Constraining timing of early Archean magmatism using stepwise Pb-Pb leaching (PbSL) dating from the Bastar Craton, central India

> Ankita Nandi\* and Ravikant Vadlamani Department of Geology & Geophysics Indian Institute of Technology Kharagpur, India



Outstanding Student & PhD candidate Presentation contest



\*(nandi.ankita94@gmail.com)



#### Lead Isotopes: A multi-faceted and powerful tool Applications in: > Archaeology Environmental science

- Forensic science
- $\succ$  Earth science
  - Planetary science • Mineral exploration



- Paleoclimate studies
- Precise dating of geological events



Ordovician age limestones on the summit of Mt Everest (image courtesy: IUGS)

## Advantages of Pb-Pb dating:

- There is no need to measure parent uranium isotopes
- The method is insensitive to the recent loss of U and Pb, as this would not affect the isotopic ratio of Pb (i.e., <sup>207</sup>Pb/<sup>204</sup>Pb, <sup>206</sup>Pb/<sup>204</sup>Pb and <sup>208</sup>Pb/<sup>204</sup>Pb)





■ Evolution of uranogenic lead in major terrestrial reservoirs → Geochemical tracing

The plumbotectonic model of Zartman and Doe, 1981

## Stepwise Pb-Pb leaching (PbSL) dating

- A silicate digestion technique based on sequential acid treatment of a mineral
- Enables direct dating of rock-forming silicates associated with metamorphic reactions that define a PT path

Facilitated by:

- increase of precision by enhancing the <sup>206</sup>Pb/<sup>204</sup>Pb and <sup>207</sup>Pb/<sup>204</sup>Pb ratios, and
- control on accuracy by revealing heterochemical inclusions via the <sup>208</sup>Pb/<sup>206</sup>Pb ratio and checking isotopic equilibrium with the host



SEM images showing the leached layer around a Otter Lake titanite grain (Frei et al., 1997)

# **Bastar Craton, Central India**

- Part of the South Indian Block (SIB)
- ~3.6 Ga high-grade gneissic basement
- Early Archean greenstone successions absent
- Ideal for testing early Archean geodynamic models

(a) Geological map of the Bastar craton, central India, which preserves one of the largest swaths of early Archean felsic crust.
(b) Indian cratons and Proterozoic basins.







Mineral assemblage: Opx + PI + Qtz + IIm + Mc + Per + Bt

Zircon U-Pb crystallization age = 3453±21 Ma (Nandi et al., 2023)

### Sample CH13

Orthopyroxene-bearing tonalite

#### Basement to the <3.1 Ga Sukma Group (Nandi et al., 2023)



### Sample C30

 ~3.6 Ga 'true granite' sample of Rajesh et al. (2009) resampled in this study



Pinkish appearance with green clusters in hand specimen
Granitic composition, as per normative

and trace element classification





Alteration of biotite grains to chlorite

 Indicates post-emplacement fluid activity during a younger tectononothermal event Evidence of extensive partial melting with newly formed microcline and perthite with remnants of plagioclase in C30



### PbSL : the procedure

Protocol after Frei and Kamber (1995) and Dahl and Frei (1998)

Leaching sequence followed:

Reagent	Time
1.5M HCI-1M	
HBr "mix"	15'
4.4M HBr	4h
8.6M HBr	14h
14M HNO <sub>3</sub>	24h
48% HF	72h
Residue	5d

Opx grains from sample CH13 after steps 1 and 2 of PbSL



Pb separation and purification using 100µL and 10µL of AG-1X8 cation exchange resin

Pb extraction from silicates column chemistry protocol after Kuritani and Nakamura (2002)



Pb isotope ratios were measured on a Thermo-Fisher Scientific Neptune Plus MC-ICPMS at IIT Kharagpur

Combining Thallium-doping with sample-standard bracketing





Post-data acquisition:

- 1) On Peak Zero correction
- 2) <sup>204</sup>Pb correction
- 3) TI-spiking; individual mass
  - fractionation corrected Pb ratios
- 4) Calculate LN values of <sup>204</sup>Pb corrected ratios





Measured isotopic ratios of Pb standard NBS981 with associated 2σ errors.

[1] Sample-standard bracketing, Taylor et al. (2015)
[2] TI-spiking, Taylor et al. (2015)
[3] DS(204-207), Taylor et al. (2015)
[4] TS(204-206 207), Galer and Abouchami (1998)
[5] DS(202-205), dashed magenta line, Todt et al. (1996)

Long-term weighted mean isotopic ratios of NBS981:  ${}^{206}Pb/{}^{204}Pb$ = 16.9350±0.0024 (2 $\sigma$ )  ${}^{207}Pb/{}^{204}Pb$ = 15.4905±0.0024 (2 $\sigma$ )  ${}^{208}Pb/{}^{204}Pb$ = 36.6958±0.0059 (2 $\sigma$ ).

NBS982  $^{208}$ Pb/ $^{206}$ Pb ratio = 1.00004±0.00019 (reference value of 1.00016±0.00036, Catanzaro et al., 1968) (n = 16)





#### In conclusion,

Sample CH13 represents a 'dry magma' emplaced at lower crustal depths during the Paleoarchean.

In contrast, despite an older zircon U-Pb crystallization age, sample C30 is not a ~3.6 Ga 'true granite' but is a product of a later ~3 Ga partial melting event related to the Mesoarchean Sukma orogeny.

Therefore, direct dating of rock-forming minerals by PbSL can better constrain the discrete tectonothermal events in a polymetamorphosed terrane than accessory minerals.

# THANK YOU

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