Dating the Duration of Deformation along a Major Shear Zone within the Eastern Peninsular Ranges Batholith

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Abstract

Understanding the formation and evolution of continental crust in Southern California is a complex inverse problem due to the ever-evolving tectonics of the region. Determining an accurate date for the formation of the unaltered protolith of the Eastern Peninsular Ranges Batholith (EPRB) will help constrain the maximum age of deformation in the Borrego Springs Shear Zone (BSSZ) and Santa Rosa Mylonite Zone (SRMZ) that transect the batholith. We conducted new $^{206}Pb/^{238}U$ zircon analyses to help provide a better picture of the geologic history of the region and aid in understanding the ductile shear zone components of the San Andreas Fault system and the complexity of the North American-Pacific tectonic boundary. These new age constraints will in turn contribute to the development of the SCEC Community Rheology Model by better describing the duration of deformation and the properties of these shear zones that serve as exposed analogs to the shear zones that extend beneath the brittle faults of the southern San Andreas Fault system.

Data and Methodology

Three samples were collected from mylonitic host rocks and two from cross-cutting dikes (one deformed and one undeformed) in the BSSZ and SRMZ during the 2018 - 2019 field season. Samples were processed using standard mineral separation procedures. Zircons were picked under a binocular microscope, mounted on epoxy, polished and imaged on a FEI Quanta 600 scanning electron microscope (SEM) with Gatan MiniCL cathodoluminescence detector at California State University, Northridge. Selected grains were then analyzed with a ThermoScientific Element2 SF-ICPMS and Teledyne Cetec Analyte G2 Excimer Laser.

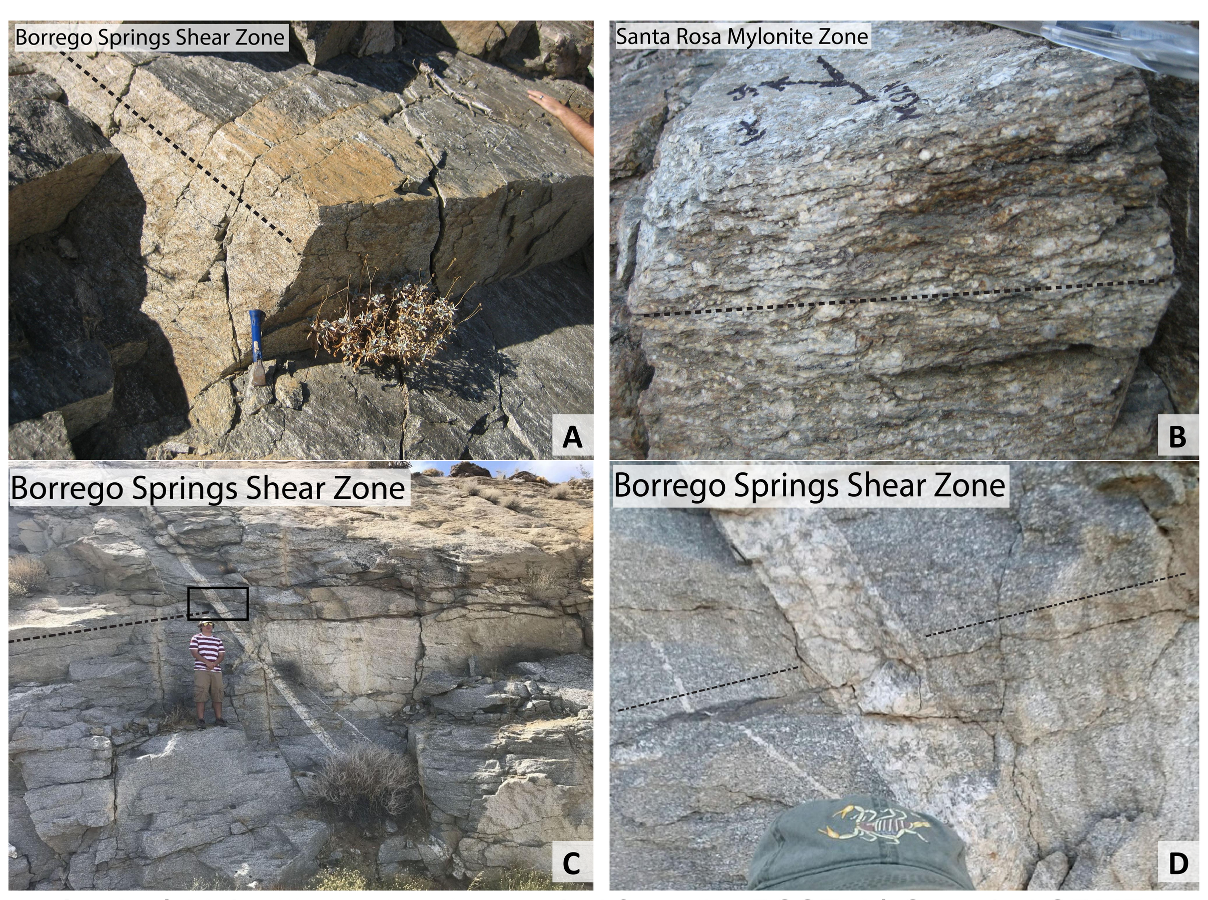


Figure 1a-d: **a)** Mylonitic host rock sampled from the BSSZ. **b)** Sampled SRMZ host rock. **c)** Undeformed dike cross-cutting mylonitic protolith. **d)** Close up of boxed area in **1c.** Foliation is indicated by dashed black line in all figures.

Analytical Methods

91500 was used as the primary zircon reference material to correct for downhole fractionation and instrument drift effects, with Temora-2 used as a secondary zircon reference material and analyzed repeatedly as an unknown to assess the precision of acquired data.

Mean weighted average of 91500 analyses = 1062.5 ± 3.8 Ma, MSWD = 0.091 (95% confidence, n=53/53). Mean weighted analyses of Temora-2 = 418.6 ± 2.0 Ma, MSWD = 3.98 (95% confidence, n=38/38). Ages are reported to 2σ and compare favorably to Black et al. (2004).

We rejected spots with $^{207}Pb/^{206}Pb$ errors >10% as bad analyses. Cathodoluminescence images were correlated with reflected light mosaics generated on the Teledyne Cetec Analyte G2 Excimer Laser and spots straddling domains or on cracks were also excluded as non-representative data.

Zircon Cathodoluminescence Images

Cathodoluminescence images of zircon grains collected on the FEI Quanta 600 SEM. Images were brightness and contrast adjusted for clarity. Laser-ablation spots are highlighted and to scale. Note chemically distinct cores in several grains from 18BORSPG4B (Figure 2a).

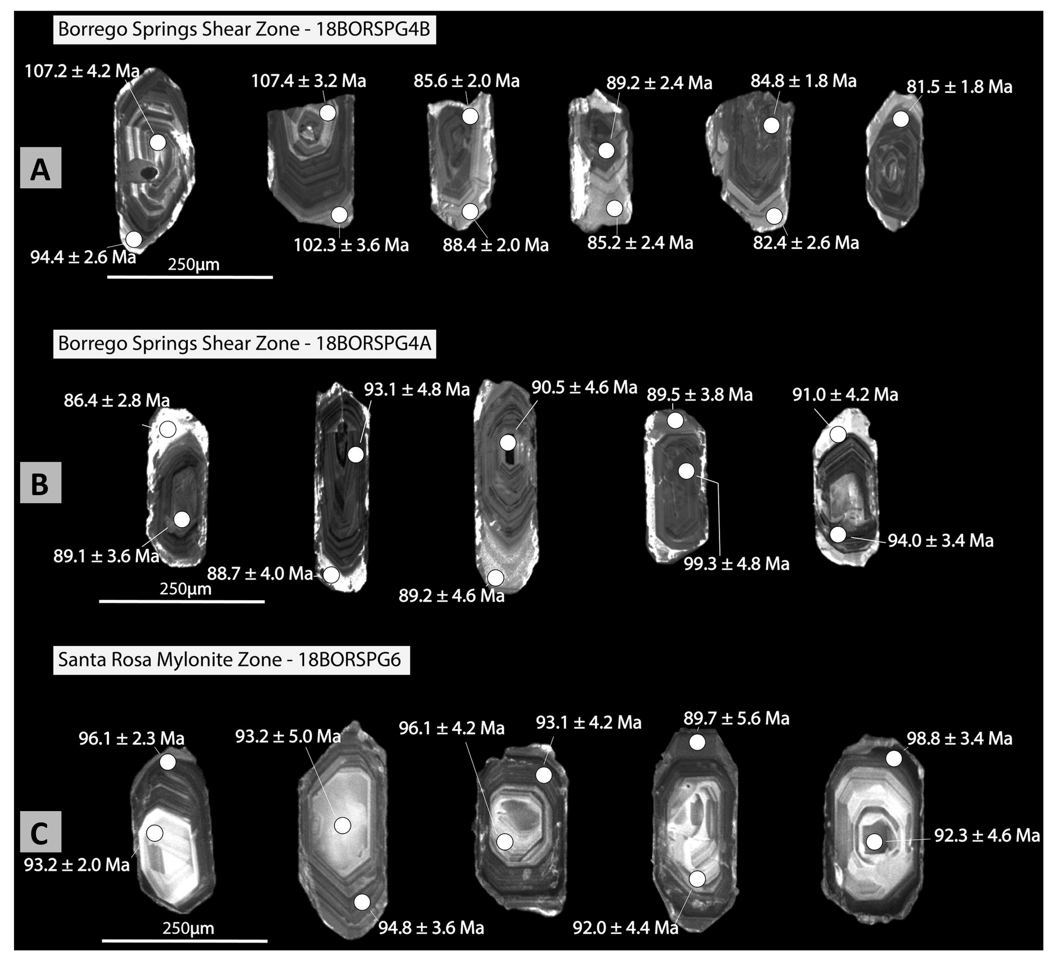


Figure 2a-c: a & b) CL images of selected zircons from the BSSZ. **c)** CL images of zircons from the SRMZ.

Timing of Pluton Emplacement

In host rocks, core and rim average ages were indistinguishable within 2σ in two samples. We take the cores and rims of these samples as single populations recording magmatism from ~100+ Ma to ~90 Ma with some individual zircons preserving records of periodic fluxes in conditions. Our data show an average protolith age of 91.9 ± 0.6 Ma (95% confidence, n=34/40) in the BSSZ and 92.6 ± 0.7 Ma (95% confidence, n=32/38) in the SRMZ.

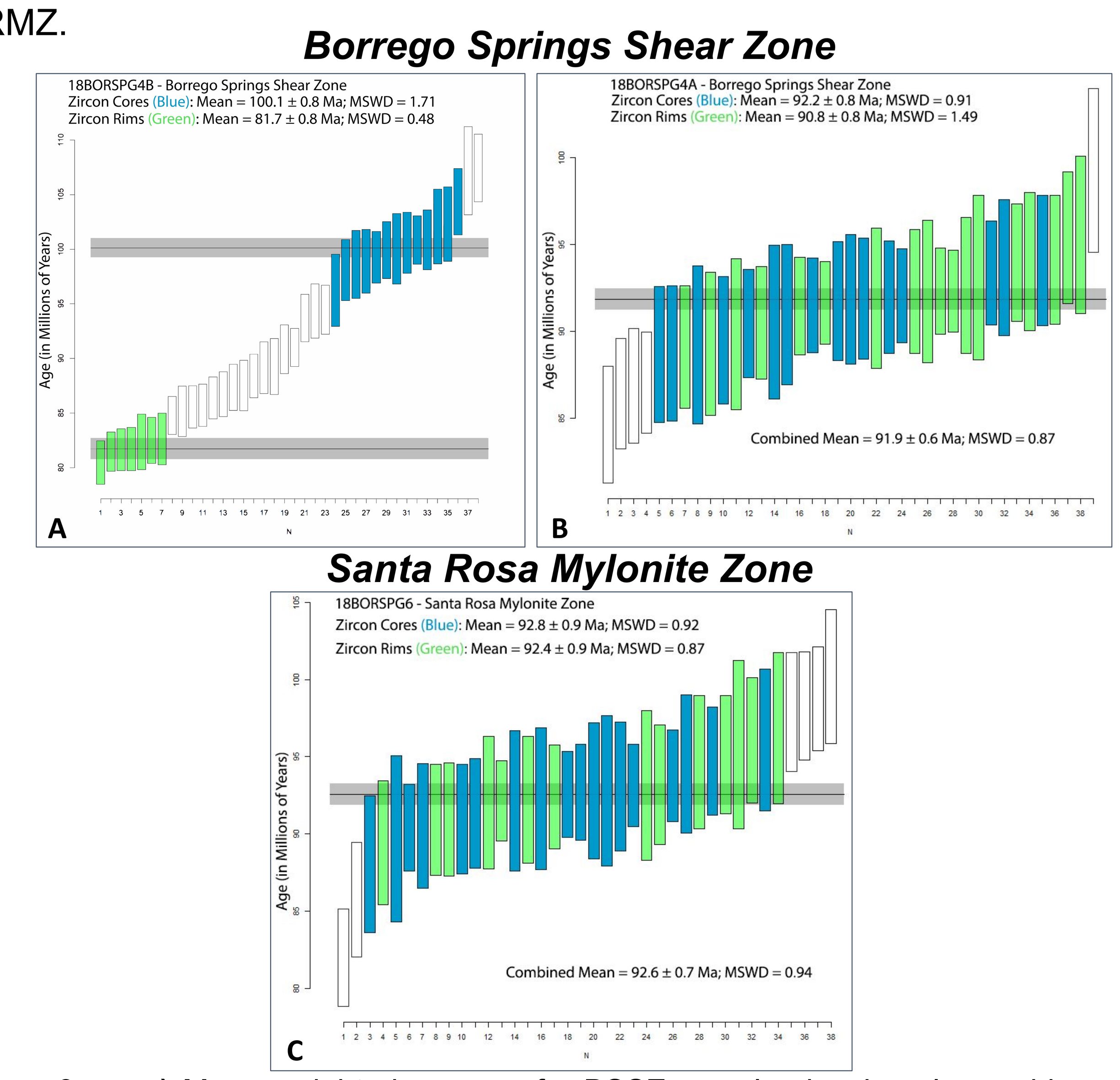
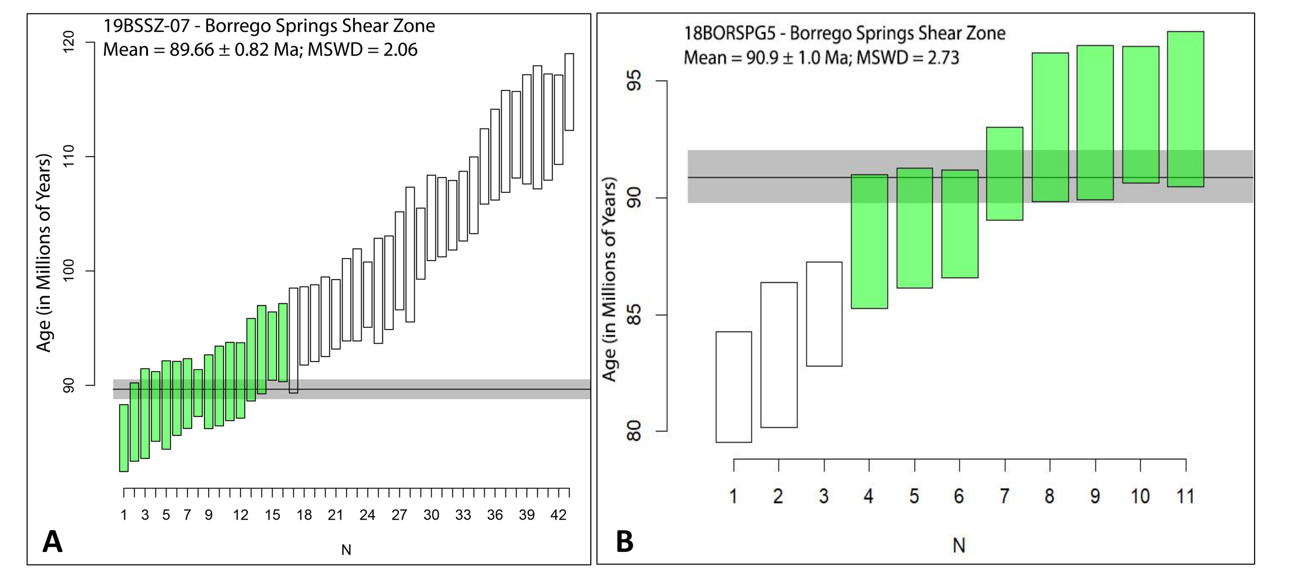


Figure 3a-c: a) Mean weighted average for BSSZ sample showing clear evidence of two separate age populations. The older core population had a mean age of 100.1 ± 0.8 Ma (95% confidence) and the younger rims a mean age of 81.7 ± 0.8 Ma (95% confidence). This younger mean post-dates both undeformed and deformed dikes. Based on low U/Th ratios (< 5.0) and correlation with CL images, we interpret the core age to likely represent inherited zircons formed coeval with our other host samples or earlier, and the younger rims to perhaps show evidence of lead loss or other alteration. **b)** Mean weighted average age for single population BSSZ sample. **c)** Mean weighted average for a mylonite sample from the SRMZ. In all figures, blue colors represent core analyses and green represent rim analyses. Unfilled bars are excluded analyses.

Constraining the Timing of Deformation in the Borrego Springs Shear Zone

Cross-cutting dikes help provide constraints on the maximum age of deformation in these ductile shear zones. One sample was collected from an undeformed dike (Figures 1c-d) and one from a deformed dike in the BSSZ.



Figures 4a-b: **a)** Mean weighted average for the undeformed dike. **b)** Mean weighted average for deformed dike. Hollow bars represent excluded analyses.

Data from the deformed dike provide a maximum age of deformation, while undeformed dike data helps constrain the minimum age. Our deformed dike was dated to 90.9 ± 0.9 Ma (95% confidence, n= 8/12) and the undeformed dike to 89.7 ± 0.8 Ma (95% confidence, n=16/44).

Summary

Our data show that magmatic zircons were crystallizing in the BSSZ from just over 100 Ma to just over 90 Ma as this part of the protolith cooled. We define a maximum age of sub-solidus deformation in this part of the study area at 91.9 ± 0.6 Ma (95% confidence) as constrained by the host rock data. Deformation appears to have been ongoing at 90.8 ± 0.9 (95% confidence) based on the age of the deformed dike. This period is bracketed on the young end by the age of the undeformed dike at 89.7 ± 0.8 Ma (95% confidence) which must have formed after deformation.

In the SRMZ, we interpret the age of our host sample to be 92.6 ± 0.7 Ma (95% confidence). This age (which also provides an upper limit of deformation), overlaps host rocks in the BSSZ at 2σ. Recent $^{206}Pb/^{238}U$ ages from titanites the same mylonitic host rocks by Jennifer Bautista, a student at CSU Northridge and SURE intern, demonstrates ages of 86.3 ± 2.2 Ma (95% confidence) in the BSSZ and 88.5 ± 1.1 Ma (95% confidence) in the SRMZ (See her poster here at SCEC 2019).

These ages agree well and overlap within 3σ, excluding one titanite date that requires further study. We take these data to imply a contemporaneous system of contraction along the EPRB during which both of these regions were emplaced and deformed.

Future Work

In addition to further investigating the timing of deformation in the Santa Rosa Mylonite Zone through the identification of undeformed dikes to sample in that area, work is required to better understand the conditions controlling the petrogenesis of the sample with two age populations.

We intend to collect, process, and analyze more zircon samples to gain more insight into the complex processes in the region.

References

Black, L.P., Kamo, S.L., Allen, C.M., Davis, D.W., Aleinikoff, J.N., Valley, J.W., Mundil, R., Campbell, I.H., Korsch, R.J., Williams, I.S., Foudoulis, C., 2004. Improved Pb-206/U-218 microprobe geochronology by the monitoring of a trace-element-related matrix effect; SHRIMP, ID-TIMS, ELA-ICP-MS and oxygen isotope documentation for a series of zircon standards. Chemical Geology 205, 115-140. **Hiess, J., Condon, D. J., McLean, N., & Noble, S. R.** (2012). 238U/235U systematics in terrestrial uranium-bearing minerals. *Science*, *335*(6076), 1610-1614. **Horstwood, M. S. A., Košler, J., Gehrels, G., Jackson, S. E., McLean, N. M., Paton, C., … Schoene, B. (2016)**. Community-Derived Standards for LA-ICP-MS U-(Th-)Pb Geochronology—Uncertainty Propagation, Age Interpretation and Data Reporting. *Geostandards and Geoanalytical Research*, *40*(3), 311–332. https://doi.org/10.1111/j.1751-908X.2016.00379.x, **Ludwig, K.R., 2012**, Isoplot 3.75: A. geochronological toolkit for Microsoft Excel: Berkeley Geochronology Center Special Publication 5, pp. 1-75., **Premo, W. R., Morton, D. M., Wooden, J. L., & Fanning, C. M. (2014)**. U-Pb zircon geochronology of plutonism in the northern Peninsular Ranges batholith, southern California: Implications for the Late Cretaceous tectonic evolution of southern California. *Peninsular Ranges Batholith, Baja California and Southern California: Geological Society of America Memoirs*, *211*, 145-180.

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