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Kinematics of strike–slip faulting, Builth Inlier, Mid-Wales

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Abstract—Strike–slip faulting in the Builth Ordovician Inlier is demonstrated by large-scale maps of the Llanelwedd Quarries near Builth Wells, and by fault plane and slickenline data. In the main quarry steep NNW-striking strike–slip faults dominate the structure, together with significant strike–slip displacement on the W-dipping bedding surfaces and bedding-parallel faults. A zone of steep N-striking extensional dip–slip faults links two of the strike–slip strands and there is a weaker E-striking set of strike–slip faults. When the four fault sets are rotated so that the regional bedding is horizontal, three become vertical and one horizontal, probably their attitude during active life in late Ordovician to early Silurian time. They formed a linked fault system capable of accommodating three-dimensional bulk strain. The fault flats have the same kinematic role in a strike–slip system as lateral ramps or transfer faults in dip–slip systems.

In the nearby Gelli Cadwgan quarry strike–slip faults are again dominant but strike E or ESE. This heterogeneity of fault pattern in the southern Builth Inlier resolves into more homogeneous domains with areas of 0.1 to 0.5 km^2 separated by E to NE-striking dextral strike–slip faults. Domainal structure, an important general feature of strike–slip tectonics, may be present on a variety of scales.

INTRODUCTION

THE TECTONIC structure of Wales (Fig. 1) is dominated by NE-trending folds and faults, usually seen as the product of SE-directed late Silurian thrust tectonics (reviewed by Coward & Siddans 1979). Early Paleozoic sedimentary and volcanic activity is seen as controlled by extensional tectonics within continental crust in a back-arc setting (Mitchell & Reading 1971), though fore-arc (Okada & Smith 1980) and passive margin (Davies & Cave 1976) settings have been proposed. However evidence reviewed by Woodcock (1984a) suggests that a strike–slip component was also important through much of late Ordovician to early Devonian time. The evidence includes structural features such as steep braided fault arrays, oblique fold/fault geometries, cleavage transec-

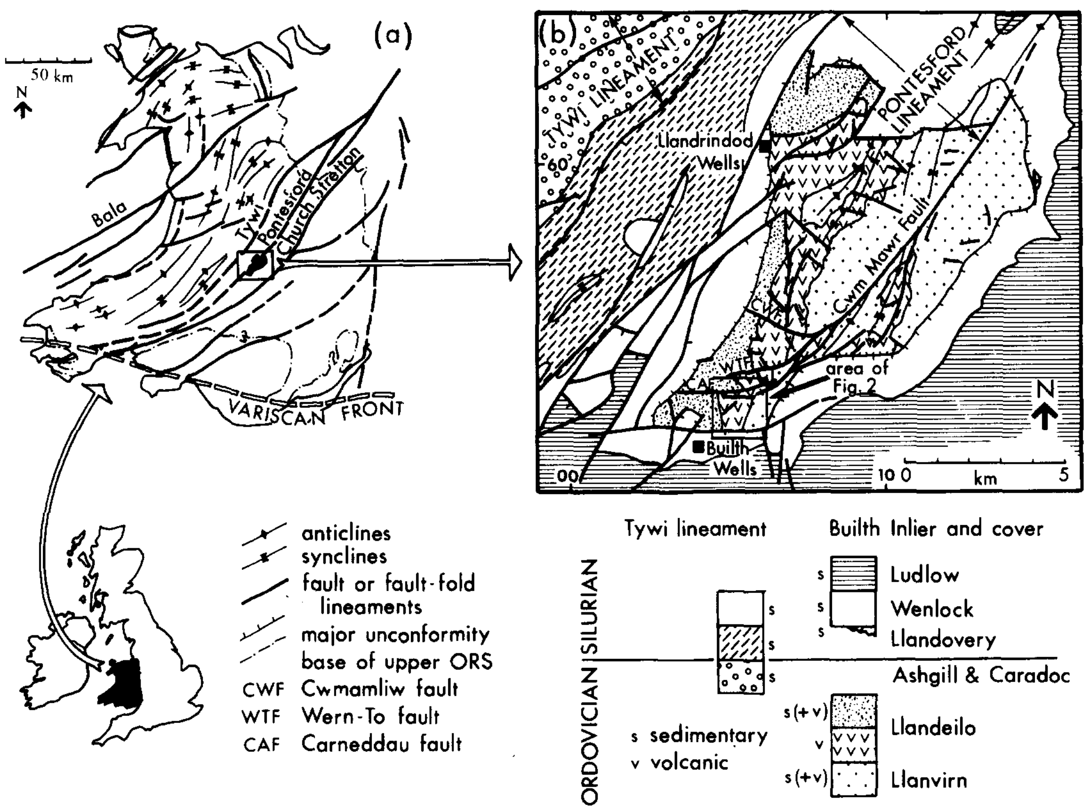

Fig. 1. Tectonic maps (a) of Wales and (b) of the Builth Inlier. Main fold and fault lineaments are marked on (a). ORS = Old Red Sandstone; for fuller nomenclature of structures see Woodcock (1984a, fig. 1).

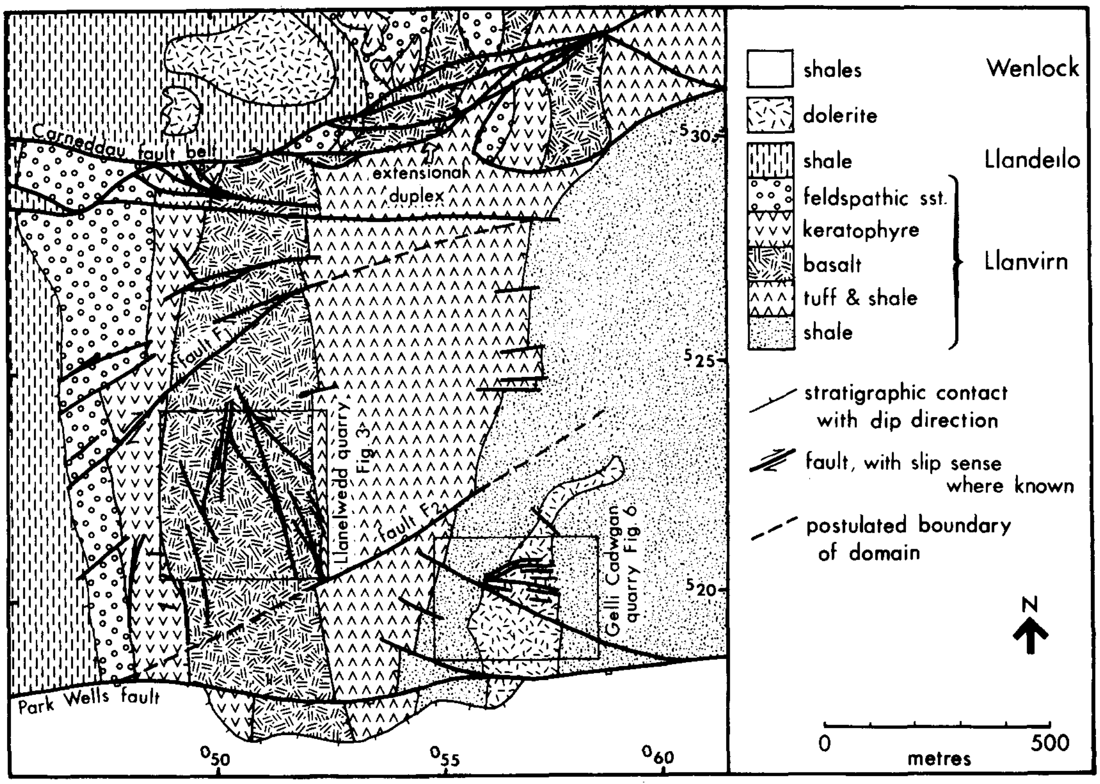

Fig. 2. Geological map of the southern end of the Builth inlier (location on Fig. 1). After Jones & Pugh (1949) and Institute of Geological Sciences (1977) with amendments from present work, particularly in areas of detailed maps (boxes) shown in Fig. 3 and Fig. 6.

tion of folds, and flower-structure geometries of fold/fault belts. Indirect evidence includes the geometry and subsidence history of the sedimentary basins, the nature and source of their fill, the character of Ordovician volcanism and some tentative matching of displaced terranes.

The first purpose of this paper is to present direct structural evidence of strike–slip tectonics along one of the major lineaments on the SE edge of the Welsh Basin, in the form of maps of well-exposed fault geometries, and plots of fault and slickenline orientation data. However the results shed light on two general kinematic processes in strike–slip tectonics; the need for more than two active fault sets to take up three-dimensional bulk strain (e.g. Reches 1978, King 1983), and the development of discrete domains of dextral and sinistral faults (Ron *et al.* 1984, Garfunkel & Ron 1985).

REGIONAL SETTING

The Builth Inlier (Fig. 1) comprises Ordovician (Llanvirn and Llandeilo) sedimentary and igneous rocks and lies along the Pontesford lineament (Woodcock 1984b) that forms a major element of the SE edge to the Welsh Basin. The inlier is cut by large steep NE–SW faults and shorter steep E–W faults with apparent dextral offset (Elles 1940, Jones & Pugh 1941, 1946, 1949, Institute of Geological Sciences 1977). Some of the faults seem to predate the marked unconformity below the Upper Llandovery to Wenlock cover to the inlier, and represent a late Ordovician (Ashgill) or early Silurian (Llandovery) event. However NE and E-striking faults cut Silurian rocks as late as Ludlow in age around and to the west of the inlier (Jones 1947), and NE-striking faults affect Pridoli rocks along the Pontesford lineament to the north (Woodcock 1984b). These demonstrate that the earlier faults were reactivated and propagated upwards into the Silurian cover. Strong control on Wenlock and Ludlow sedimentation suggests intermittent fault activity throughout Silurian time.

Jones (1954) and Baker (1971) have interpreted the NE–SW and E–W faults as a conjugate wrench system formed in response to regional pure shear with NW–SE shortening. This implies that NE–SW faults such as the Cwm Mawr fault (Fig. 1) have sinistral displacement. Woodcock (1984b) interpreted the E–W faults as splays implying dextral strike–slip on the Cwm Mawr fault and other NE–SW faults.

The two areas mapped in detail lie between the southernmost of the major E–W faults (Fig. 2). The Carneddau fault is a dextral strike–slip fault (Jones & Pugh 1949). The Park Wells fault is dominated by post Silurian south-down dip–slip (Jones 1954), giving an apparent sinistral shift of the W-dipping stratigraphy (Fig. 2). This probably records rejuvenation of a fault having a similar early history to the Carneddau Fault. Between the two main faults two substantial NE-striking faults with apparent dextral offsets have an important role as boundaries of fault domains, each with a pattern that differs from the adjacent domain. The areas mapped in detail sample the southern two of the three domains (Fig. 2).

LLANELWEDD QUARRY—DESCRIPTION

The geological map

The map (Fig. 3) was constructed from four arcuate working faces each 20 m high, together with peripheral minor faces, disused quarries and natural exposures. Basalts, mostly feldspar–phyric and highly vesicular, dominate the succession and contain intercalated agglomerates, thin sedimentary units and an intrusive dolerite. Baker & Hughes (1979) and Furnes (1978) give recent descriptions. The map is a projection onto a hypothetical smooth topographic surface that passes through the top edge of each working face at its September 1984 position. This procedure removes the confusing effect of the stepped topography, particularly on the gently dipping lithological contacts, but has involved some simplification of a complicated outcrop pattern in the lowest agglomerate on the east side of the quarry.

Mapped fault pattern

Three major fault zones are distinguished, two NNW-striking strike–slip zones connected by a central N-striking dip–slip zone (Fig. 3). The kinematic diagnosis is based on the orientation of the dominant preserved slickenlines (in the sense of Fleuty 1975) or slickenfibers (Wise *et al.* 1984), plotted on equal-area projections in Fig. 4. The tendency of some fault zones to show several of these palaeo-slip vectors is discussed later. The sense of net displacement (normal or reverse) on the dip–slip faults is easily determined from bedding offsets because their slip vector makes a high angle with the trace of bedding on the fault plane. For the strike–slip faults the slip vector is almost parallel to the bedding trace and displacement sense (dextral or sinistral) is difficult or impossible to determine. Apparent offsets of bedding are unreliable in this situation because the effect of a large strike–slip can be enhanced, negated or reversed by only a small component of dip–slip. Some slip senses were derived locally from slickenfibers, but the majority of wall rocks and mineral fills are mylonitised and did not reveal shear senses from field-scale observations.

The western strike–slip zone is dominated by a single main strand (best examined near grid reference 499215). It dips steeply ENE sub-normal to bedding. An apparent dextral shift of the highest agglomerate across this fault is probably due to the easterly downthrow on the linked dip–slip fault on its east side. Minor strike–slip faults are parallel to the major fault both to its east (e.g. 498231) and to its west (494215), where more major strands may pass through unexposed ground as continuations of mapped faults in disused quarries to the south (Fig. 2).

The eastern strike–slip zone is wider and more complex. Its western boundary is a plexus of two or three steep ENE-dipping strike–slip faults (e.g. 516212, 513225 and 510234). A sub-parallel strike–slip fault strand further east (e.g. 521215) seems to splay and lose displacement to the north, one splay linking with the third main strand in the eastern zone which strikes NE–SW and dips steeply NE, again sub-normal to bedding (e.g. 521228 and 516233). Minor offsets of the two lower agglomerates are probably due to small east-down dip–slip components. Many minor strike–slip faults are parallel to the main strands, and some strike– or oblique–slip faults also dip shallowly SW and steeply N (Fig. 3).

The central dip–slip zone is cored by three faults striking N or NNE. The eastern and westernmost dip E sub-normal to bedding and show normal, that is east-down, displacement (e.g. 502226, 500229). Followed southwards, the western fault curves to a NNE strike and apparently anastomoses with the western strike–slip zone at 498218. The central dip–slip fault is sub-vertical, with west-down displacement. The sum kinematic effect of the main dip–slip strands is bedding-parallel extension in an E–W direction. The main dip–slip core is flanked by peripheral zones of minor N to NNE striking dip–slip faults that overlap into the eastern and western strike–slip zones (Fig. 3 and inset).

Where dip–slip and strike–slip faults interact, all three possible geometric relationships occur; anastomosing of the two faults (e.g. 498218), abutment of the dip–slip against the strike–slip strand (e.g. 509237) and abutment of the strike–slip against the dip–slip strand (e.g. 502234). These relationships show that the dip–slip and strike–slip displacements were synchronous, and that both were components of local response to a single regional kinematic constraint.

Local fault and slickenline attitudes

Orientation data are presented as equal-area projections (Fig. 4) for four subareas corresponding to the western strike–slip zone, the central dip–slip zone, and the northern and southern segments of the eastern strike–slip zone. The slickenline plots emphasise the dominance of strike–slip in the western zone, with a mean slickenline orientation (plunge/trend) of 03°/339°, the north-eastern zone (mean 13/148) and the south-eastern zone (mean 07/154). This slip mostly occurs on steep faults dipping ENE approximately normal to bedding (mean fault orientations (strike/dip) 345/68, 328/64, 333/64 respectively). Dip– or oblique–slip on steep ESE-dipping faults occurs in the periphery of the central dip–slip zone. There are minor mainly oblique–slip fault sets dipping steeply NNE and moderately SW.

The central dip–slip zone has steep faults (mean 011/68) dipping E approximately normal to bedding. They mostly show dip–slip slickenlines (mean 61/072).

A common feature is a variable suite of slickenlines within any one fault plane. This is illustrated by a detailed sample (readings at approximately 1 m intervals) from the western strike–slip zone close to where the dip–slip zone anastomoses with it (Fig. 4, cf. Fig. 3). Although strike–slip indicators dominate, there are a number of oblique–slip slickensides. The varying directions may be from different layers (millimetres apart) in the mylonitised fault zone or may be continuous within the same layer, clearly demonstrating a curved slip

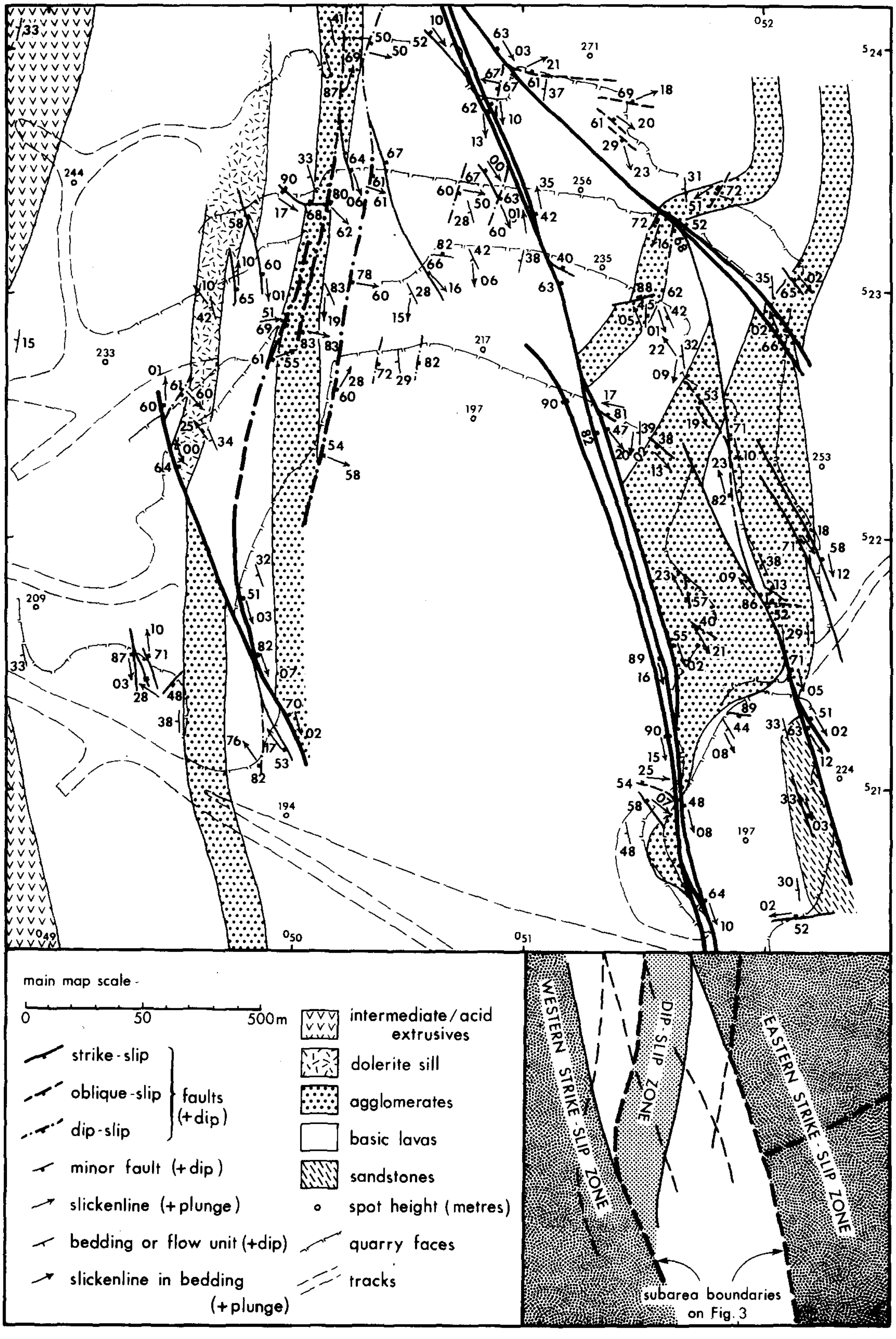

Fig. 3. Geological map of the main Llanelwedd Quarry (location on Fig. 2) with inset summary of main kinematic zones.

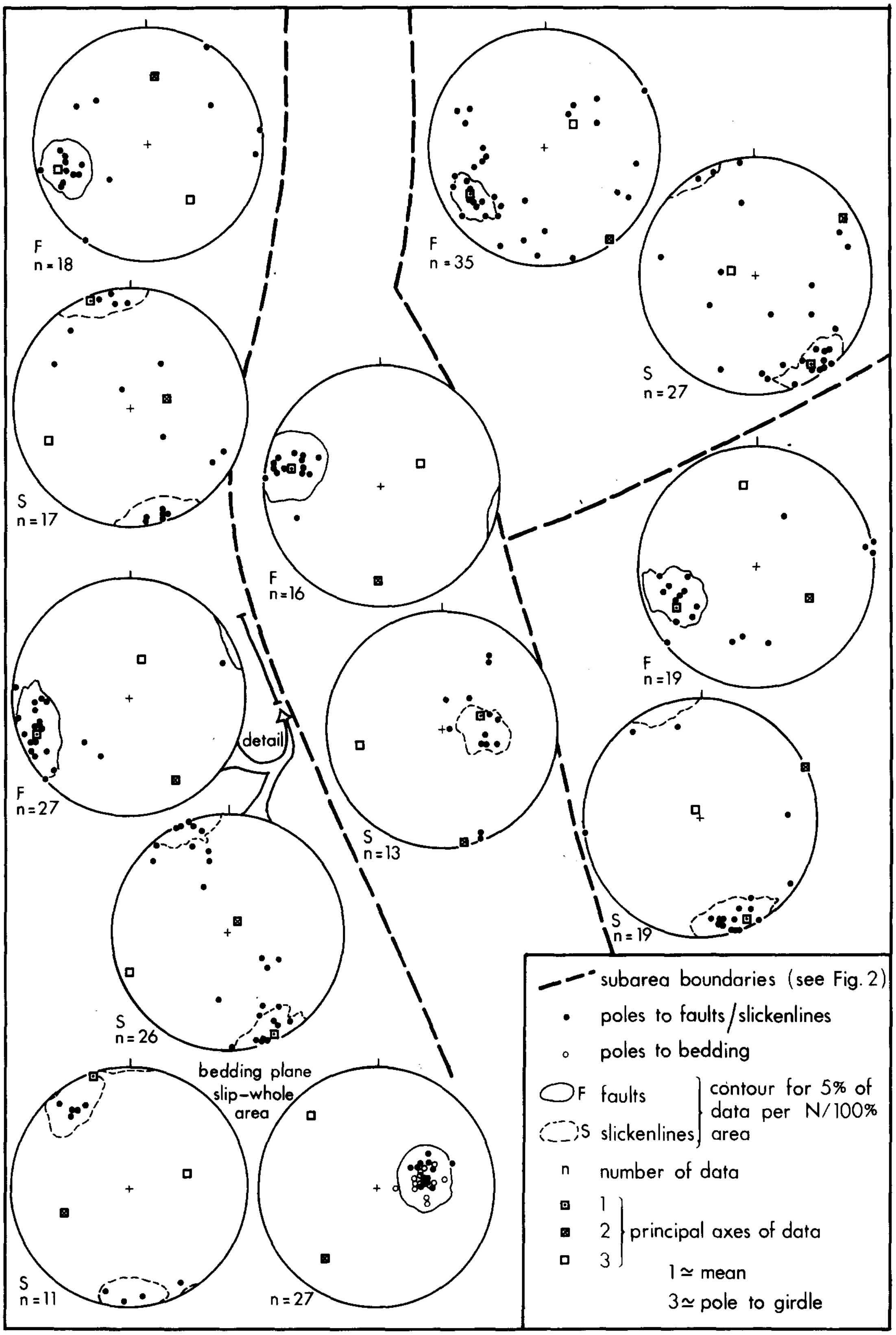

Fig. 4. Lower hemisphere equal-area projections of poles to faults and of slickenlines in subareas of the main Llanelwedd Quarry. Subarea boundaries marked on inset to Fig. 2. Principal axes of data are derived by eigenvector methods summarized by Woodcock & Naylor (1983).

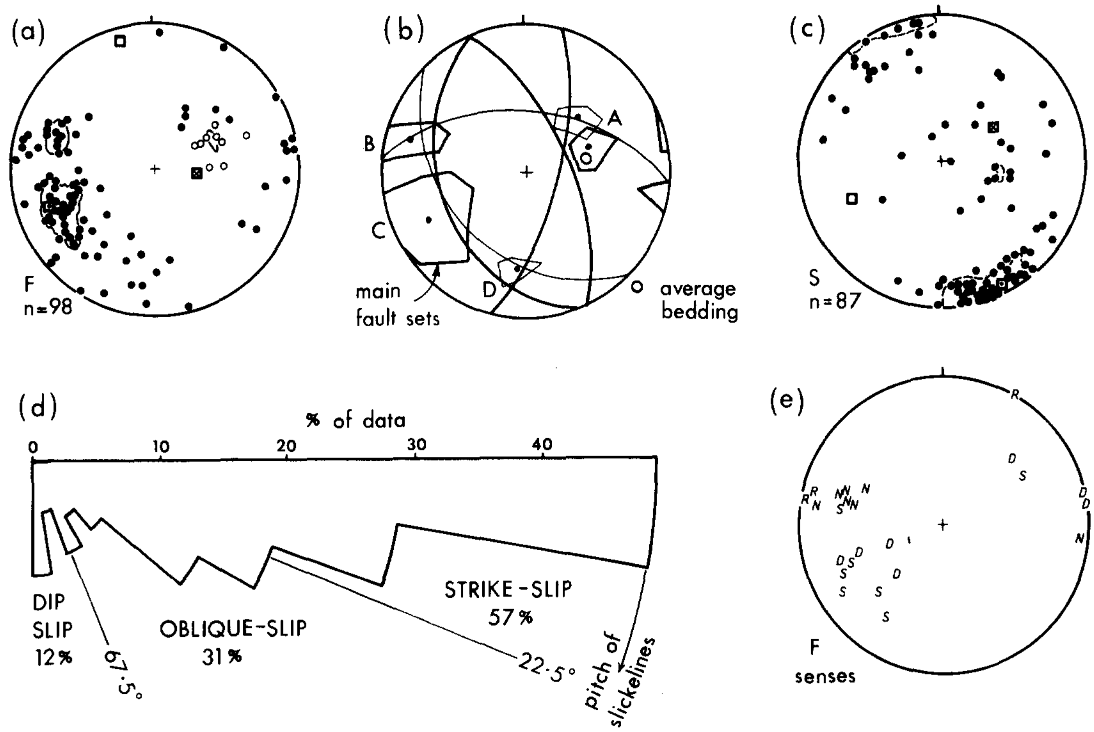

Fig. 5. Fault data combined for the main Llanelwedd Quarry. Symbols and notation as Fig. 4. Lower hemisphere equal-area projections of (a) poles to faults and bedding slip planes, (b) average groupings of poles to faults, (c) slickenlines, and (e) senses of slip plotted as fault poles (D = dextral, S = sinistral, N = normal, R = reverse). (d) Circular histogram of pitch of slickenlines within their host fault plane.

vector within the fault. Therefore, not only could strike–slip and dip–slip faults co-exist in this area but one fault strand could change its slip-vector incrementally through time.

Bedding dips moderately W throughout the quarry (Fig. 4). Some bedding planes (poles separately ornamented) show strong slickensiding, always indicating slip parallel to that on the steep strike–slip faults (average slip-vector 04/342).

Aggregated fault and slickenline attitudes

Data combined from the whole Llanelwedd Quarry emphasise some important features of the deformation (Fig. 5). A histogram of slickenline pitch within the host fault (Fig. 5d) shows that the majority (57%) are strike–slip, with 31% oblique–slip and 12% dip–slip. This dominance of strike–slip is reflected in a sub-horizontal mean for the slickenlines (06/155, Fig. 5c). The poles to faults show a multimodal pattern (Fig. 5a and summary Fig. 4b). One main set (A) is provided by the bedding planes and a subset of faults close to the bedding attitude. Both have dominant slip parallel to the steep strike–slip faults. The other three sets are steep and almost normal to bedding, two sets (B and D) being strike–slip and the other (C) being the main dip–slip set (Fig. 5e). The main sets (A, B, C) above are those defined by the largest amount of data, and with the most continuous mapped fault or bedding surfaces. They probably account for the greatest amount of displacement. However, short low-displacement faults of these orientations also occur frequently and there is no great difference between the fault geometry on different scales. This homology or self-similarity of fault orientations on different scales is predicted theoretically and is compatible with seismological data (King 1983).

The few successful determinations of displacement sense on faults (Fig. 5d) show that 70% of the dip–slip faults are normal rather than reverse and that strike– or oblique–slip faults show no significant dominance of sinistral or dextral sense. The marked lack of consistency may reflect the fact that the slickenfibers, which give the clearest sense data, form during creep events on the faults. The kinematic pattern of creep may not necessarily match fast (seismic) slip on the faults. This is partly analogous to the very varied aftershock solutions observed after some major earthquakes (e.g. Deschamps & King 1984).

GELLI CADWGAN QUARRY

This disused quarry lies about 0.5 km east of the Llanelwedd quarry (Fig. 2) in a thick dolerate sill intruded into Llanvirn mudstones dipping steeply WSW (Fig. 6). Steep ESE-striking faults cross the central part of the quarry and have strike–slip or oblique–slip slickenlines. Faults in the north of the quarry dip more moderately NNW. Followed westward these swing from E–W round to ENE and show increasingly steep and varied slickenlines. At their western ends some may anastomose with one of the ESE faults.

Along the east side of the quarry the base of the sill has apparently been shifted both dextrally and sinistrally on

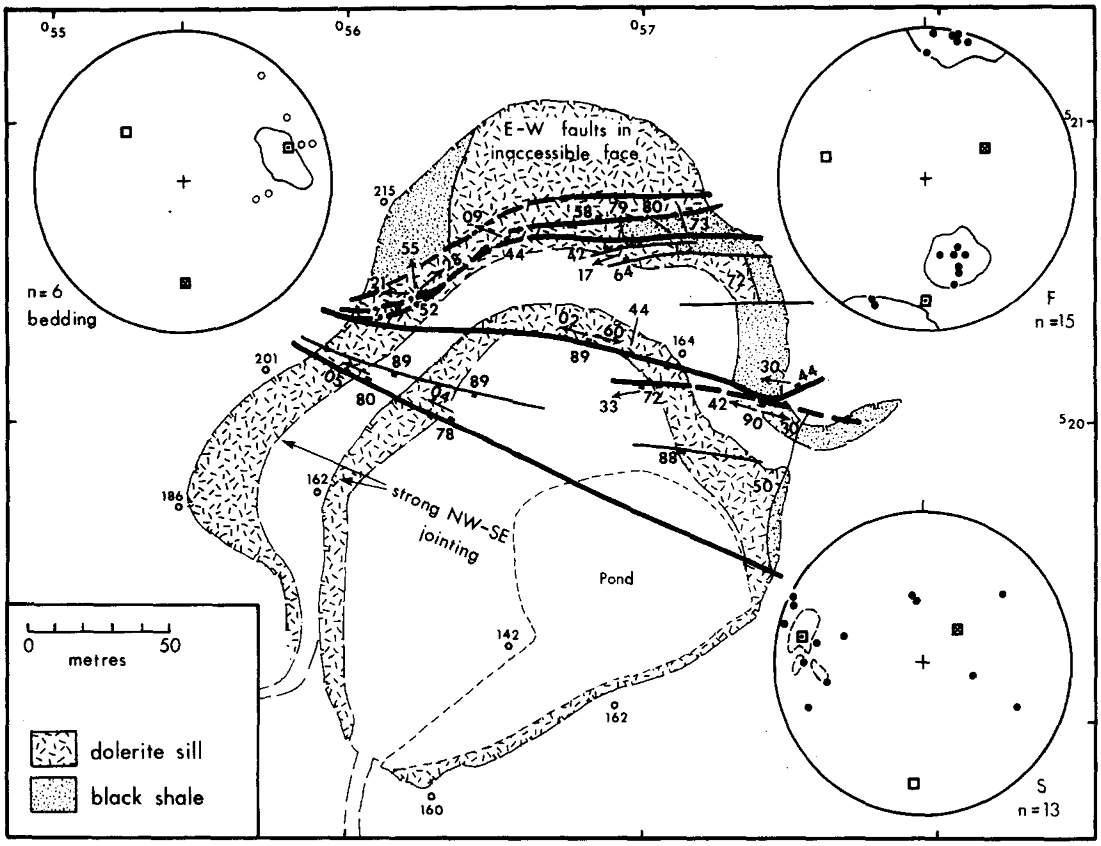

Fig. 6. Geological map of Gelli Cadwgan quarry (location on Fig. 2) with lower hemisphere equal-area projections of poles to bedding, poles to faults (F) and slickensides (S) over the whole quarry. Key as in Figs. 4 and 5.

adjacent faults, probably due to the interaction of dip–slip with strike–slip components. In the NW the top of the sill is dextrally offset. The major ESE-striking fault zones link to the WNW with a fault mapped by the Geological Survey as having a dextral shift.

KINEMATIC INTERPRETATION OF THE SOUTHERN BUILTH INLIER

The interpretation in Fig. 7 is the simplest that fits the available data, though others cannot be discounted given the limited exposure between the mapped quarries and the uncertainty about the sense of displacement on the major faults. The area appears to be dominated by E- to ENE-striking steep faults with dextral strike–slip displacement. The Carneddau fault zone is the largest of the set with offsets reaching 800 m. It has along it two extensional strike–slip duplexes (Woodcock & Fischer 1986), imbricate arrays of steep faults each with normal oblique-slip. The westernmost is formed by intersection of the Carneddau fault with extensional splays off the next major fault to the south. The eastern and larger duplex was possibly formed by linkage of en-échelon R-shears by later P-shears. In the south the Park Wells fault has been reactivated in post-Wenlock time as a dip–slip fault, but probably had a similar strike–slip role to the Carneddau fault belt. Two intervening ENE faults, labelled F_1 and F_2 (Fig. 7a), divide the area into three domains with differing fault patterns.

The northern domain has not been remapped. Jones & Pugh (1949) show mainly synthetic strike–slip faults parallel to the domain boundaries. The domain could be regarded as an integral part of the Carneddau fault belt.

The central domain has faults striking at a high angle to the domain boundaries. Most of these are interpreted as sinistral strike–slip faults accommodating clockwise block rotations between the major dextral strands. This follows a well-established model (Freund 1974, Garfunkel 1974) which has recently been further developed (Ron *et al.* 1984, Garfunkel & Ron 1985). However, the related dip–slip faults indicate a component of extension between the rotating blocks, suggesting that the central domain was undergoing area increase and vertical thinning. This is compatible with the model of McKenzie & Jackson (1983, 1985) in which the blocks are partially 'pinned' to the northern and southern domain-bounding faults rather than free to maintain contact with each other. In the Garfunkel & Ron (1985) model the necessary shortening across the zone must be balanced by elongation of the domain along the zone, and resulting expulsion of material at its ends. In the McKenzie & Jackson (1986) model all the motion is taken up within the domain, vertical thinning balances extension across the zone, and no external adjustments are required. There is no reason why both models or some combination of the two should not be appropriate in different parts of the same domain within the southern Builth inlier, depending on the exact kinematic boundary conditions imposed by the curved domain boundary faults.

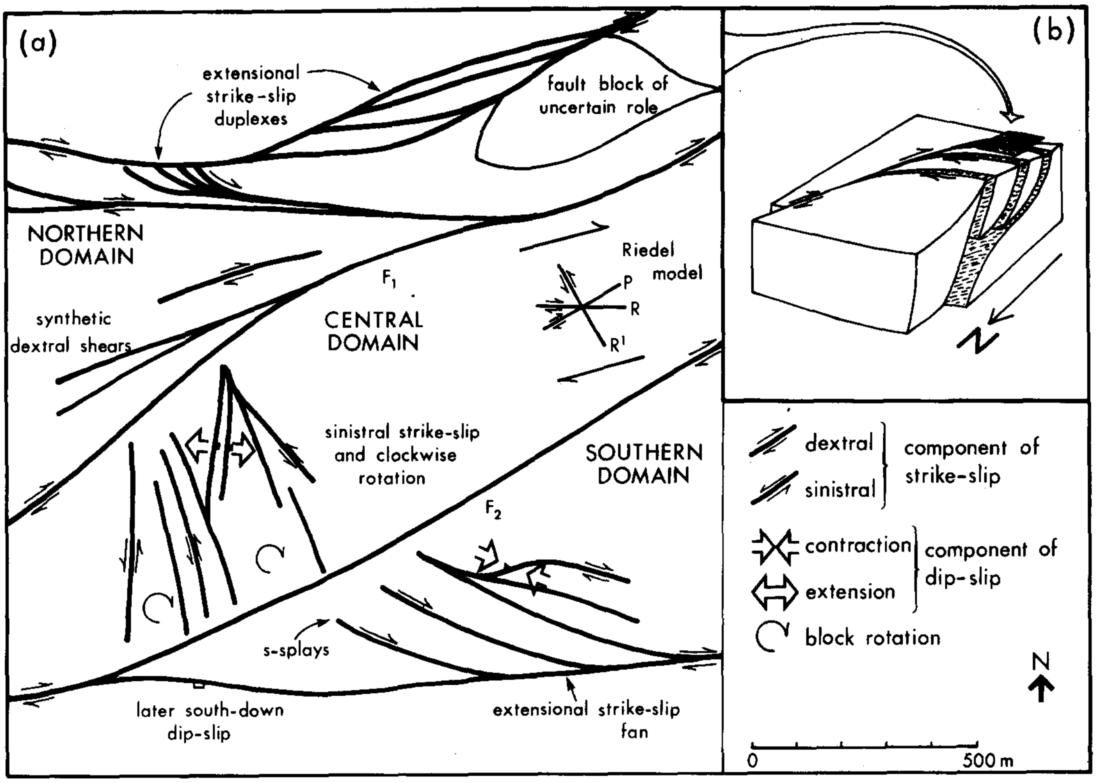

Fig. 7. (a) Kinematic interpretation of the south end of the Builth inlier; same area as Fig. 2. (b) Block diagram of Builth inlier viewed from the NW during postulated dextral strike-slip, showing extensional oblique-slip imbricate fan at the end of the Cwm Mawr fault.

It is noteworthy that the necessary oblique–slip displacements have tended to be physically resolved into dip–slip and strike–slip components taken up on different faults. This is probably a result of deformation at a shallow crustal level where the tendency for one principal stress to be vertical was a strong control.

In a conventional 'strain ellipse' model (e.g. Wilcox *et al.* 1973) of the central domain the NNW strike–slip faults could have formed as antithetic Riedel shears (R′, Fig. 7a) in a dextral system with an ENE-striking shear plane. They are now oriented clockwise of the ideal orientation, compatible with finite block rotation. The main dextral faults could be the synthetic R and P shears. The orientation of the dip–slip faults does not fit this model. One explanation might be that they are utilising early formed R′ shears now rotated substantially clockwise. Another is that the major NNE shear system was sinistral not dextral, with anticlockwise block rotations in the Llanelwedd domain. The major dextral shift on the Carneddau fault makes this model untenable unless a large north-down dip–slip component has completely overridden the effect of sinistral strike–slip.

The southern domain is dominated by E- to ESE-striking strike–slip faults interpreted as dextral splays off the Park Wells fault during the postulated dextral strike–slip phase of its history. A strain ellipse model fits best if the shear plane is approximately E–W, with the Park Wells fault as a P or D shear and the ESE faults in Gelli Cadwgan quarry as synthetic R shears. However, Naylor *et al.* (1986) have shown experimentally how early formed R shears can develop splays (denoted S) at a higher angle to the main shear direction. This is a plausible origin for the ESE striking faults if the main shear direction is ENE as in the central domain. The splays then form an extensional strike–slip fan (Woodcock & Fischer 1986). In any case the north dipping faults in Gelli Cadwgan quarry with strong oblique–slip or dip–slip components are oriented to be reverse faults.

The major E or ESE faults in the southern Builth inlier may themselves be splays off the NE-striking Cwm Mawr fault (Fig. 7b, Woodcock 1984b). They form an extensional oblique–slip fan with a component of north-down dip–slip as well as dextral strike–slip. This fan would have enabled major dextral strike–slip on the Cwm Mawr fault to be partially dissipated southwestward.

ROLE OF DOMAINAL STRUCTURE

The interpretation of fault kinematics in the previous section is an attempt to rationalise extremely varied fault patterns in terms of domains within a uniform regional shear system. Domainal structure in strike–slip belts has been discussed most recently by Garfunkel & Ron (1985). It probably develops from a conjugate system as displacements increase because of the kinematic need to avoid interference between intersecting faults. Each domain is dominated by sub-parallel faults, reducing compatibility problems within the domain, though still necessitating complex accommodation at domain boundaries. A further necessity is that fault blocks and their bounding faults within each domain must rotate as deformation proceeds, dispersing systematic fault patterns inherited from the initial low-displacement phase.

A significant difference between the domains in the southern Builth inlier and the examples discussed by Garfunkel & Ron (1985) is their size; less than 0.5 km^2 compared with 500–5000 km^2. The kinematic principles involved are the same at all scales. However the small size of the domains in the southern Builth inlier suggests the possibility of a *scale hierarchy* of domainal structure in strike–slip belts, both in Wales and in general. For instance, the area of the inlier NW of and at the S end of the Cwm Mawr fault (Fig. 1b) is dominated by E–W or even ESE-striking faults, and could be considered as a domain distinct from the area to the west of the inlier where NE-striking faults dominate. This domain would have an area of about 30 km^2. On a still larger scale, the NE-striking faults along the SE edge of the Welsh Basin (Fig. 1a) contrast with E- and ENE-striking faults in western mid-Wales and both N and E striking structures north of the Bala fault. If these too represent a domainal structure, their size is upwards of 1000 km^2. The suggestion here is that, in Wales and more generally, domains differing in area by several orders of magnitude may be *nested* within each other.

An important consequence of this nesting of domains in fault belts is that block rotations may not be as marked as where intra-domain blocks remain undeformed. Rotations in response to a dextral couple at a large scale may be damped by rotation in the opposite sense due to sinistral shear on smaller component domains (Fig. 8). This *kinematic damping* may explain why paleomagnetic directions in the southern Builth inlier are not significantly rotated with respect to the Ordovician paleopole for Britain as a whole (Briden & Mullan 1984), although averaging of poles between sites in different domains is another factor.

Domain size is probably strongly influenced by the spacing and orientation of pre-existing heterogeneities such as faults. The magnitude of finite displacement across the system is another factor, higher displacements probably favouring smaller domains.

A related aspect of the fault geometry is the extent to which small-scale faults within a fault block match the larger scale faults in orientation and slip vector. This is the concept of *self-similar faulting* (King 1983) or *fault homology*. The evidence of domainal structure in the Builth inlier shows that faults there are not homologous over the whole size range. However, within the Llanelwedd quarries there is close homology of faults with outcrop lengths in the range 400 m down to about 5 m, about four orders of magnitude in terms of surface area. The lower end of this spectrum was the chosen limit of observation in the field, but the qualitative impression is that yet smaller faults are homologous with those measured. However, there may well be further domainal breaks at smaller sizes; it is unlikely that grain-scale brittle processes are homologous with the mesoscopic faults.

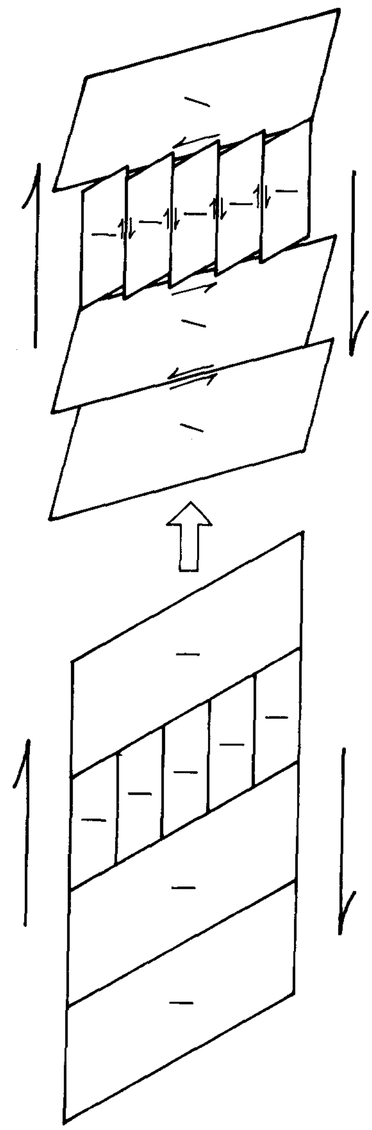

Fig. 8. Effect of dextral simple shear on a two-level domainal hierarchy of nested fault domains. Large blocks rotate clockwise between sinistral faults, small blocks rotate anticlockwise between dextral faults and achieve zero net rotation due to the kinematic damping.

ROLE OF MULTIPLE FAULT SETS

The development of fault domains is an attempt by the active fault system to minimise the kinematic problems of responding to the imposed boundary conditions, whilst ideally maintaining strain compatibility throughout. Whilst plane strain is possible in these domainal systems, non-plane strain offers another kinematic strategy. In a strike–slip system non-plane strain involves vertical displacements within the fault plane but normal to the generalized slip vector. Non-plane strain is particularly common in strike–slip belts because of the combination of steep fault planes and a free upper surface to the system.

Analysis of faulting in a three-dimensional strain field has been attempted by Reches (1978) and field examples provided by, amongst others, Aydin & Reches (1982), Bevan (1985) and Underhill & Woodcock (1987). These studies show that the Andersonian systems with two conjugate fault sets are replaced during 3-D strain by three or four fault sets. Systems symmetrically related to the bulk strain axes may develop at low irrotational strains in isotropic rock. More complex geometries develop as the faults themselves introduce a mechanical anisotropy. For strain compatibility a constraint remains that five independent slip systems must operate if the rock body is free to rotate and eight if it is confined by specified boundary conditions. This is Von Mises' criterion, familiar in deformation studies on the scale of an individual crystal (e.g. Lister & Hobbs 1980) and applied to faults by Reches (1978) and King (1983). One fault can accommodate slip in two independent directions, hence eight slip systems require four sets of faults and five systems only three sets to accommodate the bulk strain.

The fault system in the Llanelwedd quarry shows some of the consequences of 3-D strain. There are four main fault sets present which apparently operated concurrently (Fig. 5). They are not the four sets that would have developed in response to irrotational strain in isotropic rock: the bulk strain was almost certainly rotational and one, possibly two, sets reuse pre-existing structures. The low-dip faults use bedding and the boundaries to volcanic flow units, and the dip–slip faults may reuse older strike–slip Riedel shears.

The kinematic role of the steep dip–slip faults has been to take up surface area changes in the system by allowing extension or shortening parallel to layering. The kinematic model (Fig. 7) required early area increase and layer-parallel extension, but as the fault block system rotated area decrease may have been necessary, and the dip–slip component could have been reversed. Slip on faults parallel to bedding could not have taken up layer-parallel extension or shortening, though the possibility that faults close to bedding parallel (Fig. 5) operated in this way cannot be excluded. However the dominance of NNW-trending slickenlines on the bedding faults shows that their main kinematic role was to accommodate differential displacements between different vertical levels in the system (Fig. 9). Such flat-lying zones can operate in plane-strain strike–slip systems as kinematically necessary flats (Woodcock & Fischer 1986). The flats operate in a linked fault system in the same way as lateral ramps in a thrust system or transfer faults in an extensional dip–slip system. The flats parallel the plane-strain section and have a slip vector parallel to that of the steep strike–slip faults. The Llanelwedd quarry provides a particularly good example of this geometry, probably because the strength of the massive flow units themselves combined with the weakness of the boundaries favoured resolution into them of a component of slip.

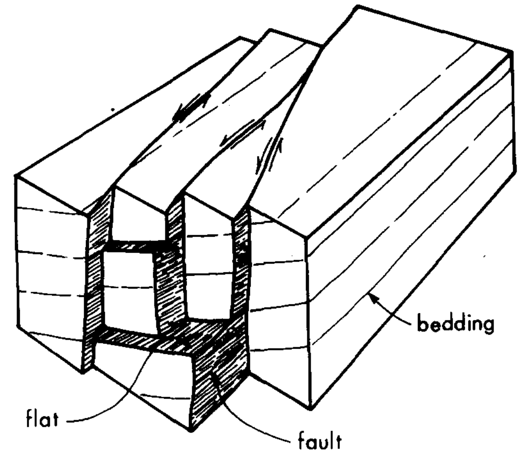

Fig. 9. Block diagram showing how variable displacements on steep strike–slip faults may be linked by kinematically necessary flats, here parallel to bedding. This idealized system is approximately plane strain; real systems will be more complicated.

CONCLUSIONS

This study has three conclusions of regional relevance and five of more general interest. The regional conclusions are:

(1) The southern end of the Builth inlier is dominated by strike–slip faulting, probably dating mainly from Caradoc, Ashgill or Llandovery time.

(2) Many faults are oblique to the regional trend and most cannot be interpreted simply in terms of 'strain ellipse' strike–slip tectonic models.

(3) The data fit best within a dextral strike–slip system oriented ENE or NE on the scale of the inlier, with a major oblique–slip extensional fan at its SW end.

The more general conclusions are:

(1) The fault system is domainal on the scale of about 0.5 km^2 with different domains dominated by fault sets in different orientations and with different slip senses.

(2) Domains are apparently nested within larger domains in a two- or three-level hierarchy. Operation of a sinistral domain nested within a larger dextral domain can cause kinematic damping of block rotations.

(3) The complexities of strike–slip kinematics required 3-D shape change of the area to have been taken up on three or four concurrently active fault sets. This is an illustration of Von Mises' criterion as applied to mesoscopic faulting.

(4) Dip–slip, oblique–slip and strike–slip faults operated in concert and probably in sequence during the deformation history.

(5) In particular, bedding parallel kinematically necessary flats played an important role in transferring strike–slip displacements on steep faults from one crustal level to another.

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