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EVIDENCE FOR VARISCAN DEXTRAL TRANSPRESSION IN THE PILTON SHALES, CROYDE BAY, NORTH DEVON

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Evidence for right lateral shear accompanying shortening during the closure of the Gramscatho and Culm basins has been accumulating in recent years. Most of the evidence has consisted of features such as the development of horizontal stretching lineations (Coward and McClay, 1983), S-C shear band frabrics (Holdsworth, 1989) and the orientation of vein arrays (Jackson, 1991).

Structures in the Devonian-Carboniferous Pilton Shales on the north and south sides of Croyde Bay (Figure 1) display features which can be put together in a unifying model of dextral transpression. The multilayered slates and thin siltstones are tightly folded into subhorizontal angular upright folds with interlimb angles of between 90 and 60°. Late dextral shear was superimposed upon the already developed folds generating east-south-east-trending dextral vein arrays, conjugate south-south-east sinistral vein arrays and an anticlockwise transecting spaced cleavage (Figure 2).

The relationship of the cleavage to the folding was tested by measuring bedding and cleavage. The data was processed as two sets (Figure 3) as there is a 500 m exposure gap across the bay. On the south side of the bay the overall structure consists of north-verging tight folds, with short limbs of several metres length and long limbs of the order of 100 m. Inspection of the data shows an anticlockwise hinge transection of 7°. This is seen in the field as a shallowly easterly-plunging SS/S1 intersection lineation on the short northerly-dipping limbs and a shallowly westerly plunging intersection lineation on the much longer southerly-dipping limbs.

On the north side of the bay south-dipping long limbs (≥100m)

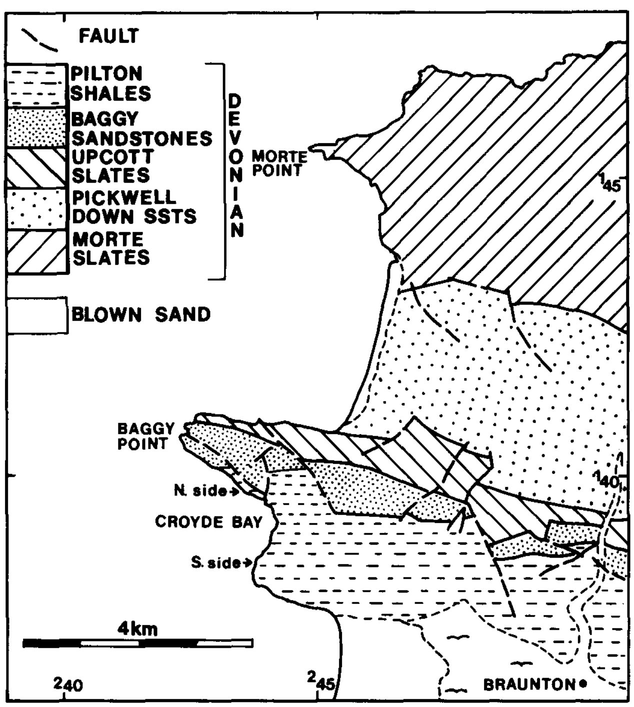

Figure 1: Location and geological setting of Croyde Bay, North Devon (after Edmonds et al. 1979).

of close asymmetric north-verging folds predominate. Anticlockwise hinge transection is around 10° with shallow westerly plunges of the SS/S1 intersection lineation on long limbs and approximately horizontal plunges on short limbs (10 m), (Figure 3). A number of north-verging parasitic folds with rounded hinges are controlled by relatively competent thin, brown-weathering, fossiliferous decalcified limestones. At a late stage during the deformation a series of arrays of extensional fractures (en-echelon tension gashes, Figure 2a) developed, especially in the decalcified limestones. Two conjugate sets comprise dextral and sinistral arrays (Figure 2b). Synthetic (dextral) arrays are most common trending about 120°.

Dextral arrays are localised along fold hinges in many cases. As the veins cross the hinges of the folds without themselves being folded, it is clear that they formed after the folds had undergone most or all of their development. Some veins precede others and some of the earlier ones have undergone small amounts of subsequent rotation. The spaced S1 cleavage, which shows evidence of extensive pressure solution, is usually truncated by the veins, but an overlap with the main phase of shortening of the basin is demonstrated where some of the veins are subsequently cut through by pressure-solution seams. The relatively early nature of such veins is apparent where they are just starting to shorten along their length by incipient folding.

Initiation of other locally transtensional east-south-easttrending dextral arrays (Figure 2c) was clearly controlled by the S1 cleavage. The overall trend of the arrays (123°) is slightly clockwise of the cleavage. Dextral slip has occurred on segments parallel to the cleavage and dilational right steps from one pressure solution seam to another are occupied by extensional veins. The sense of slip can be confirmed by right lateral offsets.

Measurements of fibres marking the incremental opening of the extensional fractures shows that statistically they are orthogonal to the vein margins, although locally both dextral and sinistral obliquity is seen. Assuming that no significant rotation of the veins has occurred

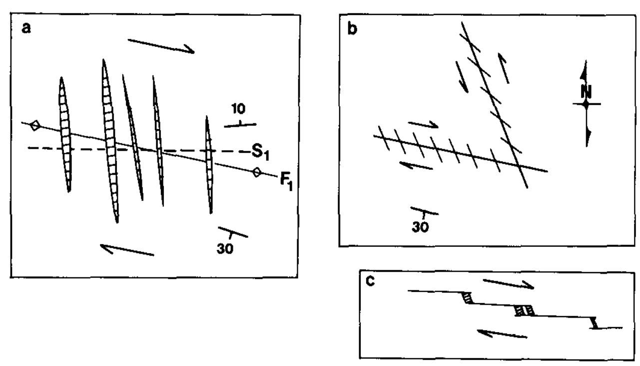

Figure 2: Geometry of vein arrays at Croyde bay. a) Transpressional dextral en-echelon array located along a parasitic fold hinge, showing the generation of extension fibres approximately orthogonal to the individual veins. The cleavage transects the fold in an anticlockwise sense. b) Conjugate arrays indicating that ?1 is locally oriented approximately NW-SE. c) Transtensional ESE-trending array. Dextral slip has been localized along segments parallel to the penetrative cleavage, but is transferred across right steps which act as local pull-aparts.

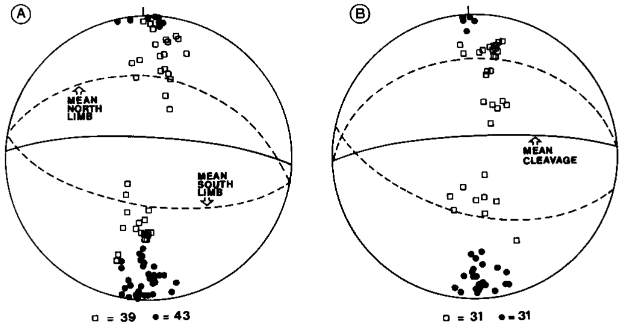

Figure 3: *Equal area stereograms of bedding and cleavage at Croyde Bay. A) Data from the south side of the bay where the folds are horizontal. Mean cleavage strikes 7° anticlockwise from mean strike of bedding. B) North side of the bay where the folds plunge gently west and cleavage strikes anticlockwise 10° from the strike of the estimated mean fold axial plane. Bedding, open squares; cleavage, filled circles.*

since their formation, this allows the prediction of the orientation of the local palaeostress axes and the incremental strain axes. The observed geometry gives an azimuth of 073° for the fibres, which for orthogonal opening corresponds to the ?3 direction and that of the maximum incremental stretch.

Interpretation of the spectrum of structures is dependent upon the way in which the data is modelled. It could be assumed that during the later stages of oblique closure of the north Devon basin, strain was resolved into shortening normal to fold hinges and shear parallel to fold hinges following the natural anisotropy of the bedding. However this is unlikely, as arrays are developed where limb dips are relatively low, i.e. 30° and some veins cut across several fold hinges without altering their trend.

If it is assumed that the local stress field and incremental strains reflect the general state of stress within the deforming basin and if the basin margins correspond with the shear zone margins, then the closure vector of the basin can be determined using the transpression model of Sanderson and Marchini (1984). The Variscan trend through southern England and South Wales is about 108°, i.e. at an angle of 35° to the incremental stretch in Croyde Bay. In simple transpression the Marchini model predicts this internal configuration of stress and incremental strain when the convergence vector makes an angle of 19° to the shear zone margins. Furthermore if this configuration was maintained from the beginning of the basin closure, then the anticlockwise transecting cleavage can be modelled. Initially folds would have made an angle of 35° to the basin margins, i.e. a trend of 073°. With a 19° convergence angle, a 50% shortening across the basin would rotate the folds through an angle of 25°, so that they would trend 098° (100° is approximate trend of the bedding at Croyde Bay where the folds have sub-horizontal axes). Internal shortening within the basin is probably greater than 50%, as a chevron fold style is developed throughout in addition to an unknown amount of thrust shortening. This has to be set against the fact that the internal shortening will be greater than the shortening across the basin, depending upon the amount of basin parallel shear. If the cleavage reflects the state of finite strain then the principal strain axes lying in the plane of the cleavage would rotate by a lesser amount than the folds (assumed to act as passive markers), causing an anticlockwise hinge transection of 6°, a figure which agrees well with the observed transection.

Generalizing the observations at Croyde Bay into a wider model for Variscan tectonics in south-west England allows quantification of the oblique nature of the displacement along the northern margins of the Variscan orogen, discussed in a qualitative way by Coward and Smallwood (1984). The predicted convergence vector, 127°, is parallel to the observed trend of the dextral arrays (123°), which greatly predominate in the exposures. More data is needed from a wider geographical base to test this hypothesis.

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