rates of spread of the grey squirrel consistent with those observed in the field. Moreover, the qualitative results that emerge, such as the pattern in which the grey squirrel spreads from small initial foci that gradually coalesce to wipe out the native red, are highly realistic. Okubo *et al.* conclude that the spread of a species overcoming another in competition is not very different qualitatively from the spread of one in a competitor-free world, except that the wave of advance may be slower. Moreover, simple diffusion, logistic population growth and some general form of rather mild competition are sufficient to account for the progressive replacement of red squirrels by grey squirrels in England and Wales.

Although it may be possible to contrive a model in which red-squirrel populations collapse for reasons that have nothing to do with the presence of alien greys, and in which greys then expand to fill the space available, such a model would appear to be intrinsically less likely and certainly more complex. Although the jury may still be out on exactly how the grey squirrel did it, it seems increasingly likely that the verdict will be 'guilty'. ☐

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1. Okubo, A., Maini, P.K., Williamson, M.H. & Murray, J.D. *Proc. R. Soc. Lond.* B**238**, 113–125 (1989).
2. Reynolds, J.C. *J. anim. Ecol.* **54**, 149–162 (1985).
3. Shorten, M. *Squirrels* (Collins, London, 1954).
4. Gurnell, J. *The Natural History of Squirrels* (Christopher Helm, London, 1987).
5. Williamson, M.H. & Brown, K.C. *Phil. Trans. R. Soc. Lond.* B**314**, 505–522 (1986).
6. Skellam, J.G. *Biometrika* **38**, 196–218 (1951).
7. Vliet, A.J. thesis, Univ. Oxford (1989).
8. Lubina, J.A. & Levin, S.A. *Am. Nat.* **131**, 526–543 (1988).
9. Mollison, D. *Phil. Trans. R. Soc. Lond.* B**314**, 675–693 (1986).
10. Okubo, A. *Diffusion and Ecological Problems: Mathematical Models* (Springer, Heidelberg, 1980).
11. Lawton, J.H. & Hassell, M.P. *Nature* **289**, 793–795 (1981).

CONTINENTAL PLATES

Flexure reveals great depth

Marcia McNutt

One of the outstanding issues in Earth sciences is the question of whether continental and oceanic lithospheric plates are thermally and chemically equivalent beneath the crust, or whether systematic differences in major-element chemistry allow the development of deeper lithospheric roots beneath continental cratons. Resolving this issue is critically important for understanding the long-term growth and stability of continents, the evolution of geochemical reservoirs and mantle dynamics. The analysis of North American gravity data by Bechtel *et al.*, on page 636 of this issue[1], reveals for the first time the variations in the stiffness of the lithosphere across the entire North American continent. The results are most easily interpreted in terms of a lithospheric plate at least 250 km thick beneath the ancient Precambrian Canadian Shield, about twice the thickness that pertains to the more geologically active continental margins and the old ocean basins.

The heterogeneity of continental crust and its long exposure to many tectonic and thermal events have made it difficult to apply the simple thermal-plate model which has been so successful in the ocean basins. For example, with different assumptions concerning the radiogenic heat production of the lower continental crust, heat-flow data can be interpreted as showing either a 125-km-thick plate beneath continents[2] or one 250 km thick[3]. From seismic surface-wave velocities and shear-wave travel times, Jordan[4] has argued that cold lithospheric roots could extend to depths as great as 400 km beneath the oldest cores of continents.

Another geophysical observation that bears directly on the thermal structure of the lithospheric thermal boundary layer is the thickness of the mechanically rigid elastic layer that supports the weight of anomalous loads placed on, within and beneath the lithosphere. The effective elastic thickness T_e of the lithosphere marks the depth of the transition between elastic and fluid behaviour of rocks subjected to stresses exceeding 100 megapascals over geological timescales. Because the creep rate of rocks is thermally controlled, in the limit of small amplitude of flexure (such that the finite strength of rocks in the elastic regime is not exceeded), T_e corresponds to the depth of an isotherm, probably somewhere between 600 and 800 °C according to laboratory experiments.

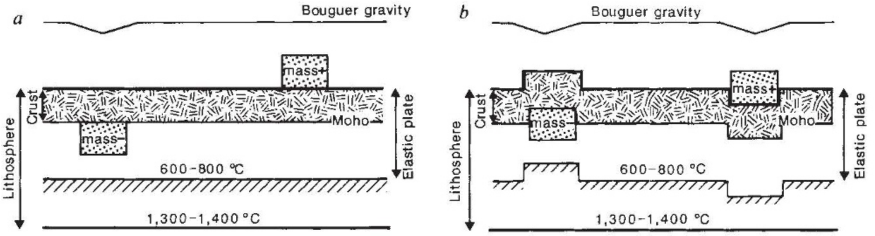
Gravity data are often used to calibrate T_e because the wavelength and amplitude of the gravity anomaly over a load are sensitive to the flexure of the elastic plate induced by that load. To date, gravity data have favoured a thicker thermal boundary layer beneath old continents, as elastic plate thicknesses well in excess of the 40–50-km maximum observed for the oceans have been reported for the stable cores of continents[5,6]. But those results, primarily obtained from observing the amplitude and wavelength of the gravity anomaly over mountain belts which were superimposed by plate convergence onto stable platforms, are often questioned because many assumptions must be made about the boundary conditions on the elastic plate, the role of subsurface loads and so on.

The map in Fig. 3 of Bechtel *et al.* (see page 638) shows variations in T_e across North America using a relatively new technique based on computing the statistical correlation between Bouguer gravity (the anomaly after correcting for the attraction of all topographic masses) and topography as a function of wavelength in subregions encompassing the entire continent. Their result does not depend on the details of modelling any individual feature, and explicitly allows for subsurface loads (see box below).

According to this analysis, from the young Basin and Range region of the western United States, characterized by

Basis of the coherence technique

Imagine loads randomly placed on the Earth's surface and at the crust–mantle boundary (the 'Moho'). If the plate is infinitely rigid, *a*, neither surface nor subsurface loads can flex the plate. The topography then measures the magnitude of surface loading, the Bouguer gravity measures the magnitude of subsurface loading, and the lack of correlation between Bouguer gravity and topography at all wavelengths indicates that the plate is perfectly rigid.



If the plate is infinitely weak, *b*, every surface mass will warp the plate to produce a subsurface density anomaly, and every Moho load will lead to surface topography. The correlation between Bouguer gravity and topography will be perfect (and negative) at all wavelengths except very short ones where it approaches zero owing to upward attenuation of the gravity from the Moho loading.

Any realistic case will fall somewhere in between these two extremes, and the particular wavelength at which the correlation changes from −1 at long wavelengths to 0 at short wavelengths is a measure of the stiffness of the plate. ☐