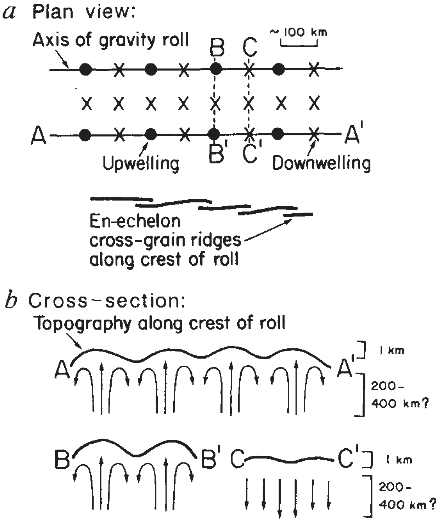
Cracks in the Pacific plate and mantle convection

SIR—Winterer and Sandwell[1] interpret 'cross-grain' ridges on the Pacific plate which are oblique to both spreading-centre parallel topography and fracture zones as large-scale tensional cracks up to 200 km long and spaced ~35 km apart. The cracks occur along topographic highs which exhibit gravity signals with wavelengths of ~200 km and a linear continuity of up to thousands of kilometres. These gravity 'rolls' may result from shallow-level convection in the upper mantle which has been sheared into rolls by the motion of the overlying Pacific plate[2].

Cross-grain ridges share two characteristics with overlapping spreading centres (OSCs) on the East Pacific Rise (EPR)[3,4], which reinforce Winterer and Sandwell's tensional crack interpretation and suggest an analogy between the two structures which further elucidates the possible connection between cross-grain ridges and mantle convection. First, both structures consist of ridges which overlap in an en-echelon fashion by a distance approximately three times their offset[1,4]. This is true of many of the OSCs which have been carefully mapped, and is characteristic of tensional cracks ranging over ten orders of magnitude in size[4,5]. Second, in both OSCs[4] and cross-grain ridges[1] the summits of the overlapping en-echelon ridges plunge over long distances towards the region of overlap.

The first similarity supports Winterer and Sandwell's hypothesis that the cross-grain structures are large tensional cracks, explains why the overlap distance is three times the offset, and suggests an explanation for their en-echelon offset. Using the displacement discontinuity method, we have found[6,7] that when a tensional stress is applied perpendicular to two parallel cracks, they propagate towards each other until the ratio of overlap distance to offset distance attains a value of ~3. For overlap to offset ratios greater than ~3, the crack propagation force decreases to a very small value[6], and propagation ceases. Our calculations also show that unless cracks are perfectly colinear (which is not possible in nature), en-echelon offsets will form, because the first interaction between the approaching crack tips is a deflection away from each other (see ref. 5, Fig. 8). A uniform 3:1 ratio of crack overlap to offset thus implies that the two cracks have been subjected to deviatoric tension oriented perpendicular to their length, that they have been active at the same time for at least part of their respective histories, that the cracks have propagated towards each other, and that propagation ceased when the ratio of overlap to offset reached ~3.



a, Plan view showing possible relationship between mantle convection, gravity rolls and cross-grain ridges. *b*, Cross-sectional views. If the analogy between overlapping spreading centres on mid-ocean ridges and cross-grain ridges is valid, then shallow places along the gravity rolls may overlie regions of mantle upwelling, whereas deep areas and the locations where en-echelon cross-grain ridges overlap may overlie regions of downwelling.

Now consider the similarity in axial depth profiles between the EPR and the cross-grain ridges; in both cases, the depths steadily increase near the tips of the en-echelon ridges (compare Fig. 4 in ref. 1 with Fig. 3 in ref. 4). For the EPR, several lines of evidence suggest that this steady increase in depth near OSCs is due to shallow convective upwelling in the upper mantle beneath high portions of the ridge. Upwelling results in decompression melting and segregation of partial melt as it migrates upward, and to flow of partial melt downhill along the strike of the ridge[4].

If the analogy between cross-grain ridges and OSCs holds, then the following hypothesis can be considered. Shallow portions of cross-grain ridges correspond to sites of short-wavelength upwelling of asthenosphere in a three-dimensional framework of mantle convection (see figure). Upwelling leads to doming and cracking of the overlying lithosphere. Partial melt segregates and rises, then migrates perpendicular to the axis of deviatoric tension (parallel to the axes of the cross-grain ridges), creating a graded and plunging profile away from the site of upwelling. Conversely, deep portions of cross-grain ridges, where en-echelon overlap occurs, correspond to sites of downwelling of asthenosphere and are relatively starved of partial melt (see figure). Bathymetric swath mapping coupled with seismic reflection and refraction measurements have supported a similar hypothesis for the EPR and similar experiments could support or refute the hypothesis offered here.

The analogy between en-echelon overlapping of cross-grain ridges and OSCs is imperfect at best because cross-grain ridges are not spreading and the sizes of the structures are quite different. But the characteristic geometry of OSCs and cross-grain ridges should not depend on spreading or on size; the relationships hold for cracks in glass on a microscopic scale and for dykes in areas that are not spreading[4].

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Periodic extinctions within the Cenozoic

SIR—I was happy to read the letter "Is the periodicity of extinctions a taxonomic artefact?" by Patterson and Smith[1] together with the reply by Sepkoski[2]. Having no expertise with either the echinoderms or fishes discussed by Patterson and Smith, nor with the statistical techniques that gave rise to the matter, I am nevertheless concerned that there is much more to the question. Namely, if the alleged 26 Myr extinction periodicity is to be taken seriously one should find good evidence for it within the Cenozoic. The Cenozoic is far better known biostratigraphically and palaeontologically than any other comparable interval since the opening of the Cambrian. Sepkoski and Raup[3] (Table 3) allege a major, 'significant' extinction event at the Eocene–Oligocene boundary, although biostratigraphers, to whom Sepkoski paid lip-service in his reply, have never recognized this as a major boundary in the same terms as the Cretaceous–Tertiary, Permian–Triassic, Triassic–Jurassic, or any of the other chief extinctions well known to biostratigraphers since the middle of the last century. Even if one accepts the Eocene–Oligocene boundary as a major, but poorly defined to date, extinction event one is still left with the problem of trying to recognize a major, 'significant' extinction event within the Miocene. No biostratigrapher of the past century and more has ever suggested the existence of a major boundary, one that could be interpreted as a global extinction event, within the Miocene. On these grounds alone the alleged 26 Myr periodicity fails. Additionally, in my own experience within the Silurian–