

Western Grampians Complex, Grampian Caledonides

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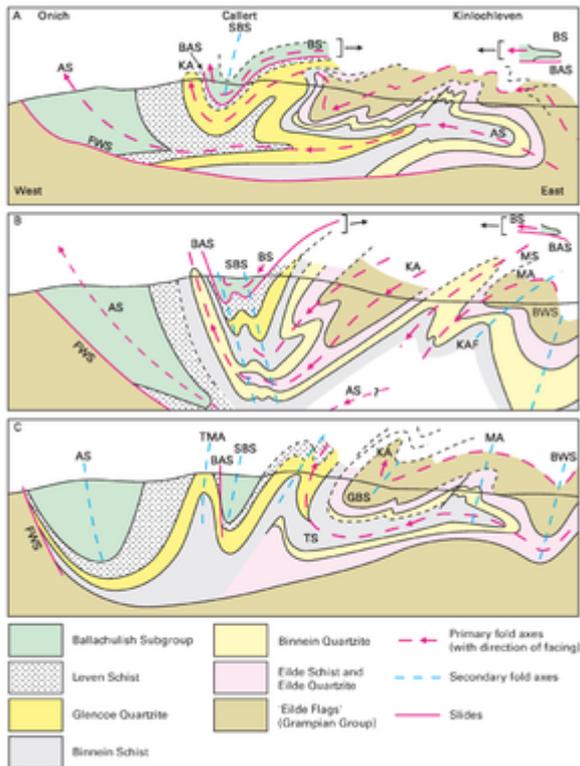
Western Grampians Complex

Former subdivisions

The folds to the north-west of the axis of the Loch Awe Syncline essentially comprise a single NW-facing major recumbent nappe, the *Islay Anticline* (Bailey, 1917; Roberts, 1974). On Islay this structure overrides the Bowmore Sandstone along the *Loch Skerrols Thrust*, which was formerly equated with the Moine Thrust (Bailey 1917, 1922; Kennedy, 1946). Subsequently, the Loch Skerrols Thrust was projected into the *Benderloch Slide* at Loch Creran, which Bailey (1992) had correlated directly across the Etive Granite Complex with the Boundary Slide of the Southern Highlands, to form what was later to become known as the '*Iltay Boundary Slide*'. This continuous major dislocation was for many years regarded as a tectonic boundary between the rocks of a composite '*Iltay Nappe*', consisting of the Islay Anticline and Tay Nappe, and those of the NW-facing recumbent folds of the '*Ballappel Foundation*'.



Block diagram of major structures in the Grampian Highlands. P915427.



Interpretations of the structure of the Loch Leven area. P915430.

More recent work has shown that stratigraphical correlation is possible between these two tectonic units (Rast and Litherland, 1970) and several models have been proposed which correlate the Islay Anticline with structures to the north-east, in what was formerly regarded as part of the 'Ballappel Foundation' (Roberts and Treagus, 1977c; Hickman, 1978; Litherland, 1982). Rast and Litherland (1970) show that the Benderloch Slide continues north-eastwards and does not connect eastwards to form an 'Iltay Boundary Slide' as originally envisaged by Bailey, so that the whole of the Western Grampians Complex as shown on [P915427](#) may now be regarded as a single tectono-stratigraphical unit.

Structural hypothesis of E B Bailey (1934)

The part of the Western Grampians Complex between Appin and Glen Roy is the most intensively studied area of the Scottish Dalradian, particularly in the well-exposed, cross-strike section along Loch Leven and Loch Eilde. The original interpretation of the regional structure by Bailey (1910) underwent several modifications, including a complete reversal of the order of stratigraphical succession and consequently the facing direction of the major folds. The final synthesis of this work (Bailey, 1934; 1960) has remained a sound basis for all subsequent work and interpretation ([P915430](#)).

Bailey recognised three NW-facing recumbent isoclinal folds, each about 15 to 20 km in amplitude. From north-west to south-east and progressing structurally upwards these are the *Appin Syncline*, the *Kinlochleven Anticline* and the *Ballachulish Syncline* ([P915430A](#)). A relatively minor recumbent fold, the *Aonach Beag Syncline*, was identified immediately underlying the Ballachulish Syncline to the east of Ben Nevis. The lower limbs of the two major synclines were considered to be largely replaced at an early stage in the deformation by tectonic slides: the *Fort William Slide* beneath the Appin Syncline and the *Ballachulish Slide* beneath the Ballachulish Syncline. Bailey made little attempt to establish a history of deformation in terms of a detailed sequence of fold phases, although

he did recognise the existence of upright secondary folds which refold the primary recumbent folds. For example, the Kinlochleven

Anticline was considered to be refolded by a major secondary complex termed the *Stob Ban Synform*; to the north-west of the synform axis, the anticline faces upwards to the north-west as the antiformal *Tom Meadhoin Anticline*, whereas to the south-east of the synform it faces downwards as a synformal anticline. In the latter area demonstrably inverted strata of the Lochaber Subgroup on the lower limb of the Kinlochleven Anticline crop-out over a cross-strike width of some 7 km to form what is known as the *Kinlochleven Inversion*.

Subsequent to Bailey's regional interpretation, more detailed investigations by several workers have concentrated on smaller-scale structures in an attempt to establish relative ages of the observed folds in a more complete structural sequence. Understandably, this has led to much criticism of the original, relatively simple concept of early recumbent folds and later coaxial, more upright folds. Weiss and McIntyre (1957) recognised an early NW-plunging generation of folds and a superimposed later generation trending north-east, with steeply dipping axial planes. By taking no account of the larger-scale structures or overall stratigraphy, they failed to recognise any earlier recumbent folds and their main conclusions were refuted by King and Rast (1959), by Bailey (1960) and later, following more detailed work, by Treagus (1974) and Roberts (1976). Bailey's model of nappes and slides was completely rejected by Voll (1964) who explained the observed outcrop pattern in the critical Loch Creran area in terms of major facies changes. However, in a later paper, the description of a large-scale early inversion corresponding to the Kinlochleven Inversion does imply the presence of recumbent folds (Kruhl and Voll, 1975).

Two major regional models of the structure of the Western Grampians Complex have emerged as a result of the many post-1960 detailed studies of the Lochaber-Loch Leven-Appin area. These are summarised respectively by Roberts and Treagus (1977c) and Hickman (1978).

Structural hypothesis of J L Roberts and J E Treagus (1977)

The hypothesis proposed by Roberts and Treagus (1977a; 1977b; 1977c) is based largely upon detailed studies in the Ardsheal Peninsula (Treagus and Treagus, 1971), around Ballachulish (Roberts, 1976) and around Kinlochleven (Treagus, 1974). It also draws upon the authors' experience in adjoining areas of the South-west Highlands (Roberts, 1974a) and the Glen Orchy area (Thomas and Treagus, 1968; Roberts and Treagus, 1975). The geometry of the major fold structures established by Bailey is largely confirmed, but some of Bailey's stratigraphical correlations are modified and the recognition of primary and secondary structures is rationalised ([P915430B](#)). A problem of any regional synthesis of this area is that many structures are interrupted by the later granitic complexes of Etive and Rannoch Moor and large areas are covered by lavas.

Three major phases of deformation are recognised. Other minor phases have been identified locally, but in the overall synthesis Roberts and Treagus (1977c) ignore these local phases in renumbering the major phases, and the regional structure is interpreted in terms of four major D_1 folds, two major D_2 folds and a late ' D_3 ' dome structure, probably equivalent to the D_4 of other authors ([P915430B](#)).

D1 folds

The Appin Syncline is confirmed as a primary fold and is traced from Ben Nevis, through a composite set of folds on the Ardsheal Peninsula, to Lismore; the Kinlochleven Anticline is correlated with the Islay Anticline, via the *Airds Hill Anticline* at Loch Creran; the Ballachulish Syncline is correlated with the *Beinn Donn Syncline* of Loch Creran and then with the Loch Awe Syncline; the

NW-facing *Glen Creran Anticline* is correlated with the SE-facing Ardrishaig Anticline. Both the Islay Anticline and the Loch Awe Syncline were regarded by Bailey as secondary structures. However, Roberts and Treagus agree with subsequent workers who interpreted them as primary folds (e.g. Cummins and Shackleton, 1955; Shackleton, 1958; Rast, 1963; Borradaile, 1973; Roberts, 1974a).

D2 folds

The Stob Ban Synform of the Ballachulish area is confirmed as a secondary fold which refolds not just the Ballachulish Syncline but also most of the D_1 folds of the Loch Creran area; a composite set of D_2 folds which deforms rocks of the Kinlochleven Inversion east of the Stob Ban Synform is termed the *Kinlochleven Antiform*.

D3 folds

A broad antiform in the area around Glen Orchy is shown on [P915427](#) as part of the Central Grampians Complex, since it folds rocks of the Glen Orchy Nappe below the Boundary Slide. This *Glen Orchy Antiform* was recognised by Bailey (Bailey and Macgregor, 1912) and by Thomas and Treagus (1968). It was first described as a late structure by Roberts and Treagus (1975). The fold has the form of a broad dome and deforms both primary and secondary structures as seen by the deflection of strike and fold axes from the Dalmally area north-westwards and then north towards Ballachulish. Possible correlations around this deflection have been given above. Correlations across the dome have been proposed by Roberts and Treagus (1977c) and include the correlation of the D_2 upward-facing Stob Ban Synform, north-west of the dome, with the downward and SE-facing D_2 Ben Lui Antiform south-east of the dome. Both folds are underlain by major slides, beneath which the Kinlochleven Antiform in the north-west is inverted across the dome to correlate with the synformal *Beinn Chuirn Synform* to the south-east. The *Benderloch Slide* of the Loch Creran area extends north-eastwards and is considered to continue as the Ballachulish Slide to the north of the Ballachulish Granite ([P915427](#), block B). It is then folded around the closure of the Stob Ban Synform and trends back southwards to Glen Etive. Roberts and Treagus (1977c) link it across the Etive Granite Complex with a slide which is folded around the Glen Orchy Antiform in the Dalmally area, to propose a single, continuous Boundary Slide. Since it is folded by D_2 folds, the initiation and main movement on the slide clearly occurred during the D_1 deformation phase, although intense D_2 movements identified in the Dalmally area indicate local reactivation (Roberts and Treagus, 1975).

The structural interpretation proposed by Roberts and Treagus (1977c) recognises primary D_1 folds that are believed to root steeply at depth and to fan outwards at higher levels to face north-west and south-east, much as proposed in earlier interpretations. The root zone is seen as originating in Grampian Group rocks, lying at depth to the north-west of the Glen Orchy Antiform. By correlating the D_2 folds and accompanying slides across this flexure, it is possible to envisage a consistently facing set of recumbent D_2 folds, collectively referred to as the Glen Orchy Nappe. These folds affect the deeper parts of the primary structures, as seen in the north-eastern part of the area, which are thus correlated with higher level structures of the Loch Awe Syncline and Tay Nappe to the south-west.

Criticisms of the model proposed by Roberts and Treagus are founded mainly upon different interpretations of the age of individual major structures and on the correlation of folds along strike. Thomas (1979) takes a different view of the Glen Orchy Antiform, based in part upon detailed work on continuation structures to the north-east, and regards Roberts and Treagus' D_2 nappes such as the Beinn Chuirn Synform as primary D_1 structures, albeit with a strong ' D_3 ' overprint. He also casts doubts upon the interpretation of the large-scale swings of strike to the south-west of the Glen Orchy Antiform, which are necessary to accommodate the proposed D_2 nappes. Litherland (1982) doubts

the magnitude of the deflections of fold axes and is critical of the proposed correlations between high-level and low-level D_1 folds. His detailed work in the Loch Creran area suggests alternative correlations involving less deflection of the fold axes. Thus he correlates the Islay Anticline with the Glen Creran Anticline (rather than the Airds Hill/ Kinlochleven Anticline), and the Loch Awe Syncline with the *Beinn Sgulaird Syncline* (rather than the Beinn Don/Balachulish Syncline). He also supports the possibility of a link between the Loch Skerrols Thrust and the Benderloch Slide, which he regards as an early D_1 reactivation of a possible synsedimentary fault. The Loch Creran area is described by Litherland (1982) almost entirely in terms of NE-trending upright D_1 folds, becoming recumbent to the east, in a simple 'mushroom-like' structure. No secondary folds of regional extent are recognised and the swing of strike and D_1 fold axes north-westwards towards upper Loch Creran is attributed to the presence, during D_1 , of a deep seated basement massif in the area now occupied by the Cruachan Granite.

Structural hypothesis of A H Hickman (1978)

A more radical approach to the structure of the area between Glen Roy and Lismore is taken by Hickman (1978) who interprets many of the large-scale structures, identified as primary by Bailey and as D_1 by Roberts and Treagus, as secondary (D_2) structures. (The numbering of phases is compatible with the regional scheme of Roberts and Treagus.) Thus large-scale recumbent folds are recognised only in the south-eastern part of the section, between Kinlochleven and Loch Treig, where the presence of the D_1 Kinlochleven Anticline, with its extensive inverted lower limb, is confirmed ([P915430C](#)). However, the underlying D_1 syncline, which Bailey took to be a south-eastern extension of the Appin syncline, is redefined as a separate *Treig Syncline*, identified during new mapping in the Loch Treig area.

In the north-western part of the section, the Appin Syncline and the Tom Meadhoin Anticline are reinterpreted as separate upright D_2 folds, rather than recumbent D_1 structures ([P915430C](#)). In this respect the model follows the interpretation of Bowes and Wright (1967; 1973), based upon detailed mapping in the Ardsheal Peninsula. Hickman traces the Appin Syncline from Glen Roy through Ardsheal to Lismore where its equivalent, the *Balygrundle Syncline*, refolds an early isoclinal fold. The Tom Meadhoin Anticline is an upright structure along its entire length from Glen Nevis to the equivalent Airds Hill Anticline in Benderloch. Hickman maintains that there is no evidence that either structure becomes recumbent to the south-east to connect beneath the D_2 Stob Ban Synform with the Kinlochleven Anticline and Treig Syncline. Since the Appin Syncline is regarded as a D_2 structure, it is also suggested that the underlying Fort William Slide, which cuts its north-western limb, is also D_2 .

The existence of the Ballachulish Syncline and the subsidiary Aonach Beag Syncline is refuted, largely on the basis of a stratigraphical interpretation which suggests that there is no repetition of strata. Thus the Stob Ban Synform is regarded as a simple upright D_2 syncline in a continuous right-way-up sequence, a conclusion also reached by Voll (1964) and Rast and Litherland (1970) in the Loch Creran area to the south-west ([P915430C](#)). This D_2 structure extends north-eastwards into the Glen Roy area.

Most of Hickman's interpretations and conclusions have been contested by Roberts and Treagus (1980), essentially on the grounds that the evidence for the nature and age of the major folds is not substantiated by the small-scale evidence. Litherland (1982) accepts Hickman's proposals as compatible with his own regional 'mushroom' model. However, several of the upright folds interpreted as D_2 by Hickman are interpreted as D_1 by both Roberts and Treagus and by Litherland (e.g. the Airds Hill Anticline and Beinn Donn Syncline). Thus the matter is far from being resolved, with many mutually incompatible features present in the various models.

The two principal modern interpretations (Roberts and Treagus, 1977c; Hickman, 1978) both accept much of the near-surface fold geometry of the original structure proposed by Bailey (1934). They differ considerably in the way in which these folds are projected to depth and are correlated across strike. Consequently there are highly significant differences in the assignation of relative ages to individual folds, much of the evidence for which depends on the detailed observation and interpretation of minor structures. Correlations of structures along strike are still problematical, and these have an important bearing upon vertical sections through different levels of the nappe pile. These sections are the basis for the various theories of structural evolution of the Grampian Highlands which will be discussed in more detail later.

North-eastern Lochaber

Mapping by the BGS around Glen Spean and Glen Roy has confirmed the presence of the major folds recognised in this area by Hickman (1978). However, the upright Appin Syncline, on the west side of Glen Roy, is regarded, as in previous interpretations, as an early fold contemporaneous with recumbent D₁ folds, such as the Treig Syncline, identified farther east. Later coaxial upright folds, including the D₂ Stob Ban Synform, tighten the early upright structures. Late cross-folds and related fabrics result in local complexity. The Fort William Slide has been traced into this area and around the closure of the Appin Syncline, but it dies out eastwards, where the Lochaber Subgroup appears to rest conformably on the Grampian Group. Between Spean Bridge and Loch Leven there is no high-strain zone at the position of the slide and the geometry of sedimentological features on either side lead Glover (1993) to suggest that, here at least, the slide is an unconformity developed during Appin Group times.

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