

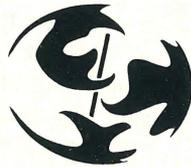
A CROSS SECTION THROUGH SOUTHWEST ENGLAND

S. C. MATTHEWS¹

ABSTRACT

Matthews, S. C. 1981 A cross section through southwest England. *In*: H. J. Zwart & U. F. Dornsiepen (eds.): *The Variscan Orogen in Europe – Geol. Mijnbouw* 60: 145-148.

The stratigraphy of the Devonian-Carboniferous of SW England resembles that of the Rheinische Schiefergebirge. The structures are different in that flat-lying folds and cleavages are common in SW England. Folds have vergences to the north or to the south. The Lizard Complex is regarded as a basement high and not as a Variscan plate margin. The structural history including the emplacement of the granite batholith is discussed.



INTRODUCTION

The late Palaeozoic rocks of southwest England have, generally, an east-west strike. The regional outcrop pattern shows Devonian in the north, a broad belt of Carboniferous in the mid-part of the region and Devonian again in the south – since Sedgwick and Murchison's time it has been accepted that a major syncline (the 'Culm Synclinorium') is one of the dominant features of the structure of southwest England. Rocks of uncertain age occur in the extreme south. Their place in the structure of the region has been a matter of some controversy in recent years.

The northern belt of Devonian outcrop includes considerable thicknesses of Old Red Sandstone facies, which serve to indicate that southwest England is a region in which Variscan geology developed closely adjacent to the Caledonian fold belt. The broad belt of Carboniferous outcrop includes a flysch succession which, according to present information, began in early Namurian time. This is followed by a molasse-type succession, the Bude Formation, much of which is taken

to be of non-marine character, and which includes the 'youngest-surviving' (Westphalian C) rocks involved in the folding. The Devonian in the south has Old Red Sandstone facies in the Lower Devonian. Above it, there is a sequence with massive limestones and also basal successions (locally including calcareous turbidites) in the middle and lower Upper Devonian, basal facies (locally with reduced 'Schwelen' successions) in the Upper Devonian, and black slates, with cherts and calcareous turbidites in the Lower Carboniferous. This is a sequence which is strongly reminiscent of the Devonian-Carboniferous in the Rheinische Schiefergebirge. But the resemblance is a stratigraphical one only, and does not extend to structure: in southwest England, the fine-grained Late Devonian and Early Carboniferous rocks have flat-lying structures, with frequent detachment surfaces, which contrast with the more vertical styles of structure developed in the same kinds of rocks in Germany. In the southernmost part of the region there is yet another Devonian succession, a thin Lower Devonian sequence which shows a Hercynian facies and is followed by a mid-Devonian flysch. This is the severely deformed set of rocks earlier regarded as an incoherent mélange produced during development of a major 'Lizard-Dodman-Start Thrust'. It has recently been argued that such a major thrust does not exist.

¹University of Bristol, Dept. of Geology, Queen's Building, University Walk, BRISTOL BS8 1TR, United Kingdom.

Basic volcanics are present in the Devonian and in the Lower Carboniferous. It may be noted that the earliest basic volcanics are found in the Lower Devonian (Gedinnian) of south Cornwall. Keratophyres are abundant low in the Devonian. A large granite batholith was emplaced among the deformed Devonian and Carboniferous rocks during late Carboniferous-early Permian time. The possibility that it exerted an influence on the pattern of the major structure and even on the character of the late part of the stratigraphic succession is the subject of special discussion below.

MATTHEWS (1977: see full references to the literature there) has published a review of these matters and has argued that the Devonian and Carboniferous of southwest England accumulated under tectonic circumstances in which there was first a tensional régime, with block-faulting and extrusion of volcanics, then later a compressional phase, involving folding of what was already a distinctly inhomogeneous pile of rocks. This present account is a brief restatement and updating of these views.

VARISCAN STRUCTURES IN SOUTHWEST ENGLAND

In the northern belt of Devonian outcrop the folds have a distinct northward vergence. A major anticline has upper Lower and lower Middle Devonian in its core.

The identity of the underlying, unexposed succession is problematic. A negative gravity anomaly, first clearly delineated by BOTT ET AL. (1958), has for many years been interpreted in terms of repetition of the succession by a large thrust-structure, the Exmoor Thrust. MATTHEWS (1974) took the view that this thrust does not exist, and proposed that the negative anomaly is instead due to the presence of a considerable thickness of Early Devonian rocks. BROOKS ET AL. (1977) have likewise doubted the existence of the thrust. They have encountered a major seismic reflector under the area and have identified it as a quartzite, possibly of late Precambrian or early Palaeozoic age. Their suggestion is that a thick underlying succession of sandstones may be the cause of the negative anomaly. MATTHEWS (in prep.) would identify the reflector as a quartzite high in the Early Devonian (an analogue of the Emsquarzit in Germany) and would continue to regard the thick underlying succession indicated by the geophysical results as being of Devonian age. MATTHEWS (1974, 1977) proposed that the thick Devonian succession of north Devon is contained in a basin bounded on the south by a major east-west fracture which was active, downthrowing to the north, during Devonian time.

The large belt of Carboniferous (mainly Namurian and Westphalian) outcrop in the centre of the region shows, in its northern part, folds which are essentially upright. Farther to the south, however, a southward vergence is progressively more obvious, and near the southern limit of the Carboniferous belt, folds are south-facing and flat-lying. This attitude of

structures does not, however, introduce younger horizons in any southward traverse. Instead, Lower Carboniferous, then Upper Devonian (each with flat-lying, south-facing structures and each including basic volcanic rocks) come to outcrop. FRESHNEY (1965) proposed that these are slices brought from deeper in the structure by normal faults, with a shallow dip to the north, which were active during the time when the Bodmin Moor Granite was in process of emplacement. In the area where these faults are concentrated there is a local second set of folds.

The Devonian in mid Cornwall and south Devon also has flat-lying structures, but these face north. Two opposed senses of facing therefore confront one another. The two sets of folds do not match one another in every point of character, however. It is plain that the northern set of folds is much the tighter of the two. A southward traverse through this Devonian belt would lead into older rocks and eventually into more vertical structures, these especially in the Lower Devonian of south Devon, which is dominantly a coarse-grained succession with a considerable thickness in Old Red Sandstone facies. Locally, again, later folds are superimposed on the first set of structures.

Early Devonian rocks are seen once more, in the extreme south. The Lower Devonian is in Hercynian facies here and its thickness has been estimated to reach only one-tenth of the thickness of Lower Devonian (with O.R.S. facies) to the north. This implies that another major east-west fracture is present and that it was already active during early Devonian time. The thin Lower Devonian has two well-developed sets of folds. Both strike northeast-southwest and both face northwestward. This succession rests unconformably on an Ordovician quartzite, which matches exactly the character of the Armorican Quartzite of northwestern France. It is taken to be younger than most of the rocks (including the serpentinite) in the Lizard Complex to the south.

COMMENTARY

The preferred interpretation of the evidence briefly sketched above is that the Lizard Complex is part of a basement high within the Variscan geology rather than a manifestation of a Variscan plate margin. South Cornwall has a stratigraphic succession which matches that of northwestern France – the Lizard serpentinite and associated rocks do not represent any sort of line separating different kinds of geology. Further, the igneous rocks in southwest England (FLOYD, 1972) produce no geochemical evidence of proximity to a plate margin. Possibly (MATTHEWS, 1978-a) there is more to be learned about the Lizard Complex by attempting comparisons with the Cabo Ortegal Complex in northwest Spain.

The basement high is to be regarded as continuing northward as far as the major fracture which is suggested to have controlled the huge change of thickness in the Lower Devonian. The high may have a further significance. It is conceivable

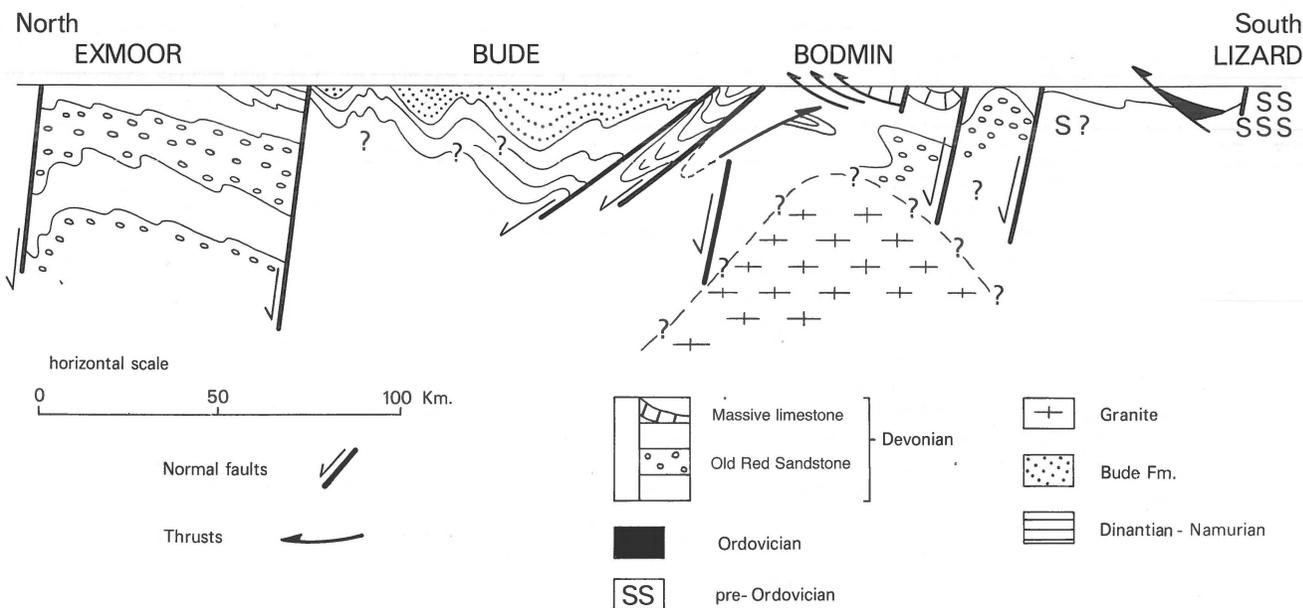


Fig. 1
Sketch section to illustrate general structural relationships in southwest England. Gross vertical exaggeration. Modified from Matthews (1977, fig. 5) to emphasise Bude Formation and granite.

ably the site from which Devonian rocks proceeded northward, under gravity, to produce the flat-lying, north-facing structures now encountered in mid Cornwall and south Devon. A notable feature of this belt is the survival in Cornwall of an inverted major foldlimb in slates. The fact that this inverted limb has not been excised by thrusting is one point in favour of an interpretation in terms of gravity tectonics. Another is the occurrence of a number of flat-lying thrusts, some of them apparently rootless, in the complementary normal (and higher) major fold-limb best seen in south Devon.

The south-facing (and tighter) structures encountered farther to the north are less readily explained. One possibility is that the southward vergence was occasioned by gross changes of facies and of thickness in rocks lower than any currently exposed – for example a change from a thick, shelf facies Middle Devonian southward into a thin basin succession of the same age. Another factor tending to produce the anomalous (in the regional context) southward sense of transport may have been the intrusion of the granite batholith. MATTHEWS, (1978-b) has argued that the youngest the Carboniferous succession, the thick, largely non-marine Bude Formation (Westphalian C) may have accumulated in a marginal trough developing adjacent to the growing batholith. MATTHEWS (1978-b) has argued that the youngest part of relatively deep burial of rocks lower in the succession and would have favoured establishment of a southward sense of transport in the tight, in places isoclinal folds now seen in Late Devonian and Early Carboniferous rocks. These are the structural units which are interpreted as having been pushed up into higher levels in the structure at a later stage in the evolution of the batholith, when the high-level cupolas were

finally emplaced. The whole history of emplacement of the batholith, on this view, may have occupied a range of time from early Westphalian (first detectable intrusion indicated by the switch from Namurian flysch to Westphalian Bude Formation) to latest Carboniferous or early Permian (last crystallisation, indicated by radiometric dates, at 285 Ma approximately) – i.e. a time span of the order of 25-30 million years.

If the preservation of these youngest rocks in the Carboniferous succession is largely due to the development of a marginal trough caused by granite emplacement, one might then ask what is the status of the 'Culm Synclinorium'? Is it, in fact, the major structural low in southwest England? MATTHEWS (1977) has proposed that a number of deep fractures striking east-west may have played a significant role in controlling stratigraphic changes and, eventually, changes of fold styles in the region. These fractures are indicated in figure 1.

The fracture in the south, already mentioned in the discussion above, and the fracture thought to exist where the two flat-lying fold styles confront one another, coincide in each case with a relative abundance of basic volcanics. The second of the two coincides with an occurrence of low greenschist-facies metamorphism in Early Carboniferous rocks (BRAZIER ET AL., 1979; it is to be noted that older, Devonian rocks away from this immediate neighbourhood show a lower metamorphic grade). A third site of major fracture is proposed in the north, where geophysical information is interpreted to mean a northward thickening of the Devonian. Possibly there is a fourth case to be included: WHITTAKER (1978) has made a brief first report of major faulting which cuts the northern limb of the large North Devon anticline and which involves downthrow to the north of the

order of 2 km or more. The collective tendency of these fractures would be to take basement progressively deeper from south Cornwall, where pre-Devonian rocks are exposed, to north Devon, where the Devonian is especially thick. The depression containing Bude Formation would appear to be a feature superimposed on the pattern of fault blocks.

REFERENCES

- Bott, M. H. P., A. A. Day & D. Masson-Smith 1958 The geological interpretation of gravity and magnetic surveys in Devon and Cornwall – *Phil. Trans. R. Soc.* 251 A:161-191.
- Brazier, S., D. Robinson & S.C. Matthews 1979 Studies of illite crystallinity in southwest England: some preliminary results and their geological setting – *N. Jb. Geol. Paläont. Mh.* 11.
- Brooks, M., M. Bayerly & D.J. Llewellyn 1977 A new geological model to explain the gravity gradient across Exmoor, north Devon – *J. geol. Soc. Lond.* 133: 385-393.
- Floyd, P.A. 1972 Geochemistry, origin and tectonic environment of the basic and acidic rocks of Cornubia, England – *Proc. Geol. Assoc.* 83: 385-404.
- Freshney, E.C. 1974 Low angle faulting in the Boscastle area – *Proc. Ussher Soc.* 1: 175-180.
- Matthews, S. C. 1975 Exmoor Thrust? Variscan Front? – *Proc. Ussher Soc.* 3: 82-94.
- 1977 The Variscan foldbelt in southwest England – *N. Jb. Geol. Paläont. Abh.* 154: 94-127.
- 1978-a Caledonian connexions of Variscan tectonism – *Z. dt. geol. Ges.* 129: 423-428.
- 1978-b Carboniferous successions in Germany and in southwest England – *Proc. Ussher Soc.* 4: 67-74.
- (in prep.) Geological models of the Exmoor region, southwest England.
- Whittaker, A. 1978 Discussion of the gravity gradient across Exmoor, north Devon – *J. geol. Soc. Lond.* 135: 353.