

Additional information regarding abstract 14187,

The Tonga-Vanuatu Subduction Complex, a Self-Optimized 3D Slab-Slab-Mantle Pump

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Ref. No.	First Author	Section	Session	Index Terms	Title
14187	Jeremy A. McCreary	T	T01	8170 9355 9605	The Tonga-Vanuatu Subduction Complex -- a Self-Optimized 3D Slab-Slab-Mantle Heat Pump
Intended session		Title			Submissions
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Recently published geophysical and geochemical data and increasingly actualistic free subduction models prompted a fresh look at 2 classics hinting, in combination, that a coupled 3D slab-slab-upper mantle interaction (Scholz and Campos, 1995; full citations at URL below) might power the prodigious surface heat dissipation (Lagabrielle et al., 1997) characterizing one of Earth's most remarkable tectonomagmatic systems, the Tonga-Vanuatu Subduction Complex (TVSC). The 3D TVSC includes (1) the kinematically, magmatically, and bathymetrically distinct North Tonga (NT, 14-26°S) and South Vanuatu (SV, 16-23°S) trenches and slabs, (2) the shared NT-SV backarc, and (3) entrained mobile upper mantle (MUM). That Earth's greatest convergence, rollback, and spreading rates; most disseminated spreading (the North Fiji Basin (NFB) ridge swarm); and greatest concentration of aggregate active ridge length coincide in a 1,500 km TVSC can't be accidental. To the north and south, the respective active NT and SV trenches swing abruptly 90° counterclockwise into continuity with the Vitiaz and Hunter fossil trenches, both active in the Late Miocene but now sinistral strike-slip loci standing over long exposed PA and AU slab edges. These 2 active-fossil trench pairs bracket a hot, shallow and geophysically and geochemically exceptional TVSC interior consisting of 2 rapidly spreading backarcs set back-to-back in free sublithospheric communication: The Lau-Havre NT backarc on the east and the ridge-infested SV backarc (NFB) on the west. The NFB and adjacent North Fiji Plateau make up the unplatelike New Hebrides-Fiji Orogen (Bird, 2003). As in the western Aleutians, the NT-Vitiaz and SV-Hunter subduction-to-strike-slip transitions (SSSTs) stand above toroidal fluxes of hot, dry PA and AU MUM driven along-trench and around the free NT and SV slab edges from subslab to supraslab regions by dynamic pressure gradients powered by slab free-fall and induced viscous couplings. These edge flows must converge and mix beneath the shared TVSC backarc, which must then shed a huge advected subslab heat load by maximizing ridge length in the area available. Found at both SSSTs are adakites indicative of a TVSC source laced with slab-edge melt and boninites consistent with flux-melting of hot, dry subslab MUM on entry to the supraslab wedge. Isotopics reveal widespread source mixing of Pacific and Indian MOR end-members. Diverging NT and VS trenches rotate clockwise at

extremely high rates about pinning points at and Euler poles near trench-floater intercepts: Louisville Ridge on PA, and West Torres Plateau-D'Entrecasteaux Ridge on AU. In this configuration, the spinning, free-falling NT and SV slabs form a highly coupled self-organized gravity-powered pump pulling hot subslab MUM beneath the TVSC with enough left-over head to power severe transition zone buckling of an 80+ Ma NT (PA) slab also actively extending toward its free edge. Several nonlinear couplings (e.g., temperature-dependent viscosity and slab damage at tightening upper hinges) feedback positively to pump efficiency. The TVSC is but one possible slab-mantle pump partaking of the strong self-optimizing tendency characteristic of all natural flow systems (e.g., Bejan and Lorente, 2006). Slab-mantle pump natural history is now under investigation, as such pumps may have allowed a shrinking post-Pangean Pacific with an unrelenting sublithospheric room problem to relieve itself of excess MUM by making efficient use of available circum-Pacific slab curtain porosity -- a commodity that may have been in very short supply through most of the Cretaceous.

Additional Resources (this document): <http://www.cliffshade.com/agufm08/addl-info-agu-abstract-14187.pdf>

Errata (corrected in the version above)

The citation "Bejan, 2007" in early abstract versions should have read "Bejan and Lorente, 2006".

References cited explicitly in abstract (additional references with full citations below)

Bejan, A., and Lorente, S., 2006, Constructal theory of generation of configuration in nature and engineering: *Journal of Applied Physics*, v. 100, p. 041301-1 to 041301-27.

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Note on the coined term *mobile upper mantle* (MUM)

The term *mobile upper mantle* (MUM) coined for this abstract refers to the totality of mantle material stirred up in the TVSC dynamic — hence the "mobile" part of MUM. While the 4D permeabilities of the 660 km seismic discontinuity (the 660) to falling slabs (e.g., Hamilton, 2002 and 2007; Goes et al., 2008) and narrow thermals (e.g., Anderson, 2007; []) rising from greater depths remain contentious, there appears to be at least tacit agreement (1) that the 660 is effectively impermeable to diffuse mass flows in both directions; and (2) that in the mode of mantle convection operant during post-Eocene if not post-Pangean time, most slabs stall at least transiently at or above the 660 (e.g., Fukao et al., 2001; Solheim & Peltier, 1994). I

conclude that the 660 floors the entire TVSC process whether or not TVSC slabs penetrate the 660 — hence, the “upper mantle” part of MUM. Deciding just how much upper mantle participates is the hard part of MUM.

MUM certainly includes all of the asthenosphere in and around the TVSC. Moreover, the asthenosphere must carry the bulk of the mantle momentum (e.g., Chase, 1979; Elsasser, 1971; Richards et al., 2001; Stein & Hansen, 2008) stirred by the TVSC dynamic. The sizeable observed density and inferred viscosity jumps at the base of the Pacific seismic low velocity zone (LVZ) and the monotonically increasing densities and viscosities inferred for greater upper mantle depths (e.g., Anderson, 2007; Čadek & Fleitout, 2003; Čadek et al., 1998; Čížková et al., 1996; Hirth & Kohlstedt, 2003; Karato & Jung, 1998; King, 1995; Mitrovica & Forte, 2004; Panasyuk & Hager, 2000; Pollitz et al., 1998; Ranalli, 2000; Richards et al., 2001; Zaranek & Parmentier, 2004) must surely channel MUM into the LVZ — especially the higher velocity fraction. Patterns of LVZ seismic anisotropy reasonably interpretable in terms of MUM flow directions in the TVSC (e.g., Fisher & Wiens, 1996; Fischer et al., 2000; Hall et al., 2000; Long & Silver, 2008; Smith et al., 2001) and elsewhere (e.g., Anderson et al., 2004; Conrad et al., 2007; Levin et al., 2004; Park & Levin, 2002; Nakajima et al., 2006; Park et al., 2002; Peyton et al., 2004; Russo & Silver, 1994; Russo et al., 1996) strongly support various portions of the LVZ flow pattern envisioned for the TVSC. Along the nearby Tonga-Hawaii corridor, the LVZ occurs at 68-166 km depth (Gaherty et al., 1996; Katzman et al., 1998).

However, there are many compelling geophysical and geochemical reasons to believe that sub-LVZ material must also participate actively in the TVSC — particularly the hot subslab mantle displaced by slab free-fall. A few of the geophysical arguments follow.

Diffuse passive upwellings of transition zone (TZ) material displaced by settling and buckling slabs appear to dominate the upward poloidal return flow balancing the downward poloidal flow dominated by sinking slabs (e.g., Anderson, 2007; Bercovici, 2003; Bercovici and Karato, 2003; Hamilton, 2007). Thus, MUM could easily include at least small amounts of deep TZ material. Indeed, lower TZ material displaced by the immense volume of PA slab material piled up within and just west of the sub-North Tonga TZ (e.g., Chen & Brudzinski, 2001 and 2003; Fischer et al., 1991; Karato et al., 2001; Okal & Kirby, 1999; van der Hilst, 1995) may figure prominently in the sub-LVZ MUM fraction.

Credible subduction models (e.g., Billen & Hirth, 2007; Capitanio et al., 2007; De Franco et al., 2006; Di Giuseppe et al., 2008; Dvorkin et al., 1993; Garfunkel et al., 1986; Lowman et al., 2007; Morra et al., 2006; Royden & Husson, 2006) consistently show or imply positive subslab dynamic pressures extending well below LVZ depths, with particularly high overpressures possible in the lower TZ subslab mantle wedge (e.g., Billen & Hirth, 2007; Capitanio et al., 2007; De Franco et al., 2006; Di Giuseppe et al., 2008; Dvorkin et al., 1993; Garfunkel et al., 1986; Lowman et al., 2007; Morra et al., 2006; Morra et al., 2008; Royden & Husson, 2006). Such overpressures would, at minimum, drive some sub-LVZ subslab mantle first laterally and then, at slab edge, upward into the LVZ for further distribution toward low dynamic pressure regions like the upper (supraslab) wedge.

From the above considerations, it's safe to assume that the proportion of sub-LVZ mantle mobilized by the TVSC dynamic, from either side of the slabs involved, falls off with depth, as long ago argued by Chase (1979), and probably quickly so. Thus, while the MUM has a hard floor at the 660, it has no distinct lower boundary.

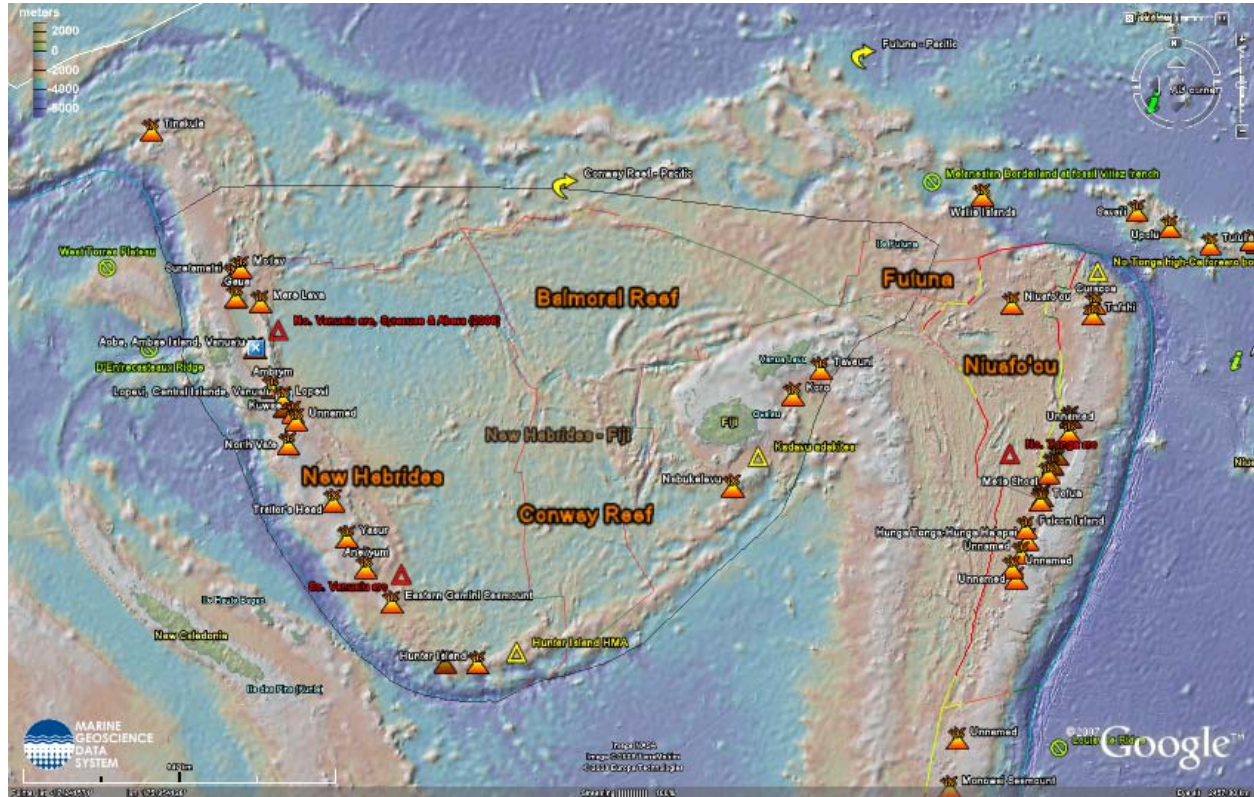


Figure 1. Google Earth rendering of the Tonga-Vanuatu Subduction Complex (TVSC) with (1) the Global Multi-Resolution Topography overlay downloaded from the [Marine Geoscience Data System](#), Lamont-Doherty Earth Observatory; (2) the PB2002 plate boundary (Bird, 2003) overlay converted to KML by Thomas Chust (URL not readily available); and (3) the [Volcanoes of the World](#) overlay maintained by the Smithsonian Institution's Global Volcanism Project.

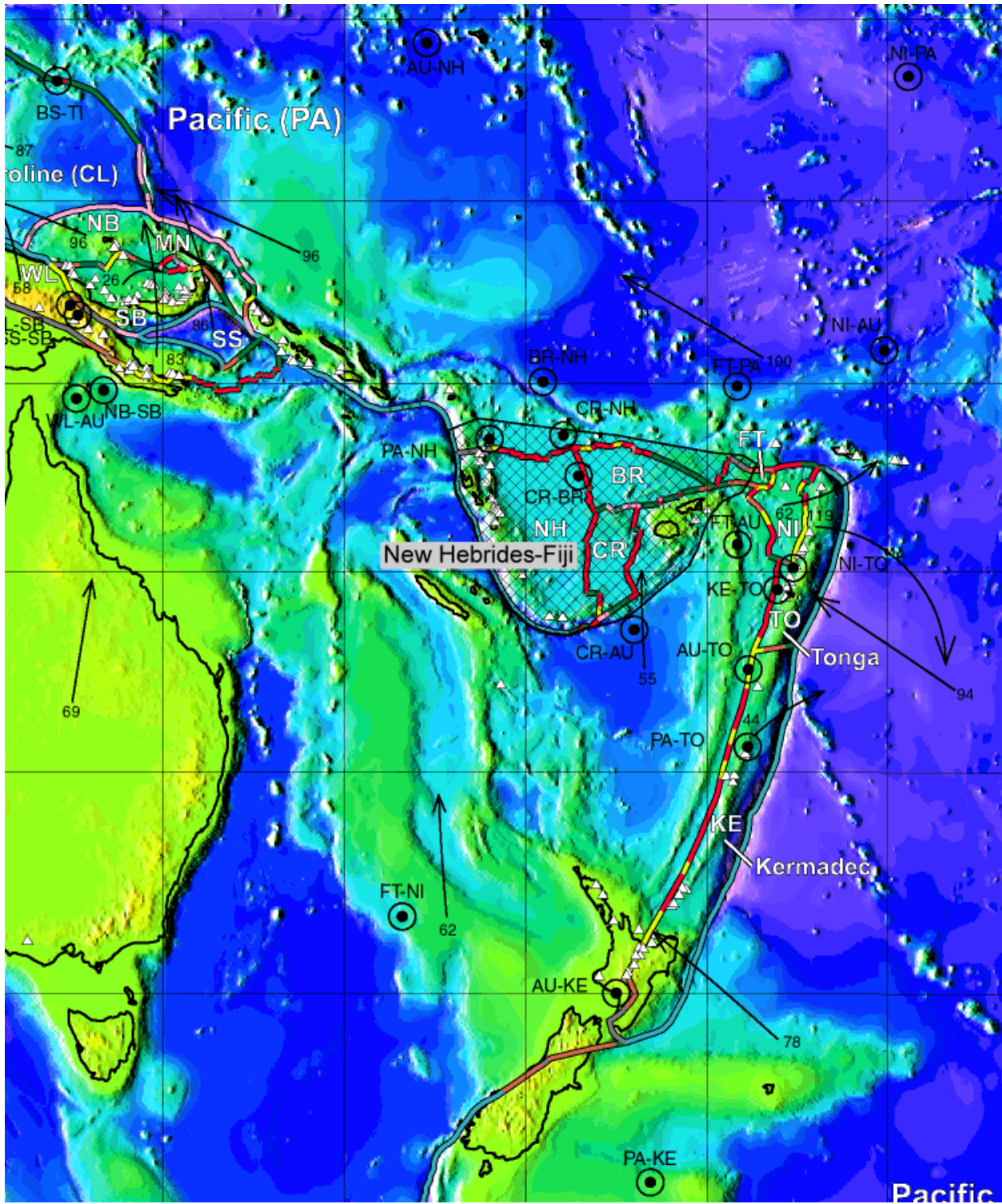


Figure 2. Regional bathymetric and tectonic setting of the TVSC, cropped from Bird's downloadable wall map of global PB2002 plate boundaries (Bird, 2003), last accessed at http://peterbird.name/publications/2003_PB2002/PB2002_wall_map.gif on 9/15/2008.

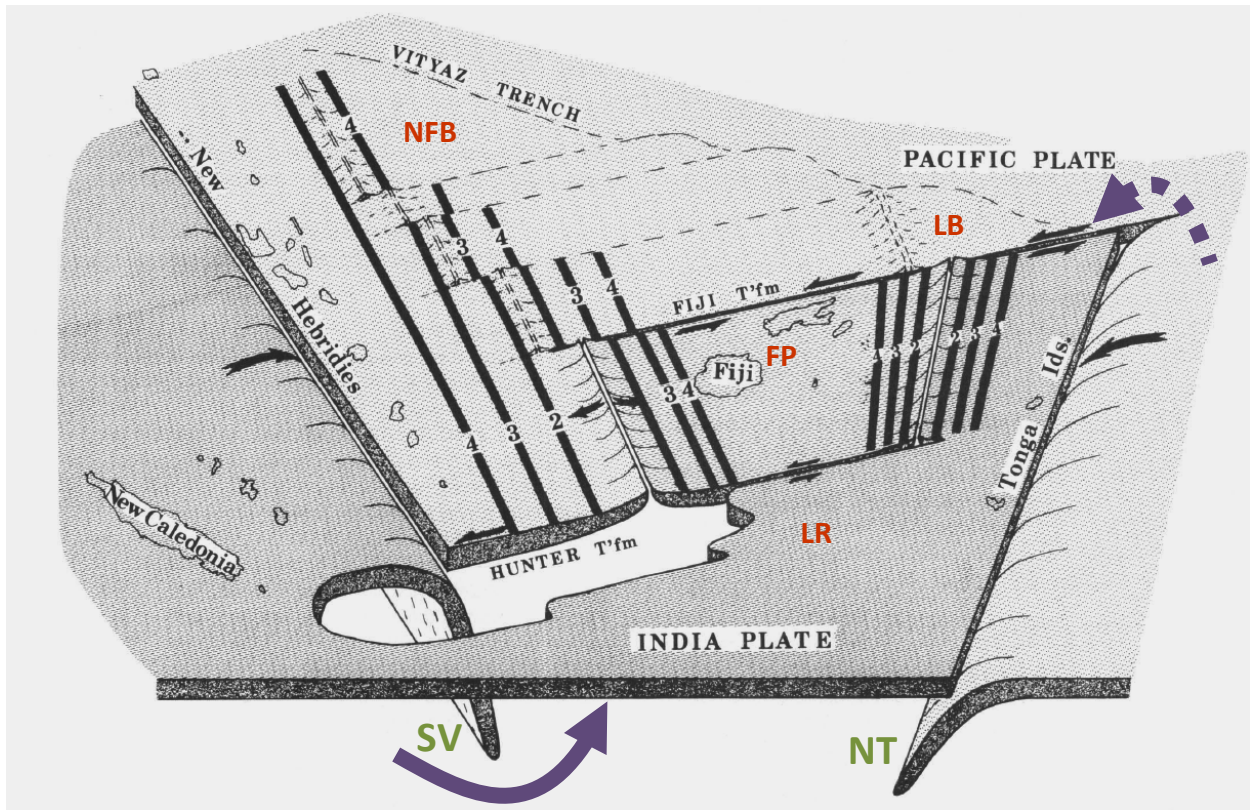


Figure 3. A 3D cutaway of the TVSC as seen from the south, after Falvy (1975). The North Fiji Basin (NFB) and Lau Basin (LB) backarc spreading center networks are grossly oversimplified here, and the Lau Ridge (LR) remnant arc extending southward from the Fiji plateau (FP) isn't shown at all, but the main TVSC components are otherwise nicely displayed. The thick purple arrows crudely depict MUM flows rounding the free northern edge of the North Tonga (NT) slab and southern edge of the South Vanuatu (SV) slab.

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