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Seismological constraints on the thermal structure and dynamics of subduction zones and back-arc basins

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Seismic tomographic models combined with results of experiments on the seismic properties of mantle materials may provide the best constraints on the temperature structure and the possible presence of fluids and melt in the mantle wedge. We explore the distribution of temperature anomalies in the Tonga volcanic arc and Lau backarc using P and S velocity [Conder and Wiens, 2005] and attenuation (Q) [Roth et al., 1999] tomographic images obtained from a deployment of ocean bottom seismographs. The seismic data are linked to mantle temperatures using temperature and grain-size dependent relations from Jackson et al [2002] and Faul and Jackson [2005]. The use of all 3 types of seismic observables (Vp, Vs, and Q) is highly desirable, otherwise the problem is underdetermined. We take two approaches for determining temperature structure. In one approach, we assume a mantle temperature field from dynamical models (e.g. Conder et al., 2001), and calculate forward models of Vp, Vs, and Q for comparison with the observed tomographic maps. Alternatively, we determine the best fitting temperature structure directly from the Vp, Vs, and Q observations in a least squares sense. Both approaches suggest that the observed Vs and Q anomalies in the upper mantle at depths less than 100 km in the arc and backarc predict temperature anomalies that are unreasonably large. This suggests the presence of melt and/or fluids, whose seismic effects are still incompletely characterized. Another seismological dataset, regional waveform inversion results, suggests systematic variation in the upper mantle structure at depths of 40-110 km for different active backarc basins. These seismic velocities correlate with bathymetry and the major element systematics of back-arc basin basalts [Kelley et al., 2005]. The seismic, bathymetric, and petrological datasets are consistent and suggest significant variation in upper mantle

temperature between different backarcs, with the northern Lau backarc showing the highest mantle temperatures and the Mariana backarc the lowest temperature. This suggests that the temperature of the mantle wedge in subduction zones may show significant variations resulting from the dynamical setting and mantle flow pattern, as suggested by 3-D mantle flow experiments.