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Unusual Hydrothermal Rims on Igneous Zircons, Tso Morari Complex, Ladakh, India

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Abstract

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Zircon crystals were separated, mounted in epoxy, polished, and imaged using cathodoluminescence (CL), Field Emission Scanning Electron Microscopy (FESEM) and Raman spectroscopy to identify zoning patterns (including inherited cores) mineral inclusion patterns, and mineral IDs. Lastly, we used the ICAP-RQ quadrupole ICP-MS to measure U-Pb ages and trace element compositions.

Most zircon crystals exhibit unusual, high-porosity rims with micro-inclusions of chemically exotic, U-, Th-, REE-rich minerals. These inclusion-rich rims overgrow inclusion-poor cores. The ages of the rims and adjacent cores are indistinguishable at ~430 Ma, younger than previously reported ages.

The association of high porosity and exotic mineral inclusions has been interpreted in other studies to reflect hydrothermal replacement of prior zircon. If so, hydrothermal dissolution-reprecipitation must have occurred about the same time as the original igneous crystallization.

Unusual Hydrothermal Rims on Igneous Zircons, Tso Morari Complex, Ladakh, India

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Geologic Background

- Sample TS3/27 is exposed in the Tso Morari massif, in the Ladakh sector of the Himalaya, northwestern India (Figure 1 and Figure 2).
- In the center of the Tso Morari massif, orthogneiss intrudes Cambrian-Ordovician sediments (Trivedi et al., 1986; Girard and Bussy, 1999).
- Primary igneous ages in the area are 479 ± 2 Ma (U-Pb zircon; Girard and Bussy, 1999). 458 ± 14 Ma (Sm-Nd igneous garnet; de Sigoyer, 1998), and 487 ± 25 Ma (Rb-Sr whole rock; Trivedi et al., 1986).

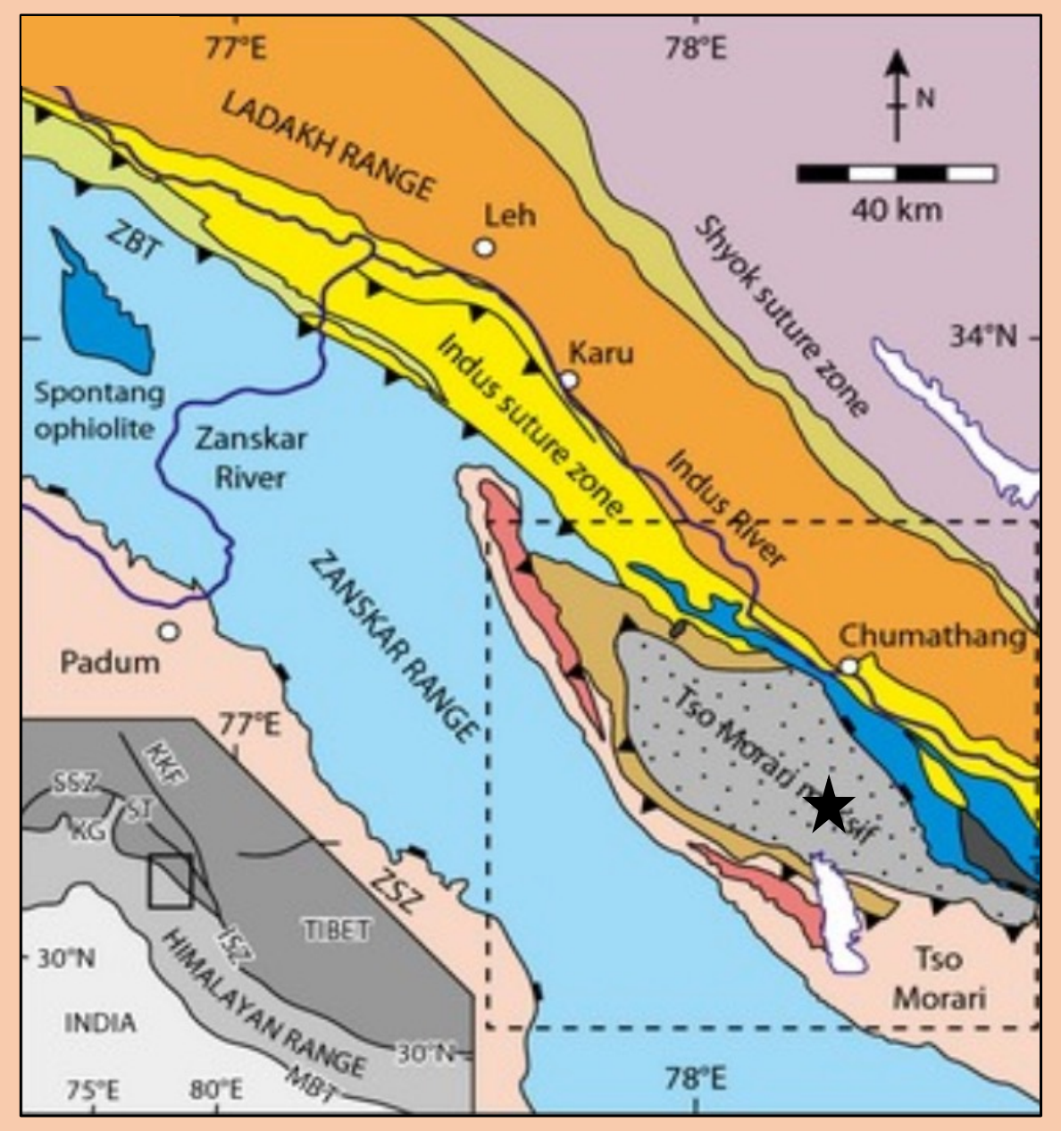


Figure 1: Geologic map of northwestern Himalaya showing geologic setting of Tso Morari massif showing primary stratigraphic units. Dashed box encompasses Tso Morari region. Black star denotes sample location (O'Brien, 2018).

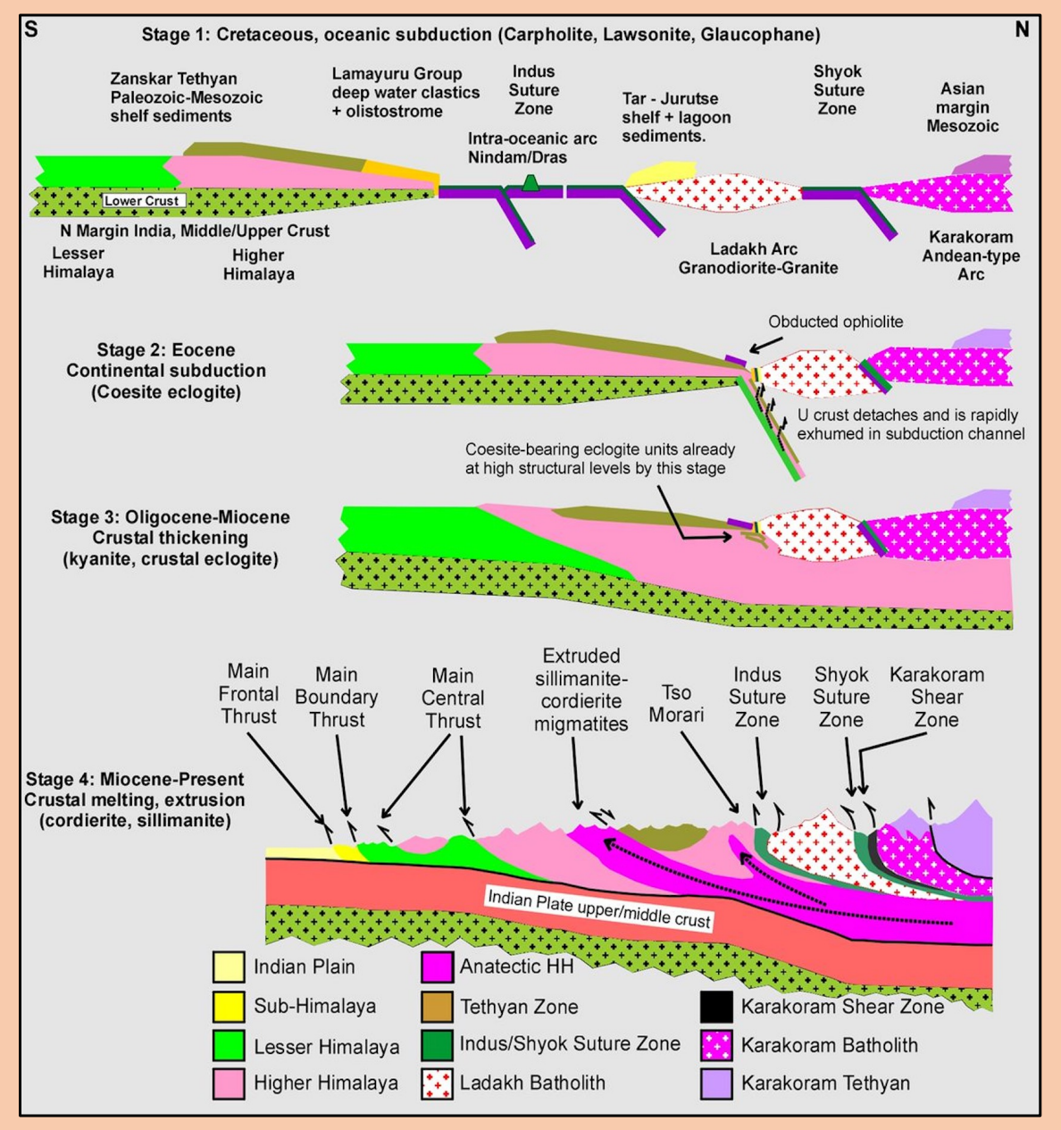


Figure 2: Tectonic history of the evolution of the Himalayan orogen from the Cretaceous to the Holocene. Stage 4 represents the exposure of the Tso Morari rocks (O'Brien, 2018).

Objective

To characterize the mineralogy, geochemistry, and timescales of hydrothermal alteration of igneous zircons.

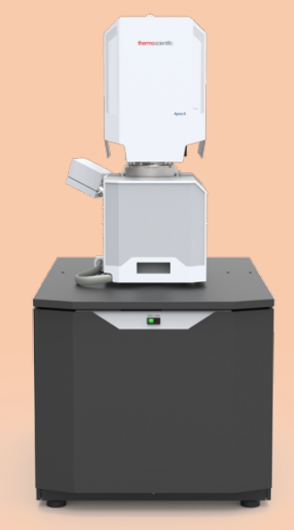
Methods

Mineral Separation:
- Separation of zircon using crushing, water table, heavy liquid and magnetic methods
- Light microscopy using a petrographic microscope
- Mounted in epoxy

Mineral Identification:
- Zoning using cathodoluminescence (CL) photomicrographs
- Inclusion identification using Field Emission Scanning Electron Microscopy (FESEM)
- SiO2 polymorph ID using RAMAN Spectroscopy.

Data Accumulation and Analysis:
- Mass spectrometry using ICAP-RQ quadrupole ICP-MS (ICP-MS)
- Common lead correction using Stacey and Kramers (1975)
- Plotted Concordia using Isoplot R Online


Petrographic Microscope


FESEM


RAMAN


ICP-MS

Key Results

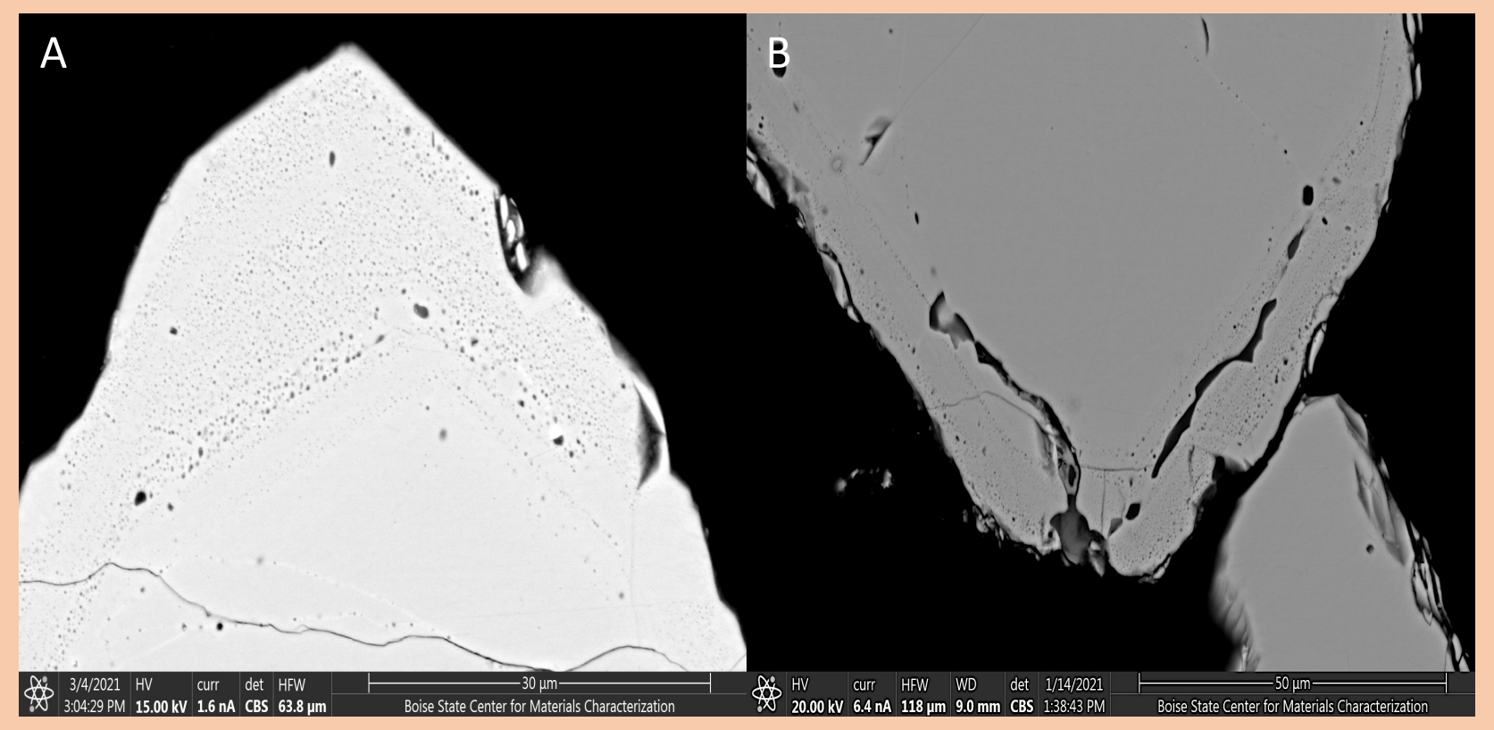


Figure 3: Images taken by the FESEM show porosity (fine black dots) with banding that follows crystallographic boundaries. Bars below each image specify the scale. (A) Microporosity bands parallel external crystal faces. (B) Macroporosity and quartz inclusions separate inner inclusion-poor zircon from porous outer rim.

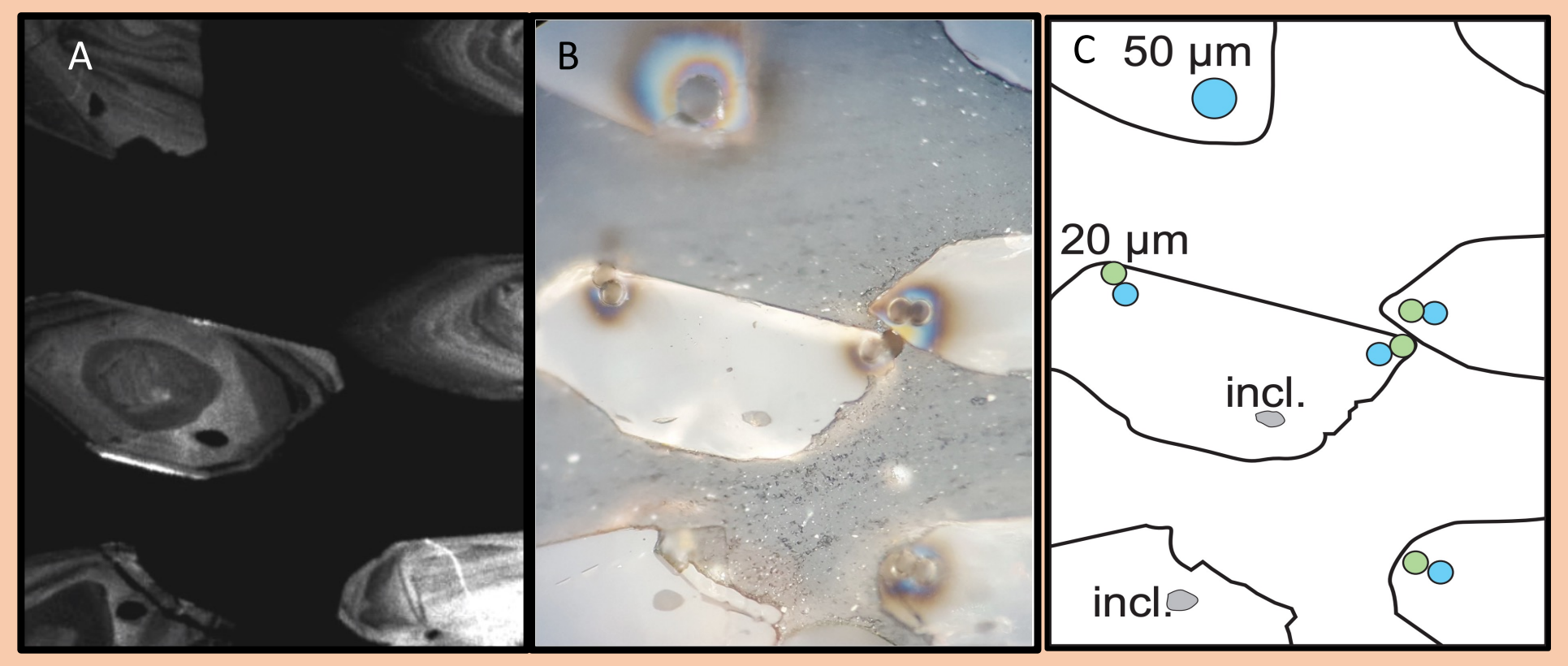


Figure 4: The three images are of the same area on a 1 inch epoxy Zircon mount. (A) Cathodoluminescence photomicrograph, pre-ablation. (B) Reflected light image post-ICP-MS ablation. (C) Sketch of the grain boundaries with included outer (green) and inner (blue) rim spots (20 µm) and a 50 µm spot (blue); grey bodies indicate inclusions.

- Zircons exhibit porous, microinclusion-rich rims, 0-30 µm thick (Figure 3). Porosity parallels crystallographic boundaries.
- Most of the inner zircon is non-porous.
- CL-distinct cores are anhedral; some have abundant inclusions, others are inclusion-free.
- Exotic microinclusions occur in porous rims and include uraninite, thorite, xenotime, and monazite, as well as common muscovite, feldspar, apatite, and quartz.
- U-Pb ages of outer and inner cluster at ~430 Ma (Figure 5).
- Some Pb-Pb ages for anhedral cores range up to ~2.5 Ga
- The outer and inner rim data overlap and are not statistically distinguishable (Figure 5).
- The ~430 Ma rim age is younger than published ages on other granites in the region (450-500 Ma; Girard and Bussy, 1999; de Sigover, 1998; and Trivedi et al., 1986; Figure 5).

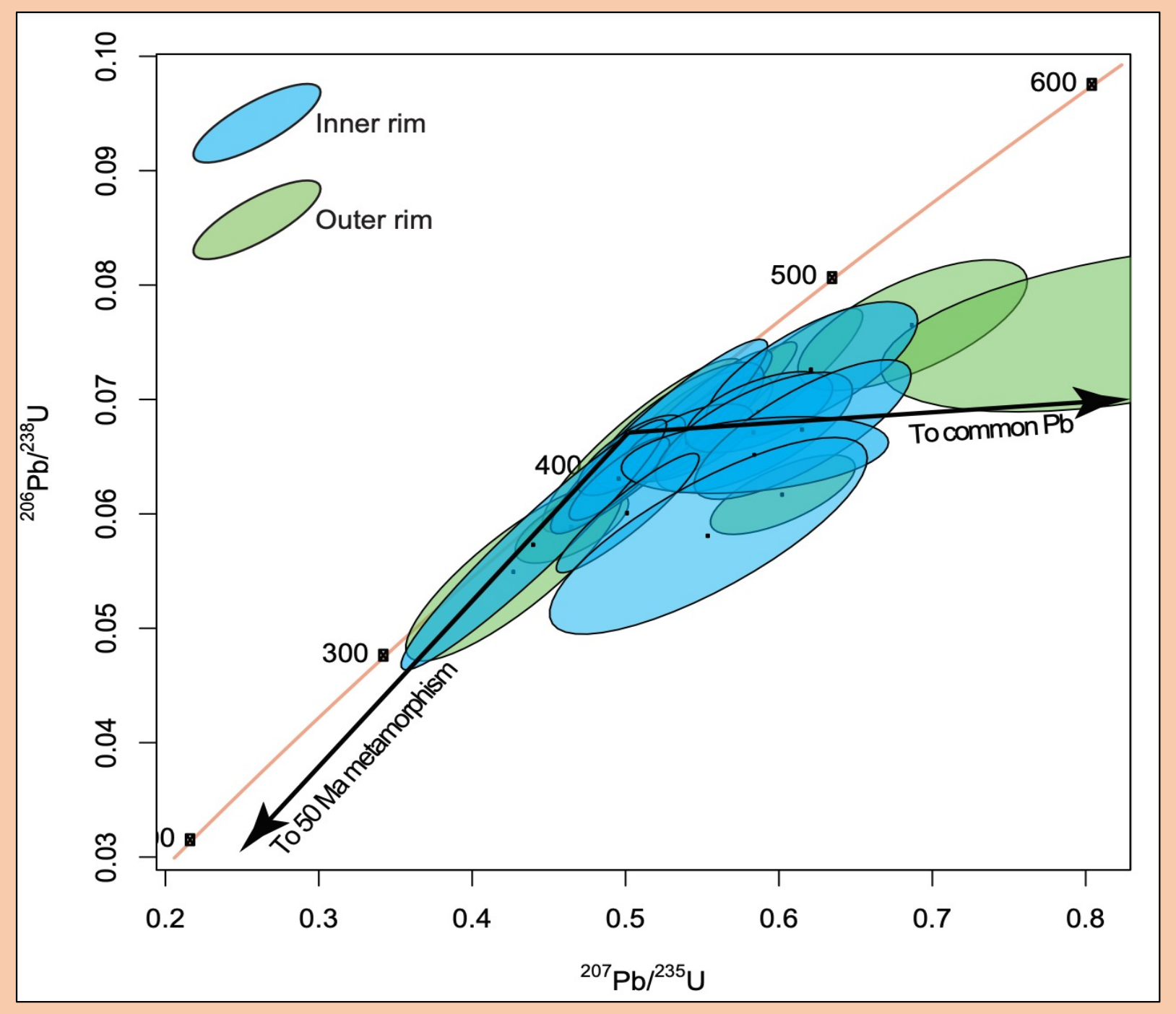


Figure 5: Concordia diagram of $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ containing both inner (blue) and outer (green) rim data with associated elliptical errors. The mass shift to the right is due to common Pb (depicted by black arrow) while the mass shift down and to the left is due to ~50 Ma metamorphism. The two sets of data are not statistically distinguishable as seen by consistent overlap.

Implications

- Porous bands in zircon are commonly interpreted to reflect dissolution and reprecipitation of older zircon, especially during metamorphic events (Tomaschek et al., 2003)
- The only metamorphic event in the region was at 50 Ma – much younger than the age of the porous rims
- The similar ages for inner and outer rims implies they formed about the same time.
- If the inner rims are igneous, the outer rims are probably associated with late-stage igneous or hydrothermal activity.
- Chemically exotic inclusions (U-, T-, REE-rich) have been associated with dissolution/reprecipitation events (Schaltegger, 2007; Figure 6 and Figure 7).
- High uranium contents paired with uraninite inclusions imply that the parent zircons were highly enriched in uranium (Figure 6).
- Lack of a well-defined metamorphic rim may be why inclusions of metamorphic minerals (especially Coesite) were not found.

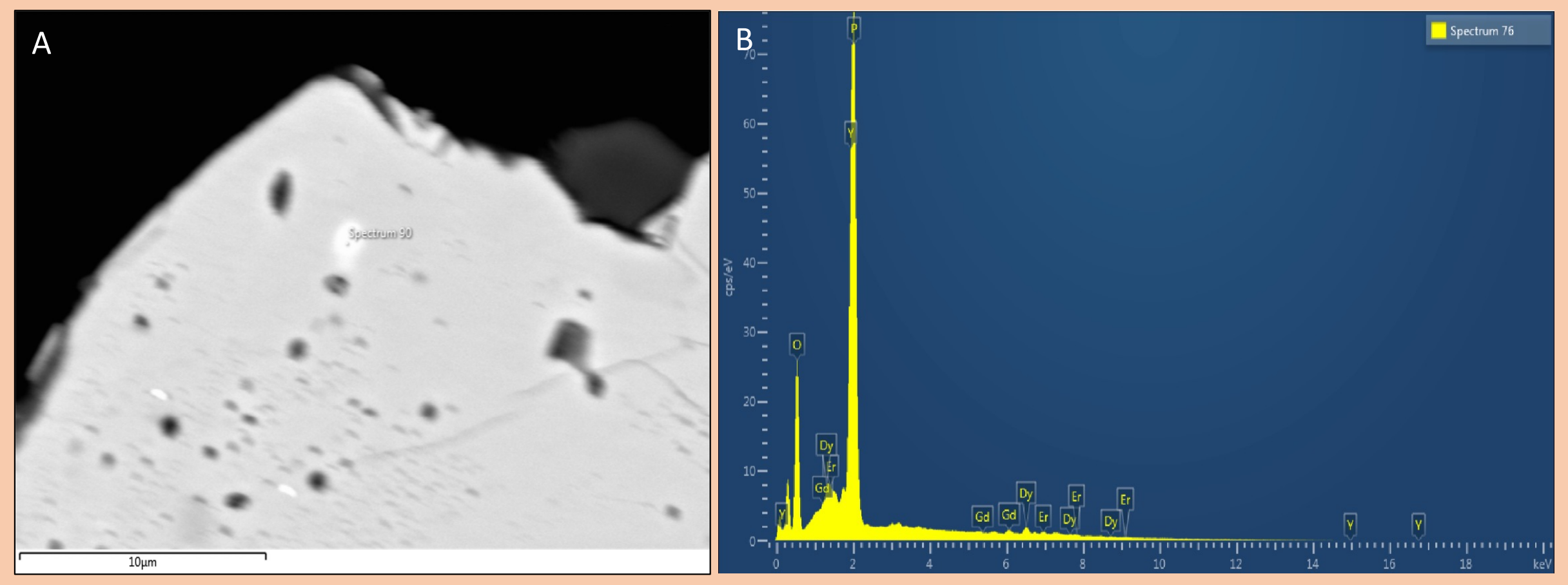


Figure 6: (A) FESEM image of analyzed inclusion in porous rim of zircon. Bright spot with "Spectrum 90" label is uraninite. Other white specks are probably also uraninite. Some larger dark spots are quartz. Solid inclusions are interspersed with porosity bands. (B) EDS spectra of xenotime found in inner rim.

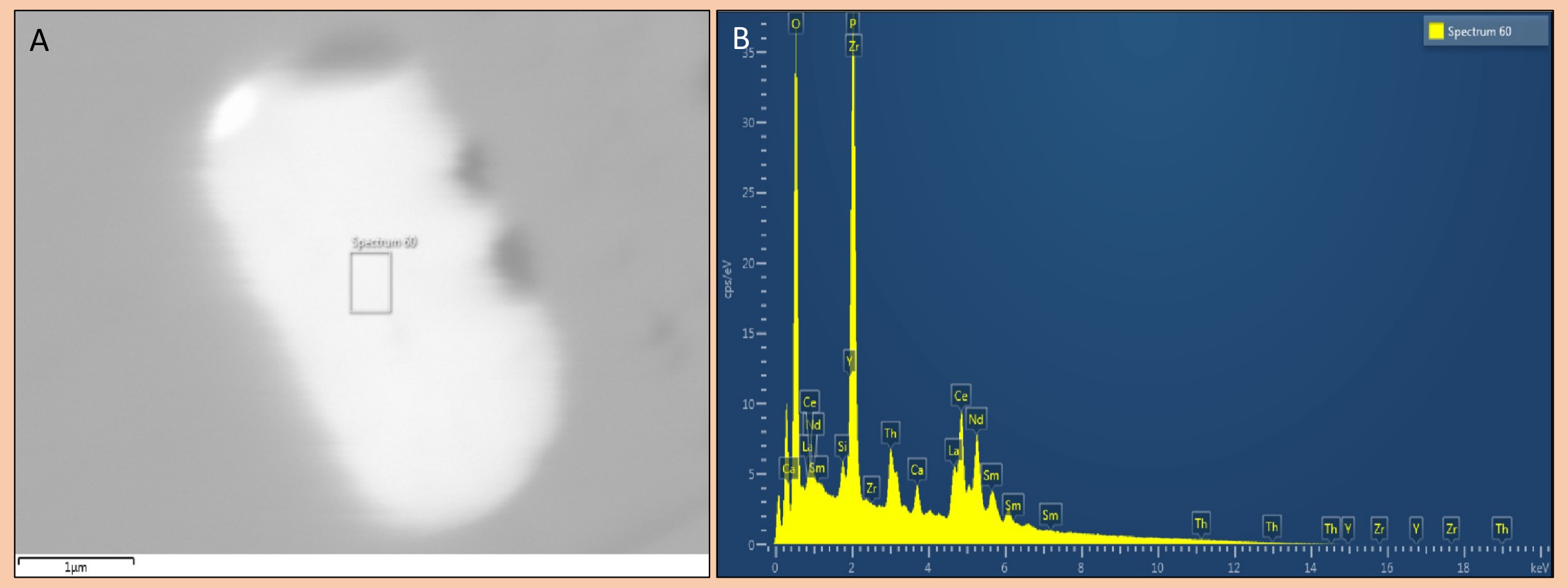


Figure 7: FESEM image (A) and EDS spectra (B) of a monazite inclusion located in the inner rim. The abundance in lanthanides combined with a moderate Th peak is indicative of monazite.

Conclusions

- Calculated ages, 430 Ma, are lower than previously calculated ages (479 ±2 Ma; Girard and Bussy, 1999) (Figure 5).
- Inner and outer rim ages are indistinguishable (Figure 5).
- Timing of hydrothermal alteration was approximately the same as igneous crystallization.
- Hydrothermal alteration coprecipitated U-, Th-, and REE-rich minerals together with zircon.
- The exotic inclusions must have scavenged trace elements from former zircon and possibly fluids.

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Acknowledgments:

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