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Late Devonian and Lower Carboniferous conodonts from north Cornwall and their stratigraphical significance

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Detailed conodont analysis in the Launceston area of north Cornwall has revealed complex localised facies development in the Upper Devonian and Lower Carboniferous. The Petherwin, Stourscombe and Yeolmbridge Beds of Selwood (1960) are raised to Formational status and sub-divided into lithologically distinct members. The association of cephalopod limestone, nodular limestone and limestone conglomerate implies that during the Famennian an important submarine rise controlled sedimentation. It is inferred that the structure had an earlier history, and may have been influential as early as the Middle Devonian. Monotonous slate successions yielding comparable ages as the rise deposits are interpreted as their basinal equivalents.

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Introduction

This paper presents the results of extensive sampling of limestone and calcareous slate horizons in the Launceston area of north Cornwall (Fig. 1) during the current resurvey of Sheet 337 by the University of Exeter for the Institute of Geological Sciences. Over 350kg of limestone has been dissolved yielding some 30000 conodonts ranging from the Upper Devonian *marginifera* - zone (Sandberg and Ziegler 1973) through to the Lower Carboniferous *anchoralis*- Zone (Bischoff 1957). Systematic conodont palaeontology is considered to be beyond the scope of this paper.

Selwood (1960, 1971) established a working stratigraphy in the Launceston area based on the localised distribution of ammonoids and trilobites, and recognised the Petherwin Beds, the Stourscombe Beds and the Yeolmbridge Beds as an ascending sequence from the Upper Devonian into the Lower Carboniferous. Detailed conodont analysis however, reveals complex localised facial variation and necessitates modification of Selwood's basic stratigraphy. Units are raised to formational status; the Stourscombe Formation is shown to be equivalent to part of the Petherwin Limestone Formation with both units passing up conformably into Yeolmbridge Formation lithologies. Basinal slate facies (including the Tredorn Slates, Kate Brook Slates and the Delabole Slates) are shown to be laterally equivalent to the highly fossiliferous Launceston successions.

Stratigraphy

Both the Petherwin Limestone and Stourscombe Formations are composed of lithologically distinct members. The Yeolmbridge Formation is represented by a widespread (although locally diachronous) black slate facies that developed at or close to the Devonian - Carboniferous boundary.

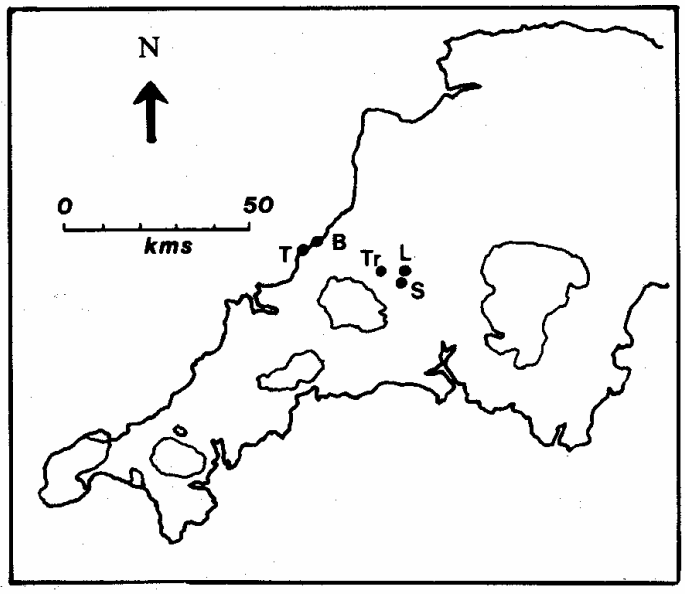

Figure 1. Location Map. L = Launceston, S = South Petherwin B = Boscastle, T = Tintagel, Tr = Trenault.

Table of Contents

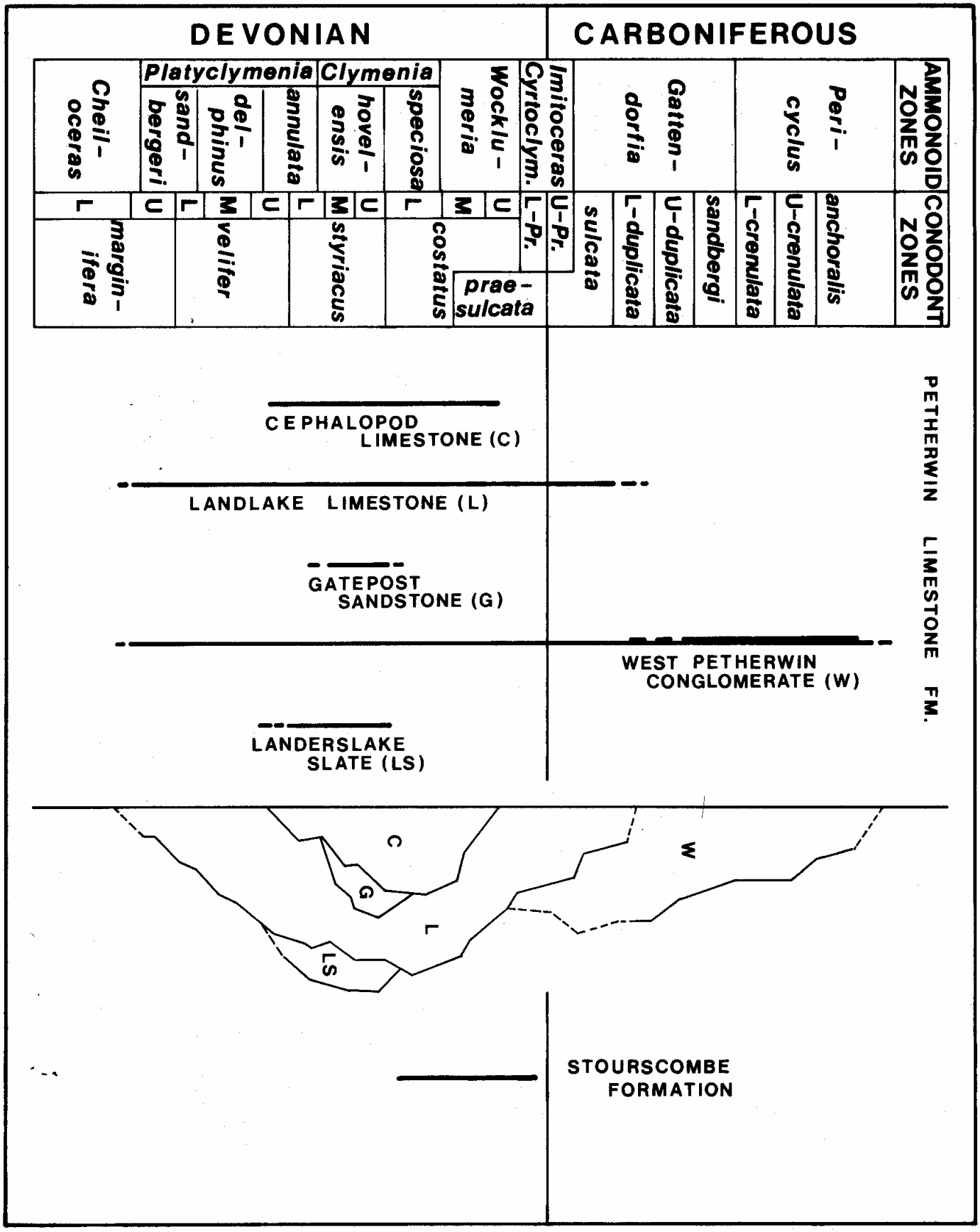

Figure 2. Range chart of the Stourscombe Formation and members of the Petherwin Limestone Formation showing schematic vertical relationships. Thick line of West Petherwin Conglomerate is implied indigenous fauna. Zonation chart based on Ziegler (1971) and Sandberg and others (1978).

Table of Contents

Petherwin Limestone Formation

Lithologies of the Petherwin Limestone Formation were first recognised by De La Beche (1832) and later described by Phillips (1841). Selwood (1960) identified two lithological components; a lower cephalopod limestone and associated strata, including a calcareous sandstone, and an upper brachiopod-bearing unit. These units are here shown to be laterally equivalent within the Petherwin Limestone Formation. Five lithologically distinct members are recognised (Fig. 2).

Cephalopod Limestone

This member, comprising highly fossiliferous flaser limestones, equates with the lower Petherwin Beds of Selwood (1960; see for details of now infilled type locality). The ammonoid range (upper *Platyclymenia* - Stufe through *Clymenia* - Stufe) is complemented by *styriacus* - Zone clydagnathids characteristic of the shallow water biofacies of Sandberg and Ziegler (1979). Conodonts extend this range into the middle *costatus* - Zone (lower *Wocklumeria* - Stufe); the youngest faunas contain reworked *velifer*- Zone conodont elements.

Landlake Limestone

Lithologies of this member form the dominant expression of the Petherwin Limestone Formation and include the upper Petherwin Beds of Selwood (1960). At the type locality, Landlake Quarry (SX 3285 8234), dark grey calcareous slates contain abundant limestone nodules, which locally coalesce to form bands up to 50cm thick. They yield a rich brachiopod fauna including *Productella (Steinhagella) membranacea* (Phillips), which suggests correlation with the Angertal Beds of the Bergischesland and the upper *Clymenia*- Stufe. However, conodonts, including *Scaphignathus velifer, Palmatolepis glabra lepta, Polygnathus diversus* and *Po. nodocostatus nodocostatus* indicate the lower *velifer* - Zone and imply that *P. (S.) membranancea* lacks the stratigraphical significance attributed to it elsewhere. At higher topographic levels at the type locality the appearance of *Pa. marginifera marginifera* in the absence of *Sc. velifer* suggests the upper *marginifera* - Zone and indicates structural inversion.

A stratigraphically more complete, though tectonically disrupted section is exposed farther to the west at the Trenault Limestone Mines (SX 2625 8292). Here a highly condensed sequence (lower *velifer*- Zone to upper *styriacus* - Zone is contained in less than two metres of strata) yields faunas that range up into the lowermost Carboniferous *sulcata* - Zone (Sandberg and others 1978). Eastwards, Landlake Limestone is seen to pass up conformably into black slate with limestone lithologies of the Ye01mbridge Formation that yield upper *costatus* - Zone conodont faunas implying a locally diachronous boundary between these formations.

Gatepost Sandstone

Included in the Lower Petherwin Beds by Selwood (1960), this areally limited calcareous sandstone unit has yielded cephalopods of the lower *Clymenia* Stufe at the type locality, Gatepost Quarry (SX 326 821). No conodonts have been recovered, though the unit is considered significant as similar lithologies are commonly associated with submarine rise sedimentation in the Rheinisches Schiefergebirge.

West Petherwin Conglomerate

This member comprises a sequence of locally developed, extensively reworked limestone and shale lithologies contained in a dark grey calcareous slate matrix. Conodont succession is mainly random (Fig. 3) and wholesale reworking of limestone units is inferred, though conodonts indicate also the occurrence of an indigenous limestone development. The exotic limestone lithologies, represented by sub-cleavage parallel nodules from less than lcm to up to 3m in length, include trilobite limestones of *Wocklumeria* Stufe age not recognised in the present outcrop area of the Petherwin Limestone Formation. On all scales, the derived limestone nodules are apparently undeformed by compaction implying relatively early limestone lithification, whereas shale clasts show pre-tectonic distortion (Fig. 4). This compares closely with lithologies described by Tucker (1973). from the Rheinisches Schiefergebirge and the Harz mountains which are considered transitional between submarine rise and basinal environments.

The topographically lowest horizons yield an abundant conodont fauna of upper *Gattendorfia* - Stufe siphonodellids, including *Si. duplicata, Si. cooperi and Si. obsoleta,* together with elements of the Upper Devonian *costatus* - Zone. Higher levels yield rare, apparently indigenous, Lower Carboniferous conodont elements, with rich reworked faunas, the stratigraphically youngest horizon (horizon 3) containing the diagnostic indices of the *anchoralis* - Zone. It is proposed, there being no evidence of sedimentary discontinuities, that this unit represents submarine rise slump deposition that developed from late in the *Gattendorfia*- Stufe through into the *Pericyclus*- Stufe. Tectonic initiation of slumping cannot be dismissed; considerable unpublished work suggests important facies changes at or close to the base of the *Pericyclus* Stufe in south-west England. It appears that a complex *schwelle* structure that developed at least as early as the upper *marginifera*- Zone persisted through into the *anchoralis* - Zone (compare Chudleigh; House and Butcher 1973).

Landerslake Slate

This name is used for a sequence of pale grey silty slates that conformably precede the Strayerpark Slate (Stourscombe Formation) in the core of a northerly facing recumbent anticline. Highly fossiliferous, bearing abundant spiriferids and chonetids, the unit was regarded as Tredorn Phyllite (Tredorn Slate of Freshney and others 1972) by the Geological Survey (Reid and Others 1911) at the proposed type locality, Landerslake Quarry (SX 2665 8110). A single limestone horizon yields a sparse conodont fauna dominated by *Icriodus* n. sp., *Po*

Table of Contents

	1	2	3	5	6	7	8	9	10	12	17	18_A	19	21	24	25
B. a. aculeatus	7	117			1	4	54		13	5	11	38		1	1	1
B. costatus	74	10-26	7			10	576		4		4	8		2		9
D. lata			1													
G. antetexanus			3													
G. delicatus			2													
G. punctatus			6													
N. ziegleri										4						
P. glabra distorta							2	1								
P. g. lepta							3						4			
P. gracilis expansa				1						23						
P. g. gonioclymeniae				1			6		5			2				
P. g. manca										5						
P. g. sigmoidalis		12					13		1		1	2				1
P. perlobata helmsi								1								
P. p. maxima										5						
P. rugosa rugosa										2						
P. r. trachytera				1												
Pe. inclinatus								1						1		
Po. diversus				2				1						1		
Po. homoirregularis										10						
Po. inornatus		2					3					2			2	
Po. styriacus										26						
Po. symmetricus												1				
Ps. brevipennatus							6			7						
Ps. m. trigonicus		8					5		1			1				
Ps. t. triangularis											1	1			3	
Ps. t. pinnatus			5													
S. anchoralis			1													
Sc. velifer				3	1			5					16	12		
Si. duplicata															42	4
Si. cooperi															7	
Si. obsoleta															4	
Si. praesulcata	6	39					3					6				

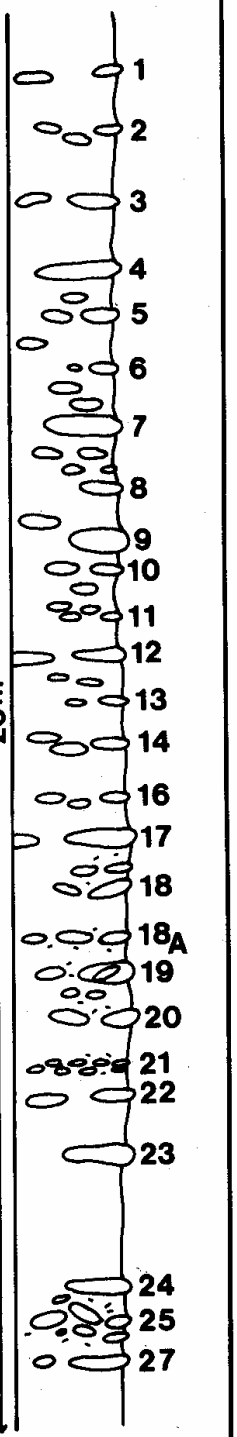

Figure 3. Conodont distribution at West Petherwin and simplified stratigraphical log.

Table of Contents

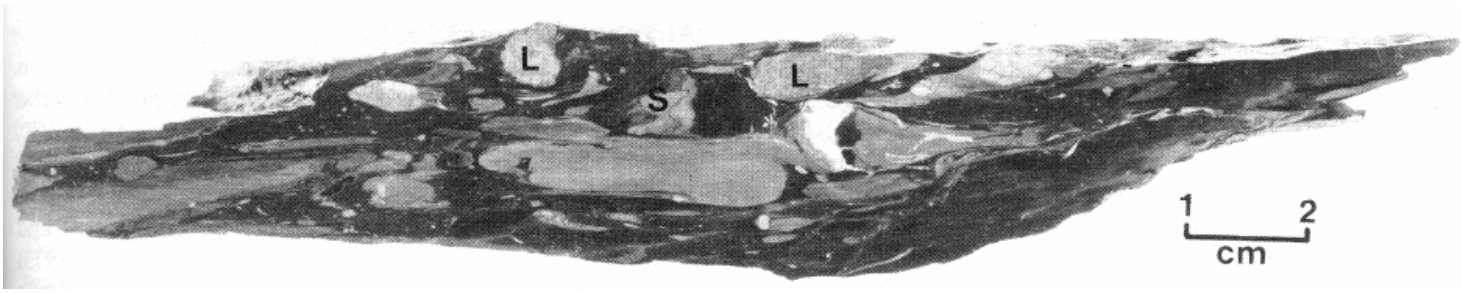

Figure 4. Section of part of horizon 20 from West Petherwin showing undeformed limestone nodules (L), and distorted shale clasts (S).

granulosus, Po. semicostatus, Pa. perlobata helmsi and *Pa. p. schindewolfi* indicative of the upper *velifer* to lower styriacus - Zones.

Stourscombe Formation

This formation, comprising a series of tectonically isolated, lithologically distinct units, can be observed to pass conformably into the Yeolmbridge Formation at several localities (Selwood 1971, p, 278). Three members are proposed; Stourscombe Beds, Strayerpark Slate and Overwood Slate. The nodular River Kensey Beds of comparable age (slate with thin chert of Selwood 1960) is here separated from the Stourscombe Formation and included in facies developed further to the east, being comparable to the Liddaton Unit (Isaac 1981) *(partim* River Lyd Slate with Lenticles group, Dearman and Butcher 1959).

Stourscombe Beds

The Stourscombe Beds are here restricted to the highly fossiliferous silicified nodular cephalopod limestone lithologies recognised by Selwood (1960). At Trekelland Farm (SX 2997 7950), lithologies identical to the type locality (see Selwood 1960) yield an abundant silicified ammonoid fauna. No conodonts have been recovered, though the ammonoids compare closely to Selwood's upper faunal division (upper *Wocklumeria* Stufe). Westwards the unit becomes more calcareous and in past passes laterally into the Strayerpark Slate.

Strayerpark Slate

The name Strayerpark Slate is here applied to a thin, areally limited succession of stratigraphically condensed green siliceous slate containing numerous cephalopod-bearing limestone nodules. At Strayerpark Plantation (SX 2651 8121), and in a nearby roadside cutting (SX 2668 8130), the unit is observed to pass up conformably into black slate lithologies of the Yeolmbridge Formation. The highest stratigraphical levels yield *Pa. gracilis gonioclymeniae, Pseudopolygnathus marburgensis marburgensis* and *Bispathodus costatus* indicating the p resence of the middle *costatus* - Zone (lower *Wocklumeria* Stufe) and show that the black slate (Yeolmbridge) facies appeared here earlier than elsewhere. Horizons immediately lower in the sequence contain *B. costatus, Pa. rugosa rugosa* and *Ps. brevipennatus* which indicate the lower *costatus* - Zone (upper *Clymenia* Stufe). Lithologically and stratigraphically the Strayerpark unit compares closely to the highest Famennian levels of the Mount Pleasant series (House 1963) that are developed in the *schwelle* controlled deposits at Chudleigh.

Overwood Slate

This member contains the green to dark grey trilobite bearing slates that contain rare siliceous and calcareous nodules regarded as a variant of the Stourscombe Beds by Selwood (1960). At Overwood Farm (SX 303 873), the unit passes conformably into the Yeombridge Formation, and yields *B. costatus* and *B. ultimus*

Table of Contents

indicative of the middle to upper *costatus* - Zone *(Wocklumeria* Stufe). This lithology is widespread at the close of the Famennian in Devon and North Cornwall and is regarded as a deeper water (though not basinal) equivalent of the ammonoid-bearing Stourscombe Formation.

Yeolmbridge Formation
Described by Selwood (1960, 1971) the unit consists of dark grey to black, commonly banded and silty slates, bearing locally abundant limestone bands and nodules which are commonly silicified. At lower horizons a widespread micaceous slate has been extensively quarried.

Gattendorfia - bearing silicified limestones at Penfoot (SX 3016 8324) yield a poorly preserved conodont fauna of *duplicata* - Zone (Sandberg and others 1978) age. *Gattendorfia* sp. is recorded (Selwood personal communications) from Treguddick Mill Quarry (SX 2764 8142) five metres below a nodular limestone horizon that yields a rich conodont fauna including *B. costatus, Ps. marburgensis trigonicus, Siphonodella praesulcata* and *Po. inornatus s.l.* Although the upper *costatus* - Zone is difficult to recognise (Ziegler 1962; 1971), the absence of *Pa. gracilis gonioclymeniae* is taken to indicate the upper *Wocklumeria* Stufe and that the Devonian - Carboniferous boundary is represented here in inverted succession.

At Yeolmbridge, where rare calcareous sandstones and siltstones are developed (Selwood 1971), the Geological Survey (Reid and others 1911) record *Phacops* sp. and a clymenid implying Upper Devonian strata. The recognition of *Wocklumeria* from Yeolmbridge (House and Selwood 1957) together with Selwood's (1960) description of lowermost Carboniferous trilobite faunas confirms the presence of the Devonian - Carboniferous boundary within this Formation. Limestone horizons at stratigraphically higher levels yield spare faunas of the *anchoralis* - Zone, lithologies at these levels becoming progressively more silicified.

The Yeolmbridge Formation is here considered as part of a widespread black slate facies that developed towards the end of the uppermost Upper Devonian times in Devon and Cornwall.

Basinal Slate Facies
Laterally equivalent to the highly fossiliferous Launceston successions are thick, typically monotonous slate sequences, sparse in macrofauna except for infrequent incursions of opportunist species such as *Cyrtospirifer verneuili.*

The Tredorn Slates (Freshney and others 1972) consist of well-cleaved, lithologically monotonous greenish-grey slate that can be traced from Trekellend in the south-east to the coast at Boscastle. A single, ostracod-rich, crinoidal limestone horizon from the Strayerpark main quarry (SX 2654 8103) yields a diverse conodont fauna that includes *Pa. glabra distorta, Pa. marginifera marginifera, Po. glaber bilobatus* and *Icriodus cornutus* which in the absence of *Sc. velifer,* imply the upper *marginifera* - Zone.

At Trevell quarry (SX 2589 8110), the slates are pale grey in colour and contain a thin tuffaceous horizon. Infrequent brachiopods and a kosmoclymenid together with the ostracods *Richterina (R.) costata* and *R. (R.) striatula* indicate the presence of the upper *Clymenia* to *Wocklumeria* Stufen. Westwards, towards Boscastle, the Tredorn Slates pass up conformably into dark grey and black slates (Batstone 1964, McKeown and others 1973) that contain a sparse trilobite fauna of the *Gattendorfia* Stufe (Selwood 1961).

The southern equivalents of the Tredorn Slates, the Kate Brook Slates (Selwood 1971) yield comparable ages. The youngest faunas, occurring as moulds on cleavage surfaces (SX 3241 6785) include, *B. costatus, B. aculeatus aculeatus* and *Pa. gracilis gracilis* and imply the presence of the *costatus* - Zone (upper *Clymenia* to *Wocklumeria* Stufen).

Delabole Slates (Freshney and others 1972) have an extensive outcrop area to the south of Tintagel, and differ fundamentally from the Tredorn Slates by containing numerous thin silty and arenaceous horizons together with locally abundant limestone. Crinoid debris limestones, crowded with pelagic ostracods from the Slate quarries at Trebarwith Strand, contain conodont faunas dominated by icriodids and peleksygnathids together with a single specimen of *Sc. velifer* implying a position in the lower to middle *Platyclymenia* Stufe.

It is not unreasonable to assume that the differing slate facies represent deposition in more widely spaced, though not necessarily completely separated, basinal environments, than is suggested by the present, tectonically controlled, outcrop pattern.

Discussion

In the Hercynian facies of the Upper Devonian Rheinisches Schiefergebirge two distinct sedimentary environments have been recognised (Schmidt 1926). A much reduced, mainly calcareous facies with nodular limestone, locally rich in cephalopods *(Cephalopodenkalk),* dominates submarine rises or *schwellen,* while a thicker, laterally equivalent argillaceous facies, often rich in pelagic ostracods *(Cypridinenschiefer),* is restricted to deeper basins or *becken.*

The cephalopod and shell concentrate limestones of the Petherwin Limestone Formation, and related strata in the Stourscombe Formation (Stourscombe Beds, Strayerpark Slate), are of the *schwellen* type and can be compared to the Mount Pleasant Series (House 1963). Although the robust nature of the brachiopod fauna of

Table of Contents

the Landlake Limestone is somewhat Rhenish in character, the lithofacies is not. The condensed nature of the beds and their direct association with cephalopod-bearing strata imply separate positions on a topographically complex *schwelle* structure. The rapid lateral and vertical variation of lithologies, particularly in beds of *Wocklumeria* Stufe age, reflect deposition in localised environments within, or on the flanks of the rise. Syn-depositional tectonic control of sedimentation may also have been important. Tectonic isolation of many of the lithological units makes palaeogeographic reconstruction difficult.

The appearance of widespread clastic sedimentation towards the end of the uppermost Upper Devonian suggest subsidence, though cephalopod limestone development in the *Gattendorfia* Stufe and the continuation of Landlake Limestone deposition implies the local persistence of positive areas. The diachronous base of the Yeolmbridge Formation indicates progressive on-lap of these beds onto the subsiding *schwelle.*

The youngest evidence of *schwelle-controlled* sedimentation in North Cornwall is of *anchoralis* - Zone *(Pericyclus* Stufe) age. Limestone conglomerates, here interpreted as (9. tectonically initiated) slump deposits, developed on the flanks of the subsiding rise. It appears significant therefore that the onset of the *anchoralis* -Zone in Devon and North Cornwall heralds the advent of new facies dominated by widespread development of chert and volcanic associations (Matthews 1977).

The origin of the Petherwin rise is unknown, but 01d quarry records indicate the presence of a massive limestone ,beneath the well-documented cephalopod limestones (Phillips 1841). The occurrence of the trilobite genus *Asteropyge* in museum collections (Reid and others 1911, p.21) appears to indicate that these limestones were at least of Frasnian age. It is tempting to suggest a similar situation to that described by House (1963) at Chudleigh where massive Givetian and lower Frasnian limestones acted as the foundation for the *schwelle.* Elsewhere (Stewart 1981a) it is suggested that the successions discussed in this paper have been tectonically transported northwards; the Petherwin *schwelle* might therefore be related to the calcareous rise proposed by Tucker (1969) as the, southern source of the Middle to Upper Devonian near - proximal calcareous turbidites of the Marble Cliff Beds.

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Table of Contents