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NORTH-SOUTH GEOFRACTURES IN SCOTLAND AND IRELAND

Sirs—Russell, in his recent (1972) and earlier papers (1968, 1969), attempts to explain features of Carboniferous crustal evolution in Scotland and Ireland by reference to initiation of lithosphere separation in the north Atlantic area. Although such a general approach is stimulating and may lead to new interpretations of the evolution of continental borderlands and young continental margins (e.g. Wright 1968), I believe that Russell’s application can be criticised in several respects:

(a) In Ireland, Russell (1968, 1972) defines three major geofractures. Geo-fracture 1 is based on the north-south alignment of four major base-metal deposits. However, geofractures 2 and 3 do not uniquely determine major base metal occurrences for only two out of four deposits fall on the supposed lines of the geofractures (Russell 1972, fig. 3 and p. 76, 81). The Kingscourt fault, partly defining geofracture 3, clearly affects both Carboniferous and Mesozoic strata (fig. 2) and may therefore be wholly post-Carboniferous in age.

In Scotland, Russell defines three more north-south trending geofractures. Geofracture 4 corresponds to a crustal inhomogeneity of unknown age and origin. Its existence depends solely on acceptance of geofractures 5 and 6 (Russell 1972, p. 82). Geofracture 5 is based on the north-south alignment of the Clackmannan syncline, the Leadhills/Wanlockhead lead-zinc deposit and the Thornhill syncline. In fact, the axis of the Clackmannan syncline (a tectonic structure related to east-west compression) does not coincide with the axis of the intra-Carboniferous sedimentary basin, the Kincardine basin. Thus Francis et al. (1970, p. 186) state ‘...the axis of maximum deposition lies more than four miles east of the axis of the syncline’. A more important criticism concerns the status of the Thornhill syncline. This is located on the Southern Uplands block, a persistent structural high throughout the Carboniferous (George 1958; Taylor et al. 1971, fig. 17). Although the block was ‘submerged’ and underwent slight subsidence in the Middle and Upper Carboniferous, in no sense was the Thornhill area a contemporary, structural/sedimentary basin. Only a total of 200 m of Carboniferous strata are present (Greig 1971), compared with more than 3 km in the Northumberland basin to the south (Day 1970). Preservation of this thin, attenuated sequence is almost certainly due to Permo-Triassic or later downfaulting (compare trend of Thornhill outlier to that of other Permo-Triassic sedimentary basins in the Southern Uplands; Bott and Masson-Smith 1960). Geofracture 6 is based largely on the supposed north-south alignment of the East Fife/Midlothian syncline.
existence of this structure as a Carboniferous sedimentary basin is demonstrated by Goodlet (1957). However, isopach trends are complex (north-north-east to south-south-west, north-east to south-west and east-west) but do not trend north–south as Russell implies (compare Russell 1972, fig. 1 with Goodlet 1957, fig. 2).

In conclusion, most of Russell's geofractures seem to be based on poor or faulty evidence. For '... major extension failures in the base of the upper crust ...' (Russell 1972, p. 75) they have left remarkably few clues as to their position.

(b) The north–south trend of the postulated geofractures leads Russell to suppose that the intra-Carboniferous stress field was dominated by east–west tension (Russell 1972, p. 75, 82). This hypothesis may be tested by examining the trends of major syndepositional faults or hinge-lines which are so characteristic of Carboniferous sedimentary basins in northern England, Scotland and Ireland (see Bott 1967; Johnson 1967). These are almost entirely normal faults of north–east—south–west to east–west trends. They indicate a tensional stress field orientated approximately north-west—south-east relative to present poles. The faults often delimit major sedimentary basins which show elongation and isopach trends in north–east—south–west directions (George 1958, figs. 11, 23, 26). Even within the complex Midland Valley basin, north–east—south–west faults and hinge-lines were prominent (Richey et al. 1925; Richey et al. 1930). Thus in Ayrshire, McLean (1966 p. 239) states: 'The important north–east—south–west faults ... give rise to large anomalies. ... It is inferred that they moved as normal faults in Carboniferous times.' Also, the Ochil fault (east–north–east to west–south–west), which cuts out geostructure 5, is thought to have exerted control over sedimentation (Francis et al. 1970, p. 247). The Burntisland Arch, which separates geostructures 5 and 6, trends north–north–east to south–south–west. A control by partial melting at depth under the arch (?)upper mantle) is attractive, for the strata over the arch axis contain a great variety of intrusive and extrusive alkaline igneous rocks, whereas the adjacent depositional troughs contain few (Goodlet 1959; Francis 1967, fig. 9). Uplift of the arch probably led to the development of the 'yoked' Kincardine and East Fife/Midlothian sedimentary basins on either side (contrast Russell 1972, fig. 1).

In Ireland, north–east—south–west normal faults figure prominently in Russell's 1968 account. Some of these, and other similarly trending faults (see George 1958, fig. 11; Pitcher et al. 1964, p. 254; Macdermot and Sevastopulo 1971), were operative or marked contemporary hinge-lines during Carboniferous times.

The trend of syndepositional fault lines are also those of numerous volcanic necks of Carboniferous age in the Midland Valley of Scotland (see Francis 1967, fig. 9, but not alignments along strike-slip faults in Fifeshire). In southern Scotland, isopachs for the Birrenswark lavas show pronounced north–east—south–west trends and indicate eruption from fissures of tensional origin (my
unpublished work). These lavas, together with a large number of slightly younger necks and plugs (Lumsden et al. 1967), define a structural north-eastern margin to the Northumberland Basin (Leeder 1971).

All the above evidence indicates that a tensional stress field dominated the upper crust during much of the Carboniferous in northern Britain and Ireland (also in Maritime Canada, see Leeder 1971). However, the orientation of the direction of relative tension was dominantly north-west–south-east (partly inherited Caledonoid trend) and not east–west as stated by Russell on the evidence of his geofractures alone.

(c) Even accepting that geofractures 2–6 existed and also reflected the intra-Carboniferous stress field, there are grave difficulties in postulating lithosphere separation in the north Atlantic during Carboniferous times. Thus the break-up of the Mediterranean carbonate platform (Hallam 1971), the intrusion of dykes in Atlantic U.S.A., Brazil and North Africa (May 1971) and palaeomagnetic evidence (Larson and LaFuntain 1970) all indicate that the first signs of initiation of lithosphere separation in the general North Atlantic area occurred in the Triassic or later. Nearer to home, the first linear magnetic anomaly off Porcupine Bank is dated at around 80 m.y. (Scrutton et al. 1971). Porcupine Bight does not have oceanic structure (Gray and Stacey 1970) and Scrutton et al. (1971) postulate a vertical subsidence model for the bight in the Mesozoic. Laughton (1971) dates the initiation of seafloor spreading between Labrador and Europe at around 80 m.y.

Even allowing a reasonable time interval between the initiation of rifting and the formation of the first ocean crust, an enormous interval still remains (c. 100 m.y.) which is difficult to explain if rift initiation off western Ireland began in the Carboniferous.

Concerning the Rockall Trough (see Russell 1972, fig. 3), Scrutton and Roberts (1970), Bott and Watts (1970) and Bailey et al. (1972) believe this to have formed by a short-lived period of spreading in the Mesozoic (pre–80 m.y.). In view of the occurrence of post-Hercynian, fault-bounded sedimentary basins of Triassic (?Permo-Triassic) age in Scotland (Bott and Masson-Smith 1960; Mansfield and Kenneth 1963; Hall 1970; Steel 1971), the northern Irish Sea (Bott 1965; Bott and Young 1970) and northern England (White 1949) it is likely that the first crustal stresses due to initiation of lithosphere separation in Rockall occurred at this time. The sedimentary basins are deep and often cut the structural grain of Lower and Upper Palaeozoic strata. They occur in former, Carboniferous, blocks and basins, apparently without preference. Many of the basins trend north–south or north-west–south-east. Others show ‘inherited’ Caledonoid trends. All probably developed by brittle failure in the upper crust (Bott 1965, p. 196).

In conclusion, I believe that much of Russell’s work is erroneous in the following respects:

(a) the existence of the majority of geofractures
(b) the existence of an east–west tensional stress field
(c) the initiation of lithosphere break-up in the north Atlantic during the Carboniferous.

The post-Hercynian tensional stress field (?initiation of Rockall Trough), the late Carboniferous stresses of Hercynian origin (with tholeiitic intrusives) and the intra-Carboniferous tensional stress field (with alkaline extrusives and intrusives) must all be rigidly separated as to cause and effect.

The origin of the intra-Carboniferous stress field is partly explained by Bott’s post-orogenic mantle-flow theory (Bott 1964, 1965). However, this does not account for the striking spatial coincidence between alkaline/alkali-basalt volcanism and block/basin margins or block areas (e.g. Northumberland Basin, Leeder 1971; Burntisland Arch, Goodlet 1959). A partial melting model (?upper mantle) causing block upwarp, and downwarp by normal faulting in adjacent areas of the upper crust may be more appropriate. Work continues on this problem.

References


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Sirs—Leeder draws attention to his forthcoming paper but from the brief preview (above) it is not possible to assess the relative merits of the two explanations for some of the sedimentary basins in the Midland Valley. Allowing that the Caledonian basement, Carboniferous lavas and different rates of sedimentation complicate the issue, it does not appear that his preferred hypothesis precludes the geofracture concept. Leeder agrees that a tensional stress field dominated the upper crust during much of the Carboniferous in northern Britain and Ireland but asserts that the orientation of the axis of relative tension was mainly north-west—south-east, since hinge lines, faults and the distribution of volcanic necks trend
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north-east—south-west. It is not possible, however, to derive the orientation of palaeo-tensile stress trajectories from fractures that are likely to have been controlled by underlying Caledonoid planes of weakness. On the other hand the postulated north-south geofractures are for the most part unrelated to the earlier structural grain and their continuity implies initiation at a depth where the lithosphere was mechanically homogeneous. They are, therefore, presumably the result of east—west relative tension. I must emphasise that 1000 m of differential vertical movement took place along the north—south trending Kingscourt Fault in the Visian (Jackson 1955, pp. 138-139) which implies an east—west relative tension acting at that time. After the formation of the geofractures, again it is not possible to obtain the orientations of the stress axes.

Leeder believes there are ‘grave difficulties’ in postulating an early age for lithosphere separation in the North Atlantic and ranges as far afield as Brazil and the Mediterranean to support his opposition as well as citing palaeomagnetic results which do not have the required precision to indicate ‘first signs of lithosphere separation’. We do know, however, that at least there was a seaway between Norway and Greenland connecting the Boreal Ocean with the Zechstein Sea in Upper Permian times (Brinkmann 1960, p. 63 and see Maync 1961, fig. 1).

Faced with the knowledge that Rockall Trough is pre-Cenozoic it is not surprising that most workers assume opening to have taken place in the Mesozoic. Regarding the trough, Leeder says, ‘In view of the occurrence of . . . fault-bounded sedimentary basins of Triassic (?Permo-Triassic) age in Scotland . . . it is likely that the first crustal stresses due to initiation of lithosphere separation in Rockall occurred at this time’. In Scotland many of these basins bottom in the Permian and in one or two cases in the Upper Stephanian (Mykura 1965; Wagner 1966). So even applying Leeder’s own argument, the stresses resulting from the initiation of lithosphere separation operated as far back as near the end of the Carboniferous period (cf. Bott 1971, pp. 321-322). I suggest that the stresses that caused this separation began to act in Lower Carboniferous times.

REFERENCES


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