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A review of basin development in central south-west England

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The Upper Palaeozoic rocks of central south-west England show complex facies changes which can be related in a half graben basin model. Facies patterns and basin development were principally controlled by E-W basement faults, but important along-strike variations in stratigraphy and structure *were* also developed across major NW-SE Hercynian fault zones. The interactions of this fault system allowed the compartmentalisation of stratigraphy and structure. The South Devon and Trevone Basins are distinct; both appear to have been inverted in early Namurian times and to have been reworked by a later northward transporting deformation. Tightening and further uplift of early structures produced by the advancing deformation front, led to the detachment of nappes which spread northwards under gravity.

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Introduction

From the earliest days of geology, the area flanking the southern margin of the `Culm Synclinorium' has been the subject of dispute and argument. The early record was chronicled by Rudwick (1985) who analysed with great skill, the diverse views current at the time of the creation of the Devonian System. At the beginning of the century, Ussher led the primary investigation into the region by the Geological Survey of England and Wales, and within two decades, maps were published. From the Sheet Memoirs it is clear that the surveyors recognised the structural complexity of the region but they lacked sufficient stratigraphic control to define it. The biostratigraphic situation was however transformed by the time the geology of the area came to be revised, in a programme of collaborative research between the University of Exeter and the British Geological Survey (formerly, Institute of Geological Sciences) initiated by Professor Scott Simpson in 1960. Old fossiliferous localities could be reassessed, and many new localities could be dated to give an extensive palaeontological data base which now constrains geological modelling. This paper views progress made in the understanding of the geology of central south-west England by research groups working from the University of Exeter.

A facies and structural model

It is generally agreed, that with the exception of parts of south Cornwall, Devonian sedimentation was initiated on continental crust forming the southern extension of the Caledonian Continent. At first, thick continental sedimentation extended across the region towards an ocean lying farther south. The progressive northward onlap of marine sediments which began in the late Siegenian was accompanied by differential subsidence of the shelf. It seems likely that this subsidence was basement controlled; movements on deep-seated EW faults allowing extensional basins to develop and fill sequentially from south to north. Many would argue that such filling took place ahead of an advancing deformation front. This gives a mix of extension and compression, which can be more readily explained in a transpressive rather than subductive regime.

Mapping has revealed shelf, basin, and rise facies in an extraordinarily complex tectonic setting. It is possible to relate these facies into a half graben basin model limited by an inner (northern) and outer (southern) shelf. Lower Devonian prerift, Middle Devonian to Lower Carboniferous synrift, and Upper Carboniferous postrift sediments are represented (Fig. 2A). With the exception of the Staddon Grits west of Bodmin Moor, all prerift sediments now exposed are located well south of the area under discussion. These grits are markedly Ienticular eastwards along their outcrop into south Devon, where Pound (1983) has proposed a fluvially dominated, low energy deltaic environment. lie suggested that these sediments were derived from ephemeral fault blocks, generated by reactivation of E-W trending synsedimentary fault /.Ones; possibly the Staddon Grits represent the reworking of earlier unconsolidated sediments. Such a fault zone could have defined the southern margin of the South Devon-Trevone Basins that were beginning to develop to the north, but there is no supporting evidence higher in the stratigraphic column.

Facies changes support the existence of an E-W fault system defining the northern margin of these basins, but overriding tectonic units now obscure its position. However it must have been positioned south of all sediments deposited on the inner shelf, and it appears to have changed latitude across the peninsula, at active NW-SE faults.

No record of the inner shelf is exposed earlier than the Upper Devonian. At its southern margin, the steepening of depositional slopes into the basin is indicated by conglomerates, slumps, and volcanic and sedimentary olistostromes. Associated intrusives and thick accumulations of volcanic rocks may be linked to the presence of deep-seated fractures defining the basin. To the north of the basin, a thick shelf sequence of grey-green mudrocks carrying thin siltstones and sandstones, and lenticular limestones was extensively developed. Rapid deposition appears to have taken place for there is virtually no bottom fauna, and macrofossils are restricted to thin horizons of thick-shelled rhynchonellid and spiriferid brachiopods which were apparently only able to colonise the sea floor occasionally. The sequence was limited northwards by a fault-controlled carbonate rise overlooking the deepening Culm Basin.

Basin development caused the outer shelf to be starved of elastic sediment and extensive Middle Devonian carbonate complexes were established which periodically shed carbonate turbidites into the basin. By late Frasnian times the reefs had ceased to grow, but not seemingly because of sudden submergence. Rather, the reef-top stood in shallow water; possibly it was even locally exposed through much of later Devonian and early Carboniferous times (Orchard 1975). Certain areas which were probably topographic highs, generated condensed cephalopod limestones, whilst in the lagoons argillites accumulated which bear brachiopod and bivalve faunas normally associated with situations much nearer shore. On the margins of the basin, nodular limestones give evidence of reworking of conodont faunas from the adjacent shelf.

In early Carboniferous times, a general rise in sea-level led to the northward spread of basinal conditions across the northern shelf margin. But to the south, paralic facies of late Devonian to early Namurian age had appeared; these indicate the rise of source rocks in the south. It appears that such sediments were initially ponded back against the reefal carbonates; though some material filtered through into the main basin, to give northward prograding flysch. This flysch was eventually to cover the whole area by earliest Namurian times.

There is now an extensive literature (e.g. Cooper and Williams 1989) describing the inversion of basins such as that modelled above. N-S regional contraction would effect shortening and upward expulsion of the contents of the half graben, through the reactivation controlling extensional fault. In this, the footwall could have acted as a buttress, allowing the production of a backwardly propagating fold system, i.e. southwards from the northern edge of the basin. The reactivated extensional fault could then come to operate as a forwardly directed out-of- sequence thrust, maybe by short cutting the footwall of the extensional fault. Continued thrusting would be likely to generate a footwall, short-cut thrust system of northward propagating horses, beneath and ahead of the initial footwall, short-cut thrust. Within the basin any convex-upwards synthetic faults developed during extension, could rotate to a steep position, and reactivate as reverse faults. Inversion of a basin with half graben morphology, could also produce back thrusting or, bipolar extrusion with northward and southward thrusting out of the basin (Hayward and Graham 1989). Such modelling of basin inversion predicts variations in fold vergence and facing.

Basin inversion constituted the first deformation (D1), but the area was also reworked by a second deformation (D2), giving northward transporting, out-of-sequence thrusts, and by a D3 event represented by gently north dipping normal faults. Although the basin exerted primary control on deformation style, it is the out-of-sequence thrusting which constitutes the most obvious structural feature.

To apply the facies and structural model, it is convenient to move from east to west, in a series of steps defined by major NW- SE fault zones (Dearman 1963; Turner 1984). These faults (Fig. 1) influenced both Variscan facies and structure, and allowed the independent development along strike of the South Devon and Trevone Basins. In this setting, geological lines are unlikely to continue boldly across the peninsula. It is safer to talk of analogous rather than identical features on passing from one fault-bounded compartment to another.

South Devon Basin

East of Dartmoor (Fig. 2B)

The area east of the Sticklepath Fault Zone, conforms closely to the facies model, except in the presence of an intrabasinal rise generated by a thick pile of volcanic rocks (Kingsteignton Volcanic Group) in early Middle Devonian times. This came to support a thick succession of carbonates, distinct from those of the carbonate platform farther south, and a complete but much condensed late Devonian to early Carboniferous succession. Sedimentation was completed by the spread of Lower Namurian flysch across the basin.

By late Devonian times deep seated E-W faulting on the inner shelf was controlling sedimentation at the southern margin of the developing Culm Basin. This is reflected in rise-slope facies about the Devonian-Carboniferous boundary in the Middle Teign Valley which give circumstantial evidence for the existence of an older positive structure, possibly a reef, south of this tectonic lineament. At the southern limit of the inner shelf, Upper Devonian grey-green, outer shelf argillites accumulated.

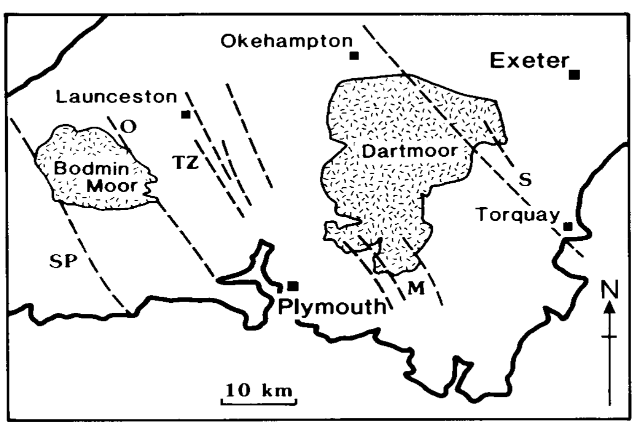


Figure 1. Location map of major fault zones (after Turner 1984).

S= Sticklepath Fault zone; M = Modbury Fault Zone; TZ = Tamar Fault Zone; O = Otterham Fault Zone; SP = St Teath-Portnadler Fault Zone.

The overlying Carboniferous successions are basinal and continuous with those of the Culm Basin to the north. Evidently during the early Carboniferous much of the inner shelf became a southern extension of the Culm Basin. Block movements which allowed this change in Lower Carboniferous times were accompanied by considerable volcanic activity.

An unconformable New Red Sandstone cover largely obscures successions on the outer shelf, but in early Namurian times there is evidence of sustained uplift some considerable distance farther south. Flyschoid conglomerates (Selwood *et al.* 1984) which spread northwards into the basin at this time, not only indicate uplift and erosion of basement rocks but also the stripping of newly deposited Lower Carboniferous cherts, presumably from some deforming basinal source immediately north of the basement high. Older shelf rocks are not involved. Such early Namurian uplift migrated rapidly northwards to deform the main basin.

The basinal sediments were deformed with, and thrust northwards over the outer edge of the inner shelf in post Lower Namurian times. Tight north-facing overfolds were developed as the basin inverted. At the same time much of the inner shelf was incorporated into a footwall horse system beneath the overriding basinal sediments. Farther north, the anticlinorial folding represented in the Middle Teign Valley is continuous with similar structures in the Culm Basin, which are of Late Westphalian/Stephanian age. Currently these late upright structures are overthrust at their southern limit. Elsewhere basin inversion, and its associated out-of-sequence thrusting, is an early Namurian event; possibly the Teign Valley thrusting is a local late adjustment along earlier thrusts.

Sticklepath Fault Zone to Modbury Fault Zone (Fig. 2C)

The complex facies changes of the Middle-Upper Devonian carbonate complex developed on the outer shelf, have been described by Scrutton (1977). About Newton Abbot, flysch of probable Lower Carboniferous age is tectonically intercalated within the reefal carbonates. These deposits were probably ponded back by the reef before filtering through to the basin lying to the north in early Lower Carboniferous times. The flysch petrology gives evidence for an uplifted basement area existing farther south at this time.

Within the basin, Middle and Upper Devonian argillites include an important volcanic development at its northern margin. On the adjoining inner shelf, the proximity of the basin margin is indicated by an interfingering of outer shelf and basinal slates, and by dolerite intrusions and lavas which are unusual within shelf facies. Nodular and thinly bedded limestones (Willcock 1982) could relate to small carbonate bioherms at the shelf margin.

During Lower Carboniferous times, basinal sedimentation spread over the inner shelf, and again there is some evidence of volcanic and intrusive activity at the southern margin. It is associated with thin limestones which could represent the dying influence of earlier carbonate build-ups. The location of igneous activity at the basin margin may relate to basement faulting. Northward prograding flysch arrived at the shelf edge in Lower Carboniferous times and covered it early in the Namurian.

The area lies entirely within the belt of overturned to recumbent north-facing folds and northward transporting thrusts characterising the eastern part of the South Devon Basin. The inner shelf and the basin shared a common deformation history related to the inversion of the basin. Within the basin tectonic disruption by reverse faults, possibly associated with some reactivation of early extensional structures, and late thrusting make regional (D1) folding difficult to identify. However small-scale structures are consistent with the style of a major overturned syncline reconstructed by Willcock (1982) at the southern margin of the shelf.

The Bickington Thrust (Selwood *et al.* 1984), the principal forwardly directed thrust, which took sediments out of the basin and over the deforming bounding northern shelf, shows complex anastomosing footwall structures (Willcock 1982). Farther north, the Holne Thrust appears to have acted as one of a series of footwall short-cut faults carrying horses of shelf northwards, beneath and ahead of the Bickington Thrust.

The younger parts of the basinal succession carried in the Bickington Nappe have run forward, in inverted succession, on flat-lying dislocations, across the Upper Carboniferous flysch developed on the shelf. These cut down, and across the more steeply inclined Holne Thrust into the underlying structure to give, in the area north of the thrust, klippen of varying sizes spread eastwards from Dartmoor to the Sticklepath Fault Zone. The largest of these klippen, which is much disrupted by late faulting associated with movements on the Sticklepath Fault Zone, includes the Rora Slate and Mount Ararat Chert Formations represented on Sheet 339. It seems that these sequences became detached, and carried forward beyond the main nappe, by late sliding from a topographic high generated during basin inversion. Tightening of structures and renewed uplift were almost certainly involved as the inverted basin was amalgamated into the regional deformation.

The sediments of the former platform to the south of the basin are currently represented in normal succession and although the limestones are not obviously folded, the underlying slates show overturned to recumbent isoclines and associated reverse faulting. Farther south, a pile of chaotically stacked carbonate and flyschoid thrust sheets are represented which override the carbonate succession to the north. It has been suggested (Selwood *et al.* 1984) that these were derived from a tectonic high, developed from successions at the southern extension of the carbonate platform where the structures have been modelled by Coward and McClay (1983). Stratigraphic considerations indicate that this deformation was broadly synchronous with that of the basin. Probably it initiated the inversion.

Modbury Fault Zone - Otterham Fault Zone (Fig. 2D)

The inner shelf record starts in early Upper Devonian times, when rise and rise-slope successions can be identified, extending E-W at the southern margin of the Culm Basin. Reefal and nodular limestones supporting the younger rise sequences are exposed through a tectonic window in Lydford Gorge (Isaac 1981), and rise slope deposits extend southwards to pass into grey-green mudrocks characteristic of the outer part of this shelf. Immediately north of the South Devon Basin, these appear to have carried further rise carbonates and argillites in localised reefal associations. Possibly such rises were defined by local uplift on the NW-SE fault zones which cut the shelf. These rises were to persist into the Viséan, when they and the whole of the exposed northern shelf were covered with black shale and chert.

Within the main basin, considerable thicknesses of Upper Devonian purple-and-green, deep water argillites accumulated. But unlike the area to the east of the Modbury Fault Zone, there is no evidence that the northern margin was then particularly active. Black shale deposition (regionally a feature of the Lower Carboniferous) signalled a deepening of the basin in late Famennian times. This deepening was almost certainly linked to the start of intense volcanic activity at the northern basinal margin, which induced the development of thick volcanic and sedimentary olistostromes in Lower Carboniferous times. The latter include large blocks, of Upper Devonian and Lower Carboniferous limestones (Turner 1982a) detached from the rise accumulations at the northern shelf margin.

In the south of the basin, thin Upper Devonian clastics heralded the steady northward progress of highly feldspathic flysch that was to continue through Dinantian and into lowest Namurian times (Whiteley 1984). The youngest flysch deposits include sequences of matrix-supported conglomerates with locally derived clasts showing soft-sediment deformation, accompanied by well rounded pebbles including Upper Devonian cephalopod limestones, Lower Carboniferous cherts, dolerites, spilites and vein quartz.

The flysch sequence was coeval with, and derived from shallow water arenites accumulating on the outer shelf during late Devonian to earliest Namurian times. These paralic sediments appear to have built out deltas northwards into the basin in Carboniferous times.

Late in the Lower Carboniferous all volcanic activity ceased; this was quickly followed by basin deformation. It seems that reversal of movement on the deep seated, extensional northern boundary fault, first led to inversion of the northern part of the basin. A backwardly propagating fold system was probably initiated southwards from the leading edge of the basin, followed by the emplacement of the Greystone Nappe northwards across the inner shelf. This stripped the Lower Carboniferous succession from the northern part of the basin. At the same time the shelf sediments underlying the nappe were folded and sliced through with the passage of the nappe. As the Greystone Nappe advanced northwards, three NW-SE high angle fault zones were activated (Turner 1984). Locally they acted as lateral ramps to internal thrusts within the nappe; they also allowed parts of the nappe to advance at different rates, and caused some compartmentalisation of structure to develop.

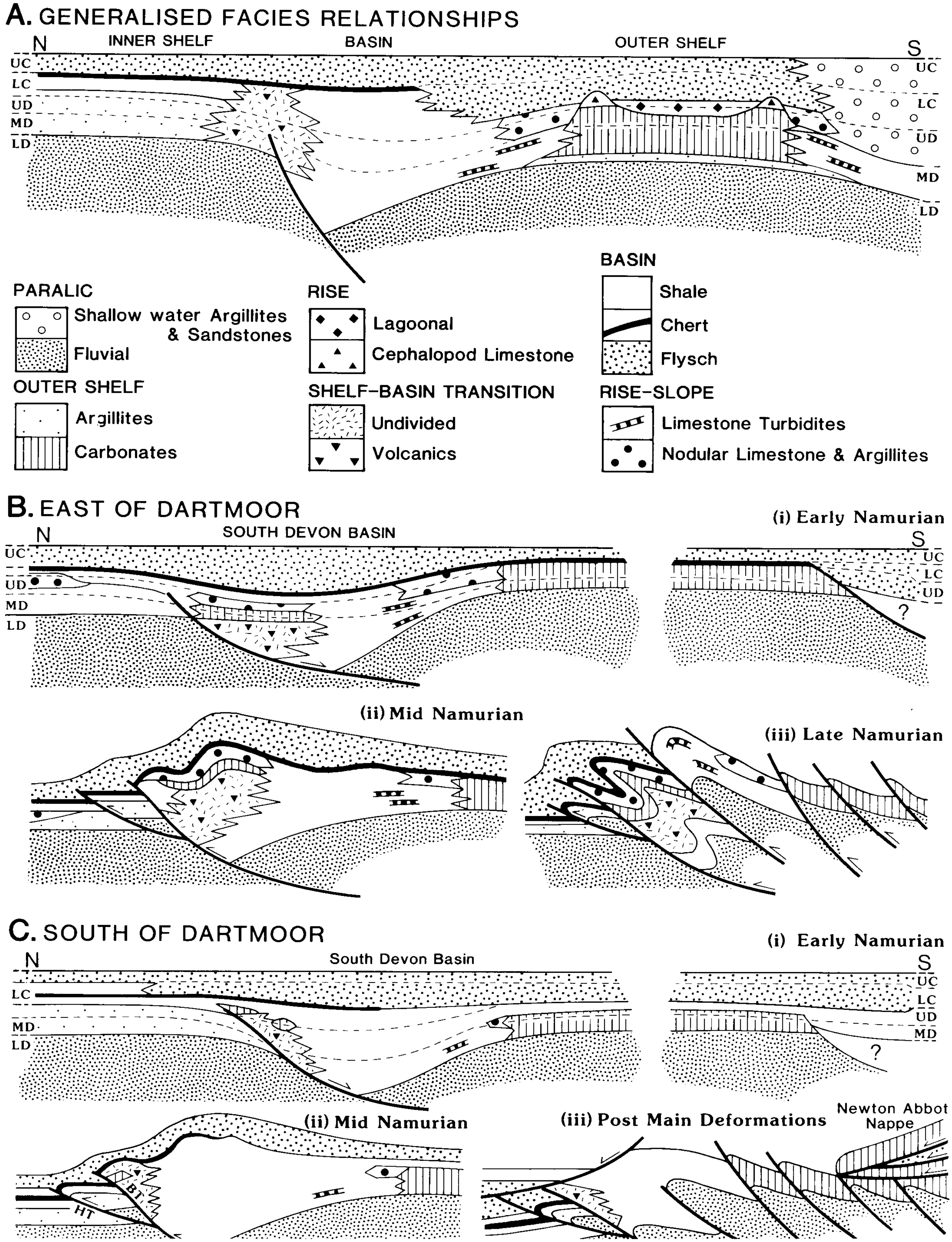
Meanwhile Lower Namurian distal flysch (Crackington Formation) from the Culm Basin to the north, had invaded the northern part of the shelf, ahead of the advancing nappe. Here it was eventually overridden by the Greystone Nappe, causing the flysch to deform and to become tectonically interleaved with the parautochthon. All thrust related structures indicate a northward sense of tectonic transport. High silica mobility at the time of thrusting, led to thrust parallel, differentiated layering (Turner 1981), which cross-cuts bedding and early structures both in the overriden beds, and in the inverted limb of the Greystone Nappe. The Whitelady Thrust, at the base of beds parautochthonous to the Greystone Nappe, shows some 30m of mylonitic fault rocks in Lydford Gorge (Isaac 1981). Rotated porphyroclasts indicate a northward transport direction. A window in this thrust exposes autochthonous rise deposits which have suffered a major contact metamorphic event in which temperatures of 500°C are indicated. Isaac (1983) ascribed this to the rise of the granite batholith in Dinantian times.

Concurrently with the northward emplacement of the Greystone Nappe, deformation of the basin spread southwards by backward fold propagation and back thrusting in the basin, to affect the thick sequences of flysch are paralic sediments accumulating there. From north to south across the basin, northward transported structures can be envisaged, giving way to upright and eventually, to southward transported structures. Such bipolar extrusion from the basin. would be consistent with a basin morphology controlled southwards by a fault, antithetic to the northern master fault.

The inversion of the basin defines the D1 event. D2 resulted from further tightening of the basin and uplift in the south accompanying the northward migration of regional deformation. This led to the detachment of flyschoid and paralic thrust sheets and their northward transport possibly by reversal of movement along D1 thrusts, across the top of the Greystone Nappe, which was thinned and reworked in consequence. Once again the NW-SE high angle fault zones played a major role in controlling the movement of these nappes northwards.

A more complicated picture is revealed west of the Tamar Fault Zone (Turner 1984). Here a thin nappe derived from an area of Upper Devonian to Lower Carboniferous rise sedimentation was detached from a marginal basinal position (possibly the Liskeard High), and was carried northwards before the arrival of the flysch and paralic nappes. This Petherwin Nappe cuts down into the western part of the Greystone Nappe. Evidently, its passage was constrained between the Otterham Fault Zone and the Tamar Fault Zone, elements of which locally acted as sidewall ramps. Turner (1982b) has assembled much evidence for northward transport from the sole thrust, Within the nappe, mappable north facing folds can be traced for over 1km along strike (Stewart 1981).

Considerations of fold-facing within the flysch, and the paralic beds which overlie the Greystone and Petherwin Nappes have led to speculation concerning the provenance of the tectonic units in which they lie. However derivation from the Culm Basin is most unlikely, for the Namurian sediments of this basin lie in conformable contact


A. GENERALISED FACIES RELATIONSHIPS
N
INNER SHELF
BASIN
OUTER SHELF
S
UC
LC
UD
MD
LD
PARALIC
Shallow water Argillites & Sandstones
Fluvial
OUTER SHELF
Argillites
Carbonates
RISE
Lagoonal
Cephalopod Limestone
SHELF-BASIN TRANSITION
Undivided
Volcanics
BASIN
Shale
Chert
Flysch
RISE-SLOPE
Limestone Turbidites
Nodular Limestone & Argillites
B. EAST OF DARTMOOR
SOUTH DEVON BASIN
(i) Early Namurian
(ii) Mid Namurian
(iii) Late Namurian
C. SOUTH OF DARTMOOR
South Devon Basin
(ii) Mid Namurian
BT
HT
(iii) Post Main Deformations
Newton Abbot Nappe

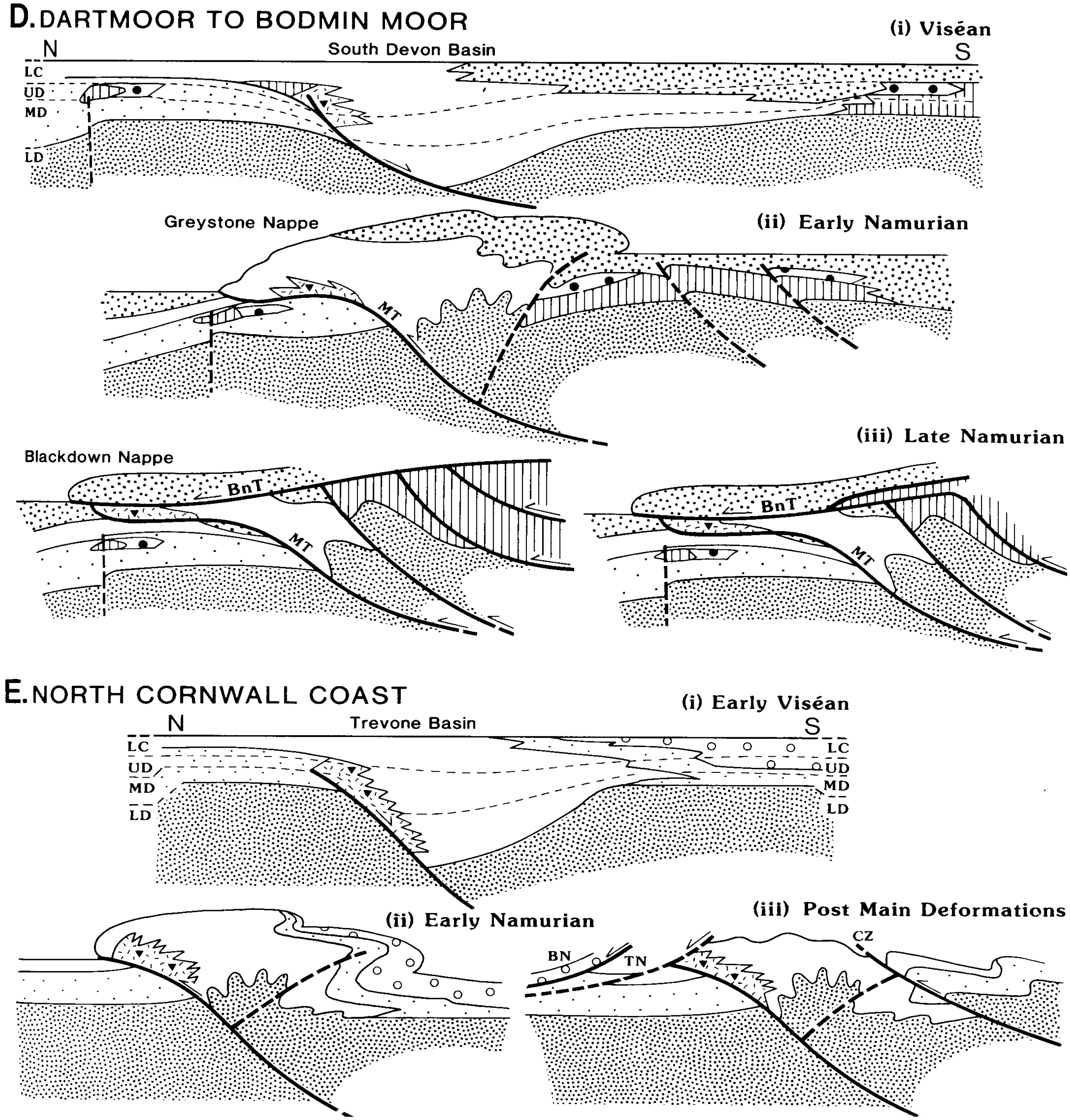


Figure 2.

A. Model relating facies in the South Devon Basin.

B. South Devon Basin: N-S section east of Sticklepath Fault Zone. i) predeformation, ii) early stage of basin deformation, showing development of shortcut footwall thrust beneath the developing Chudleigh Nappe, iii) final stage of basin deformation.

C. South Devon Basin: N-S section between Sticklepath and Modbury Fault Zones; i) predeformation, ii) basin inversion showing development of the forward directed principal thrust (BT = Bickington Thrust) and a short-cut footwall thrust (HT = Holne Thrust), iii) northward sliding of disordered thrust complex (Newton Abbot Nappe) from an uplifted area farther S, tightened and further uplifted the basin to produce gravity sliding of klippen of basinal sediments across the inner shelf.

D. South Devon Basin: N-S section between Modbury and Otterham Fault Zones; i) predeformation, Culm Basin possibly limited southwards by deepseated E-W fault, ii) bipolar inversion of basin; Main Thrust (MT) carries Greystone Nappe over inner shelf, iii) deformation of outer shelf, tightening and uplift of basin structures, leading to detachment of local gravity slides (BnT = Blackdown Thrust) towards southern margin of the Culm Basin where sedimentation continued.

E. Trevone Basin: N-S section; i) predeformation; outer shelf carries no major carbonate complex; paralic sediments prograde N into basin, ii) basin inversion leading to major backfolding, iii) deformation of outer shelf and thrusting of north-facing structures over early back fold to produce facing Confrontation Zone (CZ). Concurrently basin structures were tightened and uplifted, causing detachment of the Tredom (TN) and Boscastle (BN) nappes as gravity slides towards the southern margin of the Culm Basin, where sedimentation continued.

with autochthonous and parautochthonous sequences, and beneath the flysch and paralic nappes. Basin inversion (D1) could well have developed south-facing folds at the southern margin of the basin (Seago and Chapman 1988) but the principal thrusting event (D2) is, as the movement structures indicate, to the north. This is consistent with the view of Upper Devonian-Lower Namurian uplift to the south of the basin deduced from flysch provenance.

Evidence for a D3 event - late northward displacement along gently north-dipping normal faults - is abundantly represented (Turner 1982b). It appears to represent movement from topographic highs that were possibly steepened by the rise of the granite batholith.

The Liskeard High

South of Bodmin Moor, Burton and Tanner (1986) demonstrated the existence of a persistent shelf area between the South Devon and Trevone Basins. A shelf which is limited westwards by the St Teath Portnadler Fault Zone, and eastwards by the Otterham Fault Zone.

About Liskeard, open shallow marine shelf conditions persisted from the Emsian until the onset of basinal sedimentation in early Upper Devonian times. There is no evidence for the establishment of the reefal facies characterising the shelf south of the South Devon Basin.

The structure revealed in this area is distinct from that in the adjoining basins. Early, upright, north-facing folds with a steep slaty cleavage, are cut in the northern part of the region by major D2 folds with near horizontal E-W trending axes. These second folds show a south dipping, closely spaced crenulation cleavage. One of the structural models described by Burton and Tanner (1986, fig. 7b) could be explained by the overriding of the southerly derived tectonic slices identified north of Bodmin Moor. A view supported by the occurrence of lenticular silicified, brecciated and fine grained fault rocks, within the Middle Devonian Slates south of Bodmin Moor.

Trevone Basin

Unlike the South Devon Basin, there is little indication that the Lower Devonian continental and near-shore deposits of the outer shelf of the Trevone Basin carried a carbonate complex of Middle to early Upper Devonian age (Fig 2E). Rather, an onlap of elastic sediments from the Gramscatho Basin is observed (Holder and Leveridge 1986) which almost certainly supplied distal turbidites to the Trevone Basin. There is no evidence of an active southern fault margin, but basinal black shales indicate that the basin was already developing in Emsian times. Thick basinal argillites which characterise the Middle Devonian, include recurrent facies attributed to prograding and retreating turbidite fans (Beese 1982). A change in sedimentary regime is indicated about the Middle/Upper Devonian boundary by local limestone turbidites, widespread volcanic activity, and by the initiation of purple-and-green mudrock deposition. At this time intense volcanic activity represented in the Pentire Volcanic Group, indicates an active basin margin to the north. A view supported by the presence of associated shelf-basin transition facies, including evidence of tectonic and sedimentary instability such as slumps and conglomerates. Inner shelf facies comparable to those of the South Devon Basin, may also have existed north of the Trevone Basin.

This contrast between the northern and southern facies of the Trevone Basin led to the recognition of two distinct successions in Middle and early Upper Devonian times, though this distinction was lost in the early Famennian when purple-and-green argillites spread across the whole basin. Beds younger than Famennian are not recorded. The observed close juxtaposition of these successions poses some sedimentological problems; Gauss (1973) and Durning (1989) have argued for considerable spatial separation, and have favoured bringing the two together tectonically. Thrusting may not be the whole answer, for the possibility exists that the stratigraphy needs revision. Andrew Dean (pers. comm.) has palynological evidence that the northern succession which hitherto has proved notoriously unfossiliferous, includes beds younger than was previously thought. A green shale with clastics facies could overlie the purple-and-green slates.

It may not he coincidental that the age of the paralic sediments of the Boscastlc Nappe, which include a green shale facies carrying near shore conodonts, equates with a missing period of basin history.

Selwood and Thomas (1986) favoured restoring the paralic successions of the Boscastle Nappe and the associated Tredorn Nappe, to the southern part of the basin and its outer shelf. Here, a broad shelf/ basin transition could have been occupied by the Upper Devonian outer shelf argillites and Lower Carboniferous basinal sequence of the Tintagel Succession and its paralic facies equivalent, the Boscastle Succession. Sediments included in the latter could have built out as deltas into the basin, from highs (e.g. Liskeard High) marginal to the basin.

The deformation of the Trevone Basin in late Viséan to Lower Namurian times, proceeded either by back thrusting or bipolar inversion to give the southward transporting (D1) structures currently exposed (e.g. Andrews *et al.* 1988; Durning 1989). This inversion event could be linked to the deformation of the Gramscatho Basin farther south.

As the deformation front spread northwards from the Gramscatho Basin the sequences originating on the outer shelf were folded, and thrust northwards over the south-facing structures of the southern margin of the inverted Trevone Basin, to produce the Padstow Confrontation. This second deformation to affect the basin, would have displaced the younger uplifted parts of the basin northwards; possibly by reversing direction along early thrusts. Such movements could have caused the outer shelf and paralic beds involved in the inversion to be carried north towards their present position (Boscastle and Tredorn Nappes). The late extensional features in the already folded nappes, and the normal fault geometries in their displacement zones (Warr 1988), favour a final element of detachment and gravity sliding of these thin sheets into their present position. The down cutting by the sheets into underlying sequences, and the development of thick sequences of phyllonites (Selwood *et al.* 1985) which give evidence of considerable internal movement, support gravitational gliding. This would have been a late event in the deformation of the basin, and could be linked to further tightening of structure and uplift.

As would be expected the most far-travelled rocks, the paralic sediments of the Boscastle Nappe, lie at the highest tectonic level: At the time of their emplacement, it seems that the influence of the NWSE fault zones was relatively unimportant. The Boscastle and Tredorn Nappes spread laterally across the St Teath-Portnadler Fault Zone, and locally extend eastwards across the Otterham Fault Zone. The detachment of paralic sediments from uplifted areas to the south is a late feature of both the Trevone and South Devon Basins, and may indicate that the distinction between the basins had been lost at this time.

Many workers prefer to derive sediments represented in the Boscastle and Tredorn Nappes from the north; a view maintained from the time when most sediments of the Boscastle Nappe were thought to be Namurian flysch, and the coastal sequence interpreted as conformable and without lateral facies changes. Structures so modelled (e.g. Warr 1989) demand considerable southward overthrusting of Crackington Formation from the Culm Basin across a substantially uplifted source area for the Boscastle Formation elastic sediments, and the depositional basins of the Boscastle and Tintagel Nappes. Yet the Rusey Thrust is a local structure only represented north of the Trevone Basin, and there is no evidence that the postulated uplifted area, which presumably would have formed the southern boundary of the developing Culm Basin, left any record either in the sediments or structures of that basin. It is worth recording that the first movements in the southern part of the Culm Basin (Whalley and Lloyd 1986) were northwards.

Regional setting

The regional picture that I have been developing, is not entirely consistent with the traditional view of an ORS continent to the north, and a broad shelf carrying reefs at its outer margin which overlooked a major oceanic basin farther south. If it is accepted that the flysch in the South Devon and Trevone Basins is a product of a northward advancing deformation front, then there is little evidence for newly deformed Upper Palaeozoic sediments belonging to such a basin. Rather an intermittently uplifted basement land mass or land masses is indicated. In this setting, the Middle Devonian carbonates might have developed as fringing reefs to such land masses; and the Lower Devonian continental and shallow marine clastics might have had a southern provenance.

The orientation of the deep seated fractures, and the development of local basins described above seem to make sense in a dextral transform setting (Barnes and Andrews *1986)*. Holdsworth *(1989)* has speculated on the presence of a possible terrain boundary between the Old Red Sandstone Continent and an elongate Armorican microplate to the south. He interprets the Start-Perranporth line as an E-W basement fault forming the northern boundary to a series of pull-apart basins initiated early in Devonian times, by dextral movements along the boundary fault. Within such a strike-slip system, sporadic movement on a complex of branching faults might have generated short lived topographic highs which could appear and disappear at different times. Sediments could thus have been supplied, at various times, across the shelf to the Trevone and South Devon Basins in the north and to any pull-apart basins to the south.

Holdsworth *(1989)* incorporated the Eddystone Gneiss into a Normannian High, limited to the west by the Plymouth Bay-Portnadler Fault, and to the east by a continuation of the Otterham Fault Zone. A direct association is thus indicated with the rise separating the Trevone and South Devon Basins. The Normannian High would have been well placed to supply clastics northwards across the shelf to these basins; clastics which would have inhibited any significant reefal development in the area. A shallow water clastic cover could have been extended across the shelf and its extension between the South Devon and Trevone Basins, allowing deltaic sediments to build out into these basins. Such sediments are now represented within the Boscastle Nappe.

It would appear that structural models which demand the derivation of these sediments from a hypothetical basin between the Culm Basin and the Trevone-South Devon Basins, depart from the principles of parsimony. The flexibility of basin inversion modelling allows current stratigraphical and structural data to be integrated into the simple basin model outlined above. Though such modelling is intellectually stimulating, it is chastening to remember that all models are ephemeral; designed to be modified or rejected as new facts accumulate. Time will undoubtedly show that the true legacy of team-work at Exeter is a massive extension of the data base.

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References

Andrews, J.R. Barker, A.J. and Pamplin, C.F. 1988. A reappraisal of the facing confrontation in north Cornwall: fold-or thrust- dominated tectonics? *Journal of the Geological Society, London, 145,* 777-788.

Barnes, R.P. and Andrews, J.R. 1986. Upper Palaeozoic ophiolite generation and obduction in south Cornwall. *Journal of !he Geological Society, London. 143,* 117-124.

Beese. A.P. 1982. The argillite facies of the Middle Devonian Succession in north Cornwall. *Proceedings of the Ussher Society, 5,* 321-332.

Burton, C.J. and Tanner, P.G.W. 1986. The stratigraphy and structure of the Devonian rocks around Liskeard, east Cornwall, with regional implications. *Journal of the Geological Society, London, 143,* 95-105.

Cooper, M.A. and Williams, G.D. (eds) 1989. Inversion Tectonics. *Special Publication of !he Geological Society, London, 44*.

Coward, M.P. and McClay, K.R. 1983. Thrust tectonics of S Devon. *Journal of the Geological Society. London, 140,* 215-28.

Dearman, W.R. 1963. Wrench-faulting in Cornwall and south Devon. Proceedings *n/ the Geologists' Association,* 74, 265-87.

Durning, B. 1989. A new model for the development of the Variscan facing confrontation at Padstow, north Cornwall. *Proceedings of the Ussher Society, 7,* 141-45.

Gauss, G.A. 1973. The structure of the Padstow area, north Cornwall. *Proceedings of the Geologists' Association, 84,* 283-313.

Hayward, A.B. and Graham, R.H. 1989. Some geometrical characteristics of inversion. *In:* Cooper, M.A. and Williams, G.D. (eds) Inversion Tectonics. *Special Publication of the Geological Society, London, 44,* 17-39.

Holder, M.T. and Leveridge, B.E. 1986. A model for the tectonic evolution of south Cornwall. *Journal of the Geological Society, London. 143,* 125-134.

Holdsworth, R.E. 1989. The Start-Perranporth line: a Devonian terrane boundary in the Variscan orogen of S W England? Journal *of the Geological Society, London,* 146, 419-421.

Isaac, K.P. 1981. The Hercynian geology of Lydford Gorge, north-west Dartmoor, and its regional significance. *Proceedings of !he Ussher Society.* 5, 147-152.

Isaac, K.P. 1983. Hercynian regional and contact metamorphism in Upper Devonian and Lower Carboniferous metasediments in Launceston and Lydford area, South' West England. *Transactions of the Royal Geological Society of Cornwall, 21,* 97-112.

Orchard, M.J. 1975. Famennian conodonts and cavity infills in the Plymouth Limestone (S. Devon). *Proceedings of the Ussher Society,* 3. 49-54.

Pound, C.J. 1983. The sedimentology of the Lower-Middle Devonian Staddon Grits and Jennycliff Slates on the east side of Plymouth Sound, Devon. *Proceedings of the Ussher Society,* 5, 465-72.

Rudwick, M.J.S. 1985. *The Great Devonian Controversy.* University of Chicago Press.

Scrutton, C.T. 1977. Facies variations in the Devonian limestones of eastern south Devon. *Geological Magazine, 14,* 165-193.

Seago, R.D. and Chapman, T.J. 1988. The confrontation of structural styles and the evolution of a foreland basin in central SW England. Jou*rnal of the Geological Society, London, 145*. 789-800.

Selwood, E.B., Edwards, R.A., Chesher, J.A., Hamblin, R.J.O., Henson, M.R., Riddolls, B.W. and Waters, R.A. 1984. Geology of the country around Newton Abbot. *Memoir of the British Geological Sur*vey, *Sheet 339*.

Selwood, E.B., Stewart, LL and Thomas, J.M. 1985. Upper Palaeozoic sediments and structure in north Cornwall - a reinterpretation. *Proceedings of the Geologists' Association,* 96, 129-141.

Selwood, E.B, and Thomas, J.M. 1986. Variscan facies and structure in central SW England. *Journal of the Geological Society. London, 143,* 199207.

Stewart, I.J. 1981. The Trekellend Thrust. *Proceedings of the Ussher Society,* 5, 163-167.

Turner, P.J. 1981. Aspects of the structure of the Chillaton area, south-west Devonshire. *Proceedings of the* Ussher *Society, 5,* 153-162.

Turner, P.J. 1982a. *Aspects of the evolution of the Hercynides in Central South West England.* Unpublished PhD thesis, University of Exeter.

Turner, P.J. 1982b. The anatomy of a thrust: a study of the Greystone Thrust Complex, east Cornwall. *Proceedings of the Ussher Society, 5,* 270-278.

Turner, P.J. 1984. Hercynian high-angle fault zones between Dartmoor and Bodmin Moor. *Proceedings of the Ussher Society,* 6, 60-67.

Warr, L.N. 1988. The deformational history of the area north-west of the Bodmin Moor granite, north Cornwall. Proceedings of *the Ussher Society,* 7,67-72.

Warr, L.N. 1989. The structural evolution of the Davidstow Anticline, and its relationship to the South Culm Overfold, north Cornwall. *Proceedings of the Ussher Society, 7,* 136-140.

Whalley, J.S. and Lloyd, G.E. 1986. Tectonics of the Bude Formation, north Cornwall - the recognition of northerly directed *decollement. Journal of the Geological Society. London, 143,* 83-88.

Whiteley, M.J. 1984. Dinantian sandstones in South-west England: new evidence concerning their distribution, age and environmental setting. *European Dinantian Environments, 1st Meeting, 1984. Abstracts,* 5-7, Department of Earth Sciences, Open University.

Willcock, A.D. 1982. An introduction to the geology of the area between Buckfastleigh and Ivybridge. *Proceedings of the Ussher Society, 5, 289*295.