NUCLEAR FORENSIC APPLICATIONS INVOLVING HIGH-SPATIAL-RESOLUTION ANALYSIS OF TRINITITE CROSS-SECTIONS

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MOTIVATION

- Trinitite is a relatively well-characterized PDM – the bomb design and isotopic composition of the nuclear fuel used in the explosion are known – and it originated in a geologically simple environment.
- Trinitite composition is influenced primarily by melting of the heterogeneous local arkosic sand and incorporation of anthropogenic components (e.g., blast tower, bomb material) *(Bellucci et al. 2014)*.
- Lateral heterogeneity in Trinitite is well noted, but lesser studied is the vertical trace element and radioisotope distributions.
- We hypothesize that their near-surface (upper few mm) geochemistry would reflect greater contribution from blast products (e.g., Pu, U).

ANALYTICAL METHODS

Qualitative Sample Assessment

EDAX Orbis Micro X-Ray Fluorescence (µXRF) Imaging

- Voltage (35-40 kV) and amperage (250-350 µA) were adjusted to yield >10,000 counts and 30%-50% deadtime for a 30 µm beam size.
- Final images have resolutions of ~40-50 microns/pixel.

Alpha Track Radiography (Method of *Wallace et al. 2013*)

- CR-39 Plastic detectors were overlain on sample thin sections for 7-10 days.
- Etched in 6.25 M NaOH at 98 °C for 4 hours.
- Imaged & mosaiced to overlay on sample images.

Major and Trace Element Analysis

Electron microprobe (EMP) Transects

- Cameca SX50 electron microprobe;
  - University of Chicago, Chicago, Illinois.
- 15 kV accelerating potential.
- 30 nA probe current.
- 15 µm spot size.

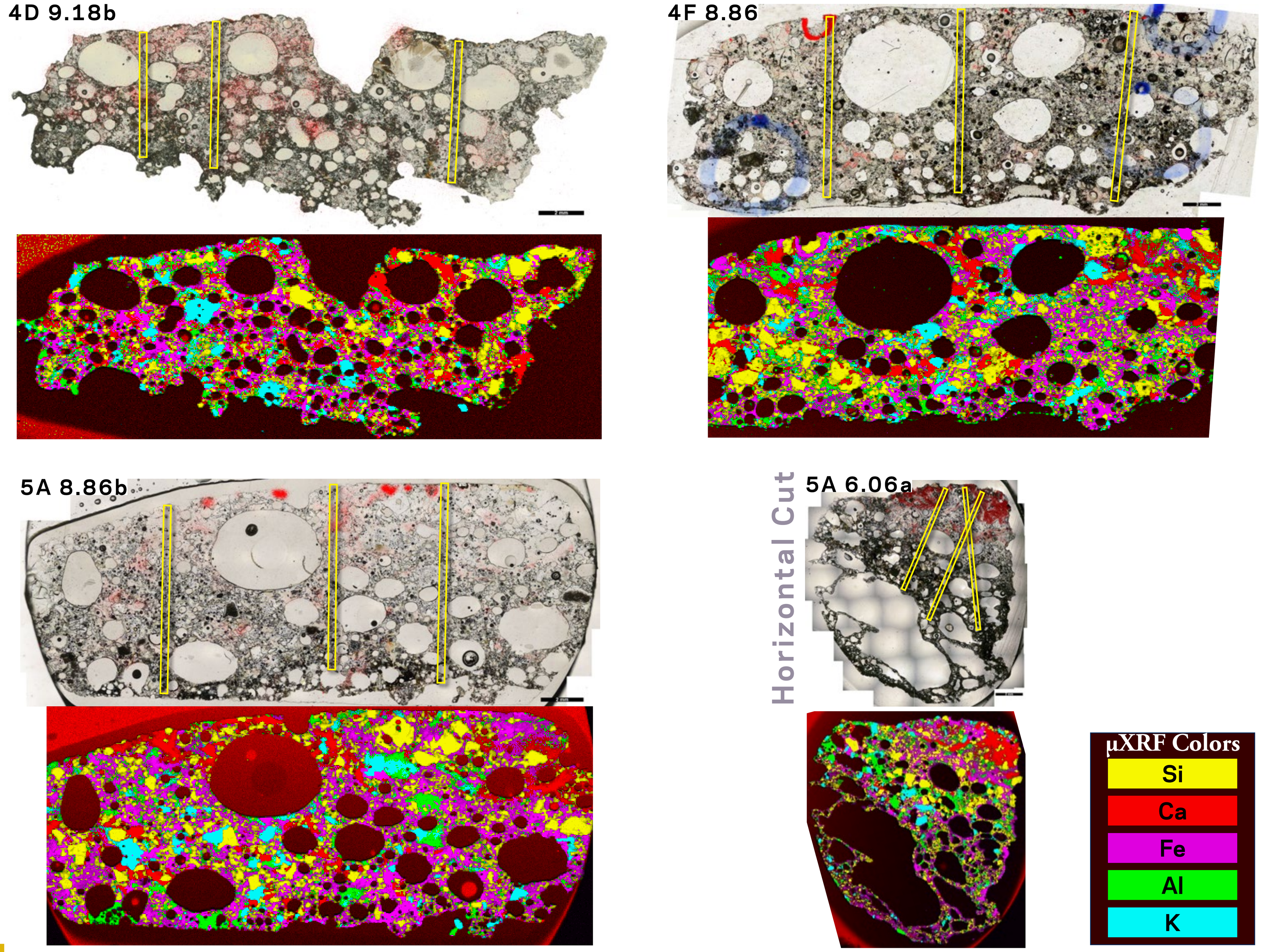
Laser Ablation (LA)-ICP-MS Transects

- Thermo Finnegan Element2 high-resolution ICP-MS.
- NewWave UP213 Nd:YAG laser ablation system.
- 5 Hz pulse rate; 40 µm spot size; fluence of 10-11 J cm^{-2}.
- Time resolved signal analysis with GLITTER© program.

SAMPLES

- Three vertical cut thin sections (**4D 9.18b; 4F 8.86; 5A 8.86b**) and one horizontally cut section (**5A 6.06a**).

Photomosaics are overlain by transect paths (yellow) and alpha tracks (red) that reflect high alpha track activity.



MAJOR ELEMENTS

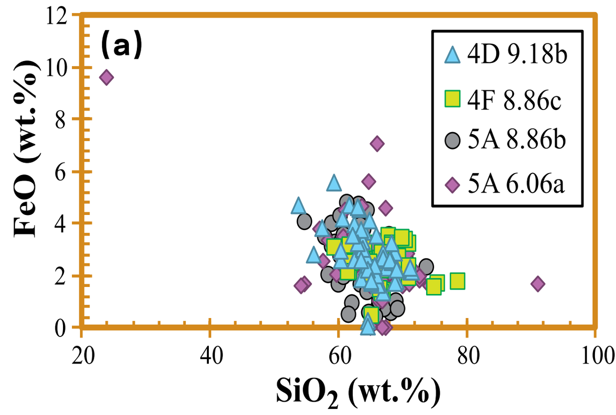


Fig 3a) Variable contribution from dominant quartz lithology in arkosic sand is reflected in high SiO_2 content.

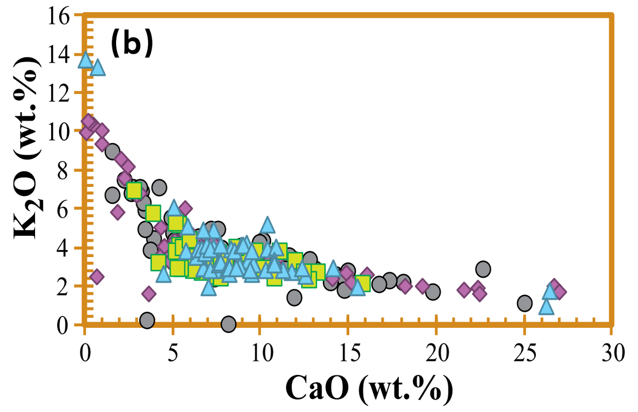


Fig. 3b) Minor elements are strongly controlled by a few minerals (e.g., Plagioclase for K_2O).

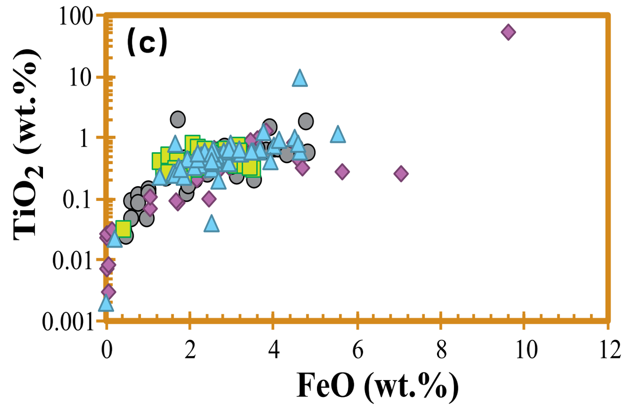


Fig 3c) There is a positive Fe and Ti correlation in all samples.

TRACE ELEMENTS

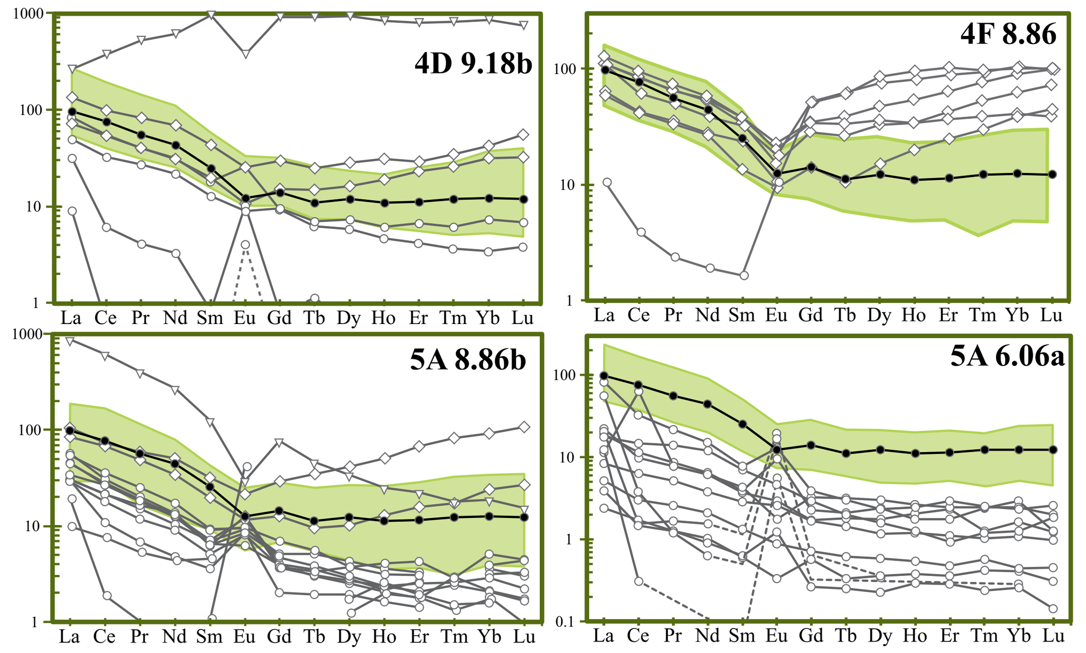


Fig. 4) CI-normalized REE-profiles (green fields) are generally parallel to unmelted sand (black line; *Bellucci et al. 2014*). Some analyses (gray lines) reflect significant contributions from minerals.

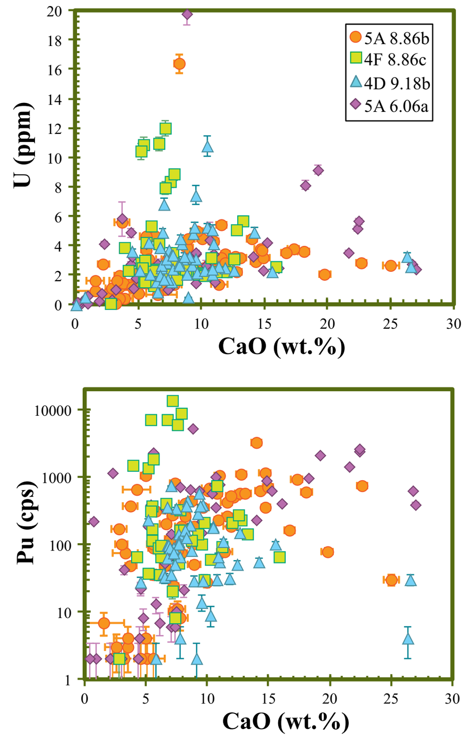


Fig. 5) High CaO correlates with elevated **(a)** U and **(b)** Pu.

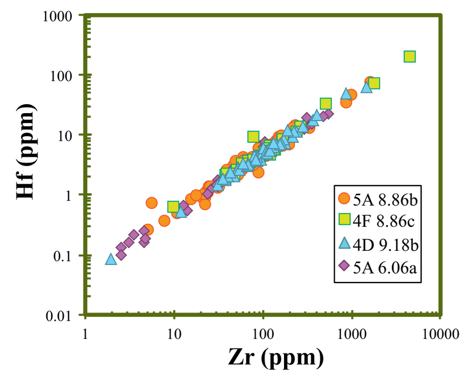


Fig. 6) Constant Zr-Hf ratios across all samples indicates zircon control.

VERTICAL PROFILES

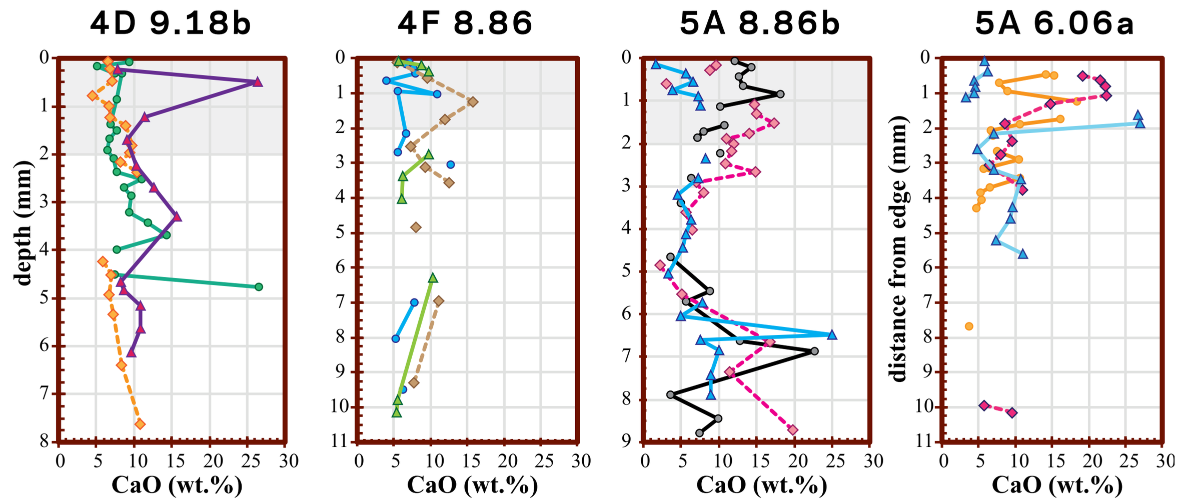


Fig. 7) CaO variation by depth within sample for the three transects of each sample. Most transects follow similar patterns of enrichment.

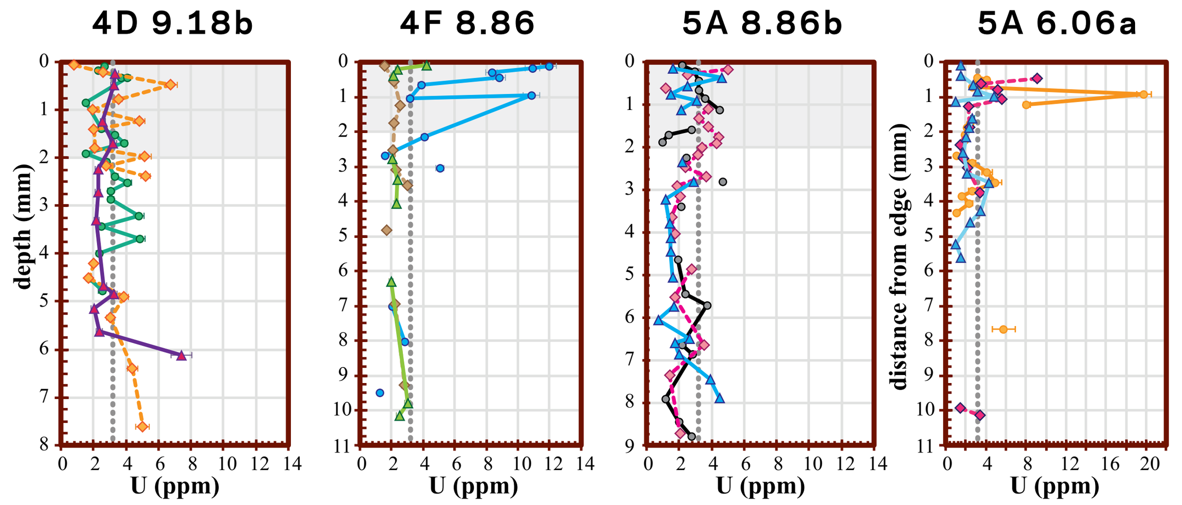


Fig. 8) U-concentration is generally similar to unmelted sand (dashed gray line). High U-concentrations are limited to the upper 2 mm.

Pu-240/239 RATIO

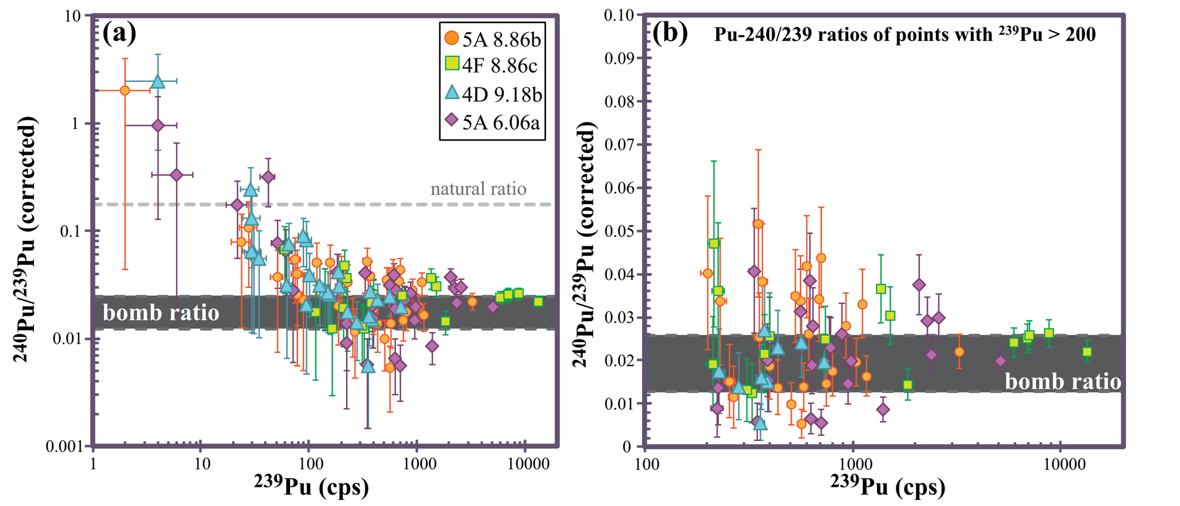


Fig. 9) Regions with **a)** <1000 cps ^{239}Pu are more likely to reflect natural Pu or give erroneously low $^{240}Pu/^{239}Pu$ ratios, whereas **b)** high Pu signal (>1000 cps) yields a consistent $^{240}Pu/^{239}Pu$ ratio similar to the Trinity device.

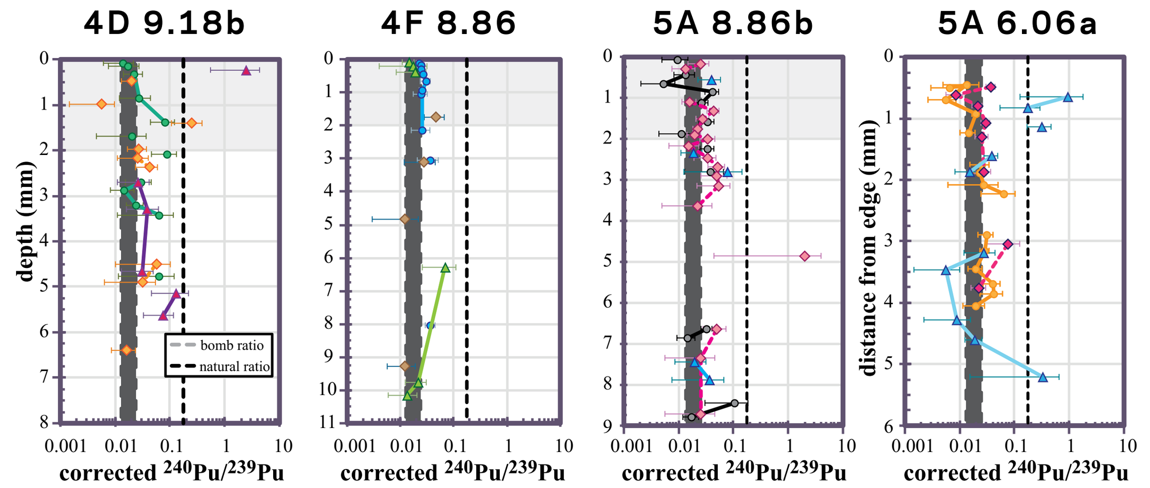


Fig. 10) Near surface $^{240}Pu/^{239}Pu$ ratios are similar to the Trinity device (0.013-0.016), though low $^{240}Pu/^{239}Pu$ ratios are also present at depth.

CONCLUSIONS

- **Even at high spatial resolution, Trinitite demonstrates trace element homogeneity at hand specimen scale.**
- **The upper 2mm of Trinitite is more likely to be enriched in bomb and anthropogenic related trace elements.**
- Potential bomb signatures (Pu and U) occur at several millimeters depth in sections.

REFERENCES

Bellucci, J.J., Simonetti, A., Koeman, E.C., Wallace, C., and Burns, P.C., 2014, A detailed geochemical investigation of post-nuclear detonation Trinitite glass at high spatial resolution: Delineating anthropogenic vs. natural components: *Chemical Geology*, v. **365**, p. 69–86.

Wallace, C., Bellucci, J.J., Simonetti, A., Hainley, T., Koeman, E.C., and Burns, P.C., 2013, A multi-method approach for determination of radionuclide distribution in Trinitite: *Journal of Radioanalytical and Nuclear Chemistry*, v. **298**, p. 993–1003.

ACKNOWLEDGMENTS

This research was funded by DOE/NNSA grant PDP11-40/DE-NA0001112. We thank Dr. Ian Steele for lending expertise and time in obtaining electron microprobe analyses at the University of Chicago (Chicago, Illinois). Sandy Dillard of the Brazos Valley Petrographic Thin Section Services Lab (Bryan, Texas) is thanked for production of thin sections of Trinitite. We also wish to thank the Center for Environmental Science and Technology at the University of Notre Dame for use of the EDAX Orbis XRF. Trinitite samples in this study were purchased from the Mineralogical Research Corporation (www.minresco.com).

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GSA 2014, Vancouver, B.C., Canada