Learning from complexity: Paired U-series and (U-Th)/He analyses of hematite fault damage from the southern San Andreas fault

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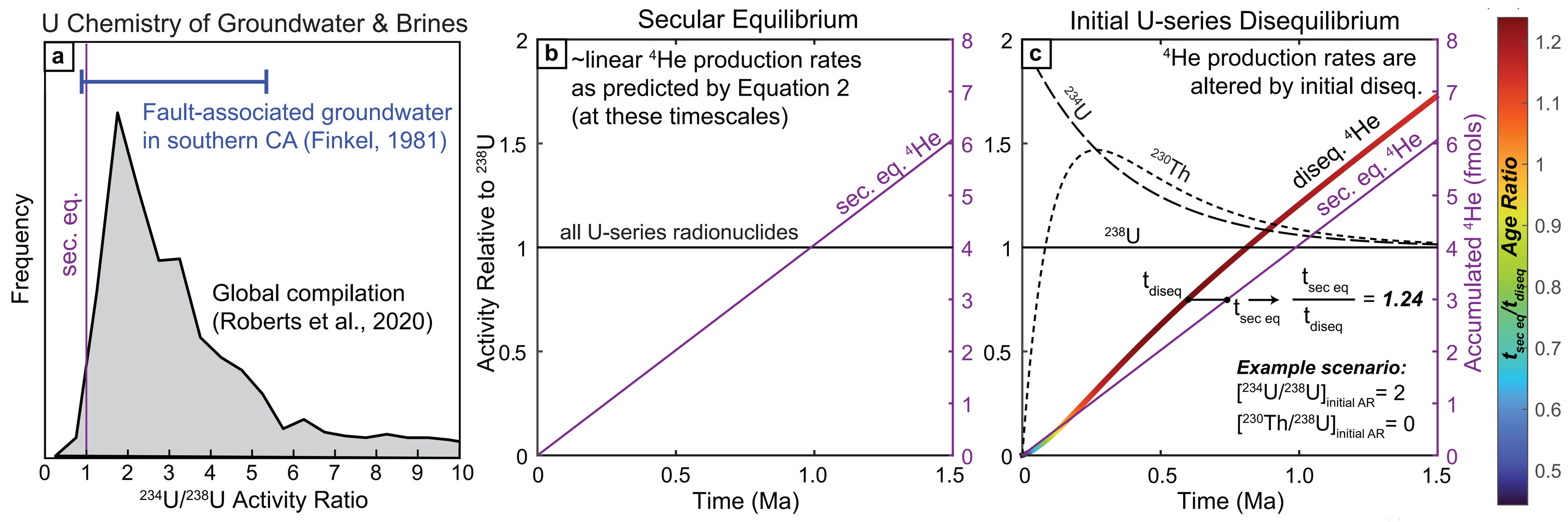
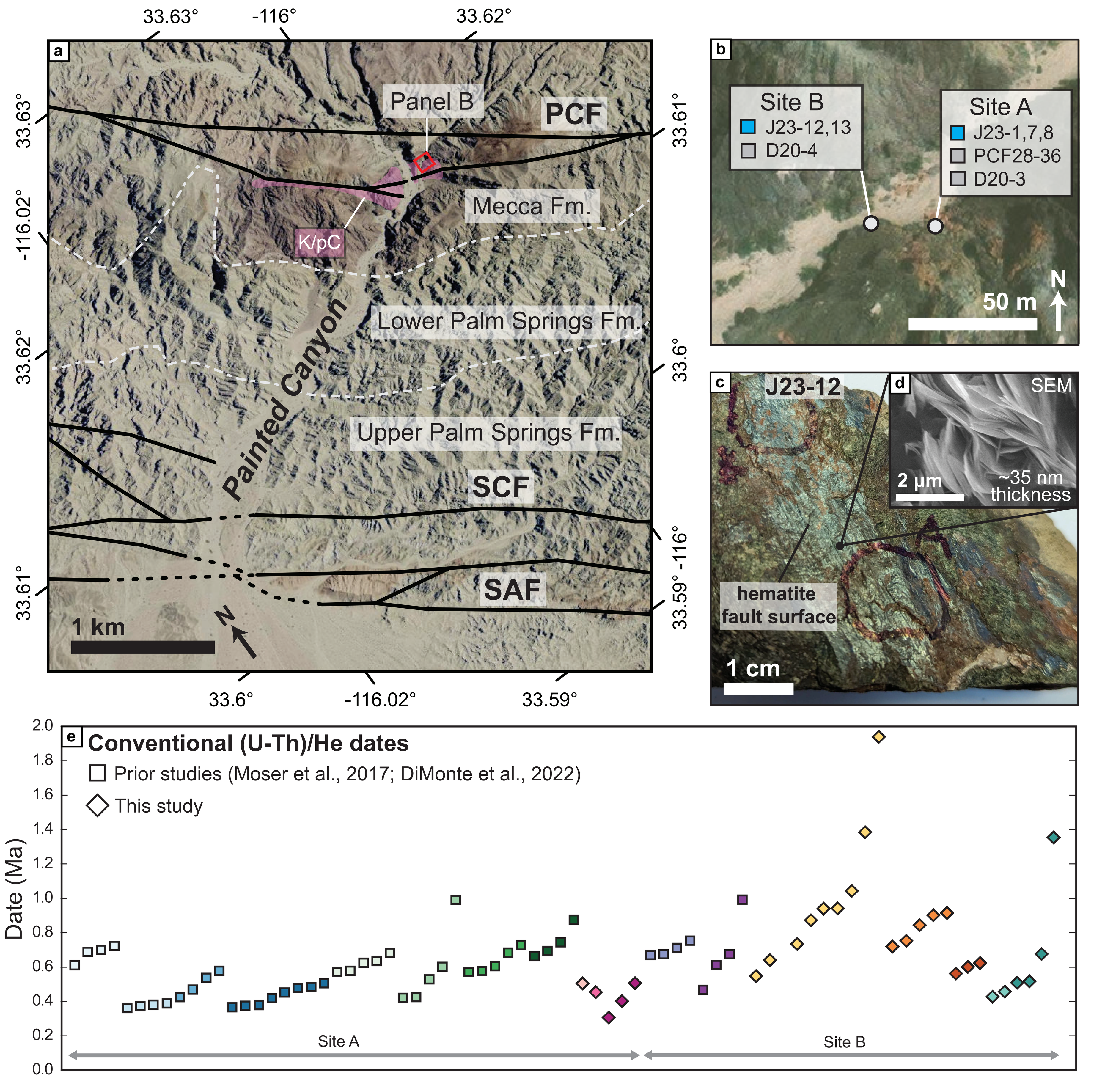
1. (U-Th)/He dating of secondary mineralization in fault zones can potentially constrain the timing of Quaternary fault activity. However, secondary minerals, like the hematite studied here, may inherit disequilibrium amounts of ^{234}U and other U-series nuclides from source fluids. U-series disequilibrium disrupts He production rates for up to ~1.5 million years and causes conventional (U-Th)/He dates to over- or underestimate formation ages.



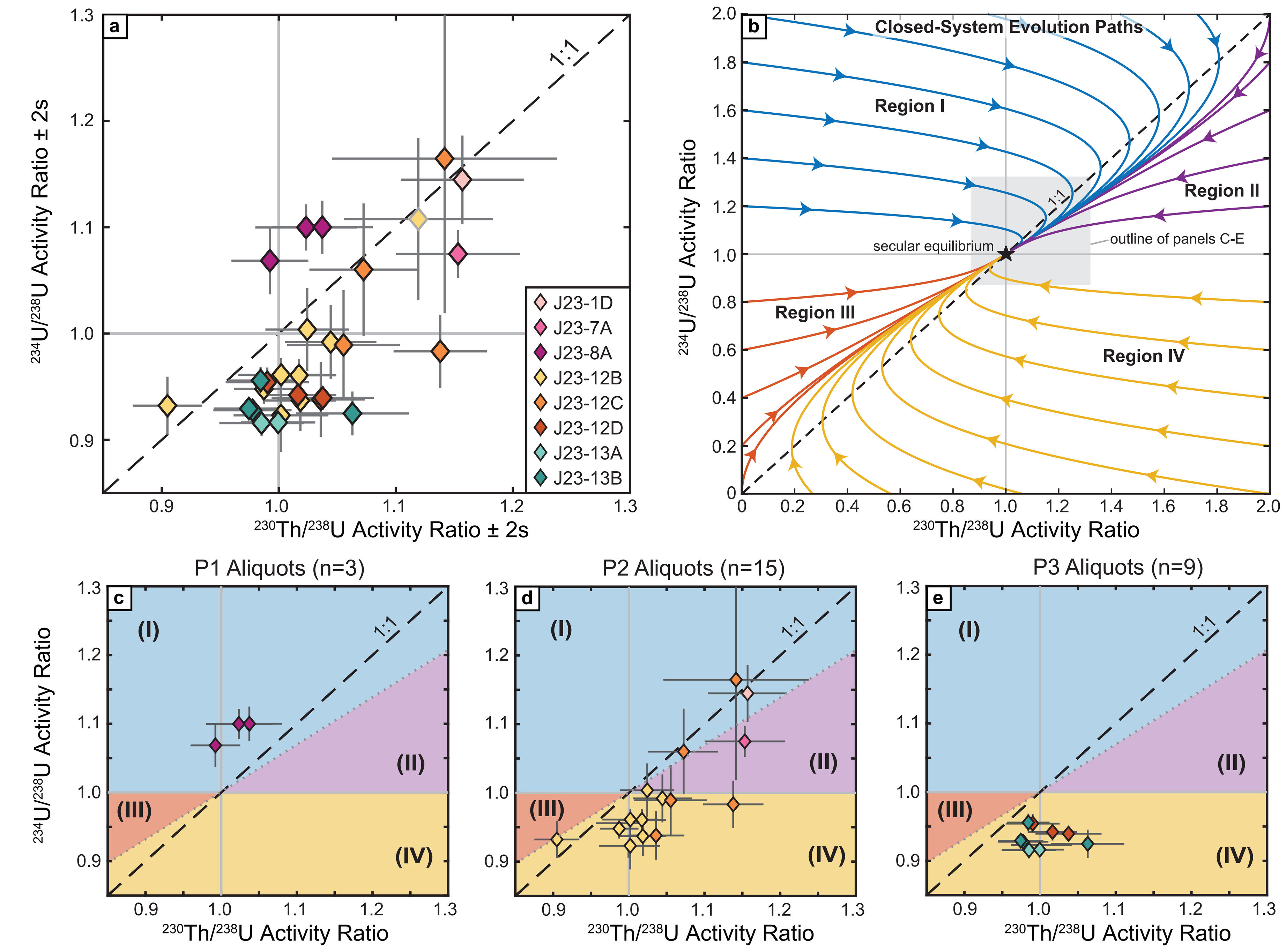
(A) $^{234}U/^{238}U$ activity ratios of global groundwaters, including some measured from near our study area. Conventional (U-Th)/He dating assumes samples started and remained in secular equilibrium (purple lines). (B-C) Activity ratio vs time plots comparing the He production of samples in secular equilibrium vs those that start with U-series disequilibrium.

2. We collected hematite slip surfaces from the Painted Canyon fault damage zone, targeting the same outcrops as prior studies that used conventional (U-Th)/He dating (Moser et al., 2017; DiMonte et al., 2022). We paired U-series and He measurements to evaluate the chronological consequences of initial disequilibrium and the potential for open-system behavior.



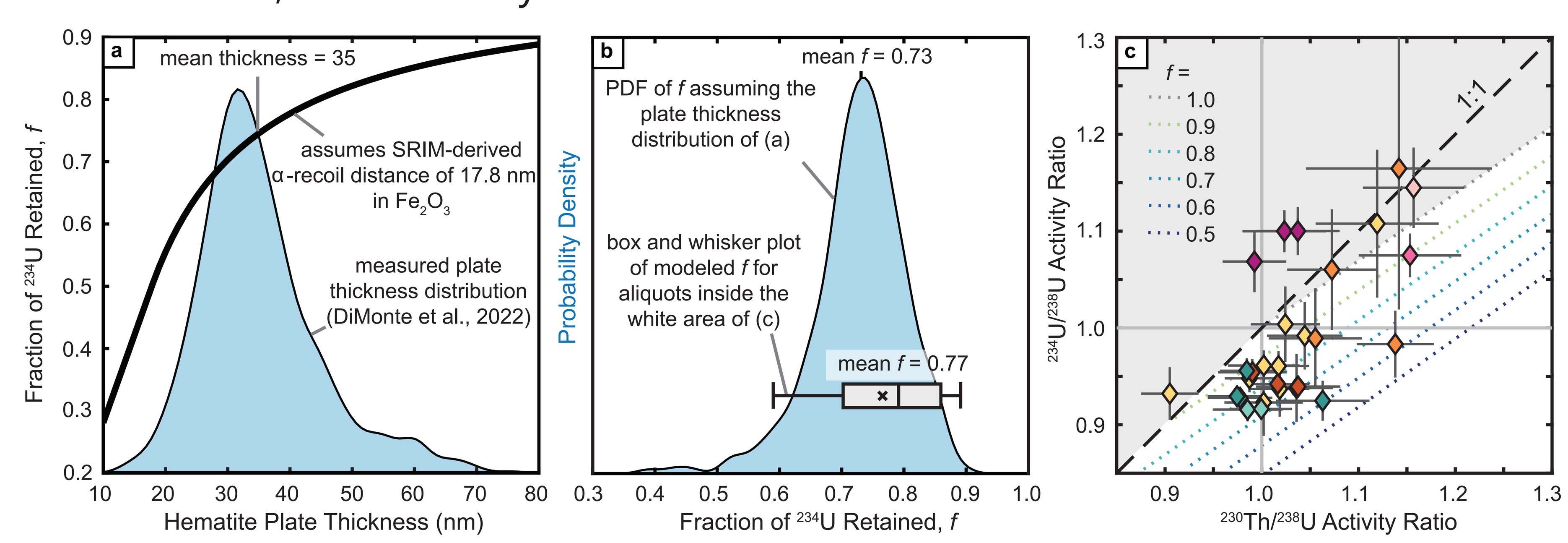
(A) Simplified geologic map of Painted Canyon, highlighting our study area (red box), crystalline basement (K/pC; pink), and regional faults, including the Painted Canyon fault (PCF), the Skeleton Canyon fault (SCF), and the San Andreas fault (SAF). (B) Detail map of our sampling locations. (C) Hand sample of a hematite fault surface. (D) Scanning electron microscope image of nm-scale hematite platelets. (E) Ranked order plot comparing conventional (U-Th)/He dates from our samples with those reported in previous studies.

3. Hematite displays U-series activity ratios that are not consistent with secular equilibrium, implying formation from fluids with disequilibrium amounts of ^{234}U and ^{230}Th. But closed-system models fail to reconcile U-series measurements and He abundances without invoking unrealistic amounts of initial ^{230}Th, suggesting aliquots were variably affected by post-formation, open-system processes.



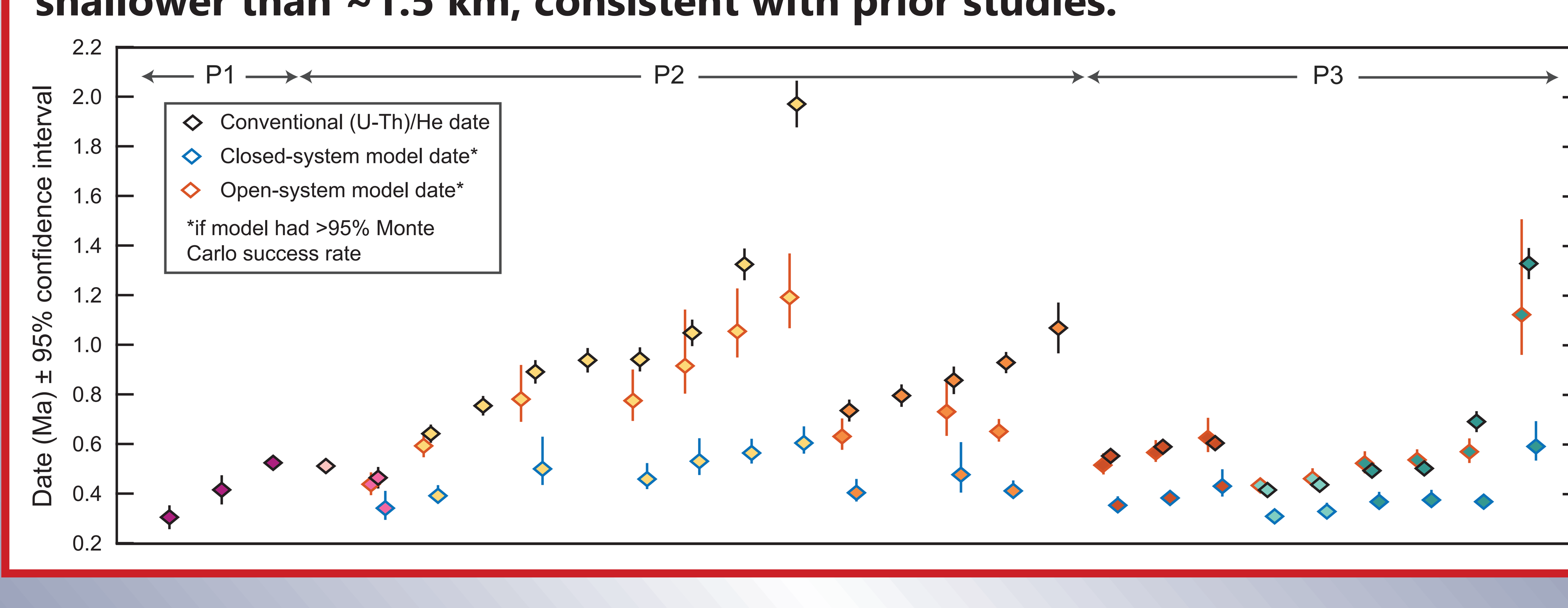
(A) Activity ratios for hematite aliquots analyzed in this study. (B) Schematic showing closed-system evolution of U-series nuclides under four distinct initial conditions, Regions I-IV. (C) Population 1 aliquots reside in Region I. (D) Population 2 aliquots that plot within Regions I, II, and IV. (E) Population 3 aliquots plot entirely within Region IV. All of P3 aliquots and a majority of P2 aliquots can be explained by fractional loss of ^{234}U (Section 4 of poster).

4. Alpha-recoil loss of ^{234}U is an important open-system process affecting Mecca Hills hematite, based on crystal size and U-series observations.



(A) Thickness distribution of measured crystals (plates) compared to fractional retention (f) of ^{234}U, which is a function of crystal size. (B) Comparison of estimated retention factors (f) calculated by two independent methods. (C) Activity ratio plot showing the maximum f required to explain aliquots plotting inside the white area.

5. "Corrected" dates do not differ substantially from conventional (U-Th)/He dates because the effects of initial disequilibrium are offset by progressive loss of ^{234}U. **We infer hematite mineralization occurred largely between ~700-400 ka at depths shallower than ~1.5 km, consistent with prior studies.**



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