Supplemental Material to:

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Appendix S1: U-Pb LA-ICP-MS analyses

Zircon grains from the samples were analyzed in three different laboratories. The U-Pb age data for the samples are reported in Tables DR1–DR3 along with age data for the standards analyzed throughout the different analytical sessions. The analytical procedures for the labs are described below.

UC Davis

Sample TB-4 and one grain mount of TB-5 were analyzed at UC Davis using a Thermo Scientific Element-XR single-collector ICP-MS coupled to a Photo Machines Analyte 193H ArF excimer laser. Laser settings for U-Pb zircon analyses were as follows: a laser energy density of 1.49 J/cm^2 or 1.2 J/cm^2 with a repetition rate of 5 Hz. A 31.4 µm diameter laser spot size was used. Each analysis was ~2 minutes consisting of 30 seconds of background, followed by 60 seconds of laser ablation, followed by 30 seconds of monitored wash out. Zircon crystal 91500 (1065 Ma; Wiedenbeck et al., 1995) was used as the primary bracketing standard. Five additional zircon crystals with well-characterized U-Pb ages were used throughout the analyses as secondary standards. Initially, Plesovice (337.1 ± 0.4 Ma; Slama et al. 2008), GJ1 (608.5 ± 1.5 Ma; Jackson et al. 2004), and B266 (559 ± 0.2 Ma; Stern and Amelin, 2003) were run as alternating secondary U-Pb age standards. After the initial series of U-Pb analyses, R33 (419.3 ± 0.4 Ma; Black et al. 2004), FC-1 (1099.1 ± 1.2 Ma; Schmitz and Bowring, 2001), and Temora 2 (416.78 ± 0.33 Ma; Black et al. 2004) were also analyzed for more robust age comparisons. The analytical sequence followed was: five 91500, three secondary standards, two unknowns, two 91500, five unknowns, two 91500, three secondary standards, two unknowns, two 91500, five unknowns, etc. Data reduction was performed using Iolite (v.2.5) with the VisualAge-UcomPbine data reduction scheme (Paton et al., 2010). For both zircon standards and unknowns, ~50 seconds of the laser ablation interval was integrated for U-Pb age calculations. Final isotopic ratios and ages are reported in Table DR2. In all the analyses, the known ages and measured ages of the standards was within 2–4 % (2s uncertainty).

For U-Pb dates older than 1100 Ma, we quote the ^{207}Pb/^{206}Pb age as the best age, and for dates younger than 1100 Ma, we quote the ^{206}Pb/^{238}U age. For Mesozoic age zircon, the low abundance of ^{207}Pb results in a relatively large uncertainty in the ^{207}Pb/^{235}U and ^{207}Pb/^{206}Pb ratios compared ^{206}Pb/^{238}U ratio. Consequently, we only refer to the ^{206}Pb/^{238}U age for Mesozoic grains and do not apply concordance filter for these grains. For dates older than the Mesozoic, we discarded data from our final interpretation if: 1) total laser ablation integration time was too short, resulting in standard errors too large to be geologically meaningful; 2) discordance was > 10%; or 3) the 2σ error on the best age was larger than 10%.

Arizona Laserchron Center

Sample JW-1Z-001 and one grain mount of TB-5 were analyzed at the Arizona Laserchron Center. The procedures for these analyses are identical to those reported in Dumitru et al. (2013, data repository 2013046) and are briefly discussed here.

Ablation analyses of zircon used a spot diameter of 30 microns on a New Wave UP193HE Excimer. Isotopes of U and Pb were analyzed using a Nu HR ICP-MS (Gehrels et al., 2006, 2008). Each analysis consisted of ~15 seconds of background collection, ~15 seconds of laser firing, and ~30 second of wash out prior to the next analysis. Ablation pits were typically ~15 µm in depth. ALC's Sri Lanka zircon standard (563.5 ± 3.2 Ma; 2σ error) was analyzed every fifth measurement and was used to correct for inter-element fractionation of Pb/U.

Data reduction was done using Iolite v. 2.5 (Paton et al., 2010) using the same procedure for the samples run at UC Davis. Uncertainties presented in the Table DR3 are at the 1σ level, and include only measurement errors. Data was discarded using the same criteria as the UC Davis samples.

UC Santa Barbara

Samples UECQ and LECQ and new mounts of TB-4 and TB-5 were analyzed at UC Santa Barbara using a Nu Instruments Plasma HR-ES multi-collector ICP-MS coupled to a Photon Machines 193 nm excimer Analyte laser. Samples were analyzed using a 19.3 µm laser spot that was set to shoot 60 shots at a rate of 4 Hz and a fluence of 2.26 J/cm^2. Each analysis consisted of ~15 seconds of background collection, followed by ~15 seconds of lasering, and ~20 seconds of washout prior to the next analysis. Zircon standard 91500 was used as the primary bracketing standard; GJ1, Plesovice, and SL1 were run as secondary standards to assess accuracy and precision (Wiedenbeck et al., 1995; Jackson et al., 2004; Slama et al., 2008).

Data reduction was done using Iolite v. 2.5 (Paton et al., 2010) using the same procedure for the samples run at UC Davis. Data was discarded using the same criteria as the UC Davis samples.

A word on comparing/combining U-Pb data from different lab groups

In this study, we pool data from TB-4 and TB-5 that were collected from different laboratories. Combining data from laboratories does not compromise our findings. The same standards analyzed at the different labs are all in excellent agreement, suggesting the data collected for TB-4 and TB-5 are comparable.

Figure DR1 compares the probability distribution functions for the ages collected for the same samples at different labs. No obvious bias is observed among the data sets. The ages collected from sample TB-4 all yield a dominant Mesozoic age range between ~180 Ma and 100 Ma, and show consistent age peaks at ~110, 125, 140 and 160 Ma. The data for TB-4 collected at UCSB shows a larger age range for older grains. However, more grains were analyzed at UCSB and the large spread of Precambrian ages likely reflects that larger population of grains analyzed in the UCSB sessions. Despite being collected in three different labs, sample TB-5 also yields strikingly similar results: the 180–100 Ma age range is present throughout, and the two major age peaks at ~110 Ma and ~140 Ma are ubiquitous. The Precambrian grains are consistently few; minor differences in the age ranges for these older grains are attributed to the different number of grains analyzed. Finally, we note that the youngest grains for TB-4 were solely from analyses at UC Davis. We cannot be entirely certain that the youngest grains are robust because the same grains were not analyzed in different labs, but we note that the MDA does not change whether we include or exclude the youngest grains (MDA of 112 ± 1 Ma with the eight youngest grains from UCD vs. 113 ± 1 Ma without the eight youngest grain from UCD using the method outlined below). For these reasons, we consider pooling the different data sets for the same samples justified.

Appendix S2: Best age and MDA determination

In addition to using the weighted mean of the three youngest grains of each sample as the MDA, we also determined the MDA using the procedure outlined in Dumitru et al. (2010). The procedure consists of selecting the youngest zircons and calculating the weighted mean age, MSWD, and probability that the group of selected grain ages conform to a single population. The number of grains within the youngest zircon population is increased by one grain until the probability that the selected grain ages comprise a single population drops below a 10% limit (Table DR4; see also Dumitru et al., 2018). This method usually resulted in MDA within 2σ error of the youngest grain.

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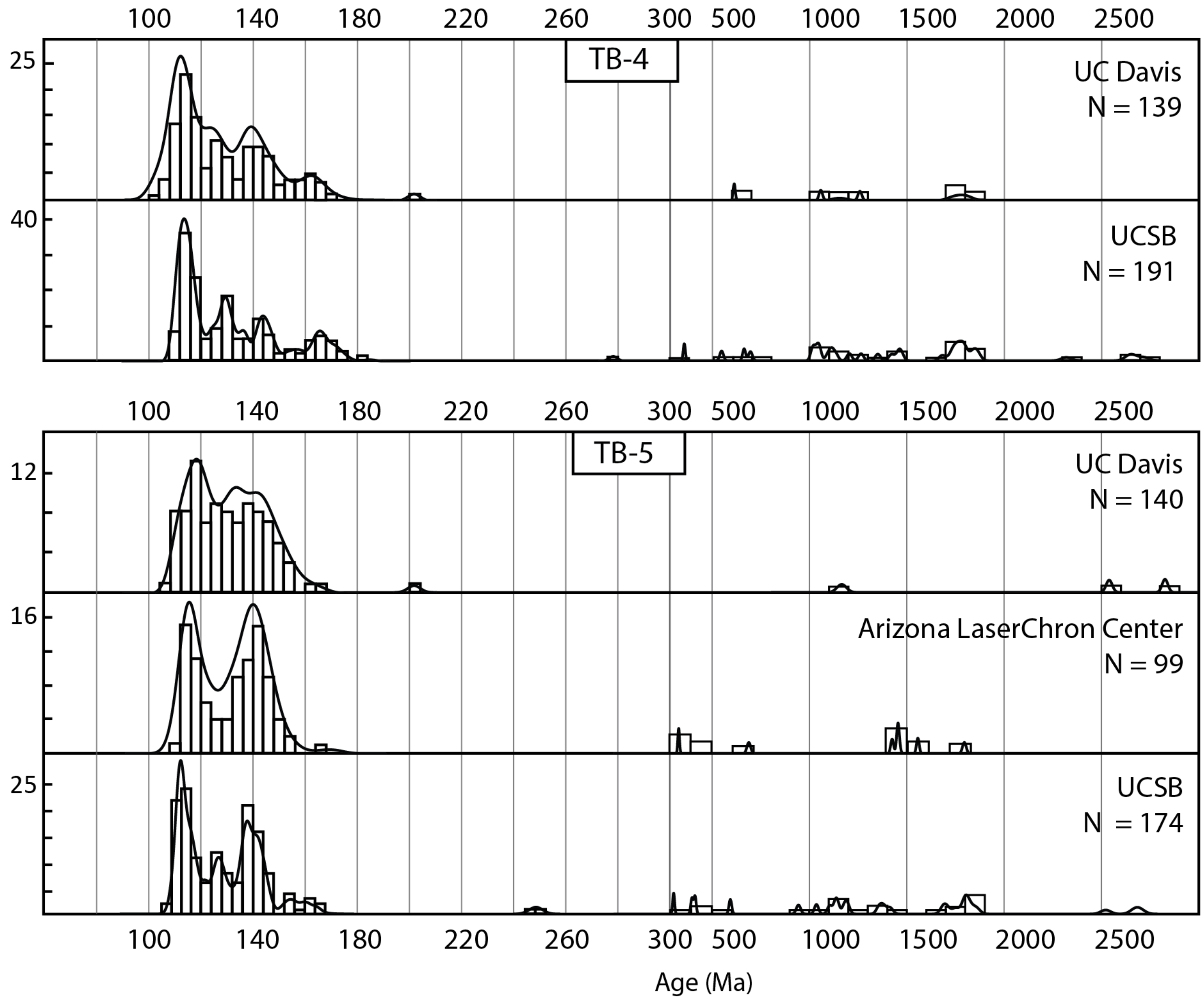

Figure S1. Comparison of U-Pb age probability-density curves for samples analyzed at different labs. Analyses at different labs yield the same age patterns for samples TB-4 and TB-5. Note that the samples are binned at 4 Ma for ages <300 Ma and binned at 100 Ma for ages >300 Ma.

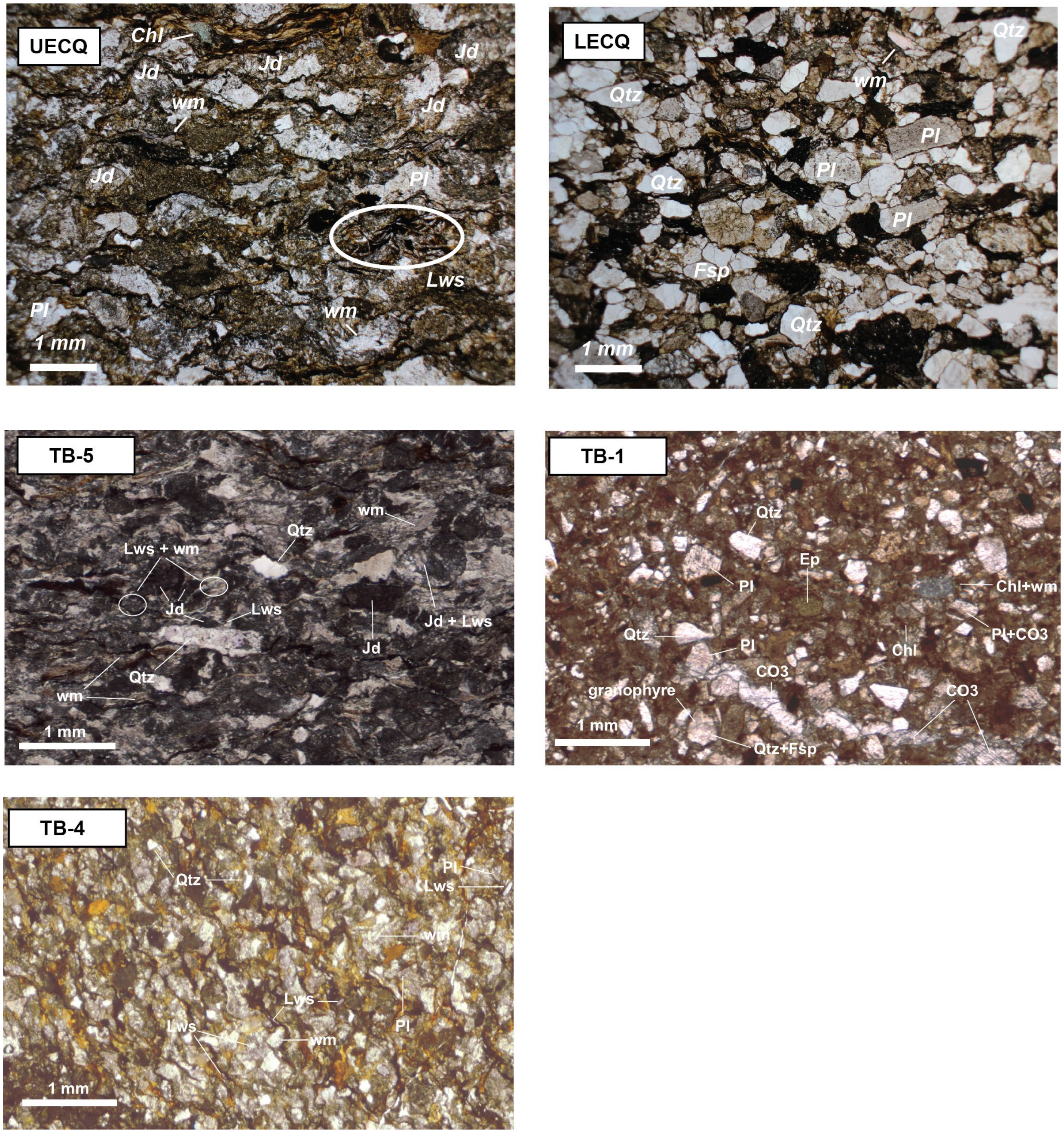

Figure S2. Representative photomicrographs of the Franciscan sandstones analyzed in this study (N=5), taken under plane-polarized. Sample TB-1 is from the same outcrop as sample JW-1Z-001. Mineral assemblages are summarized in Table 1. Mineral abbreviations are after Whitney and Evans (2010).