Further data in support of the slab-sheet slumping hypothesis

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The slab-sheet-slump hypothesis postulates the existence of relatively weak sheets of partially-hydrated and dehydrating mantle that slide down the face of lithospheric slabs as they subduct, at a rate slightly faster than the overall rate of subduction. The slab-sheet-slump hypothesis takes note of arrays of otherwise inexplicable landward-dipping tilt-blocks. These typically form and/or accentuate in the uppermost 20-25 km of slabs as they enter the subduction zone, in the time preceding, or in the immediate aftermath, of large megathrust earthquakes. The slab-sheet-slump hypothesis suggests that displacement on these headwall faults connects to detachment faults or ductile shear zones at depth, and that this detachment partially uncouples the slumping sheet from the rest of the subducting lithosphere. The dimensions vary. The width of the slump channel may range from 30—100 km. The depth extent is determined by the geometry of the paired seismic zone that forms 20-30 km beneath the slab-asthenosphere boundary.

The slab-sheet-slump hypothesis further suggests that seismogenic failure within the interior of a slumping slab-sheet leads to paired seismic zones. The surface of the slab-sheet (dominated by the oceanic crust) may fail in a brittle fashion, with fault orientation predicted by the Coulomb-Mohr failure criterion. The base of the slab-sheet may fail as the result of boudinage, with the shallowly-dipping orientation of semi-brittle or ductile faults predicted by a maximum moment condition. Occasionally, but rarely, the magnitude of stored elastic potential energy may allow major earthquakes, and these more accurately decorate the structure of the slab sheet. The 2006-2007 Kuril Islands rupture showed the first example of a $M_w>8$ earthquake on the sidewall of a slab sheet slump. The 2011 Great Earthquake was accompanied by accelerated motion in the inferred slab sheet beneath. Earthquakes within the slab sheet occasionally exceed $M_w 7$, allowing delineation of the rupture. In the upper plane, some orientations may reflect the structuring caused by the original landward-dipping normal faults. Fault orientations in the lower levels of the slab sheet may reflect structuring caused by boudinage.

Paired seismic zones otherwise present an enigma. Estimates of the elastic thickness of unstructured lithosphere range from 60-120 km. Yet paired seismic zones are rarely more than 20-30 km apart. Flexure of an uncoupled slab sheet allows explanation of this paradox, while the bending or unbending of unstructured lithosphere does not. Moment tensor data are consistent with the existence of two aseismic shear zones, one adjacent to the slab surface, with the same sense of shear as required by subduction, while the basal shear zone has the opposite sense, consistent with that required by the slab-sheet-slump hypothesis. These structures appear to be
persistent over long time periods, so they match the geomorphology of individual segments of the adjacent subduction megathrust.