# LOWER CARBONIFEROUS CONODONT FAUNAS FROM NORTH-EAST DEVONSHIRE

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ABSTRACT. Two distinct successions, the Bampton and the Westleigh, exist in the Lower Carboniferous of north-east Devonshire. The characters of the two are briefly described, mainly on the basis of field evidence. Conodonts reinforce earlier suggestions that these successions both belong in cuII and cuIII of the Lower Carboniferous. The conglomeratic limestones in the Westleigh succession include some apparently shelf-derived clasts. The conodonts indicate that these coarse limestones (with *Gnathodus bilineatus*) have received an admixture of distinctly earlier forms (*Scaliognathus anchoralis*, siphonodellids). If the reworked forms have come from shelf situations, as much as 800 m of Lower Carboniferous shelf-stratigraphy might have contributed conodonts to the Westleigh succession. The Westleigh Limestone and the Hellefelder Kalk (Lower Carboniferous, Sauerland, Germany) are briefly compared.

LOWER Carboniferous outcrop runs across north Devon from Barnstaple in the west and ends in the east at the New Red Sandstone overstep (I.G.S. 1:63,360 Sheet 310, Tiverton). The Lower Carboniferous is set in a regional succession that is apparently conformable from Famennian (Goldring 1955, 1970: lower part of the Pilton Beds) to Westphalian (Prentice 1960: Instow Beds in the west; Thomas *in* Webby and Thomas 1965: Holmingham Beds in the east). Near the eastern end of the outcrop belt, a change of facies is seen in the rocks that follow above the Pilton Beds. At Bampton (see text-fig. 1 for localities) the Doddiscombe Beds–Bampton Limestone Group succession is dominated by shales. Around Westleigh, limestones are dominant. We refer in this paper to a Bampton succession and a Westleigh succession.

## THE BAMPTON SUCCESSION

At Bampton, the Pilton Beds are succeeded by the Doddiscombe Beds (a type section is available at Doddiscombe Quarry: National Grid Reference SS985233). These shales show a fine dark grey/black lamination. The dark colours survive weathering. Broken surfaces are distinctly rough, a characteristic attributable to the fact that the original fine clastic accumulate (silt grade or lower) received some secondary silicification. The Doddiscombe Beds have a thickness of approximately 8 m. There is a gradual passage upward into the softer, less finely laminated, pale-weathering shales of the Hayne Beech Beds.

The Hayne Beech Beds are the lowest of the three units recognized in the Bampton Limestone Group. Among its pale shales there are some minor developments of impure limestone. The unit is poorly exposed in the ground north and east of Bampton, where a topographic depression marks the run of its outcrop. The best available exposure is at Hayne Beech Farm (SS992229). Good exposures were available for a time during road-widening operations north-east of Hukeley Bridge (SS972235). A small exposure in the side of a lane near Hukeley Farm

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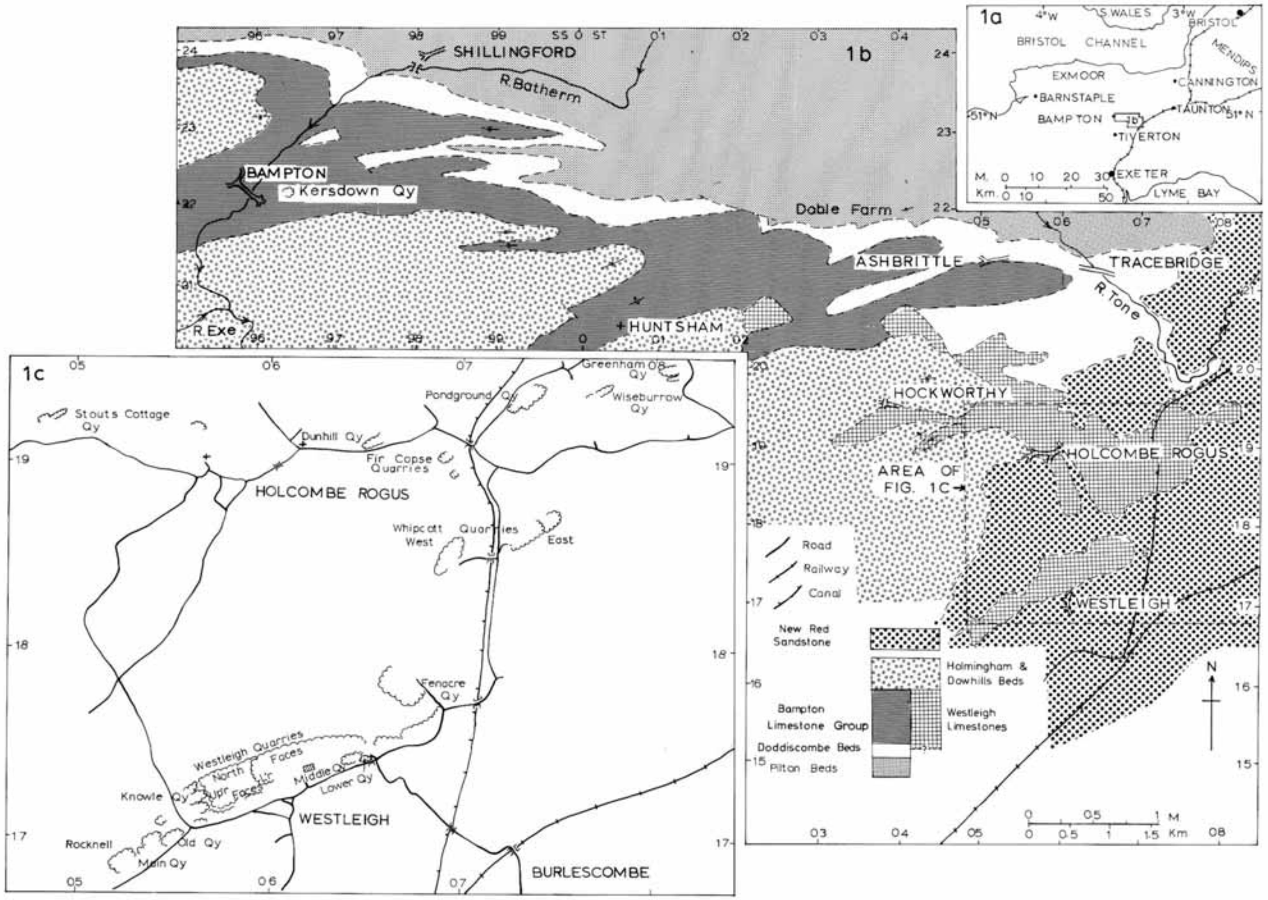


TEXT-FIG. 1. Location maps. 1*a*, top right: regional location (at centre: location of area treated in 1*b*). 1*b*, geological map of the Bampton–Westleigh area (at right: area treated in 1*c*). 1*c*, location of exposures in the Holcombe Rogus–Westleigh neighbourhood.

(SS 972 238) of uncertain stratigraphic position has produced some ostracodes (*Maternella* n. sp. aff. *circumcostata* (Rabien 1960)—A. Gooday, personal communication 1973).

The next unit in the Bampton Limestone Group, the Kersdown Chert, has cherts with interbedded shales and occasional fine-grained limestones. At the type occurrence, in Kersdown Quarry, Bampton (SS 964 222) 7 m stratigraphic thickness is exposed in a fractured anticlinal fold. Individual beds persist around this structure. The cherts are slightly calcareous. The interbedded shales are slightly silicified and contain relics of radiolarians. The fine-grained limestones are usually about 0·5 m thick. A thicker, coarser limestone, with graded bedding, occurs near the top of the section exposed. The matrix of these limestones is permeated by secondary silica. Silica occurs also as nodules, and in such cases the local matrix is completely replaced. Small corals, brachiopods, and a certain number of goniatites (Prentice and Thomas 1965, pp. 38–40: *Merocanites* cf. *similis*, *Bollandites* sp.) have been found in this unit. The Kersdown Chert outcrop corresponds with topographic highs in the area. At exposure the cherts are pale in colour and are usually well-jointed. They have a rough, porous texture due to weathering-out of calcareous material.

The highest of the three Bampton Limestone Group units is the Bailey's Beds (27 m thick). This is exposed in Bailey's Quarry, south-east of Bampton (SS 960 218). The unit has dark impure limestones interbedded with dark shales. Only minor chert developments are present, although both the nodular and the dispersed mode of occurrence of secondary silica can be found. Individual limestone beds maintain their thickness and character throughout the extent of the exposures available. The top of the Bailey's Beds (and the top of the Bampton Limestone Group) is taken at the top of the last thin limestone seen as the Bailey's Beds pass upward into the unrelieved black shales of the Dowhills Beds. The shales near the top of the Bailey's Beds have abundant large bivalves, many of them identifiable as *Posidonia becheri. Michiganites hesteri* (generic attribution as in Weyer 1972) has been found in this unit at a locality near Huntsham (ST 996 202: see Prentice and Thomas 1965, pp. 40–41). Spirally striate goniatites, including forms referable to *Neoglyphioceras spirale*, occur in the dark shales immediately overlying the highest limestones, i.e. in the Dowhills Beds.

The Bampton succession, therefore, has mainly fine-grained rocks, sometimes banded and with only relatively rare interruptions by coarser clastics. There are occasional developments of sole structures in the thin silicified limestones of the Kersdown Cherts unit, and some of these beds have a ripple cross-lamination (type C of Jopling and Walker 1968) near their tops. One example of grading has been noted above. Evidence of burrowing is also found. In the Bailey's Beds the limestones are laterally persistent (so far as the available exposures show), their bases sharply defined. Some have parallel lamination throughout, others are structureless internally, and in rare cases ripple cross-stratification is present. All are fine grained, and therefore none produces a convincing example of graded bedding. The Bampton succession is taken to represent the distal parts of a turbidite influx.

The units of the Bampton succession can be mapped eastward up to the New Red

Sandstone overstep near Ashbrittle. Southward from there, the Lower Carboniferous reappears; but it now has the characteristics of the limestone-dominant Westleigh succession.

## THE WESTLEIGH SUCCESSION

The Westleigh Limestones are well shown in numerous quarries opened near Burlescombe. The stratigraphy in the immediate neighbourhood of the Pilton Beds–Westleigh Limestones boundary is not well exposed. On the other hand, at the top of the Westleigh Limestone it is clear that the carbonate-dominant sequence is followed by a succession of fine-grained rocks exactly comparable with the Dowhills Beds of the Bampton neighbourhood (Thomas *in* Webby and Thomas 1965).

In Westleigh Quarry itself (ST 065 176) it is possible to separate a lower part (Lower Westleigh Limestone) of the succession, with relatively thin-bedded limestones and little shale, from an upper (Upper Westleigh Limestone), which has thicker limestones—often impressively coarse—interbedded with shales. Elsewhere in the area, but always in poorly exposed situations, the Upper Westleigh Limestone outcrops close to the Doddiscombe Beds. It has not yet been possible to unravel whatever stratigraphic relationships exist in such places.

The Lower Westleigh Limestone is found only in the immediate neighbourhood of Westleigh. The regular, thin-bedded limestones, like the occasional intervening calcilutites, have finely disseminated secondary silica in their matrix. Graded beds are occasionally seen. Bioturbation is common. Near the top of the Lower Westleigh Limestones there are some coarse conglomerates whose clasts range up to a maximum seen in a slab that measures some 2 m long and 0·15 m thick. The clasts vary in shape from angular to moderately well rounded. The base of the Upper Westleigh Limestone is taken at the first occurrence of shales. These often have a fine colour-banding, and frequently show bioturbation. The majority of the shales are slightly calcareous. Some calcilutites (including the *crenistria* Bed, mentioned below) are also present. Certain laminae in the shales have flattened specimens of goniatites, orthocones, and large lamellibranchs (*Posidonia becheri*). Occasionally, representatives of epibenthonic faunas are also present (athyrid and productid brachiopods, crinoid calices, and crinoid stem material, often found in a good state of articulation). These shales are interbedded with limestones whose thickness ranges between 0·5 cm and 10 m, with a mean around 0·6 m. The limestones are often conglomeratic, with clasts whose dimensions may be of the order of several cm. Angular blocks of fine- and medium-grained limestone are common. Ooliths and pellets, and bryozoan, crinoid, coral, and brachiopod debris can be recognized. The whole fabric is matrix-supported (ooliths and crinoid debris in a fine calcareous matrix for example, or large clasts in an oolitic-crinoidal matrix). Each limestone has a sharp base. Sole marks are few. Graded bedding is seen in rare cases, always involving beds whose thicknesses are in the 15 to 20 cm range. The thicker units have thoroughly mixed grain sizes through the major part of a bed's thickness, with finally a good grading ('delayed graded bedding' of Kuenen 1964) through some 5 cm of thickness leading into the shale above. Some beds, usually fine calcarenites with no large clasts, are laminated throughout (cf. Piper 1972), but most lack regular internal structure and have clasts randomly distributed through all but the topmost part of the bed. Nodular developments of chert occur at various levels in the thick limestone beds. In the Upper Westleigh Limestone, trace-fossils occur in the limestone bands only in the form of simple burrows descending from shale above.

There are no stratigraphically useful fossils in the Lower Westleigh Limestone. *Posidonia becheri* occurs through most of the Upper Westleigh Limestone, but in the uppermost parts of the succession it is apparently replaced by the smaller *Caneyella membranacea*. In a number of exposed sections *Michiganites hesteri* occurs near the base of the Upper Westleigh Limestone, and rare goniatites of the *hudsoni-maximus* group have been found in shales slightly higher in the succession. Higher still, specimens of *Goniatites granosus*, *G.* cf. *granosus poststriatus*, *G.* cf. *sphaericostriatus*, *Sudeticeras* cf. *crenistriatus*, and *Neoglyphioceras spirale* have been found, indicating that the Upper Westleigh Limestone ranges into younger horizons than are represented in the Bampton Limestone Group (compare the record of *Neoglyphioceras spirale* from low in the Dowhills Beds at Bampton).

It was suggested above that the Bampton Limestone Group represents a distal turbidite situation. The Lower Westleigh Limestone might have been produced by a similar set of processes, but delivering here a greater abundance of fine carbonate debris. Some graded beds are found in the Lower Westleigh Limestone. Beds with bioturbation are very common, and concentrated burrowings may have obliterated the primary sedimentary characteristics of some beds. The Lower Westleigh rocks are usually silicified to such an extent that they cannot be broken down in 10% acetic acid. Beds which will break down produce a great deal of insoluble residue, much of it possibly originally delivered as volcanic ash. The thicker limestones of the Upper Westleigh Limestone have quite a different set of sedimentary characteristics, and their interbedded shales record the occasional establishment of epibenthonic faunas. The Upper Westleigh Limestone, it seems, might record a proximal turbidite situation, which is not represented in the Bampton succession and which was still in existence at Westleigh after the last of the thin limestones had been deposited at Bampton.

## THE CONODONT FAUNAS

The goniatites reported by Prentice and Thomas (1960, 1965) were sufficient to show that the Bampton Limestone Group and the Westleigh Limestones are of much the same age. It was hoped at the outset of the present project that conodonts might provide for more detailed correlations between the two successions. However, the results so far have been disappointing in some ways. For example, the lower parts of the successions, which have produced relatively few macrofossils, have been almost equally unobliging as far as conodonts are concerned. Also, in the higher parts of the Westleigh succession, where conodonts are abundant, the results are complicated by frequent indications of reworking. There are, nevertheless, some useful finds to be recorded. And the evidence of reworking, at first sight confusing, can be made to yield information on the range of age of the rocks that contributed material to the Westleigh succession.

The conodonts listed below have been mounted on 32-cavity slides and the slides deposited in the Geology Museum, University of Bristol. Five-figure numbers prefixed BU, cited at the end of the faunal lists, identify slides. Numbers with a suffix, as cited in the plate explanations, identify the particular cavities that contain individual figured specimens.

*Pilton Beds* (sample taken from a small lens of limestone set among slates in the courtyard of Doble Farm, National Grid Reference SS 0415 2205): *Gnathodus* cf. *semiglaber*, *Siphonodella* sp., *Spathognathodus* cf. *stabilis* (BU 22413).

This fauna, though very small, is important in that palaeontological information is rare in the upper part of the Pilton Beds (see a review of present information on the Pilton Beds in Goldring 1970). The Doble Farm fauna may be correlated tentatively with the upper *Siphonodella crenulata* Zone of Germany (Voges 1959, 1960) which some might wish to identify with the lower part of the *Ammonellipsites*-Stufe (but see Matthews 1970). More abundant conodonts of these kinds have recently been found in the Cork Beds of south-west Ireland (Matthews and Naylor 1973). The Doble Farm sample, like the Irish ones, produced a relatively heavy acid residue dominated by skeletal debris (ostracode, gastropod, and crinoid material) preserved in iron oxide.

*Kersdown Chert* (sample taken from a limestone high in the succession of siliceous rocks exposed in Kersdown Quarry, Bampton. Ref. SS 9635 2220): *Gnathodus commutatus homopunctatus*, *G. delicatus*, *G. semiglaber*, *G. texanus pseudosemiglaber*, *G. texanus texanus*, *G.* sp. indet., *G.* sp., *Mestognathus beckmanni*, *Pseudopolygnathus* sp. (BU 22418).

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EXPLANATION OF PLATE 50

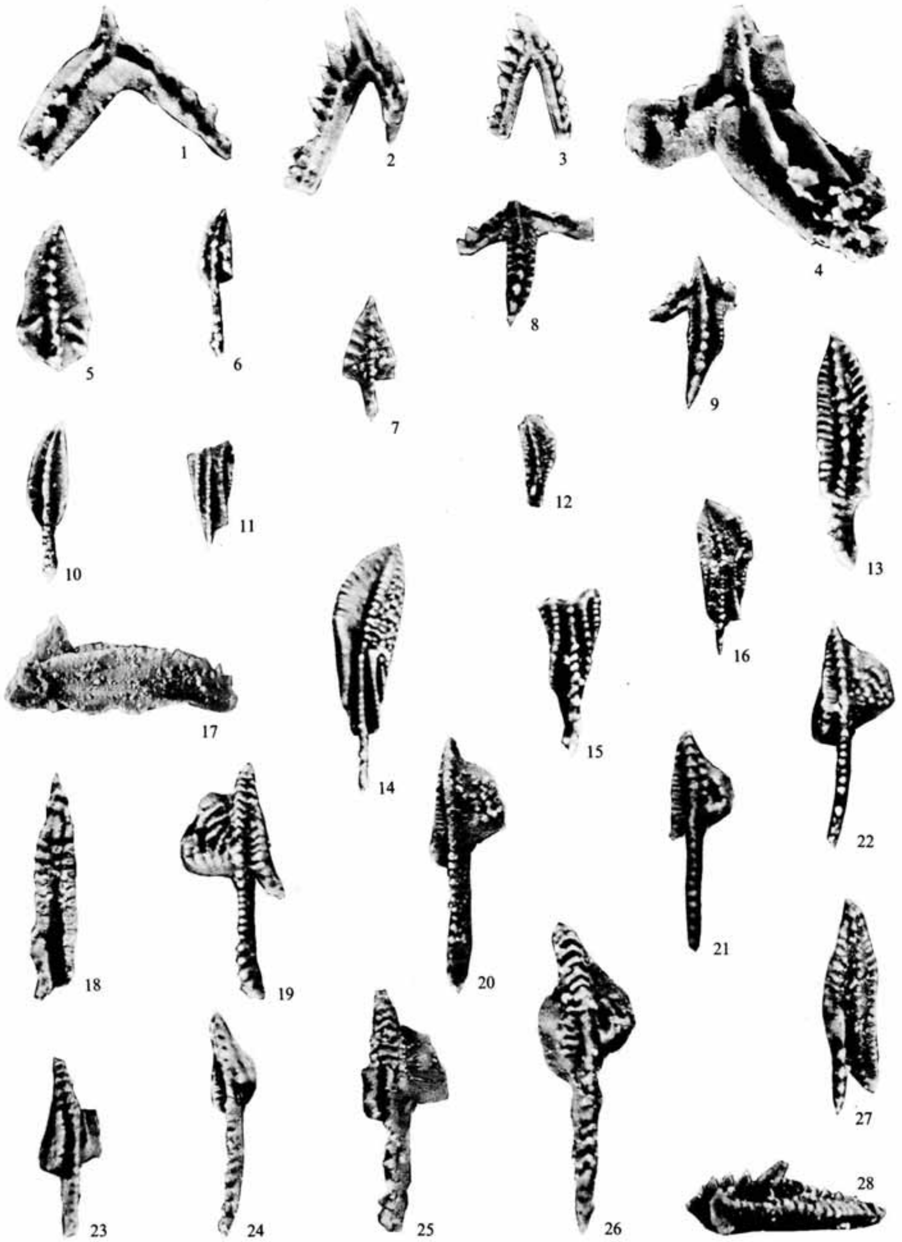
Specimens dusted with ammonium chloride. All ×25.

Figs. 1–22 from immediately below the *crenistria* Bed at Westleigh Quarry (see discussion of Westleigh Limestone).

Figs. 1, 4. *Geniculatus claviger*. BU 22422/11, BU 22420/20.
Figs. 2, 3. *Apatognathus* sp. BU 22422/5, BU 22422/4.
Fig. 5. *Polygnathus communis carina*. BU 22422/7.
Figs. 6, 10. *Polygnathus communis communis*. BU 22422/8, BU 22422/6.
Fig. 7. *Pseudopolygnathus triangulus triangulus*. BU 22422/1.
Figs. 8, 9. *Scaliognathus anchoralis*. BU 22422/3, BU 22422/2.
Figs. 11, 12, 15. *Siphonodella* sp. BU 22422/14, BU 22422/15, BU 22422/17.
Fig. 13. *Polygnathus inornatus*. BU 22422/16.
Fig. 14. *Siphonodella cooperi*. BU 22422/13.
Fig. 16. *Siphonodella isosticha*. BU 22422/12.
Figs. 17, 18. *Cavusgnathus unicornis*. Lateral and upper views of BU 22422/10.
Fig. 19. *Gnathodus bilineatus*. BU 22420/2.
Figs. 20, 22. *Gnathodus* sp. BU 22420/1, BU 22420/4.
Fig. 21. *Gnathodus delicatus*. BU 22422/18.

Figs. 23–28 from the Kersdown Chert at a point high in the succession exposed in Kersdown Quarry (see discussion of Kersdown Chert).

Figs. 23, 25, 26. *Gnathodus texanus pseudosemiglaber*. BU 22418/1, BU 22418/3, BU 22418/4.
Fig. 24. *Gnathodus texanus texanus*. BU 22418/2.
Figs. 27, 28. *Mestognathus beckmanni*. Upper and lateral views of BU 22418/5.




MATTHEWS and THOMAS, Carboniferous conodonts

A loose block of limestone found in Kersdown Quarry, and presumed to have come from much the same site in the stratigraphy as the sample above, yielded: *Gnathodus commutatus commutatus*, *G. delicatus*, *G. texanus pseudosemiglaber*, *G. texanus texanus*, *Siphonodella* sp. (BU 22417).

Rare conodonts can be found in the cherty rocks of the quarry. They include nothing that does not appear in the two lists above. An interesting feature of these two lists is that they each have one conodont that is distinctly older than the others. It would be dangerous, however, to conclude from this that the Bampton succession, as well as the Westleigh, has reworked conodonts. The Kersdown Quarry samples have each produced only one 'questionable' specimen, and the possibility of contamination cannot be excluded. The question of reworking remains open.

Kersdown Quarry has produced a specimen of *Merocanites* cf. *similis* and a *Bollandites* sp. (Prentice and Thomas 1965). The succession in the quarry probably equates with a high part of the German *Ammonellipsites*-Stufe (see a discussion of conodonts and goniatites of this age in Weyer 1972). Neither the conodonts nor the goniatites give any indication of *Goniatites*-Stufe horizons.

*Westleigh Limestone.* The calcilutite bed with abundant specimens of *Goniatites crenistria* is a useful marker in the quarries around Burlescombe and Holcombe Rogus. At Westleigh Quarry itself, in the Middle Quarry (ST 065 176; see text-fig. 1*c*), a coarse limestone situated immediately below the *crenistria* Bed has produced abundant conodonts, including the following: *Apatognathus* sp., *Cavusgnathus unicornis*, *Geniculatus claviger*, *Gnathodus bilineatus*, *G. commutatus commutatus*, *G. commutatus homopunctatus*, *G. delicatus*, *G. girtyi* subspp., *G. semiglaber*, *G.* sp.

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EXPLANATION OF PLATE 51

Specimens dusted with ammonium chloride. All ×25.

Figs. 1, 2, 3, 18, 19. *Gnathodus* sp. indet. BU 22422/27, BU 22422/28, BU 22420/8, BU 22422/29, BU 22422/30 respectively. Immediately below *crenistria* Bed, Westleigh.

Figs. 4, 8, 9. *Gnathodus* sp. BU 22422/32, BU 22422/21, BU 22422/31 respectively. Immediately below *crenistria* Bed, Westleigh.

Fig. 5. *Gnathodus commutatus nodosus*. BU 22442/5. From high in the Upper Westleigh Limestone (see discussion of higher horizons in the Westleigh Limestone), Whipcott Quarry east.

Fig. 6. *Gnathodus commutatus homopunctatus*. BU 22422/26. Immediately below *crenistria* Bed, Westleigh.

Fig. 7. *Pseudopolygnathus triangulus pinnatus*. BU 22430/20. Stout's Cottage Quarry.

Figs. 10, 11. *Gnathodus commutatus commutatus*. BU 22422/20, BU 22422/19 respectively. From immediately below *crenistria* Bed, Westleigh.

Figs. 12–15, 20–24. *Gnathodus bilineatus*. 12, BU 22420/6. 13, BU 22434/2. 14, BU 22420/3. 15, BU 22434/3. 20, BU 22434/1. 21, BU 22434/4. 22, BU 22420/5. 23, 22420/9. 24, BU 22420/4. Specimens in figs. 13, 15, 20, 21 high in the Upper Westleigh Limestone, Westleigh Lower Quarry; others immediately below *crenistria* Bed, Westleigh.

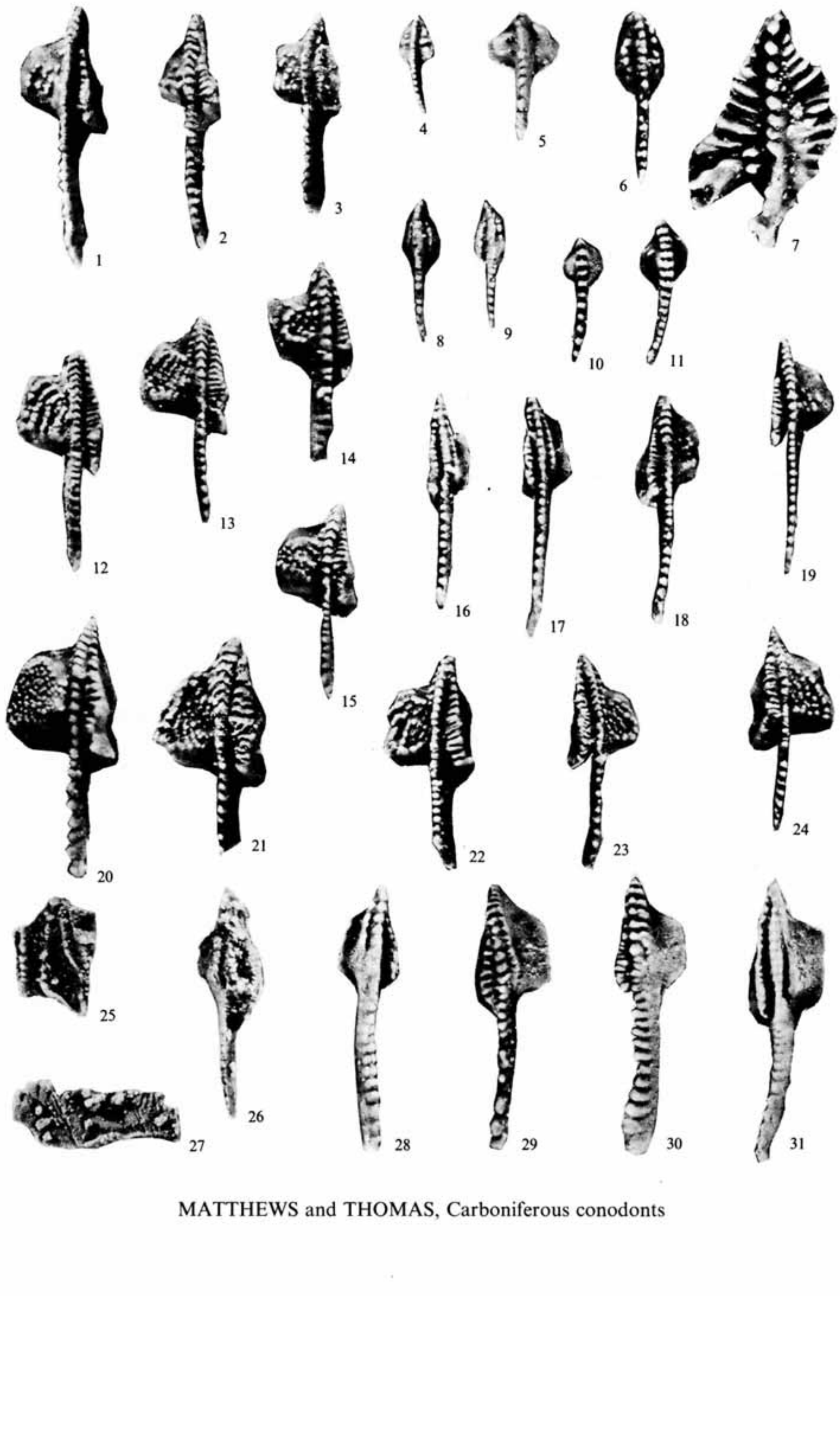
Figs. 16, 17, 28, 31. *Gnathodus girtyi*. BU 22422/23, 24, 22, 25 respectively. Immediately below *crenistria* Bed, Westleigh.

Fig. 25. *Siphonodella* sp. BU 22413/14. Pilton Beds, Doble Farm.

Fig. 26. *Gnathodus* cf. *semiglaber*. BU 22413/12. Pilton Beds, Doble Farm.

Fig. 27. *Spathognathodus* cf. *stabilis*. BU 22413/13. Pilton Beds, Doble Farm.

Figs. 29, 30. *Gnathodus girtyi*. BU 22434/5 and 6 respectively. High in the Upper Westleigh Limestone, Westleigh Lower Quarry.




MATTHEWS and THOMAS, Carboniferous conodonts indet., *G.* cf. *bilineatus*, *G.* cf. *semiglaber*, *Mestognathus beckmanni*, *Polygnathus communis communis*, *P. communis carina*, *P. inornatus*, *P.* sp., *Pseudopolygnathus triangulus triangulus*, *Scaliognathus anchoralis*, *Siphonodella cooperi*, *S. isosticha*, *S.* sp. (BU 22420, 22421, 22422).

At East Whipcott Quarry (ST 074 187) the *crenistria* Bed is again available. The bed immediately below produced *Doliognathus latus*, *Gnathodus bilineatus*, *G. commutatus commutatus*, *Gnathodus* cf. *texanus*, *G.* sp. indet. (BU 22423) and from a second sample *Cavusgnathus naviculus*, *Gnathodus bilineatus*, *G. commutatus commutatus*, *G. commutatus homopunctatus*, *G. girtyi* subsp., *Mestognathus beckmanni*, *Siphonodella* cf. *obsoleta* (BU 22424, 22425, 22426, 22427).

At Fir Copse Quarry (ST 069 189), where no reference to the *crenistria* Bed as a marker is available, the coarse limestones again produced a mix of *Gnathodus bilineatus* and older forms: *Geniculatus claviger*, *Gnathodus bilineatus*, *G.* cf. *bulbosus*, *G. commutatus commutatus*, *G. texanus pseudosemiglaber*, *G.* sp. indet., *Mestognathus*? sp., *Polygnathus communis carina*, *Scaliognathus anchoralis*, *Siphonodella* sp., *Spathognathodus scitulus* (BU 22431).

A second Fir Copse Quarry sample, collected from a coarse limestone situated immediately below an ash development, produced *Gnathodus bilineatus*, *G. girtyi* subsp., *G.* sp. indet., *Mestognathus beckmanni*, *Siphonodella* sp. (BU 22432).

At Stout's Cottage Quarry (ST 038 192), a sample taken from a point 7 m above the *Michiganites hesteri* occurrence (Prentice and Thomas 1965, p. 41) yielded the following: *Gnathodus bilineatus*, *G. commutatus commutatus*, *G. commutatus homopunctatus*, *Pseudopolygnathus triangulus pinnatus*, *Pseudopolygnathus* cf. *dentilineatus* (BU 22430).

These faunas (Westleigh, Whipcott, Fir Copse, and Stout's Cottage Quarries) must be dated by reference to the youngest forms present. The occurrences of *Gnathodus bilineatus*, supported by the *G. girtyi* subspecies, *G. commutatus commutatus* and *G. commutatus homopunctatus*, suggest low *Goniatites*-Stufe horizons. It is satisfactory that this estimate of the age of these mixed faunas can be confirmed at Westleigh and Whipcott by occurrences of *Goniatites crenistria*, the zone fossil for cuIII$\alpha$ in the German orthochronology. Dr. W. H. C. Ramsbottom has kindly confirmed the identification of *G. crenistria* and has observed that it is *G. crenistria crenistria*, and not *G. crenistria schmidtianus* (see Nicolaus 1963), that is involved. The *crenistria* Bed itself has few conodonts. On the other hand, it was discovered during acid preparation that lightly silicified 'ghosts' of ostracode valves are especially abundant in this calcilutite.

*Higher horizons in the Westleigh Limestones produce faunas which include* Gnathodus commutatus nodosus. A particularly good fauna has been obtained from the section on the upper bench (eastern side) of East Whipcott Quarry: *Gnathodus bilineatus*, *G. commutatus commutatus*, *G. commutatus homopunctatus*, *G. commutatus nodosus*, *G. girtyi* subspp. (BU 22442).

This can be dated as being no older than cuIII$\beta$ of Germany (cf. Meischner 1971*a*, fig. 2). Similar faunas occur in the highest stratigraphy available in the old Lower Quarry (see text-fig. 1*c*) at Westleigh. None of them have given any sign of reworked material. The highest parts of the Westleigh stratigraphy obviously deserve further attention. Whipcott Quarry, abandoned when the sample listed above was taken, is now active again. When the section on the eastern side of the quarry is stable, it should be possible to integrate conodont, goniatite, trilobite, and brachiopod evidence there.

## REWORKED CONODONTS IN THE WESTLEIGH LIMESTONE

Since the faunas collected from horizons about the *crenistria* Bed are obviously mixed, there would be little point in making counts of individuals—no indication of the proportions by number of any original, 'natural' associations of forms can have survived. Also, since any of the specimens might have travelled some distance before final burial, the faunal lists above do not necessarily stand as records of 'basin-associated' conodonts.

The evidence of reworking can be used as a basis for comment on the source from which the conodonts were derived. It should be said first that the fact of redeposition is already clear in the lithological evidence. The limestones are of mixed character and include coarse 'shelf' debris (a particularly good example has been found in Stout's Cottage Quarry, where one bed contains a clast, $10 \times 10 \times 10$ cm approx., of the colonial coral *Lithostrotion arachnoideum*). There are also some signs of internal reworking—clasts of the red shaly interbeds are common, and at Westleigh, where the *crenistria* Bed is clearly recognizable, clasts of this same distinctive calcilutite occur 2 m higher in the succession, in a conglomeratic limestone. The conodonts, however, suggest that reworking might have been operating on a much greater stratigraphic scale than this.

An estimate of the maximum range of stratigraphy that might have contributed conodont material to the Westleigh succession can be constructed as follows:

1. The mix of conodonts found in the coarse limestone immediately underlying the *crenistria* Bed at Westleigh includes *Gnathodus bilineatus*, a form which can be regarded as occurring at its proper position in the succession.

2. *G. bilineatus* may be taken to indicate approximate equivalence with the Hotwells Limestone ('D Zone') of the 'Avonian' shelf succession. Note that this is a somewhat uncertain matter: Rhodes, Austin, and Druce (1969, p. 46) observed that *G. bilineatus* is available near the base of $D_2$ both on the North Crop of the South Wales Coalfield and in the Avon Gorge; but on p. 95 and fig. 51 of their paper they made no record of having found *G. bilineatus* in the Bristol stratigraphy (and, incidentally, the range-information given on p. 95 of Rhodes, Austin, and Druce 1969 would suggest that *G. bilineatus* is confined to the highest unit—the *G. girtyi collinsoni* Zone—of their zonal scheme, although elsewhere in their paper (pp. 44, 45) they observe that *G. bilineatus* is one of the characteristic forms in each of the two zones below—their *Mestognathus beckmanni*–*Gnathodus bilineatus* Zone and *G. mononodosus* Zone). The suggestion that *G. bilineatus* might occur in the Hotwells Limestone rests at present on no better basis than Rhodes, Austin, and Druce's information. Eventually, it may prove to occur somewhat lower.

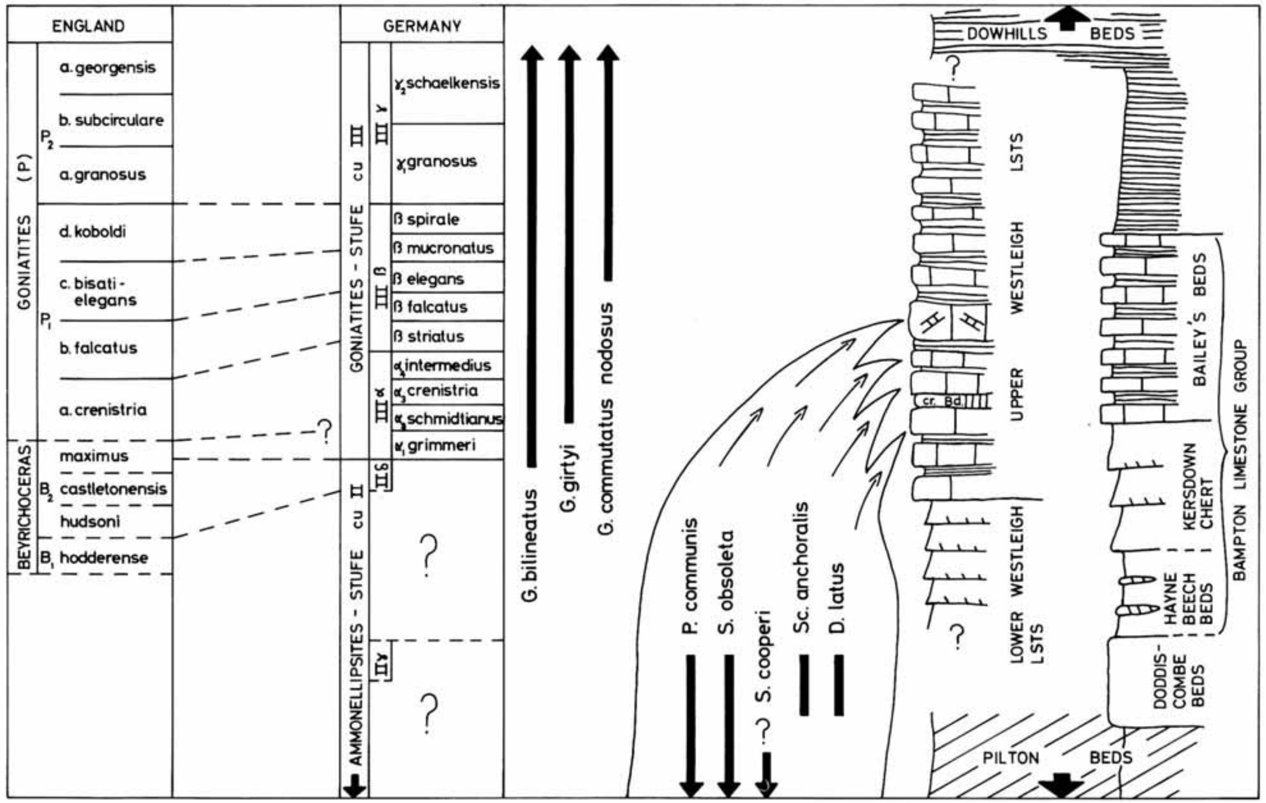
3. The coarse limestone immediately below the *crenistria* Bed at Westleigh includes also such forms as *Scaliognathus anchoralis*, which is found in the Black Rock Limestone of the eastern Mendips, and siphonodellids such as can be found in the upper

part of the Lower Limestone Shale and the lower part of the Black Rock Limestone there (Butler 1973).

The estimate of the range of stratigraphy that contributed conodonts to the Westleigh Limestone could therefore be set at 800 m—approximately the thickness that exists between the top of the Lower Limestone Shale and the base of the Hotwells Limestone in the Mendip Hills. This maximum estimate refers to the shelf situation. It is, of course, imaginable that sedimentary material due to be added to the Westleigh succession acquired some of its admixed conodonts from sources closer to the eventual point of final burial at Westleigh itself; but, because of the lithological evidence, shelf situations deserve examination as a possible source. Also, if one looks to the conodont evidence itself, one can observe that the admixed conodonts encountered at Westleigh are in almost every case forms that are now known from the 'Avonian'—*Doliognathus latus* has not yet been discovered there, but Butler (1973) records a *Doliognathus* sp.—and certainly include no form (Devonian, say, or earliest Carboniferous) that is unlikely to have been available in the shelf succession.

## WESTLEIGH LIMESTONE AND HELLEFELDER KALK

The Lower Carboniferous succession in the Sauerland region of Germany includes a limestone development, 100 m thick at maximum (Helmkampf 1969), which has been mapped for some 20 km along the strike. It is known as the Westenfelder Kohlenkalk (Helmkampf 1969) or the Hellefelder Kalk (Gauglitz 1967; Meischner 1971*b*). It may be compared with the Westleigh Limestone in several respects. The two occupy approximately the same range of Dinantian age. They are set among what are generally fine-grained and to some extent siliceous basinal sediments. The limestones can in each case reach coarseness above sand grade, and the ranges of bed thicknesses are comparable. In each case there are thin, reddish, shaly interbeds, and chert, often nodular, is common near the bases of individual thick limestones. The Hellefelder Kalk (see Gauglitz 1967, fig. 10), like the Westleigh Limestone (see above), gives clear evidence of internal erosion, and in both cases reworked conodonts are found. The two developments of limestone are of the same facies-type, and are of much the same age; but they are in one respect entirely different. The Westleigh Limestone, it seems, acquired much of its substance from a shelf situated generally to the north. The Hellefelder Kalk was derived from southerly sources. Its carbonate sediment ('pre-sorted' according to Meischner 1971*b*) was recycled from reefs of Devonian age in the Attendorn neighbourhood. These reefs, originally grown near the shelf margin of late Middle and early Upper Devonian times, supplied carbonate sediment for delivery northward into the more extensive basin of early Carboniferous time. The Hellefelder Kalk includes among its examples of reworked conodonts Devonian as well as Lower Carboniferous forms. The Westleigh Limestone sediment, derived from an entirely different source but eventually assuming the same set of facies-characteristics, carried with it only Lower Carboniferous conodonts such as might be found in the Carboniferous Limestone.




TEXT-FIG. 2. At left, association of English and German proposals on Viséan goniatite zones, following Weyer 1972. At right, the Westleigh (cr. Bd. = *crenistria* Bed) and the Bampton succession, placed according to goniatite information (no attempt made to indicate thicknesses). At centre, ranges of conodonts (following Meischner's 1971*a* association of conodont ranges and goniatite zones): upper left, conodonts regarded as being approximately in place; lower right, conodonts regarded as reworked.

## SYSTEMATIC NOTES

The reworking must be assumed to have upset the original sets of variants of particular forms. There is therefore no case for attempting a formal systematic discussion of the conodonts found. It is hoped that the photographic illustrations will be taken as sufficient justification of the names entered in the faunal lists above. The species listed are in most cases interpreted as by German authors (Bischoff 1957; Voges 1959; Meischner 1971*a*) since this makes for convenient reference to German stratigraphic interpretations. *Gnathodus texanus texanus* and *G. texanus pseudosemiglaber* are interpreted as in Thompson and Fellows (1970). One name used in the lists above deserves special discussion.

### *Gnathodus* sp. indet.

Plate 51, figs. 1, 2, 3, 18, 19

*Remarks*. Gnathodids listed by this name have an outer platform which is of variable width and is ornamented by nodes. In slimmer forms there are relatively few nodes on the posterior part of the outer platform. The outer platform is highest near its anterior margin and is never as broad and flat as in *G. bilineatus* (Roundy), nor does its margin have the clear posterior-lateral angle common in that species. The outer platform of *G.* sp. indet. better resembles that of *G. semiglaber* Bischoff, but the inner side of the platform is more parapet-like than would be typical of *G. semiglaber*. This inner parapet is well developed beside an anterior part of the carina, but does not accompany the carina to the posterior end. In this respect *G.* sp. indet. again differs from *G. bilineatus*.

In Boogaert (1967) *G. delicatus* Branson and Mehl is interpreted in a way that would admit specimens of the present kind (see Boogaert 1967, pl. 2, figs. 14, 15). However, the broadly developed forms of *G. delicatus* are normally expected to show a better-developed parapet than is present in Boogaert's figured specimens, and often have a line of nodes accompanying the posterior course of the carina on its outer side. Certain of the slimmer forms of *G.* sp. indet. show some resemblance to *G. typicus* Cooper. Thompson and Fellows (1970), who have studied and refigured Cooper's holotype, suggest that the gnathodid identified as *G. typicus* by Boogaert (1967, pl. 2, fig. 21) might better belong in their *G. texanus pseudosemiglaber*. It is likely that the same judgement would be made of certain of the specimens figured as *G. typicus* by Marks and Wensink (1970, pl. 4). If so, the validity of Marks and Wensink's (1970, pp. 249–250) *G. typicus* Zone, proposed as following immediately above the *anchoralis* Zone, would come into doubt.

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