Evidence for new class of mantle upwellings from dynamic models

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Forward models of New Zealand- Antarctica conjugate margins since 80 Ma

In forward models of Antarctica-New Zealand (ANT-NZ), anomalous geophysical observations are consistent with upwellings at mid-to-upper mantle depths above a lower-mantle anomaly linked to Gondwana subduction. Modeled upwellings in ANT-NZ are unusual in that they are above a subducted slab, possibly suggesting that significant hydration and/or melting occurs above subducting slab below 660 km. The inferred relative viscosity ratio between lower and upper mantle from ANT-NZ models is relatively high and could be related to extensive pileups of cold (more dense and viscous) slabs in lower 1000 km of the mantle regionally.

Seismic tomographic evidence

We find that the geoid lows are correlated with both high velocity anomalies near the base of the mantle and low velocity anomalies in the mid-to-upper mantle in the same regions. These low-seismic-velocity anomalies are found at depths of up to 1000 km and have absolute amplitudes that are at least as large as the deeper high-velocity anomalies. We speculate that these low-seismic-velocity anomalies represent upwellings that are well defined in the Ross Sea, northeast Pacific and west Atlantic, and poorly defined in the Indian Ocean.

Summary

We develop two sets of mantle convection models with the goal to investigate possible association of the regions of geoid minima with mantle upwellings. Time-dependent forward models of New Zealand- Antarctica conjugate margins show that anomalous observations of residual bathymetry, tectonic subsidence and geoid can be explained by an evolving mid-to-upper mantle upwellings located in the Ross Sea region. We investigate geoid lows in instantaneous dynamic models and we find that the geoid minima are globally associated with mantle upwellings located in depths up to 1000 km.

Global instantaneous models and prediction of geoid lows

We develop global instantaneous models of mantle flow with the density field constrained by dynamic topography. These models demonstrate that mid-to-upper mantle upwellings have to be positioned above the inferred positions of ancient subducted slabs to reproduce the geoid minima in the Ross Sea, northeast Pacific, west Atlantic and Indian Ocean. We find that the high-density lower mantle slab graveyards reproduce the long-wavelength geoid trough, while upwellings shallower than 1000 km depth cause discrete lows within the larger trough. We suggest these upwellings are present globally and are probably caused by buoyant hydrated mantle that was created by processes around and above subducted slabs.

Table: Seismic tomographic evidence

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>ΔVs/Vs (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-90 km</td>
<td>0.6</td>
</tr>
<tr>
<td>20-20 km</td>
<td>0.3</td>
</tr>
<tr>
<td>300-1000 km</td>
<td>0.0</td>
</tr>
<tr>
<td>1000 km</td>
<td>-0.3</td>
</tr>
</tbody>
</table>

Figure 1. S20RTS tomography in NZ-ANT region

Figure 2. Thermal anomalies cross sections at 80 and 0 Ma

Figure 3. Dynamic topography predictions at 80, 40 and 0 Ma

Figure 4. Observed (A) and predicted (B) geoid

Figure 5. Subsidence of Campbell plateau

Figure 6. New Zealand- Antarctica margins bathymetry

Figure 7. Observed geoid

Figure 8. Stacked topography in 2000-2890 km (A) and 300-1000 km (B) depth

Figure 9. Mean tomography value in zones of geoid low

Figure 10. Tomography cross-sections in zones of geoid minima

Figure 11. Predicted geoid with red circles indicating four regions of geoid minima

Figure 12. Geoid predictions with upwellings removed in upper 660 km of mantle (Note that geoid minima are not predicted in the Ross Sea, northeast Pacific and west Atlantic)

Figure 13. Geoid predictions with upwellings removed in upper 1000 km of mantle (Note that geoid minima are not predicted in the Ross Sea, northeast Pacific and west Atlantic)

Figure 14. Observed geoid

References


Publications


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