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STRUCTURE OF THE DEVONIAN LIMESTONE AT BRIXHAM

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Abstract. The Devonian limestones at Brixham show a structure which is transitional in style between the overturned folding of the South Hams region and the thrusting found east of Dartmoor, and can be accounted for by a single phase of deformation.

1. Introduction

The Middle to Upper Devonian limestones at Brixham are well exposed, and occur in a structurally simpler setting than those to the north. This paper is based upon structural mapping of the area south of Tor Bay and east of the River Dart.

2. Stratigraphy and structure

The E-W trending upright anticline of St. Mary's Bay duplicates the outcrop of the limestones, and 150m or so of grey Eifelian shales are exposed in the core of this double-hinged fold (Fig. 1). As shown in Figure 2, the northern flank of the anticline exposes 300m of limestone, divisible into three units of roughly equal thickness. The uppermost unit, of poorly-bedded limestone with little crinoid content, passes laterally into the massive algal stromatoporoid reef limestone of Berry Head. The middle unit, of thin-bedded crinoidal limestone, reappears from below the massive Berry Head limestone in the core of the upright, angular, ENE trending Shoalstone Beach anticline. The lowermost unit comprises bands of crinoidal limestone 10-20cm thick, separated from each other by 1-2cm thickness of red shales. Slaty cleavage in the shales and fracture cleavage in the limestones (except where they are massive) trend generally E or ENE, and dip S at 30°-50°.

Although the bulk of the limestone ranges from late Eifelian to Frasnian in age, the absence of Eifelian shales south of the Sharkham Point outcrop presents a problem which Ussher (1903) overcame by postulating an E-W thrust to separate the limestone outcrop from that of the Staddon Beds. The evidence of critical localities is discussed below.

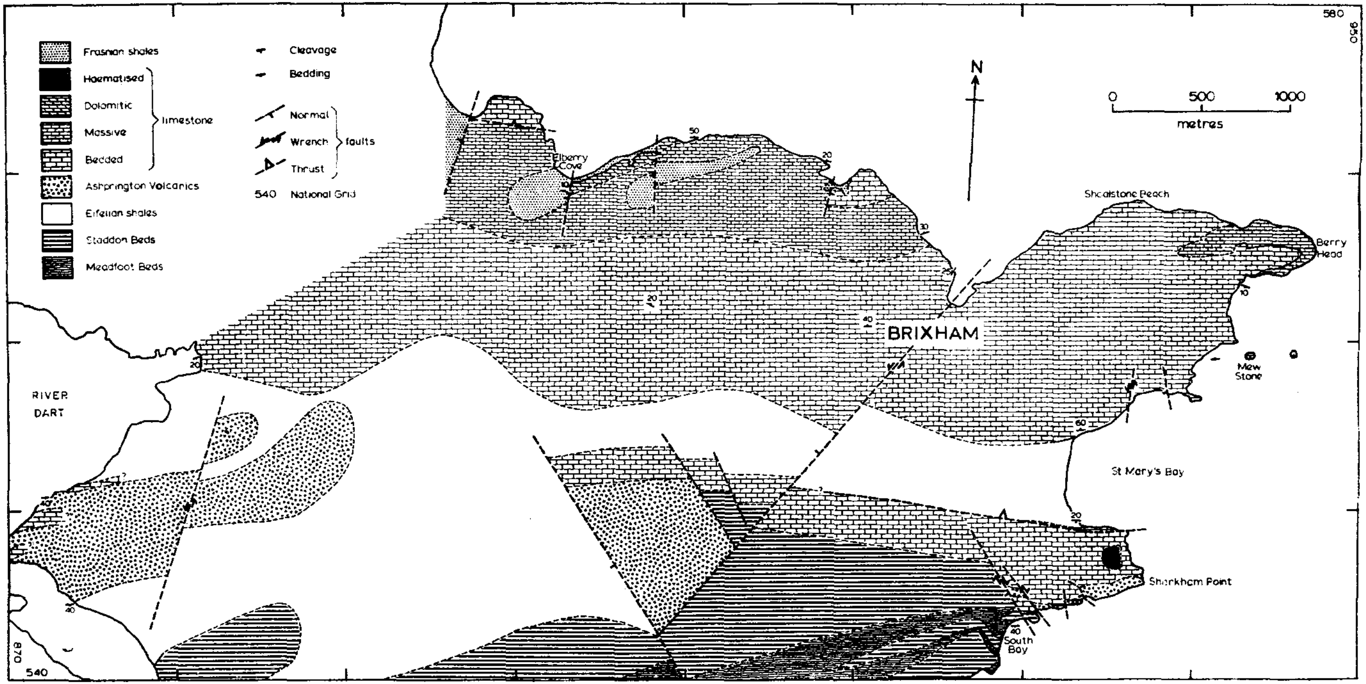

FIGURE 1. Geology of the Brixham district.

(*a*) *South Bay* (*SX* 929543)

In the N-S cliff section uppermost Meadfoot Beds (steely-grey and black slates) and lowermost Staddon Beds (lilac-red sandstones and slates) are affected by tight folds with horizontal E-W axes and with axial planes which dip S, parallel to the slaty cleavage, at about 40°. To the east of the Cove (SX 93005438) the Staddon Beds are cut off by a large NW-SE trending oblique-slip dextral wrench fault dipping SW at about 80°. On the north-east side of the fault Staddon Beds forming a small islet (SX 93045438) can be traced northwards through 15-20m of transitional red shales, with thin limestones, into thickly-bedded crinoidal limestone dipping south at 50-60°. The limestone here (SX 93025443) has yielded a fauna of icriodid conodonts characteristic of the lower Eifelian (S. C. Matthews, pers. comm.).

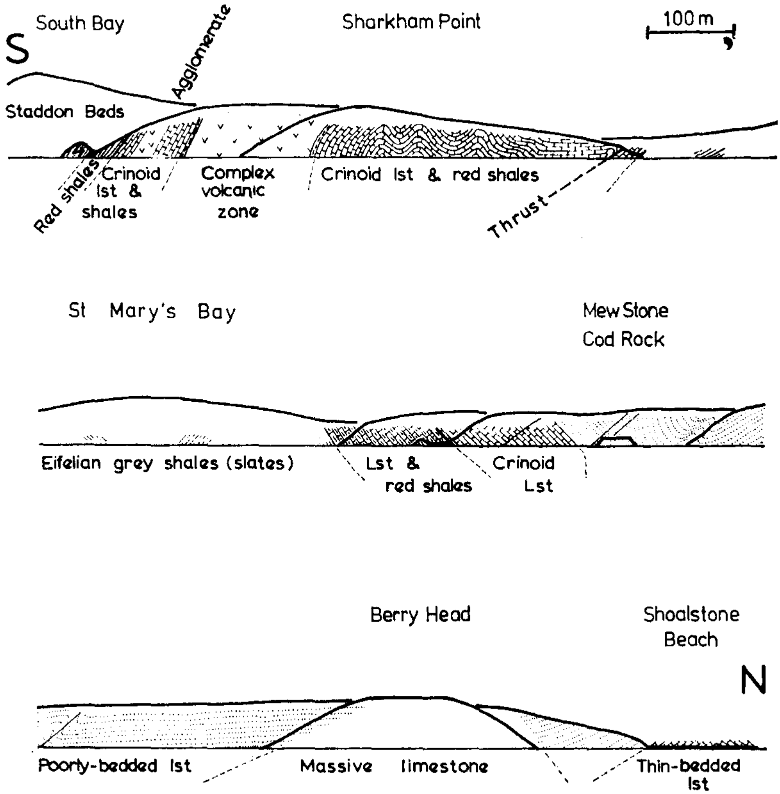

FIGURE 2. Section along the eastern coastline from South Bay to Shoalstone Beach. No vertical exaggeration.

(*b*) *Coast west of Sharkham Point* (*SX* 937546)

A highly altered sequence of tuffs, agglomerates and shales, the most easterly outcrop of the Ashprington Volcanic Series, overlies the southern outcrop of the limestone, but structurally underlies the limestone at South Bay, which contains two agglomerate beds. The structure is complex, due principally to late normal faulting. A certain degree of symmetry in the distribution of beds about an E-W trending surface suggests, however, that the volcanics occupy a synclinal fold closure, flanked on either side by limestone. The fold axial surface dips south at 50-60° near South Bay, but is vertical and cut by several faults at Sharkham Point.

(*c*) *Coast north of Sharkham Point* (*SX* 936548)

Approximately 50m of crinoidal limestones and shales, locally rich in rugose corals, and in places almost completely replaced by disseminated haematite, are folded into fairly open upright E-W folds. Along the south side of St. Mary's Bay the roughly horizontal limestone is overturned above a large E-W trending thrust plane which dips south at 30-40° (SX 93565488). The beds below the thrust (transitional thin shaly limestones overlying the Eifelian shales) are, however, parallel to the thrust plane.

(*d*) *Brixham town* (*SX* 925560)

A large NE-SW trending fault is postulated to run through Brixham harbour (Fig. 1). It separates the mainly horizontal limestone tract to the east from the outcrop of flat-lying recumbently folded limestone to the west. In the vicinity of this fault, both bedding and cleavage in the limestones and shales swing parallel to its trend.

(*e*) *Elberry Cove area* (*SX* 903570)

The massive limestone along the south coast of Tor Bay, west of Brixham, shows recumbent minor folds trending E-W and facing north. From Elberry Cove (SX 904570) to Ivy Cove (SX 908571) the limestone (here dolomitised) structurally overlies bright red shales. Goniatites and conodonts from the shales and limestones indicate that they are of Frasnian age (House 1963, Tucker and van Straaten 1970). The red shales overlying the limestone, 50m above, on Churston golf course (SX 908570) may be the same age.

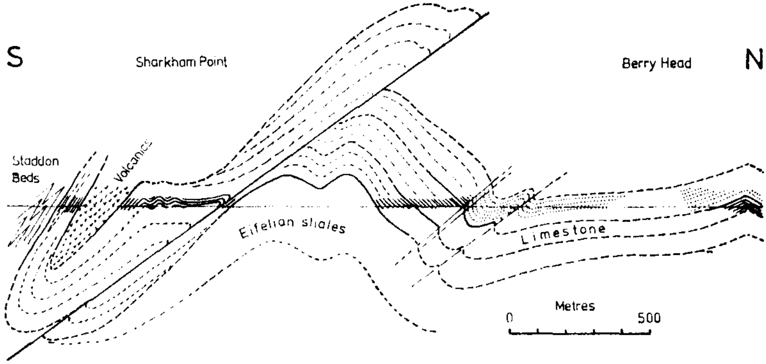

FIGURE 3. Structural interpretation of the section from South Bay to Shoalstone Beach. No vertical exaggeration.

3. Structural interpretation

The simplest interpretation of the geology of the Sharkham Point—South Bay area is shown in Figure 3. For the purposes of geometrical reconstruction, similar folding has been assumed, as it is difficult to assess the relative importance of similar and concentric folding during the deformation. However, any errors in geometry caused by this assumption are likely to be less than those involved in reconstruction of the stratigraphic sequence. As the Sharkham Point thrust cuts across a large fold, with the dip of the rocks above and below differing by 40-50°, a large displacement is inferred. This is confirmed by the scale of the 'drag' above the thrust plane, which bends the beds with a radius of 5-10m through an arc of 150°. Furthermore, the apparently different Eifelian successions at St. Mary's Bay and South Bay can be more readily reconciled if thrusting as well as folding has brought them close together.

It is tempting to imagine that the Brixham harbour fault was initiated as a sinistral wrench, complementary to the major dextral wrench faults of the Dartmouth-Kingswear district, but there is no evidence for any hade, and the downthrow is opposite in sense to that of the minor sinistral wrench faults. As the axial plane of the St. Mary's Bay anticline here dips south at about 70°, a downthrow to the north-west and a sinistral horizontal component of displacement, each of about 100m, is estimated.

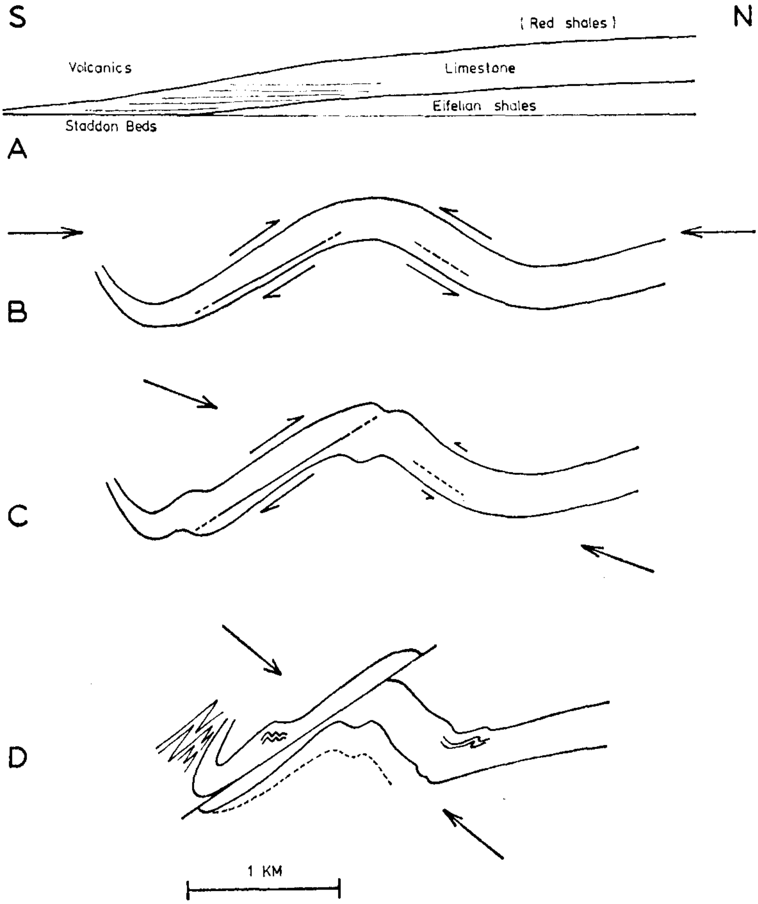

FIGURE 4. Development of the major folds and Sharkham Point thrust. Full-headed arrows show components of maximum principal compressive stress, half-headed arrows show components of shear stress.

Towards the River Dart the St. Mary's Bay anticline becomes progressively tighter and more overturned to the north, more similar in style to the large folds in the Lower Devonian to the south. On its southern flank the limestone has been almost entirely replaced by several hundred metres of volcanics, which probably underlie stratigraphically the interfolded thin shaly limestones.

4. Geological history

The Brixham limestone is strongly diachronous ; in early Eifelian times it is laterally equivalent to the grey shales further north, and later on is coeval with the volcanics to the west and south (Fig. 4A). The Sharkham Point area may thus have been the original site of a swell separating shallow water to the north from deep water to the south. The apparent migration northwards of the swell and growth of a reef in the Berry Head area is consistent with differential subsidence of the Middle Devonian continental shelf, the greater relative downwarping being in the south, but with deposition keeping pace with the subsidence (Dineley 1961).

Rheologically the limestone will behave as a competent wedge set in incompetent shales and volcanics. The maximum principal compressive stress during the main phase of folding, which probably occurred in the Lower Carboniferous (Sanderson and Dearman 1973) must have been initially horizontal, and secondary shear stresses would have been set up on the flanks of the large open flexural folds first formed (Fig. 4B). As the maximum stress rotates during regional tectonic transport (Smythe 1971) and becomes progressively inclined to the north, the secondary shear stress on the northern flank of the main anticline is reduced, whereas that on the southern flank is increased (Fig. 4C). Bedding surfaces provide a ready plane of weakness for thrusting, while the displacements toward either end of the thrust are taken up by folding. The culmination of the main phase of deformation is the development of medium-scale and minor asymmetric folds overturned to the north, and the growth of the slaty and fracture cleavages parallel to the axial planes of these folds (Fig. 4D).

The oblique-slip wrench faults were possibly formed at about this time, as the orthogonal stress system for the faulting is identical to that for the folding, except that σ_2 and σ_3 are interchanged. This interchange results naturally from considering the rock either as an elastic solid or as a viscous fluid ; deformation then occurs by faulting or by folding respectively. As all the wrench faults of the area, including the large dextral wrench faults east of Kingswear, are oblique-slip and explicable by the stress system shown in Fig. 5, it seems possible that the major dextral wrenches of the area, throughout perhaps the whole of SE Devon, originated during the Variscan orogeny, and not in the Tertiary, as suggested by Dearman (1963), although the major displacements along most of them probably did occur in the mid-Tertiary.

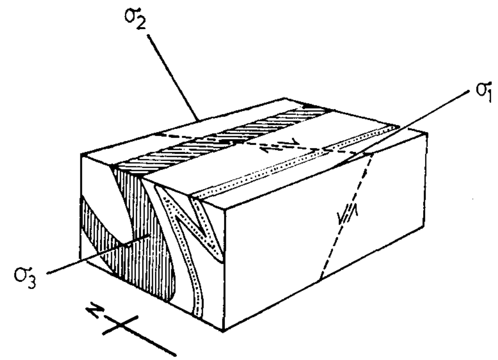

FIGURE 5. Block diagram of the stress system resulting in oblique-slip dextral wrench-faulting at South Bay, looking down to the NE. Folding in limestone (vertical ruling) and Staddon Beds (dotted) shown diagrammatically. σ_2 is parallel to the fault plane.

The structure of the district illustrates that the change from overturned folding in south Devon to recumbent folding with large-scale thrusting further north (Simpson 1969, Sanderson and Dearman 1973) is transitional rather than abrupt, and that both styles of deformation can be accounted for by a single stress field, which was more intense in the north.

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