Read at the Annual Conference of the Ussher Society, January 1990

A model for the tectono-thermal evolution of north Cornwall

C.F. PAMPLIN

Pamplin, C.F. 1990. A model for the tectono-thermal evolution of north Cornwall. *Proceedings of the Ussher Society, 7,* 206-211.

Fluid inclusion and vitrinite reflectance data along with illite crystallinity data are used to construct palaeothermal gradients across north Cornwall. These in turn place constraints on the structural evolution of the area. A simplified model is developed in which peak metamorphism to the south of the Camel Estuary is related to basin-inversion (D1) whilst in the Tintagel High Strain Zone it is related to post-basin-inversion thrusting (D2).

C.F. Pamplin, Department of Geology, The University, Southampton, SO9 5NH. (Currently at 16 Egerton Grove, Chorley, Lancashire, PR 7 2HQ)

Introduction

This paper develops a tectono-thermal model for the geological evolution of South West England utilising the results of a combined structural and metamorphic analysis of the north Cornwall coastal section (Fig. 1). Fluid inclusion and vitrinite reflectance data are used to constrain absolute P-T conditions whilst detailed illite crystallinity data are used to construct palaeothermal gradients. This integrated approach allows an improved appreciation of the geological evolution of north Cornwall.

The earliest phase of deformation in north Cornwall is identified with northwards transport of argillaceous sediments (D1s). This produced north-facing, recumbent folds (F1s) on a regional scale, with an associated axial-planar slaty cleavage (S1s). This deformation event can be recognized from south of Newquay to the Camel Estuary. The next phase in the deformation sequence (D1n) is identified with the southwards transport of Upper Devonian and Lower Carboniferous sediments north of the Camel Estuary. This is the first deformation event observed in these rocks. It is characterised by the regional development of recumbent southward-facing folds (F1n), with an associated flat-lying slaty cleavage (S1n). In the area of the Camel Estuary the two D1 events meet. This zone of confrontation, defined as the region of overlap of northwards (D1s) and southwards (D1n) shear, is restricted to a 2km stretch of coast (the Greenaway) between Polzeath and Daymer Bay: the Padstow Facing Confrontation.

The second phase of deformation was generated by northwards transport along a major south dipping shear zone during the Upper Carboniferous. The deformation associated with this shear zone intensifies towards the basal shear. Consequently, the intensity of D2 increases northwards as the basal shear zone approaches the surface. The shear zone outcrops as the High Strain Zone around Tintagel.

Regional extent of the Facing Confrontation

The development of a confrontation zone between north- and south-facing structures has recently been reported from Cargreen, near Plymouth (Seago and Chapman 1988). However, there are a number of important differences between the 'Cargreen Confrontation' (as described by Seago and Chapman 1988) and the Padstow Confrontation.

At Cargreen the structures of the southern zone are considered to overprint the northern zone and thereby generate D2. Despite this, Seago and Chapman (1988) interpret the Cargreen Confrontation in terms of a north-dipping backthrust generated during D1. In the Padstow Confrontation it is structures of the northern zone that overprint structures of the southern zone. Both D1n and Des are subsequently overprinted by renewed northwards transport (D2). Apparently, D1s is not present in the deformation sequence described by Seago and Chapman (1988). However, it now seems likely that the D2 structures at Cargreen are not a local development and belong to the regional D2 deformation phase (Chapman pers. comm.). This simplifies the structural history at Cargreen and supports the proposed correlation of the Padstow and Cargreen structures.

Furthermore, assuming that Seago and Chapman's north-dipping backthrust is the expression along strike of the Padstow Confrontation creates a problem. The Upper Devonian spillites around Plymouth lie in the footwall of the Cargreen Confrontation whilst those at Pentire Point lie in the hanging wall of the Padstow Confrontation. If the two facing confrontations are equivalent and formed by backthrusting then movement on the backthrust must be minor. If there was any major movement on the proposed backthrust the spillites at Pentire Point would be expected to life to the south of those at Plymouth.

Regional extent of the High Strain Zone

Sanderson and Dearman (1973) recognised that the High Strain Zone passes inland from Tintagel towards Tavistock. The recent work of the `Exeter Group' has demonstrated that the Tavistock area is dominated by northwards directed thrusting. This deformation is equivalent to that responsible for the development of the High Strain Zone i.e. it is D2. As the number of thrust planes increases, so the intensity of deformation associated with each decreases and the width of the zone increases. The High Strain Zone is therefore only developed in north Cornwall where D2 thrusts become confined to a relatively narrow zone. The most likely reason for this localisation of D2 strain is that the High Strain Zone represents a lateral ramp to the thrust sheet complex recognized inland.

Before considering a new model for the tectono-thermal evolution of north Cornwall it is instructive to review earlier models.

Previous models

A popular explanation for the generation of D1n and the Facing Confrontation has involved southwards directed backthrusting as

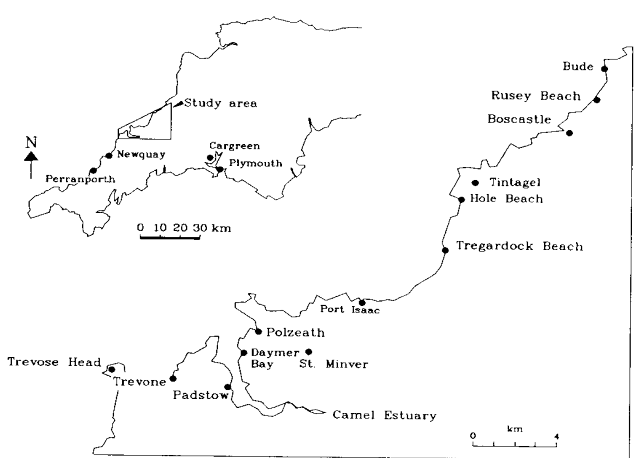

Figure 1. Location map of study area.

movement on the basal decollement associated with D1s is temporarily halted (Shackleton *et al.* 1982; Coward and Smallwood 1984; Andrews *et al.* 1988). In such a model it is unlikely that a laterally extensive yet narrow zone of confrontation would be generated since the backthrust transports hanging wall rocks above the D I s basal thrust. The hanging wall rocks would be expected to show widespread development of D1s features prior to D1n. This is not observed. It is only in the Confrontation Zone that first phase, D1n confronts first phase D1s in a narrow zone of interference.

Contributions by Selwood and Thomas (1986a, b, 1988) downgrade the significance of the D1n event, and hence the Padstow Facing Confrontation. These authors extended the thrust tectonic model, which the Exeter Group developed from studies in central South West England, to the north Cornish coast. They recognised the importance of northwards thrust transport but have not reconciled this with the presence of large areas of inverted and southwardsfacing strata (Pamplin and Andrews 1988; Andrews *et al.* 1990 in discussion of Selwood and Thomas 1988).

Durning (1989) has suggested that in the Padstow Facing Confrontation the earliest fabric formed is D1n and that this is overprinted by D1s. Furthermore, it is argued that continued northwards transport related to D1s overprints D1n to generate D2n structures. Unfortunately this reinterpretation relies mainly on the evidence of facing. This type of evidence has been shown to be inconclusive (Pamplin and Andrews 1988).

In support of the new chronology Durning (1989) presents SEM photomicrographs of the cleavages developed in the purple layers at Trebetherick Point. However, this type of evidence is also inconclusive. Pamplin and Andrews (1988) regard the flat-lying cleavage to represent D2 reactivation of the original flat-lying D1s cleavage. It is during this reactivation that the steeper S1n cleavage becomes deformed and recrystallisation occurs. The evidence of sense of shear criteria remains as the least subjective method available in defining the structural chronology within the Facing Confrontation.

Illite crystallinity analysis

Preliminary results from the application of illite crystallinity techniques to the slates of South West England are given by Brazier *et al.* (1979). Their work concentrated on the rocks exposed along the south Devon and north Cornish coasts. Their results in north Cornwall were confirmed by Primmer (1985a) and extended northwards into west Somerset by Kelm (1986).

The more detailed work of Primmer (1985a,b) resulted in an appraisal of the P-T history of the region. Using the tectonic model of Selwood *et al.* (1985), Primmer considered the metamorphic history in terms of a nappe pile underthrusting the undeformed Culm Basin flysch. This induced backthrusting and local crustal thickening in the Tintagel area. In this structural framework Primmer recognised a synchronous M1-D1 event up to greenschist facies temperatures (T=350-400°C). This was followed by a post-kinematic M2 event at a higher temperature, but lower pressure, and a final phase of retrograde metamorphism. A major shortfall of these studies is that they pay little or no attention to the detailed structure of the areas under consideration. Recent reviews (e.g. Andrews *et al.* 1988) of the tectonic model of Selwood *et al.* (1985) have reassigned the deformational and metamorphic chronology of north Cornwall. This has resulted in the need to reappraise the P-T history of the region.

Illite crystallinity sampling procedure

The present study covers the coastal section between Rusey Beach [SX 12459349] and Trevone [SW88807590] (Fig. 1). Samples were collected at 100m intervals along the coast, where possible within 5m of sea level. This systematic approach was adopted to produce a sample set on which there is good geographical control. Particular attention was paid to the structural setting of each sample i.e. relation to thrusts, folds and the number of cleavages developed. Sampling close to intrusions was avoided. All the coastal samples have undergone weathering processes by sea and rain. The effects of such alteration on the illite crystallinity is negligible since `crystallisation' is an irreversible process. However, clay minerals produced during weathering, especially those with characteristic 10Å reflections can interfere with measurement of the illite diffraction peak.

Sample preparation techniques

In the interpretation of the results of any illite crystallinity determinations it is important to be aware of the preparation procedure adopted and the machine operating conditions during analysis. All samples have been prepared in the following way:

1) Whole rock passed once through the jaw crusher.

2) Dry sieve separation of the <200μm fraction.

3) Immersion of half the <200μm fraction in distilled water and placement in an ultra-sonic vibrator for 5 minutes allowing all fine grained material to be released into suspension. 4) Addition of 2ml/1 of Calgon (Na_6PO_4) to each sample to prevent flocculation of the clay.

5) Gravity-accelerated settling at 28°C for 7 mins/cm to separate the <5μm fraction.

6) Addition of 2ml/1 of $MgCl_2$ to the decanted <5μm fraction.

7) Centrifugal-accelerated settling of <5μm fraction: washed twice in tap water to remove excess $MgCl_2$

8) Production of 2 smear slides for each sample.

In the size fraction selected, the peak broadening effects of very fine grained (<0.2μm) non-crystalline illite appears to be counteracted by peak-sharpening detrital micas in the >2μm fraction (Pamplin 1988).

The machine operating conditions for all X-ray determinations are given below:

Radiation	CuKa, Ni filtered
kV	35
mA	25
Slits	$^1/_2$° divergence
	0.02 scatter
	$^1/_2$° receiving
Scan Speed	$^1/_2$°Θ/minute
Chart Speed	2cm/minute
Time Constant	1
Angular Range	8.00-10.00°2Θ

Illite crystallinity indices

The suggested ranges of the three most common crystallinity measures are shown below:

INDEX	DIAGENESIS	ANCHIZONE	EPIZONE
Weaver (1961)	<2.3	2.3-12.1	>12.1
Kübler (1964)	>4.0mm	4.0-2.5mm	<2.5mm
	>0.3°2Θ	0.3-0.2°2Θ	<0.2°2Θ
Weber (1972)	>125	125-80	<80

The Weber index requires the normalisation of the illite crystallinity peak height against that of quartz, but is not widely used. The sharpness ratio (Weaver) is an excellent measure for poorly crystalline illite, however it produces large errors if applied to highly crystalline samples. Conversely, the error in the Kübler Index decreases with increasing crystallinity. Blenkinsop (1988) comments that the Kübler Index is marginally more accurate at all grades.

All samples analysed are from areas previously determined to be above diagenetic grade (Primmer 1985a). For this study the Kübler Index is considered to be the most appropriate.

Standards

Three polished slate samples from north Cornwall were analysed by Dr H. Kisch (Ben Gurion University of Israel) and subsequently used as laboratory standards. In turn, 5 inter-laboratory polished slate standards prepared by Kisch were analysed on the machine used in this study. The results of this analysis are shown in Table 1. The variation in counts per second (CPS) is due to the relatively low setting of voltage and current on the machine used for this study. The two machines produce very similar results for crystallinity values less than 0.26°2Θ. Most of the Cornish samples are more highly crystalline than this.

Table 1. Results from the analysis of standards

Sample	Peak width (Kisch)	Intensity (cps)	Peak width (This study)	Intensity (cps)
13B 8	0.16	2600	0.16	660
47A 2	0.13	5100	0.13	990
59A 3	0.245	1300	0.25	310
65 8	0.29	1500	0.285	430
10C 7	0.35	900	0.308	225

Through this interchange of standards the illite crystallinity values obtained during this study are comparable to the results of Kisch. In particular it can be assumed that 0.21°2Θ) represents the boundary between the epizone and anchizone. The standard was run at the beginning and end of each period of operation. At no time during this work was any appreciable machine drift noted.

Illite crystallinity results

A total of 278 samples were collected from the coast between Tintagel and Polzeath (Fig. 2). By plotting the results of the illite crystallinity determinations against the geographical location of the samples (Figs 3, 4) two conclusions can be drawn:

1) On the local scale, the structurally complex Padstow Facing Confrontation, shows no marked discontinuities in illite crystallinity values (compare Fig. 3b, c with the Rusey Fault on Fig. 3a);
2) On the regional scale there is a very close correlation (Fig. 4) between the outcrop pattern of the St. Minver Synclinorium (i.e. the Facing Confrontation) and the metamorphic low.

In order to explore this sensitivity to scale further, it is necessary to consider the regional correlation of metamorphic episodes in South West England.

Hypothetical peak temperature profiles

The illite crystallinity isopleths (Fig. 4) reflect the maximum palaeogeothermal gradients across north Cornwall. By considering the form of these gradients it is possible to constrain models for the geological evolution of the area. Around Tintagel mineral associations demonstrate that peak D1n-M1n temperatures are in the order of 250-300°C (Primmer 1985b). Fluid inclusion studies in the Tintagel High Strain Zone (Pamplin 1988) fix D2n-M2n temperatures at >450°C. This temperature is of the same order as that suggested by Primmer(1985b) for peak metamorphism temperatures of between 450°C-500°C. Peak metamorphic temperatures in the region of the Facing Confrontation are likely to be in the order of 270320°C reflecting mid-anchizone conditions (Mullis 1979).

Wilkinson (pers. comm.), on the basis of fluid inclusion data constrained by vitrinite reflectance studies, has suggested D1s-M1s temperatures in the Porthleven area of 330°C at 3.4kb and D2s-M2s temperatures of 250°C at 0.8kb.

Utilizing these peak metamorphic temperatures it is possible to construct hypothetical thermal profiles, i.e. plots of palaeotemperature against geographical location. Fig. 5a shows the resulting peak temperature profile generated when the assumption is made that the D2-M2 episode at Tintagel is equivalent to that at Porthleven (i.e. across Cornwall). This model predicts a metamorphic low around Truro and shallow palaeothermal gradients both to the north and south. This clearly does not fit with the observed metamorphic low at Padstow and the steep thermal gradient between Padstow and Tintagel.

Fig. 5b shows the preferred thermal profiles for South West England if the D1-M1 and D2-M2 phases north and south of the Facing Confrontation are considered distinct and separate episodes. This

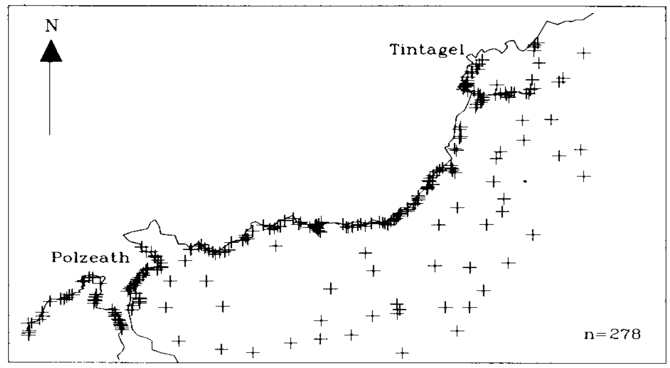

Figure 2. Elite crystallinity sample sites.

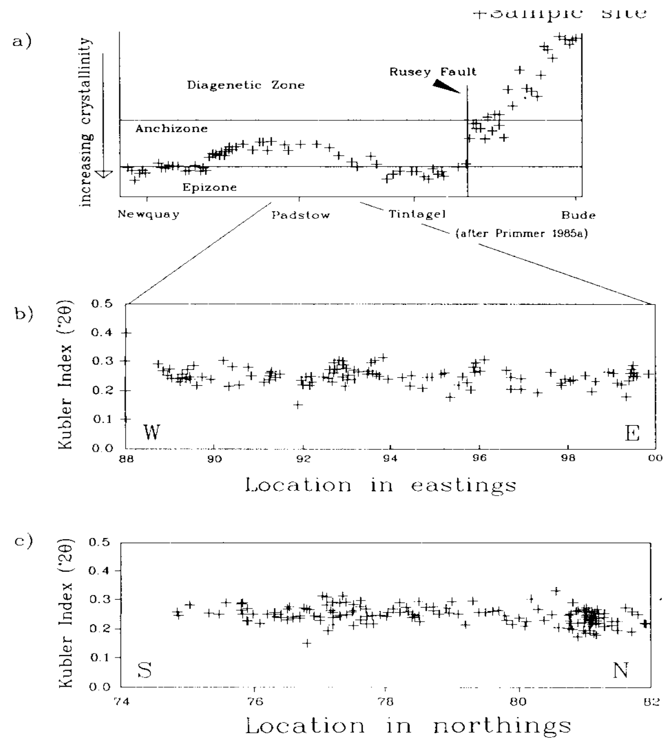

Figure 3. a) Variations in illite crystallinity between Bude and Newquay (after Primmer 1985a). The illite crystallinity results from this study are presented for the area of the Facing Confrontation, plotted in relation to b) casting position and c) northing position. The confrontation is not reflected in the illite crystallinity data.

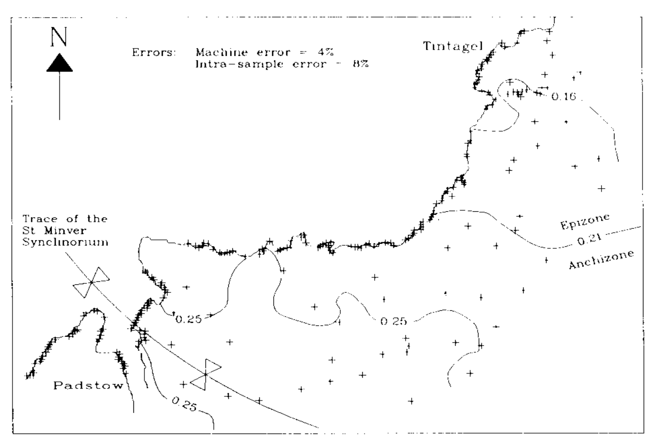

Figure 4. Contour map of the illite crystallinity data. The approximate trace of the St. Minver Synclinorium is shown to emphasise the close correlation between the Facing Confrontation and the metamorphic low. The error values are 1σ values.

arrangement of palaeogeothermal gradients predicts the steep thermal gradient between Tintagel and Padstow, the metamorphic low centred on the Facing Confrontation and the subsequent increase in grade towards Newquay.

The following model integrates this arrangement of palaeogeothermal gradients into the tectono-thermal evolution of north Cornwall.

A basin inversion model for the tectono-thermal evolution of north Cornwall

Fig. 6a is a schematic section through South West England prior to plate collision in the Upper Devonian (Barnes and Andrews 1986). At the start of the Devonian, north-south extension across the continental shelf south of the Laurentia and Avalonia landmass, generated

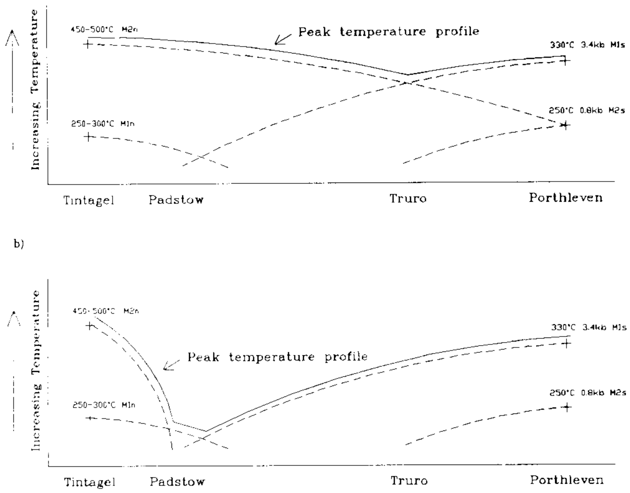

Figure 5. Hypothetical peak thermal profile plots generated when assuming a) equivalence of M2n and M2s and b) non-equivalence of the M2 episodes. Dashed lines show hypothetical thermal profiles, solid lines show peak thermal profiles.

east-west trending basins:- the Trevone Basin to the north and the Gramscatho Basin to the south. The elongation of these basins suggests a tectonic control to their development. This is probably related to the presence of a major east-west trending strike-slip fault system now thought to have been active from pre-Devonian times (Barnes 1982; Sanderson 1984; Barnes and Andrews 1986). In this setting the continental shelf is divided into a series of horsts and basins. Within each basin, listric transtensional faults developed in response to continued crustal thinning (Fig. 6a).

The basins continued to subside throughout the Lower and Middle Devonian and developed characteristic sediment fills. The Gramscatho Basin was supplied with southerly derived flysch deposits formed by the erosion of a cratonic source. These are variably considered to represent a continental margin volcanic arc (Floyd and Leveridge 1987) or a passive continental margin (Barnes 1982). The Trevone Basin received a sediment-fill dominated by fine grained silts and muds. This suggests that the Trevone Basin was isolated from any source of coarse detritus, a not uncommon situation in block and basin terranes (e.g. present day south California coastal margin, Scholz 1977). During the Upper Devonian, submarine volcanism on the northern margin of the Trevone Basin produced the Pentire Pillow Lavas and their distal tuff equivalents, the Longcarrow Cove Beds (Fig. 6b). Crinoidal shoals developed on the horst, the erosion products of which swept southwards into the Trevone Basin to form the Marble Cliff Beds.

Active subsidence of the Trevone Basin ceased by the Upper Devonian and the Polzeath Slates were deposited across the basin's northern margin and the intervening sea-floor towards the newly opened Culm Basin (Fig. 6b). The Culm basin received detritus dominated by coarse turbidites derived from the Laurentia and Avalonia landmass. Sedimentation continued through to the Lower Carboniferous when the continental shelf was beginning to shorten as a result of plate collision to the south (Barnes and Andrews 1986; Holder and Leveridge 1986). The first expression of this north-south compression was the obduction of the ocean floor of the Gramscatho Basin (the Lizard Complex Fig. 6c), possibly as early as Upper Devonian times (Barnes and Andrews 1986). As compression continued, renewed movement on the basal decollement carried the Lizard Complex northwards. The south dipping faulted margin of the Gramscatho Basin was reactivated as a northwards directed thrust (Fig. 6c). This led to the expulsion of the Gramscatho Flysch and is recognised today as the Perranporth Line. The northern margin of the Gramscatho Basin was carried over the southern margin of the Trevone Basin before movement was transferred back onto the basal decollement.

Compression of the shelf continued by inversion of the Trevone Basin. This began in the Viséan by the reversal of movement on the listric basin-forming faults (Fig. 6c) and produced the overturned northwards-facing folds of D1s. The northwards migrating fold nappe travelled along a Middle/Upper Devonian sea-floor decollement, decoupling the Upper Devonian sediments above (Fig. 6c).

Since the Pentire Pillow Lavas, considered to lie close to the northern margin of the Trevone Basin, are not deformed during D1s, the northern lobe must have travelled only a short distance. Fig. 6c represents the section through South West England after the closure of the Gramscatho and Trevone Basins. The relative levels of the Frasnian-Famennian (dashed line) and Famennian-Dinantian (dotted line) boundaries are indicated. Continued continental compression caused the closure of the Culm Basin in a similar manner during the Upper Carboniferous (Fig. 6d). The listric faults became thrusts as the basin-fill was ejected. A backthrust from the basal decollement, utilizing the listric basin margin faults, transported sediments on the southern margin southwards.

The generation of an extensive southwards facing fold nappe (Fig. 6d) resulted in the compression of the Polzeath Slates in the hanging wall to D1n. This compression was finally halted by the development of a northerly directed backthrust and the formation of a triangle zone (Jones 1982). This developed between the Gravel Caverns Conglomerates and the Polzeath Slates (the Polzeath Thrust of Selwood and Thomas 1988). The minimum amount of southwards translation of the southern fold nappe can be estimated from the amount of shortening in the `buffering' Polzeath Slates. These show tight upright and recumbent decametric early folds. Total shortening is estimated to be at least 70%, i.e. the present 3km of exposure represents an original distance of some 10km.

The Culm Basin north of the Rusey Fault Zone displays the classic features of a basin which has been compressed and the contained sediments ejected. Large recumbent north-facing folds in the north pass into upright chevron folds around Bude and then into southwards-facing recumbent chevron folds just north of the Rusey Fault Zone (Fig. 6e). Assuming that the Rusey Fault is not a major basinal boundary, and that the sediments on the southern side form part of the Calm Basin sediment fill, the fanned geometry of the nappe pile continues southwards with folds becoming recumbent and nearly isoclinal. The recognition of the High Strain Zone as a product of intense northwards compressional shear presents a problem in that it is no longer feasible to explain the distinct asymmetry in the Culm Basin fan (i.e. the cross-strike extent of southwards-facing folds) in terms of extension along low angle normal faults. These are clearly contractional and related to the High Strain Zone, and therefore act to shorten the section south of Rusey Beach (compare Figs 6d and e).

Sanderson (1979) describes a mechanism which generates recumbent folds from originally upright chevron folds. This involves increasing southwards directed simple shear towards the base of the evolving fold pile. This type of model has been further promoted by Lloyd and Whalley (1986) working north of the Rusey Fault. These models explain the generation of south-facing chevron folds from original upright D1n chevron folds, and the presence of low angle normal faults, in terms of localised zones of intense southwards

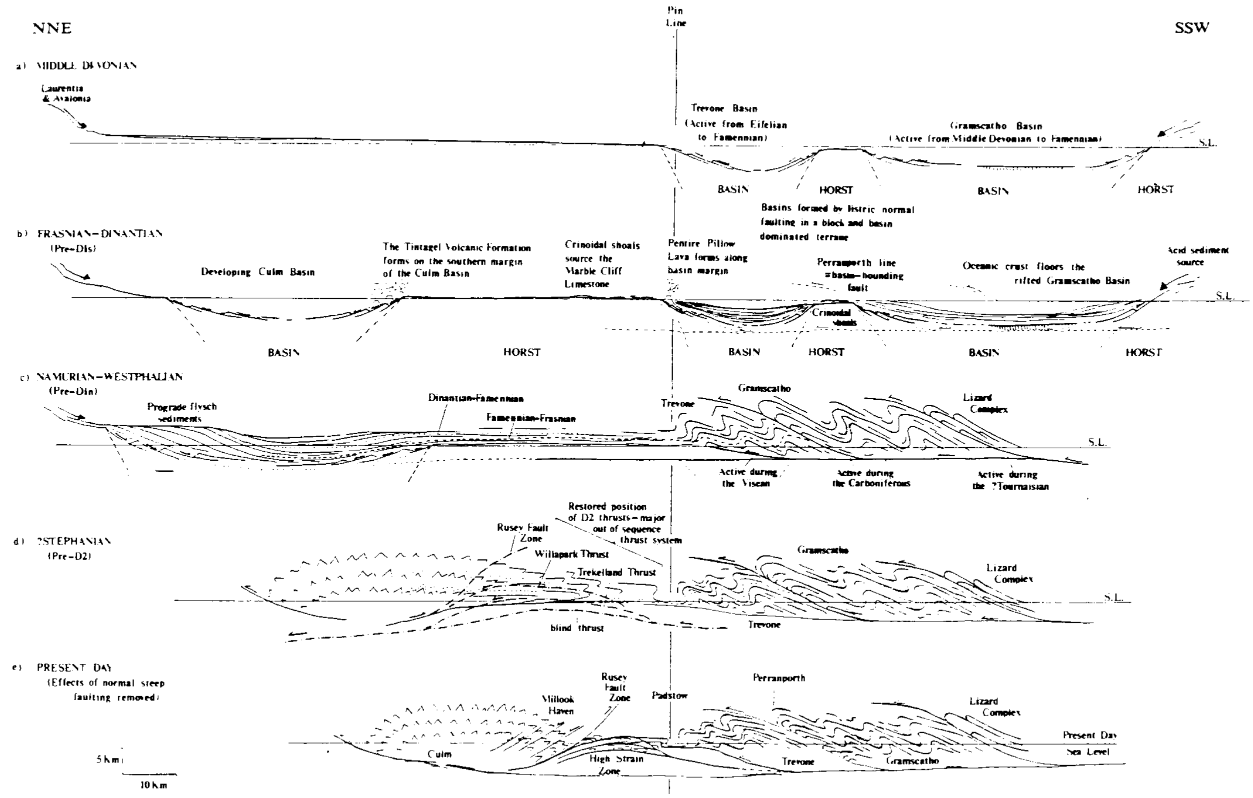

Figure 6. Schematic model of the geological evolution of South West England. Elongate (E-W) strike-slip dominated basins are inverted following continental collision in the Lower Carboniferous. Sequential inversion of the Gramscatho, Trevone and Culm Basins, controlled by the initial geometry of the bounding faults and their spatial geometry, generates D 1 features such as the Lizard Complex, the Perranporth line and the Padstow Facing Confrontation. Further shortening was taken up on a late out-of-sequence thrust system in the Tintagel area, the High Strain Zone.

shear. Lloyd and Whalley (1986) assign the southwards shear to backthrusting in D1. However, local underthrusting of the Culm sediments during D2 (Andrews *et al.* 1988) would produce a similar effect. The involvement in these models of either underthrusting (D2) or backthrusting (Dl) accounts for the observed southwards shear (Fig. 6e).

The Sanderson (1979) model cannot now account for the High Strain Zone as there is no evidence of high strain during D1n. Furthermore, the generation of sheath folds by intense northwards shear (D2a) along the S1 surface demonstrates that S1n, and consequently F1n, lay sub-horizontal prior to D2. If this were not the case the early D2a strain would be expected to rotate and deform S1n. A pre-D2 recumbent F1n fold geometry must indicate the generation of an extended southern fold nappe during basin inversion Fig. 6d). This, coupled with the modified fold geometry north of the Rusey Fault Zone, accounts for the observed asymmetry in the present day Culm sediments.

This model for the generation of the Padstow Facing Confrontation accounts for the narrow zone of confrontation, the structural geometry of the Polzeath Slates and the arrangement of sedimentary facies in north Cornwall. In this model, the pattern of metamorphism within each inverted sedimentary pile would reflect the original depth of sediment burial, and therefore, the increasing metamorphic grades towards each nappe core. This model can, therefore, account for the development of a Dl metamorphic low centred on the Facing Confrontation.

An out-of-sequence thrust model for the evolution of the High Strain Zone

After closure of the final basin on the continental margin (the Culm Basin) a change in the deformation style was required to accommodate continued shortening. Out-of-sequence thrusts developed, climbing from the basal decollement. The restored position of these thrusts is shown in Fig. 6d. The High Strain Zone is the surface exposure of one such thrust zone (the Trekellend Thrust). Its present day geometry is controlled by the Late Carboniferous Davidstow Anticline. Rotation of the High Strain Zone across the anticline, itself probably the result of a blind thrust ramping at depth, results in the Trekellend Thrust passing down beneath the section. Progressively higher structural levels are encountered moving northwards from the core of the Anticline. At Boscastle, a higher level shear zone, with less early ductile deformation than is observed in the Trekellend Thrust is exposed: the Willapark Thrust (Selwood and Thomas 1986b). This is seen as an early D2 thrust tip which had propogated to shallow crustal levels. The Boscastle Nappe, carried on this thrust zone, underthrusts the Culm sediments at Rusey Beach.

The K-Ar uplift dates (Dodson and Rex 1971) from the northern area are between 310 and 270Ma. Since peak metamorphism was associated with D2 thrusting, these dates must represent, in part at least, the timing of D2 rather than D1n basin inversion.

In the High Strain Zone there is good evidence of a progression from early ductile deformation parallel to S1 n to late brittle deformation generating Fib folds of bedding and S1n (Andrews *et al.* 1988). This represents a progressive localisation of strain. In the High Strain Zone the Trekellend Thrust is confined to the black slates of the Trambley Cove Formation. Hobson and Sanderson (1983) attempted to explain the geometry of the High Strain Zone, and in particular the repetition of the Tredorn Slates, in terms of major (100's m) fold closures. This idea has since been abandoned in favour of a thrust tectonic interpretation (Andrews *et al.* 1988). However, a common feature of the High Strain Zone is that thrusts are apparently totally confined within the black slates. Clearly if this were the case they could not be responsible for the repetition of strata. Until it is possible to detect, or reject, the presence of major folds in the Tredorn Slates at such localities as Hole Beach the importance of large scale folding must remain enigmatic.

The distribution of the various structural features after D2 is shown in Fig. 6e. This is essentially a cross section through present day South West England. Late normal faults have not been shown.

Conclusions

The Padstow Facing Confrontation is generated as a D1 structure by basin inversion of the Trevone (D1s) and Culm (D1n) basins. The metamorphism increases towards the core of the nappes resulting in a metamorphic low where the two structural regimes meet. The High Strain Zone is the product of a late out-of-sequence thrust system (D2n) at much greater depth and consequently higher temperature. This resulted in an overprinting of the M1 n metamorphic signature by a much more intense M2n episode. However, the structural control on the development of this second thermal episode prevented it overprinting the metamorphic low previously developed around Padstow.

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.

Andrews, J.R., Pamplin, C.F. and Barker, A.J. 1990. Discussion on "reappraisal of the facing confrontation in north Cornwall: fold- or thrust dominated tectonics?" *Journal of the Geological Society, London, /47, 408-4* 10.

Barnes, R.P. *1982. The geology of south Cornish melanges.* Unpublished PhD thesis. University of Southampton.

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

Blenkinsop, T.G. 1988. Definition of low-grade metamorphic zones using illite crystallinity. *Journal of Metamorphic Geology,* 6, 623-636.

Brazier, S., Robinson, D. and Matthews, S.C. 1979. Studies of illite crystallinity in southwest England: some preliminary results and their geological setting. *Neues Jahrbuch Geologic' Palaeont, 11,* 641-662.

Coward, M.P. and Smallwood, S. 1984. An interpretation of the Variscan tectonics of SW Britain. *in:* Hutton, D.H. and Sanderson, D.J. (eds) Variscan Tectonics of the North Atlantic Region. *Special Publication of the Geological Society, London, 14,* 89-102.

Dodson. M.H. and Rex, D.C. 1971. Potassium-argon ages of slates and phyllites from south-west England. *Quarterly Journal of the Geological Society, London, 126,* 469-499.

Durning, B. 1989. A new model for the development of the Variscan facing confrontation at Padstow, north Cornwall. Proceedings *of the Ussher Society, 7,* 141-145.

Floyd. P.A. and Leveridge, B.E. 1987. Tectonic environments of the Devonian Gramscatho basin, South Cornwall: framework model and geochemical evidence from turbidite sandstones. *Journal of the Geological Society. London, 144,* 531-542.

Hobson, D.M. and Sanderson, D.J. 1983. Variscan deformation in southwest England. *In:* Hancock, P.L. (ed) *The Variscan fold-belt in the British Isles,* Hilger, Bristol, 108-129.

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. Jones, P.B. 1982. Oil and gas beneath east-dipping underthrusts in the Alberta foothills. *In:* Powers, R.B. (ed) *Geologic Studies of the Cordilleran Thrust Belt (Vol. 1),* Rocky Mountain Association of Geologists, Denver, Colorado, 61-74.

Kelm, U. 1986. Mineralogy and illite crystallinity of the pelitic Devonian and Carboniferous strata of north Devon and western Somerset. *Proceedings of the Ussher Society,* 6, 338-343.

Kübler, B. 1964. Les argiles, indicateurs de metamorphisme. *Rev. Inst. Franc. Petrole., 19,* 1093-1112.

Lloyd, G.E. and Whalley, J.S. 1986. The modification of chevron folds by simple shear: examples from north Cornwall and Devon. *Journal of the Geological Society, London, 143,* 89-94.

Mullis, J. 1979. The system methane-water as a geologic thermometer and barometer from the external part of the central alps. *Bull. Mineral., 102,526*536.

Pamplin. C.F. 1988. A *re-examination of the Tintagel High Strain Zone and the Padstow Facing Confrontation, Cornwall.* Unpublished PhD thesis, University of Southampton.

Pamplin, C.F. and Andrews, J.R. 1988. Timing and sense of shear in the Padstow Facing Confrontation, north Cornwall. *Proceedings of the Ussher Society,* 7,73-76.

Primmer, T.J. 1985a. A transition from diagenesis to greenschist facies within a major Variscan fold/thrust complex in S.W. England. *Mineralogical Magazine, 49,* 365-374.

Primmer, T.J. 1985b. The pressure-temperature history of the Tintagel district, Cornwall: metamorphic evidence on the evolution of the area. *Proceedings of the Ussher Society,* b, 218-223.

Sanderson, D.J. 1979. The transition from upright to recumbent folding in the Variscan fold belt of southwest England: a model based on the kinematics of simple shear. *Journal of Structural Geology, 1,* 171-180.

Sanderson, D.J. 1984. Structural variation across the northern margin of the Variscides in NW Europe. *In:* Hutton, D.H. and Sanderson, D.J. (eds) Variscan Tectonics of the North Atlantic Region. *Special Publication of the Geological Society, London, 14,* 149-165.

Sanderson, D.J. and Dearman, W.R. 1973. Structural zones of the Variscan fold belt in S.W. England, their location and development. *Journal of the Geological Society, London,* 129, 527-536.

Scholz, C.H. 1977. Transform fault systems of California and New Zealand: similarities in their tectonic and seismic styles. *Journal of the Geologic a/ Society, London, 133,* 215-229.

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

Selwood, E.B. and Thomas, J.M. 1986a. Observations on the Padstow Confrontation, north Cornwall (Abs). *Proceedings of the Ussher Society , 6,* 378.

Selwood, E.B. and Thomas, J.M. 1986b. Upper Palaeozoic successions and nappe structures in north Cornwall. *Journal of the Geological Society, London, 143,* 75-82.

Selwood, E.B. and Thomas, J.M. 1988. The Padstow confrontation, north Cornwall: a reappraisal. *Journal of the Geological Society, London. /45,* 801-808.

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

Shackleton, R.M., Ries, A.C. and Coward, M.P. 1982. An interpretation of the Variscan structures in SW England. Journal *of the Geological Society, London,* 139, 533-541.

Weaver, C.E. 1961. Clay minerals of the Ouachita structural belt and adjacent foreland. */n: The Ouachita system.* Austin, Texas, 147-160.

Weber, K. 1972. Notes on determination of illite crystallinity. *Neues Jahrbuch Mineralogie, Stuttgart,* 1972(6), 267-276.