Titanite petrochronology of ultrahigh-temperature (UHT) calc-silicates from southern Madagascar

laser-ablation split-stream ICP-MS spot analyses and depth profiles; EPMA trace-element maps

Robert M. Holder & Bradley R. Hacker; University of California, Santa Barbara: contact rholder@umail.ucsb.edu

This presentation participates in OSPP

Outstanding Student Poster & PICO Contest

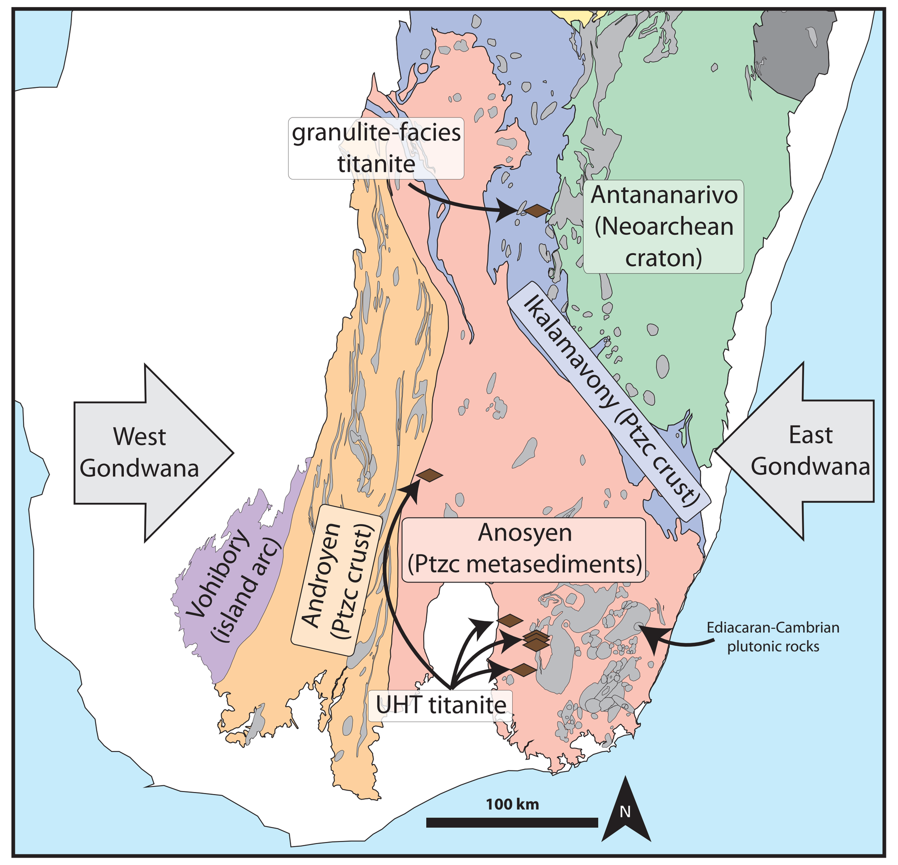
UCSB UNIVERSITY OF CALIFORNIA SANTA BARBARA

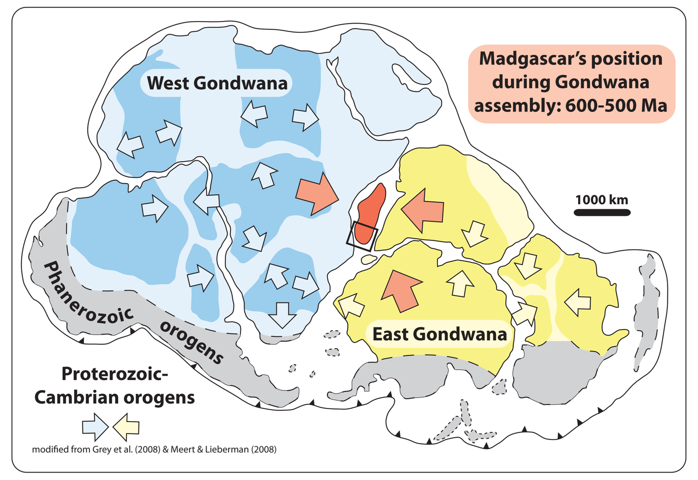
EGU2017-1175
GMPV3.4
Progress in Metamorphic Geology: Petrochronology

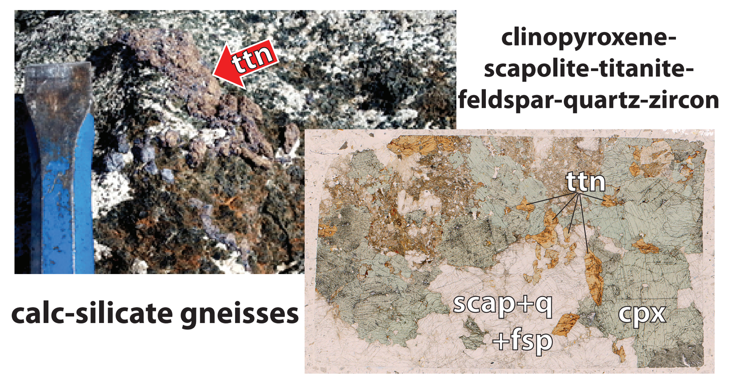
Abstract

Calc-silicate rocks are often overlooked as sources of pressure-temperature-time data in granulite-UHT metamorphic terranes due to the strong dependence of calc-silicate mineral assemblages on complex fluid compositions, as well as a lack of thermodynamic data on common high-temperature calc-silicate minerals such as scapolite. In the Ediacaran–Cambrian UHT rocks of southern Madagascar, clinopyroxene–scapolite–feldspar–quartz–titanite calc-silicate rocks are wide-spread. U-Pb dates of c. 540-520 Ma from unaltered portions of titanite correspond to cooling of the rocks through granulite to upper-amphibolite facies & indicate UHT metamorphism occurred before 540 Ma. Zr concentrations in these domains preserve growth temperatures of 900–970 ºC, consistent with peak temperatures calculated by pseudosection modeling of nearby pelitic rocks. Younger U-Pb dates (c. 510-490 Ma) correspond to fluid-mediated Pb loss from titanite grains, which occurred below their diffusive Pb-closure temperature, along fractures. The extent of fluid alteration is seen clearly in back-scattered electron images as well as Zr-, Al-, Fe-, Ce-, and Nb-concentration maps. Laser-ablation depth profiling of idioblastic titanite grains shows preserved Pb diffusion profiles at grain rims, but there is no evidence for Zr diffusion, indicating that it was effectively immobile even at UHT.

Geologic setting, outcrop, & thin section







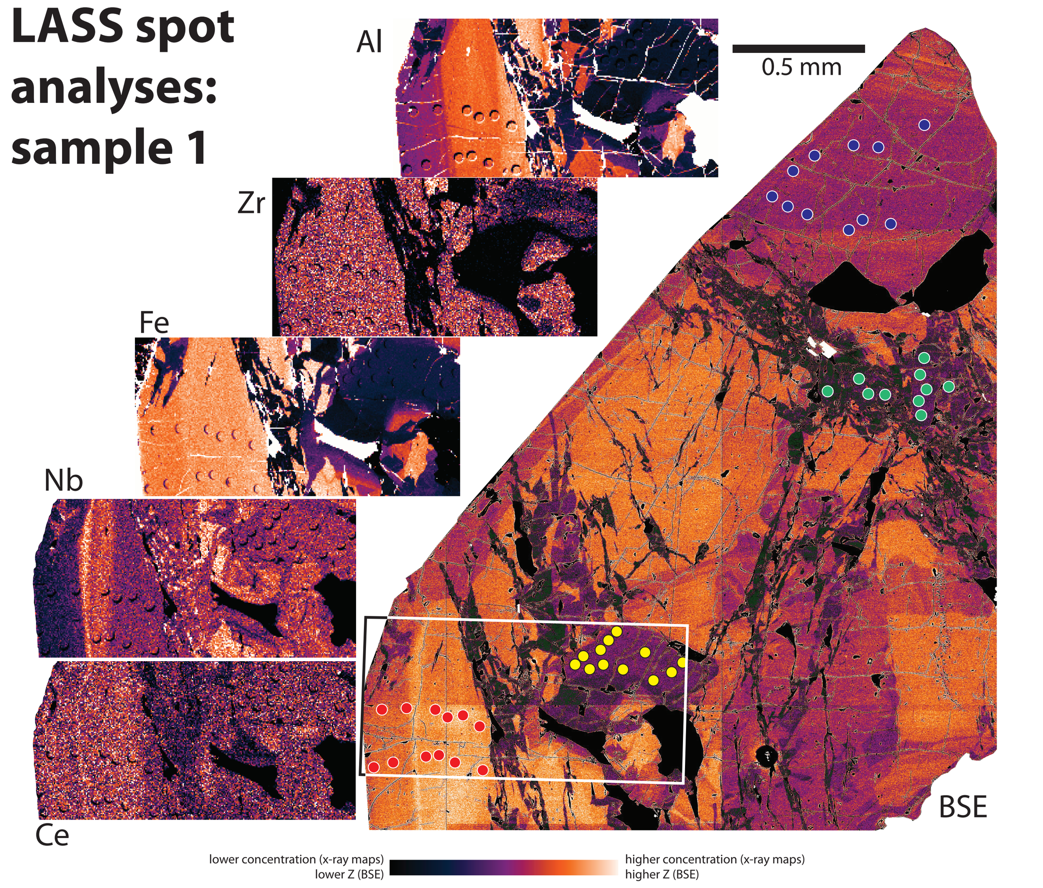
Conclusions

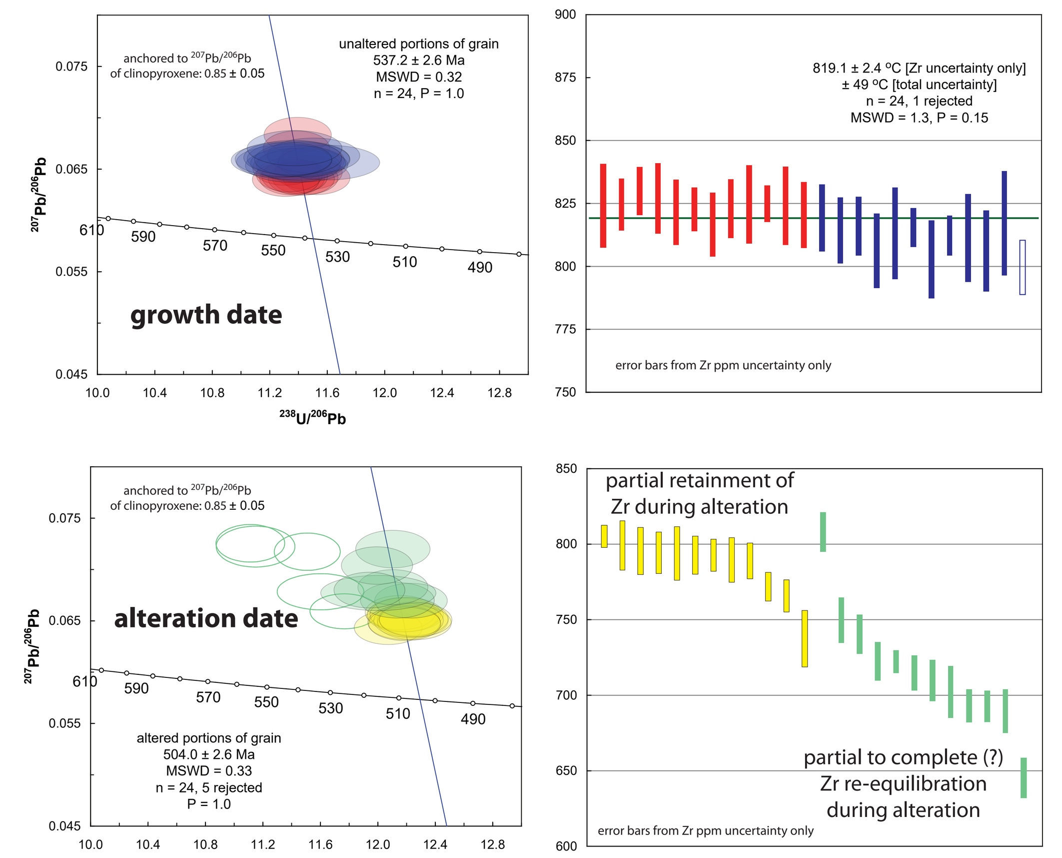
Zr in titanite: Peak temperatures calculated from Zr in titanite are 970 ± 60 ºC (P = 6 ± 2 kbar, aTiO2 = 0.75 ± 0.25: Hayden et al., 2008). These agree with the highest temperatures estimated by other methods. Changes in Zr concentration are only observed as a result of alteration (interface-coupled dissolution-reprecipitation: ICDR), suggesting that Zr was diffusively immobile, even at UHT. This may be related to an absence of a hydrous fluid to mediate elemental transport during high-grade metamorphism (Spencer et al., 2013; Kohn et al., 2016; Garber et al., accepted J. Pet.).

U-Pb titanite dates: Dates change toward the rims of grains & along alteration fronts, suggesting both diffusion & ICDR are important mechanisms in resetting U-Pb dates in high-grade titanite. Dates between 540-520 Ma record cooling & U-Pb resetting by volume diffusion. Dates 520-490 Ma record alteration (ICDR) of titanite below the diffusive closure temperature of Pb.

Granulite-facies titanite examples (not UHT)

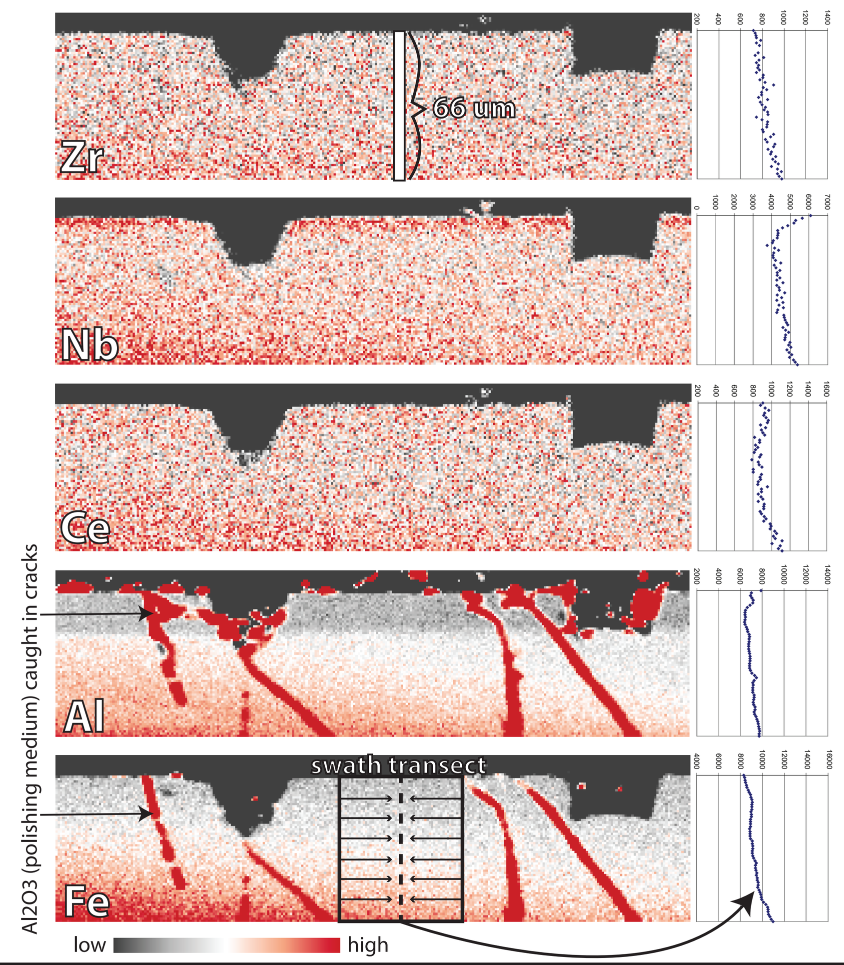
LASS spot analyses: sample 1



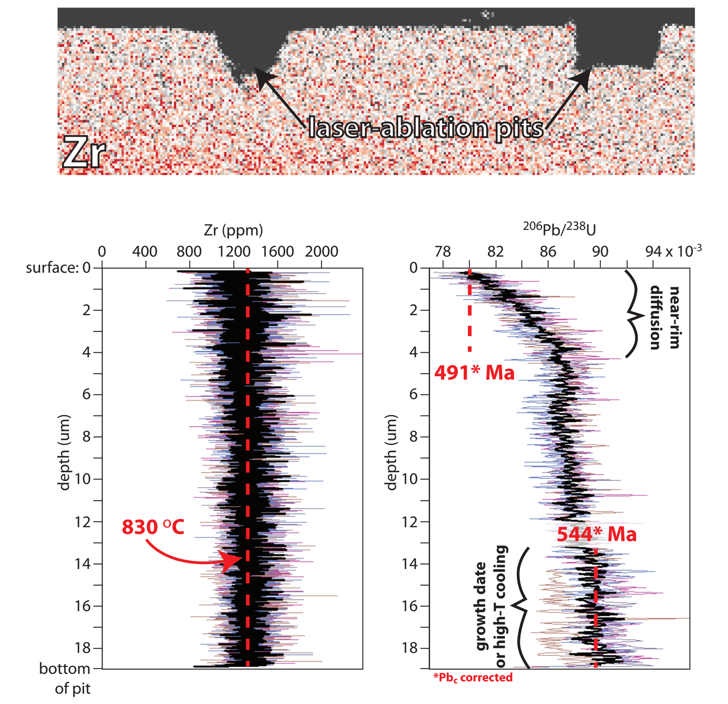


EPMA depth profiles: sample 1

(maps made perpendicular to grain surfaces)



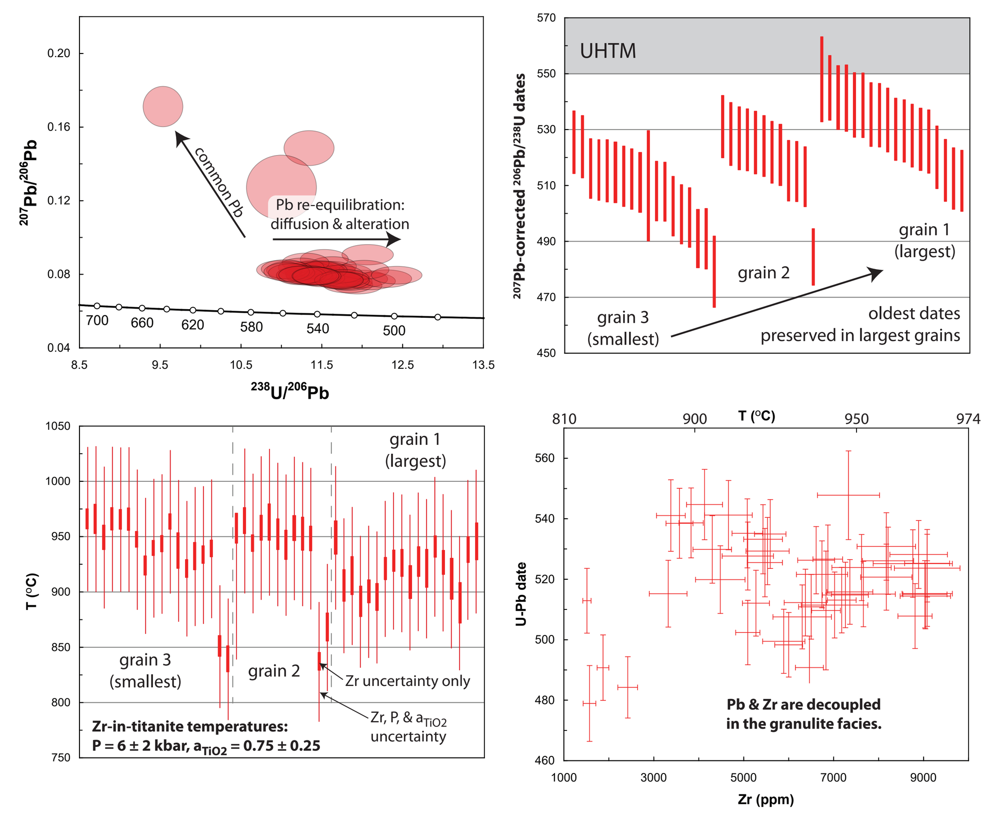
LASS depth profiles: sample 1



Only Pb shows clear diffusive modification near grain rims. Al, Fe, Nb, Ce, & Zr remained immobile.

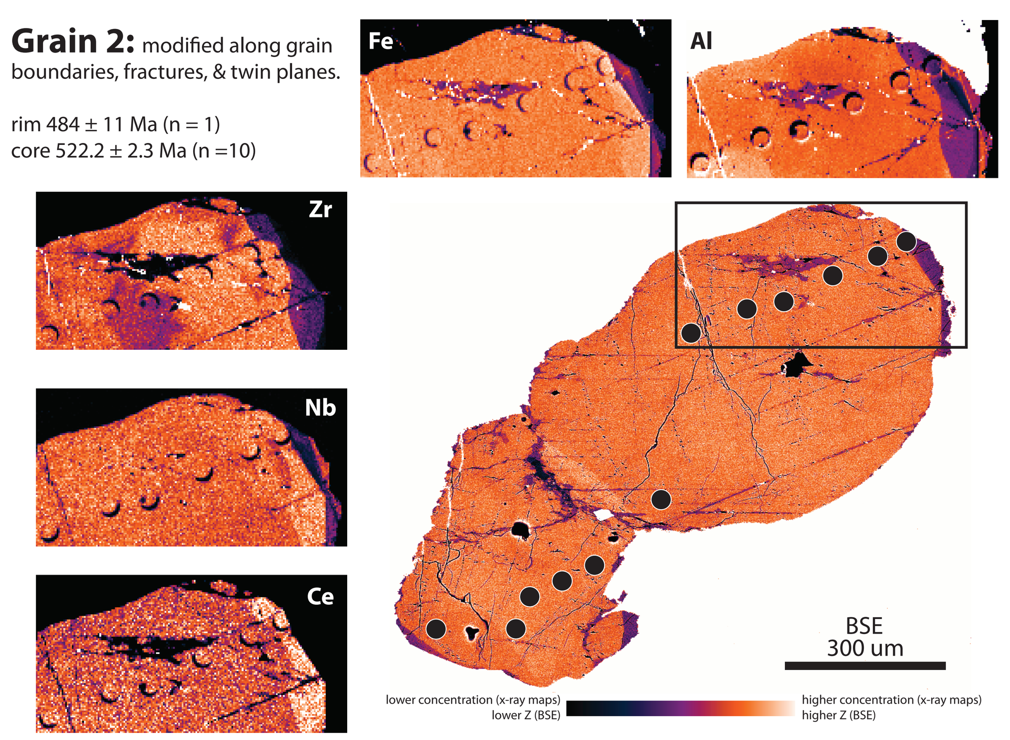
UHT titanite examples

LASS spot analyses: sample 2

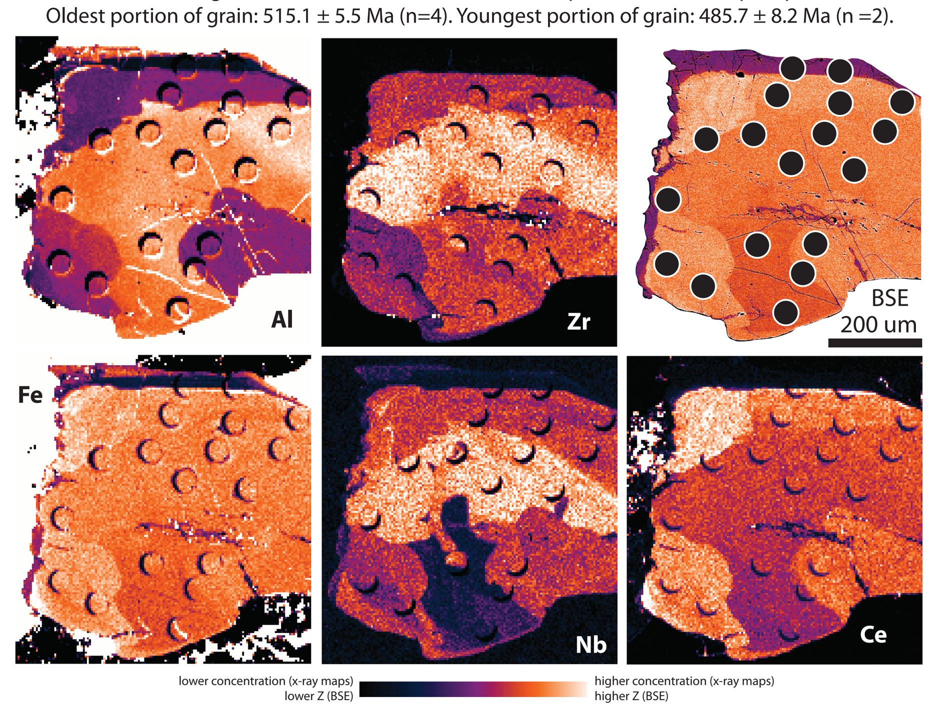


Grain 2: modified along grain boundaries, fractures, & twin planes.

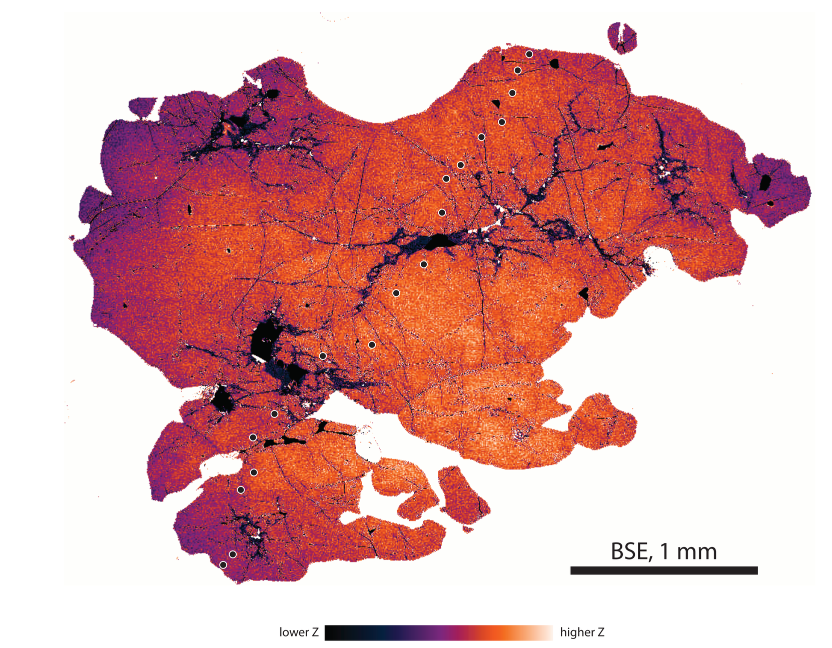
rim 484 ± 11 Ma (n = 1)
core 522.2 ± 2.3 Ma (n = 10)

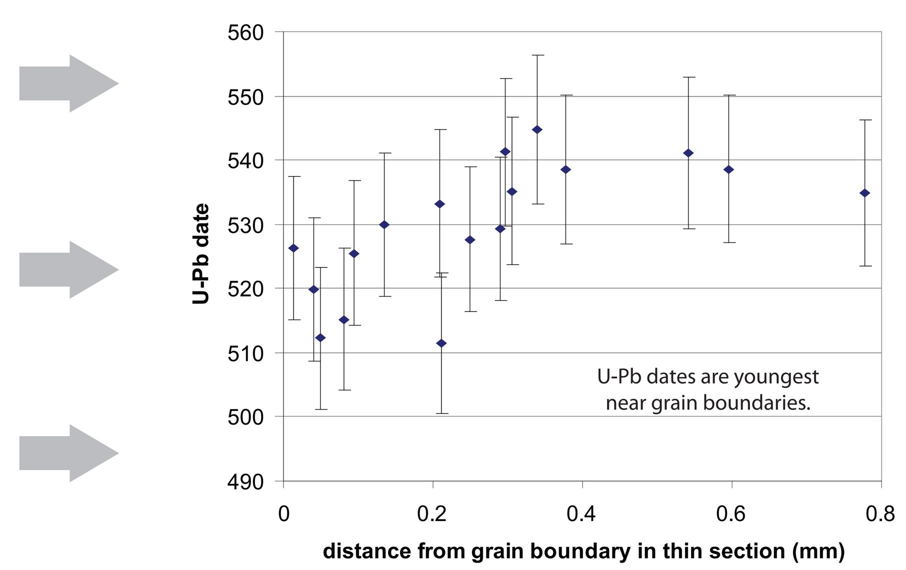


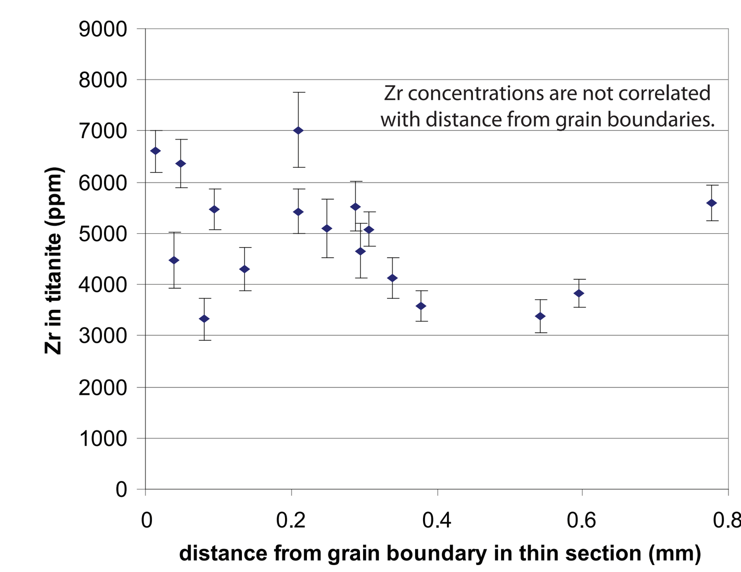
Grain 1: ≥ 3 generations of alteration (interface-coupled dissolution-reprecipitation). Oldest portion of grain: 515.1 ± 5.5 Ma (n=4). Youngest portion of grain: 485.7 ± 8.2 Ma (n = 2).



Grain 3: U-Pb dates are youngest near the rim. Oldest dates are > 0.3 mm from grain boundaries. Zr concentration does not correlate with distance from grain boundary.

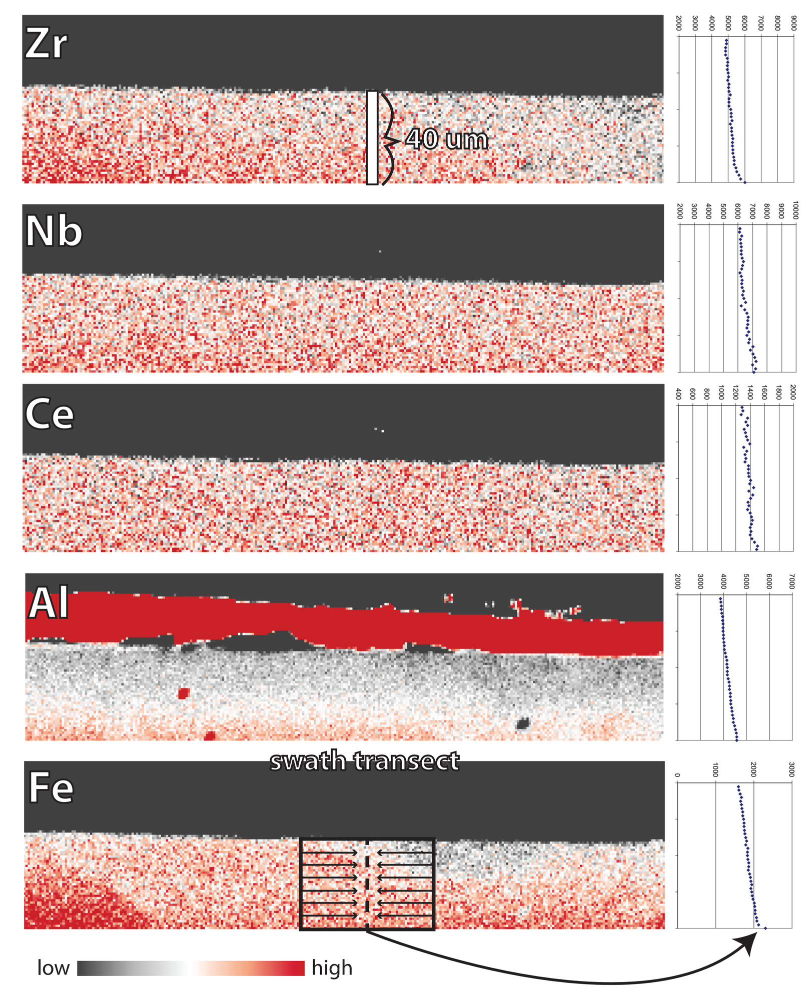






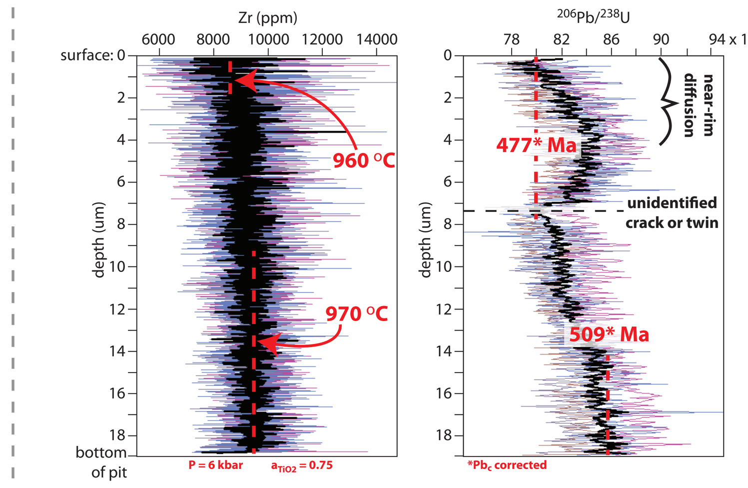
EPMA depth profiles: sample 3

(maps made perpendicular to grain surfaces)



LASS depth profiles: sample 3

Laser-pits were heavily fractured during cutting & repolishing; they are not visible in x-ray maps (left).



-Al, Fe, Nb, Ce, & Zr decrease toward rim, but decrease is not perpendicular to crystal face (most pronounced in Fe & Zr).

-U-Pb dates show modification near the rim & around an unidentified feature (possibly a crack or twin).