matters arising

Seismic evidence for Mesozoic sedimentary troughs on the Hebridean continental margin

JONES'S interpretation of seismic refraction lines on the NW British continental shelf[1] provides welcome corroboration of the Mesozoic sedimentary basin between the Flannan Isles and Lewis first postulated by Bullerwell (see refs 2–4). As we have already suggested that the Rockall Trough developed by seafloor spreading in the early Permian[5–7], we wish we could also welcome Jones' interpretation of the structure of the NW British margin, which suggests that the development of the Trough, at least in part, goes back to Permo-Triassic times. However, we interpret the high velocity refractor ($V_P = 4.4 \pm 0.3$ km s^{-1}) as corresponding merely to the top of a layer of Palaeocene–Eocene basalts, because (1) regional mapping and study of interval velocities using commercial 24-fold reflection lines and aeromagnetic coverage shows that basalts extend southwards from the Faeroes over almost the whole of the Rockall Trough north of Anton Dohrn seamount (as was suggested by Roberts[8]) and also over the outer NW Scottish shelf from the Wyville–Thomson Ridge to about 58° N; (2) the high-frequency negative magnetic anomaly field characteristic of these basalts at shallow depth is clearly seen both on Jones' magnetic profile[1] and on the IGS aeromagnetic map[2]; and (3) the refractor velocity is similar to that for basalts elsewhere on the NW European margin[9–11], but probably too high for Permo–Triassic sediments; although the interval velocity for pure Permo–Triassic sandstones at ~4 km depth in wells in the Viking Graben[12] and West Shetland Basin[13] can exceptionally attain values as high as 4.5 km s^{-1}, the usual range of velocity is 3.6 – 4.1 km s^{-1} for Permo–Triassic sandstones in these areas. The Permo-Triassic beneath the Little Minch has a $V_P \sim 3.9$ km s^{-1}, obtained by refraction shooting[14]. Above the basalts, the refractors with apparent $V_P \sim 2.8$–3.1 km s^{-1} could be due to Quaternary glacial till; measurements on data from the West Shetland area show that glacial till up to 100 m thick can have interval velocities $V_{int} \sim 2.6$–2.9 km s^{-1}. However, the Tertiary sediments between the Quaternary and the basalts have a lower V_{int}, so the top of the basalts is somewhat shallower than that given by Jones' profiles.

The gravity suggests that there may be sediments beneath the basalts, but we have no way of estimating their age. Thus we conclude that Jones' results have no relevance to the early evolution of the Rockall Trough, and, furthermore, his attempt to estimate the hydrocarbon prospects of this part of the margin is misleading; prospects here are poorer than elsewhere, because of the basalt cover. However, our reconstruction[7] suggests that in mid-Jurassic times Orphan Knoll was situated at the south-east margin of the Rockall Trough. The neritic Bajocian sands found beneath the Knoll[15] may therefore occur elsewhere along the margins of the Trough, and may also overlie downfaulted basins of Carboniferous age on the outer continental margin, developed during an intracontinental rifting phase[6] before early Permian spreading. Therefore along the margins clear of Tertiary basalt cover, for example, the south-east Faeroe–Shetland Trough margin between 60 and 62° N, and both margins of the Rockall Trough south of about 58° N, the hydrocarbon prospects may be very good.

D. K. SMYTHE
N. KENOLTY
Institute of Geological Sciences, Marine Geophysics Unit, Murchison House, West Mains Road, Edinburgh, UK

M. J. RUSSELL
Department of Applied Geology, University of Strathclyde, James Weir Building, 75 Montrose Street, Glasgow, UK

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JONES REPLIES—The uncertainties involved in estimating stratigraphical ages from seismic velocities in the Hebridean region were emphasised in my paper[1] and I am therefore grateful to Smythe *et al.* for their early comments. Although these are primarily based on their unpublished reflection profiles, velocity data and regional maps, some further pertinent remarks can be made.

Smythe *et al.* accept my conclusion that Mesozoic sediments occur immediately west of Lewis, an area in which the age of the sediment cover was previously undefined[2]. My inference that Mesozoic sediments also lie close to the sea floor north-west of the Flannan Ridge is based on the observation that the 2.8–3.1 km s^{-1} values on lines JM-9 and JM-10B are significantly higher than published velocities in Tertiary–Quaternary sequences[1]. Thus constrained, I was unable to interpret the deeper 4.0–4.4 km s^{-1} refractor as the top of a pile of Tertiary basaltic lavas. Using 'measurements on data' from an unspecified location near the Shetlands, Smythe *et al.* attribute the 2.8–3.1 km s^{-1} values to glacial till, which then allows them to suggest that the 4.0–4.4 km s^{-1} layer is much younger than I proposed. As they do not indicate the water depths in which the high Pleistocene velocities were determined, the method of measurement and also local velocity changes, it is not clear whether a direct comparison with shallow refractor velocities near the Flannan Isles is justified. Are their 2.6–2.9 km s^{-1} values sufficiently typical of the Pleistocene to permit an extrapolation over a large area? Their results may be of regional importance but as careful mapping by Eden[3] and others has revealed marked and often rapid lateral variations in Pleistocene deposits off northern Britain, Smythe *et al.* need to provide additional evidence to show that thick, high velocity boulder clay is likely to lie near the shelf break, some 300 km south-west of the Shetlands. They must also account in their interpretation for the presence of pre-Quaternary reflectors[4,5] within the westwards continuation of their proposed Quaternary sequence.

In their discussion of the 4.0–4.4 km s^{-1} refractor, four references are misleadingly quoted (their refs 10–13) to add weight to their contention that it represents Tertiary basaltic lavas and not pre-Jurassic sediments. Seismic velocities for basalts are omitted in ref. 10. Talwani and Eldholm[11] ascribe velocities near 4.4 km s^{-1} on the Norwegian margin, not to basalts, but to pre-Cretaceous sediments. A limiting 4.5 km s^{-1} for Permo–Triassic sediments is not included in their refs 12, 13. My values of 4.0–4.4 km s^{-1} seem to be well