Supplemental File.

Methods.

Data sources. All data were measured using laser-ablation, ICP-MS. At Boise State, compositions were measured using a Thermo XSeries2 Quadrupole ICP-MS (inductively-coupled plasma mass spectrometer) in conjunction with a NewWave UP-213 laser ablation system. Laser parameters included spot diameters 40-100 μm, a repetition rate of 4-10 Hz, and a fluence of 4-6 J/cm^2. We measured ^{27}Al, ^{29}Si, ^{43}Ca, ^{49}Ti, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{153}Eu, ^{157}Gd, ^{159}Tb, ^{163}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{172}Yb, ^{175}Lu, ^{178}Hf, ^{181}Ta, ^{202}Hg, ^{204}(Hg+Pb), ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, and ^{238}U. Count times were all 10 ms, except for ^{90}Zr (40 ms) and U-Th-Pb (^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, ^{238}U = 100, 300, 100, 50, and 50 ms respectively). Because of high count rates, ^{27}Al, ^{29}Si, and ^{49}Ti were analyzed at high resolution. All data were standardized against BLR titanite (Mazdab, 2009) and normalized to ^{29}Si as an internal standard. Detection limits cannot be evaluated completely rigorously, but we routinely reproduce REE concentrations at levels ≤10 ppb, and assume this is typical, at least for masses above c. 100 amu.

Published sources include Yang and Rivers (2000), Sassi et al. (2000), Zack et al. (2002), Spandler et al. (2003), Frei et al. (2004), Hokada and Harley (2004), Bea et al. (2006), Rubatto et al. (2006), Liebscher et al. (2007), Orejana et al. (2011), Lü et al. (2012), Jiao et al. (2013), and Xiao et al. (2013). We used experimental calibrations to calculate Zr contents of titanite (Hayden et al., 2008) and rutile (Watson et al., 2006). Otherwise, except for garnet and hornblende, we were unable to resolve any clear temperature dependence to Zr contents for other minerals, and for simplicity assumed constant Zr contents for all calculations. We chose the median of measurements (rather than the average) as the least biased estimator of saturation contents, noting that an occasional zircon micro-inclusion can spuriously inflate apparent Zr contents, whereas high Zr backgrounds during analysis (e.g. after having ablated a zircon) can spuriously reduce apparent Zr contents.

MORB Models. Our first model used the Holland and Powell (1998) thermodynamic database updated for mixing properties in numerous minerals, especially amphiboles (e.g., Dale et

al., 2005; Diener et al., 2007). These models vastly overestimated the stability fields of garnet towards low P-T conditions, and of actinolite + glaucophane across the blueschist facies. In the latter case, an extensive literature search identified ~100 reports worldwide of coexisting glaucophane plus either actinolite or tremolite, but all except a half-dozen are clearly disequilibrium, usually overgrowths of one amphibole on the other or obvious overprinting textures. Metabasalts are common in blueschist terranes worldwide, which sample a large array of P-T conditions. Thus the disparity between a large predicted stability field for glaucophane + actinolite assemblages and their rarity in nature implies that the amphibole mixing models or endmember thermochemical properties (which are correlated to the mixing models) in the updated Holland and Powell (1998) database are grossly in error. Recent revisions to amphibole and omphacite mixing models (Diener and Powell, 2012) and the Thermocalc thermodynamic database (Holland and Powell, 2011) strongly contract the stability field of garnet to more realistic elevated P-T conditions, but do not alleviate the coexisting amphibole problem.

Consequently, we constructed a second model based on the Berman (1988) thermodynamic database. This database has only simplified amphibole models (essentially ternary endmember mixing), and generally lacks data for Mn-endmembers for many metamorphic minerals, which are needed to model garnet growth. We estimated these properties using Fe-Mg-Mn exchange enthalpies, entropies and volumes (e.g. see Kohn et al., 1993), assuming heat capacities from Fe-Mg endmembers. These models more accurately predict garnet stability, but underestimate amphibole abundances, particularly glaucophane.

These exercises suggest to us that the two different approaches – complex vs. simple amphibole modeling with overpredicted vs. underpredicted amphibole abundances in the blueschist facies – probably bracket the likely range of mineral assemblages. Fortunately, both models make nearly identical predictions with respect to Zr modeling. So we view our results as flawed in petrologic detail, but sufficiently accurate for Zr mass balance to identify impacts on zircon abundance.

Metapelite Model. Our metapelite model followed closely the approach of Kelsey et al. (2008; thermodynamic database of Holland Powell, 1998), but with some modifications. We used a metapelite composition recommended by Spear et al. (1990) modified by adding 1 wt% TiO_2 and 200 ppm Zr (Taylor and McLennan, 1985). This composition is somewhat more Fe-rich and Si-, Ti- and Ca-poor than Kelsey et al.'s assumed composition. These differences tend to form less rutile and stabilize paragonite in some P-T regions (paragonite is combined with muscovite/phengite in our diagrams as "white mica"). We assumed rocks were H2O-saturated below 600 °C, but reduced H_2O content to 3 wt% for models above 600 °C to conform better with expectations that rocks progressively dehydrate during metamorphism. This adjustment reduces the predicted amount of melt considerably, and consequently is more conservative about the magnitude of zircon dissolution. Most importantly, Kelsey et al. (2008) and Kelsey and Powell (2011) presented models only up to P=12 kbar, whereas we wanted to emphasize eclogite-facies models. Thus, we expanded the P-T range of the model and included omphacite and sodic amphibole as potential minerals.

As with models of MORB, we encounted some problems with potential solution models. Complex amphibole models (e.g. Diener et al., 2007) predicted unlikely multiple amphibole assemblages and a large stability region for glaucophane + biotite, which is virtually unknown as an equilibrium assemblage worldwide. Similarly, use of recent ilmenite and biotite models (White et al., 2007; Tajčmanová et al., 2009) predicted widespread glaucophane + biotite assemblages, as well as ilmenite and biotite in blueschists and eclogites, whereas in nature rutile and phengite are ubiquitous. Simple ideal mixing for ilmenite, and biotite and muscovite models that omit Ti (Holland and Powell, 1998), produced more realistic results. Melts were modeled using mixing properties of White et al. (2007), and the Zr content of partial melts was modeled using the recent calibration of Boehnke et al. (2013).

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