The faunal phases and palaeoecology of ostracod-mussel bands in the coal measures of the north and England

Pollard, John Ernest

THE FAUNAL PHASES AND PALAEOECOLOGY OF OSTRACOD-MUSSEL BANDS IN THE COAL MEASURES OF THE NORTH OF ENGLAND

by

John Ernest Pollard, M.A., F.G.S.

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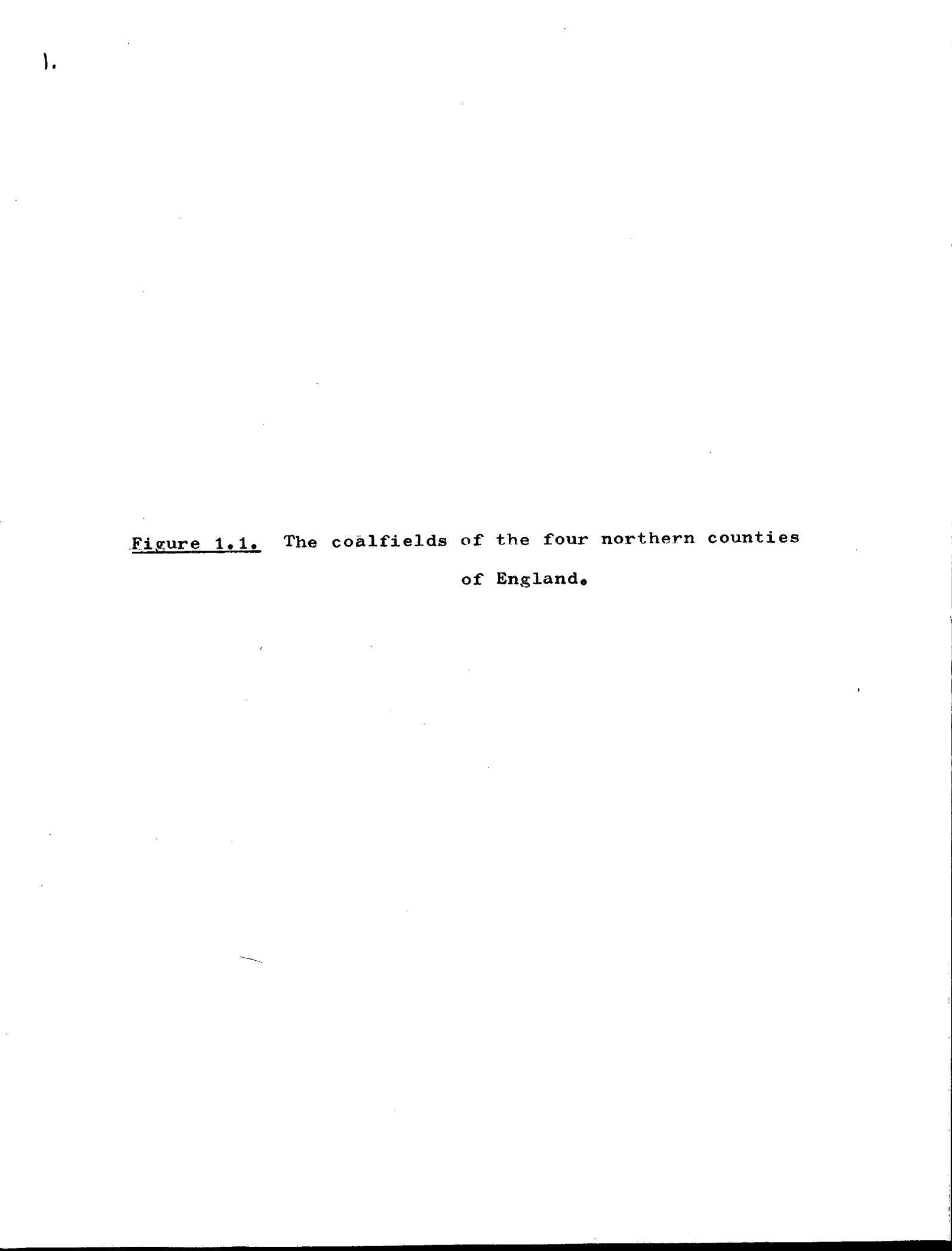


Figure 1.1. The coalfields of the four northern counties of England.

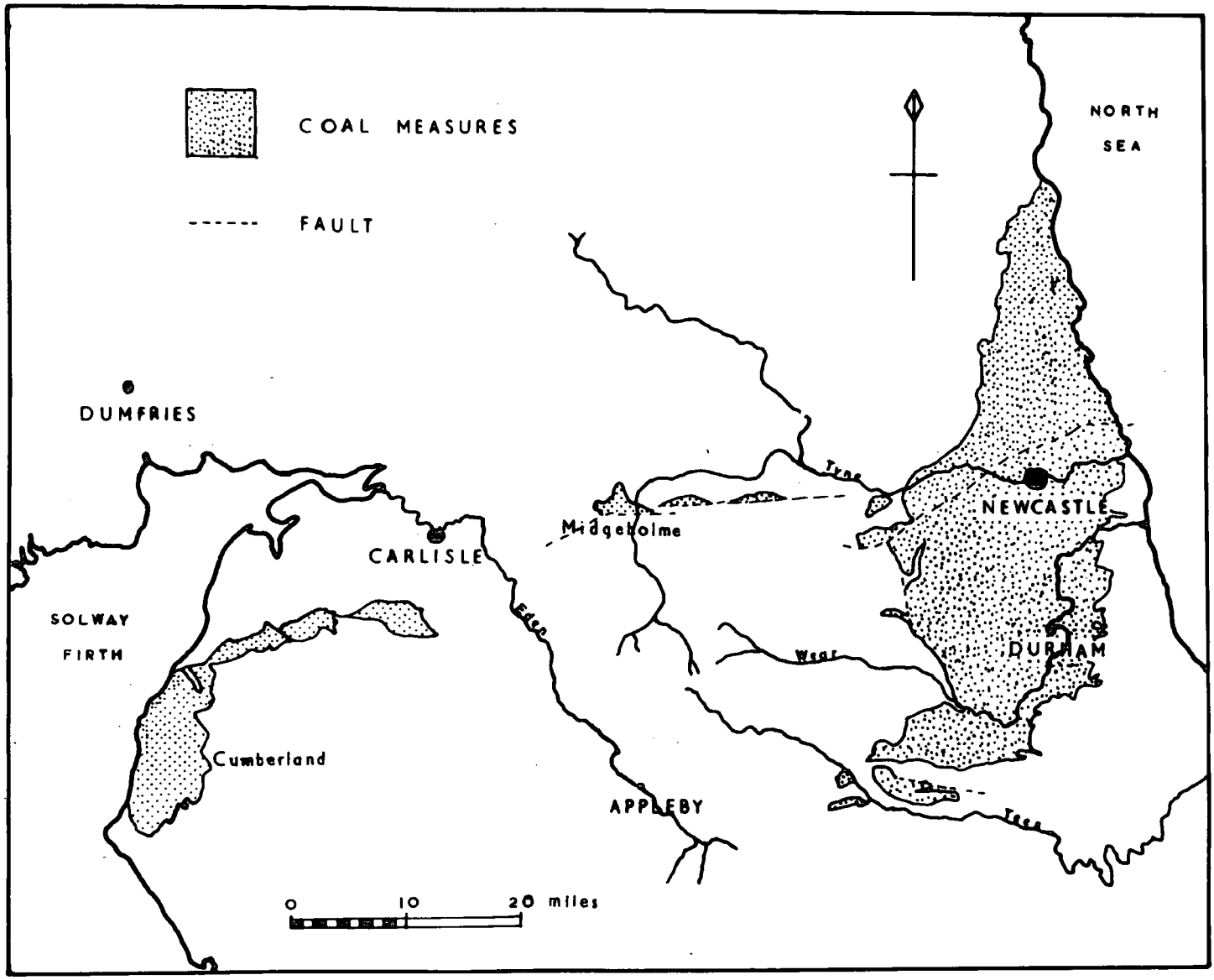

COAL MEASURES
FAULT
NORTH SEA
DUMFRIES
CARLISLE
SOLWAY FIRTH
Cumberland
Midgeholme
Tyne
NEWCASTLE
Eden
Wear
DURHAM
APPLEBY
Tees
0 10 20 miles

Figure 1.2. A generalised sequence of the Durham Coal Measures

DURHAM

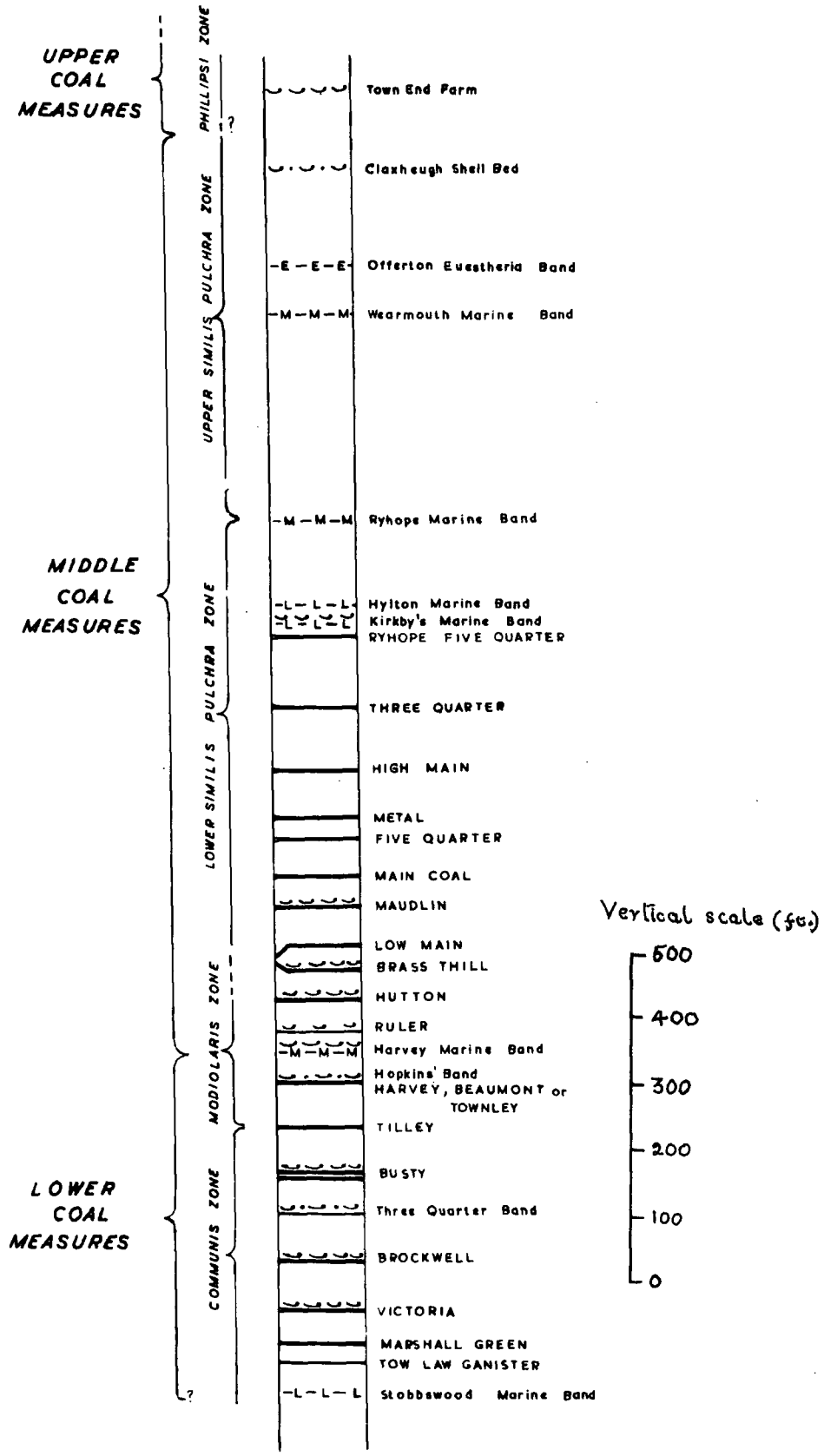

UPPER COAL MEASURES
MIDDLE COAL MEASURES
LOWER COAL MEASURES
PHILLIPSI ZONE
UPPER SIMILIS PULCHRA ZONE
LOWER SIMILIS PULCHRA ZONE
MODIOLARIS ZONE
COMMUNIS ZONE
Town End Farm
Claxheugh Shell Bed
Offerton Euestheria Band
Wearmouth Marine Band
Ryhope Marine Band
Hylton Marine Band
Kirkby's Marine Band
RYHOPE FIVE QUARTER
THREE QUARTER
HIGH MAIN
METAL
FIVE QUARTER
MAIN COAL
MAUDLIN
LOW MAIN
BRASS THILL
HUTTON
RULER
Harvey Marine Band
Hopkins' Band
HARVEY, BEAUMONT or TOWNLEY
TILLEY
BUSTY
Three Quarter Band
BROCKWELL
VICTORIA
MARSHALL GREEN
TOW LAW GANISTER
Stobbswood Marine Band
Vertical scale (ft.)
500
400
300
200
100
0

Figure 1.3. Comparative generalised sections of the coalfields of Cumberland, Midgeholme and Durham.

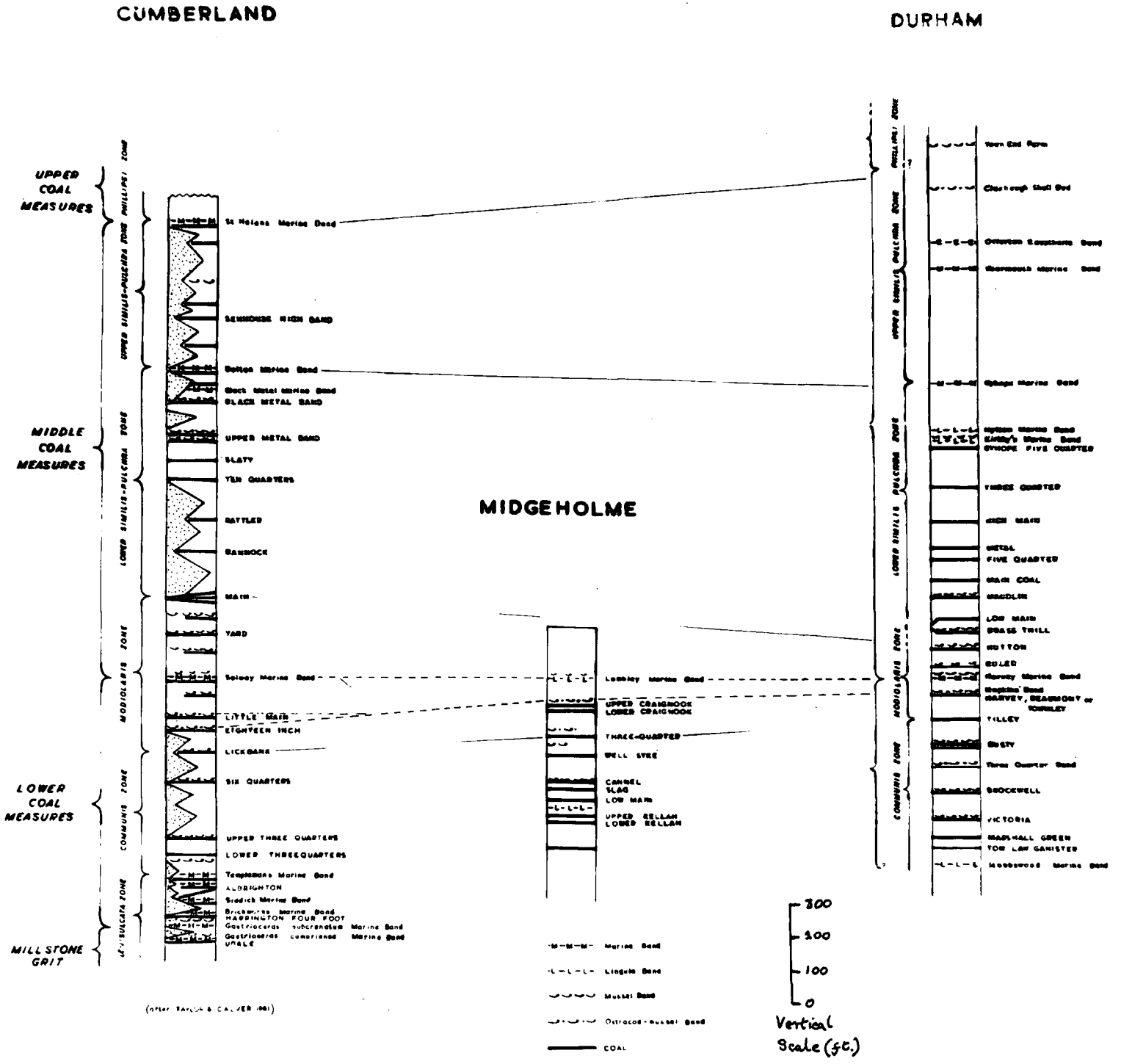

CUMBERLAND
DURHAM
UPPER COAL MEASURES
MIDDLE COAL MEASURES
LOWER COAL MEASURES
MILLSTONE GRIT
MIDGEHOLME
St Helens Marine Band
SEAMHOUSE HIGH BAND
Bolton Marine Band
Black Metal Marine Band
BLACK METAL BAND
UPPER METAL BAND
SLATY
TEN QUARTERS
RATTLED
BASSNOCK
MAIN
YARD
Soloey Marine Band
LITTLE MAIN
ETGHTEEN INCH
LICKBANK
SIX QUARTERS
UPPER THREE QUARTERS
LOWER THREEQUARTERS
Templetown Marine Band
ALBRIGHTON
Sudrick Marine Band
Brickworks Marine Band
HARRINGTON FOUR FOOT
Gastrioceras subcrenatum Marine Band
Gastrioceras cumbriense Marine Band
ARNALE
Lonsdale Marine Band
UPPER CRAIGHOOK
LOWER CRAIGHOOK
THREE-QUARTER
WELL SYKE
CANNEL
SLAG
LOW MAIN
UPPER BELLAH
LOWER BELLAH
Marine Band
Lingula Band
Mussel Band
Ostracod-mussel Band
COAL
300
200
100
0
Vertical Scale (ft.)
(after TAYLOR & CALVER 1961)

Figure 1.4. Map of sampling localities of the strata of the Hopkins' Band and Three Quarter Band in Northumberland and Durham.

Locality 1.- Longhurst Drift , Northumberland.
2.- 2½ miles north-east of Bates Pit, Blyth.
3.- Fenwick Pit, East Holywell, Northumberland.
4.- WardleyNo 1. Pit, Follonsby, Durham.
5.- Pelton Colliery, Durham.
6.- Bearpark Colliery, Durham.
7.- Whitworth Opencast, Durham.
8.- Dean and Chapter Pit, Ferryhill, Durham.
9.- Hedley Park Drift, Northumberland.
10- Chopwell East Drift, Durham.
11.- Tanfield Lea Colliery, Durham.
12.- Washington F & J Pit, Durham.
13.- Hylton Colliery, Durham.
14.- Silksworth Colliery, Durham.
15.- Ryhope Colliery, Durham
16.- Eden Colliery, Leadgate, Durham.
17.- Lanchester drift, Durham.
18.- Sherburn Hill Colliery, Durham.
19.- Eppleton Colliery, Durham.
20.- Bowburn Colliery, Durham.
21.- Tuersdale Colliery, Durham.
22.- Fishburn Colliery borehole 36.S.B.5.
23.- Durham Main Colliery,(disused), Durham.
24.- Harton Colliery, South Shields, Durham.
25.- Blaydon Burn Barlow Drift, Durham.
26.- East Walbottle Colliery, Northumberland.
6. Fishburn Borehole (6)., Durham
7.- Fishburn Borehole (7)., Durham.

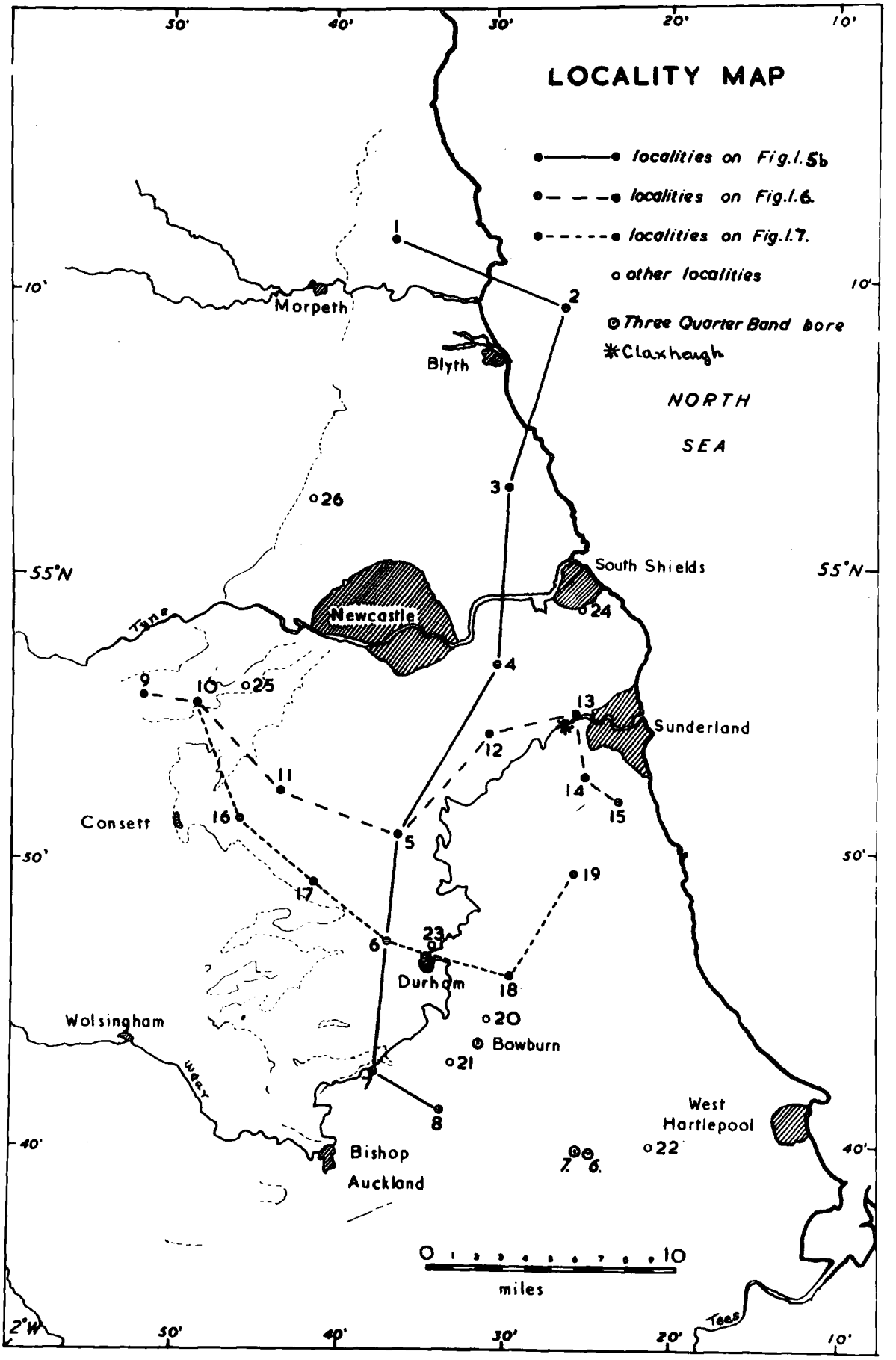

LOCALITY MAP
localities on Fig.1.5b
localities on Fig.1.6.
localities on Fig.1.7.
other localities
Three Quarter Band bore
Claxheugh
NORTH
SEA
Morpeth
Blyth
South Shields
Newcastle
Sunderland
Consett
Durham
Wolsingham
Bowburn
West
Hartlepool
Bishop
Auckland
Tyne
Wear
Tees
miles
50'
40'
30'
20'
10'
55°N
2°W

Figure 1.5.a. The lithologies represented on the vertical sections on Figures 1.5.b., 1.6. and 1.7.

LEGEND


Seatearth


Coal


Cannel coal


Cannel shale


Ankeritic mudstone conglomerate


Black shale


Grey shale


Grey mudstone


Grey mudstone with ironstone


Grey siliceous mudstone


Grey siltstone


Massive sandstone


Sandstone with plants


False bedded sandstone


Shale with ostracods


Mussel band


Fish band

Top of Harvey-Beaumont Seam

Figure 1.5.b. Vertical sections of the strata immediately above the Harvey - Beaumont Seam in an approximately north to south direction from Longhurst to Ferryhill. (As on Figure 1,4.1 (Base of the columns is the top of coal Seam)

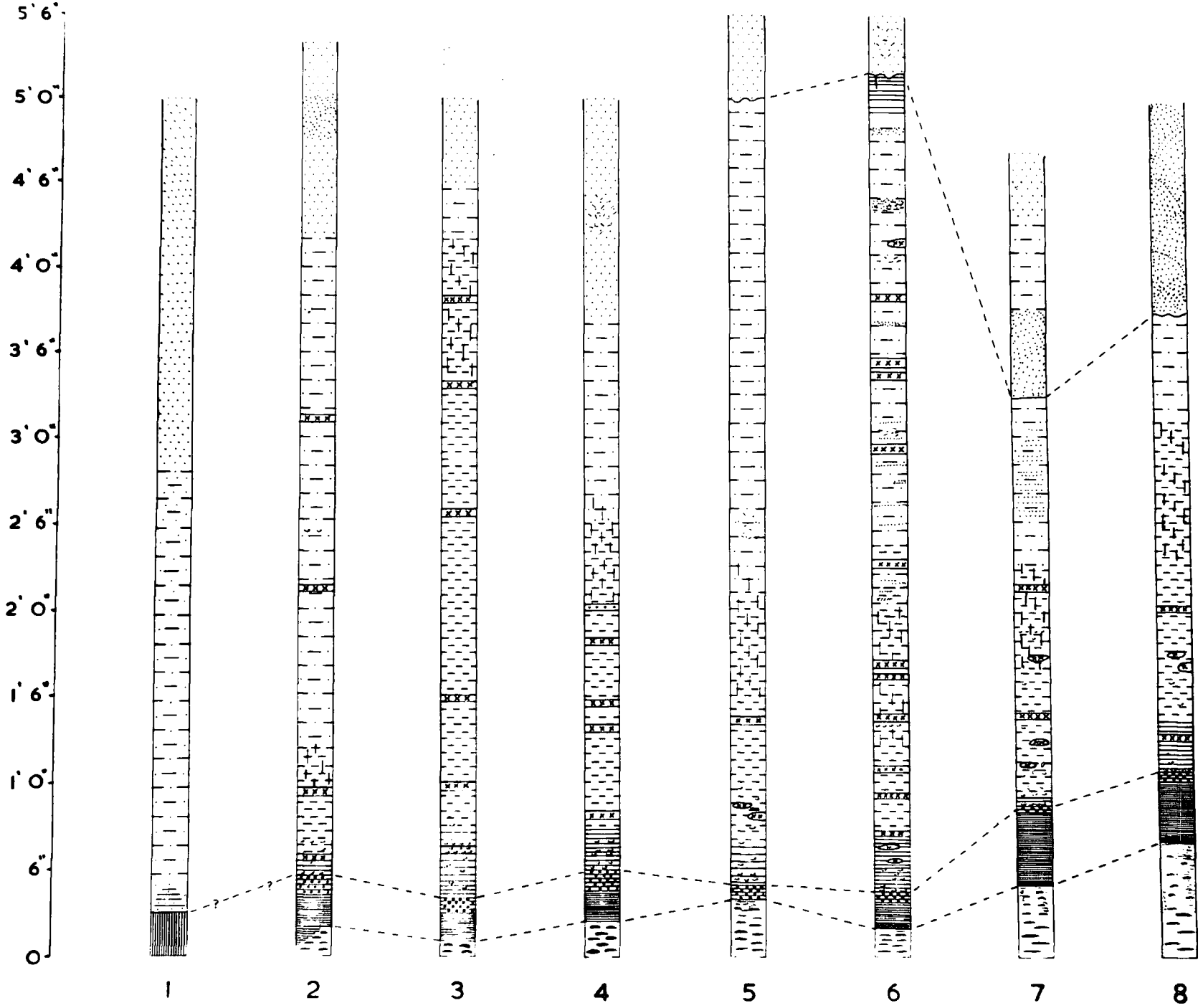

5' 6"
5' 0"
4' 6"
4' 0"
3' 6"
3' 0"
2' 6"
2' 0"
1' 6"
1' 0"
6"
0
1
2
3
4
5
6
7
8

Figure 1.6. Vertical sections of strata immediately above the Townley-Harvey Seam in an approximately east-west direction , from Hedley Park to Ryhope (Localities as on Figure 1.4)

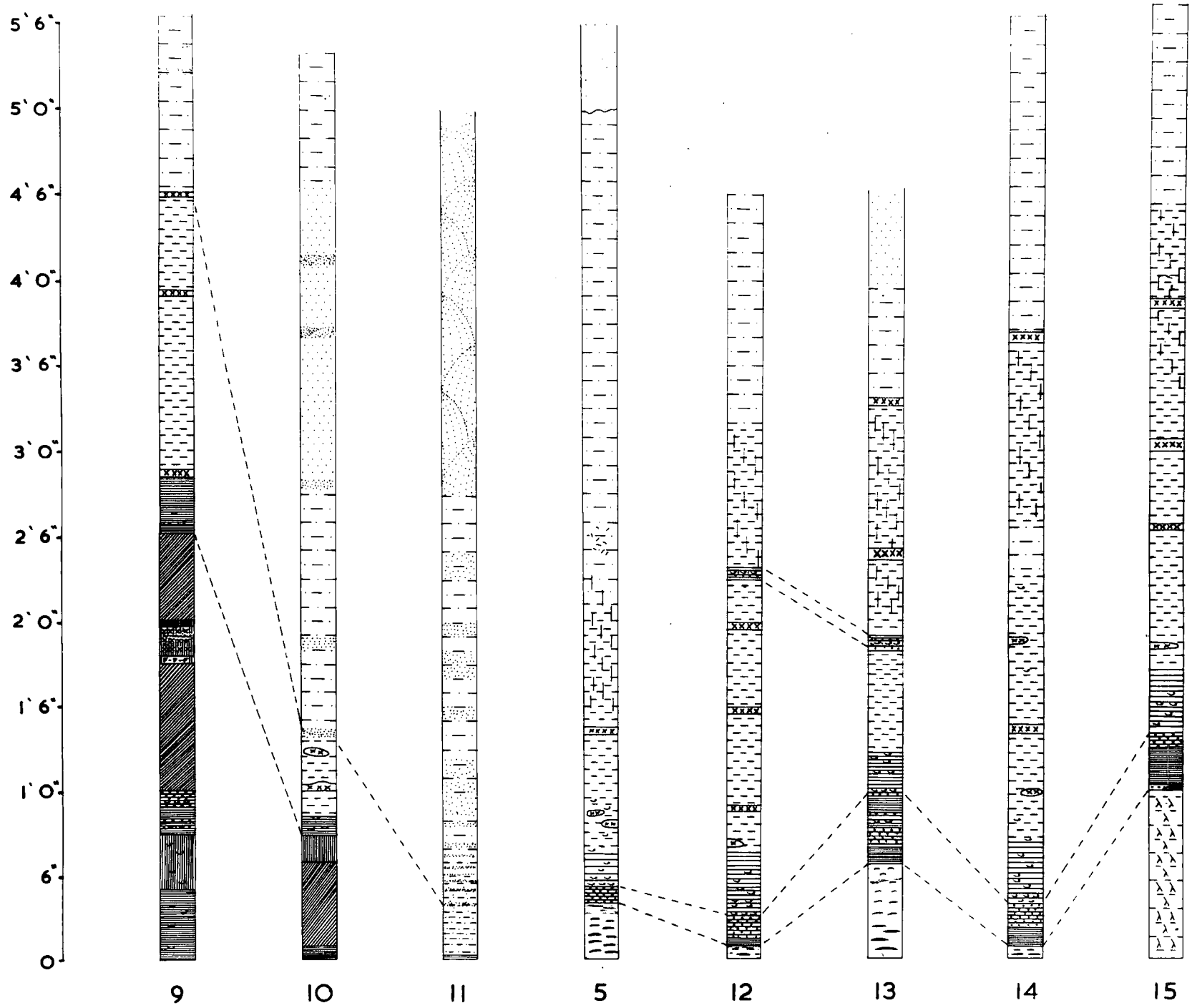

5' 6"
5' 0"
4' 6"
4' 0"
3' 6"
3' 0"
2' 6"
2' 0"
1' 6"
1' 0"
6"
0
9
10
11
5
12
13
14
15

Figure 1.7. Vertical sections of strata immediately above the Townley-Harvey Seam in an approximately north-west to south-east direction, from Chopwell to Eppleton.
(Localities as on Figure 1.4.)

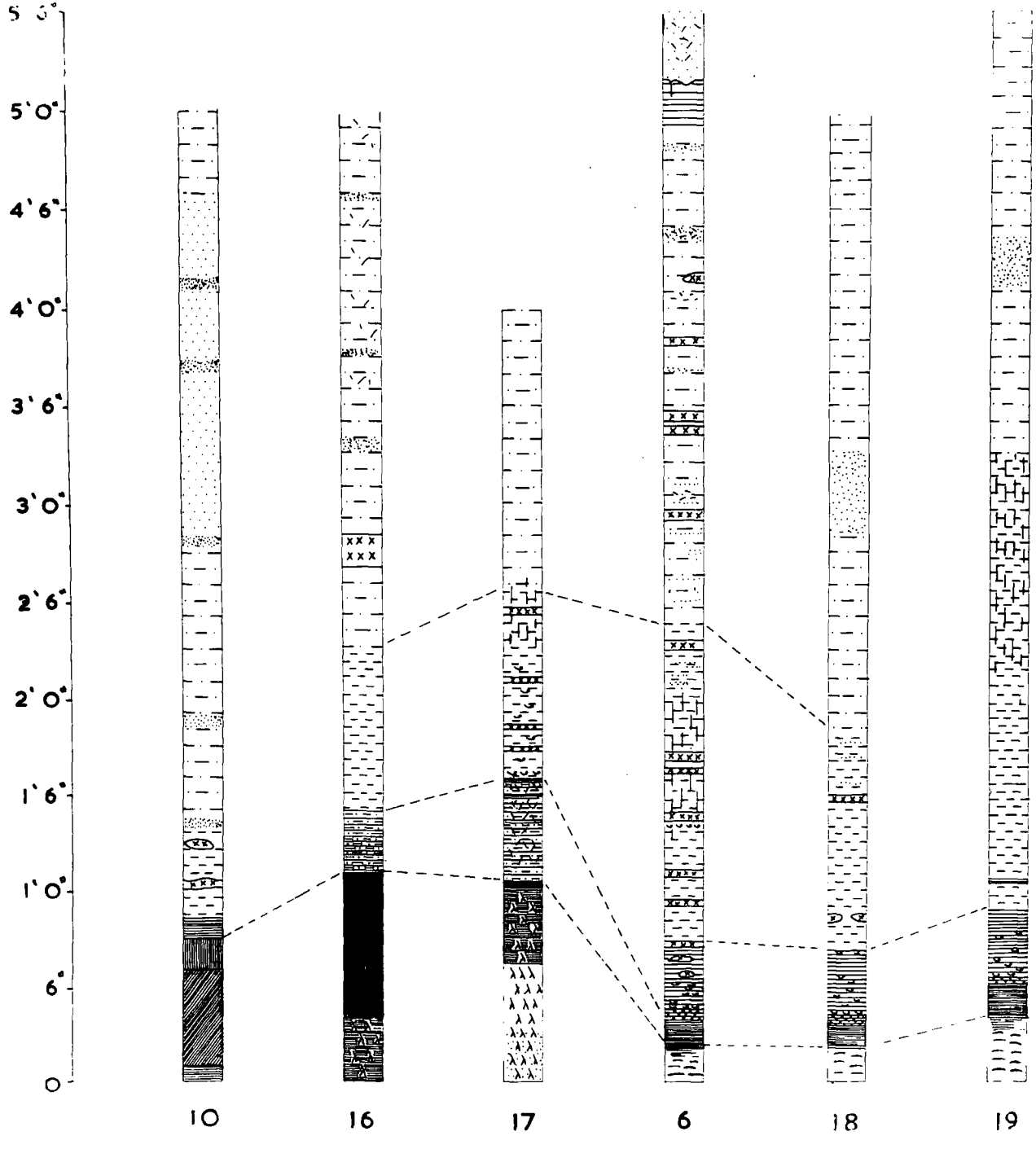

5'0"
4'6"
4'0"
3'6"
3'0"
2'6"
2'0"
1'6"
1'0"
6"
0
10
16
17
6
18
19

Figure 1.8. Lithofacies map of the 3ft. of roof strata of the Harvey-Beaumont Seam in Northumberland and Durham.

(The information for this map has been derived from the sampling localities of Figure 1.4. and examination of 130 borehole records.)

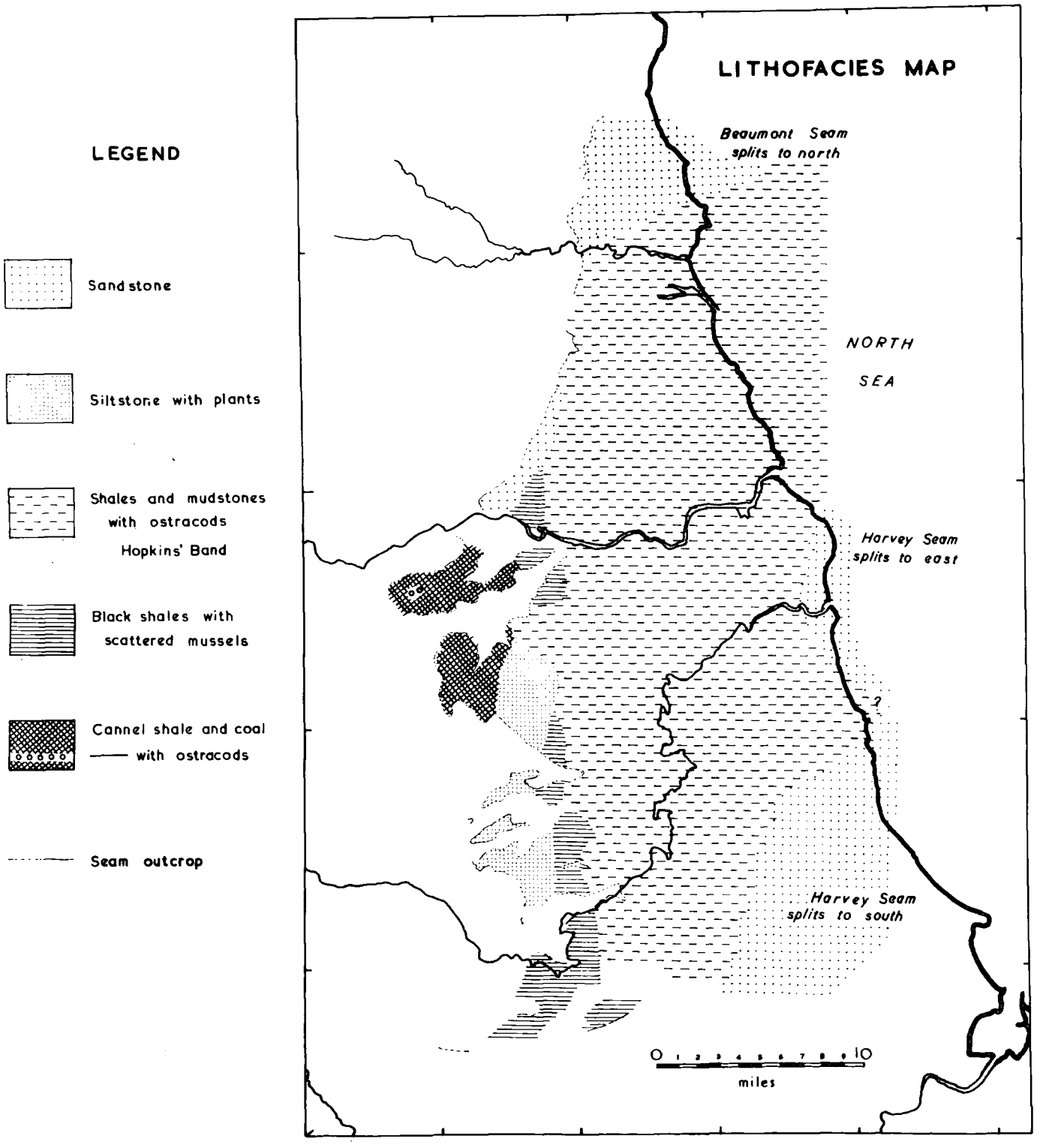

LEGEND
Sandstone
Siltstone with plants
Shales and mudstones with ostracods
Hopkins' Band
Black shales with scattered mussels
Cannel shale and coal with ostracods
Seam outcrop
LITHOFACIES MAP
Beaumont Seam splits to north
NORTH SEA
Harvey Seam splits to east
?
Harvey Seam splits to south
0 1 2 3 4 5 6 7 8 9 10
miles

Figure 1.9. Map showing the sampling localities of the ostracod-mussel band above the Eighteen Inch Seam of Cumberland.

Locality A. - Nelson Park Pit (disused), Broughton Moor
B. - Hennow Hall Opencast Site, Cumberland.
C. - Borehole nr. Branthwaite, Cumberland.
D. - Risehow No 10. underground borehole, Risehow Colliery, Maryport, Cumberland.
E. - Crosby NO. 6. borehole, Crosby, Cumberland.
F. - Crosby No. 7. borehole , Crosby, Cumberland.
G. - Bullgill Station, Cumberland. (Ostracod-mussel band above Little Main Seam.)

The numbered boreholes are those given by Taylor and Calver (1961)

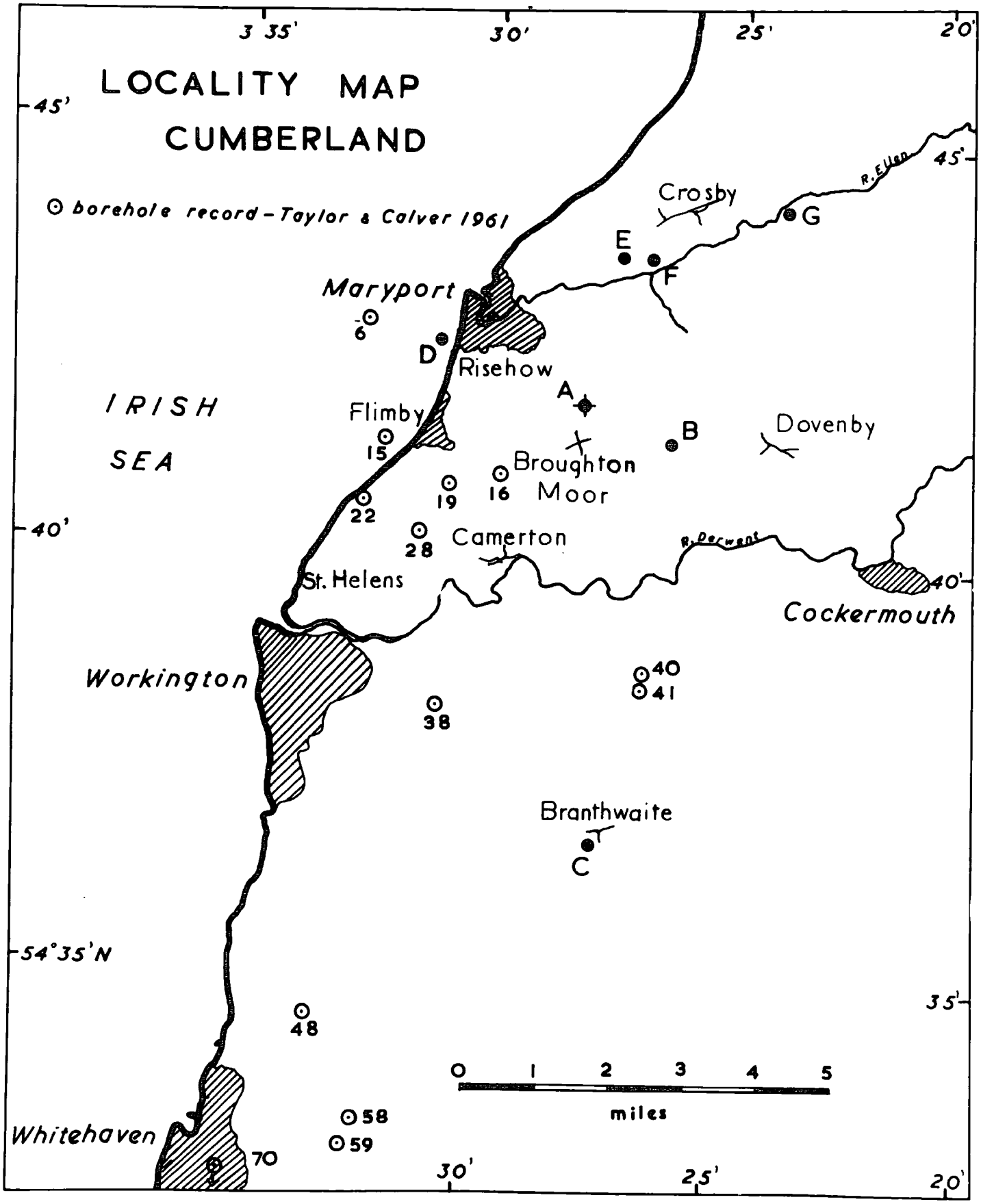

LOCALITY MAP
CUMBERLAND
⊙ borehole record - Taylor & Calver 1961
3 35'
30'
25'
20'
45'
40'
54°35'N
R. Ellen
R. Derwent
Crosby
G
E
F
Maryport
6
D
Risehow
A
B
Dovenby
IRISH
SEA
Flimby
15
Broughton
Moor
16
19
22
28
Camerton
St. Helens
Cockermouth
Workington
40
41
38
Branthwaite
C
48
58
59
70
Whitehaven
0 1 2 3 4 5
miles

Figure 1.10. Comparative sections of ostracod-mussel bands equivalent to the Hopkins' Band in Cumberland, Midgeholme and Durham.
(Lithologies represented as on Figure 1.5.a.)

CUMBERLAND MIDGEHOLME DURHAM

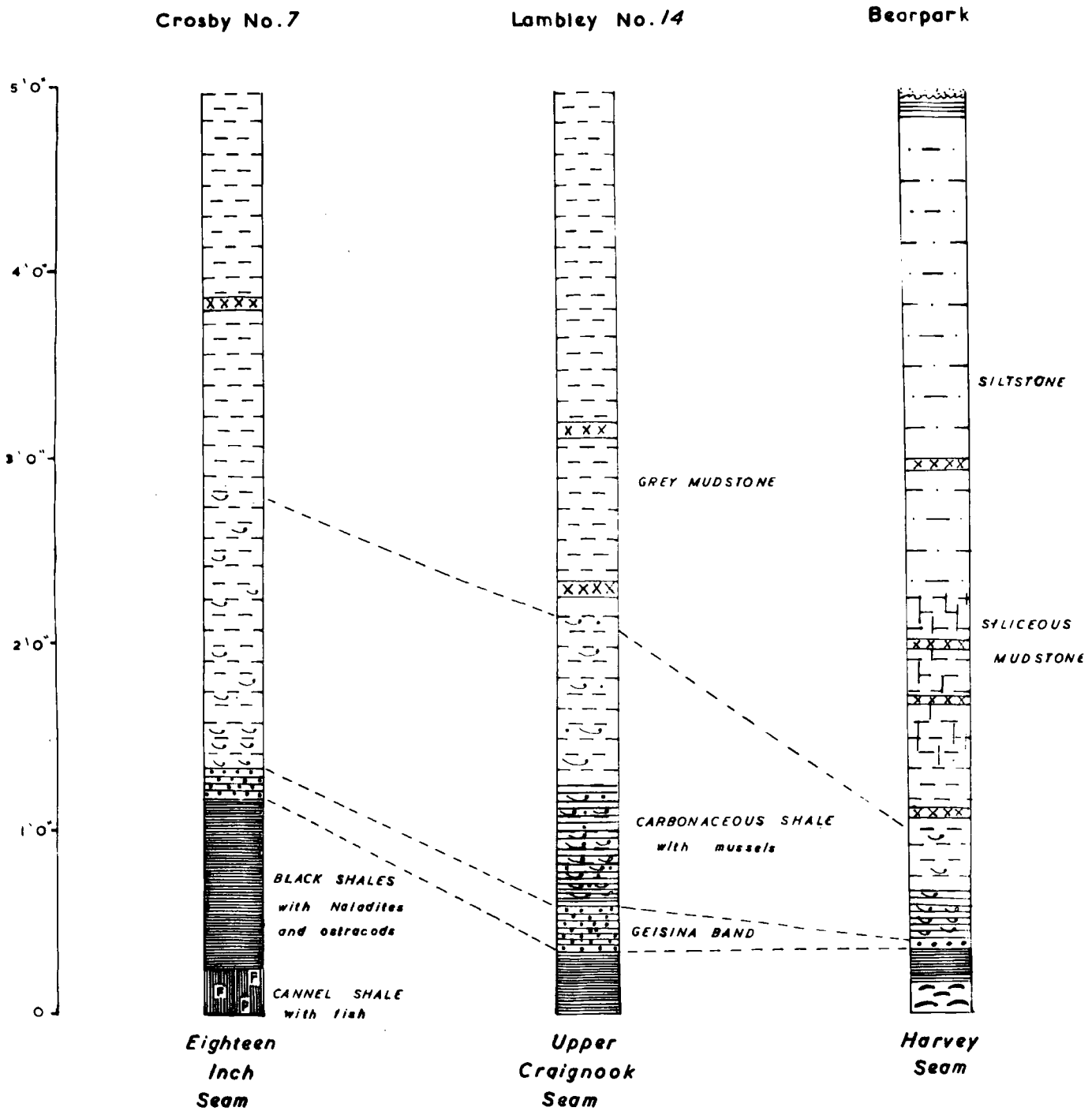
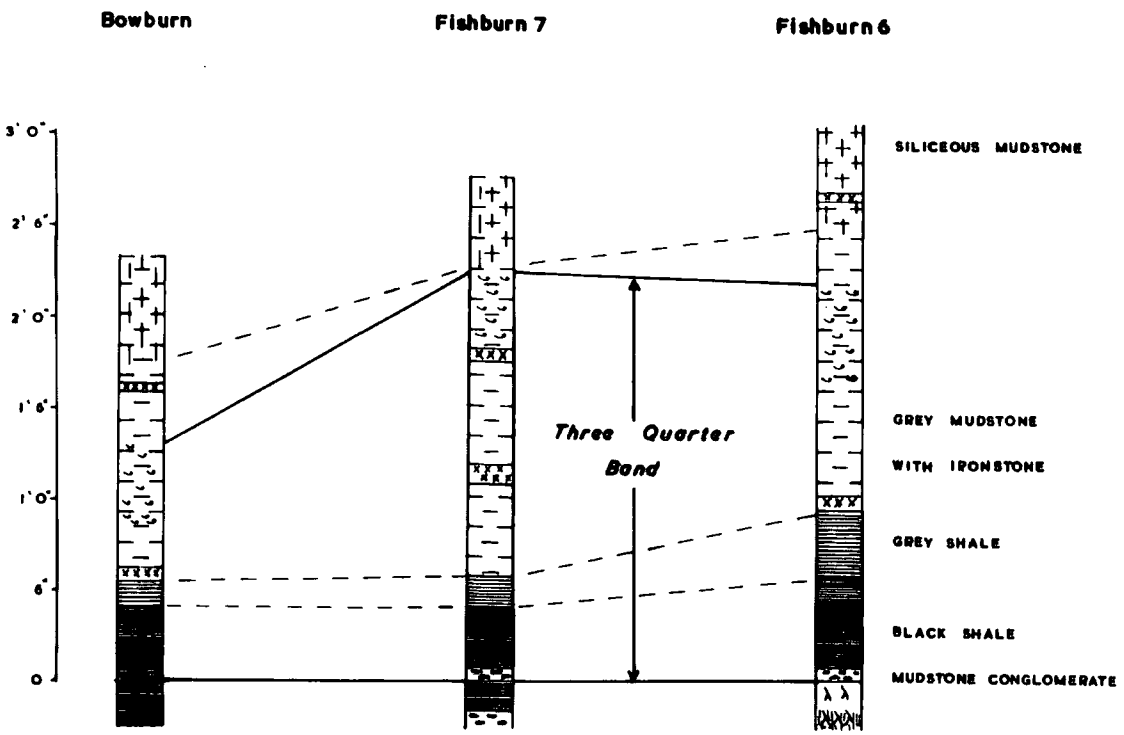


Figure 1.11. Comparative sections of the Three Quarter Band boreholes.

Figure 1.12. The vertical section of the Claxheugh Shell Bed, north bank of River Wear, opposite Claxheugh Rocks, North Hylton, Sunderland, County Durham.



Section of CLAXHEUGH SHELL BED

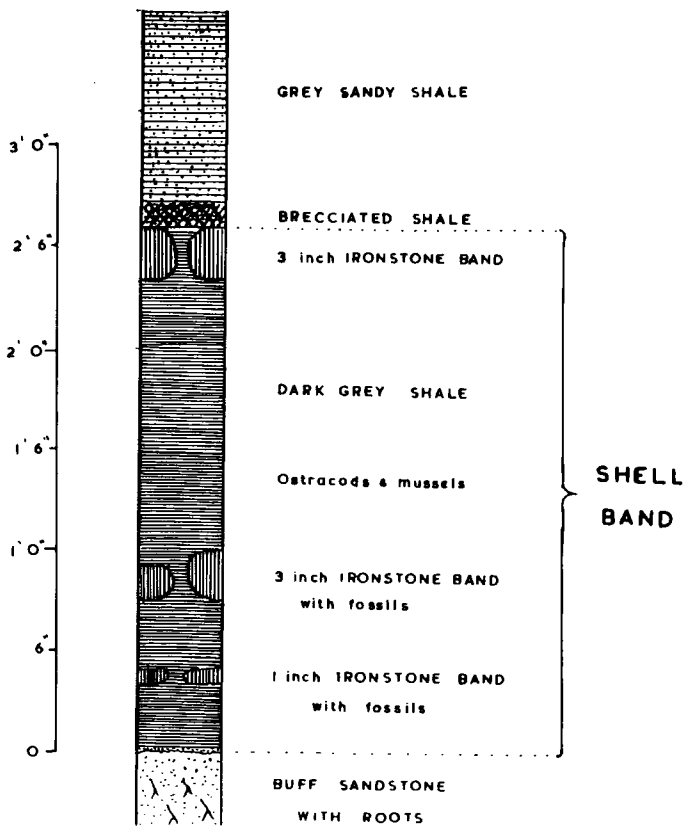


Figure 2.1. Variation in the genus Carbonicola in the Hopkins' Band. Form a is C. venusta , l- C. oslancis , j & i - C. embletoni, f -C. cf. oslancis , n & o- C. cf. bipennis , u - C. pectorata , p & q- C.cf. communis , and r - C. cf. rhomboidalis.

(The underlined specimens are figured on Plates I & II. The localities of the mussels are various so this is not a true community pictogram.)

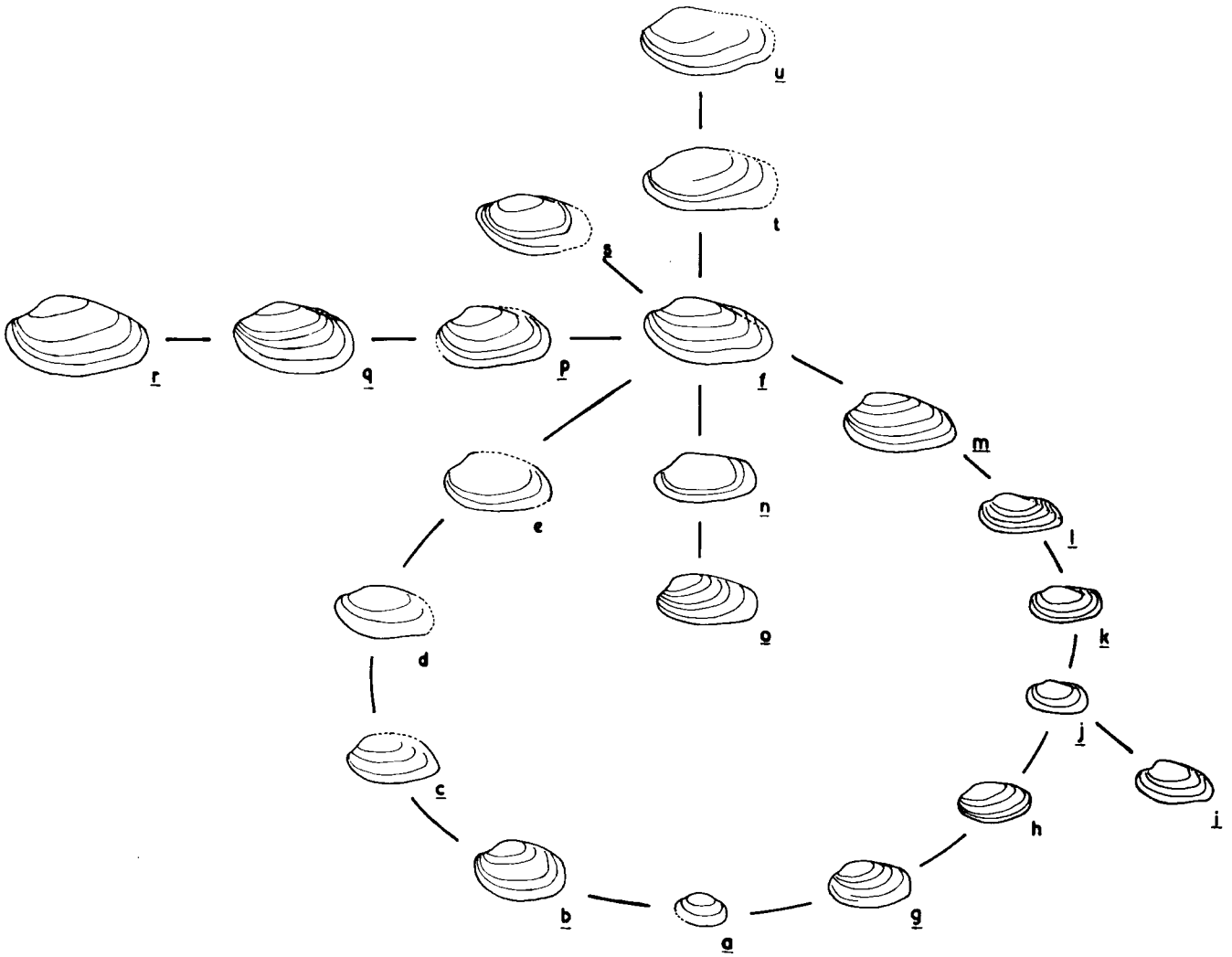

u
t
s
r
q
p
f
m
e
n
l
d
o
k
j
c
h
i
b
g
a

Figure 2.2. Graph of the dimension ratios of *Carbonicola oslancis* and related species.

A/L = ratio anterior to length.

H/L = ratio height to length.

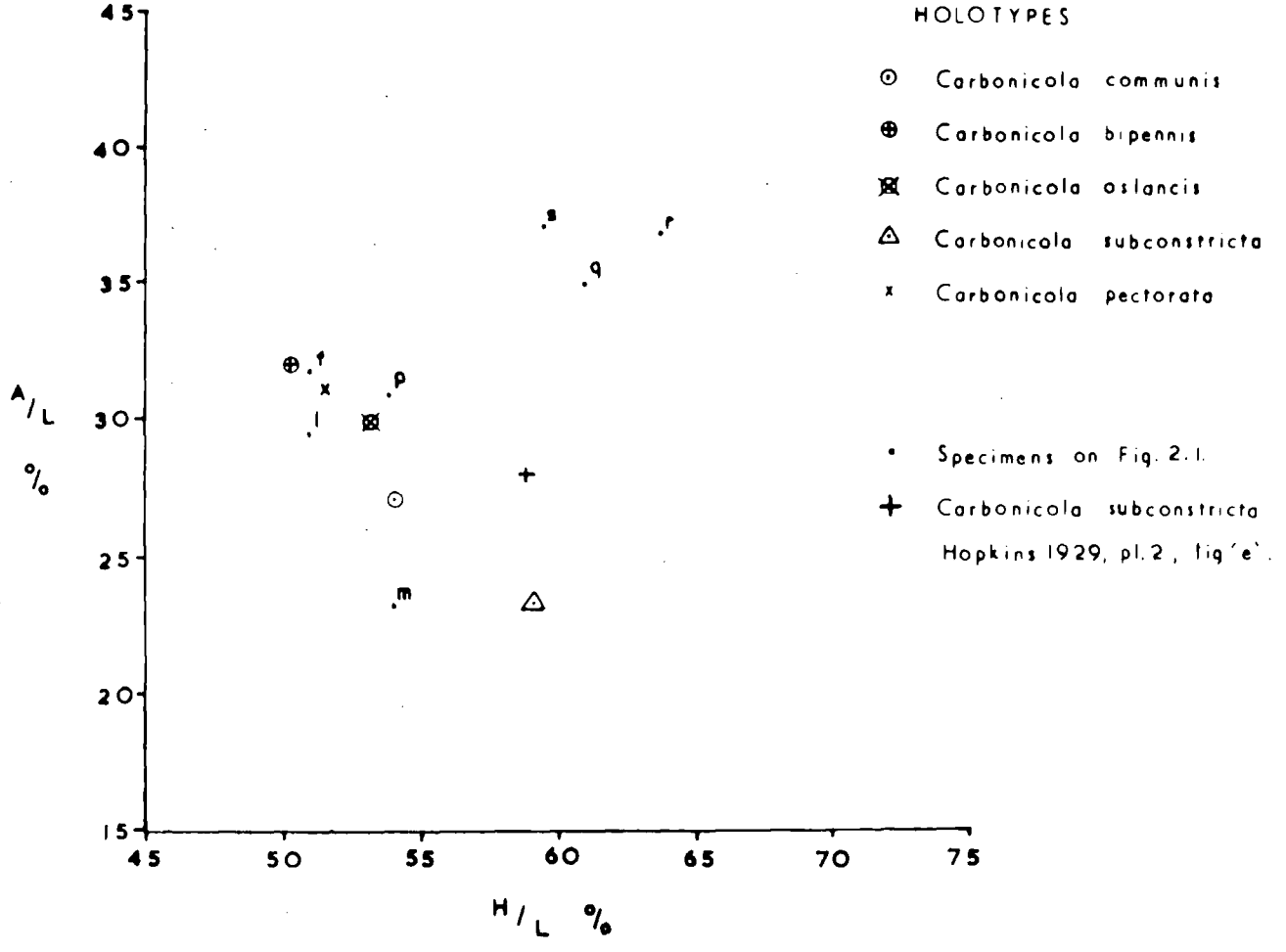

45
40
35
30
25
20
15
A/L %
45
50
55
60
65
70
75
H/L %
HOLOTYPES
Carbonicola communis
Carbonicola bipennis
Carbonicola oslancis
Carbonicola subconstricta
Carbonicola pectorata
Specimens on Fig. 2.1.
Carbonicola subconstricta Hopkins 1929, pl. 2, fig 'e'.

Figure 2.3. Variation in the genus Anthracosia in tne Hopkins' Band. N - A. regularis , L & K - A. cf. ovum , I - A. cf. aquilina, and A - A. cf. retrotracta (Underlined specimens are figured on Plates II & III. Not a community pictogram, localities various.)

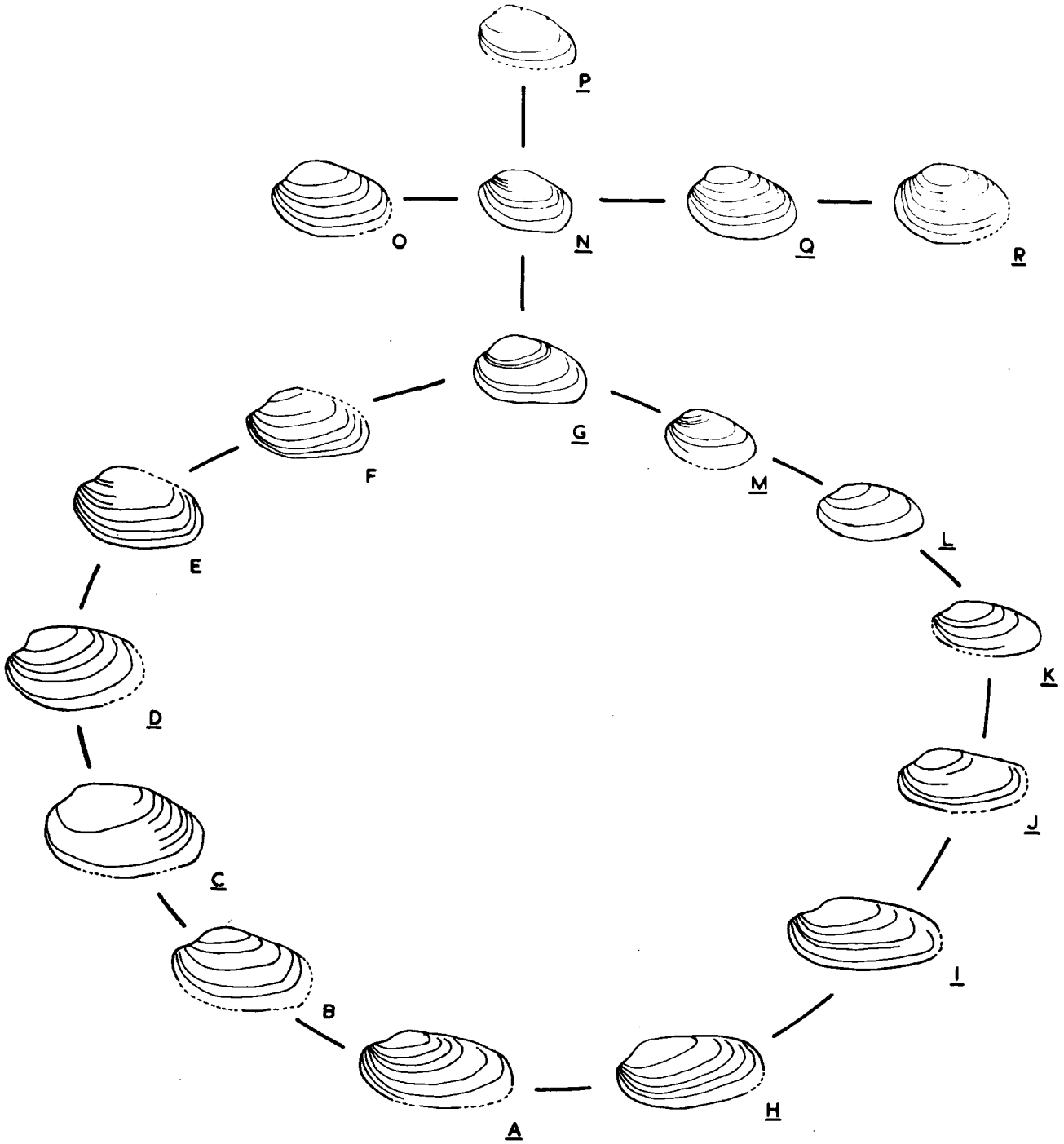

P
O
N
Q
R
G
F
M
E
L
K
D
J
C
I
B
H
A

Figure 2.4. Variation in the genus Naiadites in the Hopkins' Band. i- N. cf. triangularis, iii - N. productus, viii - N. cf. subtruncatus, ix - N. cf. quadratus , xi - N. cf. carinatus xii - N. cf. flexuosus .

(Underlined specimens are figured on Plates IV & V.)

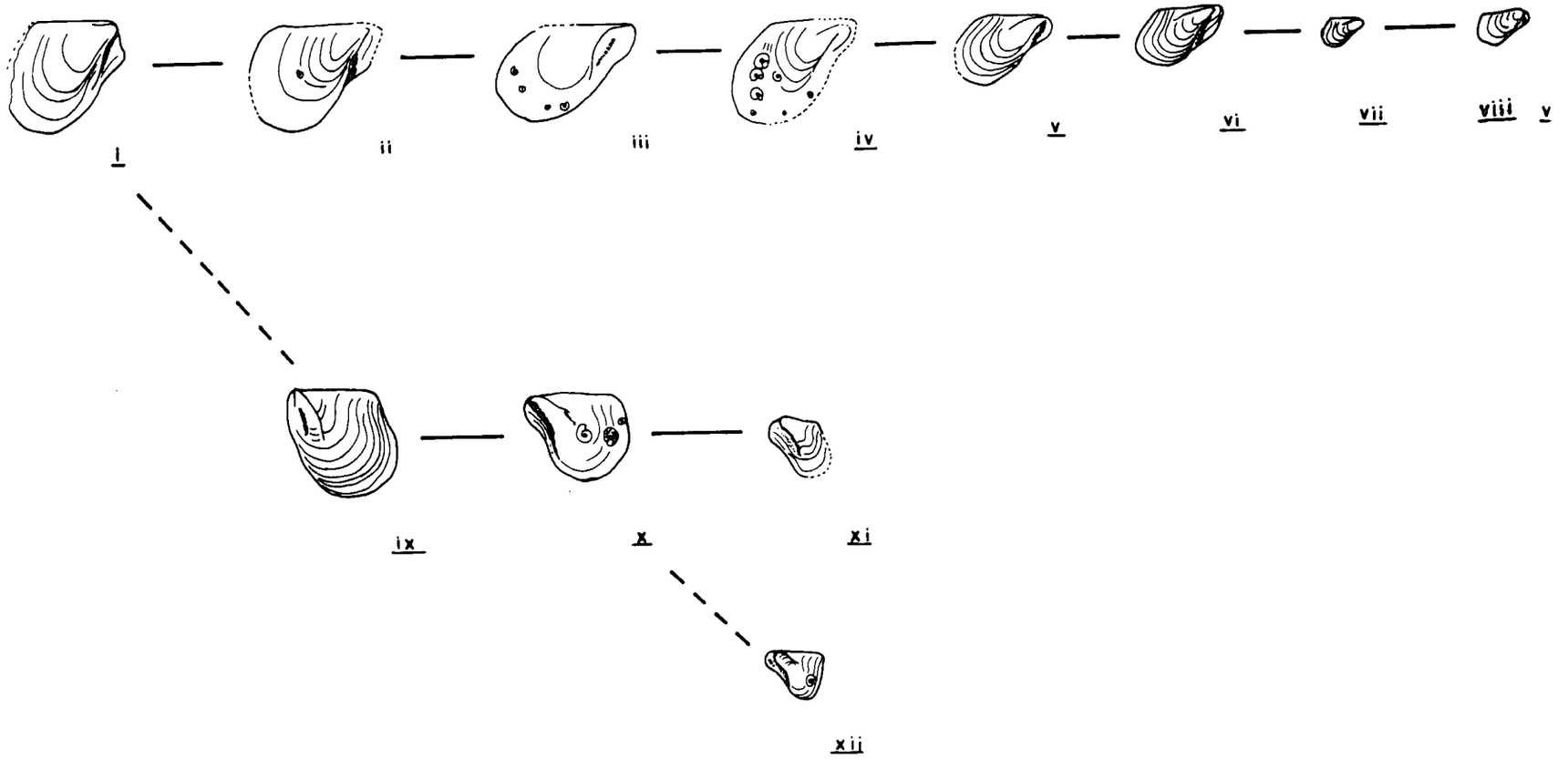

i
ii
iii
iv
v
vi
vii
viii
v
ix
x
xi
xii

Figure 2.5. Variation in the genus Anthraconaia in the Hopkins' Band. Form Z - A. cf. curtata, Y - A. modiolaris, U - A. williamsoni, and V - A. cf. fugax.
(Underlined specimens are figured on Plate V)

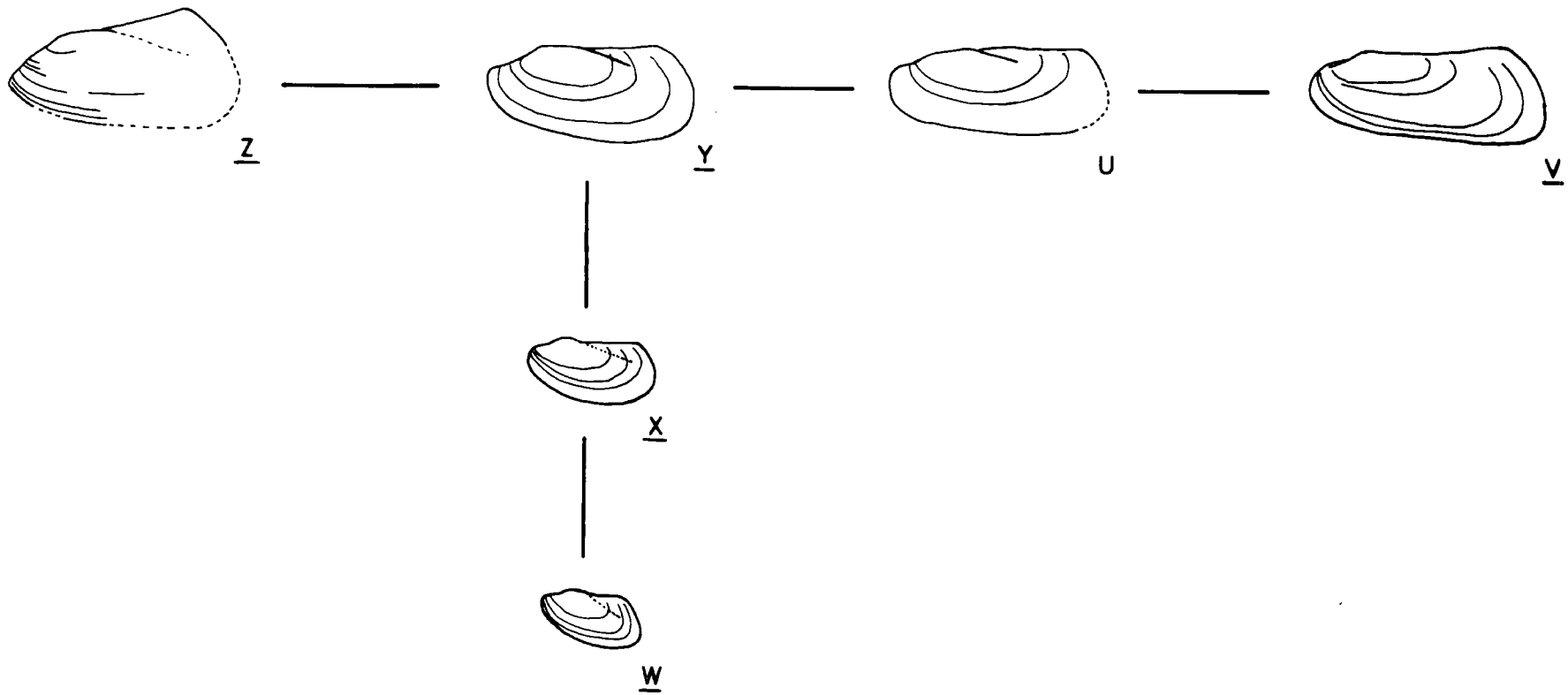
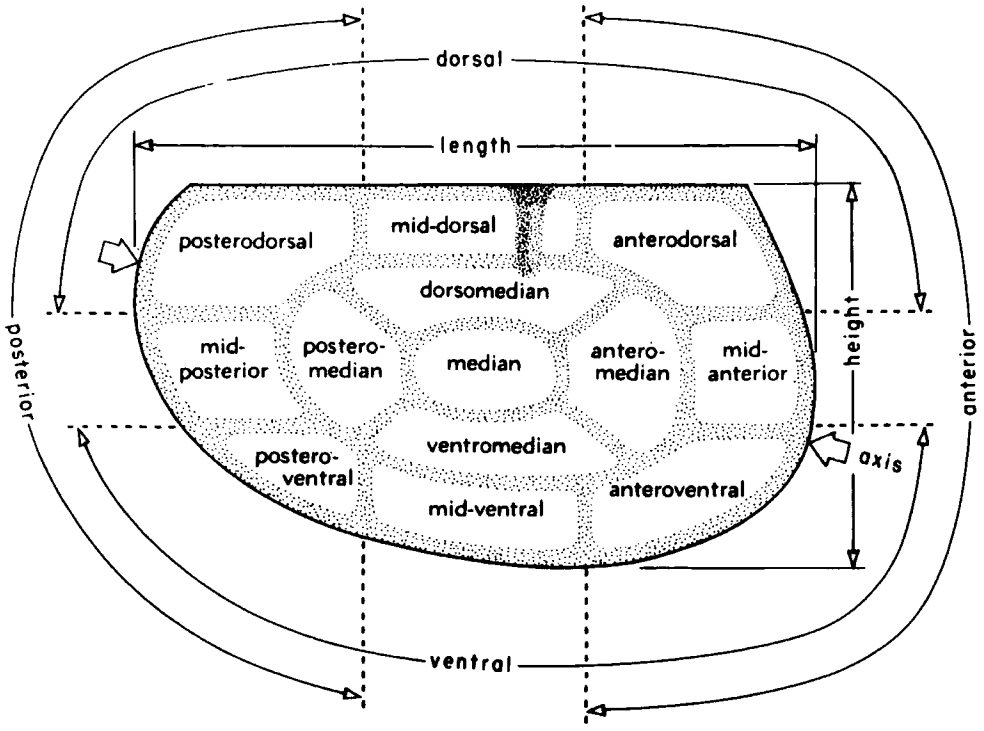

Z
Y
U
V
X
W

Figure 3.1. Nomenclature of the areas on the lateral surface and features relating to orientation and dimensions of a straight backed ostracod. Right valve. (After Moore et al 1961, fig. 18.)

Figure 3.2. Carapace nomenclature of a typical straight backed ostracod.

(After Moore et al 1961, fig.16.)



Shell Morphology—External Features

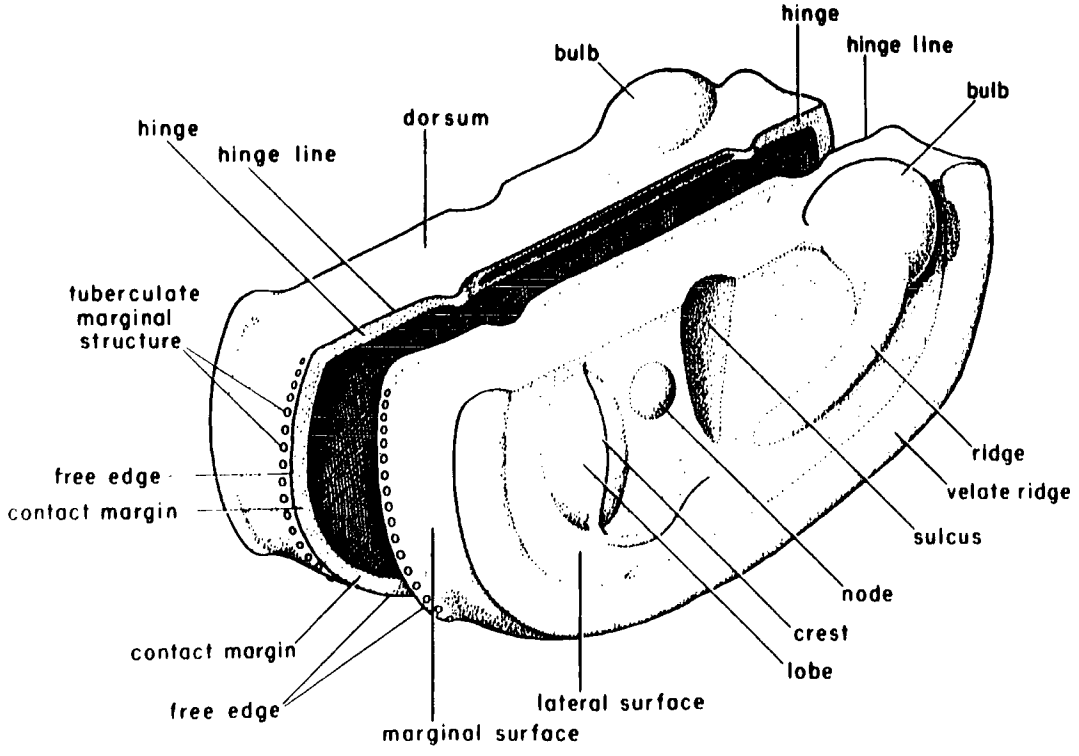
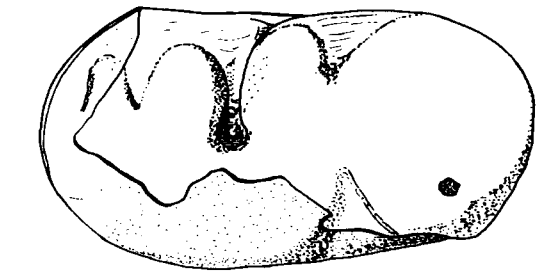


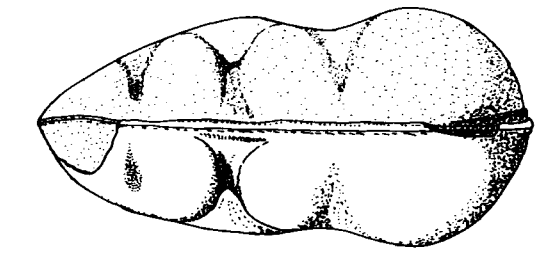
Figure 3.3. Line drawings of the lectotypes of *Jonesina fastigiata* Jones and Kirkby. x 73. approx. Specimens with British Museum numbers.

Jonesina fastigiata Jones and Kirkby

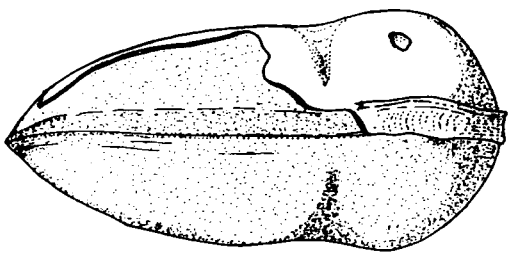
Female B.M. I1774



left valve

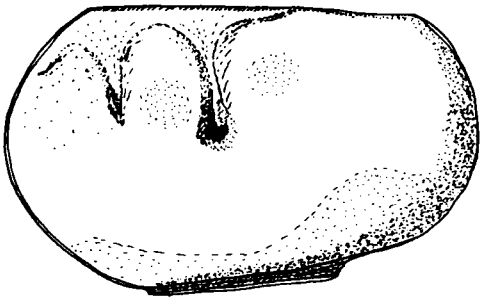


dorsal view

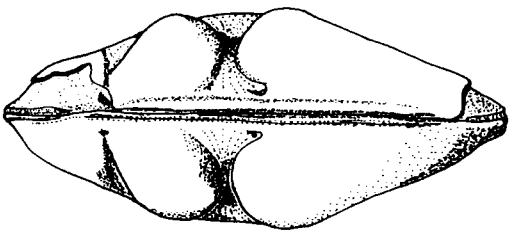


ventral view

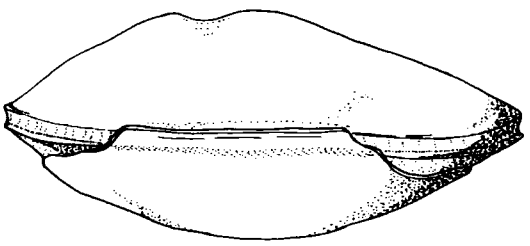
Male B.M. In 32496



left valve



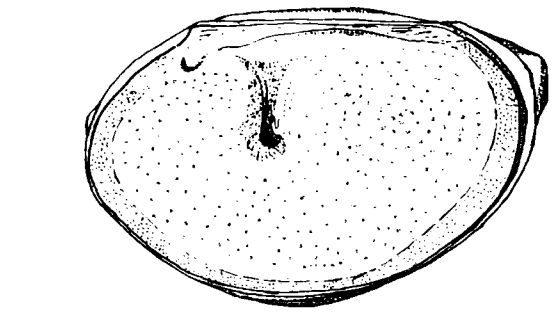
dorsal view



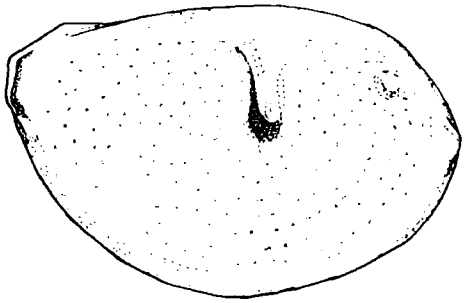
ventral view

Figure 3.4. Line drawings of the lectotype of Geisina arcuata Bean. x 50. approx. adult female. The interior view of the right valve of female is a specimen from above the Flockton Coal of Yorkshire and not the lectotype.

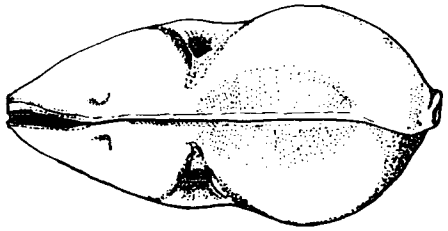
Geisina arcuata Bean



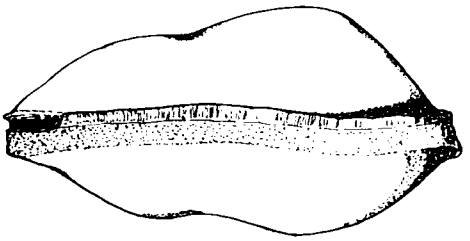
left valve



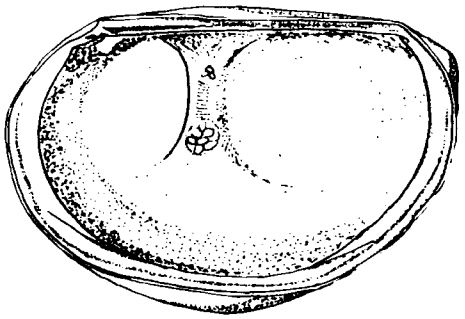
right valve



dorsal view



ventral view

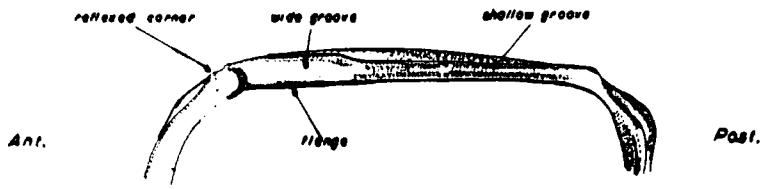


interior right valve

Figure 3.5. The hinge of Geisina arcuata Bean. x 65 approx. The full hinge is drawn from the Flockton specimen of Fig. 3.4. while the transverse sections are reconstructed from sectioned specimens in the Geisina Band of Durham.(Plate XIII, figs. 1 & 2)

Figure 3.6. External and internal moulds of dimorphic adult specimens of Geisina arcuata Bean, from the Geisina Band at Eppleton Colliery, Co. Durham. x 40 approx.

Hinge of Geisina arcuata – right valve



Transverse section of hinge

Dorsal outlines of Geisina arcuata

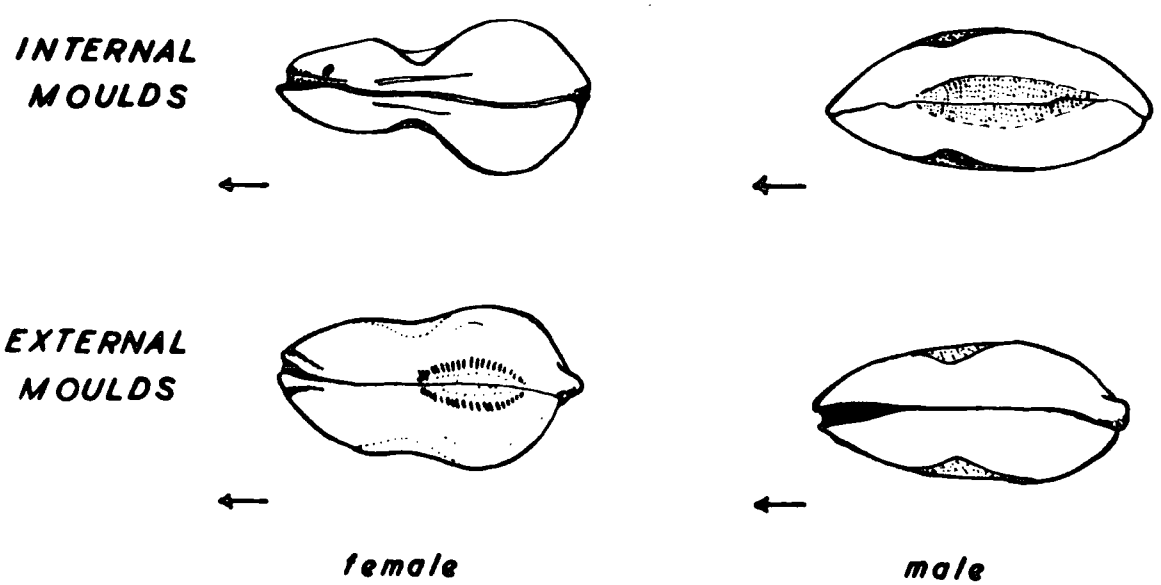
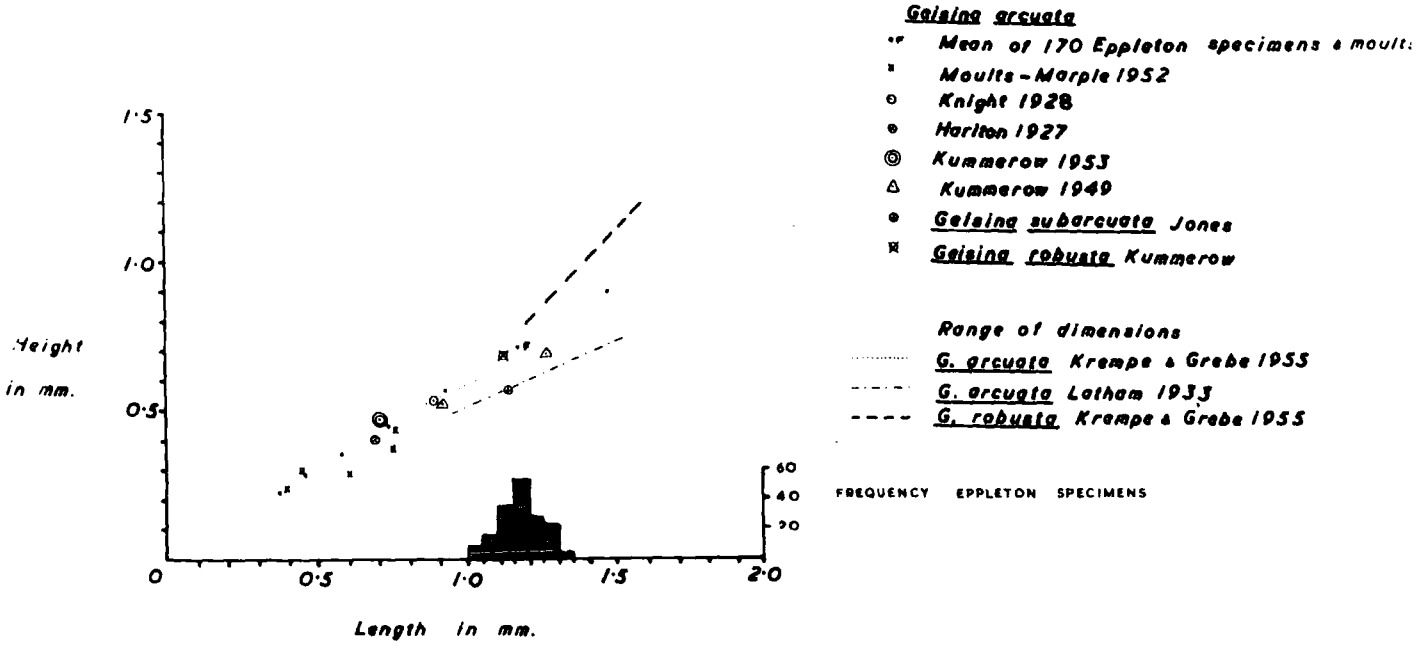


Figure 3.7. Graph of the height and length dimensions of Geisina arcuata Bean and related species. Eppleton specimens and other authors.

Figure 3.8. Frequency graph of the ratio of median to posterior thickness in 180 specimens of Geisina arcuata , from Eppleton Colliery, Co. Durham.



Geisina arcuata

Relationship of median to posterior thickness

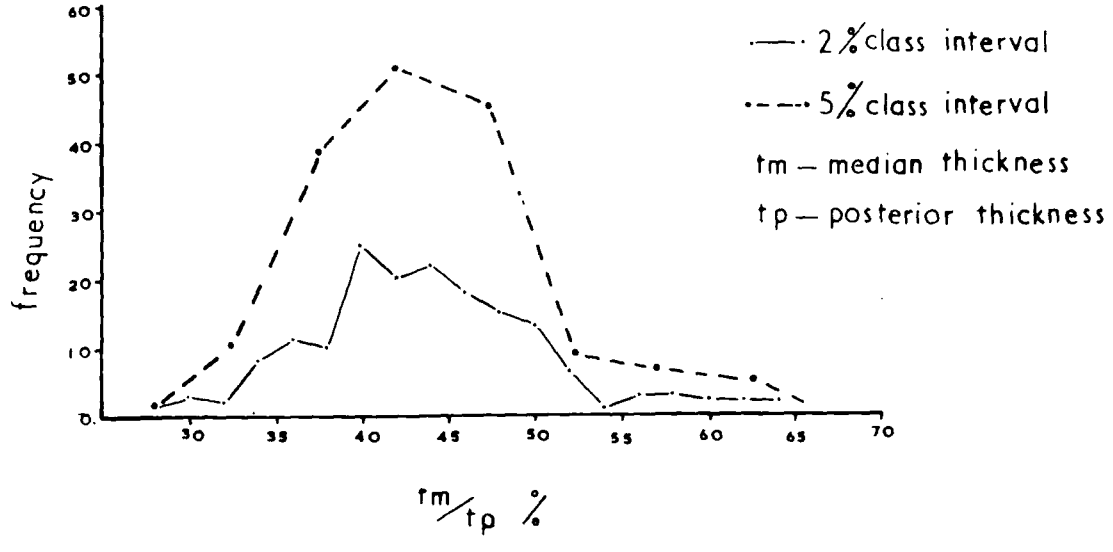
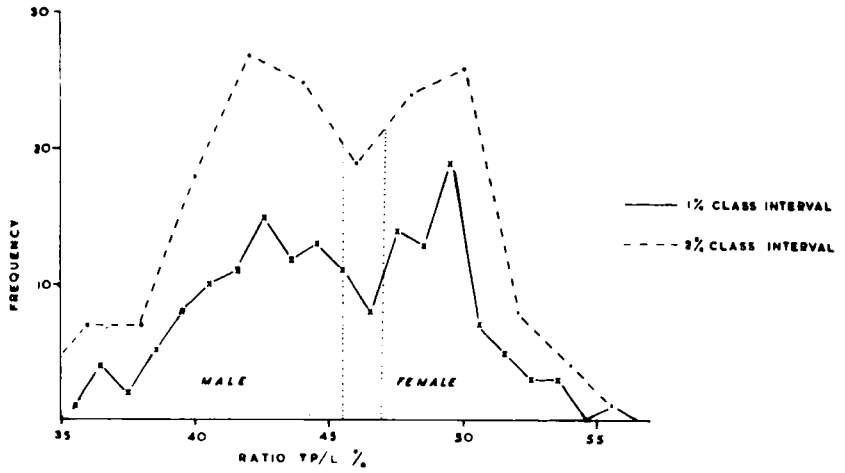


Figure 3.9. Frequency graph of the ratio of posterior thickness (TP) to length (L) in 180 specimens of Geisina arcuata , from Eppleton, Co. Durham.

Figure 3.10. Distribution graph of the ratio posterior thickness to length and height to length for 180 specimens of Geisina arcuata , from Eppleton, Co. Durham.

Relationship of length to posterior thickness in Gelsina arcuata



Correlation of sex and form ratio

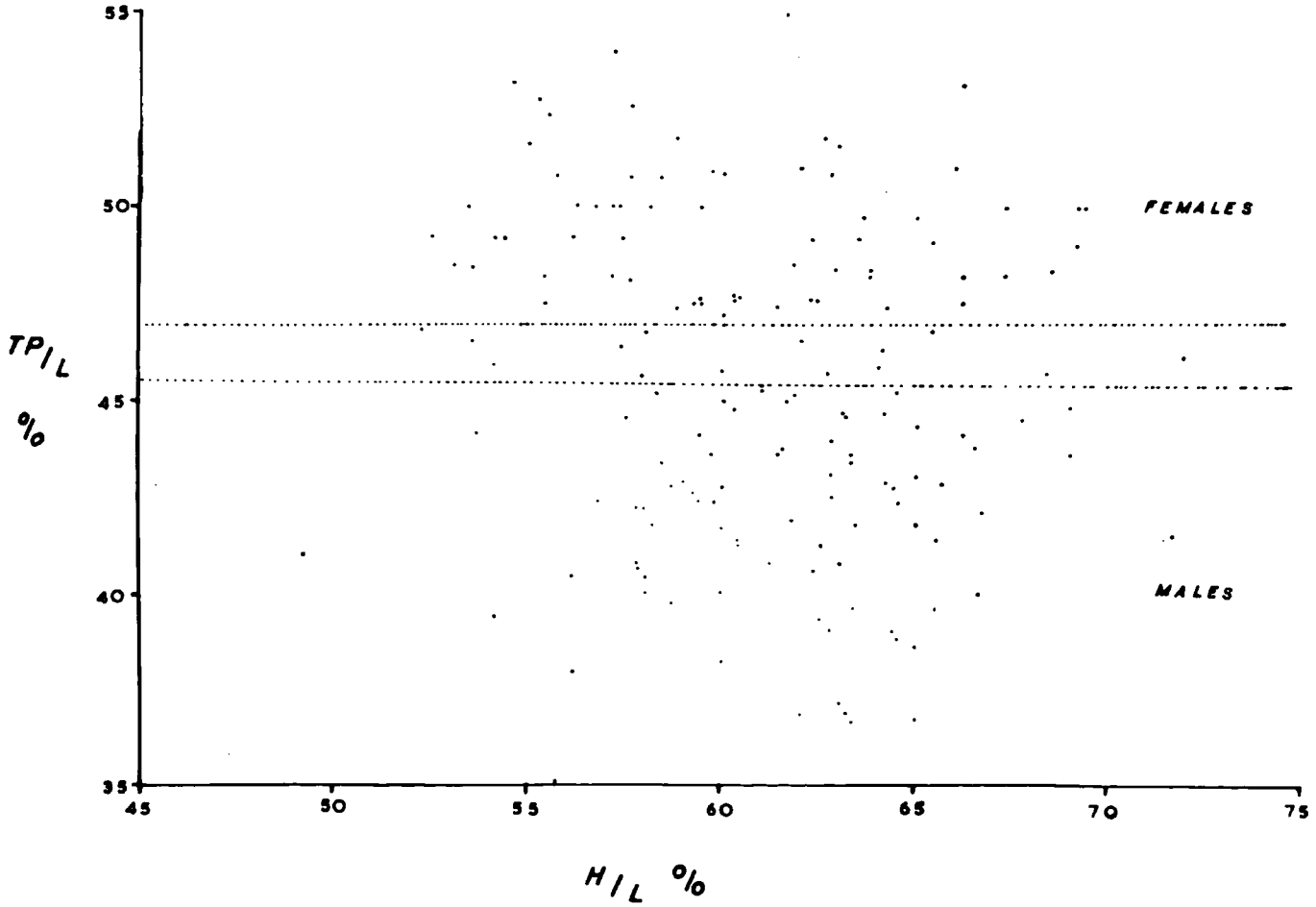
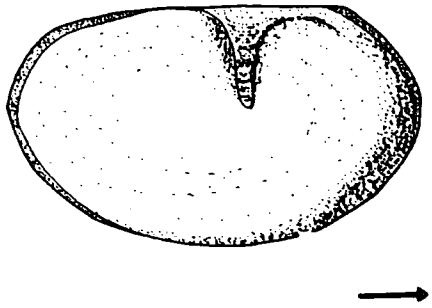


Figure 3.11. Line drawings of Geisina subarcuata Jones. x 40 approx Figs. a & b are Neotypes in Durham Palaeontology Collections, specimens c & d are in personal collections. All the specimens are from the Claxheugh Shell Bed , North Hylton , Sunderland, Co. Durham.

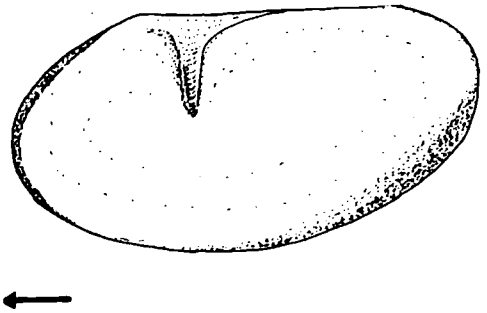
Geisina subarcuata Jones

Female

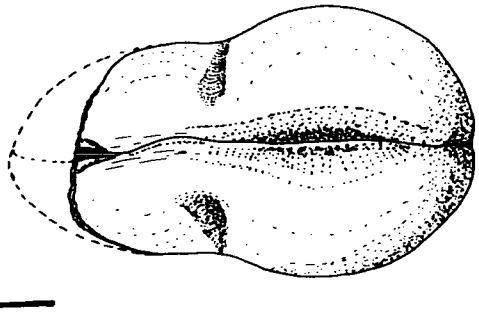
Male



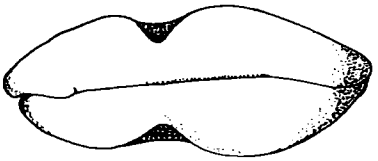
a. right valve



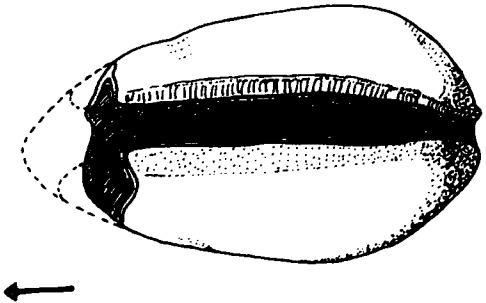
b. left valve



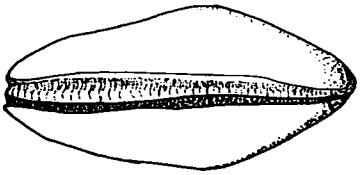
c. dorsal view



d. dorsal view young male

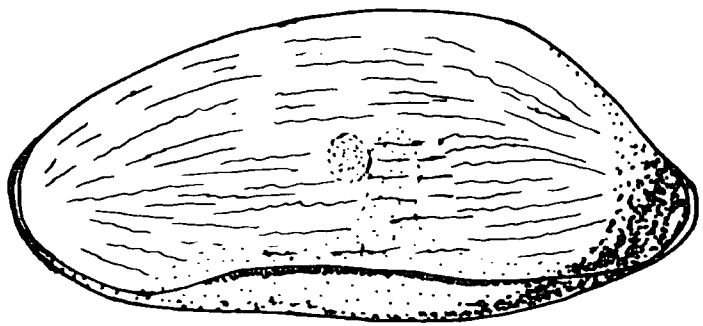


e. ventral view

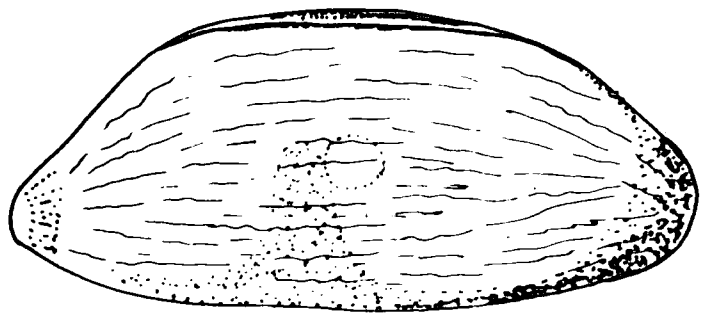


f. ventral view young male

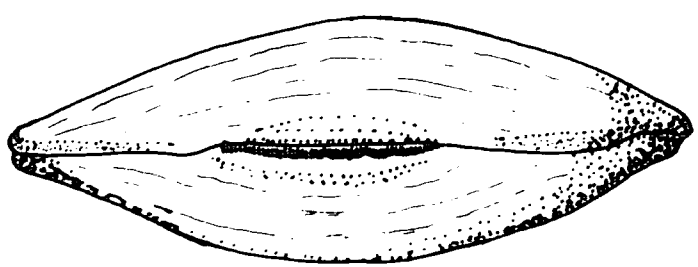
Carbonita c.f. *evelinae*



left valve



right valve

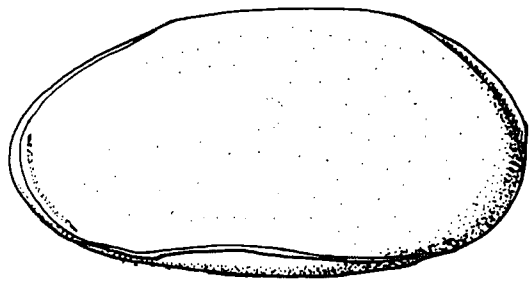


dorsal view

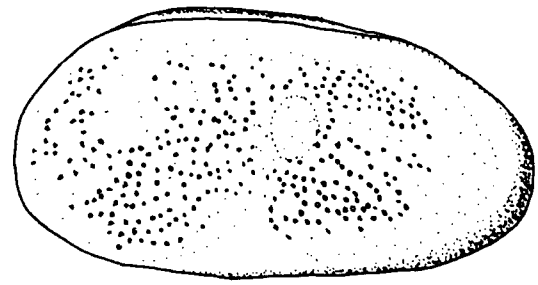
ventral view

Figure 3.14. Line drawing of Carbonita cf. rankiniana Jones and Kirkby. x 70 approx. The four external views are of a specimen from above the Flockton Coal of Yorkshire and the internal mould from the Geisina Band at Ryhope Colliery, Co. Durham.

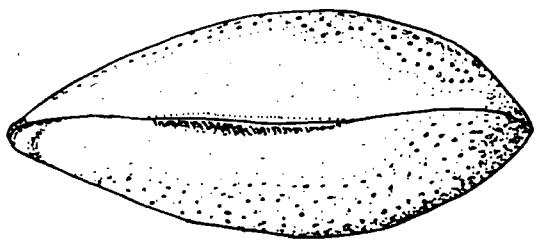
Carbonita c.f. *rankiniana*



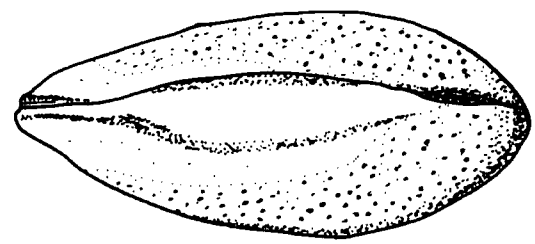
left valve



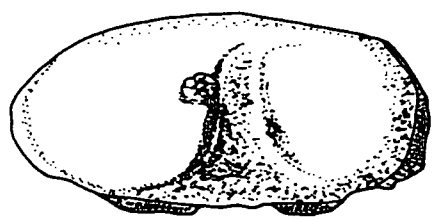
right valve



dorsal view

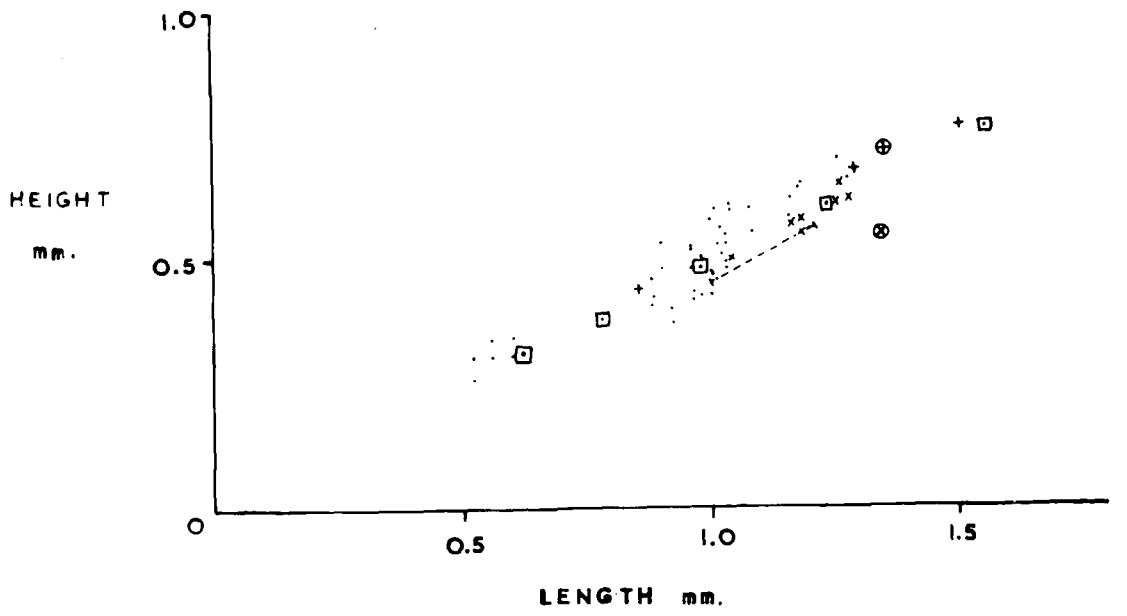


ventral view



internal mould

Figure 3.15. Graph of height and length relationships in *Carbonita* cf. *rankiniana* and related species.



CARBONITA RANKINIANA

· HOPKINS BAND SPECIMENS

⊡ MOULTS (PRZIBRAM FACTOR)

× FLOCKTON SPECIMENS

⊢---⊣ DIMENSIONS OF LATHAM 1932

\+ *C. AGNES* KPEMPE & GREBE 1955

⊕ *C. SALTERIANA* COOPER 1946

⊗ ·· ·· JONES & KIRKBY 1890

Figure 3.16. Line drawings of dimorphic forms of Carbonita humilis. x 63 approx. The figured specimens are neotypes, locality and numbers as recorded in the specific description.

Carbonita humilis

Male *Female*

left valve

right valve

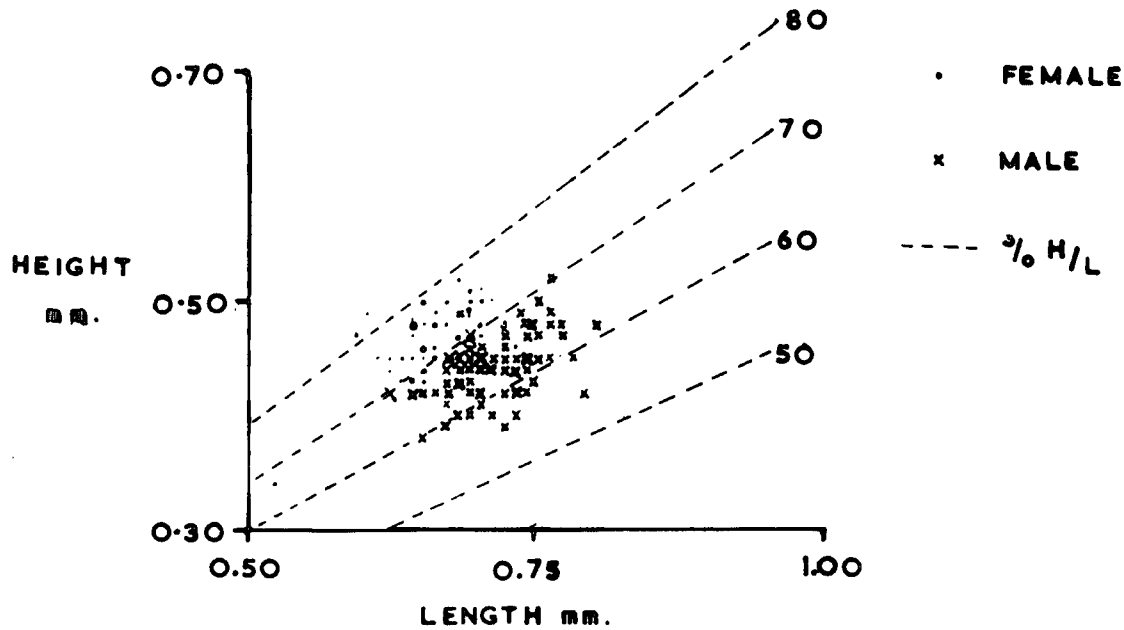
dorsal view

ventral view

Figure 3.17. Graph showing dimorphism in terms of height-length ratio in apopulation of Carbonita humilis frpm the Geisina Band at Silksworth, Co. Durham.

Figure 3.18. Line drawing of Carbonita pungens Jones and Kirkby., This specimen is from the black shale at Bearpark, BP. 105 series. x 38 approx.

DIMORPHISM IN *CARBONITA HUMILIS* FROM SILKSWORTH



Carbonita pungens

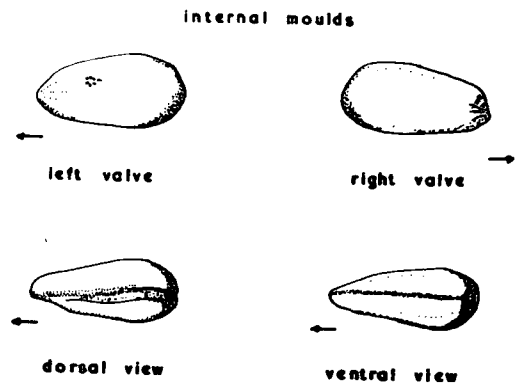
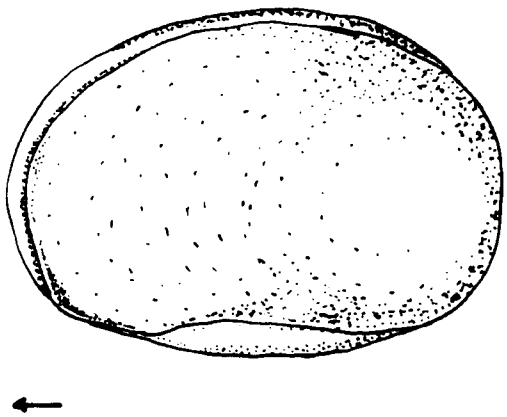
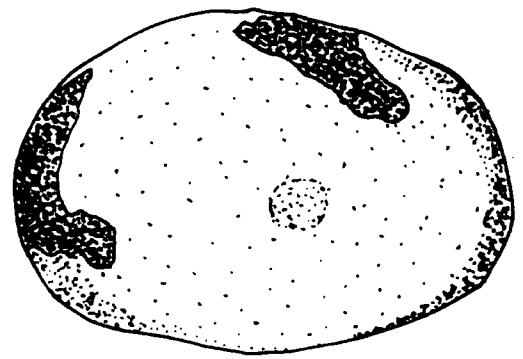


Figure 3.19. Line drawing of Carbonita inflata Jones amd Kirkby, from the Geisima Band at Hylton Colliery, Co. Durham. x 67 approx.

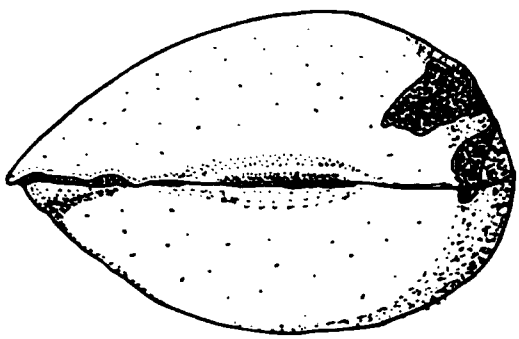
Carbonita inflata



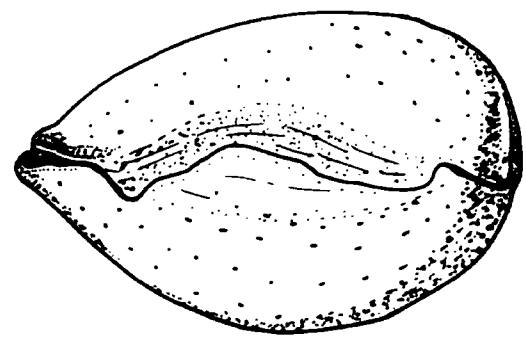
left valve



right valve



dorsal view

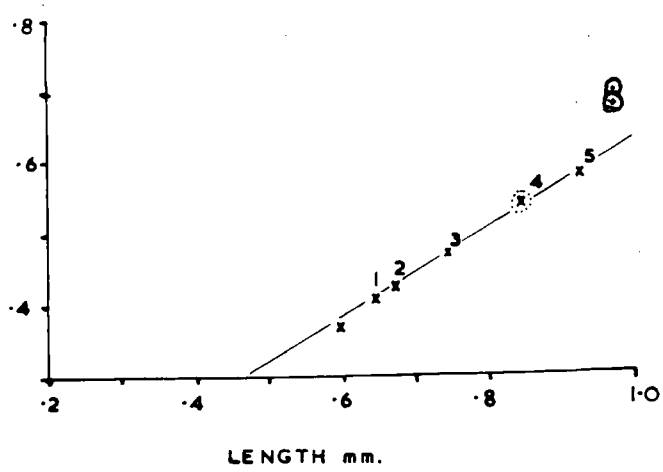


ventral view

Figure 3.20. Graph of height - length relationships in Carbonita inflata and synonomous species. (After Cooper 1946, fig.32, but redrawn with additions and corrections.)

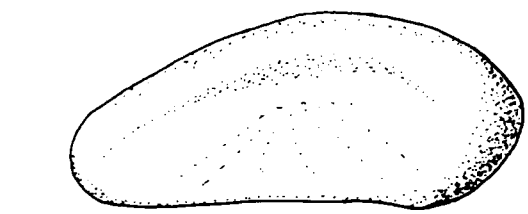
Figure 3.21. Line drawing of the internal mould of the left valve of Carbonita secans Jones and Kirkby from the black shale at Bearpark, BP. 105 series . x 60 approx.

DIMENSIONS OF *CARBONITA INFLATA*



1. Carbonita inflata COOPER 1946
2. " tumida UPSON
3. Whipplella depressa HOLLAND
4. " cuneiformis HOLLAND
5. Carbonita inflata JONES & KIRKBY
⊗ " " " " 1879
⊙ HOPKINS BAND SPECIMENS

Carbonita secans



internal mould left valve

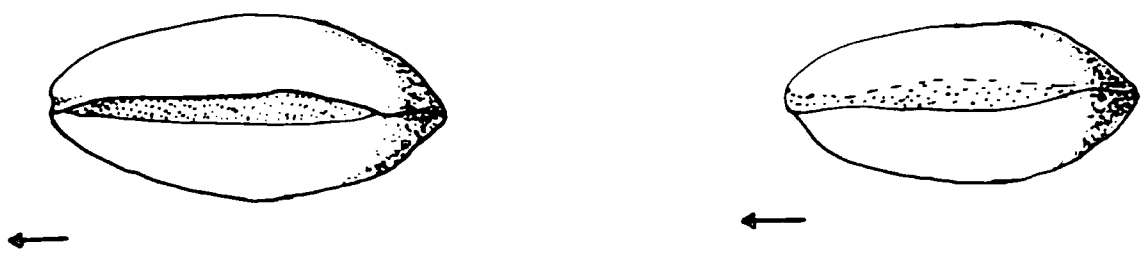
Figure 3.22. Line drawing of the internal mould of Carbonita concava Vangerow. nom. nov. x 85 approx. The specimen on the left is slide (11).10. and on the right slide (11). 11. Both specimens came from the grey mudstone above the Geisina Band at Bearpark.

Carbonita concava

internal moulds

left valve

dorsal view



ventral view

Figure 3.23. Stratigraphical horizons and species of ostracods recorded from the Durham Coal Measures. The authorities for some of these records are given in the text.

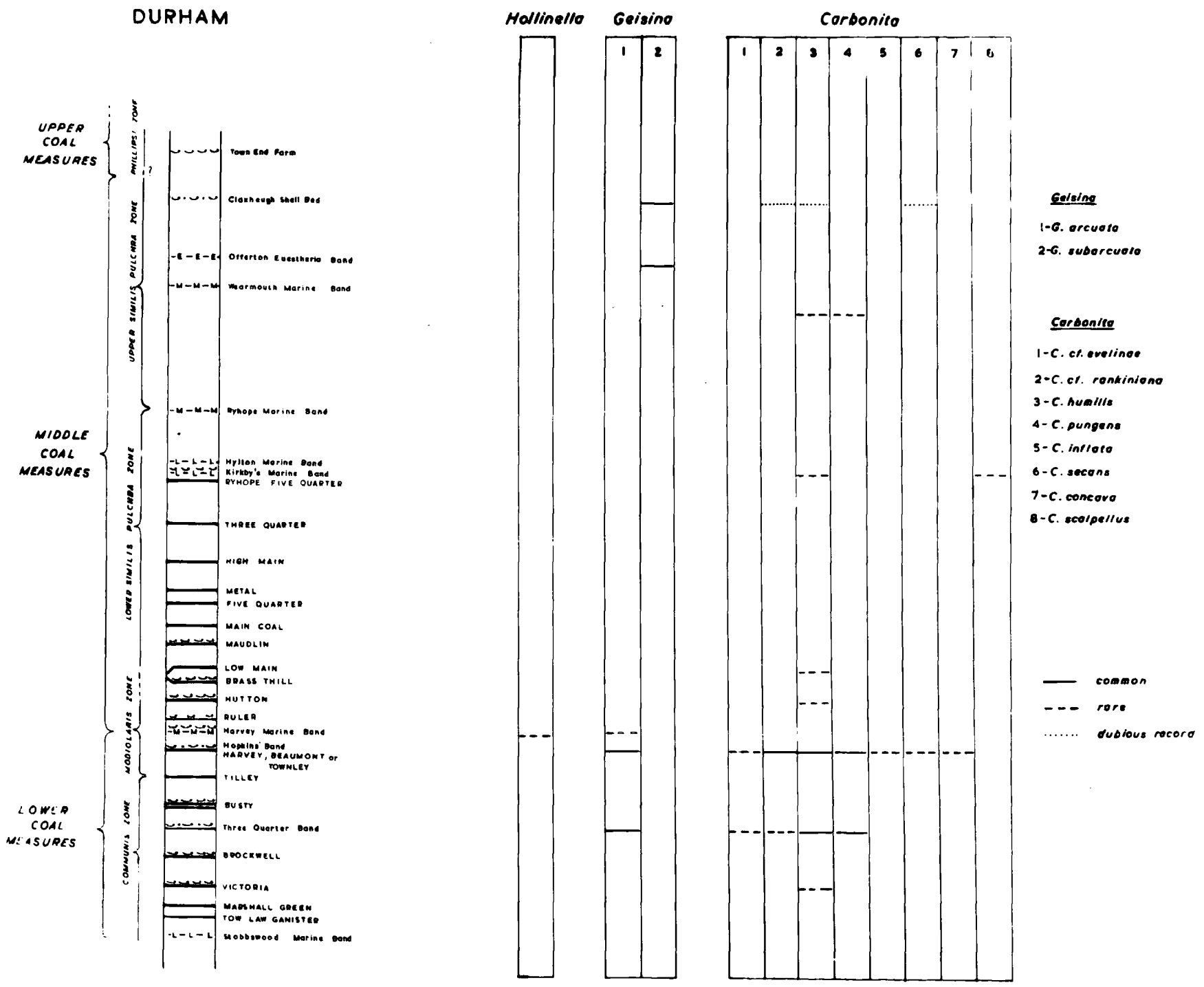
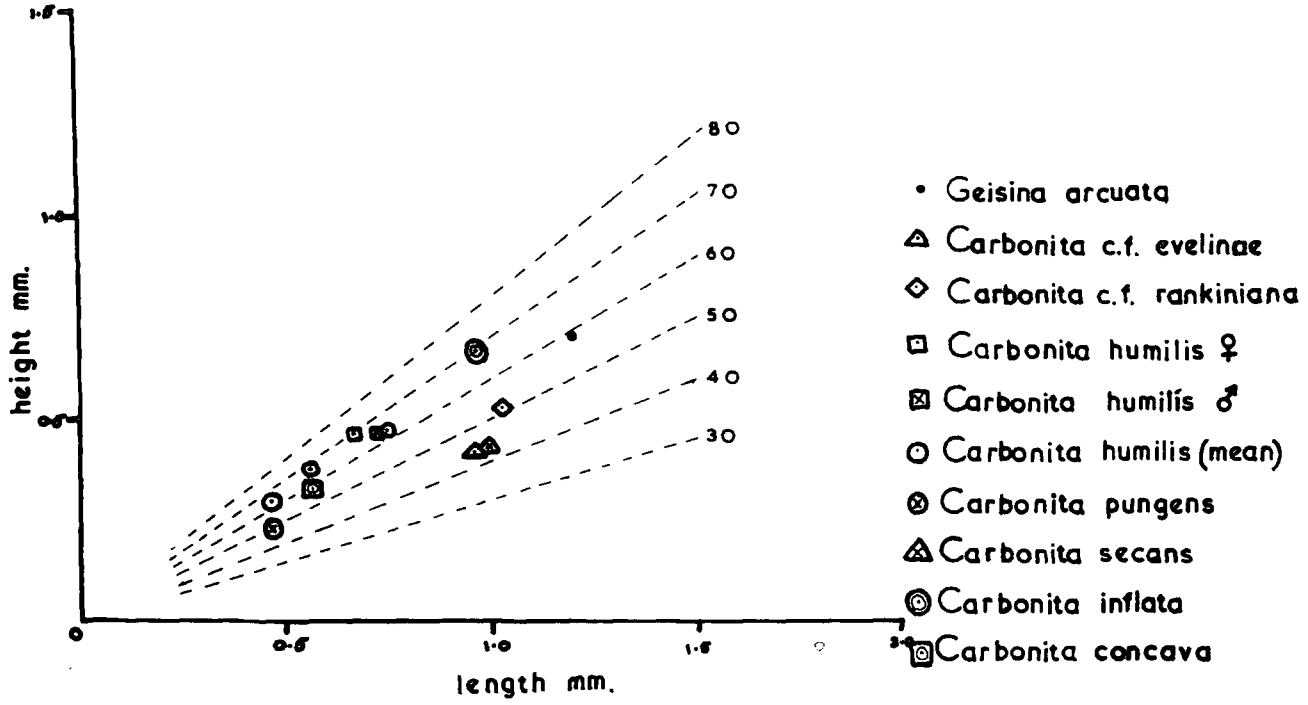

DURHAM
UPPER COAL MEASURES
MIDDLE COAL MEASURES
LOWER COAL MEASURES
PHILLIPSI ZONE
UPPER SIMILIS PULCHRA ZONE
LOWER SIMILIS PULCHRA ZONE
MODIOLARIS ZONE
COMMUNIS ZONE
Town End Farm
Cleadeugh Shell Bed
Offerton Euestheria Band
Wearmouth Marine Band
Ryhope Marine Band
Hylton Marine Band
Kirkby's Marine Band
RYHOPE FIVE QUARTER
THREE QUARTER
HIGH MAIN
METAL
FIVE QUARTER
MAIN COAL
MAUDLIN
LOW MAIN
BRASS THILL
HUTTON
RULER
Harvey Marine Band
Hopkins' Band
HARVEY, BEAUMONT or TOWNLEY
TILLEY
BUSTY
Three Quarter Band
BROCKWELL
VICTORIA
MARSHALL GREEN
TOW LAW GANISTER
Stobbswood Marine Band
Hollinella
Geisina
1
2
Carbonita
1
2
3
4
5
6
7
8
Geisina
1-G. arcuata
2-G. subarcuata
Carbonita
1-C. cf. evelinae
2-C. cf. rankiniana
3-C. humilis
4-C. pungens
5-C. inflata
6-C. secans
7-C. concava
8-C. scalpellus
common
rare
dubious record

Figure 3.24. Graph of the mean height - length dimensions of the adult and juvenile instars of the various species of ostracods found in the sediments of the Hopkins' Band from several localities.

Figure 3.25. Graph of height- length relationships of species of Carbonita found in the Geisina Band at Hylton , Co. Durham.
The instar mean positions have been extrapolated from the adult using Przibram Growth factor.
Dashed lines are percentage height of length.

Hopkins' Band ostracod population



SPECIES OF *CARBONITA* FROM HYLTON

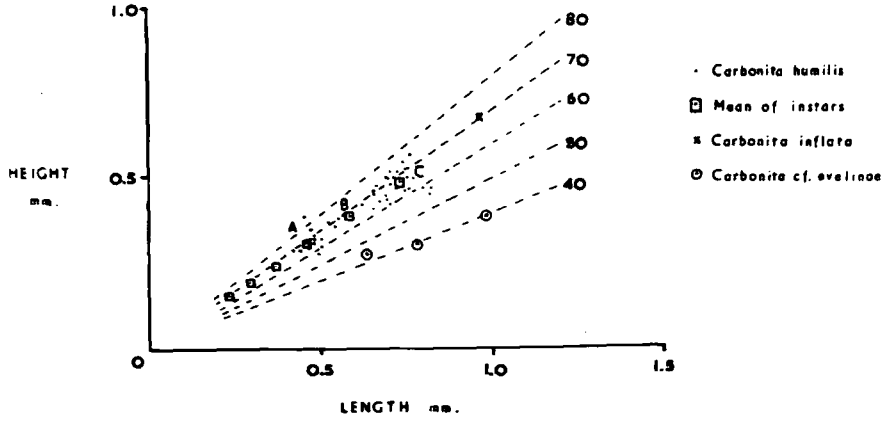


Figure 3.26. Graph of the height - length dimensions of *Geisina subarcuata* Jones , from the Claxheugh Shell Bed and ironstones from the Upper Similis-Pulchra Zone of North Staffordshire.

$H/_L$ relationships in *Geisina subarcuata*

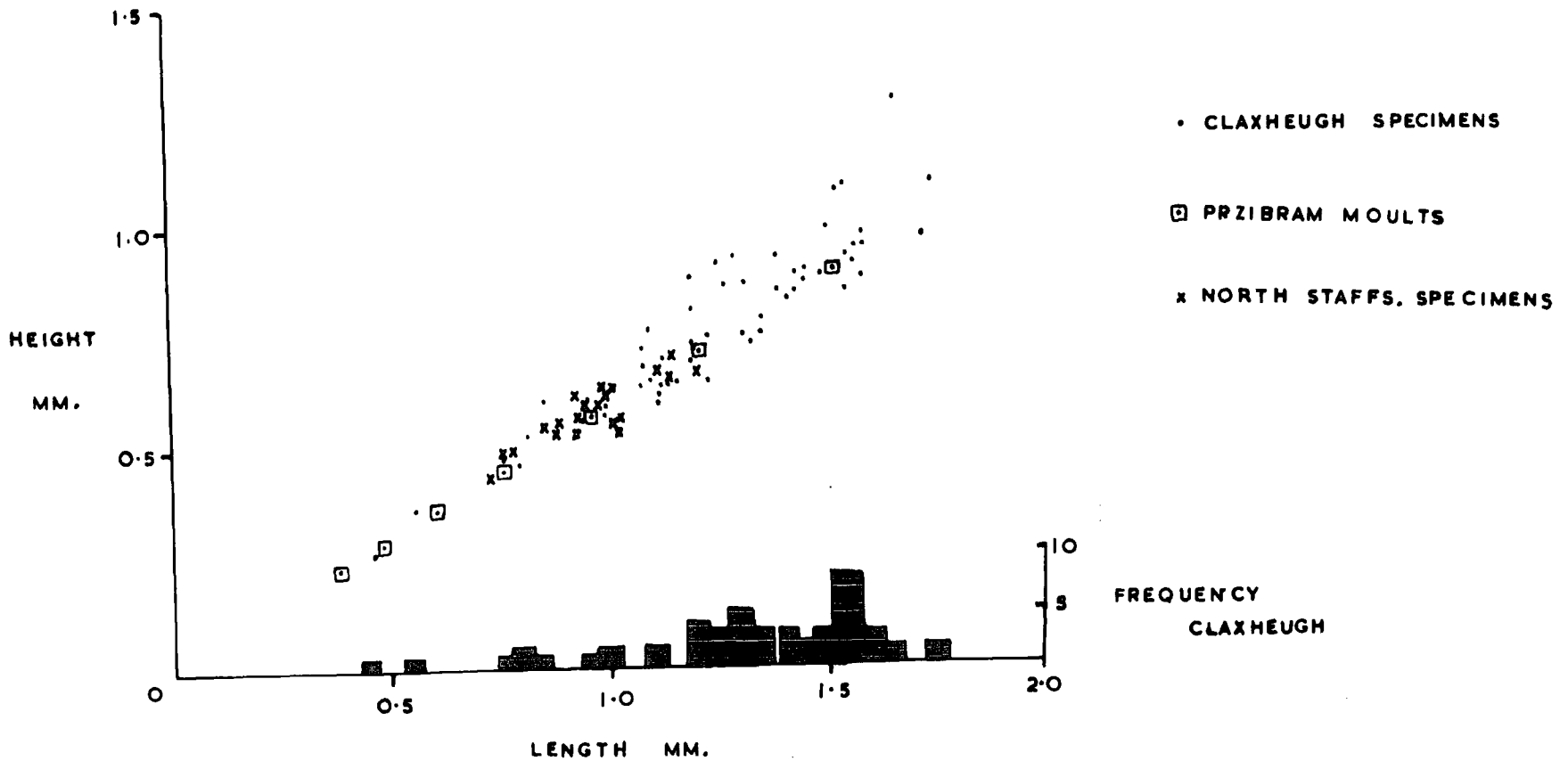


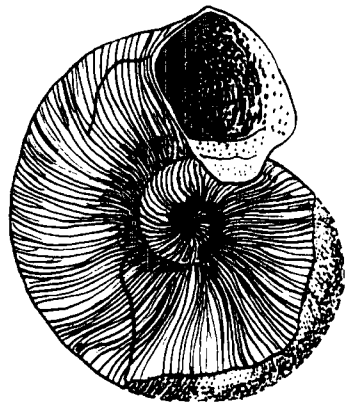
Figure 4.1. Growth forms of Microconchus (Spirorbis) pusillus Martin, from the sediments of the Hopkins' Band.

Form a. is from the Geisina Band at Fenwick Colliery, East Holywell, Northumberland.

Form b. is from the sheley mudstone above the Geisina Band at Bearpark, BP. 105. series.

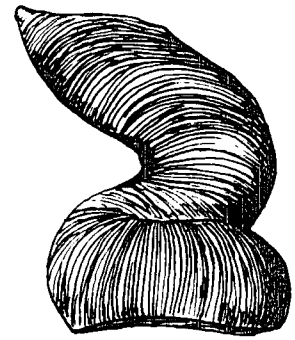
Figure 4.2. The internal mould of the tube of Microconchus (Spirorbis) pusillus from the Geisina Band at Whitworth Opencast. Co. Durham.

Microconchus (Spirorbis) pusillus



1·0mm.

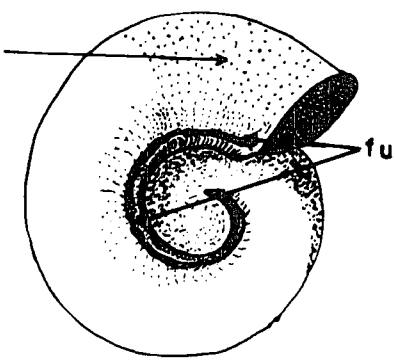
form a.



1·0mm.

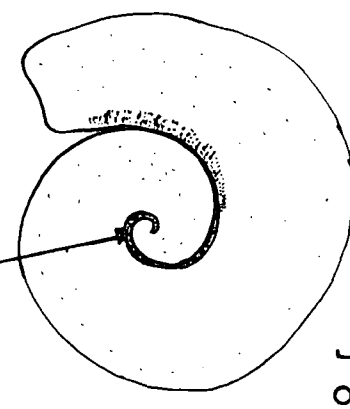
form b.

internal moulds



0·50mm.

ventral view



0·50mm.

dorsal view

Figure 4.3. Internal features and wall structure of the tube of Microconchus (Spirorbis) pusillus and Spirorbis borealis Daudin. Figs. c & d are not to scale.

Fig. a. is a shell fragment showing the internal spine from the shaley mudstone at Bearpark.

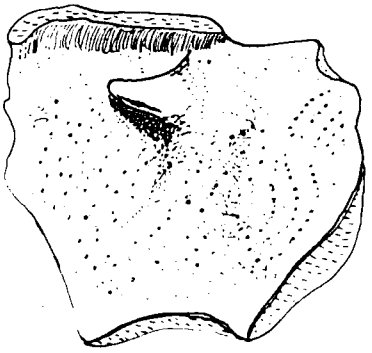
Fig. b. is a sectioned tube on slide 809 from grey shaley mudstone at Bearpark.

Fig. c. is a reconstruction of the wall structure of the tube of S. borealis, collected from the sea shore at Hartly Bay, Northumberland.

Fig. d. is a reconstruction of the tube wall of M. pusillus , from fragments and sections seen in the sediments of the Hopkins' Band.

a.

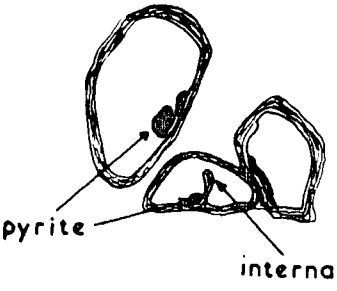
aperture →



0·50mm.

internal spine

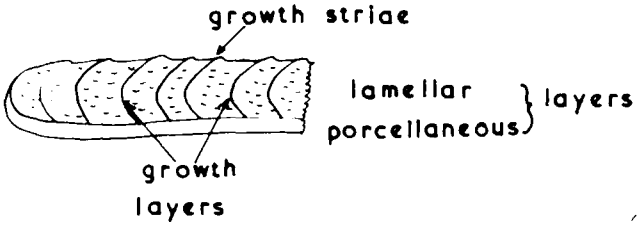
b.



0·50mm.

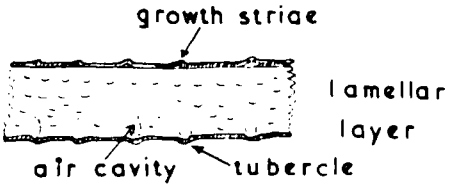
transverse section

c.



S. borealis Recent

d.



'S.' pusillus Hopkins Band

Figure 4.4. Diagram showing the correlation of lithology, relative frequence, growth form and hosts, of specimens of Microconchus (Spirorbis) pusillus in the sediments of the Hopkins' Band at Bearpark.

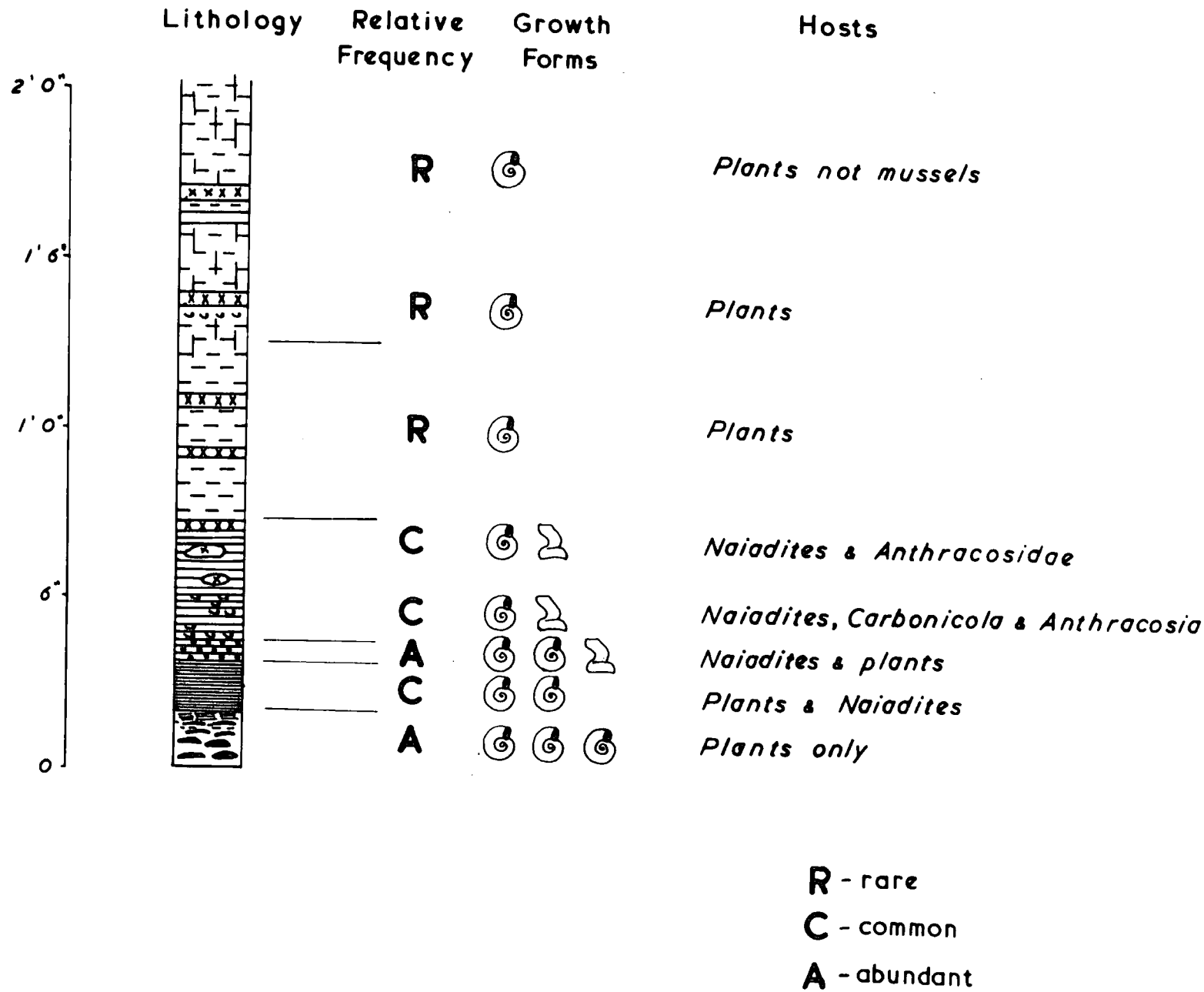
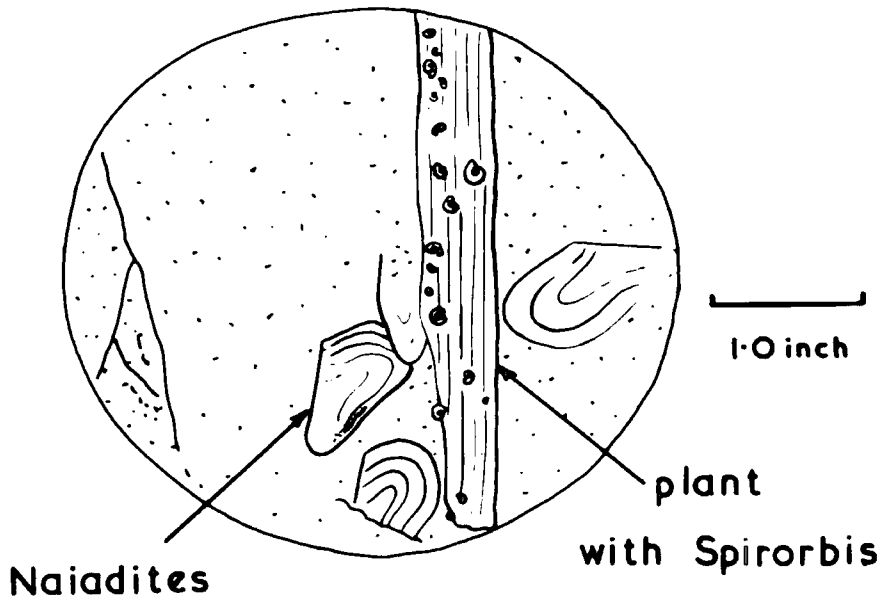

Lithology
Relative Frequency
Growth Forms
Hosts
2'0"
1'6"
1'0"
6"
0
R
R
R
C
C
A
C
A
Plants not mussels
Plants
Plants
Naiadites & Anthracosidae
Naiadites, Carbonicola & Anthracosia
Naiadites & plants
Plants & Naiadites
Plants only
R - rare
C - common
A - abundant

Figure 4.5. Tubes of M. pusillus on a Cordaites leaf, rather than a Naiadites shell in the silty mudstone above the Hopkins' Band. The specimen is from a borehole at Tynemouth pierhead, Northumberland

Figure 4.6. Reconstruction of attachment and feeding positions of M. pusillus , to explain the advantages of uncoiling in the Hopkins' Band.



Borehole core of silty mudstone

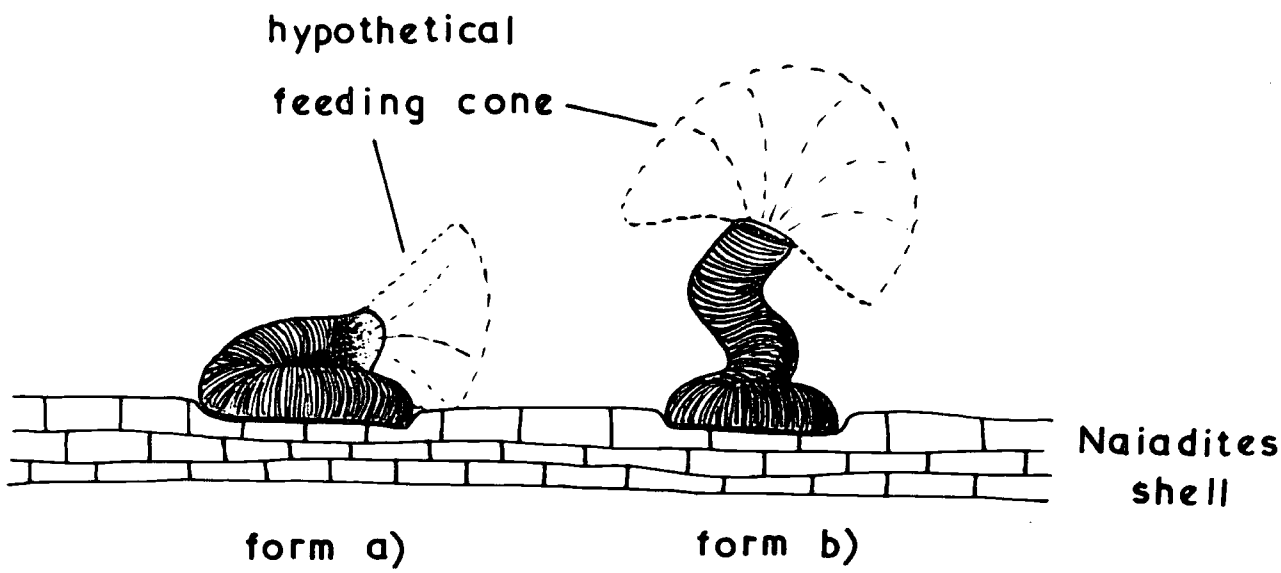


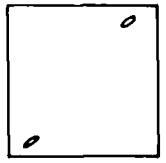
Figure 5.1. Key to the interpretation of the Faunal Phase diagrams, Figures 5.2. to 5.9.

KEY TO FAUNAL PHASE DIAGRAMS

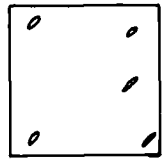
Relative Density

Description

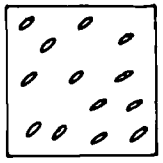
Representation



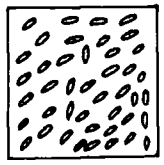
RARE



SCATTERED



COMMON



ABUNDANT

Orientation of fossils

MUSSELS

Anthracosia & *Carbonicola*

Separate valves

Joined valves

Life position

Naiadites

Parallel to bedding

Fragmented

OSTRACODS

Geisina

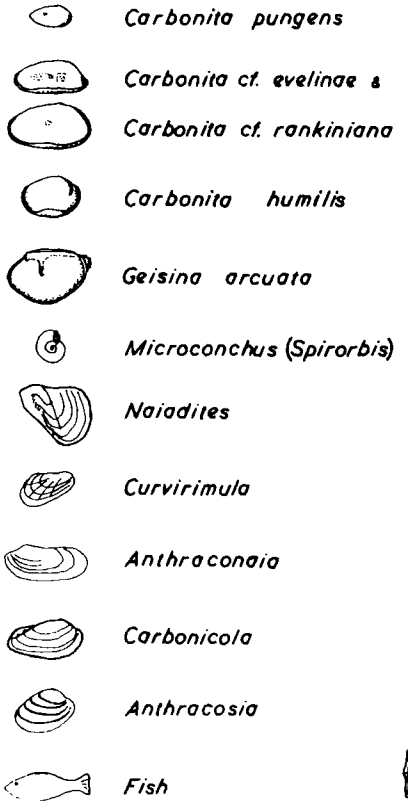
Complete carapaces

Single valves

Carbonita

Complete carapaces

Fossils represented



Carbonita pungens

Carbonita cf. evelinae &

Carbonita cf. rankiniana

Carbonita humilis

Geisina arcuata

Microconchus (Spirorbis)

Naiadites

Curvirimula

Anthraconaia

Carbonicola

Anthracosia

Fish

Lepidodendron bark

Calamites stem &

Cordaites leaves

Figure 5.2. The Faunal Phases of the Hopkins' Band at the " type section" , Bearpark, locality 6.

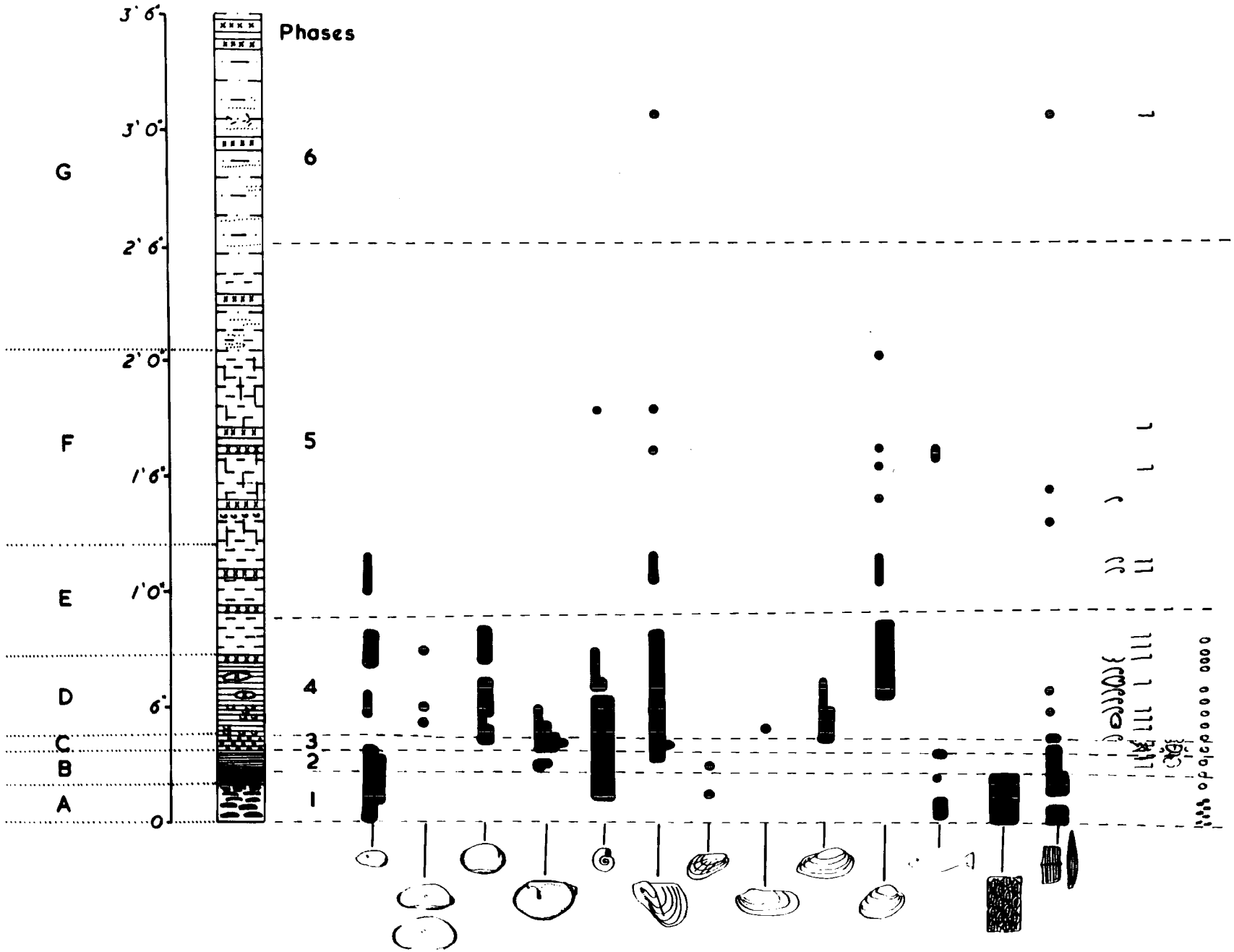

Type section : BEARPARK locality 6
Litnology
Phases
3' 6"
3' 0"
2' 6"
2' 0"
1' 6"
1' 0"
6"
0
G
F
E
D
C
B
A
6
5
4
3
2
1

Figure 5.3. The Faunal Phases of the Hopkins' Band at Whitworth Opencast, locality 7.

WHITWORTH OPENCAST locality 7

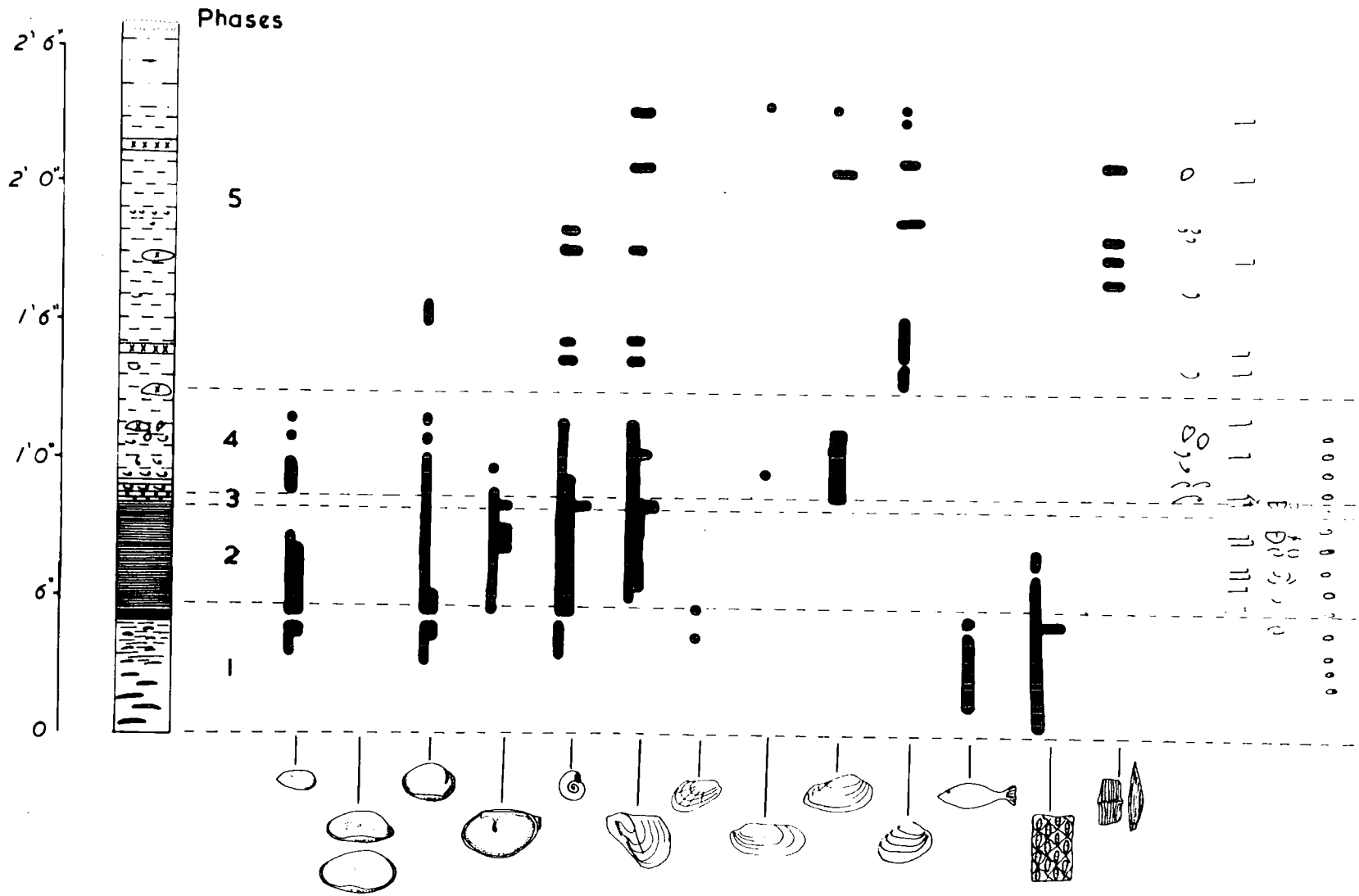


Figure 5.4. The Faunal Phases of the Hopkins' Band at Fenwick Colliery, East Holywell, Northumberland. locality 3.

EAST HOLYWELL locality 3

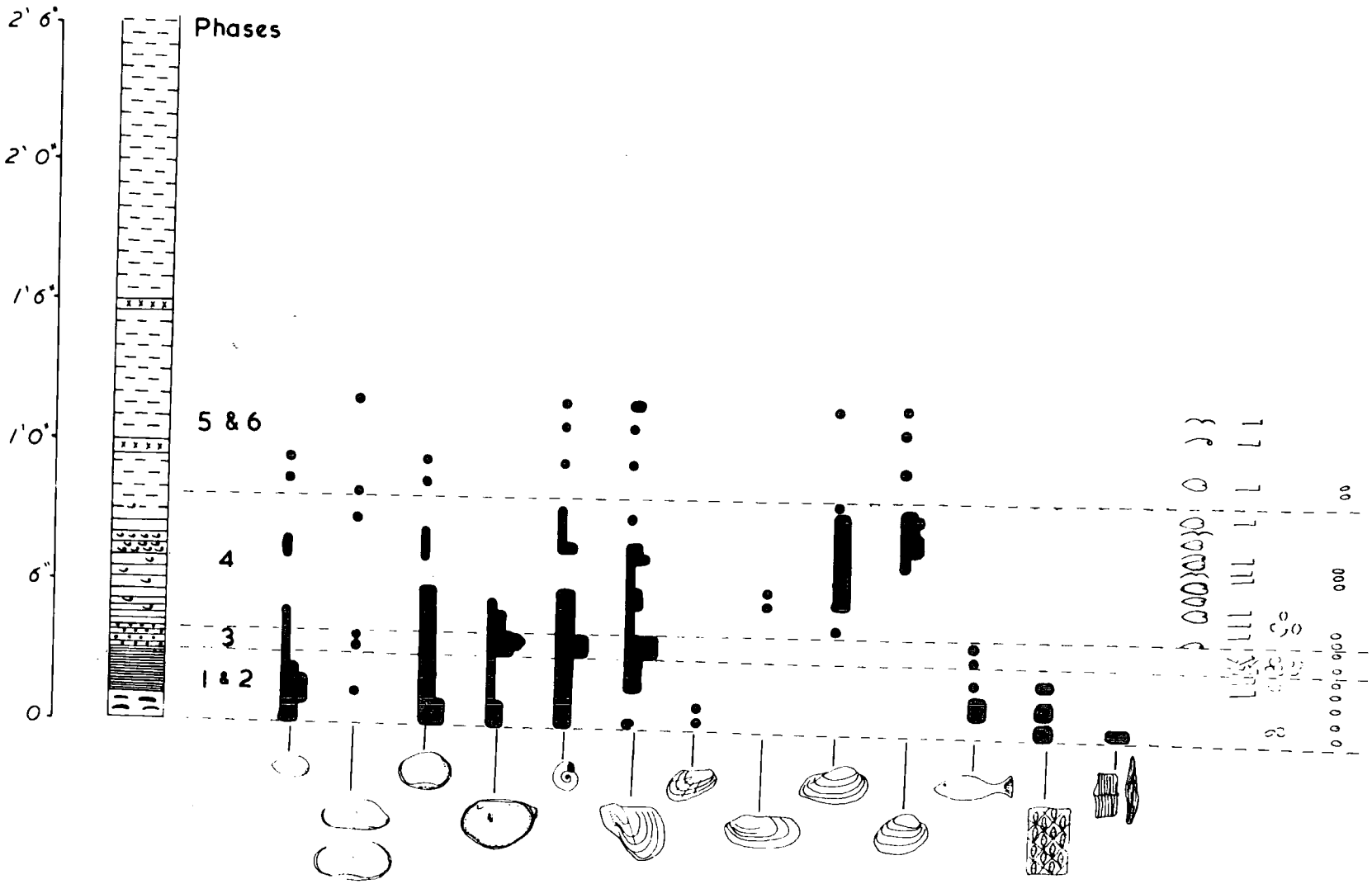


Figure 5.5. The Faunal phases of the Hopkins' Band 2½ miles north-east of Bates Pit, Blyth, Northumberland. ,locality 2.

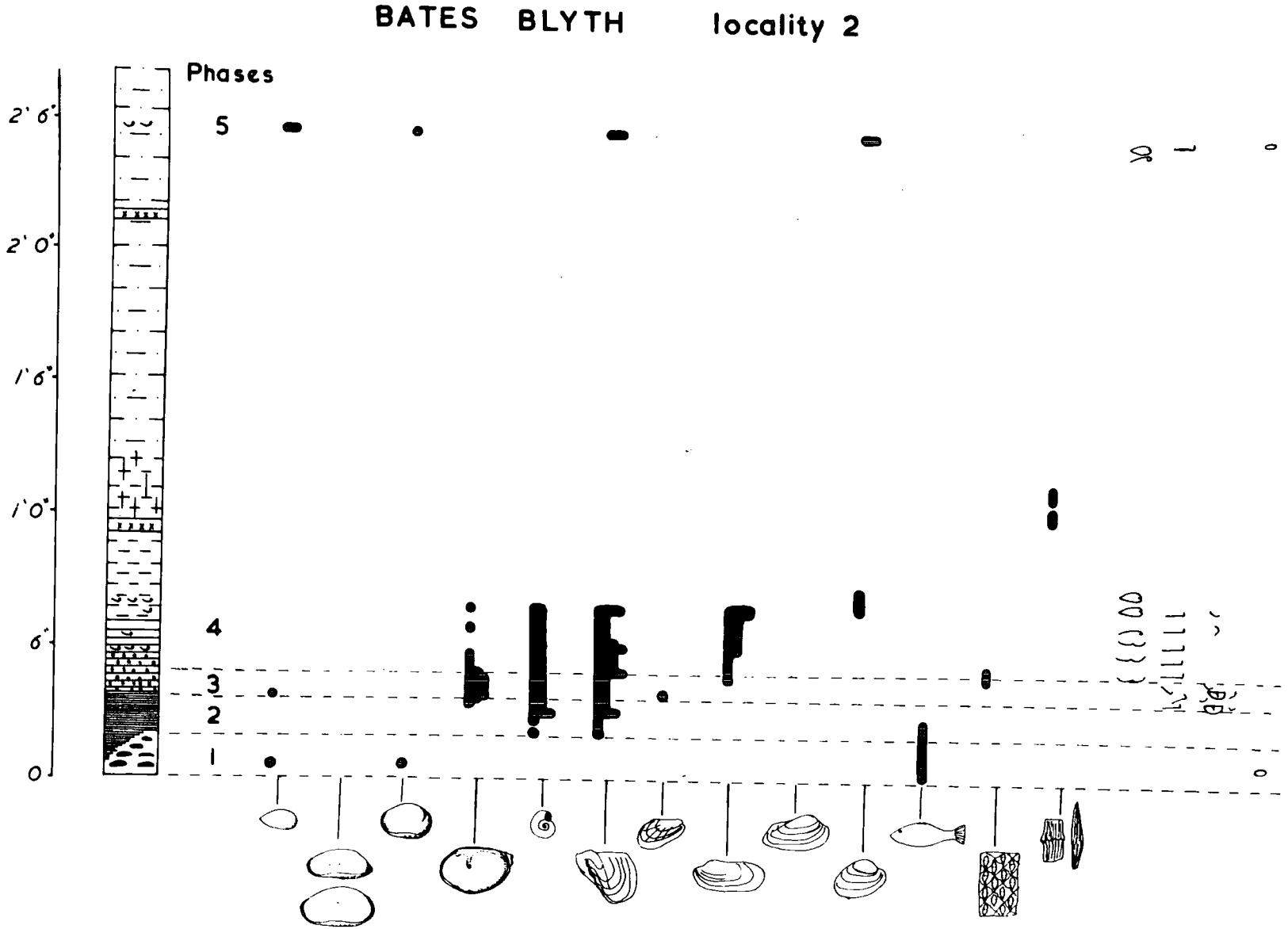

BATES BLYTH locality 2
Phases
5
4
3
2
1
2' 6"
2' 0"
1' 6"
1' 0"
6"
0

Figure 5.6. The Faunal Phases of the Hopkins' Band at Silksworth, locality 14.

SILKSWORTH locality 14

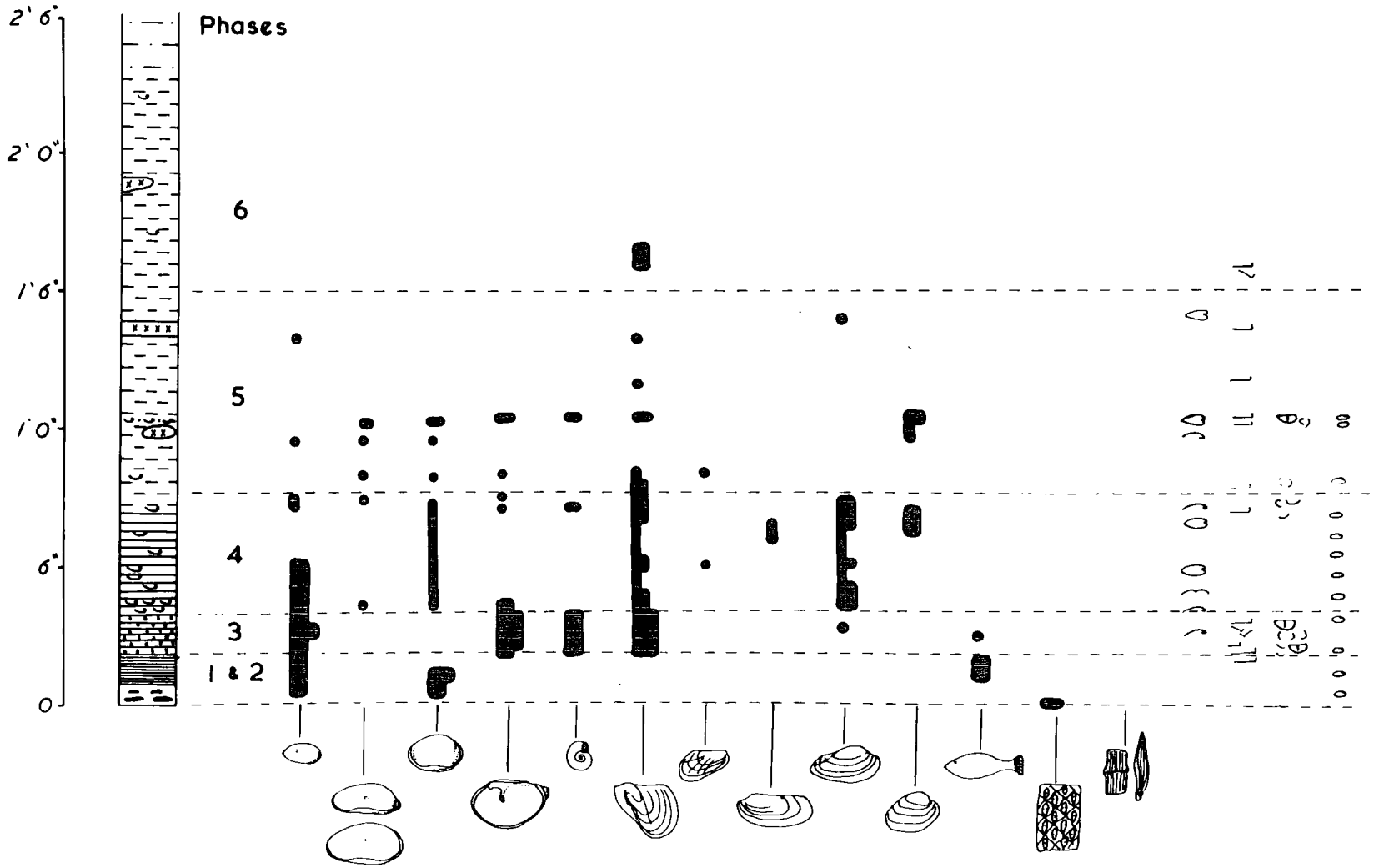


Figure 5.7. Faunal distribution in strata equivalent to the Hopkins' Band at Lanchester, locality 17.

LANCHESTER locality 17

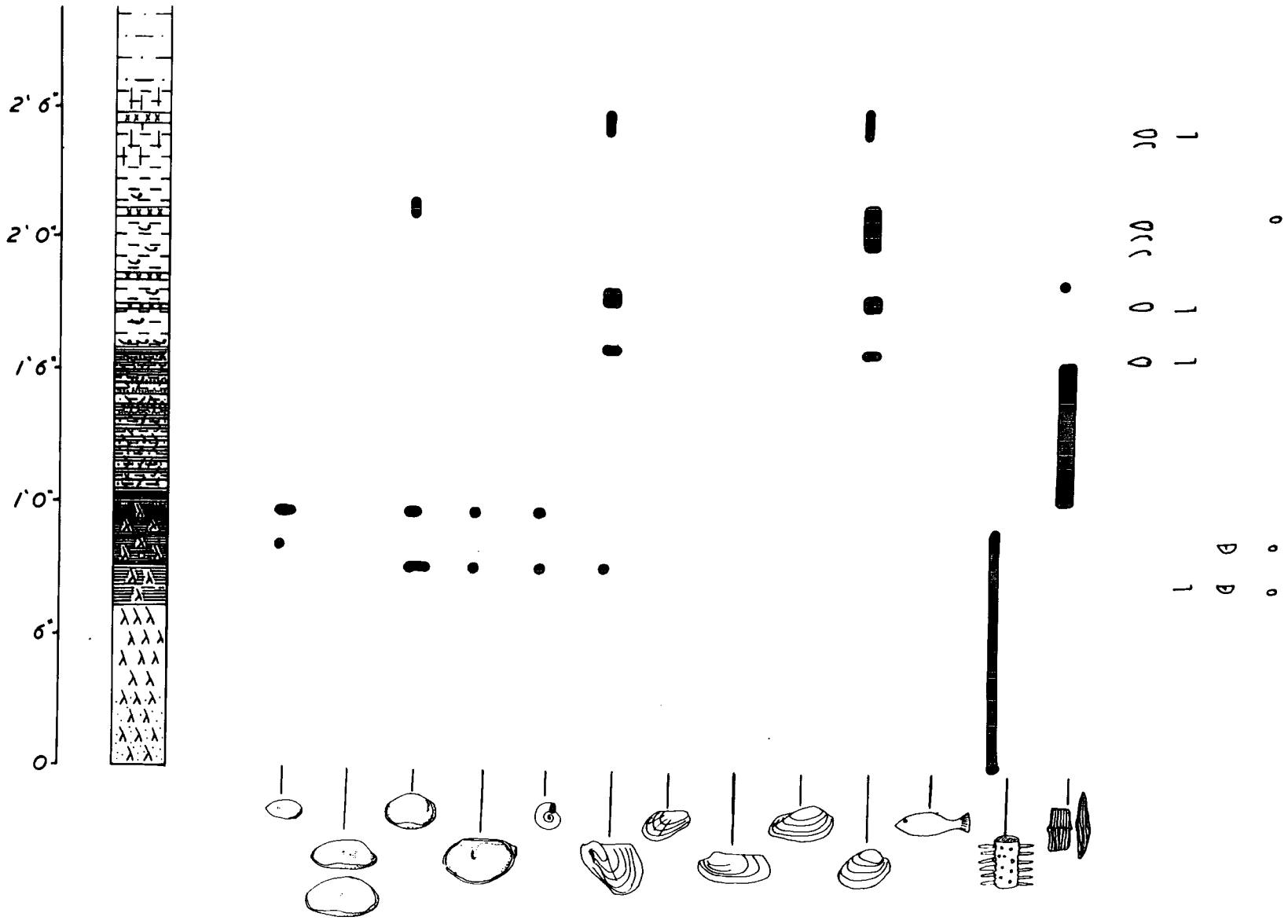


Figure 5.8. Faunal distribution in the channel succession equivalent to the Hopkins' Band at Hedley Park, locality 9.

HEDLEY PARK locality 9

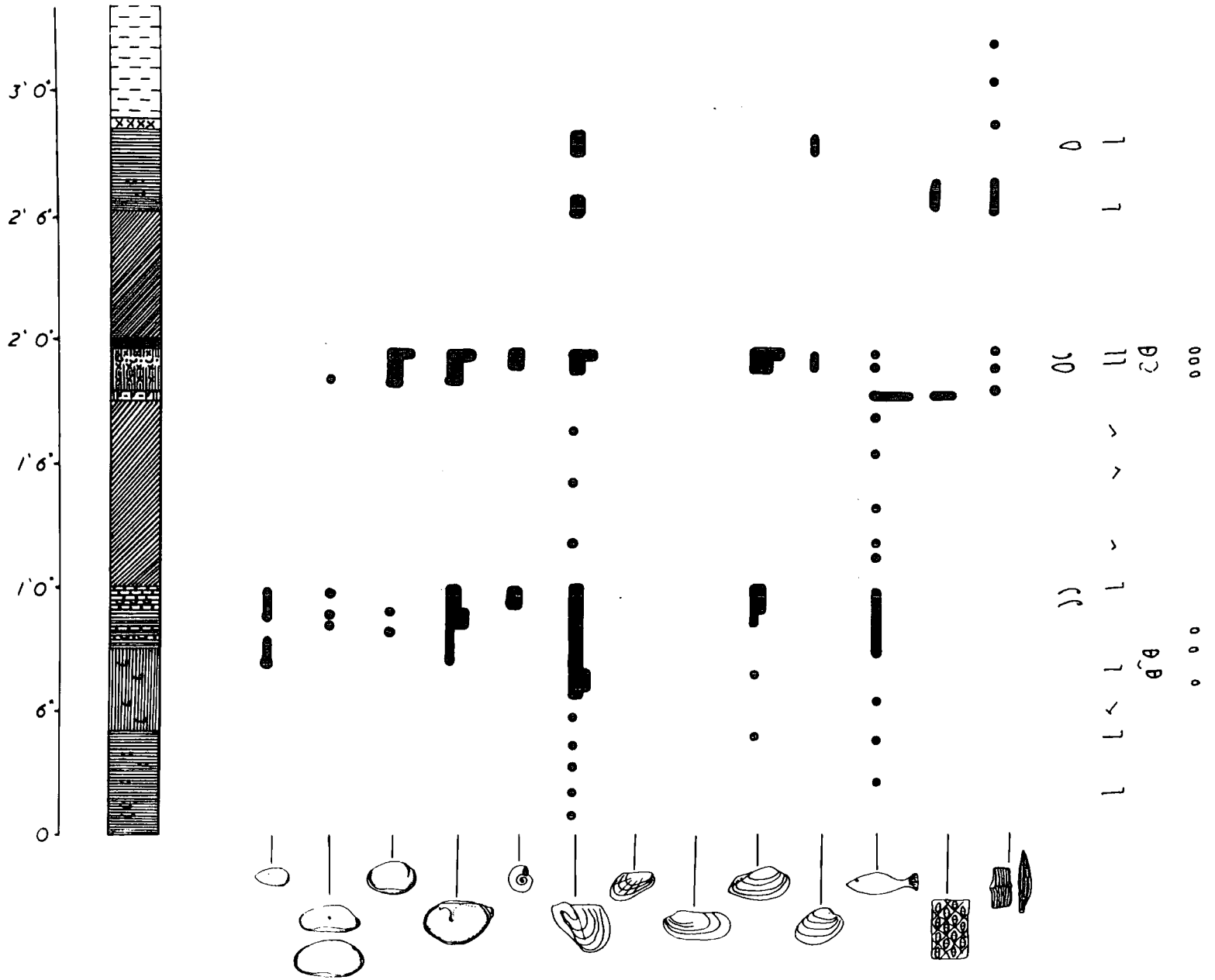


Figure 5.9. The Faunal Phases of the Three Quarter ostracod-mussel Band in borehole Fishburn 7.
(Symbolism and indexing of lithologies as for the Hopkins' Band diagrams.)

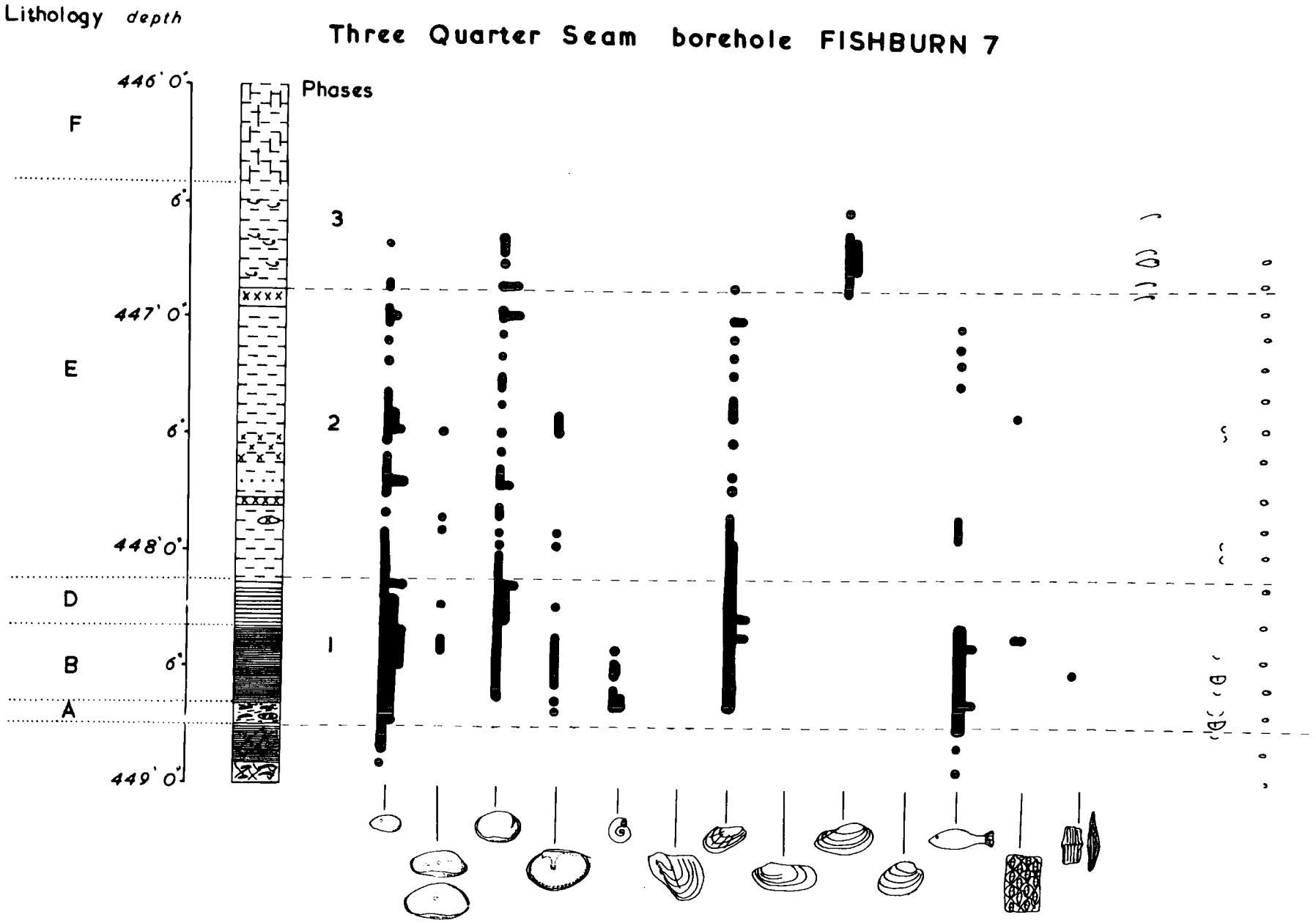

Lithology depth
Three Quarter Seam borehole FISHBURN 7
446' 0"
F
6"
447' 0"
E
6"
448' 0"
D
B
6"
A
449' 0"
Phases
3
2
1

Figure 6.1. Comparison of X-ray mineralogical data and petrographic details of the sediments including the Hopkins' Band at Bearpark " type section", sampled in BP. 105 series.

The X-ray data is derived from the samples lettered A1 to V in the left hand column , while petrographic details are from slides 800 - 824 in the right hand column. Numbers on the X-ray lines refer to the 2θ angle of the peak represented.

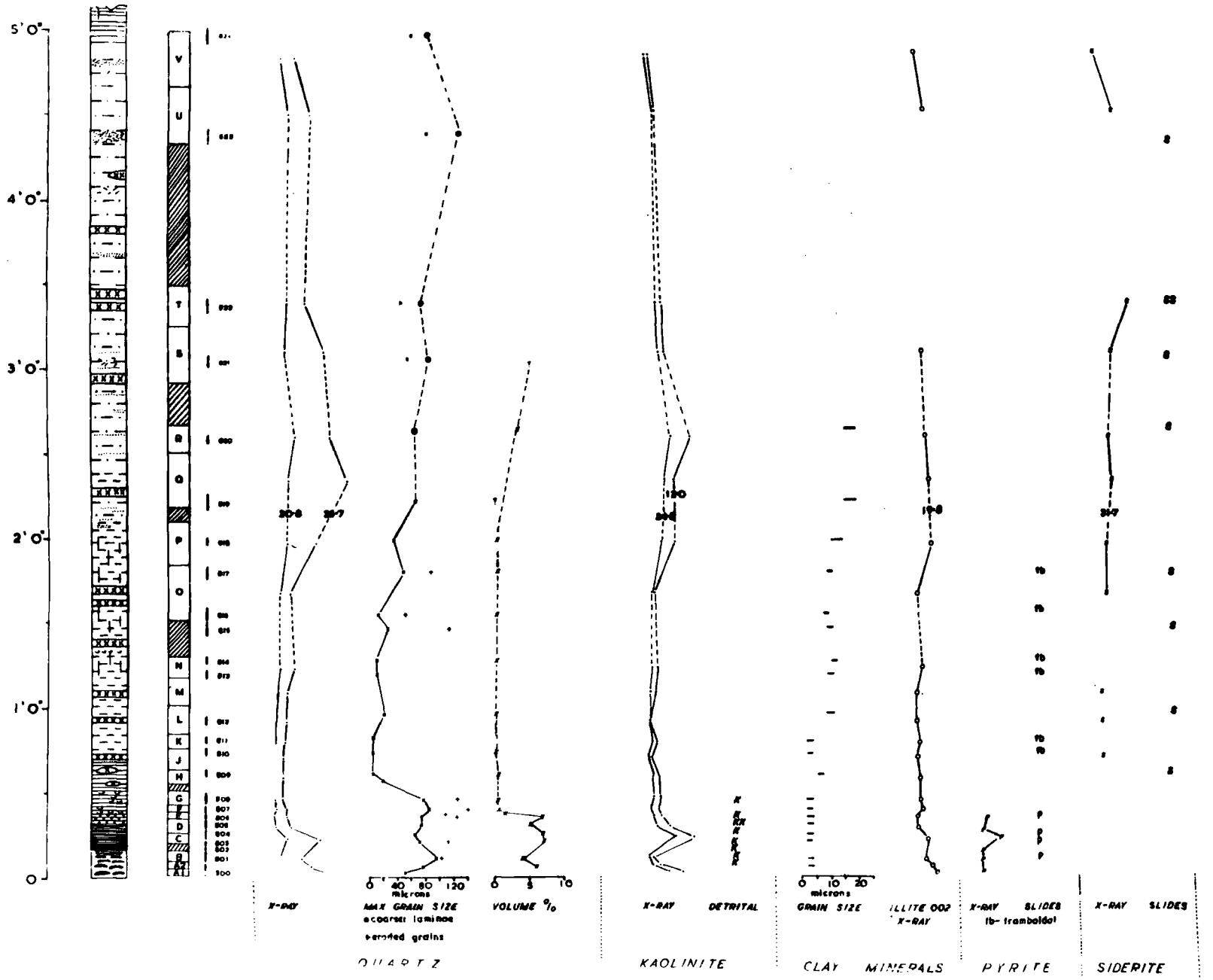

5'0"
4'0"
3'0"
2'0"
1'0"
0
X-RAY
MAX GRAIN SIZE
coarser laminae
eroded grains
0 40 80 120
microns
VOLUME %
0 5 10
QUARTZ
X-RAY
DETRITAL
KAOLINITE
GRAIN SIZE
0 10 20
microns
ILLITE 002
X-RAY
CLAY MINERALS
X-RAY
SLIDES
fb- framboidal
PYRITE
X-RAY
SLIDES
SIDERITE

Figure 7.1. Typical X-ray diffraction patterns of the sediments , including the Hopkins' Band , sampled at Bearpark in BP. 105 series. Each sample represents a particular lithological type.

The lowest two defractometer traces, A2 & C , have a greater background intensity as no discriminator was used on the defractometer.

Exposure details : CuK radiation at a speed of $\frac{1}{2}^{\circ}$ 2θ per minute, chart speed 400 mm. per hour.

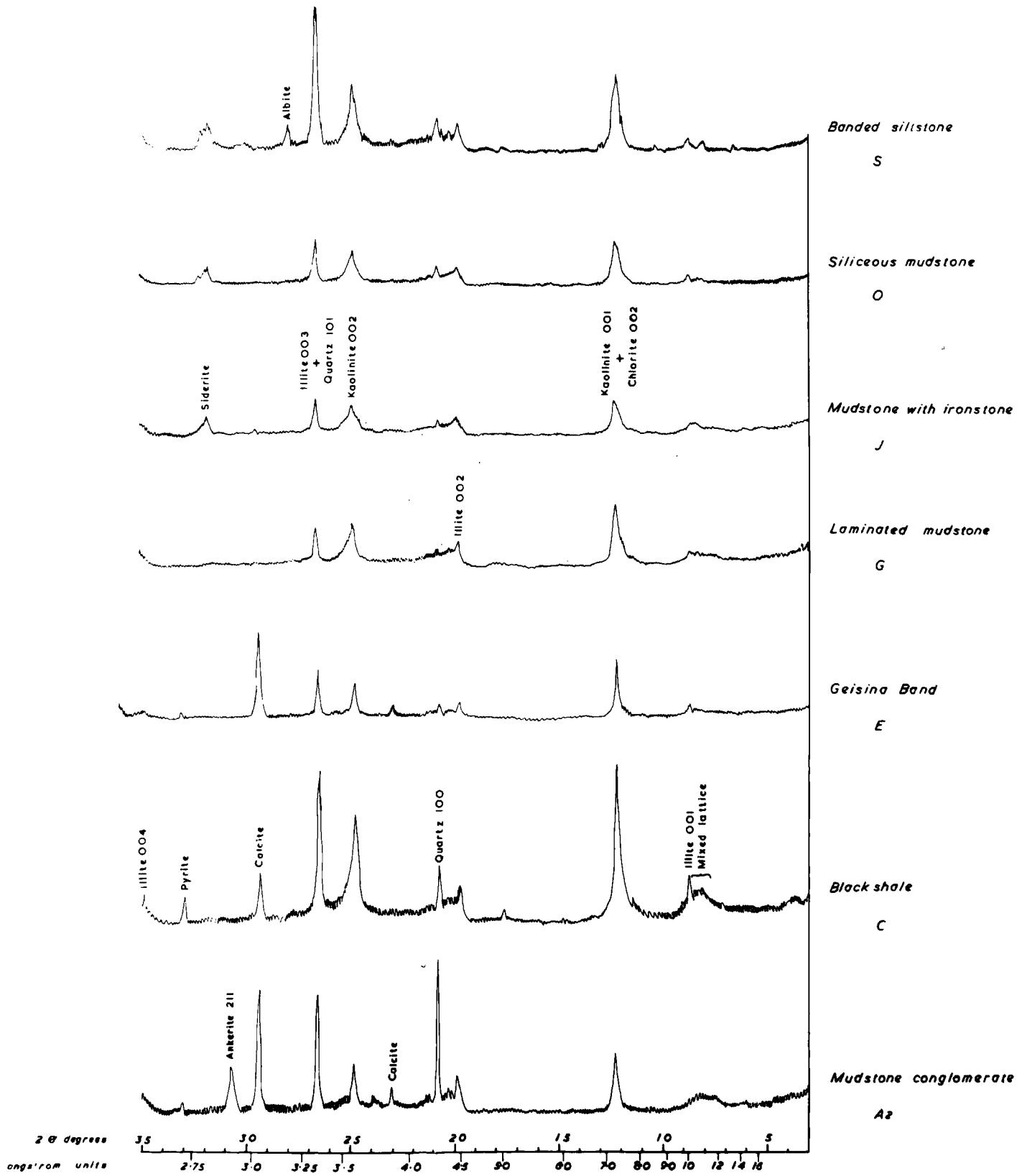

Albite
Banded siltstone
S
Siliceous mudstone
O
Siderite
Illite 003
+
Quartz 101
Kaolinite 002
Kaolinite 001
+
Chlorite 002
Mudstone with ironstone
J
Illite 002
Laminated mudstone
G
Geisina Band
E
Illite 004
Pyrite
Calcite
Quartz 100
Illite 001
Mixed lattice
Black shale
C
Ankerite 211
Calcite
Mudstone conglomerate
A2
2 θ degrees
35
30
25
20
15
10
5
ongs'rom units
2·75
3·0
3·25
3·5
4·0
4·5
5·0
6·0
7·0
8·0
9·0
10
12
14
18

Figure 7.2. Comparison of X-ray diffraction and petrographic details of the fossiliferous sediments of the Hopkins' Band at Bearpark, "type section".

The X-ray data is provided by 17 vertical samples in the BP. 17 series, and petrographic details from the 17 thin sections shown.

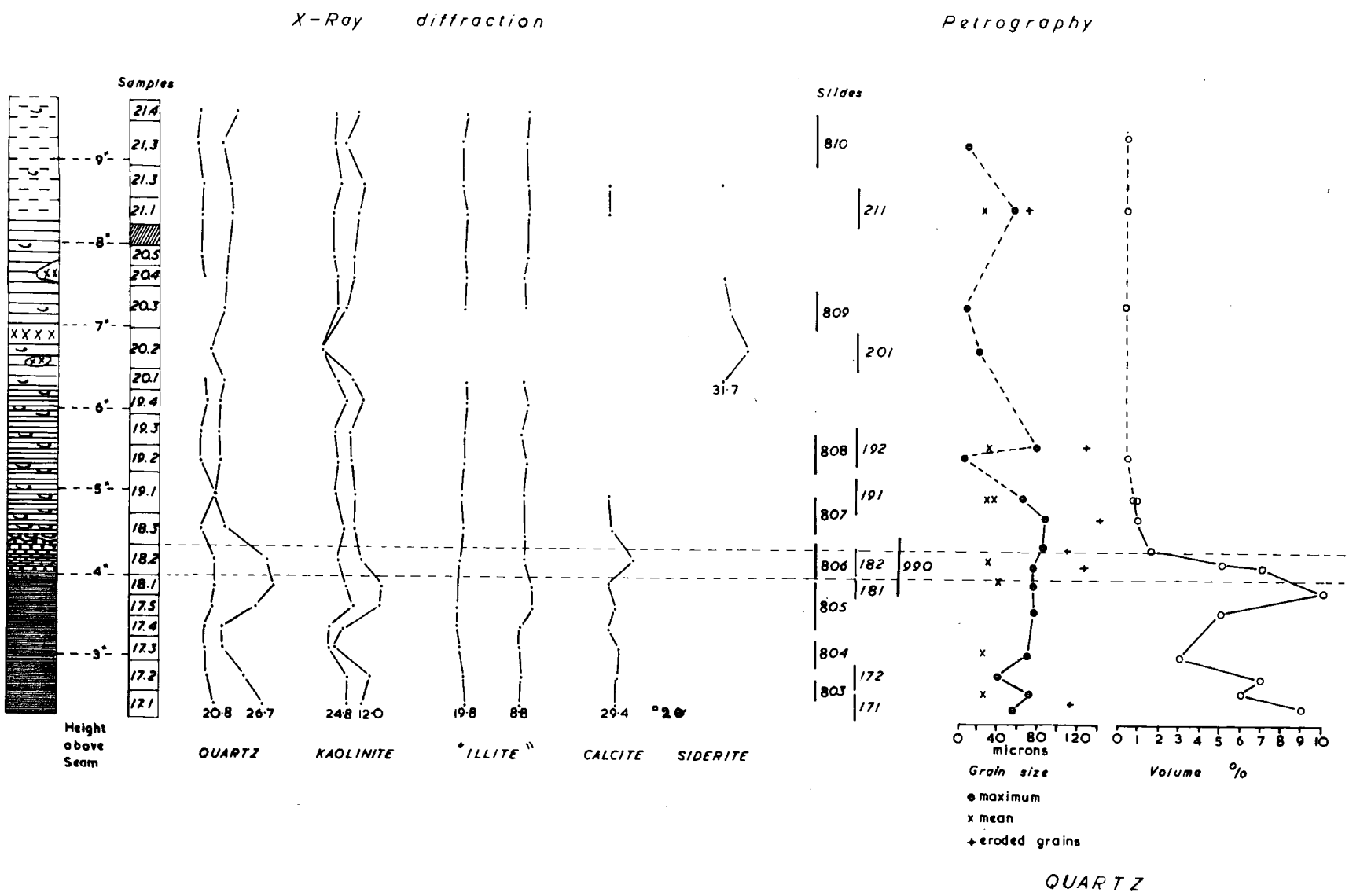

X-Ray diffraction
Petrography
Samples
Slides
9'
8'
7'
6'
5'
4'
3'
21.4
21.3
21.3
21.1
20.5
20.4
20.3
20.2
20.1
19.4
19.3
19.2
19.1
18.3
18.2
18.1
17.5
17.4
17.3
17.2
17.1
810
211
809
201
808
192
191
807
806
182
181
805
804
803
172
171
990
20·8 26·7
24·8 12·0
19·8 8·8
29·4
31·7
Height above Seam
QUARTZ
KAOLINITE
"ILLITE"
CALCITE
SIDERITE
0 40 80 120
microns
Grain size
0 1 2 3 4 5 6 7 8 9 10
Volume %
maximum
mean
eroded grains
QUARTZ

Figure 7.3. Variation in chemical composition of the sediments including the Hopkins' Band at Bearpark sampled in the BP. 105 series.

Samples lettered A1 to V and cross-hatched areas indicate unsampled strata. The lithological symbolism as on Figure 1.5.a. The absolute chemical compositions are recorded in Appendix III.

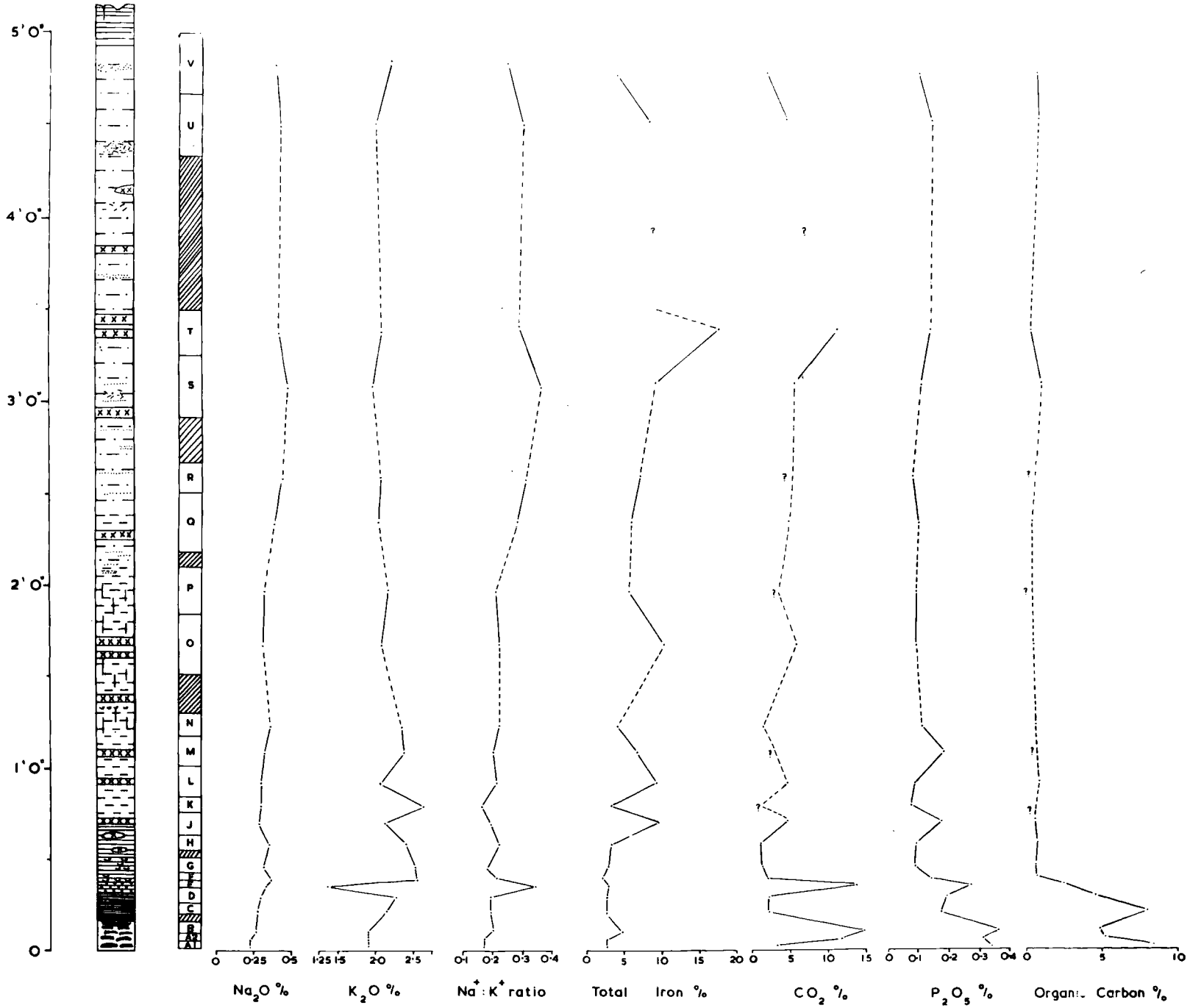

5'0"
4'0"
3'0"
2'0"
1'0"
0
V
U
T
S
R
Q
P
O
N
M
L
K
J
H
G
F
E
D
C
B
A
0 0·25 0·5
Na2O %
1·25 1·5 2·0 2·5
K2O %
0·1 0·2 0·3 0·4
Na+ : K+ ratio
0 5 10 15 20
Total Iron %
0 5 10 15
CO2 %
0 0·1 0·2 0·3 0·4
P2O5 %
0 5 10
Organic Carbon %

Figure 7.4. Eh - pH stability fields for $Fe(OH)_3$, $FeCO_3$ and FeS at 20°C and 1 atmosphere pressure for $[\Sigma$ dissolved sulphur ionic species$] = 10^{-3}$ mols/litre and $[\Sigma$ dissolved carbonate ionic species$] = 10^{-3}$ mols / litre.

The probable chemical conditions in the Bearpark sediments are shown by the points, A, B, C, & D.

(After Nicholls and Loring 1962, fig.4, with additions .)

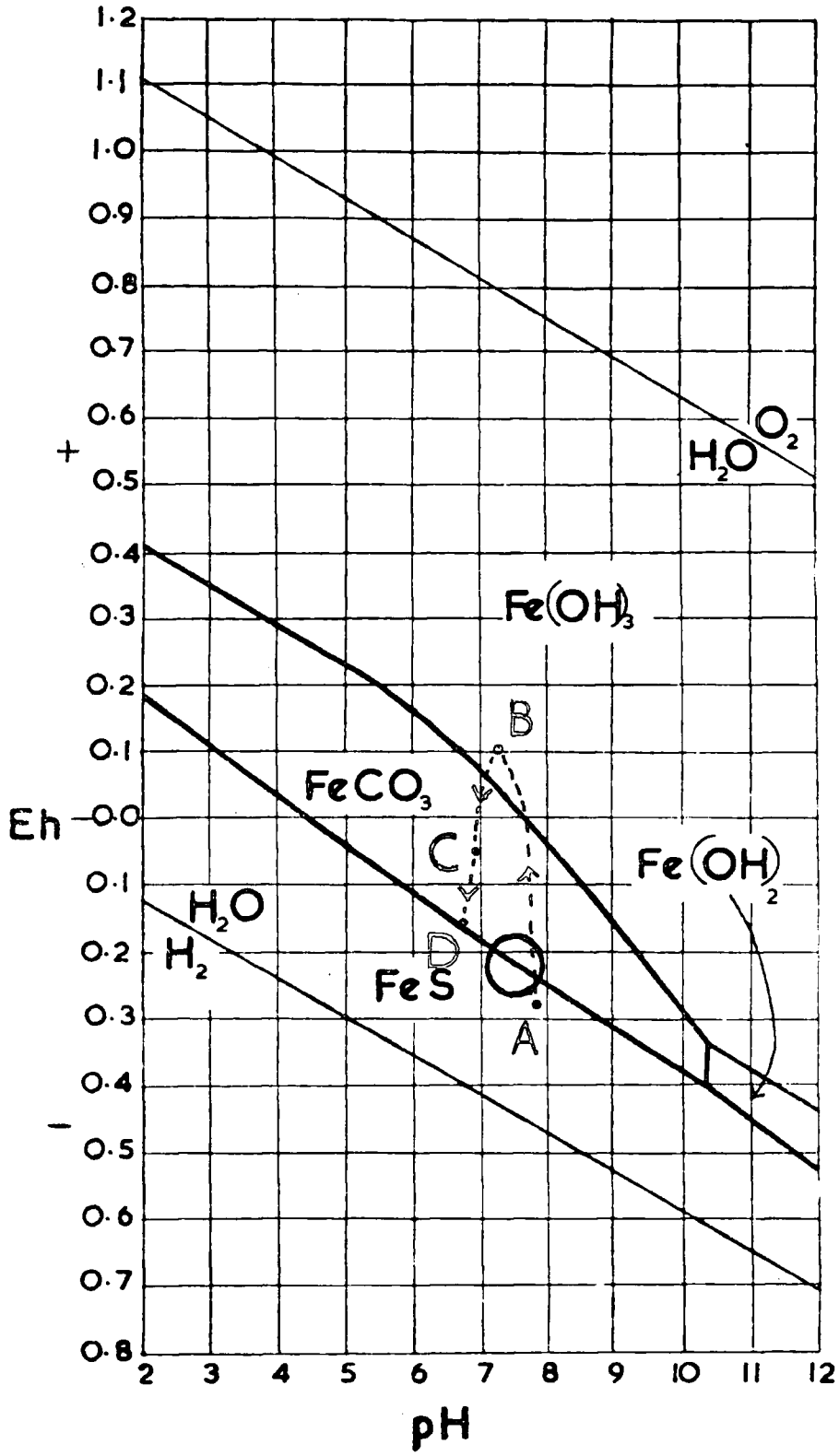

1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
+
Eh
−
2
3
4
5
6
7
8
9
10
11
12
pH
H_2O O_2
$Fe(OH)_3$
$FeCO_3$
$Fe(OH)_2$
H_2O
H_2
FeS
A
B
C
D

Figure 7.5. Sedimentary associations in relation to environmental limitations imposed by oxidation potential (Eh) and pH.
(After Mason 1958, fig. 33.)

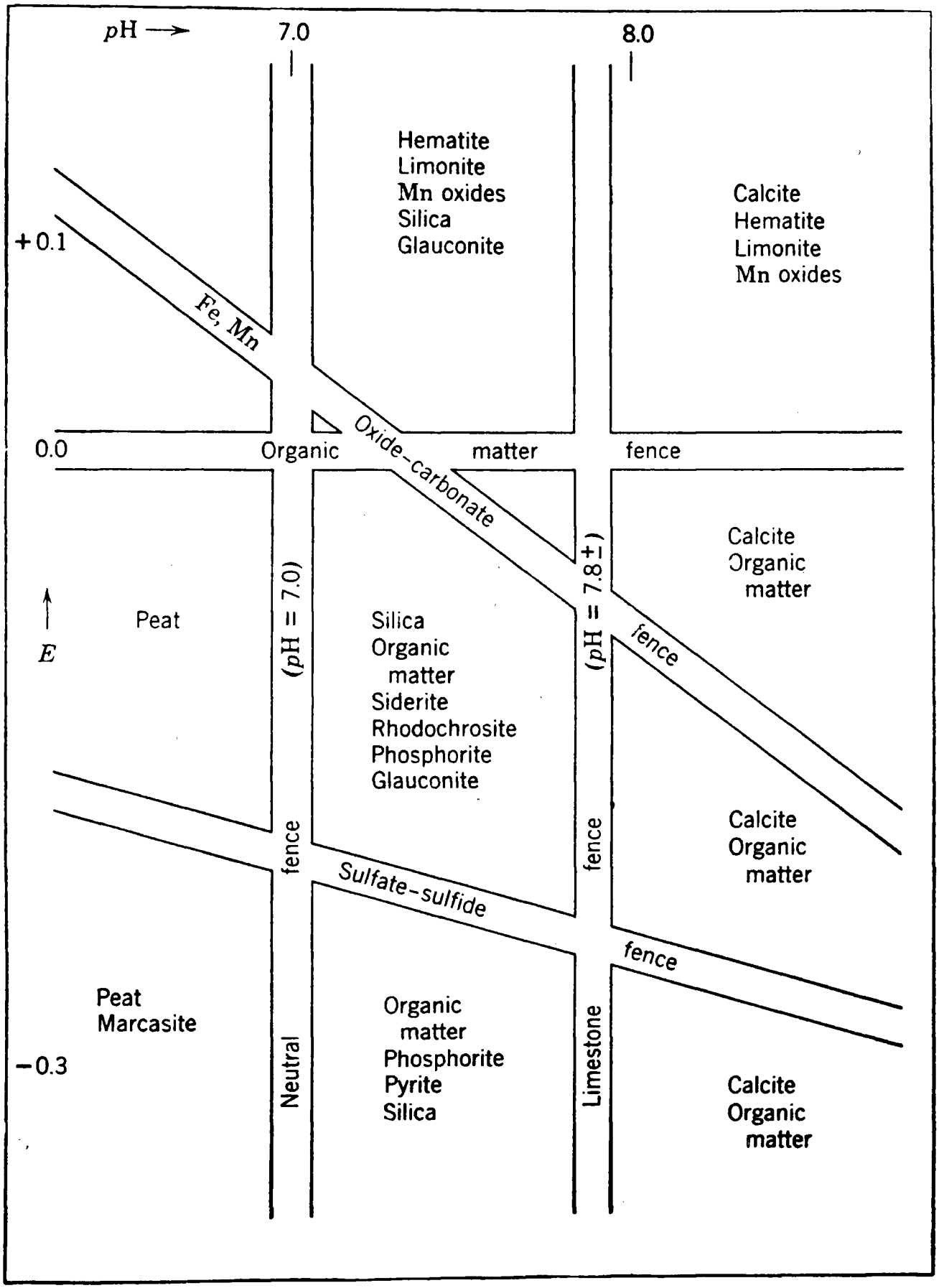

pH →
7.0
8.0
Hematite
Limonite
Mn oxides
Silica
Glauconite
Calcite
Hematite
Limonite
Mn oxides
+0.1
Fe, Mn
0.0
Organic
matter
fence
Oxide–carbonate
Calcite
Organic
matter
E
Peat
(pH = 7.0)
Silica
Organic
matter
Siderite
Rhodochrosite
Phosphorite
Glauconite
(pH = 7.8±)
fence
Calcite
Organic
matter
fence
Sulfate–sulfide
fence
Peat
Marcasite
−0.3
Neutral
Organic
matter
Phosphorite
Pyrite
Silica
Limestone
Calcite
Organic
matter

Figure 8.1. Diagram to illustrate the possible course of burial and preservation of mussel shells after death, related to sedimentation rate and compaction of the enclosing sediment.

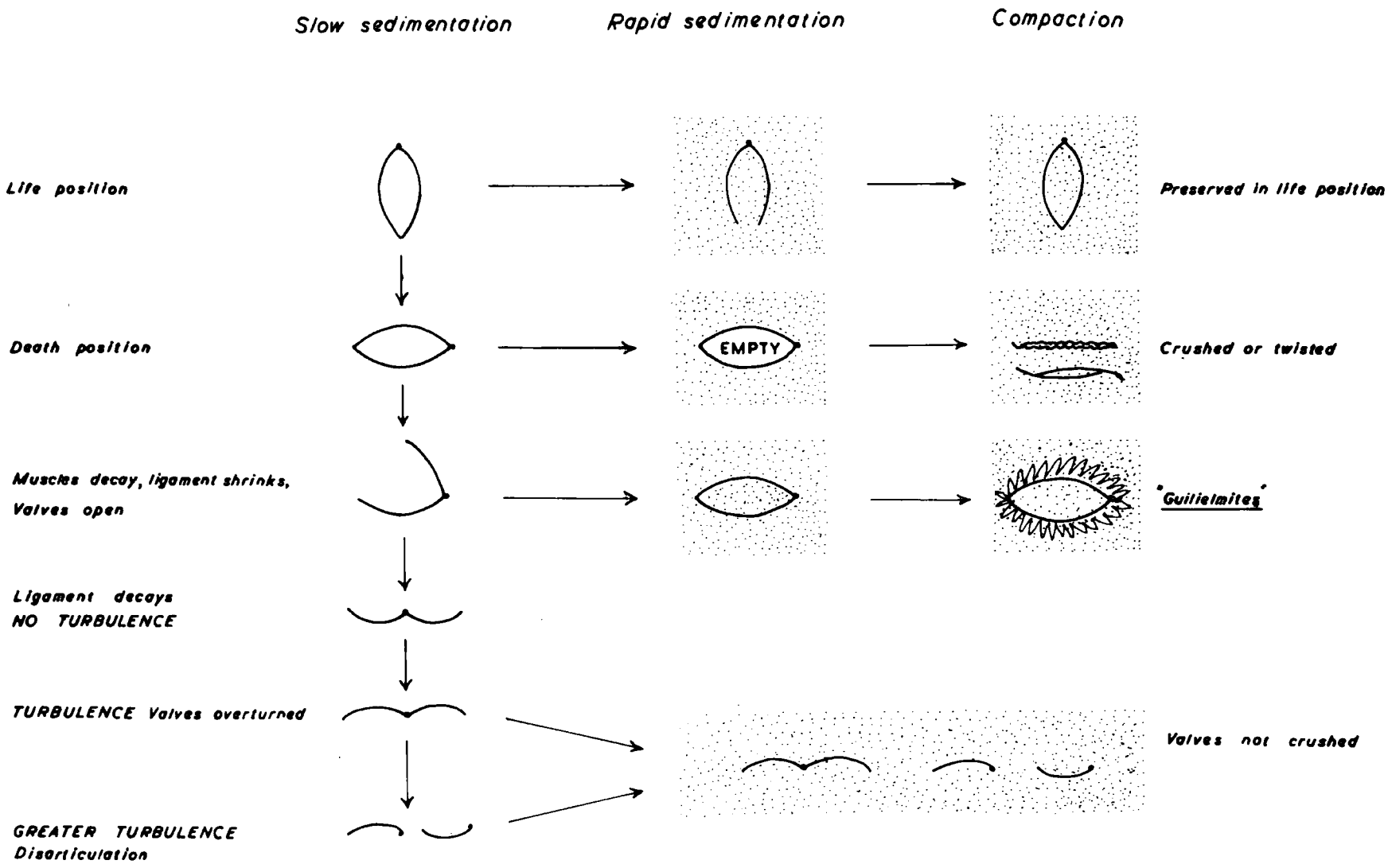

Slow sedimentation
Rapid sedimentation
Compaction
Life position
Preserved in life position
Death position
EMPTY
Crushed or twisted
Muscles decay, ligament shrinks,
Valves open
"Guilielmites"
Ligament decays
NO TURBULENCE
TURBULENCE Valves overturned
Valves not crushed
GREATER TURBULENCE
Disarticulation

Figure 8.2. Correlation between Boron content and the occurrence of fossils interpreted in terms of palaeosalinity. " Salinity facies " diagram of Upper Carboniferous fossils , Ernst, Michelau and Tasch 1961, fig.5.

The range of Carbonita is added from boron values given by Ernst, Krejci-Graf and Werner (1958).

* = Carbonita sp.

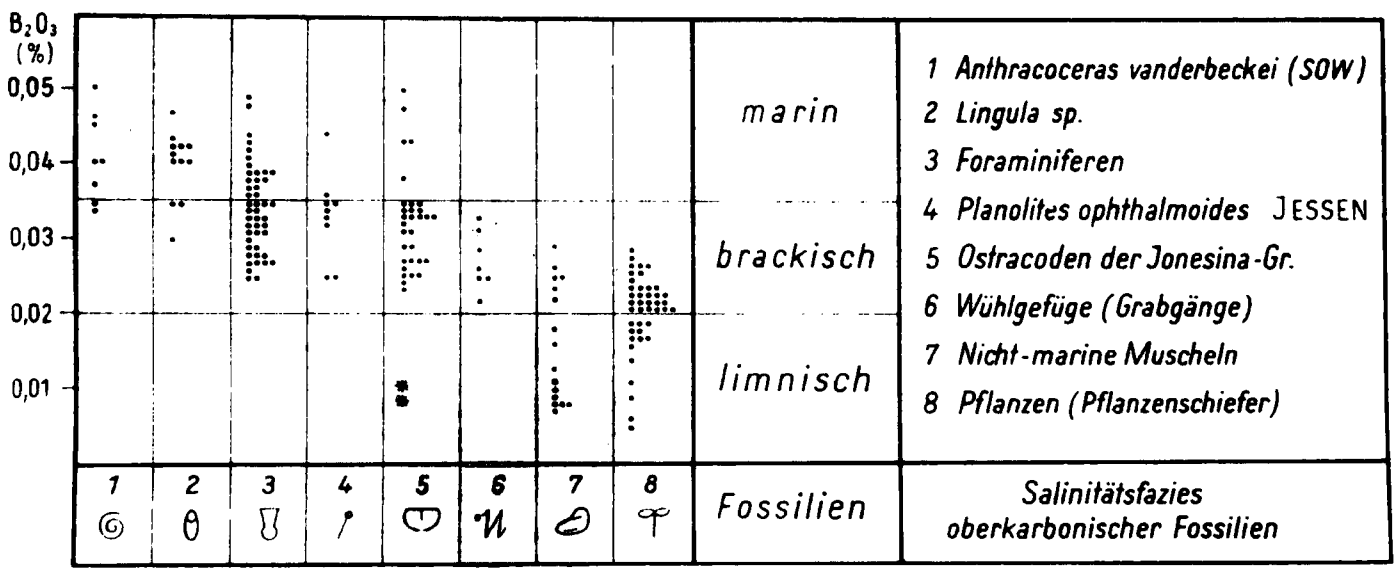
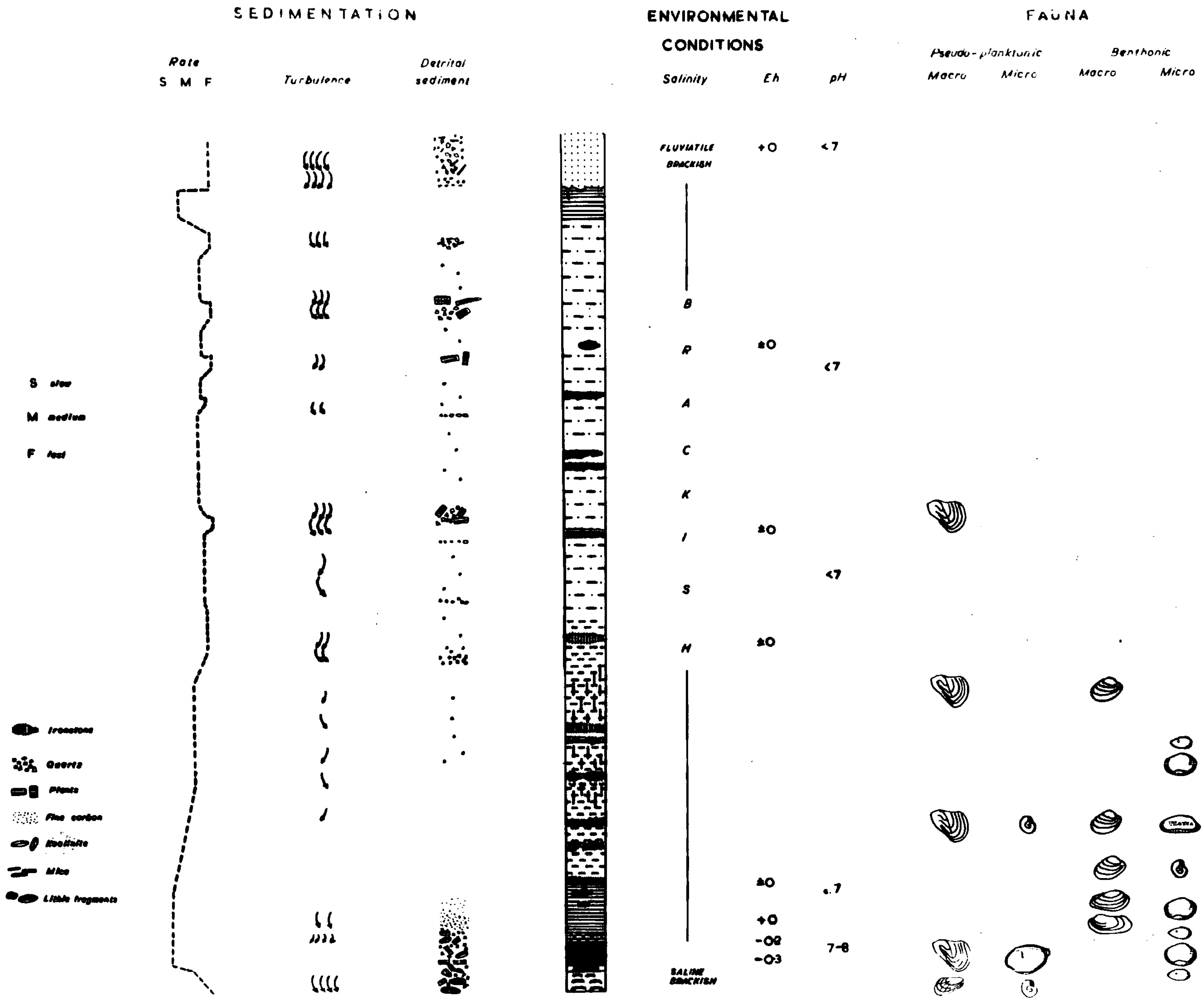

B_2O_3 (%)
0,05
0,04
0,03
0,02
0,01
marin
brackisch
limnisch
1 Anthracoceras vanderbeckei (SOW)
2 Lingula sp.
3 Foraminiferen
4 Planolites ophthalmoides JESSEN
5 Ostracoden der Jonesina-Gr.
6 Wühlgefüge (Grabgänge)
7 Nicht-marine Muscheln
8 Pflanzen (Pflanzenschiefer)
1 2 3 4 5 6 7 8
Fossilien
Salinitätsfazies oberkarbonischer Fossilien

Figure 9.1. Diagram to illustrate the reconstruction of sedimentation, environmental conditions and distribution of the fauna, during the deposition of the sediments including the Hopkins' Band at Bearpark.

The suggested rate of sedimentation is purely relative and the size and number of arrows are only to give a relative idea of the degree of turbulence. The Eh values suggested are those at, or just below, the sediment - water interface. The symbolism of the fossils is that of Figure 5.1.



SEDIMENTATION
Rate
S M F
Turbulence
Detrital sediment
ENVIRONMENTAL CONDITIONS
Salinity
Eh
pH
FAUNA
Pseudo-planktonic
Benthonic
Macro
Micro
Macro
Micro
FLUVIATILE BRACKISH
B R A C K I S H
SALINE BRACKISH
+0
±0
±0
±0
±0
+0
-0.2
-0.3
<7
<7
<7
.7
7-8
S slow
M medium
F fast
Ironstone
Quartz
Plants
Fine carbon
Kaolinite
Mica
Lithic fragments

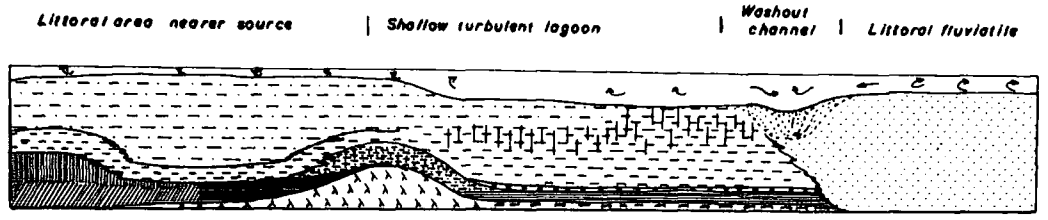
Figure 9.2. Reconstructions in space and time of the succession of sedimentary environments across the Durham Coalfield, that deposited the sediments including the Hopkins' Band.

Representation of lithologies as on Figure 1.5.a. Arrows indicate turbulence or current action. The base line of each reconstruction is the top of Harvey Seam and the top line the water level in the environment. The swamp in Reconstruction I consists of Lepidodendron, Cordaites and Calamites.

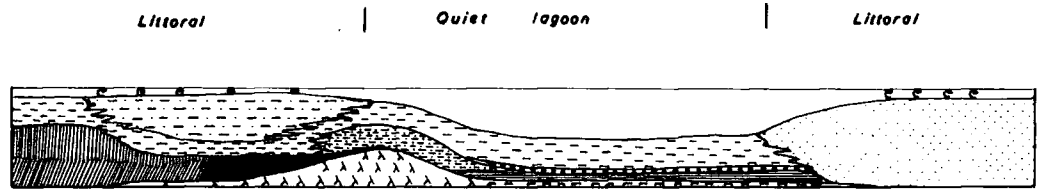
RECONSTRUCTION

9 10 16 17 6 20 22

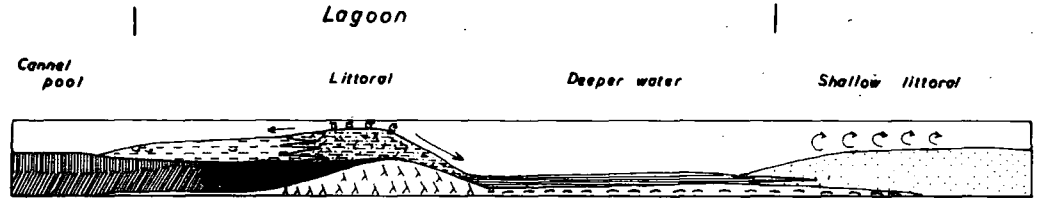
Equivalent sedimentation at Bearpark



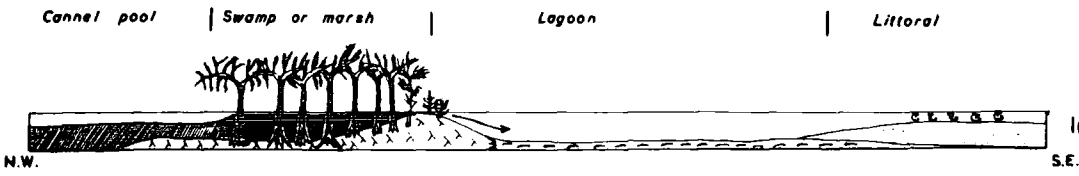
IV — Siltstone deposition



III — Hopkins Band sediments



II — Black shale deposition



I — Initial inundation

localities 9 10 16 17 6 20 22

top of Harvey Seam

water level

horizontal scale 0 5 miles vertical not to scale

PLATES

PLATE I

Mussels from the Hopkins' Band.

Fig. 1. Carbonicola oslancis Wright. x2. specimen l, fig.2.1. Grey shale above Harvey Seam, Whitworth Opencast, Co. Durham.

Fig. 2. Carbonicola cf. oslancis Wright. x2. ,specimen f ,fig.2.1. Grey shaley mudstone above Harvey Seam, Bearpark, Co. Durham.

Fig. 3. Carbonicola aff. oslancis Wright. x2, specimen m, fig.2.1. above Harvey Seam, Hylton Colliery, Co. Durham.

Fig. 4. Carbonicola cf. venusta Davies and Trueman. x2. specimen b, fig. 2.1., above Harvey Seam , Whitworth Opencast.

Fig. 5. Carbonicola venusta Davies and Trueman. x4. specimen a, fig. 2.1. , locality as Fig.3.

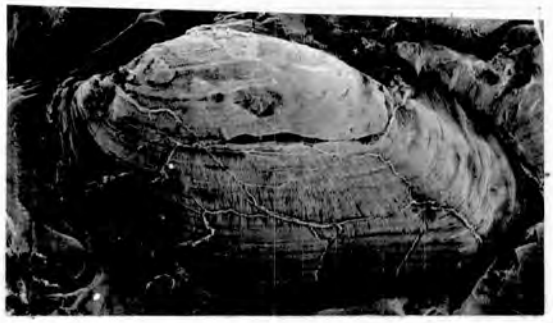
Fig. 6. Carbonicola cf. embletoni Brown. x3., specimen i, fig. 2.1. above Beaumont Seam, Fenwick Pit, East Holywell, Northumberland.

Fig. 7. Carbonicola cf. embletoni Brown. x2. specimen g , fig.2.1. locality as Fig. 2.

Fig. 8. Carbonicola cf. oslancis Wright. x3. (juvenile). specimen j ,fig. 2.1 , locality as Fig. 6.

Fig. 9. Carbonicola aff. pectorata Wright. x2. specimen u , fig.2.1. above Harvey Seam , Eppleton Colliery, Co. Durham.

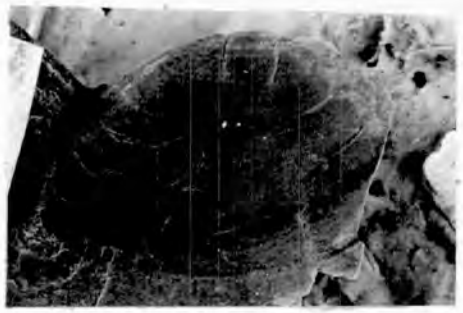
1



2

3

4

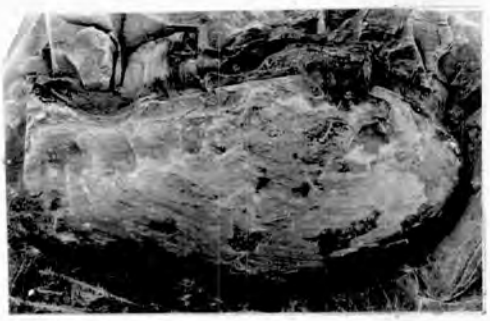


5

6

7

8



9

PLATE II

Mussels from the Hopkins' Band.

Fig. 1. Carbonicola cf. communis Davies and Trueman. x2. specimen p fig. 2.1. above Harvey Seam, Bearpark Colliery, Co. Durham.

Fig. 2. Carbonicola cf. rhomboidalis Hind. x2 specimen r , fig.2.1. above Harvey Seam, Eppleton Colliery, Co. Durham.

Fig. 3. Carbonicola cf. communis Davies and Trueman. specimen q, fig. 2. x2. above Harvey Seam, Wardley Colliery, Follonsby, Co. Durham

Fig. 4. Carbonicola cf. martini ? Trueman and Weir. x2. specimen s, fig. 2.1. above Beaumont Seam, Fenwick Pit, East Holywell, Northumberland.

Fig. 5. Carbonicola cf. bipennis Brown. x2. specimen o, fig.2.1. locality as Fig. 3.

Fig. 6. Carbonicola cf. bipennis Brown. x2. specimen n, fig. 2.1. locality as Fig. 1.

Fig. 7. Anthracosia cf. regularis Trueman. x2. specimen R, fig.2.3. Mudstones above Harvey Seam, Whitworth Opencast, Co. Durham.

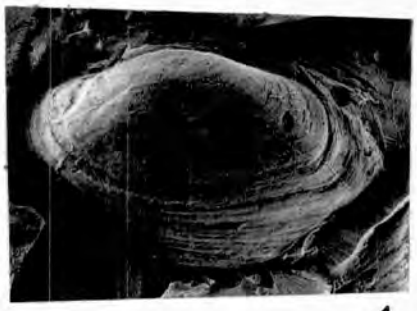
Fig. 8. Anthracosia aff. regularis Trueman. x2. specimen M , fig.2.3. locality as Fig. 1.

Fig. 9. Anthracosia aff. regularis Trueman. x2.5. specimen Q, fig.2.3. above Harvey Seam , Hylton Colliery, Co. Durham.

1

2

3



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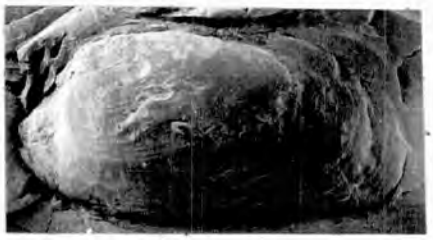

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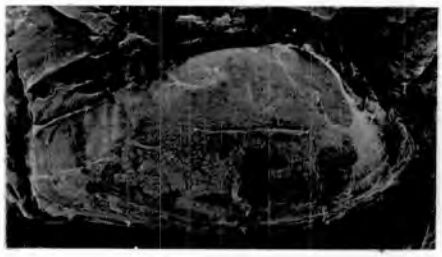

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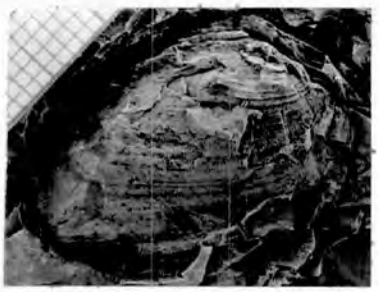

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PLATE III

Mussels from the Hopkins' Band.

Fig. 1. Anthracosia regularis Trueman. x2. specimen N, fig.2.3. above Beaumont Seam, Fenwick Pit, East Holywell, Northumberland.

Fig. 2. Anthracosia regularis Trueman. (+ Spirorbis) x2. specimen P, fig.2.3. Above Harvey Seam, Bearpark, Co. Durham.

Fig. 3. Anthracosia regularis Trueman. x2. specimen G, fig.2.3. above Harvey Seam, Hylton Colliery, Co. Durham.

Fig. 4. Anthracosia cf. retrotracta Wright. x2.5 . specimen C, fig.2.3. above Harvey Seam, Whitworth Opencast, Co. Durham.

Fig. 5. Anthracosia cf. ovum Trueman and Weir. x2.5. , specimen K, fig. 2.3. locality as Fig 4.

Fig. 6. Anthracosia cf. retrotracta Wright. x2. specimen D, fig.2.3. locality as Figg. 4 & 5.

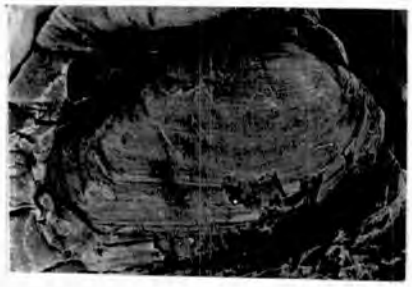
Fig. 7. Anthracosia cf. aquilina-retrotracta x2. specimen A, fig.2.3. locality as Fig. 4.

Fig. 8. Anthracosia ovum-aquilina x2. specimen J, fig. 2.3. locality as Fig. 4.

Fig. 9. Anthracosia cf. aquilina J. de C. Sowerby. x2. specimen I, fig.2.3. locality as Fig. 4 etc.

Fig.10. Anthracosia aff. ovum Trueman and Weir. x2. specimen L, fig.2.3. above Beaumont Seam, Fenwick Pit, East Holywell, Northumberland.

Fig. 11. Anthracosia aquilina -retrotracta x2. specimen H, fig.2.3. locality as Fig .4. etc.



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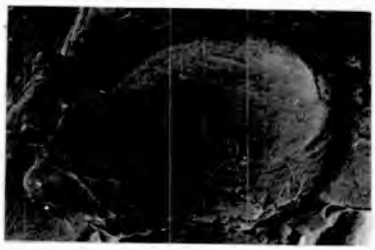

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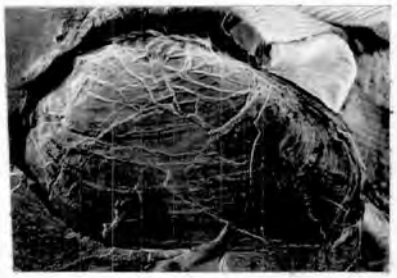

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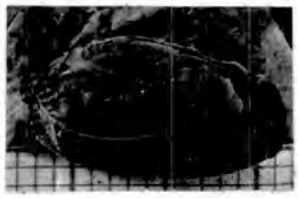

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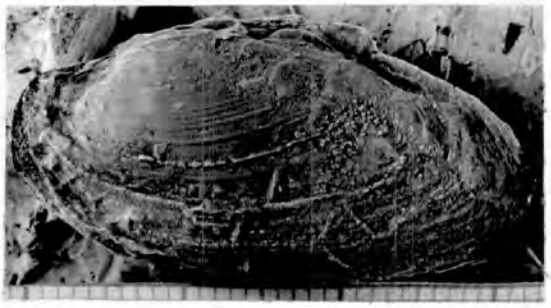

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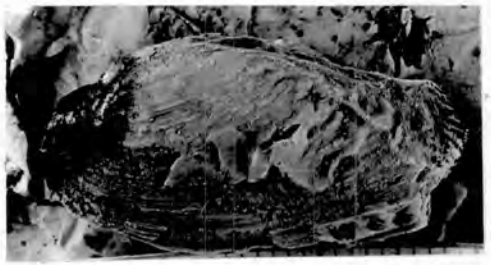

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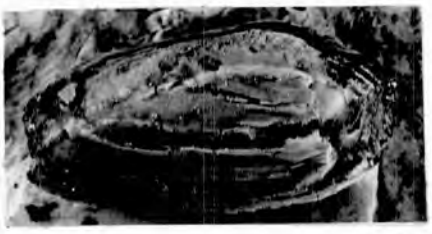

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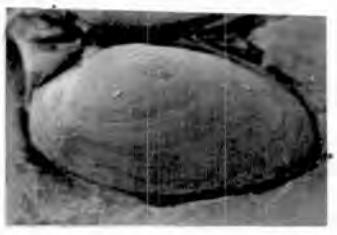

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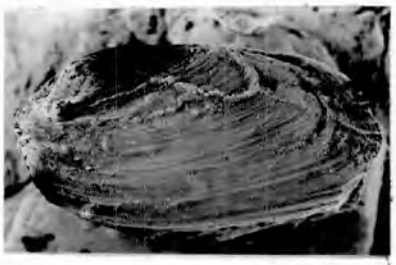

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PLATE IV

Mussels of the Hopkins' Band .

Fig. 1. Naiadites productus Brown. x2 . specimen v, fig.2.4. from the mudstones above the Harvey Seam, Silksworth, Co. Durham.

Fig. 2. Naiadites aff. productus Brown. x2. specimen vi , fig.2.4. Mudstines above the Harvey Seam, Bearpark , Co. Durham.

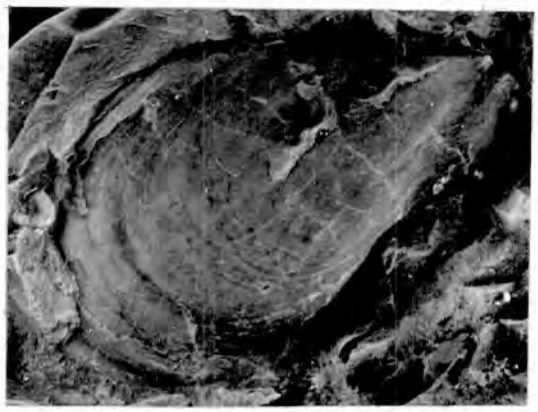
Fig. 3. Naiadites productus towards subtruncatus x1, specimen vii fig.2.4. Siliceous mudstone above the Harvey Seam , Whitworth, Opencast , Co. Durham.

Fig. 4. Naiadites productus towards triangularis x1.5 . specimen iv fig.2.4. Grey shale above Harvey Seam, Whitworth Opencast.

Fig. 5. Naiadites carinatus J. de C. Sowerby . x3 . specimen xi, fig.2.4. above Harvey Seam, Silksworth, Co. Durham.

Fig. 6. Naiadites cf. quadratus J. de C. Sowerby. x2. specimen ix , locality as Fig. 2.

Fig. 7. Naiadites subtruncatus Brown. x 2.5 . specimen viii, fig.2.4. horizon and locality as Fig. 2.



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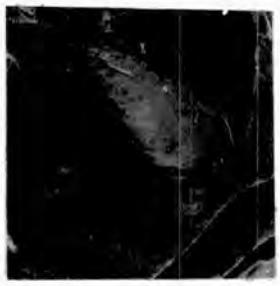

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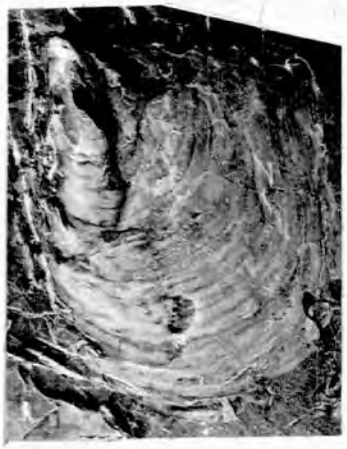

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PLATE V

Mussels from the Hopkins' Band.

Fig. 1. Naiadites cf. flexuosus Dix and Trueman. x2. specimen xii, fig.2.4. above Beaumont Seam. Fenwick Colliery, East Holywell Northumberland.

Fig. 2. Naiadites between quadratus and carinatus x2. (+Spirorbis) specimen x, fig.2.4. above Harvey Seam , Whitworth Opencast, Co. Durham.

Fig. 3. Anthraconaia modiolaris J. de C. Sowerby. x1. specimen Y, fig.2.5. above Beaumont Seam , 2½ miles north-east of Bates Pit, Blyth , Northumberland.

Fig. 4. Anthraconaia modiolaris (juvenile) x3. specimen W, fig.2.5. horizon and locality as Fig. 3.

Fig. 5. Anthraconaia cf. fugax Eagar. x2. specimen V, fig. 2.5. above Harvey Seam, Hylton, Colliery, Co. Durham.

Fig. 6. Anthraconaia modiolaris (juvenile). x2 . specimen X , fig.2.5. horizon and locality as Fig. 5,

Fig. 7. " Mussel Band " above the Geisina Band at Fenwick Colliery, East Holywell x1. The mussels if this Band have been counted and their orientations analysedin Chapter VIII.

Fig. 8. " Carbonicola carissima" Wright. x2 . Stunted or juvenile forms of Anthracosia sp. from the siliceous mudstone above the Harvey Seam at Whitworth Opencast.

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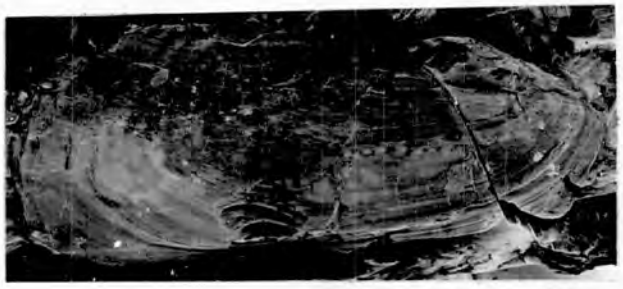

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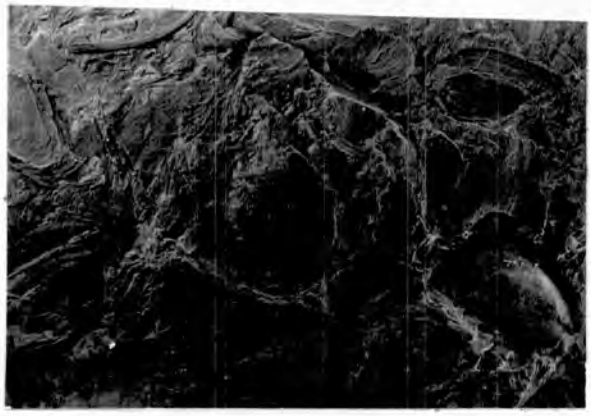

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PLATE VI

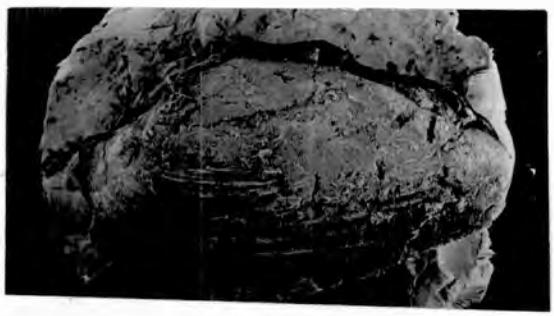
Mussels from the Three Quarter Seam horizon.

Fig. 1. Carbonicola between communis and pseudorobusta x½. Shales above the Three Quarter Seam, Medomsley Colliery, Consett, Co. Durham.

Fig. 2. Carbonicola cf. cristi-galli Wright. x2. horizon and locality as for Fig. 1.

Fig. 3. Curvirimula cf. belgica Hind. x4 . Form named "Anthraconauta" subovata var. candela Dewar. In Three Quarter horizon ostracod-mussel band in borehole Fishburn 6.

Fig. 4. Carbonicola declevis Trueman and Weir. x2. horizon and locality as for Fig. 3.



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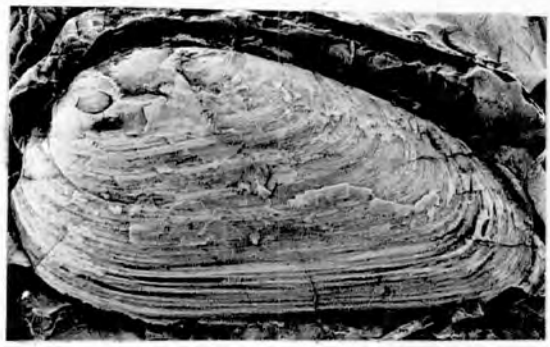

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PLATE VII

Geisina arcuata Bean.

Figures 1 - 4 are of an adult female from the Geisina Band at Eppleton Colliery, Co. Durham. Figures 5 & 6 are shell fragments from the same locality and horizon.
The arrow on each figure points anteriorly with respect to the orientation of the ostracod.

Fig. 1. Lateral view of the Left valve. Note : The impressed sulcus, the overlap of the right valve over the Left around the entire margin ; and the right angled posterior dorsal corner. x50 approx.

Fig. 2. Lateral view of the Right valve. Note: raised dorsum: rectangular bulb at posterior dorsal corner; pointed bulb at median anterior margin and pitted surface. x 50 approx.

Fig. 3. Ventral view. Note: thickened ventral rim of the Right valve ; and prominent posterior dorsal bulb. x 50 approx.

Fig. 4. Dorsal view. Note: straight hinge line and the advance of the right valve over the Left at both cardinal angles. x 60 approx.

Fig. 5. Interior of part of the Left valve. Note: thin hinge structure with upward reflexed anterior dorsal corner; thickened anterior rim to the valve; internal swelling due to sulcus. x 60 approx.

Fig. 6. Interior of the anterior dorsal part of the Right valve. Note: Shallow grooved hinge narrowing posteriorly. x 60 approx

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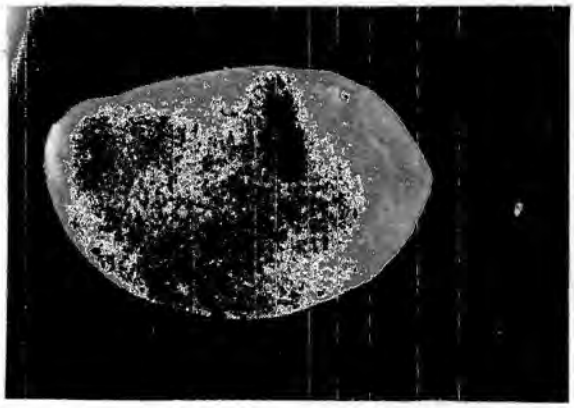

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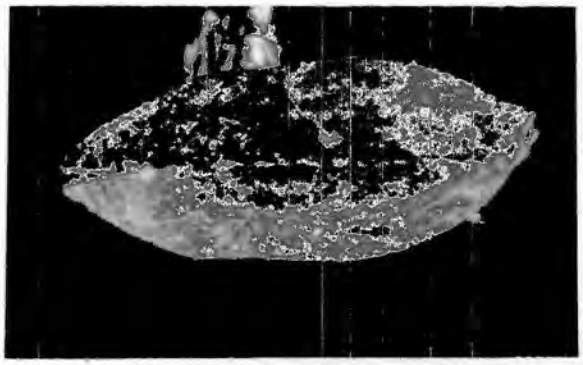

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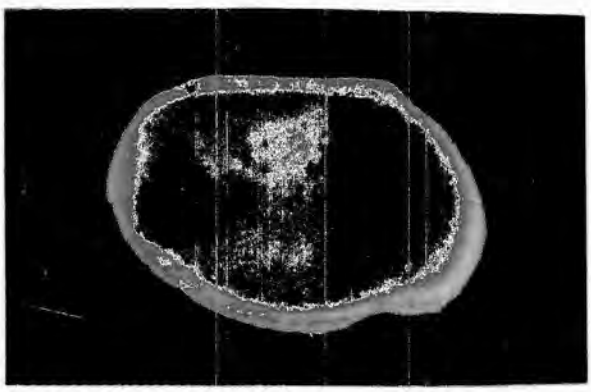

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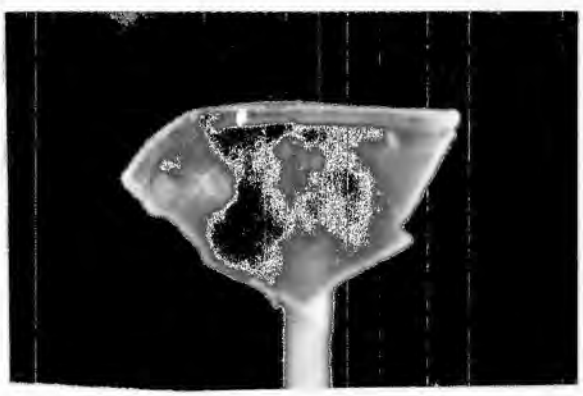

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PLATE VIII

Fig. 1. The strata of the Hopkins' Band above the Harvey Seam at Whitworth Opencast, Co. Durham.

Figure 2. The shale sedtion of the Claxheugh Shell Bed, north bank of River Wear, North Hylton, Co. Durham. The ostracod fauna comes from the thick ironstone band by the hammer head.

PLATE VIII

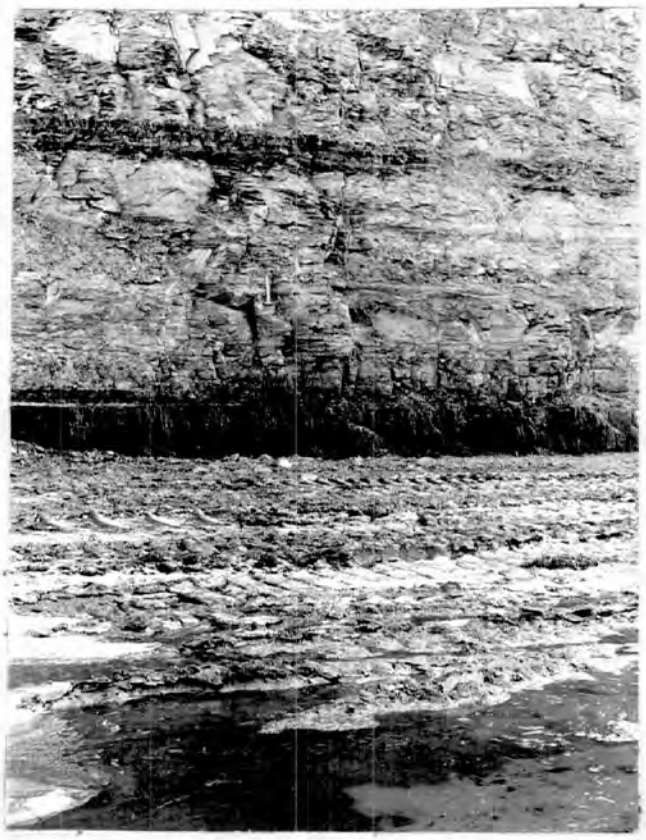

Figure 1.

Figure 2.

PLATE IX

Figure 1. Strata including the Hopkins' Band above the Harvey Seam at Whitworth Opencast. Harvey Seam at the base overlain by the leached basal layers of the mudstone conglomerate then black shale and grey shale and mudstone above.

Figure 2. Mudstone conglomerate, black shale and grey mudstone above the Harvey Seam at Whitworth Opencast. The blocky weathering mudstone conglomerate at the base, has an irregular base and distinct carbon parting at the top. The thin Geisina Band is present at the top of the black shale.

PLATE IX

Figure 1.

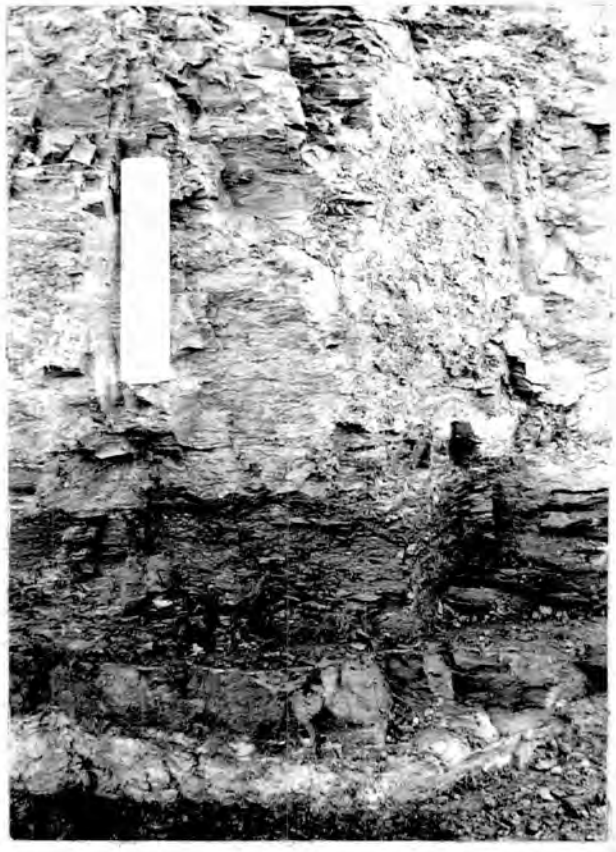

Figure 2.

PLATE X

Figure 1. Grey mudstone 2 feet above the Harvey Seam at Whitworth Opencast.

Figure 2. Sediments 1 to 3 feet above the Harvey Seam at Whitworth Opencast. Grey mudstone below and grey quartz banded siltstone above, by the ruler.

PLATE X

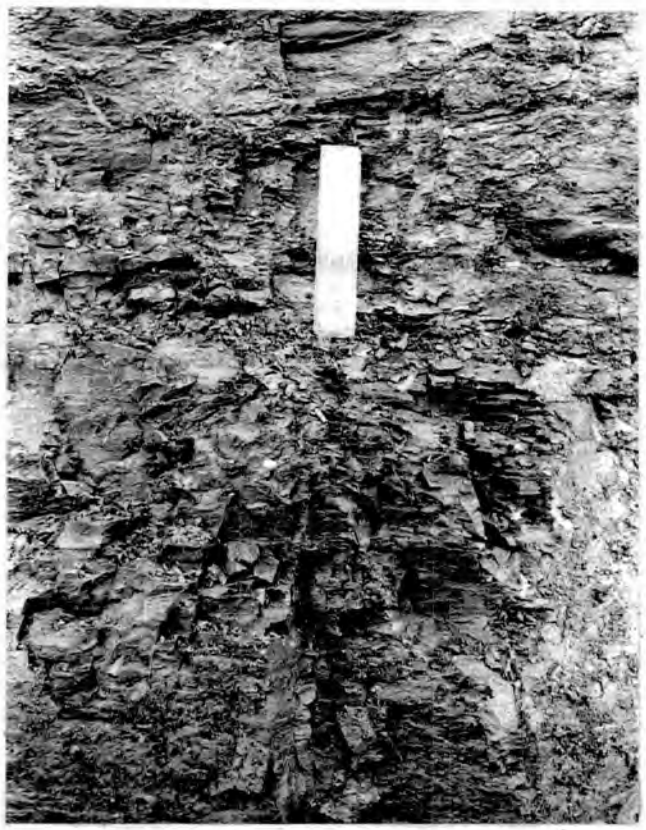

Figure 1.

Figure 2.

PLATE XI

Figure 1. Photomicrograph of mudstone conglomerate, 2½ miles north-east of Bates Pit, Blyth. slide 730. x 40 approx. polarised light.

Pale coloured carbonate fragments in a matrix of cabon, clay minerals and quartz.

Figure 2. Photomicrograph of the top of the mudstone conglomerate base of the black shale at Bearpark. slide 801. x 40 approx ordinary light.

Dense black patches of carbonaceous matter, paler patches of quartz, and clay minerals with some carbon. Bedding N.W. to S.E. direction. Ostracods probably Carbonita humilis seen in transverse section.

PLATE XI

Figure 1.

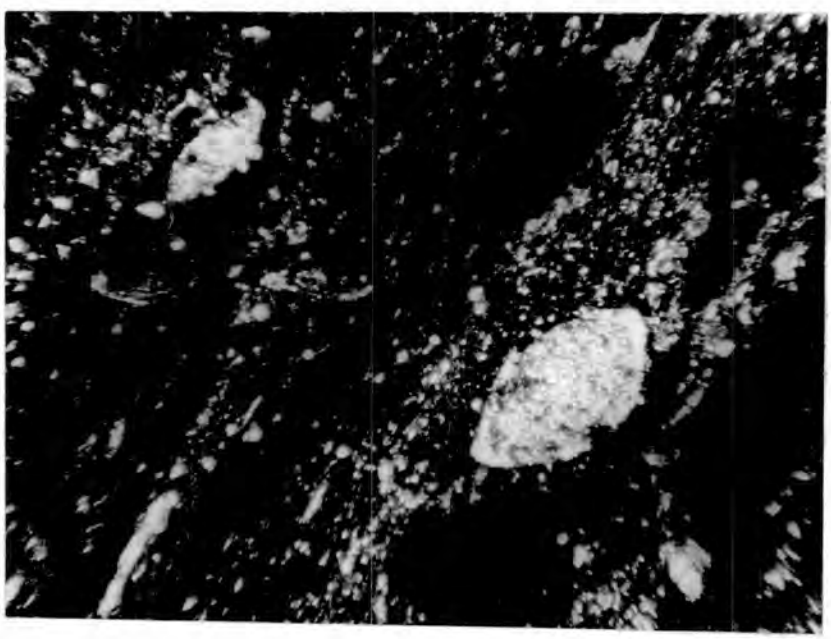

Figure 2.

PLATE XII

Figure 1. Photomicrograph of the black silty shale below the Geisina Band, nr. Bates Pit ,Blyth. slide 733. x 40 approx . Ordinary light. Carbonaceous shale , very rich in detrital quartz and with Naiadites shells parallel to the bedding.

Figure 2. Photograph of a thin section of the Geisina Band at Eppleton. slide 725. x 5.5 . ordinary light. Black shale below with scattered patches of Naiadites -ostracod coquina, pale grey shale above with fine " cryptophyllite" texture. Complete ostracod carapaces and J ∂ shaped cross section of a Spirorbis tube in the grey shale.

PLATE XII

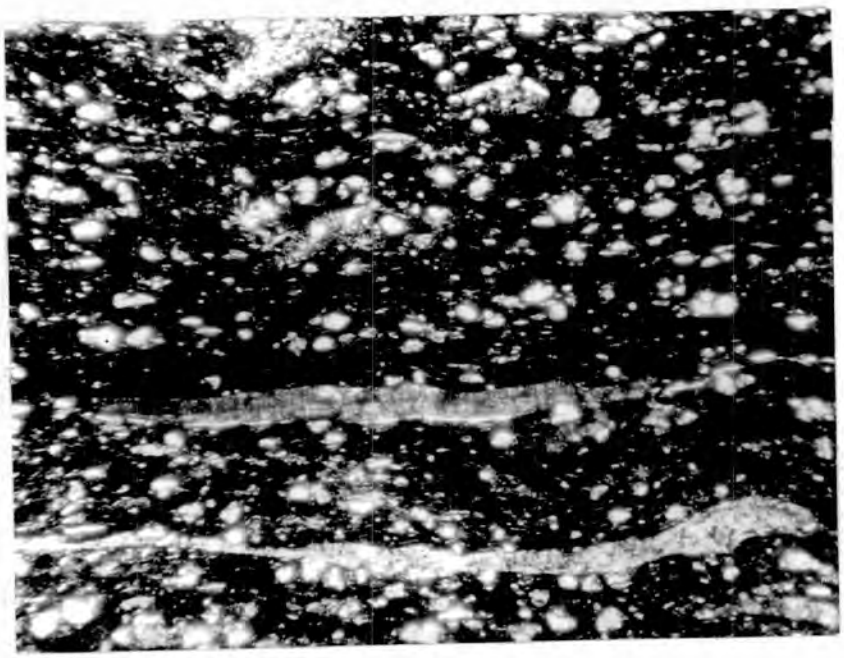

Figure 1.

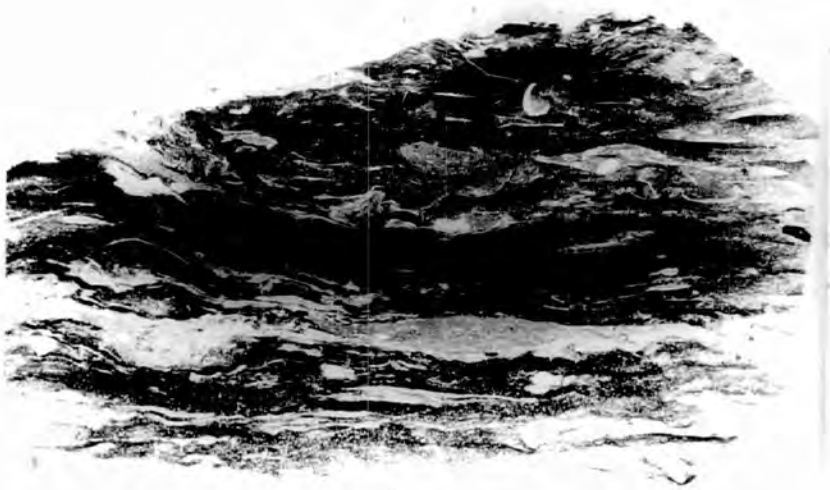

Figure 2.

PLATE XIII

Figure 1. Photomicrograph of the Geisina Band at Whitworth Opencast. slide 705. x 40 approx. Polarised light.

Interlaminated shale and shell coquina.

Longitudinal section of a complete carapace of Geisina arcuata . Note : the thickening of the ostracod shell internally to the sulcus and at the posterior end of the right valve. (Bulb described in taxonomic section Chapter III)

Figure 2. Photomicrograph of the Geisina Band at Follonsby slide 726. x 40 approx. polarised light.

Dense Naiadites - Geisina - Spirorbis coquina with a carbon rich matrix.

A - G. arcuata transverse section . ventral thickening of the overlapping edge of the R. valve.

B - G. arcuata longitudinal section of the carapace, crushed

C - C. humilis , transverse section crushed.

D - Spirorbis , transverse section

E - Naiadites shell transverse section, showing prismatic structure.

PLATE XIII

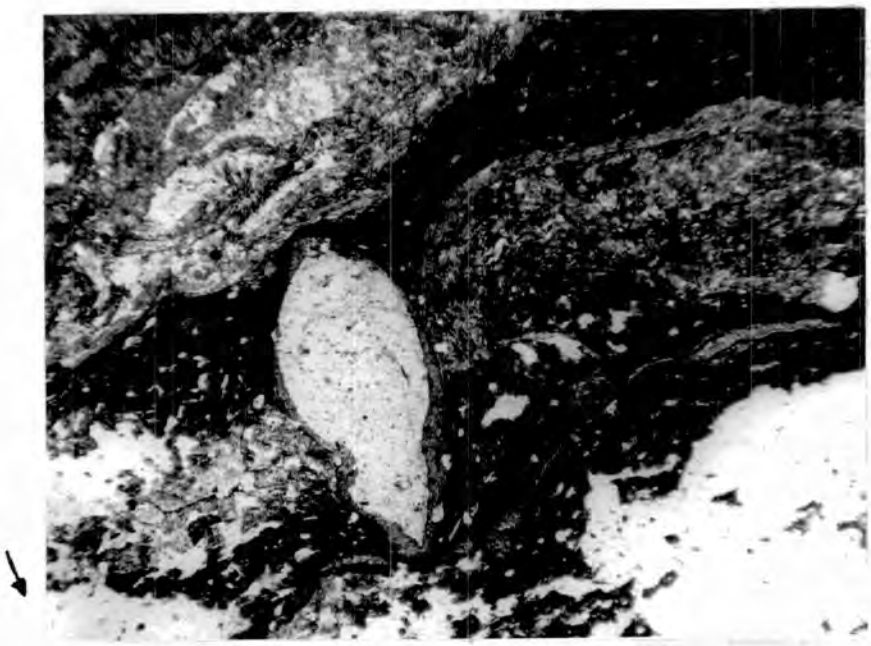

Figure 1.

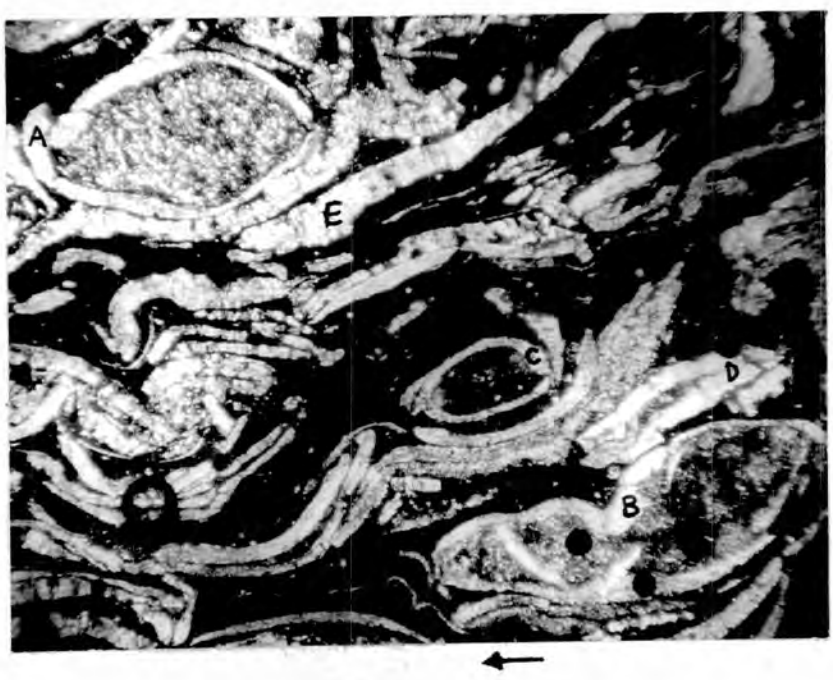

Figure 2.

PLATE XIV

Figure 1. Photomicrograph of the grey shaley mudstone 5 to 6 inches above the Harvey Seam at Bearpark. slide 192. x 40 approx. polarised light.

Virtually pure clay mineral rock, " cryptophyllite" texture and bedding running N.W. to S.E. , disturbed around fossil fragments. Separated ostracod valve on extreme left, large eroded quartz grain 190 by 125 microns seen in top right hand corner.

Figure 2. Photomicrograph of grey shaley mudstone $8\frac{1}{4}$ to $8\frac{3}{4}$ inches above the Harvey Seam at Bearpark. slide 211. x 40 approx. ordinary light.
Horizontal bedding " cryptophyllite " texture
Left half of the photograph is enriched in finely divided carbon. Crushed carapace of G. arcuata in bottom right hand corner.

PLATE XIV

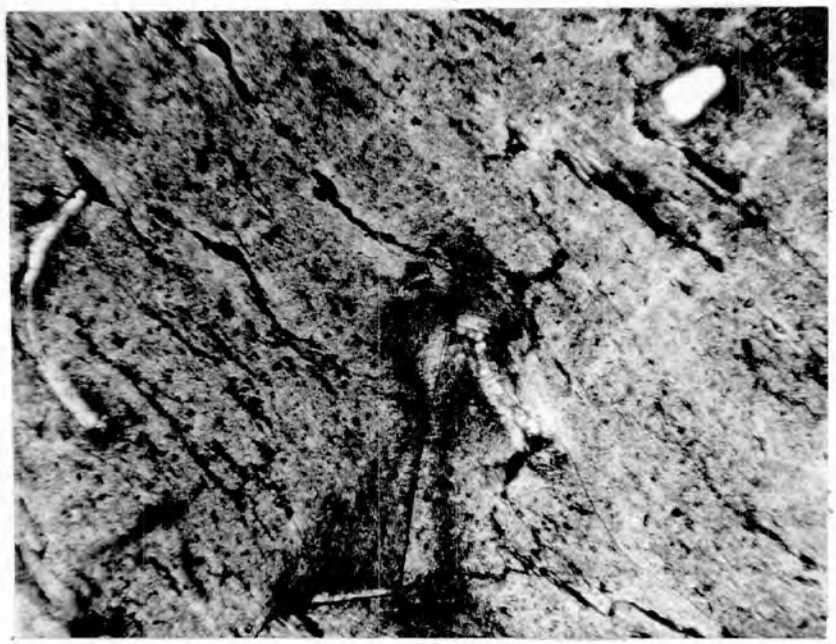

Figure 1.

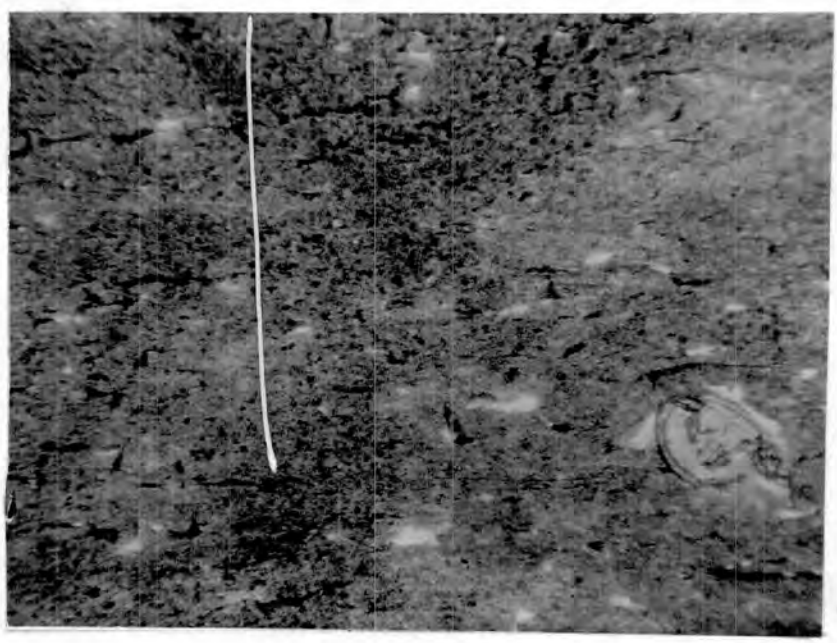

Figure 2.

PLATE XV

Figure 1. Photomicrograph of the pale grey mudstone 11 to 12 inches above the Harvey Seam at Bearpark.
slide 812, x 100 approx. polarised light.
Coarse texture of distinctly micaceous clay minerals , about 10 microns in length, sub-parallel arrangement bedding top left to bottom right. Ironstone nodule in the top right hand corner.

Figure 2. Photomicrograph of the siliceous or slightly silty mudstone 2 ft. 3inches above the Seam at Bearpark.
slide 819. x 100 . polarised light.
Clay minerals 15 - 20 microns grain size , fine quartz , random orientation of the clay minerals
Fine granules of sphaerosiderite in the groundmass causes dark colour.

PLATE XV

Figure 1.

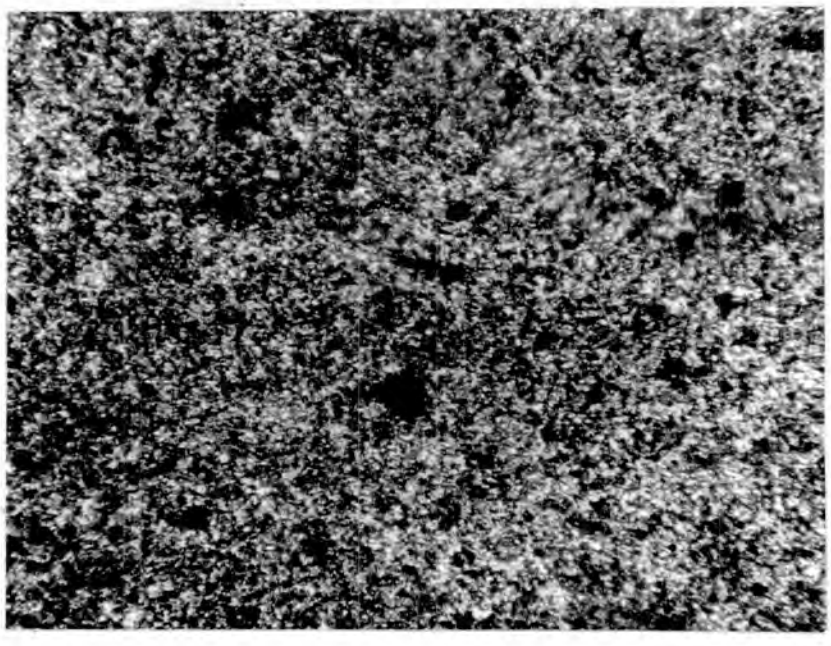

Figure 2.

PLATE XVI

Figure 1. Photograph of a thinsection of the laminated muddy siltstone, 3ft. above the Seam at Bearpark. slide 821. x 4 approx. ordinary light.

Dark laminae of carbon and clay minerals, pale laminae of quartz and muscovite. Disturbance of the laminated texture in the upper part due to a burrowing organism .

Figure 2. Photograph of a thin section of siltstone and mudstone about 5 ft. above the Seam at Bearpark. slide 824. x 4. ordinary light.

Mudstone with coase quartz-muscovite laminae below ,siltstone above. A worm burrow curving to the left descends from the siltstone through the underlying mudstone.

PLATE XVI

Figure 1.

Figure 2.

PLATE XVII

Figure 1. Photograph of a thin section of a cross-bedded quartz - mica sandstone, 3ft. 4in. above the Harvey Seam at Whitworth Opencast. slide 710. x 4. ordinary light.

Very rich in carbonaceous matter that outlines the cross - bedding.

Figure 2. Photomicrograph of the sandstone in Fig. 1. x 40 . ordinary light.

Equigranular texture of angular quartz and muscovite with patches of dense carbonaceous matter.

PLATE XVII

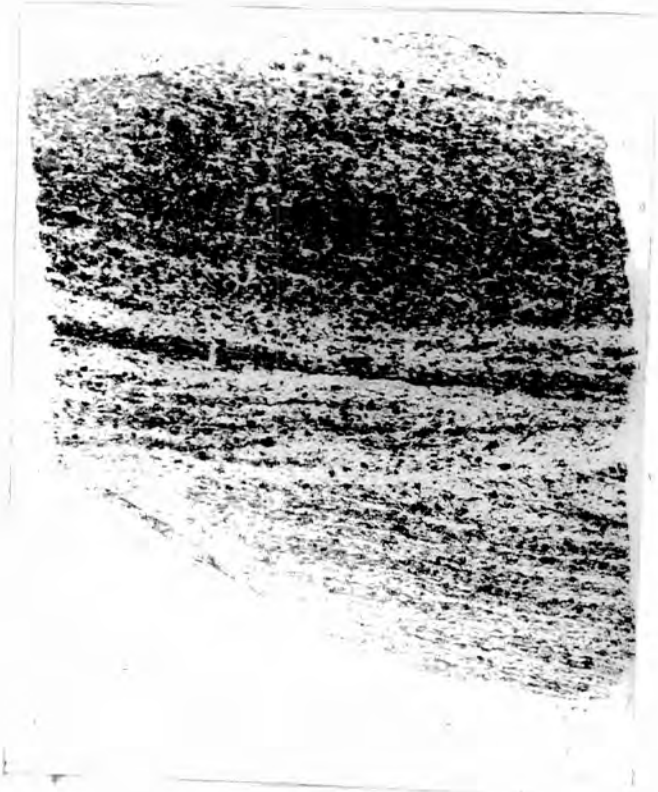

Figure 1.

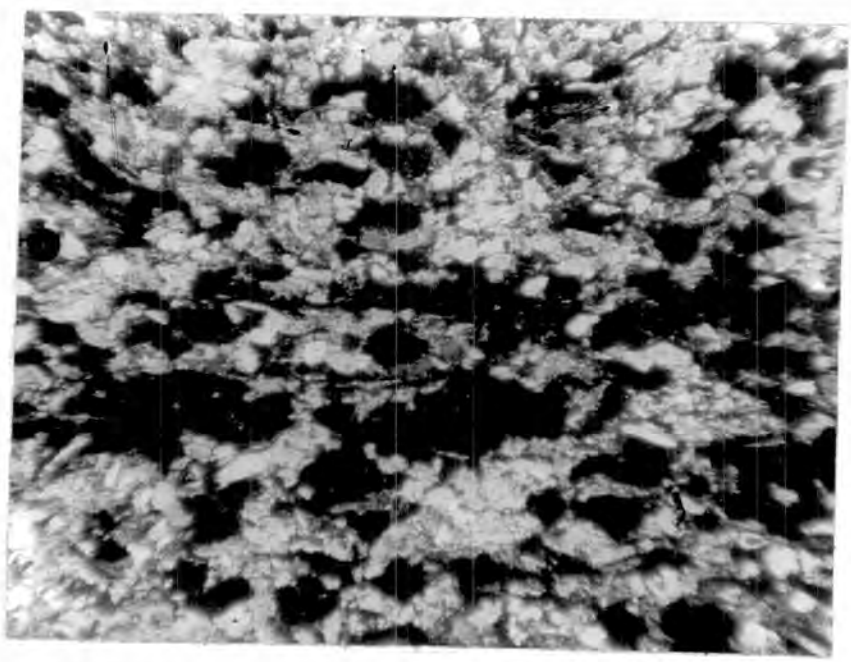

Figure 2.