matters arising

Spreading rate in Iceland

WALKER has proposed a new interpretation of Icelandic tectonics in which he recognises the existence of a number of parallel or *en echelon* rift zones[1]. He showed that the aggregate width of the active zones is greatest in southern Iceland and, by postulating that this width is proportional to spreading rate, inferred that the spreading rate in southern Iceland may be three to four times faster than in northern Iceland or the adjacent mid-ocean ridges.

There is one serious objection to this idea. An excess spreading rate in the southern part of Iceland would generate a greater length of lithospheric plate, and either this would have to be taken up in a zone of plate consumption, or else it would result in major compressive deformation of at least one of the plates. There is no evidence that either effect occurs, and I suggest the following explanation of the observations.

The increased widths of young rock outcrops and the greater number of active volcanic centres and thermal fields in the south of Iceland, cited by Walker in support of his hypothesis, are in fact very good evidence of increased magmatism, though they do not necessarily imply an increased spreading rate. The excess material produced can be accommodated by crustal thickening rather than accelerated spreading, thus avoiding the plate-tectonic complications mentioned above. There is abundant geophysical evidence that there is in fact a thickened crust under Iceland as a whole[2], though it is not clear whether the thickening increases towards the south. It seems quite possible that the resultant thicker lithosphere would distribute tectonic stresses over a wider area, giving rise to a pattern of rift zones such as that observed by Walker, and obviating the need to assume that the width of the active zones is proportional to spreading rate.

The same reasoning may be applied to Afar and the Azores, each of which has an excessively thick crust[3,6] and complex rift zones (ref. 4 and D. C. Krause and B. A. McGregor, unpublished) analogous to those described for Iceland. Schilling[5] has proposed that the thicker crusts in all three areas arise from excess magmatism generated by mantle blobs or plumes, and Walker's observations of increased magmatism in southern Iceland represent a partial confirmation of that, and suggest that it is in southern Iceland that the present plume discharge is centred.

ROGER SEARLE

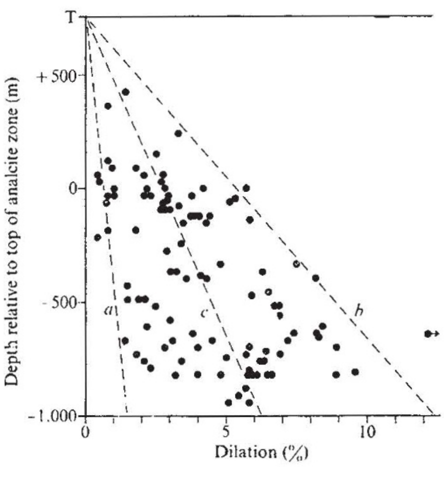
Institute of Oceanographic Sciences, Wormley, Godalming, GU8 5UB, UK

1 Walker, G. P. L., *Nature*, **225**, 468–471 (1975).
2 Palmason, G., *Societas Scientarium Islandica*, **40**, 187pp. (1971).
3 Searle, R. C., in *Afar Depression of Ethiopia* (edit. by Pilger, A., and Rosler, A.), 113–120 (E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, (1975).
4 Tazieff, H., Varet, J., Barbei, F., and Giglia, G., *Nature*, **235**, 144–147 (1972).
5 Schilling, J. G., *Nature phys. Sci.*, **242**, 2–5 (1973); *Nature*, **242**, 565–571 (1973); *Earth planet. Sci. Lett.* **25**, 103–115 (1975).
6 Searle, R.C., *Geophys J. R. astr. Soc.*, **44**, 537–546 (1976).

WALKER REPLIES—I fully accept the awkward implications of excess spreading in the southern part of Iceland, as raised by Searle. Some excess spreading could, however, be accommodated by an outward bulging of this part of Iceland, but a determination of its extent must await the delineation of magnetic strip anomalies around the east of the country. Some excess material produced by volcanism could be accommodated by the observed crustal thickening.

An alternative possibility is that basalt is destroyed on a large scale low down in the Icelandic crust, and this is supported by a significant anomaly in the geology of Iceland. This anomaly, the existence of which has apparently not hitherto been pointed out, is the low dyke intensity gradient in the Icelandic dyke swarm. It should be explained that quantitative studies of the Tertiary swarm have been made at many sites in the fjordlands of eastern Iceland[1,2], and everywhere reveal that the dyke intensity increases linearly downwards. On Fig. 1 all the best dyke intensity data, quoted as a percentage dilation, are plotted against depth relative to the top of the analcite zone; this zeolite zone boundary is the most convenient datum level, and is believed to lie 750 m below the original (pre-erosion) top of the Tertiary crust. Much scatter appears on Fig. 1, because at any one level the dyke swarm varies in intensity according to the position of the measuring site relative to local sub-swarms. The intensity gradient varies between 1% dilation per 140 m and 1% per 1,100 m depth, and the median gradient is ~ 1% per 280 m depth.

Fig. 1 Plot of variation in percentage dilation of the dyke swarm against depth in the Tertiary lava pile of eastern Iceland, relative to the top of the analcite zeolite zone. Each dot is based on the measurement of dyke thicknesses in a strip of well-exposed country on average 1 km long. *a*, 1% dilation per 1,100-m gradient; *b*, 1% per 140-m gradient; *c*, 1% per 280-m gradient.



A requirement of crustal spreading by the conventional dyke injection model is that the dyke swarm intensity should attain 100% at the base of the crust. Extrapolation of the measured intensity gradient yields 100% dilation at a depth between 14 and 110 km, or 28 km if the median gradient is taken. The crustal thickness is not known for eastern Iceland, but from similar areas elsewhere in Iceland is likely to be ~ 15 km (refs 3, 4). A discrepancy therefore clearly exists: if the median intensity gradient is taken, then > 10 km of crust would seem to be missing.

The magnitude of the discrepancy is critically dependent on the nature of crustal layer 3: whether it consists of metamorphosed basalts[3], or is largely made of intrusive sheets[5]. Layer 3, the lowermost crustal layer, with a P-wave velocity averaging 6.5 km s^{-1}, is found beneath the whole of Iceland and in eastern Iceland occurs on average ~ 3 km below sea level (or 4 km below the original top of the crust). At the top of layer 3 the extrapolated dyke intensity is between 3.6 and 29%, or 14% taking the median gradient. If layer 3 consists largely of an intrusive sheet swarm, then the basaltic lavas in the layer are in effect greatly attenuated by the sheets and the discrepancy is therefore greatly increased. if the median gradient is taken, then several tens of kilometres of crust may be missing.

There is another relationship which seems to support the same general con-