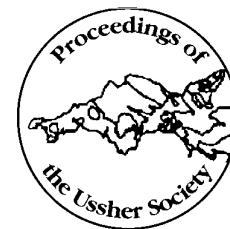


NEW CONODONT INFORMATION RELATING TO THE DEVONIAN STRATIGRAPHY OF THE TREVONE BASIN, NORTH CORNWALL, SOUTH-WEST ENGLAND



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Austin, R. L., Dreesen, R., Selwood, E. B., and Thomas, J. M. 1992. New conodont information relating to the Devonian stratigraphy of the Trevone Basin, north Cornwall, south-west England. *Proceedings of the Ussher Society*, **8**, 23-28.

Ramiform and diagnostic Pa elements of the conodont genera *Polygnathus*, *Schmidtnathus* and *Icriodus* have been recovered from a turbidite limestone in the Trevose Slate Formation in the Pentire Succession at Rumps Point. On the basis of the presence of *P. limitaris*, *P. cristatus* and *S. peracutus* and the absence of *Palmatolepis* an assignment to the Givetian Upper *hermanni* subzone is proposed. The fauna is indicative of a polygnathid biofacies (deep subtidal). A new record of a Frasnian (lower *Ancyrognathus triangularis* Zone) fauna is reported from a megaclast at the base of a pillow lava sequence at Com Head. This is based on the occurrence of the following diagnostic forms: *An. triangularis*, *An. tsiensi*, *Palmatolepis proversa*, *Pa. hassi*, *Pa. plana*, *Pa. punctata* and *Ancyrodella lobata*. The fauna indicates a mixed palmatolepid-polygnathid-icriodid-ancyrodellid-biofacies, representing redeposited debris in a perireefal setting. Both faunas have a conodont CAI estimated at 5. The Pentire Succession is revised in the light of this data; the post-lower *An. triangularis* Zone age of the Pentire Volcanic Formation, suggests a mainly Famennian age for the Pentire Slate Formation. The separate development of the Pentire and Trevone successions across the St Minver Synclinorium is reaffirmed.

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INTRODUCTION

British Geological Survey 1:50 000 Geological Sheets (335 and 336) illustrating the geology of the Padstow area, north Cornwall, are dominated by a large-scale outcrop pattern interpreted as the St Minver Synclinorium (Reid *et al.*, 1910): a complex east-west structure showing multiphase deformation in which structural interpretations have been confused by imperfect stratigraphic control (Figure 1).

Contrasting stratigraphic sequences represented across the fold, led Gauss and House (1972) to recognise the Pentire and Trevone successions in the northern and southern limbs respectively (Figure 2). Although both successions developed within the Trevone Basin (Matthews, 1977), their present juxtaposition has involved considerable tectonic shortening; with a number of workers (e.g. Gauss, 1973; burning, 1989) quoting significant thrusting.

The biostratigraphy of the Trevone Succession has been reviewed by Beese (1982, 1984). House and Dineley (1985, p.307) noted that "perhaps the best and thickest well-documented conodont sequence in Europe relevant to the boundary [Middle-Upper Devonian] is known from Marble Cliff, Trevone, North Cornwall. The sequence commences in the Trevone [Trevose] Slate, passes through limestone turbidites of the Marble Cliff Beds and continues in the Longcarrow Cove Beds". In the same paper Kirchgasser revised the zonal assignments of his classic work (1970) and its subsequent development by Mouravieff (1977) and House *et al.* (1978).

The continued importance of conodonts in the age determination of Variscan strata in south-west England is emphasised in this paper. However, many of the earlier records need to be reappraised with regard to changes in stratigraphic nomenclature, conodont biostratigraphy and palaeoecological interpretations.

The Pentire Succession is distinguished from the Trevone Succession principally by the presence of the Pentire Pillow Lava Group (Gauss and House, 1972); a thick sequence of volcanic rocks and basic intrusions, now more appropriately referred to as the Pentire Volcanic Formation. The only established dates in the Pentire Succession come from the Trevose Slates from which Tucker (1969) reported '*Polygnathus varca*' Zone conodonts [SW 931 812].

Details of another locality [SW 9350 8102] given by Dr S. C. Matthews in Gauss and House (1972), suggest an horizon near to the

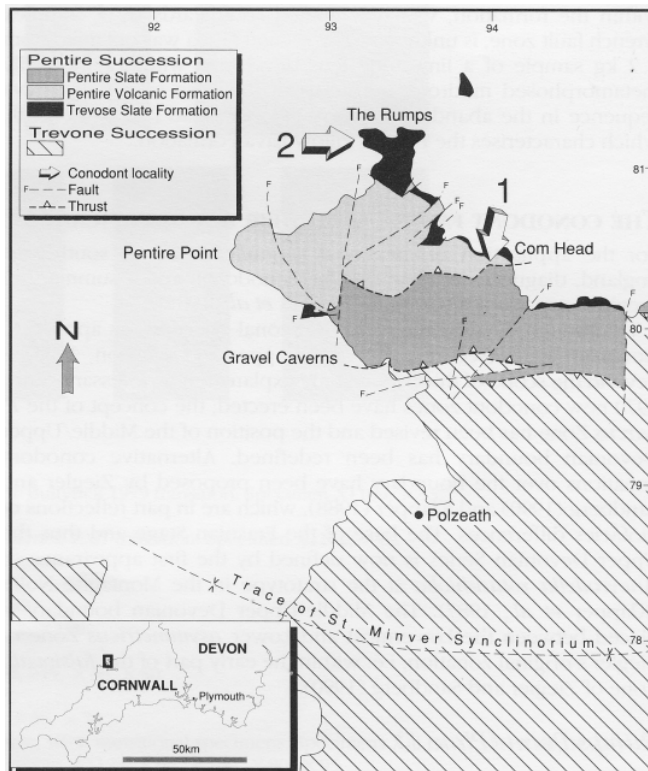


Figure 1: Locality Map showing the geology of the coastal section of the St Minver Synclinorium: trace of synclinorium after Pamplin (1990).

SERIES	STAGE	TREVONE SUCCESSION	PENTIRE SUCCESSION
UPPER DEVONIAN	L. FAMENNIAN	Polzeath Slates	Polzeath Slates
		Harbour Cove Slates	Gravel Caverns Congl.
	FRASNIAN	Merope Island Beds	Pentire Slates
		Longcarrow Cove Beds	Pentire Pillow Lava Gp
		Marble Cliff Beds	
MIDDLE DEVONIAN	GIVETIAN	Trevese Slates	Trevese Slates
	U. EIFELIAN		

Figure 2: The Trevone and Pentire successions: modified from Gauss and House (1972).

Eifelian/Givetian boundary. The middle Frasnian goniatites reported by House (1963) from the Gravel Caverns Conglomerate Member of the Pentire Slate Formation have subsequently been reinterpreted (House, 1977) as a derived fauna; a view consistent with recent palynomorph data (Dean, 1991). Since formational boundaries are largely obscured by faulting, the interpretation of the overall sequence within the Pentire Succession is tenuous.

This paper reports on conodont faunas from two localities within the Pentire Succession. The first is from 4 kg of a graded limestone turbidite within the Trevese Slate Formation at Rumps Point [SW 9320 8114]. This rare limestone occurrence crops out on a bare ledge at the foot of a grassy slope immediately above a sheer cliff south of the main dolerite headland. Its stratigraphic position within the formation, which is limited southwards by a complex wrench fault zone, is unknown. The second fauna was obtained from a 2 kg sample of a limestone lens developed within a thermally metamorphosed mudrock megaclast at the base of a pillow lava sequence in the abandoned quarry at Com Head [SW 9400 8050], which characterises the Pentire Pillow Lava Formation.

THE CONODONT FAUNAS AND THEIR AGE SIGNIFICANCE

For the application of the zonal sequence used in south-west England, diagnoses of characteristic conodonts, and a summary of previous conodont research, see Austin *et al.* (1985).

Although detailed discussion on zonal concepts, as applied to Devonian strata (see House, 1988; Klapper and Johnson, 1990) is beyond the scope of this paper, some explanation is necessary. Since 1970 new conodont zones have been erected; the concept of the *P. varcus* Zone has been revised and the position of the Middle/Upper Devonian boundary has been redefined. Alternative conodont zonations over the boundary have been proposed by Ziegler and Sandberg (1990) and Klapper (1988), which are in part reflections of biofacies differences. The base of the Frasnian Stage and thus the Upper Devonian Series is now defined by the first appearance of *Ancyrodella rotundiloba* at the stratotype in the Montagne Noire (Klapper *et al.*, 1987). The Middle-Upper Devonian boundary is placed between the Lowermost and Lower *asymmetricus* Zone of Ziegler's original zonation, i.e. within the early part of the *falsiovalis* Zone of Ziegler and Sandberg (1990).

Rumps Point (Plate 1)

Pa elements of the following species are reported from the sample collected:- *Belodella devonica*, *Icriodus difficilis*, *Polygnathus ansatus*, *P. cristatus*, *P. dubius*, *P. xylus ensensis*, *P. latifossatus*, *P. limitaris*, *P. ovatinodosus*, *P. timorensis*, *P. xylus* and *Schmidognathus peracutus*.

SERIES	STAGE	CONODONT ZONE	PENTIRE SUCCESSION (This paper)	
LOWER CARBONIFEROUS	TOURN	<i>sulcata</i>		
UPPER DEVONIAN	FAMENNIAN	<i>praesulcata</i>	Gravel Caverns Conglomerate Member	
		<i>expansa</i>		
		<i>postera</i>	Pentire Slate Formation	
		<i>trachytera</i>		
		<i>marginifera</i>		
		<i>rhomboidea</i>		
		<i>crepida</i>		
		<i>Pa. triangularis</i>		
		FRASNIAN	<i>gigas</i>	Pentire Volcanic Formation
			<i>An. triangularis</i>	*1
	<i>asymmetricus</i>		Trevese Slate Formation	
	<i>disparilis</i>			
	MIDDLE DEVONIAN	GIVETIAN	<i>hermanni</i>	*2
			<i>varcus</i>	

Figure 3: Revised Pentire Succession: conodont biozones after Austin *et al.* (1985) and House (1988). For subsequent revisions and alternative conodont zonations see Ziegler and Sandberg (1990), Klapper (1988), and Klapper and Johnson (1990). NB, the lower *An. triangularis* Zone is equivalent to the Late *hassi* Zone of Ziegler and Sandberg (1990). The precise correlations of lithostratigraphic and chronostratigraphic boundaries are unknown. *1 Com Head conodont horizon, *2 Rumps Point conodont horizon.

Non-assigned Pb, M and S elements have also been recovered.

The conodont abundance is 1,100 specimens per kilo. The fauna is assigned to the Upper *hermanni* subzone (Klapper and Johnson, 1980; 1990) which is near, but not at, the top of the Givetian Stage (Figure 3). The determination is based on the presence of *P. cristatus* and *P. limitaris*, but without *Palmatolepis* (see also Feist and Klapper, 1985). This level probably correlates within an 11 m interval embracing Horizons 36-54 of Kirchgasser in the Marble Cliff Beds (see House and Dineley, 1985).

Com Head (Plate 2)

Pa elements of the following species are reported from the sample collected:- *Ancyrodella gigas*, *A. lobata*, *Ancyrognathus asymmetricus*, *An. triangularis*, *An. tsiensi*, *Icriodus symmetricus*, *Palmatolepis hassi*, *Pa. plana*, *Pa. proversa*, *Pa. punctata*, *Polygnathus decorosus* and *P. webbi*. In addition the Pb elements *Nothognathella bicristata* and *N. brevidonta* and non-assigned M and S elements, together with other Pb elements have been identified. The conodont abundance is in excess of 1,000 specimens per kilo. An assignment is made to the lower part of the *An. triangularis* Zone [Late *hassi* Zone] (see Ziegler and Sandberg, 1990), based on the occurrence of *An. triangularis*, *An. tsiensi*, *Pa. plana*, *Pa. proversa* and *Pa. punctata*. It is of early Frasnian age. Recently a taxonomic revision of *An. triangularis* and *An. tsiensi* has been undertaken by Sandberg *et al.* (in press); specimens we assign to *An. tsiensi* are restricted to the lower part of the Late *hassi* Zone.

BIOFACIES

A summary of the development of the concept of Devonian conodont biofacies is given by Austin *et al.* (1985), and Mawson and Talent (1989).

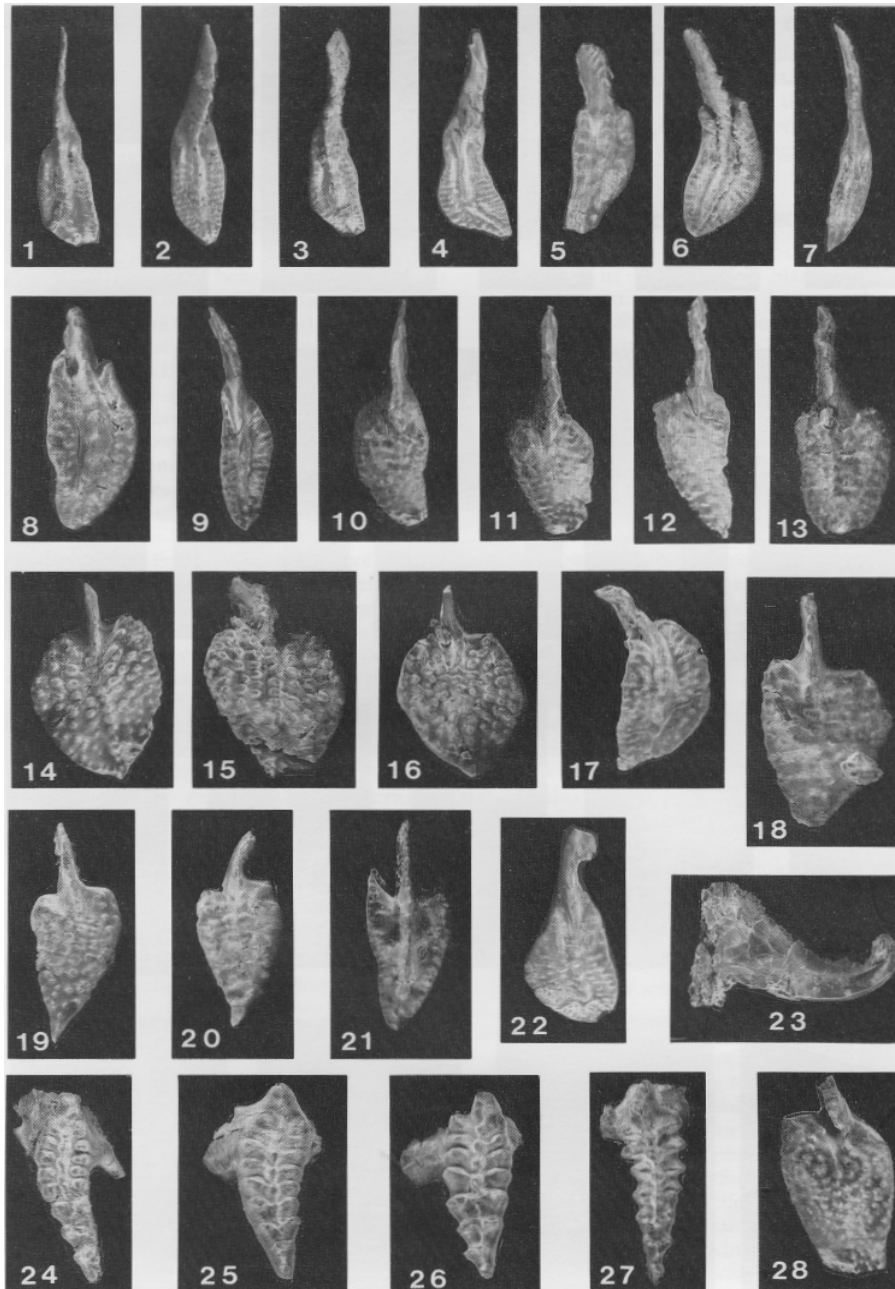


Plate 1. Rumps Point conodonts, (All except 23 are upper views of Pa element).

- 1: *Polygnathus xylus* Stauffer, 1940. Specimen X1099; x 100.
 2: *Polygnathus ovatinodosus* Ziegler and Klapper, 1976 - *Polygnathus denisbriceae* Bultynck 1979 transition. Specimen X1100; x 55.
 3: *Polygnathus ansatus* Ziegler and Klapper, 1976. Specimen X1101; x 70.
 4: *Polygnathus ansatus* Ziegler and Klapper, 1976. - *Polygnathus hemiansatus* Bultynck 1987 transition. Specimen X1102; x 60.
 5: *Polygnathus latifossatus* Wirth, 1967. Specimen X1103; x 120.
 6: *Polygnathus dubius* Hinde, 1879. Specimen X1104; x 60.
 7: *Polygnathus timorensis* Klapper, Philip and Jackson, 1970, Specimen X1116; x 80.
 8: *Polygnathus xylus ensensis* Ziegler, Klapper and Johnson, 1970, Specimen X1112; x 100.
 9: ?*Polygnathus dubius* Hinde, 1897. Specimen X1116; x 70.
 10-12: *Schmidognathus peracutus* (Bryant) 1921. Specimens X1105, X1107, X1108; $\diamond 45$, x 40, x 50.
 13 & 28: *Schmidognathus* sp. Specimens X1117, X1127; x 50, x 50.
 14-16: *Polygnathus cristatus* Hinde, 1879. Specimens X1120, X1121, X1122; x 75, x 80, x 70.
 17-18: *Polygnathus limitaris* Ziegler and Klapper, 1976 - *Polygnathus cristatus*, Hinde, 1879. transitional specimens. Specimens X1119, X1111; x 80, x 90.
 19-22: *Polygnathus limitaris* Ziegler and Klapper 1976. Specimens X1109, X1110, X1118, X1128; x 60, x 100, x 80, x 95.
 23: *Belodella devonica* (Stauffer) 1940 lateral view. Specimen X1114; x 150.
 24-27: *Icriodus difficilis* Ziegler, Klapper and Johnson 1976. Specimens X1123, X1124, X1126; x 85, x 110, X 90, X 120.
 Illustrated specimens are deposited in the British Museum (Natural History) to whose catalogue X numbers refer.

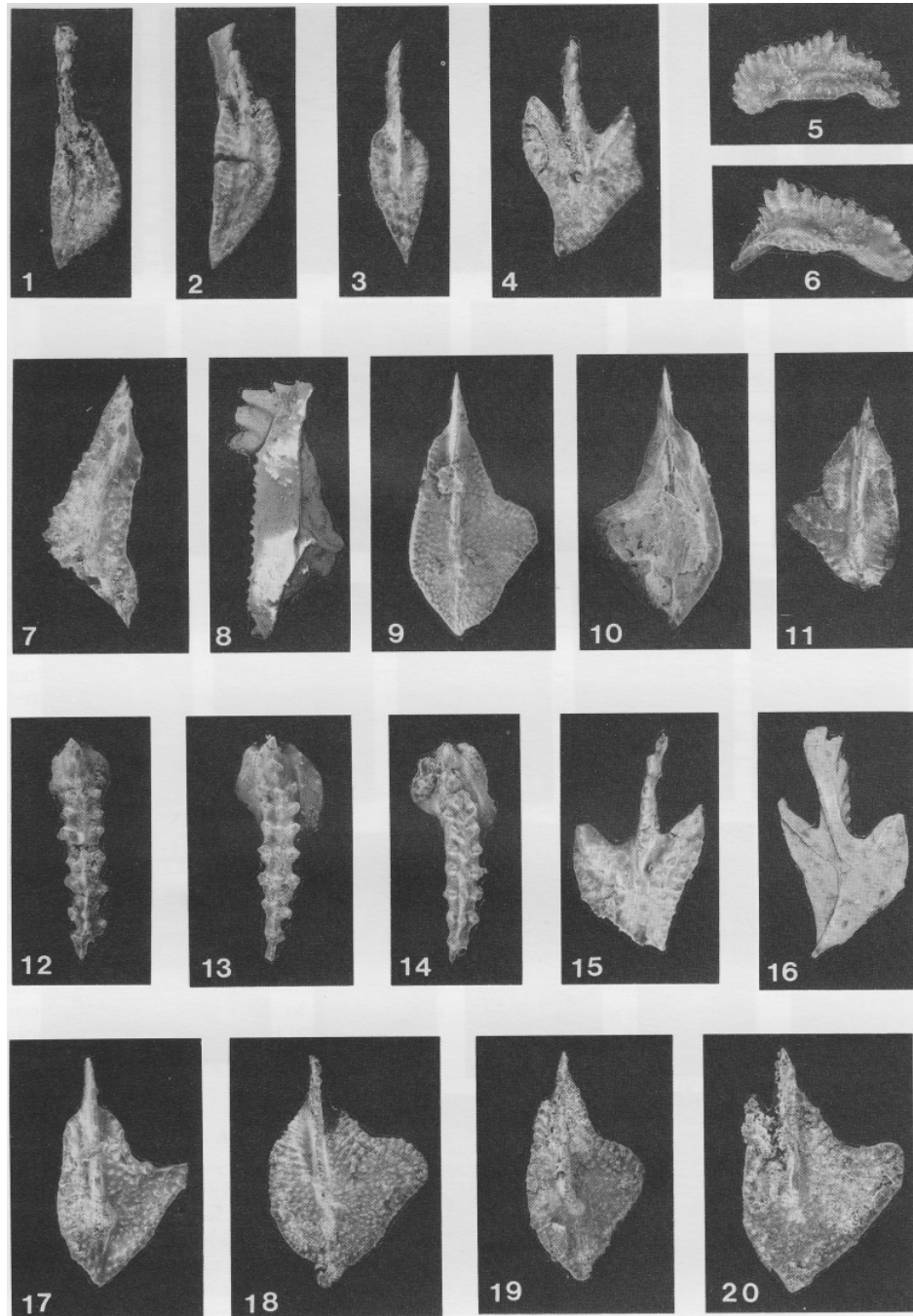


Plate 2. Com Head conodonts, (All except 5, 6, 8, 10 & 16 are upper views of Pa element).

- 1: *?Polygnathus webbi* Stauffer, 1938. Specimen X1080; x 70.
 2 & 3: *?Polygnathus decorosus* Stauffer, 1938. Specimens X1081, X1082; x 90, x 70.
 4: *Ancyrodella lobata* Branson and Mehl, 1934. Specimen X1086; x 50.
 5: *Nothognathella brevidonta* Youngquist, 1947. Lateral view Pb element. Specimen X1083; x 80.
 6: *Nothognathella bicristata* Youngquist and Miller, 1948. Lateral view Pb element. Specimen X1084; x 70.
 7 & 8: *Ancyrognathus tsiensi* Mouravieff, 1982. Fig. 8 lower view. Specimen X1085; x 70.
 9 & 10: *Palmatolepis hassi* Muller and Muller, 1957. Fig. 10 lower view, Specimen X1098; x 70.
 11: *Ancyrognathus triangularis* Youngquist, 1945. Specimen X1088; x 80.
 12-14: *Icriodus symmetricus* Branson and Mehl, 1934. Specimens X1089, X1090, X1091; x 80, x 100, x 110.
 15 & 16: *Ancyrodella gigas* Youngquist, 1947. Fig. 16 lower view. Specimen X1092; x 100.
 17 & 20: *Palmatolepis proversa* Ziegler, 1958. Specimens X 1094, X1097; x 95, x 100.
 18: *?Palmatolepis punctata* (Hinde) 1879. Specimen X1095; x 75.
 19: *Palmatolepis plana* Ziegler and Sandberg, 1990. Specimen X1096; x 80.
 Illustrated specimens deposited in the British Museum (Natural History), to whose catalogue X numbers refer.

For further details of Middle Devonian biofacies see Bultynck (1976), Chatterton (1976), Schumacher (1976) and Weddige and Ziegler (1976).

Ninety per cent of the 2,266 Pa elements recovered from the Rumps Point limestone are of the genus *Polygnathus*. Pa elements of *Icriodus* (6%), *Schmidognathus* (3%) and the genus *Belodella* (1%) make up the rest of the fauna. The fauna represents the polygnathid biofacies; interpreted as a deep subtidal facies by Schumacher (1976), but as a more open, deeper water, marine biofacies by Chatterton (1976). The conodont fauna reported by Kirchgasser (1970, 1985), from the Marble Cliff and Longcarrow Cove Beds at Marble Cliff, also represents the polygnathid biofacies.

Sandberg (1976) proposed five biofacies belts for a late Devonian zone, and although the number of belts has remained the same for the Upper Devonian, subsequent refinement (Sandberg and Ziegler, 1979, Sandberg and Dreesen, 1984, Sandberg *et al.*, 1988) permits recognition of eleven biofacies (numbered I-XI in a landward direction), with four of the biofacies (V-VII, IX) probably restricted to the Famennian (Ziegler and Sandberg, 1990). Each biofacies (Sandberg *et al.*, 1988) was named after the one or two most abundant platform genera; however, standard biofacies names are not applied to mixed faunas in which two genera do not constitute at least 70% of the population. For biofacies determination, the Pb and ramiform component of the fauna is discounted from the calculations.

The composition and nature of Frasnian conodont biofacies is unresolved (Druce, 1976; Klapper and Lane, 1985; Mouravieff, 1970; Sandberg *et al.*, 1989, 1990; Vandelaer *et al.*, 1989; Ziegler and Sandberg, 1990). Klapper and Lane (1985) favoured analysis of conodont biofacies at the specific level, and considered their *Polygnathus* biofacies, recognised in Canadian faunas, to be possibly analogous with the polygnathid-icriodid biofacies of the *stryiacus* Zone as reported by Sandberg (1976).

Examination of the 1,145 Pa elements from the Com Head fauna gives the following percentages for the genera represented expressed as a percentage of the total):- *Polygnathus* 44%, *Icriodus* 35%, *Ancyrodella* 10%, *Palmatolepis* 10% and *Ancyrognathus* 1%. This represents a polygnathid-icriodid biofacies, according to the criteria of Sandberg *et al.* (1988), and a polygnathid biofacies according to the criteria of Klapper and Lane (1985). However, an association with *Polygnathus*, *Icriodus*, *Ancyrodella* and *Palmatolepis*, all present at, or in excess of 10%, together with the presence of *Belodella*, suggests that the Com Head conodont fauna indicates a mixed biofacies with a significant contribution of elements from very shallow and shallow water environments (see Sandberg *et al.*, 1990), and represents redeposited debris in a perireefal setting. A similar Lower Frasnian mixed biofacies has been reported from Belgium (Vandelaer *et al.*, 1989).

In a pioneer study on the hydrodynamics of conodont elements, McGoff (1991) noted that samples which have undergone significant post-mortem sorting, reflect only the hydrodynamic regime prevalent at the time of deposition. Thus caution is needed in the recognition of conodont biofacies. The hydrodynamics of Pa, Pb, Sd and Sc elements of *Polygnathus* and the Pa elements of *Icriodus*, *Palmatolepis* and *Ancyrodella* were investigated by McGoff, who distinguished those faunas formed through down-slope mixing of conodonts of several environments, from mixed faunas resulting from regression (Sandberg *et al.*, 1988).

McGoff's study would also suggest that conodonts such as the broad and narrow Pa elements of *Polygnathus*, and the Pb elements of *Polygnathus* and *Palmatolepis* would each be transported differently. A further consideration is the size of the fauna and its composition; different interpretations may arise from using small, as opposed to large faunas and the inclusion of diagnostic non-Pa elements of genera (see Klapper, 1988). Studies at the species level should be more informative than those at the generic level. Transport of the Rumps Point fauna is indicated by the consistent size of the dominant slender Pa elements of *Polygnathus*. Furthermore, non-Pa elements (2,335) are under-represented compared to the number of Pa elements (2,266). Sorting is indicated also by the presence of 167 Pb elements and only 6 M, 2 Sb and 2,160 indeterminate ramiform elements. Similarly there has been sorting of the Com Head fauna, since the ramiform elements (81 Pb, 30 M, 7 Sb and 528 indeterminate), are again under-represented.

CONODONT COLOUR AND ITS SIGNIFICANCE

The conodonts from both samples are black in colour and have been assigned a Conodont Colour Alteration index of 5 (Epstein *et al.*, 1977). The CAI 5 indicates that the conodonts have been affected by regional metamorphic temperatures in excess of 300°C since incorporation into the enclosing sediment.

STRATIGRAPHIC IMPLICATIONS

Conodont evidence from Rumps Point refines the age of the turbidite limestones in the Trevoise Slate Formation within the Pentire Succession to the Upper *hermanni* Subzone. Both age and polygnathid biofacies are consistent with determinations within the Marble Cliff Limestone of the Trevone Succession. It is reasonable to assume that the Rumps Point occurrence represents a short-lived, distal extension of the Marble Cliff Beds within the Trevone Basin. Gauss and House (1972) suggested that these limestones were derived from intra-basinal shoals rather than reefs; this would be consistent with the conodont biofacies interpretation. Mouravieff (1977) noted that Lower *asymmetricus* Zone conodonts in the Marble Cliff Beds, extend through the succession at Porthmissen Bridge towards Longcarrow Cove.

Within the Pentire Succession, the dating of the megaclast at the base of the pillow lava sequence at Com Head shows that the principal eruptive phase (Pentire Volcanic Formation), post-dates the lower part of the *triangularis* (Late *hassi*) Zone. This limestone, which was lithified prior to the transportation of the megaclast, is a bioclastic packstone/grainstone with calcispheres, unspecified small deformed lime-mud intraclasts, peloids and bioclasts including ostracods, crinoids, brachiopod shells and spines, rare trilobites and conodonts. The calcispheres include *Vicinesphaera*, *Radiosphaera* and *Archaeosphaera*; some questionable dasyclads (palaeoberesellids) could also be represented. The lithology is indicative of a relatively shallow carbonate-ramp environment, containing elements of restricted marine facies. Such evidence indicates the existence of significant Frasnian shoaling and instability at the northern margin of the Trevone Basin: a direct link with developing volcanicity appears most likely. Clearly elements represented within the limestone have suffered both pre- and post-lithification displacement downslope. Although the enclosing sedimentary sequence appears basinal in character, total transport from the carbonate ramp need not be great, for the associated volcanic rocks suggest significant shoaling (Dr G. Borley, pers. comm.).

Regionally it now appears that the onset of the main phase of extrusive volcanism in the Pentire Succession largely post-dates that in the Trevone Succession which was completed by Upper *asymmetricus* Zone times (top of Harbour Cove Slate Formation, Beese, 1984).

In a report on mapping completed for the forthcoming edition of the British Geological Survey 1:50,000 Geological Sheet 335 & 336 (Trevoise Head and Camelford), Smith (1990) abandoned the concept of a distinct Pentire Succession, and argued for a single succession across the St Minver Synclinorium. The Trevoise Slate Formation was extended upwards to include the Pentire Volcanic Formation, and the overlying Pentire Slate Formation was referred to the Harbour Cove Slate Formation. Apart from the lithological dissimilarities between the Pentire Slate and Harbour Cove Slate formations, this interpretation also presents formidable biostratigraphic difficulties. Whilst the Harbour Cove Formation in the Trevone Succession predates upper Frasnian ostracod faunas determined from the base of the overlying Polzeath Slate Formation (Beese, 1984), the Pentire Slate is unlikely to be older than Famennian (Figure 3). It overlies the Pentire Volcanic Formation (the base of which post-dates the lower part of the Frasnian *An. triangularis* Zone) and ranges up to, at least, the upper Famennian (Dean, 1991). The diachronous northward extension of the Harbour Cove Formation into the Pentire Succession which is thus demanded by the amalgamation of the Trevone and Pentire successions, is not supported by the age of the Polzeath Slate Formation. The upper Frasnian to middle Famennian age range of this formation, which is placed at the top of the Trevone Succession, necessarily excludes it from the Pentire Succession where the equivalent interval is represented by other formations (Figure 3).

In our opinion the Trevone and Pentire successions are quite distinct, although they will not be differentiated on the revised 1:50,000 Trevoise Head and Camelford geological map.

ACKNOWLEDGEMENTS

Facilities and funding by the Universities of Exeter (EBS, JMT) and Southampton (RLA) and by the Institut Scientifique de Service Public, Liege (RD) are acknowledged with gratitude. We also thank Mrs D. Woods, who prepared the samples and patiently picked and sorted the faunas, Dr B. Creesey for her SEM contribution to the plates, Mr B. Marsh for photography, Mr R. Saunders for technical assistance and Mr T. J. Bacon for drafting the text figures. Critical comments made on the manuscript by Professor M. R. House and Dr M. J. Whiteley are appreciated.

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