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 $V_{\text{int}} \sim 2.6$–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 intra-continental 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.

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1. Jones, E. J. W. *Nature* **272**, 789–792 (1978).
2. Bullerwell, W. *Aeromagnetic Map of Part of Great Britain and Northern Ireland, Sheet 12* (Geol. Surv. G.B., 1968).
3. Eden, R. A., Wright, J. E. & Bullerwell, W. *Rep. Inst. geol. Sci.* No. 70/14, 111–128 (1971).
4. Dunham, K. *The Sub-Pleistocene Geology of the British Isles and Adjacent Continental Shelf* (Inst. geol. Sci., 1972).
5. Russell, M. J. in *Implications of Continental Drift to the Earth Sciences* (eds Tarling, D. H. & Runcorn, S. K.) 581-597 (Academic, London, 1973).
6. Russell, M. J. *Scott. J. Geol.* **12**, 315-323 (1976).
7. Russell, M. J. & Smythe, D. K. in *Petrology and Geochemistry of Continental Rifts* (eds Neumann, E. R. & Ramberg, I. B.) 173–179 (Reidel, Dordrecht, 1978).
8. Roberts, D. G. *Deep-Sea Res.* **18**, 353–360 (1971).
9. Pálmason, G. *Tectonophysics* **2**, 475–482 (1965).
10. Chalmers, J. A., Dobinson, A., Mould, A. & Smythe, D. K. *Geophys. J. R. astr. Soc.* **49**, 288 (1977).
11. Talwani, M. & Eldholm, O. *Bull. geol. Soc. Am.* **83**, 3575-3606 (1972).
12. Kent, P. E. *J. geol. Soc. Lond.* **131**, 435–468 (1975).
13. Cashion, W. W. in *Offshore Europe 75*, Paper OE-75-216 (Spearhead, Kingston-upon-Thames, 1975).
14. Smythe, D. K., Sowerbutts, W. T. C., Bacon, M. & McQuillin, R. *Nature phys. Sci.* **236**, 87–89 (1972).
15. Laughton, A. S. *et al.* in *Init. Rep. DSDP* Leg 12 33–159 (1972).

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

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within the permissible range for Permo-Trias as the refraction profiles of Browitt[6] show velocities of 4.6–4.8 km s^{-1} at a level in the West Shetland Basin where Cashion's sections[7] reveal thick sediments of this age. Thus, pre-Jurassic deposits cannot be dismissed at the depths I have indicated. They correctly note that magnetic anomalies occur over the 4.0–4.4 km s^{-1} layer but, rather than arising from Tertiary lavas, these can be interpreted as reflecting small basic intrusions within a thick Mesozoic section and magnetisation contrasts in the Precambrian basement.

In denying that my results are relevant to the early evolution of the Rockall Trough, Smythe *et al.* have ignored my demonstration of major faulting and crustal subsidence. As they accept a Mesozoic age for the Flannan Trough they must also accept the existence on the continental margin of NNE-trending faults which were active during Mesozoic time. As these run approximately parallel to the continental slope north of St Kilda and have increasingly larger displacements northwestwards[1], it is difficult to resist the conclusion that the faulting is directly associated with the major phase of downwarping in the Rockall Trough. My section showing thick pre-Jurassic sediments north-west of the fault-bounded Flannan Ridge is compatible with the Permian opening first suggested by Heirtzler and Hayes[8] but it does not establish that seafloor spreading took place at this time.

Commenting on petroleum prospects off northern Britain, Smythe *et al.* offer a comparison with other parts of the Rockall Trough that hinges on unpublished data and a geometrical argument which is questionable because the extent of oceanic crust in the region is unknown. Several parts of the Rockall Trough clearly deserve detailed commercial exploration, although my appraisal of prospects would be less sweeping than that given by Smythe *et al.* Moreover, in view of the geophysical indications of thick sediments and major Mesozoic faulting west of Hebrides, it seems premature for them to take a firm, pessimistic stand on a large section of the Scottish margin, especially since drilling investigations are at such an early stage.

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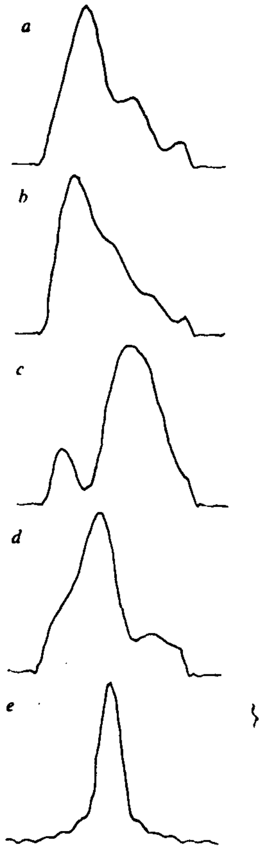
1. Jones, E. J. W. *Nature* **272**, 789–792 (1978).
2. Dunham, K. *The Sub-Pleistocene Geology of the British Isles and the Adjacent Continental Shelf* (Inst. geol. Sci., 1972).
3. Eden, R. A., Holmes, R. & Fannin, N. G. T. *Rep. Inst. geol. Sci.* No. 77/15 (1978).
4. Jones, E. J. W., Ewing, M., Ewing, J. I. & Eittreim, S. L. *J. geophys. Res.* **75**, 1655–1680 (1970).
5. Ruddiman, W. F. *Geol. Soc. Am. Bull.* **83**, 2039–2062 (1972).
6. Browitt, C. W. A. *Nature* **236**, 161–163 (1972).
7. Cashion, W. W. in *Offshore Europe 75*, Paper OE-75-216 (Spearhead, Kingston-upon-Thames, 1975).
8. Heirtzler, J. R. & Hayes, D. E. *Science* **157**, 185–187 (1967).

Object reconstruction from intensity data

GULL AND DANIELL[1] have recently proposed a new maximum entropy algorithm for the reconstruction of an object field from incomplete and noisy measurements of its Fourier transform. This new algorithm may encourage other workers to apply maximum entropy techniques to their own problems. For this reason we point out here that the application of maximum entropy techniques for object reconstruction in the absence of phase information could lead to wholly false conclusions due to ambiguities. We shall illustrate some of the problems using a specific example. Many such examples may easily be generated and the one chosen here is not unusual.

Figure 1 shows four different, real and positive objects which all give rise to the scattered intensity shown in Fig. 1*e*. Families of dissimilar objects whose Fourier transforms have the same modulus occur whenever the scattered intensity has non-zero minima[2]. Such minima indicate the presence of complex zeros in the scattered field. For each such zero there are two possible positions, which correspond to different objects whose Fourier transforms have identical moduli. The possible positions for these zeros are symmetrical with respect to the real axis and thus one speaks of 'flipping' zeros about this axis in order to generate different objects. The example in Fig. 1 was produced by 'flipping' such zeros. Clearly the four objects thus created are very different, for example, in the number and position of their peaks.

Fig. 1 All four different real positive objects shown in *a*, *b*, *c* and *d* produce the same far field intensity, shown in *e*. The four different objects have been generated by reflecting or 'flipping' the zeros of $F(z)$ about the x-axis, as described in the text.



The maximum entropy algorithm should converge to one of these possible solutions but the only criterion it has as a basis for the selection of that solution is that of smoothness, as all the possibilities are real and positive. However, inspection of the four possible solutions shows that none may be disregarded as unphysical—they are all 'smooth'. It would only be possible to identify one of these possibilities as the solution if one has some extra information, such as approximate phase values which may provide a basis for such discrimination. On the basis of the intensity alone there can be no unique solution, unless all minima are zero. The selection of one solution using an entropy criterion is dangerous. For example, if the algorithm chose the third solution one might conclude that the object consisted of two distinct peaks, whereas the other possible solutions show that such a conclusion is unfounded.

The example given here is simpler than may be expected in general—there are few complex zeros—and thus 'real' data may be expected to result in even greater ambiguity. In these conditions it is vital that some measure of the ambiguity is established. The maximum entropy algorithm does not give such a measure[3].

For convenience the analysis used to produce the example in Fig. 1 is one-dimensional but similar ambiguities will exist in two-dimensional systems.

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1. Gull, S. F. & Daniell, G. J. *Nature* **272**, 686 (1978).
2. Burge, R. E., Fiddy, M. A., Greenaway, A. H. & Ross, G. *Proc. R. Soc.* **A350**, 191 (1976).
3. Dainty, J. C., Fiddy, M. A. & Greenaway, A. H. *IAU/URSI Colloquia on Formation of Images from Spatial Coherence functions in Astronomy*, No. 49 (Groningen, The Netherlands, in the press).

Human reproduction reconsidered

MAY'S article in News and Views, '*Human Reproduction Reconsidered*'[1], fails to mention that the research on the demography of the !Kung hunter-gatherers, reviewed by Short and by