LATE- TO POST-VARISCAN STRUCTURES ON THE COAST BETWEEN PENZANCE AND PENTEWAN, SOUTH CORNWALL

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The occurrence of two generations (D1/D2) of folds and cleavage, compatible with a top to the north-north-west sense of shear during Variscan convergence is confirmed. A subsequent change in the stress regime ($\sigma_1 \approx$ vertical, $\sigma_3 \approx$ north-north-west-south-south-east) brought about the extensional reactivation of convergence-related features. The resultant D3 structures are diverse and include zones of distributed shear within the footwall of the Carrick Thrust, together with detachments and high angle brittle extensional faults within the hangingwall. D3 deformation probably initiated during the Stephanian, prior to lamprophyre intrusion, but persisted into the early Permian and was partially synchronous with granite emplacement and high temperature mineralization. Changes in the stress regime during the Permian ($\sigma_1 \approx$ east-north-east-west-south-west, $\sigma_3 \approx$ north-north-west-south-south-east to $\sigma_1 \approx$ north-north-west-southsouth-east, $\sigma_3 \approx$ east-north-east-west-south-west) resulted in strike-slip faulting and the formation of steeply dipping cleavages. Triassic rift-related extension is also recognised ($\sigma_1 \approx$ vertical, $\sigma_3 \approx$ east-north-east-west-south-west). Low temperature base metal mineralization was in part synchronous with Permian and Triassic faulting. This study demonstrates that the Variscan basement in south Cornwall preserves a valuable record of the late Palaeozoic to Mesozoic tectonic evolution of the region.

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INTRODUCTION

Geological structures within the Variscan basement of south Cornwall preserve a record, not only of Variscan convergence, but also the subsequent latest Palaeozoic and Mesozoic tectonic evolution of the region (Shail and Wilkinson, 1994). During the last two years, we have systematically investigated the nature and distribution of these later structures, and established their chronology relative to magmatic activity, mineralization and offshore sedimentary basin development. This contribution presents the results of investigations on the south coast, between Penzance and Pentewan, and complements our study of the north coast between Perranporth and St. Ives (Alexander and Shail, 1995).

REGIONAL SETTING

The Variscan basement in the study area comprises the Gramscatho Group metasediments and metabasites, the Lizard Complex ophiolite, and the St. Michaels's Mount, TregonningGodolphin and Carnmenellis granites (Figure 1). The Gramscatho Group represents the ?Lower to Upper Devonian infill of a deep marine rift basin which was locally floored by the oceanic lithosphere of the Lizard Complex ophiolite (Isaac *et al.,* in press). Variscan convergence probably initiated in the Middle Devonian, but was briefly interrupted by Upper Devonian rifting (Isaac *et al.,* in press). Renewed convergence brought about closure of the basin by the earliest Carboniferous and the continued north-north-west directed thrusting of continental basement, deep marine sediments and oceanic lithosphere above a regional décollement (Andrews *et al.,* in press). Maximum thrust-related burial depths were approximately 12 to 13 km (Barnes and Andrews, 1981; Wilkinson, 1990). A major change in tectonic regime occurred during the latest Carboniferous and was contemporaneous with the onset of magmatic activity and high temperature mineralization (Hawkes, 1981; Shail and Wilkinson, 1994). Deformation was predominantly extensional and brought about both reactivation of convergence-related structures and propagation of new faults and fractures within the basement (Shail and Wilkinson, 1994; Alexander and Shail, 1995). Similar basement structures are inferred to have controlled the development of adjacent Permian to Mesozoic offshore sedimentary basins (Chapman, 1989; Harvey *et al.,* 1994).

STRUCTURES EXPOSED BETWEEN PENZANCE AND PENTEWAN

We have undertaken detailed field-based investigations of the orientation, style, kinematics and relative chronology of geological structures exposed along the coastal sections between Penzance and Pentewan. These were classified as primary, secondary or late, largely in accordance with schemes proposed by previous workers (eg. Rattey and Sanderson, 1984).

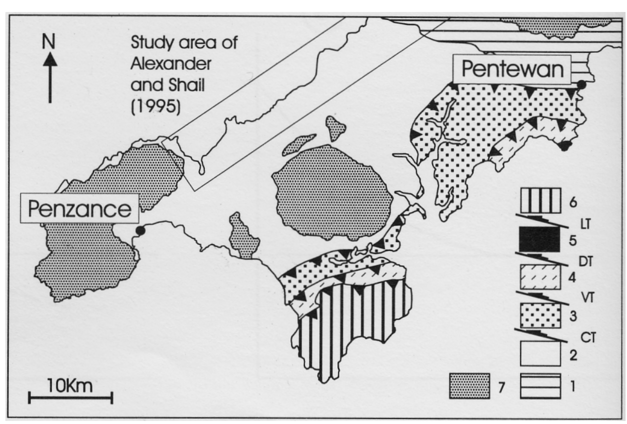

Figure 1. Simplified geological map of south Cornwall, showing current study area and that of Alexander and Shail (1995). (1) Meadfoot Group; (2) Parautochthonous Gramscatho Group and Mylor Slate Formation; (3) Portscatho Formation; (4) Pendower, Carne and Roseland Breccia Formations; (5) Dodman Formation; (6) Lizard Ophiolite Complex; (7) Granites; CT- Carrick Thrust; VT- Veryan Thrust; DT- Dodman Thrust; LT-Lizard Thrust (modified after Leveridge et al., 1990).

Primary structures

Primary tight to isoclinal folds within the metasediments generally verge and face to the north-north-west (eg. Rattey and Sanderson, 1984). However, in the Helford River area [SW 7831 2678], primary folds are highly oblique to the regional trend and face to the west (eg. Dearman *et al.,* 1980). Facing in Pentewan Bay is predominantly to the south-west, eg. Portgiskey [SX 0184 4638]. All primary folds are associated with a penetrative axial planar spaced or slaty cleavage which, over most of the area, is bedding-parallel and dips gently or moderately towards the south-east. The strike of this cleavage closely follows the inferred trace of the Carrick Thrust (Figure 1). Mineral stretching lineations and pyrite pressure shadows developed within the cleavage consistently plunge towards the south-east. High strain zones are commonly marked by boudinaged, cleavage-parallel, quartz veins, eg. St. Just-in-Roseland, [SW 8448 3555] and Polstreath [SX 0172 4533].

In the Lizard Complex, high strain zones related to north-north-west directed internal imbrication during early Variscan convergence are preserved within the lower levels of the exposed ophiolite (Vearncombe, 1980; Jones, 1994). Sheath folds are coinmonly developed, eg. Lizard Point [SW 6995 1162] and Porthallow [SW 8000 2325]. These structures are distinct from the approximately north-west striking ductile shear zones within the Lizard gabbros which have been attributed to north-east—southwest extension during the formation of oceanic crust (Gibbons and Thompson, 1991; Roberts *et al.,* 1993).

Secondary structures

Secondary folds, also with a dominant north-north-west vergence, occur in well developed zones, eg. Loe Bar [SW 6455 2375], St. Mawe Castle [SW 8397 3274], and Hemmick Beach [SW 9941 4052], and have been described by previous workers (eg. Rattey and Sanderson, 1984). These folds are open to tight, and are associated with a variably developed axial planar crenulation cleavage which is commonly paralleled by quartz veins. These secondary folds and cleavages are often localized in the hanging-wall of brittle thrust faults, eg. Toll Hole [SW 7851 2682]. At several localities, notably in the Roseland area, there is more than one generation of secondary folds and cleavage, as noted by Turner (1968) and Leveridge (1974), eg. Porthbeor Beach [SW 8611 3187]. Shear zones are developed in the olistostromes of the Roseland Breccia Formation, and primary cleavage is deformed by metre scale extensional shear bands that indicate a top to the north-north-west shear sense, eg. Paradoe Cove [SW 9147 3764]. Elsewhere, the close association between shear bands and secondary folds with a north-north-west vergence, eg. Porthbeor Beach [SW 8625 3189], suggests approximately synchronous formation. Similar structures are developed within Pentewan Bay, but where bedding and the early cleavage are steep, the shear bands commonly show a dextral shear sense, eg. Cockaluney Beach [SX 0186 4618]

Late structures

Late structures consistently cross-cut or fold those previously described. At outcrop scale, they can be subdivided into five main types: zones of distributed shear, detachments, brittle faults, vein arrays, and steep cleavages.

Zones of distributed shear

These structures are exclusively developed within the Mylor Slate Formation. Excellent examples occur in Mount's Bay, between

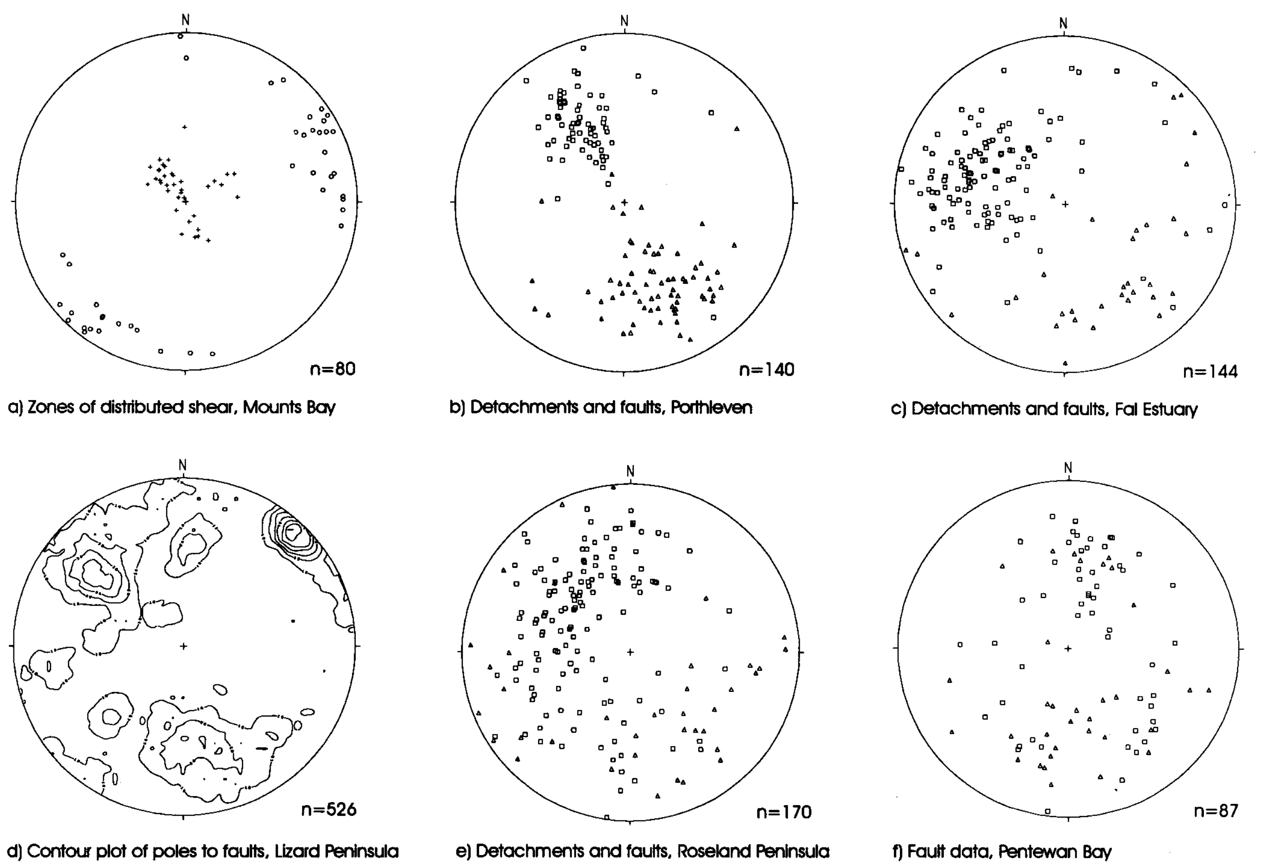

Figure 2. Equal area lower hemisphere stereograms showing orientation data for zones of distributed shear, detachments and brittle faults between Penzance and Pentewan (crosses, S3 cleavage; circles, F3 fold axes; squares, poles to fault planes; triangles, slickenline/slickencryst orientations).

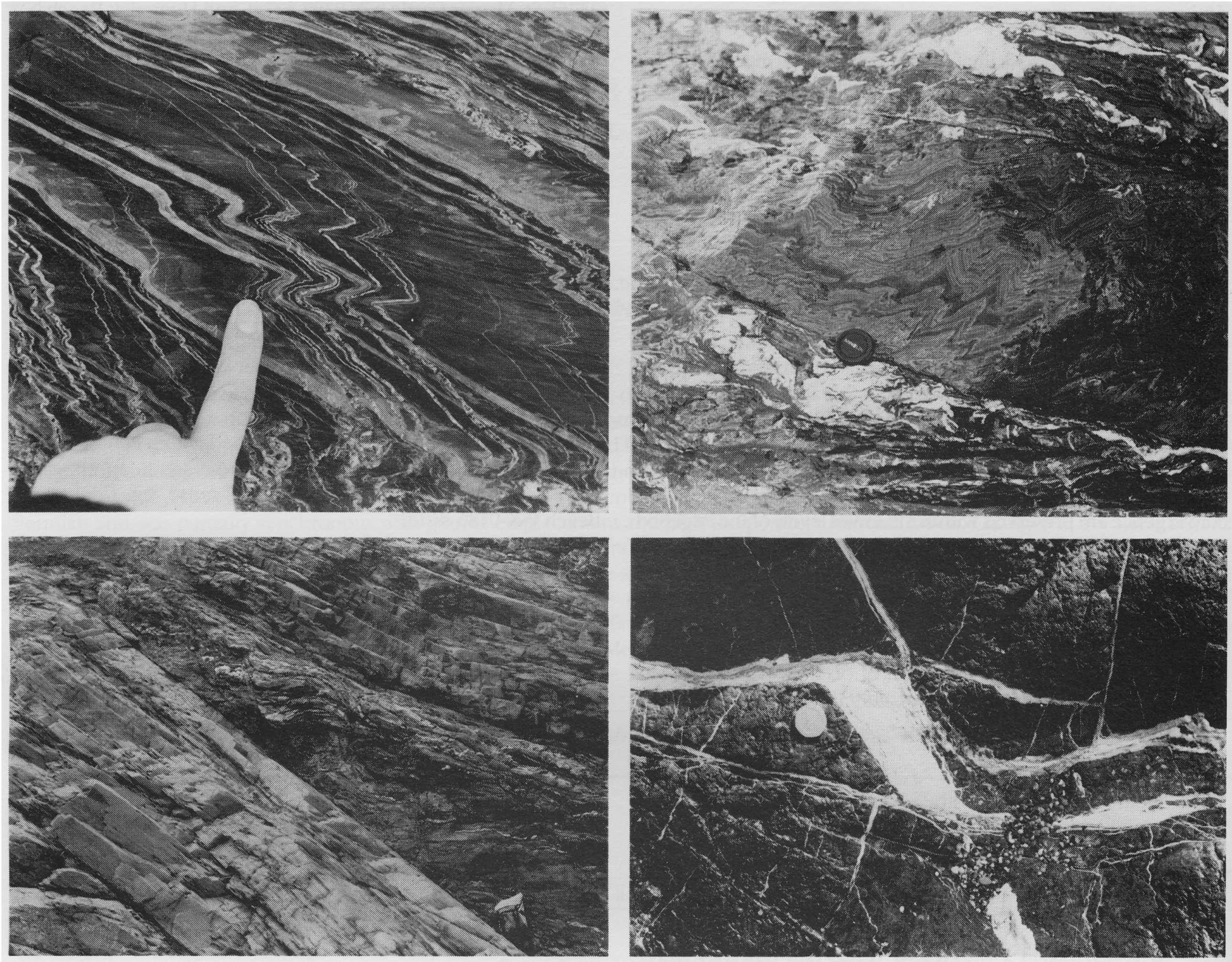

Figure 3. Field photographs of structures showing: (a) South-east verging F3 folds within a zone of distributed shear; deforming both bedding and moderately south-east dipping S2 parallel quartz veins, Porthleven [SW 6318 2523], (b) Bedding parallel detachment fault with hanging-wall Riedel and tensile fractures, Porthleven [SW 6486 2329], (c) Zone of intense F3 folding and imbrication within a detachment zone, Porthleven [SW 6477 2338], (d) Talc-carbonate filled dilational jog within a brittle dextral north-east striking fault/ vein system, Kennack Sands [SW 7402 1673].

Penzance and Porthleven (eg. Stone, 1966; Rattey, 1980); similar structures are also exposed in coastal outcrops around the margin of the Land's End Granite. The easternmost exposure at which this style of deformation has been observed is on the southern margin of the Carnmenellis Granite at Roscarrack Quarry [SW 7878 3142]. Bedding, primary and secondary cleavages are deformed in these zones into tight, often recumbent, small-scale folds. These are associated with a sub-horizontal axial planar crenulation cleavage which often transposes earlier fabrics, eg. Rinsey Cove [SW 5911 2693]. In low strain areas, such as at Porthleven [SW 6359 2486], folds verge towards the south-east and a cleavage is only developed within hinge regions (Figure 3a). In the high strain areas, fold axes have a variable orientation ranging from north-south to east-west (Figure 2a). However, kinematic indicators such as rotated quartz boudins consistently reveal a top to the south-east sense of shear, eg. Kenneggy Sands, [SW 5584 2803].

Detachments

Low angle (<45° bedding or cleavage-parallel detachment surfaces are common (Figure 3b). These have been briefly described from the Mounts Bay area by Turner (1968) and from the Roseland area by Leveridge (1974). South-east verging folds, together with synthetic faults and Riedel shears, are often localized adjacent to these structures (Figure 3c). Fold vergence is generally down the dip of the detachment and therefore varies with bedding or cleavage orientation. However, in some cases, curvilinear fold axes result in highly variable fold vergence. Short limb lengths are typically less than 1 m. Axial planar cleavages associated with these folds are poorly developed but, where observed, dip to the north-west. These structures are particularly well developed along the trace of the Carrick Thrust, eg. Loe Bar [SW 6395 2437], Mawnan [SW 7822 26831, Flushing [SW 8180 3352] and Restronguet Point [SW 8200 3732], although none were observed in Pentewan Bay. Detachments also occur in the vicinity of the Dodman Thrust [SW 9938 4054]. Lamprophyre sheets (<3 m thick) were emplaced within, and deformed by, detachments near Mawnan [SW 7912 2722].

East-north-east—west-south-west trending faults

The majority of the high angle (>45°) faults exposed between Penzance and Pentewan strike between north-east and east-northeast, and dip towards the south (Figure 2b, d, e), although in the Fal Estuary area they strike north-north-east and parallel the inferred trace of the Carrick Thrust (Figure 2c). These faults cross-cut all previously described structures, as well as lower angle faults of the same orientation, eg. Porthleven [SW 6358 2486]. Kinematic indicators may record strike- and/or dip-slip displacement(s), suggesting reactivation in some cases. Slickenlines and slickencrysts generally have a high pitch, although in some instances low pitch slickenlines or slickencrysts are also present (Figure 2). In areas of steep bedding and cleavage, faulting is characterised by bedding parallel slip, the development of minor hanging-wall folds, and zones of brecciation up to 2 to 3 m wide, eg. Zone Point [SW 8563 3145] and Porthbeor Beach [SW 8651 3212]. There is a well defined zone of intense brittle faulting up to 1 to 2 km south-east of the Carrick Thrust, eg. Blue Rocks [SW 6490 2325], Dennis Head [SW 7845 2578], and St. Mawes Castle [SW 8397 3274]. Dilatant jogs within east-north-east striking extensional faults are commonly infilled with quartz and/or carbonate within the metasediments, carbonate-talc in the Lizard serpentinites, and carbonate-prehnite in the lizard gabbros and schists (eg. Figure 3d).

North-north-west—south-south-east trending faults

A second set of high angle faults strike between north-west and north (Figure 2c, d, e). They cross-cut primary and secondary structures, and usually cross-cut detachments and east-north-east striking high angle faults. Kinematic indicators may record strike- and/or dip-slip displacement(s), suggesting reactivation in some cases. Faults with gently pitching slickenlines or secondary fractures that indicate dextral or, more rarely, sinistral strike-slip are usually overprinted by more steeply pitching slickenlines, eg. Kennack Sands [SW 7350 1650] to Black Head [SW 7792 1630]. Exposed fault zones are up to 5 m wide and may exert a strong influence on bedding/cleavage orientation, eg. Kiberick Cove [SW 9258 3808]. Some of these faults host base metal mineralization (eg. Wilkinson, 1990); infills of galena, sphalerite, siderite, pyrite and quartz occur in the metasediments and metabasites, particularly in the west of the area, eg. Kenneggy Sands [SW 5593 2818] and Vellin Gluz [SW 6381 2464]. In the Lizard Complex, infills include sepiolite in the serpentinite, and zeolites and adularia in the gabbros and schists. The quartz-carbonate, talc-carbonate and prehnite-carbonate assemblages described from the east-north-east striking faults also occur, eg. Kennack Sands [SW 7400 1677].

West-north-west—east-south-east trending faults

A third set of high-angle faults strike approximately east to east-south-east and occur principally in the Lizard and Roseland peninsulas (Figure 2d, e, f). Cross-cutting relationships with the east-north-east and north-north-west striking fault sets are inconsistent. These faults often indicate a significant sinistral or dextral slip component, although extensional dip-slip displacements are also observed. Faults of this orientation may host quartz and/or carbonate in the metasediments, carbonate, talc and sepiolite in the Lizard serpentinite, and carbonate, prehnite, zeolites and adularia in the Lizard gabbros and schists.

Fractures and veins

Steeply dipping fractures and veins are ubiquitous. The dominant set strikes north-north-west, and a subordinate set strikes north-east to east-north-east. Cross-cutting relationships between the two sets are inconsistent. In the metasediments, either set may posses a quartz and/or carbonate infill, whilst in the Lizard serpentinite talc-carbonate infills occur. Crack-seal textures are frequently displayed, eg. Church Cove [SW 7142 1298]. North-north-west striking subvertical en-echelon veins that define conjugate arrays are well exposed on bedding planes at Mawnan Shear [SW 7850 2678]. The north-east—south-west, east-west and east-south-east—west-north-west trending arrays indicate a dextral shear sense, whilst the north-south trending arrays indicate a sinistral shear sense. These conjugate vein arrays crosscut quartz and carbonate slickencrysts associated with down-dip movement on the east-north-east striking faults.

Steep cleavages

Two late cleavages are variably developed and have been noted by previous workers (eg. Rattey and Sanderson, 1984). A north-north-west striking, steeply dipping, zonal crenulation cleavage, often related to broad open folds is widespread, and may locally be associated with sigmoidal north-east dipping quartz-chlorite veins, eg. Vellin Gluz [SW 6370 2469]. An east striking, steeply-dipping, zonal crenulation cleavage is also evident at several localities, principally in the Mount's Bay areas, eg. Kenneggy Sands, [SW 5584 2802].

DEFORMATION CHRONOLOGY AND KINEMATICS

Primary structures

The primary structures (F1 folds, Si cleavage and associated mineral lineations) described from the coast between Penzance and Pentewan can be ascribed to D1 deformation (Turner, 1968; Leveridge, 1974; Rattey, 1980). They indicate a dominant top to the north-north-west sense of shear consistent with convergence (Rattey and Sanderson, 1984; Leveridge *et al.,* 1990). The obliquity of folds around the Fal Estuary area suggests that there was some degree of sinistral shear, possibly associated with an oblique ramp in the Carrick Thrust (eg. Leveridge *et al*., 1990).

Secondary structures

Secondary structures (F2 folds and S2 cleavage) can be ascribed to D2 deformation (Turner, 1968; Leveridge, 1974; Rattey, 1980). They also reflect a top to the north-north-west sense of shear. The progressive nature of deformation leads to the local development of two generations of folds and cleavages (Turner, 1968; Leveridge, 1974). In the areas where two generations coincide it seems fair to postulate the presence of a thrust ramp at depth (eg. Beutner *et al.,* 1988). D2 folds and cleavages are superposed on the D1 structures either coaxially (where F1 folds parallel the regional trend) or non-coaxially (where F1 folds are oblique to the regional trend). The extensional shear bands generally indicate a top to the north-north-west shear sense and are probably D2 in age. Dextral shear bands in the Pentewan area may have initiated in a similar manner but have been subsequently rotated in a major backfold (eg. Hobson and Sanderson, 1983). Several authors have suggested that many of the north-north-west striking faults may have initiated during Variscan convergence as strike-slip transfer faults (eg. Coward and Smallwood, 1984).

Late structures

The relative chronology and kinematics of the late structures have been synthesized, and allow us to define four sequential stress regimes. The palaeostress estimates are approximate and were derived "in part" using the PT-dihedra method of Angelier (1984).

$\sigma_1 \approx$ vertical, $\sigma_3 \approx$ north-north-west—south-south-east

Zones of distributed shear, detachments and early east-northeast striking faults are here related to D3 deformation after Alexander and Shail (1995). Although the east-north-east striking high angle faults cross-cut the ductile D3 structures, they are kinematically similar and may indicate a progressive transition to brittle deformation during extensional exhumation. Zones of distributed shear within the footwall of the Carrick Thrust may have developed contemporaneously with the detachments and high-angle brittle faults within the hangingwall. Strike-slip deformation on north-north-west striking faults may have initiated as transfers. We re-affirm our view that D3 deformation represents the reactivation of convergence related structures during northnorth-west—south-south-east extension.

$\sigma_1 \approx$ east-north-east—west-south-west, $\sigma_3 \approx$ north-north-west—south-south-east

Changes in the stress regime brought about both the reactivation of high-angle D3 faults and the formation of new structures. The east-north-east striking, subvertical tensile veins; the northeast striking dextral, and east striking sinistral oblique- and strike-slip faults are all consistent with east-north-east—west-south-west shortening. This is also implied by the north-north-west striking steeply dipping post-D3 cleavage. High temperature Sn-W mineralization, hosted by east-north-east striking subvertical tensile fractures within the St. Michael's Mount granite, may be compatible with either this or the previous stress regime.

$\sigma_1 \approx$ *north-north-west-south-south-east,* $\sigma_3 \approx$ *east-north-east-west-south-west*

The formation of north-north-west striking, subvertical tensile fractures, dextral reactivation of east- and north-east striking faults and vein arrays, and sinistral reactivation of north striking faults and vein arrays are all compatible with north-south to north-north-west—south-south-east shortening. Such a regime would also be compatible with localized development of the east striking subvertical post-D3 cleavage.

$\sigma_1 l \approx$ *vertical,* $\sigma_3 \approx$ *east-north-east—west-south-west*

Extensional reactivation of north-north-west striking faults and the formation of new fractures implies a change to east-north-eastwest-south-west extension. In addition, strike-slip deformation on east-north-east striking faults may imply that they have acted as transfer faults. Low temperature hydrothermal activity, including base metal mineralization, may have initiated during north-northwest—south-south-east shortening but is certainly synchronous with this later east-north-east—west-south-west extension.

This Study	Stone (1966)	Turner (1968)	Rattey (1980)	Leveridge et al. (1990)	Alexander & Shall (1995)
D1	-	D1	D1	D1	D1
D2	D1	D2	D2	D2	D2
				D4	
D3	-	-	-	D3	D3
	D2	D3	D3	D5	

Table 1. Comparisons between the chronology of previous workers and that proposed here (D1-D3).

DISCUSSION

Comparison with previous work

Table 1 compares the chronology of structures established during this study with previous schemes. Structures associated with D1 and D2 deformation have been recognised by most workers (eg. Turner, 1968; Leveridge, 1974; Rattey, 1980). However, Turner (1968) and Leveridge (1974) both implied that two generations of structures were combined within the D2 event; the latter was subsequently redefined as D4 (Leveridge *et al*., 1990).

D3 structures, in particular folding within the zones of distributed shear, have also been recognised by previous workers (eg. Stone, 1966; Turner, 1968; Rattey, 1980). Detachments and brittle faults were subsequently included within the D3 event by Alexander and Shail (1995). F3 folds have been related to vertical shortening during granite emplacement and it was suggested that culminations in vergence could be distinguished across the granite plutons (eg. Turner, 1968; Rattey, 1980). However, in high strain areas, vergence is an unreliable kinematic indicator as the overturned limb enters the extensional field of the strain ellipsoid and becomes attenuated (eg. Alexander and Shail, 1995). In addition, variable fold axis orientations in the high strain zones may be related to the formation of sheath folds. The changes in vergence described by these authors may therefore reflect variations in finite strain during extension rather than granite emplacement. The lack of zones of distributed D3 shear at the Penryn Bypass [SW 7912 3376], within 200 m of the granite contact, further questions the link between these structures and granite emplacement. This study confirms that the zones of distributed shear and detachments formed during non-coaxial top to the south-east simple shear, consistent with the extensional reactivation of thrust faults, as suggested by Alexander and Shail (1995).

Whilst Leveridge *et al*. (1990) also relate their subhorizontal S5 cleavage to the extensional reactivation of thrust faults, they suggest that south-easterly verging folds and detachments were formed during a D3 backthrust event. These authors also infer that the intervening north-north-west verging D4 folds formed as a consequence of continued convergence. We would argue that the D3 and D5 structures of Leveridge *et al*. (1990) are essentially contemporaneous and equivalent to our D3, since we have found no evidence of significant post-D3 north-north-west verging folds, either on the south or north coast. We therefore suggest that the D4 of Leveridge *et al*. (1990) be included within D2 as originally envisaged by Turner (1968).

North-north-west and east striking subvertical cleavages have been recognised by several authors, including Rattey and Sanderson (1984), although no workers to date have specifically correlated these late stages to fault kinematics. Hobson and Sanderson (1983) proposed a regional east-west shortening event on the basis of the widespread development of the north-north-west—south-south-east crenulation cleavage. Although many authors have recognised and briefly described faults and fractures, particularly within the mineralized belts, detailed investigations of their relative chronology, kinematics and distribution are lacking.

Constraints on timing

The youngest sediments to be incorporated into the Variscan thrust stack are late Famennian suggesting that primary deformation within the metasediments occurred during the Tournaisian (Wilkinson and Knight, 1989). The intrusion of lamprophyres into extensional fault zones at Toll Point [SW 7912 2722] provides evidence of synchroneity between extension and igneous activity; most lamprophyres have been dated as Stephanian (eg. Hawkes, 1981; Goode and Taylor, 1988). The Tregonning-Godolphin granite contains xenoliths with a well developed S3 cleavage and also cross-cuts and intrudes parallel to the S3 cleavage, eg. Megiliggar Rocks [SW 6097 2673], suggesting that the change from north-north-west—south-south-east shortening to extension took place prior to 281.5 ± 1.6Ma (^{40}Ar-^{39}Ar zinnwaldite; Chesley *et al*., 1993). At Rinsey Cove the granite intrudes a tensile fracture in the hangingwall of a east-north-east striking extensional fault which displaces the S3 subhorizontal cleavage. Subsequent east-north-east—west-south-west shortening and strike-slip deformation may have become important during high temperature mineralization in the Camborne-Redruth area (Farmer, 1991), and may have brought about formation of the east-north-east striking greisen veins and joints in the St. Michael's Mount stock. Low temperature base metal mineralization in the north-north-west striking tensional crosscourses within the Tamar Valley has recently been dated as mid-Triassic by Scrivener et al. (1994). Adularia is hosted by joints and faults of all orientations, within the Lizard gabbros and schists, but post-dates strike-slip deformation associated with north-north-west—south-south-east shortening. The earliest dates for adularia suggest an age between 220- 210Ma, with a possible resetting at 170-160Ma (K-Ar; ^{40}Ar-^{39}Ar; Halliday and Mitchell, 1976; Seager *et al*., 1978). Thus, it seems likely that the change to east-north-east—west-south-west extension may have initiated during Triassic rifting.

The post-convergence structures within the Variscan basement formed synchronously with the adjacent offshore sedimentary basins. The dates and kinematic data presented above compare favourably with existing tectonic interpretations from offshore seismic records. Harvey *et al.* (1994) suggest that basin evolution initiated during Stephanian-Permian north-north-west-south-south-east extension, prior to a change to strike-slip deformation during the Permian. Triassic east-north-east-westsouth-west rift-related extension has been documented from the along strike Melville sub-basin by Chapman (1989).

CONCLUSIONS

The tectonic evolution of the Variscan basement exposed along the coastal section between Penzance and Pentewan is summarized in Table 2. The following conclusions have been reached:

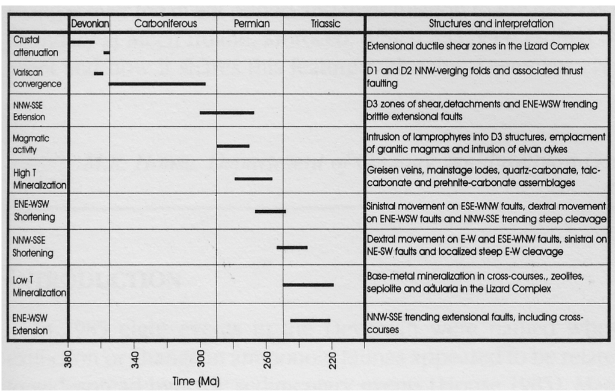

Table 2. Summary tectonic evolution and interpretation of the area between Penzance and Pentewan, south Cornwall.

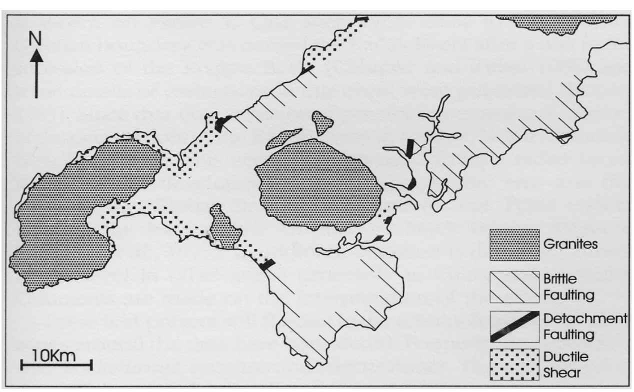

Figure 4. Distribution of D3 deformation styles. Ductile D3 structures are confined to the footwall of Carrick Thrust and detachments commonly follow reactivated thrusts (see also Figure 1). Note, however that brittle faults may overprint the zones of distributed shear and detachments and therefore can be found throughout south Cornwall. Poor inland exposure does not allow correlation of structural styles across the peninsula

1. Convergence related deformation is characterised by folds, cleavages and extensional shear bands developed during top to the north-north-west directed thrusting (D1 and D2).

2. A diverse range of structures related to D3 north-northwest-south-south-east extensional (re-)activation of convergence related thrusts and fabrics are developed. These range from zones of distributed shear in the footwall of the Carrick Thrust to high angle brittle extensional faults within the hangingwall (Figure 4). The D3 folds and cleavages interpreted by Turner (1968) and Rattey (1980) as forming during vertical shortening associated with granite emplacement are related to top to the south-east non-coaxial shear. Detachments commonly follow the trends of reactivated thrust faults. D3 deformation probably initiated during the Stephanian, prior to lamprophyre emplacement, but persisted into the early Permian and was partially synchronous with granite emplacement. This stage of deformation implies a stress regime with $\sigma_1 \approx$ vertical and $\sigma_3 \approx$ north-north-west-southsouth-east.

3. Reactivation of high angle extensional faults and the formation of new fractures, vein arrays and steep cleavages implies changes in the stress regime during the Permian. Two dominant stress regimes have been identified: $\sigma_1 \approx$ east-northeast-west-south-west and $\sigma_3 \approx$ north-north-west-south-south-east and $\sigma_1 \approx$ north-north-west-south-south-east, $\sigma_3 \approx$ east-northeast-west-south-west.

4 East-north-east-west-south-west Triassic rifting is in part synchronous with low-temperature base metal mineralization.

5. The style and chronology of post-convergence deformation within the Variscan basement of south Cornwall is similar to that inferred to control the development of the offshore Permian to Mesozoic sedimentary basins to the south and west of the peninsula.

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