Searle,′ M.P., Waters, D.J., Garber, J.M., Rioux, M., Cherry, A.G., and Ambrose, T.K., 2015, Structure and metamorphism beneath the obducting Oman ophiolite: Evidence from the Bani Hamid granulites, northern Oman mountains: Geosphere, v. 11, doi:10.1130/GES01199.1.

Supplemental Text File. Titanite Analytical Methods

Titanite grains from each sample were imaged in thin section using back-scattered electrons on an FEI Quanta 400f scanning electron microscope (SEM) at UCSB. Samples were ablated in thin section using a Photon Machines 193 nm ArF excimer ultraviolet laser with a HelEx ablation cell coupled to a Nu Instruments Plasma high-resolution multi-collector inductively coupled plasma mass spectrometer (MC-ICPMS) and an Agilent 7700S quadrupole ICP. The laser spot diameter was 30 μm for JC98 and 40 μm for JC106, and the laser fluence was ~1 J/cm^2. The laser was fired twice to remove common Pb from the sample surface and this material was allowed to wash out for 11 seconds. Material was then ablated at 4 Hz for 20 seconds, resulting in a pit depth of ~8 μm. Analyses of unknowns were bracketed by analyses of titanite reference material (RM) BLR [1047.4 ± 1.4 Ma concordia date, Aleinikoff et al., 2007], which was used as the primary RM for U-Pb analyses. Additional titanite reference material Y1710C5 [388.6 ± 0.5 Ma ID-TIMS date, Spencer et al., 2013] and two in-house titanite RMs [long-term LA-ICPMS dates of 385 Ma (RM-A) and 105 Ma (RM-B), A. Kylander-Clark, personal communication] were included as further monitors of accuracy. During the course of this study we obtained ages of 392.7 ± 5.7 Ma for Y1710C5, 383.2 ± 2.2 Ma for RM-A, and 106.6 ± 2.5 Ma for RM-B. These ages are accurate to within 1.1, 0.5, and 1.5% of the reference values, respectively.

Analyses of unknowns were also bracketed by analyses of glass reference material NIST SRM 610 (Pearce et al., 1997; Rocholl et al., 1997); for sample JC106, titanite glass reference materials TNT150 and TNT1500 (Klemme et al., 2008) were included. Because the titanite glasses have a composition similar to end-member titanite (Klemme et al., 2008), the use of TNT150 and TNT1500 as a

primary RM should account for time-dependent mass fractionation better than the NIST glass (e.g., Eggins et al., 1997; Liu et al., 2008), and therefore should yield more accurate trace element abundances in titanite unknowns. However, chondrite-normalized REE patterns are nearly identical regardless of the choice of primary trace element RM (Figure DR2). Furthermore, TNT150 and TNT1500 contain minimal Eu, Tb, Dy, Ho, Er, Tm, and Yb, yielding imprecise MREE-HREE abundances (and requiring extensive interpolation) if either of the TNT glasses are used as primary RMs. For these reasons, all chondrite-normalized REE patterns for both samples are reported with NIST SRM 610 as the primary RM, but note that REE abundances may be inaccurate by ±15–20% and are only discussed qualitatively to establish age and trace element populations. In contrast, Zr abundances for JC106 were reduced using TNT150 as the primary RM and TNT1500 as a secondary RM, yielding data that is demonstratively more robust and is therefore addressed more quantitatively. (Using NIST SRM 610 as a primary standard yields Zr-in-titanite temperatures that are only ~10 ºC higher.)

On the Plasma HR, masses ^{204}Pb+Hg, ^{206}Pb, ^{207}Pb, and ^{208}Pb were measured on secondary electron multipliers, and masses ^{232}Th and ^{238}U were measured on Faraday detectors. Elemental data collected on the 7700S were reduced using ^{43}Ca (assuming 19.25 weight % total Ca in titanite) as an internal standard. For the trace element routine, peaks were measured on ^{27}Al, ^{28}Si, ^{31}P, ^{43}Ca, ^{49}Ti, ^{51}V, ^{52}Cr, ^{56}Fe, ^{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, and ^{182}W. The Iolite plug-in (Paton et al., 2011) for the Wavemetrics Igor Pro software was used to correct measured isotopic ratios for baselines, time-dependent laser-induced inter-element fractionation, plasma-induced fractionation, and instrument drift. Baseline intensities were determined prior to each analysis. The mean and standard error of the measured ratios of the backgrounds and peaks were calculated after rejection of outliers more than 2 standard errors beyond the mean.

The uncertainty of individual measurements is dominated by counting statistics and signal stability. Each $^{207}Pb/^{206}Pb$ measurement requires an additional 2% external error attributable to variation in ablation or transport characteristics, mass balance instabilities, or plasma loading effects; this was added in quadrature. Long-term analysis shows that this equipment and method are capable of measuring the baseline- and fractionation-corrected $^{206}Pb/^{238}U$ of a primary reference material (e.g., BLR) with a long-term precision of ±0.7%; the baseline and fractionation-corrected $^{207}Pb/^{206}Pb$ can be measured with a long-term precision of ±0.4% (2σ) (Spencer et al., 2013). When combined with uncertainties in the isotopic ratios of the primary RM and the U decay constants, the date of a homogeneous unknown has an external uncertainty of 2% due to secular variations in the behavior of the laser, the laser-stream transmission, or the ICPMS (Spencer et al., 2013).

The $^{238}U/^{206}Pb$ and $^{207}Pb/^{206}Pb$ isotopic ratios for each analysis were plotted on Tera–Wasserburg [1972] diagrams using Isoplot (Ludwig, 2003). All date uncertainties are reported at the 95% confidence interval, assuming a Gaussian distribution of measurement errors. Because the two samples in this study exhibit a broad spread of U-Pb ratios – and thus, a well-constrained common $^{207}Pb/^{206}Pb$ ratio – we report the $^{238}U/^{206}Pb$-$^{207}Pb/^{206}Pb$ isochron date or '207-corrected $^{206}Pb/^{238}U$' date.

For the Zr-in-titanite thermometry data plotted in Figure 12c, the thick colored bars show the internal 2σ uncertainties on temperatures calculated for each spot analysis, which include only the propagated random measurement uncertainty in Zr abundance. In our experience analyzing titanite trace elements in both standards and unknowns, we typically observe Zr-in-titanite temperature scatter that significantly exceeds analytical uncertainty. This type of data, therefore, rarely yields single populations (MSWD ≈ 1) even for samples in which other petrologic and geochemical data imply a limited range of titanite (re)crystallization temperatures. To account for this excess scatter, we propagate an additional 2% temperature uncertainty (in quadrature) to each spot analysis, shown by the

thinner colored bar, prior to calculating a weighted mean average. The calculated weighted mean temperatures for each trace element population (black horizontal lines) were calculated using the enhanced internal uncertainties, and each weighted mean is shown with an associated internal 2σ uncertainty (darker grey bar) and external 2σ uncertainty (lighter gray bar). The external 2σ uncertainty includes the internal 2σ uncertainty of the mean with additional propagated systematic uncertainties in pressure, a_{TiO2}, and the thermodynamic terms in the calculation.

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