Model Supplementary Data

The numerical method used for experiments is based on an explicit finite element technique similar to the Fast Lagrangian Analysis of Continua (FLAC) method (Cundall, 1989). It has been used to investigate local deformation (e.g. Polikov and Buck, 1998; Lavier et al., 2000 and refs. therein) and regional deformation (Buck et al., 1999, 2001). At each time step, Newton's second law is solved at every grid point. The effects of inertia are damped in order to approximate quasi-static processes. The forces present at each grid point are summed, and the "out-of-balance" forces and the mass at the grid point are used to calculate the acceleration. The accelerations are integrated to calculate the velocities which are used to determine the increment of strain at each grid point. Using Mohr-Coulomb criterion for plasticity and Maxwell's criterion visco-elasticity, the corresponding stress increments and the forces they produce on the surrounding grid points are summed to determine the new "out-of-balance" forces. This dynamic response is damped to approach a quasi-steady static equilibrium.

The explicit time-marching scheme calculates a new time step after each calculation based on the elastic-plastic properties of the model. For our model parameters, the time step is governed by the elastic properties. To decrease CPU time, we increase the speed of calculations by setting the boundary displacement as a fraction of grid spacing per time step. To set the boundary displacement, we chose a ratio of boundary velocity to sound velocity of 5×10^{-5}. We find this ratio allows for fast runs while minimizing the error on the strain calculation. Time steps are on the order of 5 to 6 years and model runs to 25 m.y. take about a day to complete.

The initial mesh of the model is made of quadrilaterals subdivided into two pairs of superimposed constant-strain triangular zones. Since the method is Lagrangian, i.e. the numerical grid follows the deformation, the simulation of very large deformations involves remeshing to overcome the problem of degradation of numerical precision when elements are distorted. We trigger remeshing when one of the triangles in the grid elements is distorted below a critical angle, set to 30 degrees. With remeshing, strains at each grid point are interpolated between the old deformed mesh and the new undeformed mesh using a nearest-neighbor algorithm. The new state of strain is used with the rheological laws to calculate the stress and resulting out-of-balance forces to start the time step cycle again. The element phases, represented the diabase or olivine rheology, are treated similarly during remeshing. New material with the same properties as the bottom mantle layer is added to replace lithosphere that is pulled out of the sides of the model box.

The brittle strength of the lithosphere is assumed to be limited by Mohr-Coloumb yielding with a friction coefficient of 0.6 and an initial cohesion of 44 MPa. Linear strain weakening is applied in the model (Lavier et al., 2000). Between plastic strain values of 0 to 1.2, the cohesion decreases from 44 to 4 MPa. The temperature-dependent viscous rheology of the crust is based on a creep flow power-law for diabase, and the mantle has an olivine rheology (Kirby and Kronenberg, 1987).

Advection and diffusion of heat are tracked as temperature changes affect the deformation. Initial temperature profiles are calculated using conductive heat transport and radiogenic heat production in the crust that decreases exponentially with depth as: : $H = H_0 e^{\frac{-y}{hr}}$, where H is the concentration of radiogenic elements, y is depth, and h_r is 10 km (Turcotte and Schubert, 2002). Temperature profiles are altered by varying thermal conductivity of crust, κ_c, from 2.0 - 2.7 $Wm^{-1}K^{-1}$, the thermal conductivity of the mantle, κ_m, from 3.0 - 3.6 $Wm^{-1}K^{-1}$, and the concentration of radiogenic elements at the surface, H_0, from 0.28 μWm^{-3} - 5.9 μWm^{-3}. The κ of diabase can range between 2-3 $Wm^{-1}K^{-1}$ depending on the ratio of mafic to felsic minerals, and measurements of olivine's κ range from 3-5 $Wm^{-1}K^{-1}$(Clauser and Huenges, 1995). Kirby and Kronenberg (1987) report values of 2.5 and 3.3 for diabase and olivine, respectively. Bücker et al. (2001) reports concentrations of radiogenic elements from 0.5 -2 μWm^{-3} in the Victoria Land Basin, which would agree with the low values required in our model to achieve a cold to moderate initial Moho.

The temperature at the base of the grid is fixed to the initial 1-D steady-state value under the plateau using: $T = T_{0+} \frac{q_m z}{k} + \frac{\rho H_0 h_r^2}{k}(1 - e^{\frac{-z}{h_r}})$, where T is the temperature, T_0 is the surface temperature set to 0°C, q_m is the mantle heat flux set at .029 W m^{-2}, ρ is the density, k thermal diffusivity set to 10^{-6} m^2 s^{-1} , and z is depth (Turcotte and Schubert, 2002). Tests using an initial 2-D steady-state temperature structures, calculated by letting the model run without extension until a steady state temperature is achieved, have yielded similar results. The initial thermal conditions for the example model shown in the main body of the text are κ_c = 2.7 $Wm^{-1}K^{-1}$, κ_m = 3.4 $Wm^{-1}K^{-1}$, and H_0 = 2.8 μWm^{-3}. Though this example's surface concentration of radiogenics is high in comparison to the values reported in Bücker et al. (2001), they are reasonable (Turcotte and Schubert, 2002), and the low T_m in the example is a result of a high end member κ_c.

In all models, the initial plateau is 296 km wide, and adjacent areas are 252 km for a total model width of 800 km at time 0 my. Initial plateau crustal thickness, including initial topography, is 55 km, and adjacent crust is 32 km thick. Mantle material underlies the crust under both regions to 80 km. Grid spacing is set at 4 km. This spacing allows models to be completed in a reasonable amount of time while still allowing enough detail to examine regional features. Initial plateau topography is a rectangle elevated 3 km above the background and is isostatically compensated at depth. The depth of 20 km for the plateau's root was selected because it is 5 grid elements, enough to clearly demonstrate whether our idea worked or not. Given the grid spacing and root size, the topography followed. We do not propose that these values for crustal thickness and initial topography are absolute in terms of Antarctic history, but they are useful for testing our hypothesis and are reasonable for the scenario we propose.

References

Buck, W.R., L.L Lavier, A.N.B. Poliakov, How to make a rift wide, *Phil. Trans. Royal Society of London*, 357, 671-693, 1999.

Buck, W.R., Accretional curvature of lithosphere at magmatic spreading centers and the flexural support of axial highs, *Journal Geophysical Research*, 106 (B3), 3953-3969, 2001.

Bücker, C.J., R.D. Jarrard, and T. Wonik, Downhole Temperature, Radiogenic Heat Production, and Heat Flow from the CRP-3 Drillhole, Victoria Land Basin, Antarctica, *Terra Antartica*, *8* (3), 151-159, 2001.

Clauser, C. and Huenges, E, 1995, Thermal Conductivity of Rocks and Minerals, in Rock Physics and Phase Relations: A Handbook of Physical Constants, eds. Ahrens, T.J., AGU Reference Shelf, v. 3, p. 105-126.

Cundall, P.A.. Numerical experiments on localization in frictional materials, *Ing. Arch.*, 58, 148-159, 1989.

Kirby, S.H. and A.K. Kronenberg, Rheology of lithosphere: Selected topics, *Rev. Geophys.*, 25, 1219-1244, 1987.

Lavier, L.L., W.R. Buck, A.N.B. Poliakov, Factors controlling normal fault offset in an ideal brittle layer, Journal *of Geophysical Research*, 105 (B10), 23431-23442, 2000.

Poliakov, A.N.B., and W.R. Buck, Mechanics of stretching elastic-plastic-viscous layers: Applications to slow-spreading mid-ocean ridges, in Faulting and Magmatism at Mid-ocean Ridges, Geophysics Monogram Series, ed. Buck, W.R. et al., v. 106, p. 305-325.

Turcotte, D.L. and Schubert, G., 2002, Geodynamics, 2nd. Edition, p. 118-210.