segment joins directly to normal-spreading ridge segments to its north and south (Fig. 1*a*), so this case does not correspond to any of those considered by Atwater and Macdonald (their Fig. 1).

In June and July 1977 *RRS Discovery* made a survey of part of Charlie–Gibbs FZ using the long-range sonar GLORIA. I have recontoured the available bathymetric data using the sonar results for control, and also incorporated some unpublished results from the Deep-Tow survey (made available by P. Lonsdale). The resultant charts show that the spreading axis south of the fracture zone is completely orthogonal (92°±2°) to the fracture zone trend. On the north side of the fracture zone, the spreading axis is indeed highly oblique to the spreading direction, as reported by Atwater and Macdonald, but probably only over a distance of some 30–40 km from the fracture zone (Fig. 1*b*). From about 53° to 56° N the spreading axis is at least roughly orthogonal to the spreading direction.[3]

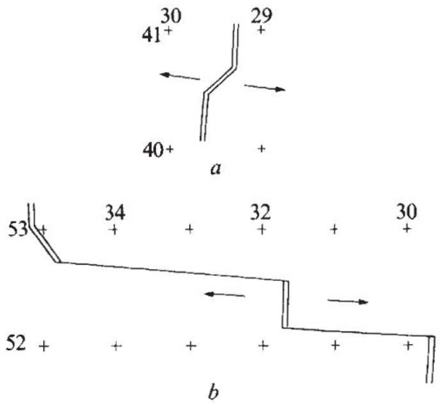


**Fig. 1** Spreading axes (double lines), transform faults (single lines), and spreading directions (arrows) at *a*, Kurchatov FZ and *b*, Charlie–Gibbs FZ.

Thus there are apparently two types of oblique spreading: a general obliquity, up to about 18°, on slow-spreading ridges, and a stronger obliquity of about 40° near some fracture zones. In the latter case, the obliquity corresponds to the trend of tension cracks produced in initial shearing of virgin material[4], suggesting that oblique spreading near fracture zones results from the response of the lithosphere to local shearing[2].

Sea-floor lineations (probably fault-scarps) trending about 40° from the spreading normal have been observed in all the fracture zones studied with GLORIA[5], as well as Siqueiros FZ on the fast-spreading East Pacific Rise[6] and in Afar, North-east Africa[7]. However, the extent to which oblique spreading develops obviously varies, as evidenced by the fact that it extends 30–40 km on the north side of Charlie–Gibbs fracture zone but is negligible on the south side. This development may therefore depend critically on factors such as local crustal thickness or lithospheric strength (thicker or stronger lithosphere would distribute mantle-derived shear stresses over a wider area), or possibly relative motion between the plates and the underlying asthenosphere in directions parallel to the ridge axis (the 'leading edge' of a fracture zone in such an environment would experience only divergent motion, whereas the 'trailing edge' would be subjected to shear persisting in the asthenosphere after the fracture zone had passed over it).

R. C. SEARLE
*Institute of Oceanographic Sciences, Wormley, Godalming, UK*

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ATWATER REPLIES—In our paper we discussed the relationship between transform faults and nearby spreading centres. In fact, it is more interesting to address two related but more fundamental questions. First, are all transform faults parallel to the relative motion of their adjacent plates? And second, are spreading centres perpendicular to that motion? Because of the ambiguities surrounding the Oceanographer Fracture Zone, the relative motions between the African and North American plates are uncertain, so that we were unable to consider these questions in the FAMOUS area.

Although Collette and Slootweg only consider spreading centre–transform relationships, their comments suggest that in fact the centres may be nearly perpendicular to the plate motion direction, while the trend of transform faults may or may not be parallel to that direction, depending on the length of offset. Since their discussion is based on unpublished data, we cannot comment at present, except to say that this is a very important and interesting observation, if true. The region studied by Collette and Slootweg is especially appropriate for consideration of this question because the Vema FZ is a very long, clean cut fracture zone, probably a dependable indicator of plate motion direction. We look forward to the publication of their data. We shall be especially interested in examining their track layout over the features of interest. In our paper we had to reject several surveys for lack of sufficient resolution of the small angular differences we were measuring.

Both respondents commented on the obviously anomalous behaviour of the Kurachatov FZ. Although we included it for completeness, we agree that its direction seems to be spurious. To include it with the FAMOUS fracture zones A and B, however, may be a mistake, since the trends of the latter are consistent from one to the next and are closer to the spreading direction. Indeed, if the more southeasterly trend of the Oceanographer FZ is taken, as Collette and Slootweg suggest, the obliquity at the FAMOUS fracture zones is reduced to 5–10°.

TANYA ATWATER
*Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*

# Benthic nutrient regeneration and high rate of primary production in continental shelf waters

ROWE *et al.*[1] have recently contended that nutrient regeneration in sediments is the major factor responsible for the relatively high rate of primary production observed in continental shelf waters. They state: "If there were no contribution (of $NH_4^+$) from the bottom sediments the system would lose this feedback and the production of the plant biomass, dependent only on water column regeneration, would be reduced to rates similar to those found beyond the continental shelf." The contention of Rowe *et al.* is based primarily on two tenets: first, that there is a gradient of decreasing $NH_4^+$ concentration between the benthos and overlying water; second, that $NH_4^+$ release can be estimated from measurements of respiration in bottom sediments. We feel that on the continental shelf the sediments play a minor part in cycling nitrogenous nutrients for phytoplankton.

It is clear from several studies (refs 2–4 and L. Conway, personal communication), that an above-bottom $NH_4^+$ gradient is not a ubiquitous feature of the northeastern United States shelf. As there is great lateral variability in $NH_4^+$ concentration on the shelf, together with a mean water current velocity of about 5 to 6 cm $s^{-1}$ (ref. 5), the horizontal advection of sediment-generated $NH_4^+$ must be much greater than the vertical; and therefore this latter term must be lower than the authors' estimate.

The $NH_4^+$ flux rates could not be as high as claimed, as there is not enough energy available to support the required benthic metabolism. Using three of Corwin's[4] $NH_4^+$ profiles from over a 'typical sand bottom' on the shelf south of Long Island, Rowe *et al.* calculated

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