A TEMPERATURE AND GRAVITY MODEL OF SPREADING CENTRE SUBDUCTION.

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The Chile Rise spreading centre is currently subducting south of the ridge-trench-trench Chile Triple Junction, between the Antarctic, Nazca and South American plates (figure 1). The Nazca and Antarctic oceanic plates are approaching South America at relative speeds of 80 $mmyr^{-1}$ and 20 $mmyr^{-1}$ respectively, and the Chile Rise spreading centre itself is approaching the trench at 50 $mmyr^{-1}$. South of the Chile Triple Junction, the geometries of the subducted plates, and the kinematics of the subducted spreading centre, are poorly known.

Our objective was to investigate the geometry and kinematics of ridge-subduction. The model predicts the temperature history of a subduction zone, as a ridge subducts, and is constrained using gravity data. Two hypotheses were tested for Southern Chile:

1) the plates continue to separate after subduction, with no change in kinematics;
2) the plates cease to separate when the ridge segment collides with the trench, and both subducting plates adopt the Antarctic plate velocity.

We used a kinematic thermal conduction-advection model, solved using a finite difference scheme, to predict the temperature cross-section during subduction of a spreading centre, for a variety of slab dips and velocities of the subducting plates. Density deviations were computed from the temperatures, and also included density deviations due to the 400 km olivine-spinel phase change and the 700 km spinel-oxides phase change. Bouguer and Free Air anomalies were calculated from the density deviation fields, and from bathymetry and Moho topography. No independent data exist to constrain the Moho beneath Southern Chile, and the continental crust was assumed to be in perfect Airy isostasy with the southwest Atlantic ocean crust. The modelled gravity anomalies were compared with observed gravity data, comprising land Bouguer anomaly data, collected by University of Liverpool teams, and marine Geosat Free Air data.

Pre-Ridge Subduction:

The slab dip north of the Chile Triple Junction, where segments of the Chile Rise have not yet collided with the trench, was investigated by comparing modelled gravity with observed gravity along the profile denoted "-3 Ma" on figure 1, for a Nazca plate velocity of 80 $mmyr^{-1}$ and an Antarctic plate velocity of 20 $mmyr^{-1}$. The upper plot of figure 2 shows the comparison between modelled and observed gravity for this profile, for slab dips of 20° (dashed line), 25° (solid line) and 30° (dotted line). Observed gravity is shown by the grey band; the width of the band corresponds to the error in the observed data. The lower plot of figure 2 shows the modelled temperature field for the pre-ridge subduction profile.

There are short wavelength misfits in the south-east Pacific (0 - 1250 km) and in the south-west Atlantic (2500 - 3000 km), of approximately 20mgal in amplitude. These are probably caused by sedimentary basins in the south-west Atlantic, and variations in crustal thickness in the south-east Pacific, which are not included in our model. The very short wavelength, high amplitude error at 500 km is related to a seamount. A similar error at the trench (1150 km) exists because the components of modelled gravity are varying rapidly at the trench, and a slight horizontal misalignment between the components generates a large but very localised error. Our modelled gravity generally fits observed gravity beneath South America (1250 - 2300 km) very well. Over the active margin (1250 - 1400 km), modelled gravity fits observed gravity best for a slab dip of between 20° and 25°. Beneath the Argentinean continental shelf (1800 - 2300 km), the best fit was obtained for a slab dip between 25° and 30°.

Post-Ridge Subduction:

We compared modelled and observed gravity for three post-ridge subduction profiles:

1) a profile through the triple junction itself ("0 Ma" on figure 1);
2) a profile south of the Chile Triple Junction, through a subducted ridge segment which collided with the trench 3 Ma ago ("+3 Ma" on figure 1);
3) the southern-most profile, corresponding to a subducted ridge-segment which collided with the trench 6 Ma ago ("+6 Ma" on figure 1).

Modelled gravity was computed for two kinematic cases:

i) the subducting plates continue to separate after subduction;
ii) the subducting plates cease to separate immediately when the spreading centre segment collides with the trench.

Modelled gravity generally fits observed gravity for the post-ridge subduction profiles best for a 30° slab dip. For the +3 Ma post-ridge subduction profile, a better fit is obtained above the subducted ridge segment if the subducting plates continue to separate, than if they cease to separate. The difference in modelled gravity predicted between continuing and ceasing separation of the subducting plates is, however, only marginally larger than the probable error in the model, and therefore the conclusion that the subducting plates continue to separate after subduction of the ridge segment is tentative. For the +6 Ma post-ridge subduction profile, the gravity difference predicted between continuing and ceasing separation of the subducting plates is certainly less than the error in the model, so we cannot predict the kinematics of old subducted ridge segments.

Long-Wavelength Misfits Between Modelled and Observed Gravity:

There are no long-wavelength misfits between modelled and observed gravity for the pre-ridge subduction profile (figure 2). For the post-ridge subduction profiles, two long-wavelength misfits exist:

1) observed gravity is up to 40 mgal lower than modelled gravity in Southern Chile (200 -300 km east of the trench) on the 0 Ma and +3 Ma profiles, but not on the pre-ridge subduction and +6 Ma profiles;
2) observed gravity is up to 30 mgal higher than modelled gravity in Argentina (400 - 700 km east of the trench) on all three of the post-ridge subduction profiles.

These long-wavelength misfits are all east of the subducted ridge segments, and above the subducted Nazca plate.

The locations of the misfits do not correlate with surface geology, and they are sufficiently long wavelength to suggest a deep source, at Moho or slab depths. We speculate that the misfits reflect either deviations of the Moho from Airy isostasy, or thermal anomalies in the upper mantle.

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Figure 1. Regional tectonic map of southern Chile, centred on the Chile Triple Junction. The horizontal and vertical axes are longitude and latitude respectively. The observed gravity anomaly map (Bouguer anomaly on land; Free Air anomaly at sea) is shown by the continuous grey-scale shading. The locations of the modelled profiles are shown.

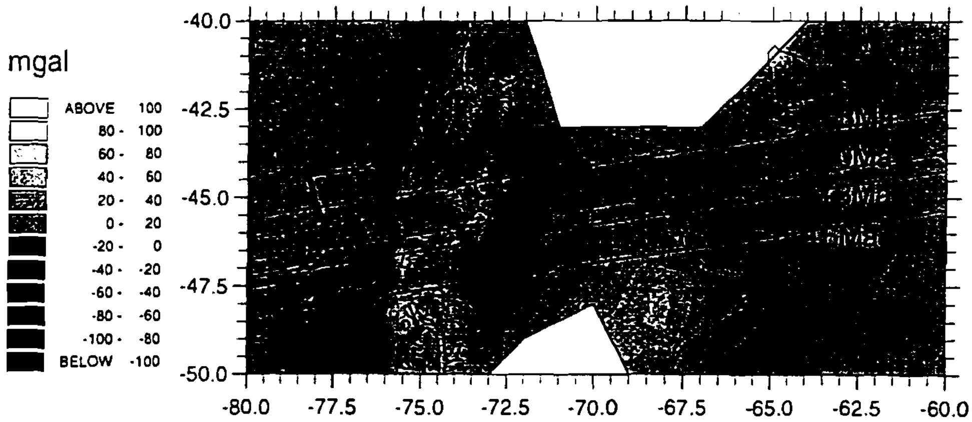

Figure 2. Comparison for modelled and observed gravity for the pre-ridge subduction (-3 Ma) profile. The lower plot shows the temperature field, contoured at a 200°C interval. In the upper plot, the grey band shows observed gravity, and the black lines show modelled gravity for 20° (dotted line), 25° (solid line) and 30° (dashed line) slab dips.