

FIELD EXCURSION TO STUDY DAMAGE ZONES AROUND STRIKE-SLIP FAULTS AT CRACKINGTON HAVEN, NORTH CORNWALL

Y. S. KIM, J. R. ANDREWS AND D. J. SANDERSON



School of Ocean and Earth Science, University of Southampton, Southampton Oceanography Centre, SO14 3ZH

INTRODUCTION

A number of well-exposed small-scale strike-slip faults at Crackington Haven [SX 138 973] *Figure 1*, show a variety of damage zone styles. Damage zones around faults (e.g. McGrath and Davison, 1995) are deformed wall-rocks close to faults. They accommodate strains necessitated by changes in displacement along the fault. Zones of increased damage are associated with high displacements and with high displacement gradients (e.g. where faults tip out), particularly where two faults interact (e.g. Pollard and Segall, 1987; Bilham and King, 1989). The age of the faults is not presently known. They do not fall into the pattern of known Variscan faults but may relate to late Cretaceous or Alpine Tertiary north - south shortening (Lake and Karner 1987; Chadwick, 1993; Willemsse *et al.*, 1997).

Namurian turbiditic sandstones and shales (e.g. Freshney *et al.*, 1972; Selwood *et al.*, 1985; Enfield *et al.*, 1985) at Crackington Haven have been strongly deformed into south-facing overturned to recumbent folds (Ramsay, 1974) with a well developed slaty cleavage developed in the shaly intervals. Deformed goniatites can be seen where bedding and cleavage lie close to each other. The hinge to a large fold bisects the beach. Flat-lying right-wayup beds are predominant on the north side of the bay whilst north-dipping overturned beds on the south side display a variety of sole structures indicating north-east — south-west current flow (after restoration to the palaeohorizontal).

On the south side of Crackington Haven a number of strike-slip faults intersect horizontal cleavage surfaces in the hinge of a recumbent fold which is parasitic to the larger fold. The fault displacements can be precisely determined here because the beds dip very steeply and strike nearly perpendicularly to the faults. There are few, if any, other localities in Devon or Cornwall which meet these criteria. The best exposures lie just below the promontory which marks the south side of the Haven and just adjoining the wave cut platform. Quantitative data (*Figure 2*) have been obtained by mapping the offsets of vertical bedding planes and measuring the attributes of the fault and associated veins (e.g. fault length, fault displacement, vein length, vein width). Two families of faults of different age occur. The predominant family trends north-north-east and exhibits right-lateral offsets. A subsidiary and later family trends north-east, i.e. slightly clockwise of the first set, these exhibit left-lateral offsets.

The faults display several features of damage zones, including:

- *Horsetail splays* - curved fault splays near the end of a strike-slip fault that merge with that fault (e.g. Christie-Blick and Biddle, 1985; Sylvester, 1988; McGrath and Davison, 1995),
- *Wing cracks* - fractures which are wing-shaped in cross-section. They are defined as an opening crack assumed to form and propagate away from the fault terminations at an angle which maximizes the local tensile stress acting across the incipient crack path (Erdogan and Sih, 1963; Pollard and Segall, 1987),
- λ faults - produced when one fault approaches and intersects another to define a ' λ ' shape (Du and Aydin, 1995),
- Synthetic and antithetic faults, often developed along planes of pre-existing weakness (e.g. bedding),

- *Oversteps* - a discontinuity between two approximately parallel overlapping or underlapping faults (e.g. Aydin and Nur, 1985; Biddle and Christie-Blick, 1985)
- Block rotations (e.g. Martel *et al.*, 1988; McGrath and Davison, 1995)

The faults are here described in order of damage zones of increasing complexity.

ISOLATED FAULT AND TIP DAMAGE (F8, FIGURE 2)

Fault F8 is a right-lateral fault, dipping 78° north-west. It is 2 m long, with both tips exposed, and has a maximum displacement of 2 mm. It is over 2 m from the nearest adjacent fault (F2) and hence is regarded as an isolated fault. It displays horse-tail fractures at the fault-tips (e.g. Christie-Blick and Biddle, 1985; Sylvester, 1988; McGrath and Davison, 1995), defining damage zones in the extensional quadrants of strike-slip faults (see e.g. Bilham and King, 1989). These are associated with loss of displacement around the tips. Most of the displacement is compensated by generation of extensional fractures. The angles between the main fault and the splay faults range from 25° to 40°. The local orientation of the maximum principal compressive stress (σ_1) during failure is assumed to have been parallel to the orientation of the splay faults (c. 050°- 70° east).

EXAMPLES OF WING CRACKS, DILATIONAL JOGS AND CROSSCUTTING FAULTS (F2, F3 AND F11 FIGURE 2)

Figure 2 shows two sub-parallel right-lateral faults (F2 and F11; trending 030° and 038°) cross-cut by a later left-lateral fault (F3 at 060°). Fault F3 is left-lateral with rapidly diminishing displacement towards its north-east tip where a *wing crack* is developed in the extensional quadrant (note the change of polarity between this and the dextral example above). Right-stepping segmentation of right-lateral fault F2 has produced a dilational jog (e.g. Sibson, 1986; 1989) where displacement is transferred across on a right-stepping overstep which has broken through. Vein quartz now occupies the space created. Measurement of displacement (d) with distance (x) from the fault tips shows displacement is conserved across the jog (e.g. Peacock, 1991).

CONTRACTIONAL OVERSTEPS (F2 AND F9, FIGURE 2)

Two right-lateral faults (F2 and F9; striking and dipping 033°/ 80° north-west and 027°/79° north-west) interact, transferring displacement across a left-stepping contractional overstep (*Figure 2*). Although there are no conspicuous fault bridges, which are defined as inclined sectors of unfaulted rock lying between the enechelon fault relays, developed in the overstep zone (Ramsay and Huber, 1987), there is an overall displacement decrease where the segments overlap. This has been demonstrated by construction of a combined plot of displacement-distance (d-x) profiles for both faults. The minimum in the total displacement of the two faults is typical of contractional segment overlaps (Peacock, 1991; Peacock and Sanderson, 1991).

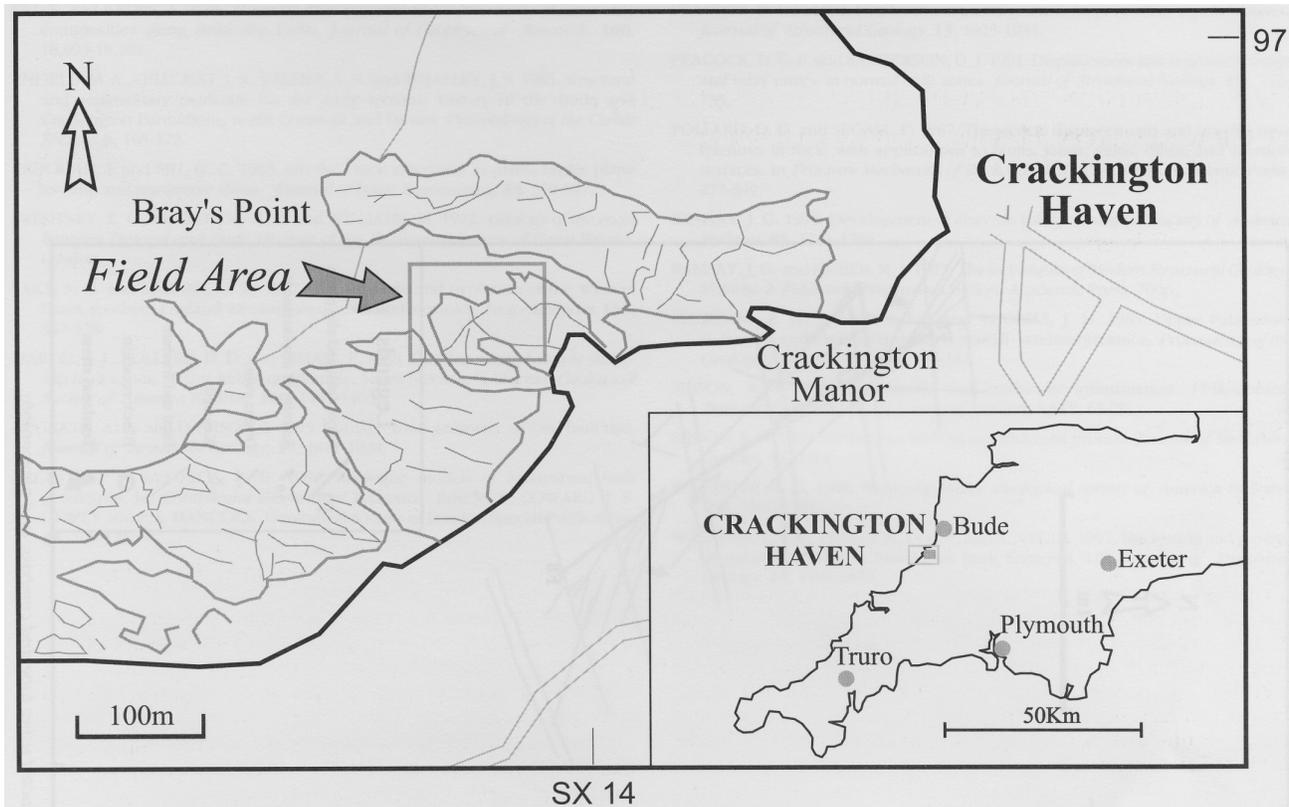


Figure 1. Map showing the location of strike-slip faults at Crackington Haven (SX129 968). The faults lie within the boxed area indicated by the arrow, beneath the promontory to the east and just above the wave-cut platform.

ROTATED FAULT BLOCKS SHOWING LOCAL FAULT DAMAGE (F1, FIGURE 2)

Fault F1 is a right-lateral fault (strike/dip; $032^{\circ}/88^{\circ}$ north-west) which has a relatively large amount of displacement (max. 270 mm) and shows a highly damaged west wall (Figure 2). Wall-rock strain has been accommodated by a combination of left-lateral slip along bedding planes and a right-lateral slip along a subsidiary fault, causing rotation of blocks bounded by the faults and bedding. Triangular shaped quartz veins are developed at the intersection of the main fault and subsidiary faults (inset a and b, Figure 2). At least four rotated blocks along the main right-lateral fault can be recognised. The opposing shear couples acting on the bounded blocks have internally deformed them such that arrays of extensional veins have been generated. A rectangular quartz vein with a vertical axis is developed at the intersection of the principal displacement surface with two offset bed-parallel left-lateral slip surfaces (inset b, Figure 2). During faulting, the evidence of compensatory vein development suggests enhanced porosity and permeability of the west wall which would have facilitated transfer of considerable volumes of fluid up or down the fault.

λ FAULTS AND DEFORMATION AT FAULT BENDS (F4, F5, F6, F7 AND F10, FIGURE 2)

The linked left-lateral fault system F5 - F4 - F10 is remarkable because fault F5 bends around by 48° to follow the bedding (F10) with F4 propagating a short distance (~ 600 mm) onwards to create a λ fault. This linked fault set shows a maximum (~ 500 mm) amount of displacement hereabouts. A small (~ 30 mm) amount of displacement is accommodated by fault F4. Most of the displacement on F5 (strike/dip: $052^{\circ}/87^{\circ}$ south-east) is transferred onto F10 (strike/dip: $080^{\circ}/63^{\circ}$ south-west) as it runs parallel to bedding for about 10 m before returning to a north-easterly trend (eastwards out of Figure 2). A zone of extensive damage (ranging up to 2 m southwards from fault

F10) is located in the south wall and marked by a conjugate pair of faults (F6 and F7; striking 005° and 050°) which extend the bedding. These can be attributed to local extension associated with movement of the bedding around the fault bend in a manner reminiscent of listric extensional faulting. Restoration of the bedding shows that about 25% local extension parallel to the bedding has occurred. The conjugate faults are analogous to normal faults in a crestal-collapse graben for example as seen in sand box models (McClay and Ellis, 1987) caused by antiformal arching as the beds roll over.

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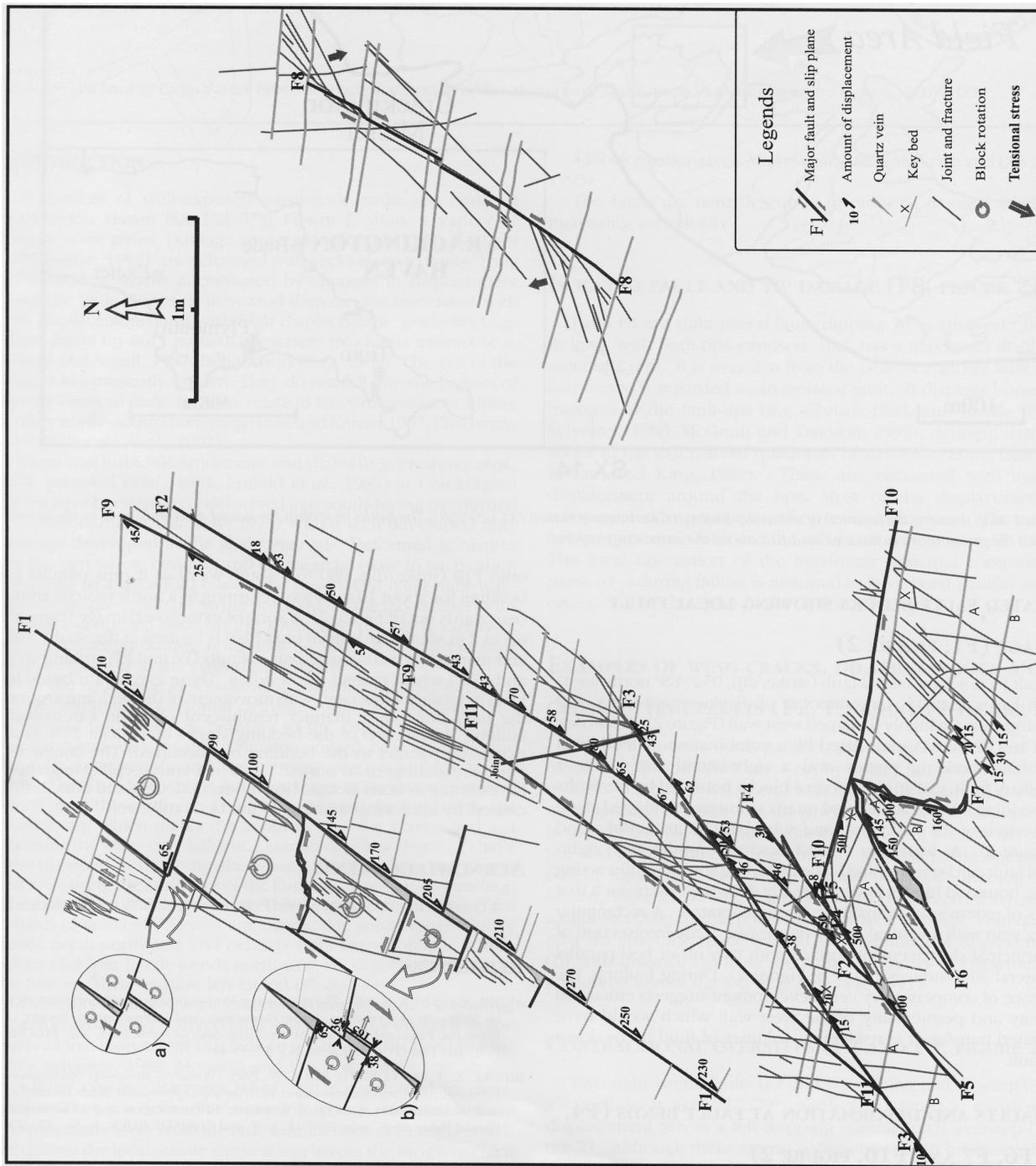


Figure 2 Detailed map of strike-slip faults at Crackington Haven. The map was constructed using tape and compass, and photographs.

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