The morphology, ethology and palaeoecology of certain trace fossils from the Jurassic rocks of England

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Plate One

The North Sea coast of northeast Yorkshire south-southeast of Blea Wyke Point, showing the backshore from which many trace fossils described in the text were collected.

Photograph taken from the track which leads down the cliff from Ravenscar under the Coast-guard hut.

The feature at the top of the undercliff is made by the Ellerbeck Bed.
The North Sea coast at Cloughton Wyke, showing the limited "spray-zone" where trace fossils are well preserved, beneath which algae prohibit examination.

The cliff is formed of the higher Middle Deltaic Series.
Plate Two (B)

The "Spray-zone" immediately north of Cloughton Wyke, showing the abundance of fallen material in the form of large tabular blocks of ideal size for the application of the Quadrat technique.

The blocks with excellently developed parting lineation come from a persistent sandstone in the Middle Deltaic Series.
Plate Three

Vertical section of loose block of S.3.32, a sandy limestone from the Scarborough Beds of Ravenscar, showing almost 100% re-working by burrowing organisms, with the complete destruction of original bedding.
Two loose blocks of Lower Liassic
limestone Earl on the foreshore west
of Lyme Regis, showing diagenetically
enhanced preservation of the trace fossils
Thalassinoides, Corophioides lynensis,
Chonarites and Rhizocorallium.
Plate Five

Close-up of *Coropnioides lymensis* (right) and *Ruzocorallium jenense* (left) from the base of the Ellerbeck Bed beneath Staintondale, showing the preservation of delicate scratch markings on the walls of burrows impressed into very fine-grained kaolinitic silts of the Lower Deltaic Series. x 10
Plate Six

Recent colony of *Arenicola marina* in littoral mud, Sandsfoot, Dorset.

Note the varying preservation of the inhalent funnel due to differences in thixotropy.
Plate Seven

Recent trails of *Littorina littorea* preserved in littoral mud.

A. Close-up of typical trail made in mud with low thixotropy; notice the marked transverse ridges (HANTZSCHEL).

B. General view of trail showing the variable preservation of the transverse ridges, caused by thixotropic differences (HANTZSCHEL): scale = 10 cm.

C. General view of a set of parallel trails with very pronounced lateral ridges but poor transverse ridges, constructed under thin sheet of water (FARROW): pencil = 9 cm.
Plate Eleven

*Arenicolites skeltonensis* sp. nov. from basal Upper Lias, immediately above the Sulphur Band, North Skelton.

Top. Type specimen, showing the striking bed-junction preservation, associated *Chondrites*, and black burrow-lining. Note the burrow with the funnel penetrated by protrusive laminae to the right of the photograph.

Bottom. Specimen showing the highly polished burrow walls and the tube constrictions caused by resistant bands in the siderite mudstone.
Plate Ten

_Clypeolithus_ from the Middle Liassic Sandy Series

A. Preserved by bed-junction sedimentation,
   from a loose block north of Skinningrove.

B. Associated with _Curvolithus_ and _Entolium_,
   preserved by bed-junction sedimentation
   accentuated by baking from the Cleveland Dyke;
   from Cliff Rigg quarry, near Great Ayton.
Plate Nine

A. *Eione noniliformis* TATE G., a beaded trace fossil from the Namurian of Howick, Northumberland (type specimen)

B. Beaded trace fossil from Swath Beck Hush, Moor House National Nature Reserve, with sharp lateral ridges.

C. Related trace fossil from same locality lacking a beaded appearance and possessing pronounced lateral ridges.
Plate Eight

A. Close-up of typical beaded trail of the amphipod *Corophium volutator*, preserved in mud with low thixotropy.

B. General view of a set of Recent trails of *Corophium volutator*, showing unbeaded areas caused by subsequent thixotropic flow.
A. Close-up of a vertical section showing the "sagging" of the laminae on the inside of the 'U'.

Note the depressed laminae of the inhalent and the plugged tube of the exhalent limb of the burrow to the left.

B. Plan view of a horizontal section showing the slit-like cross-section of the burrows.
Plate Twelve

Oblique view of loose block of laminated sandstone (S.B.35) from the Scarborough Beds of Ravenscar, showing both vertical and horizontal aspects of *Arenicolites stattheri* BATLER.

Plate Thirteen

View of vertical face of sandstone, showing *Arenicolites stattheri* descending from the plane of a small unconformity.

Note the solid tube-casts in many of the burrows.

The hammer = 38 cm. in length.
Plate Fifteen

A. Calcareous gritstone dogger from the Bencliff Grits east of Osmington Mills showing slump structure associated with an immediately post-depositional fracture.

B. Calcareous gritstone dogger from the Bencliff Grits on the backslope just west of Reccliff Point, showing deeply eroded slots of Diplocraterion armelli sp. nov. Note the large size, and umbrella-shaped cross-section. x 0.15

C. Smaller examples of retrusive Diplocraterion armelli associated with sharp linguoid ripples. Note the smaller size, sausage-shaped cross-section, and lower density. x 0.06
Plate Sixteen

A.

Vertical section of *Diplocraterion arkelli* from Nothe Grits of Bowleaze Cove showing the strong *Spreite* and indistinct limbs. \(x \frac{1}{3}\)

B.  

C.

Horizontal section  
Vertical section  
showing ringed aperture  
across *Spreite* with 
and faecal pellets. \(x 1\)  
retrusive laminae. \(x 1\)
Plate Seventeen

Large loose block of sandy limestone (s. 3, 26) from the Scarborough Beds on the backshore at Iron scar, with retrusive Diplocraterion arkelli occurring in high densities.
Plate Eighteen (A)

Diplocraterion statheri sp. nov. from a large loose block of sideritic sandstone from the Dogger in Saltwick Bay, near Whitby; maximum burrow density recorded.
Plate Eighteen (3)

_Diplocraterion stattheri_ at intermediate density;

Old Nab, Saltwick Bay.
Diplocraterion statheri at low density;
beneath Whitby High Light.
Ironstone nodules from the base of the Ellerbeck bed with *Corophioides lymensis* (COYSH)

A. Associated with oblique *Rhizocorallium jenense* ZEMER and *Chondrites*.

B. Showing the delicate transverse striae, and the 'key-hole'-shaped crosssection.

In each specimen, notice the striking contrast with the white kaolinitic, soft, silts of the Lower Deltaic Series. x 4
Rhizocorallium (Corophicoides) jenense LONKERT; vertical crustacean burrows descending from the base of the Dogger into the Alum Shales in Long Rise, East Cliff, Whitby.

A. Vertical face showing the coarsely scratched spreite on the right, and slickensided shale with selenite crystals on the left.

B. Slickensiding along the burrow sides of basal 'U'

C. Basal 'U' of large burrow showing the very coarse scratches on limbs and spreite
Skolithos c.f. linearis MALLOMAE from Sec 6 of the Esminston Oolites, Black Head.

A. Burrows descending perpendicularly with respect to a cross-set of strata. To the left of the photograph, burrows with bed-junction preservation; to the right, above the hammer-head, concealed bed-junction preservation.

B. Close-up of vertical face of oolite, showing concealed bed-junction preservation.

C. Horizontal section through the burrows of B, showing their circular cross-section, and coarsely oolitic filling.
Plate Twenty-five

Close-up of *Thalassinoides suevicus* from the condensed Hambleton Colite Series of Filey Brigg. Notice the bleached nature of the burrows compared with the matrix, where serpulids and *Exogyra* are very abundant.

Near the fountain-pen (length= 13 cm.) one burrow may be seen cutting another. Normally they anastomose.
Plate Twenty-four

*Thalassinoides suevicus* preserved as white, horizontal Y-shaped burrows set in brown calcareous grit; loose block of Hambleton Oolite on Filey Brigg.
A. large *Thalassinoides suevicus* (QUEN.) from the *Trigonia hudlestoni* Bed, Redcliff Point, showing the dichotomous branching and peripheral furrows, where loosely compacted shelly matter has been removed by erosion.

Burrow width = 5 cm.

B. isolated burrow system of *Thalassinoides suevicus* in sandy limestone (S.B.28) from the Scarborough Beds; Cloughton Wyke (54/020951). Note the very regular dichotomy.

*Teichichnus* accounts for 90% of the ichnofauna.
Essentially horizontal hummocky masses of *Thalassinoides saxonicus* (GEIN.) from coarse calcareous grit (S.B.28) of the Scarborough Beds; loose block on the backshore south-southeast of Blea Wyke (45/993012).

Note the annelid-like axial core running through many of the burrows.
Plate Twenty-one

Ophiomorpha borneensis XEIJ from the Corallian

A. From the Bencliff Grit of Redcliff Point, showing the wart-like lining of the burrows.

B. From Bed 6 of the Osmington Colites of Black Head, showing the eroded lining, smooth core, and dichotomous branching.

C. From Bed 7b of the Osmington Colites of Black Head, showing the regular pits along the burrow margins.
Plate Twenty-six

Rhizocorallium cicatricosus (TATE & BLAKE) from the Main Seam of the Middle Lias Ironstone Series, Old Nab, southeast of Staithes (45/794187); bed 52 of HOWARTH (1955).

Notice the apparent absence of Spreite, the area being highly disturbed by Chondrites, and the lacerated limbs.

Specimen whitened with ammonium chloride.
Plate Twenty-five (1)

View of an Ellerbeck Bed ironstone nodule from beneath, showing the *spreite* of an oblique *Rhizocorallium jenense* ZEMER, and many 'key-hole' cross-sections of *Corophioides lynensis* (CCYSH)

Notice the starting bed-junction preservation, and the great detail of the *spreiten* sculpture.
Plate Twenty-seven

A.

Rhizocorallium cicatricosus
showing U-shaped vertex and absence of Spreite.
Locality as in Pl.26

C.

Rhizocorallium cicatricosus,
showing very long flexuous burrow and thick limbs.
Loc. as in Pl.26

3.

Small initial section of
Rhizocorallium commune SCHMIDT
associated with Taenidium,
Chondrites, serpulid colonies
and pinna (vertical); grey beds
(Seds 80 of DEAN 1954); Peak.
Plate Thirty

Polished sections of *Rhizocorallium cicatricosus*.

A. Vertical transverse section showing the siderite-plugged limbs which appear mottled with faecal pellets.

B. Horizontal longitudinal section showing irregularly ellipsoidal faecal matter (in the top limb) and Chondrites in the lower two limbs.

Locality as in Plate 26
Plate Twenty-eight

*Rhizocorallium cicatricosus* with 'kink' in the return limb caused by a vertical obstruction.

Locality as in Plate 26 \( x \frac{1}{2} \)
Plate Thirty-one

Succession of burrows of *Rhizocorallium commune* from argillaceous limestone with symmetrical ripple-marks (*wavelength = 3½ *")*; Scarborough Beds (S.B.32) beneath Ravenscar.

Note the different ethological patterns of successive burrows.

(See also Text-figure 29)
Plate Thirty-two

Terminal 'kinking' of *Rhizocorallium commune* from silty limestone (S.B.32) of the Bajocian Scarborough Beds beneath Ravenscar, showing scratch markings within the area of the Spreite and sets of diamond-shaped claw impressions.

Notice the pod-like *Pelecypodichnus* SEILACHER within the Spreite. x 1
The Recent stomatopod crustacean *Squilla serrata*, one of the few organisms known to produce *Rhizocorallium*-like structures at the present-day.

Note the six-pointed sub-chelae. $\times 1\frac{1}{2}$
Plate Thirty-four

A. Typical orthodox *Rhizocorallium commun* from silty limestone (S.3.32) of the Scarborough Beds from beneath Ravenscar showing the narrow, lacerated limbs; poorly developed *Spreite*; and remarkably constant gauge.

B. Slightly oblique vertical transverse section of *Rhizocorallium* (probably *R. cicatricosus*) from the Middle Band of the Main Seam of the Ironstone Series at North Skelton Mine, showing the siderite-plugged limbs and well-developed *Spreite* filled with opaline ooliths.

The matrix is dominantly siderite mudstone highly burrowed by *Chondrites*.

N.3. The object just beneath, and to the left of the *Spreite*, is an ammonite chamber.
Asterosoma fosteri sp. nov. from the Dogger of Loop Wyke, northwest of Whitby.

A. Plan view showing the radiating lobes

B. Side view showing the strongly raised centre and the flat lobe profile.
Plate Thirty-six

A. Radially incomplete Radially complete
   Asterosoma c.f. radiciforme example, distinctly
   from sandy limestone (S.3.32) ovoid in outline
   beneath Ravenscar x 3

B. Beneath Beast Cliff.

C. Oblique view of Asterosoma multilobatum sp. nov. from
   sandy limestone (S.3.28);
   Cloughton Wyke (54/993012).
   Note the large number of lobes in very high relief.
Chondrites from the upper block of the main Seal at Old Nab, southeast of Staithes (45/794187).

Bed 54 of MOWARTH (1955) x 6
A. Pinnate branching of *Chondrites* in very coarse conglomeratic Middle Lias sandstone from Chideock, Dorset; associated by "*Cylindrites*". Note the occurrence of the *Chlamys* shell. x 1

B. *Chondrites* within the shell of a decalcified bivalve from the Blea Wyke Beds of Peak. x 5
Chondrites from coarse grey siltstone of Ironstone Series (Bed 41 of JCUMBA 1955); Hawsker Bottoms (45/952076); showing tunnel systems of two sizes. Note the constriction in tube diameter at the point of branching in the larger system. x 5
Plate Forty

**Teichichnus** from fine-grained sandy limestone (s.3.32) beneath Beast Cliff, Ravenscar.

A. Example with 5 cm. vertical development and horizontal translation; and no translation.

B. Example with 3 cm. vertical development.

C. Recent trace of *Nereis*, caused by the lateral migration of several dwelling tubes (*SCHÄFER*).

D. T-shaped apparent intersection of two *Teichichnus*.

Locality as in A) and B)
a. *Teichicinus* associated with general spiral disturbance of surrounding sediment.

b. Oblique *Teichicinus* associated with horizontal *Gyrochorte c.f. comosa* HEER.

Locality and horizon as Plate 40a.
Plate Forty-two

*Planolites ophthalmoides* JESSEN from loose block of grey, fine-grained deltaic sandstone with rib-and-furrow structure; beneath Ravenscar.
Plate Forty-three

A. Loose block of cross-laminated sandstone (\emph{? Lower Deltaic Series}) beneath Ravenscar, with aggregations of faecal pellets.

B. Close-up of the faecal pellets. Notice the impressions of many smaller pellets which have been removed by erosion.
Plate Forty-four

Recent crab pellets in two sizes (kREJGI-GRHR) from tropical shores around Hong Kong.
Larger pellets identical in size to those illustrated on Plate 43.
Plate Forty-five

Two loose blocks of deltaic sandstone with *Gyrochorte carbonaria* SCHLEICHER and the pod-like *Pelecypodichnus* SEILACHER.
The Namurian trace fossil *Crossopodia embletonia* TATE G. from Northumberland, an example of the Pascichnia, which are completely absent from the Jurassic.
Plate Forty-six

Sandstone with symmetrical ripple-marks (S.3.35) from the Scarborough Beds below Ravenscar showing randomly oriented Gyrochorte carbonaria.
Plate Forty-seven

Gyrochorte carbonaria SCHLEICHER

A. Examples from the Ellerbeck Bed of Goathland trending parallel to the crests of symmetrical ripple-marks.

B. Examples from laminated siltstones with parting lineation from the Namurian of Haltwhistle Burn, Northumberland showing the pronounced orientation of the trails.
C. U-shaped *Gyrochorte carbonaria* oriented at right-angles to the parting lineation.

D. Two U-turns developed in adjacent trails; oriented at right-angles to parting lineation.

Both examples from the Carboniferous of Haltwhistle
Two broad U-turns developed by adjacent *Gyrochorte* trails in ripple-marked sandstone from the Ellerbeck Bed of Goathland.
Plate Fifty-one

Hundale Point seen from the cliffs above Cloughton Wyke.

The scar is formed by the thick sandstone above which occur the Scarborough Beds.
Plate Fifty

Trough cross-lamination in the basal sandstone of the Scarborough Beds (S.3.36); in situ at 45/990010.

The notebook is 16 cm. in length.
The outcrop of the Scarborough Beds in the cliffs to the southeast of Blea Wyke Point (45/990010) showing the sphaeroidal weathering of the coarse calcareous grit member (S.W.28) on which the hammer rests, the sandstones at the top of the succession, and the impure limestones, in the foreground. The gently sloping part of the cliff is formed by the thick shale member (S.B.27).
Plate fifty-three

A. Bowleaze Cove; cliffs west of Redcliff Point; showing prominent feature made by the large tabular blocks of the *Trigonia hudlestoni* Bed.

B. Bed 7b of the Csnington Oolite, Black Head; showing "churned" limestone overlain by massive oolite. The horizontal hollows are cross-sections of *Ophiomorpha borneensis*. In situ photograph.
Plate Fifty-two

Mixed trace-fossil assemblage in sandy limestone from the Scarborough Beds at Iron Scar; dominated by *Teichichnus*, but with ferruginous *Thalassinoides suevicus* and *Rhizocorallium commune*.

Pencil = 12 cm. in length
APPENDIX IV : MEASURED SECTION OF STRATA THROUGH THE BAJOCIAN SCARBOROUGH BEDS 1/2 MILE SOUTHEAST OF RAVENSCAR STATION

2'10"
9"
3/4"
4" 
2"
6-9"
8"
1'1"
3-5"
6"
3/4"
4"
3/4"
6"
2-3"
8"
3/4"
4-7"
3/4"
4"
3-5"
7-10"
6-8"
51' 0"
4"0"
2' 4"
2' 0"
3' 5"
2' 2"
1' 0"
2' 0"
2' 2"
10' 6"
9"
2' 1"
5' 7"
4' 8"

Astarte minima, Melagrinella lyceottii, Catinula sp.; rare
Chlamys common; Pleuronyx casts; Modiolus; gastropods indet. rare
Chlamys rare; Catinula rare-common
Peleuronyx casts, Catinula common
Catinula, M. lyceottii, Pterocardiella rare
Catinula, M. lyceottii, Pleuronyx casts very common

M. lyceottii, Lima rare
Monotypic M. lyceottii very common

Chlamys common; Catinula, M. lyceottii rare
See TABLE 15 for details
Rhisocorallium commune; no shelly fossils
Gervillella acarburgensis, Camptonectes lenta, M. lyceottii, belemnites
Gervillella, Isognomon very common; gregarious

Astarte, Pteroperna very common
Asteroidea c.f. radiiforme, Teichichnus; shelly fossils very rare
Gervillella very common

Catinula, Pleuronyx casts, M. lyceottii along local erosion planes
Catinula rare
Fig. 1. The Jurassic Succession in the vicinity of Robin Hood's Bay, Yorkshire, showing the cyclic repetition of extensively burrowed strata; the most abundant genera at each horizon are shown on the right. (Compiled mainly from Arkell, 1933; Fox-Strangways, 1892; Tate and Blake, 1876; emendations and additions from Hemingway, 1949; Hemingway et al., 1963; Dean, 1954; Howarth, 1955, 1962; Wilson, 1949; and the author.)
Fig. 1. Detailed stratigraphy of the coastal escarpment of the Scarborough Bay showing the lateral variation in the sedimentology and fauna of the area from Blea Wyke Point to Grinstead Bay.