SnT 2023
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
HOFBURG PALACE - Vienna and Online
19 TO 23 JUNE

Measuring Explosively Driven Elemental Diffusion in Geological Matrices as Potential Signatures

April J. Carman and Martin Liezers
Pacific Northwest National Laboratory

Pacific Northwest NATIONAL LABORATORY

INTRODUCTION

Geologic properties influence movement of elements in explosion debris. Through bench-scale explosions, we are exploring how different geology types could change remotely-measured signatures like the ratio of xenon isotopes from an explosion.

METHODS/DATA

Exploding Bridge Wires (EBW), which can be detonated in open air or placed within materials, are used to mimic the effects of explosions on materials. This method is employed in conjunction with air sampling ICP-MS to study the propagation of volatile elements in geologic media.

START

RESULTS

Detonation of an EBW in granodiorite (igneous rock similar to granite) resulted in release of several gaseous elements including Cu, Zn, Br, Rb, Y, Sn, Sb, Te, I, Nd, Hg and Pb through the rock with a range of delays

CONCLUSION

Mercury and iodine are most likely to be detected at the greatest distance through rock (1-2 cm). Iodine displays significant post explosion mobility long after any obvious thermal-pressure gradients have dissipated.

Please do not use this space, a QR code will be automatically overlayed

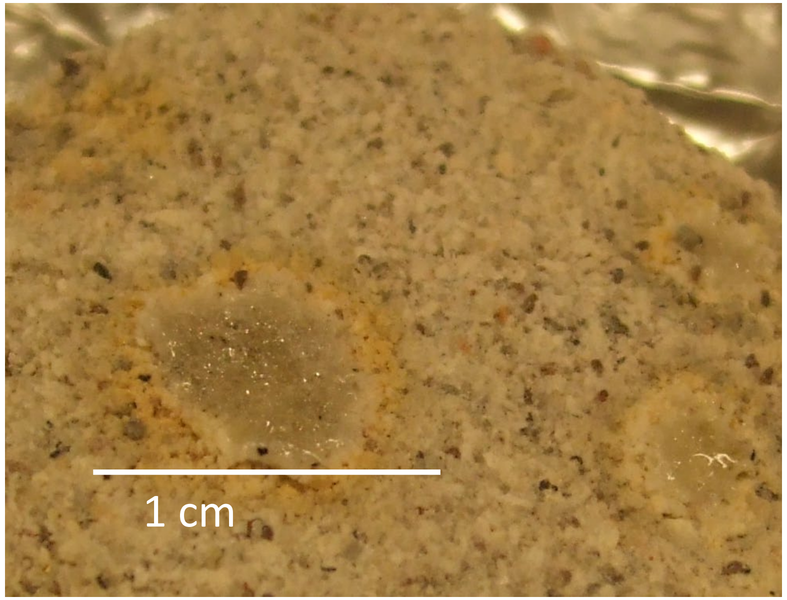
P2.4-347

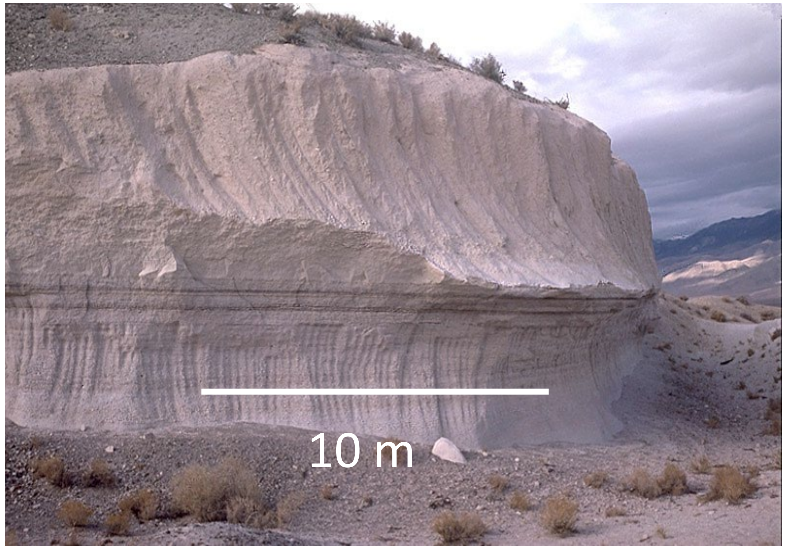
PNNL-SA-186074

Introduction

Geologic properties influence movement of elements in explosion debris. Through bench-scale explosions, we are exploring how different geology types could change remotely-measured signatures like the ratio of xenon isotopes from an explosion.

- Are there stable element signatures from UNEs that have been previously overlooked that can now be measured?
- How long does the explosion signature persist and will it transit the subsurface?
- Do stable isotopes always behave like their radioactive counterparts?
- Can bench top experiments:
  - mimic signatures generated by a small UNEs?
  - be applied to prove new technologies prior to field testing?
- How do material properties alter the explosive effects generated at the microscale when extrapolated to the macroscale?





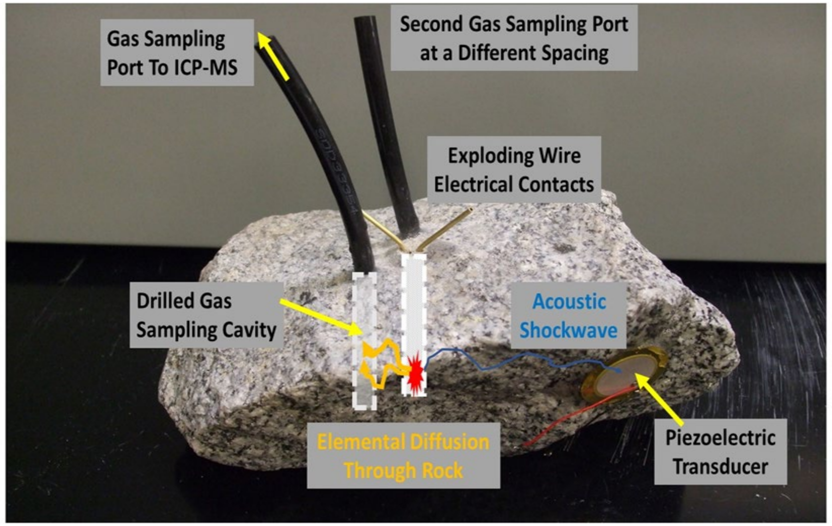
Please do not use this space, a QR code will be automatically overlayed

Objectives

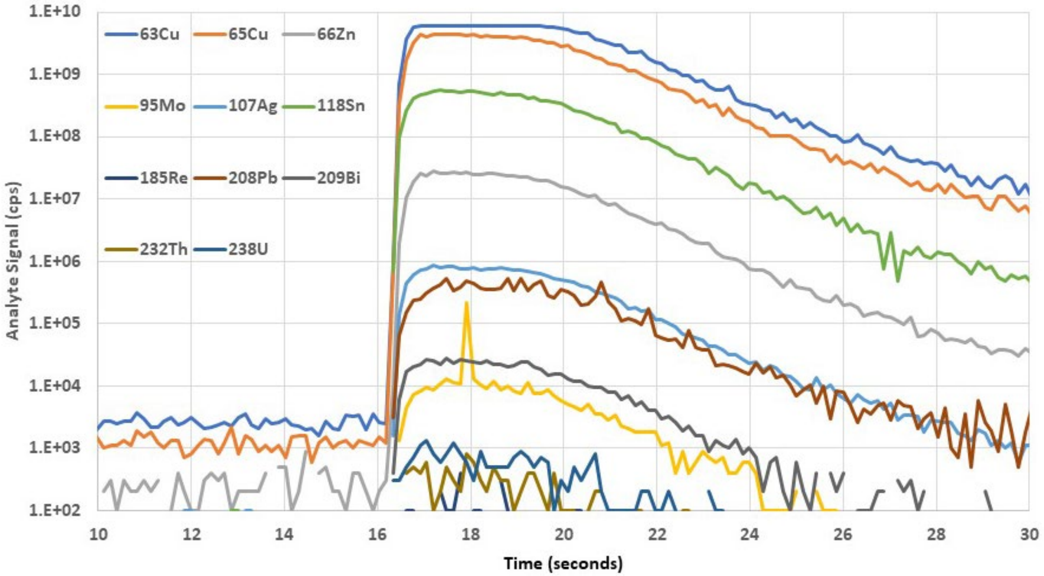
Objective: Detect new elemental signatures from solid matrices subject to thermal-explosive shock.

Exploding Bridge Wires (EBW) can be used to mimic the effects of explosions on materials. The thermal explosive shock from an EBW causes release of elements within the rock, that may not otherwise be released into the atmosphere.

Exploding Wire Embedded in Rock



Sub-ppm detection of impurities in a 2.5 mg copper wire.



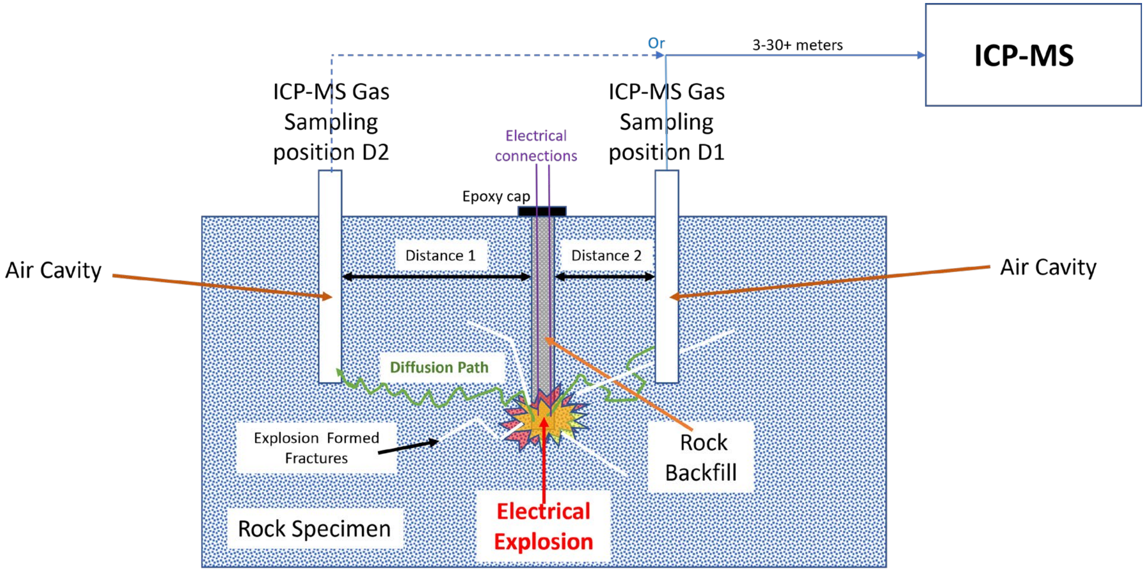
If we can detect sub-ppm levels of impurities in a 2.5 mg Cu wire, what else can we detect?

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

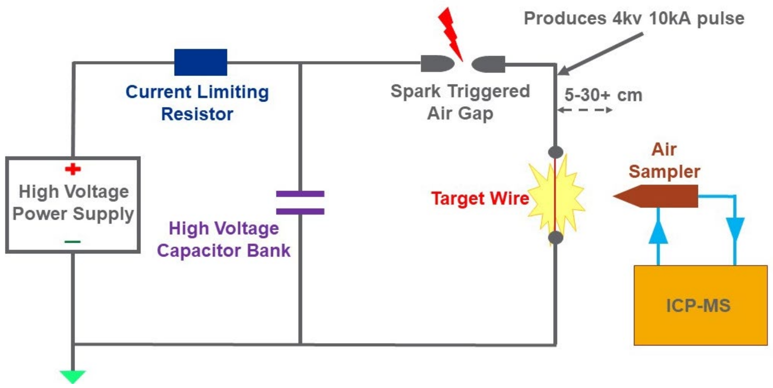
Methods

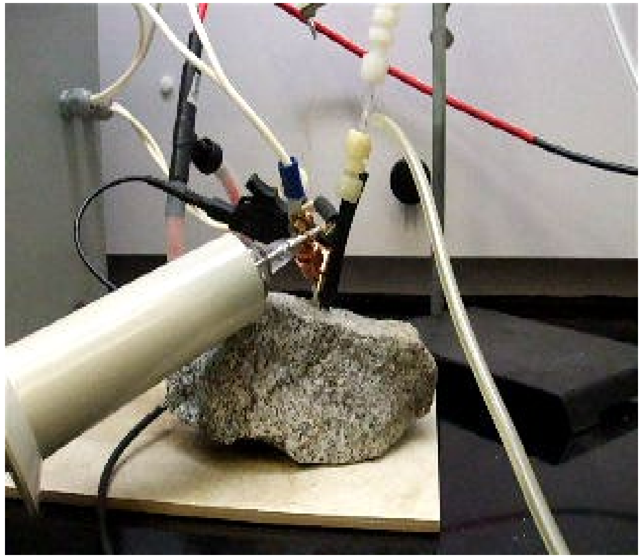
The wires can be detonated in the open air or placed within materials of interest. An EBW was embedded within rock with air sampling using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at varying distances from the source to study the propagation of volatile elements in geologic media.

100 J in a wire 0.25 mm dia, 3 mm long
equates to an energy density of 6.8×10^{11} J/m^3
TNT in comparison 6.6×10^{9} J/m^3



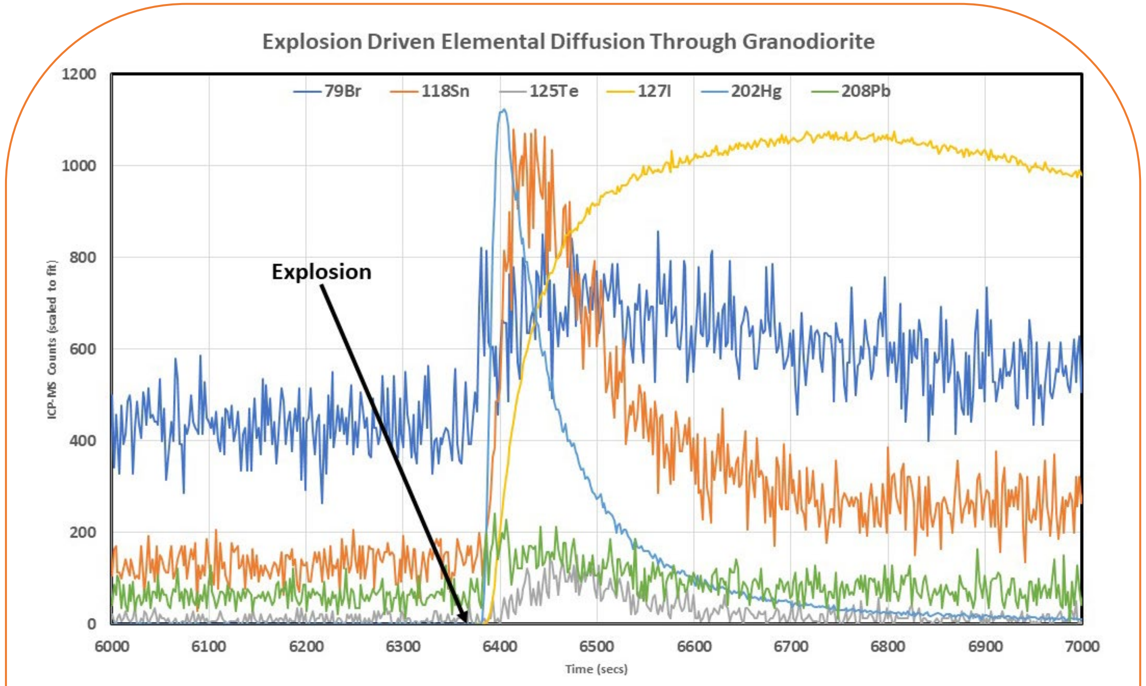
Exploding Bridge Wire Circuit





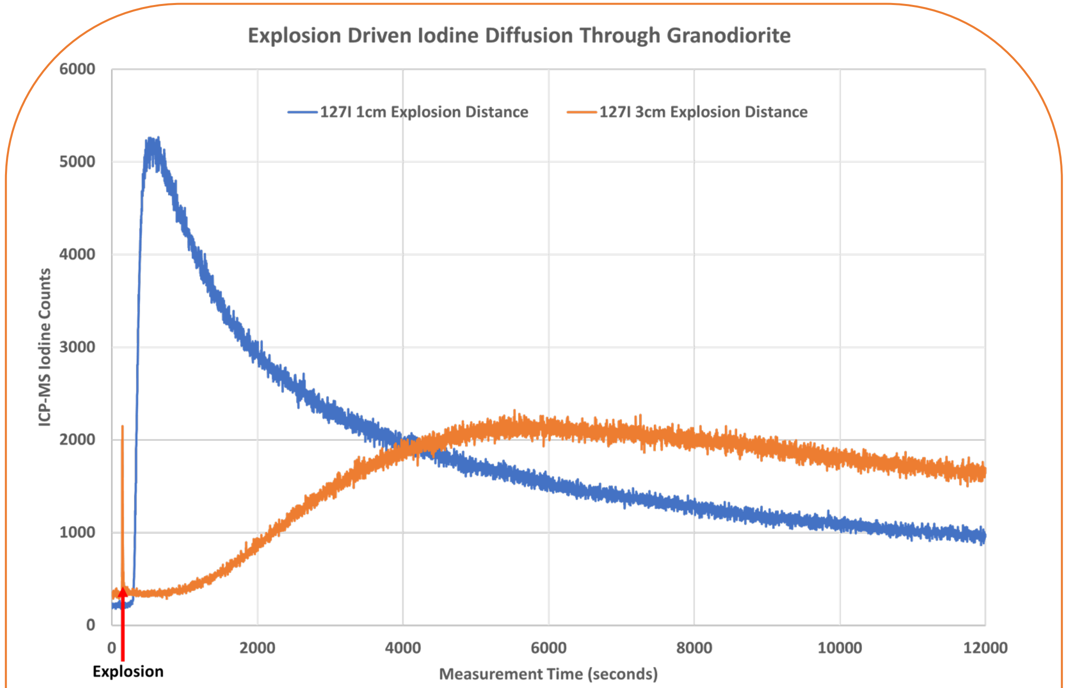
INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

Results



Detonation of an EBW in granodiorite (igneous rock similar to granite) resulted in release of several isotopes, shown above.

The isotopes behave differently: I shows a slow rise, while Hg shows a rapid peak and quickly tails off.



Examining I-127: Migration through granodiorite is shown with iodine counts at two distances – 1 cm and 3 cm.

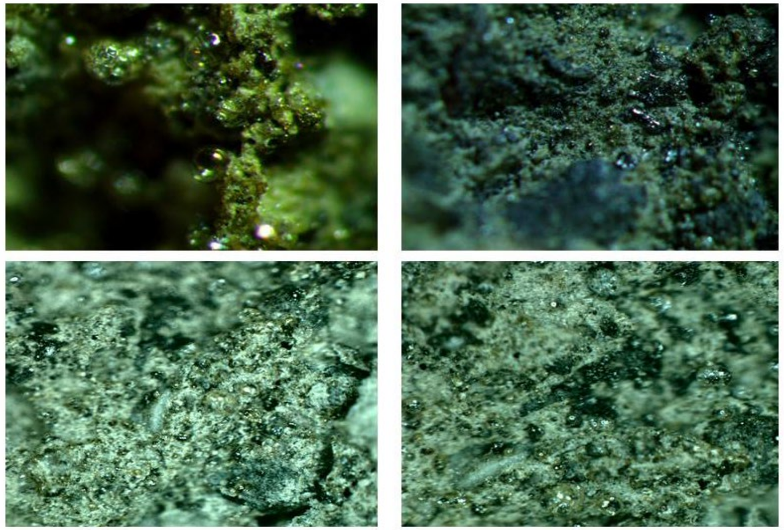
INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

Conclusions

Conclusions -

- We have successfully embedded EBWs in geological materials, detonated them, and observed volatile emanations.
- Volatile elements Hg and I display significantly different diffusion rates and behaviors.
- Hg and I most likely to be detected at the greatest distance through rock (1-2cm). Iodine displays significant post explosion mobility long after any obvious thermal-pressure gradients have dissipated.
- Consider monitoring Hg levels in boreholes during tests (gaseous mercury analyzers are relatively cheap and more portable than an ICP-MS).

EBW Post-Detonation Glassy Formations resulting from high temperatures interacting with the embedding media



INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION

References

"Remote Sensing Volatile Elements for New Signatures from Underground Nuclear Explosions"
Liezers M.; G.C. Eiden, and A.J. Carman.
J Radioanal Nucl Chem, 318, 55–64 (2018) PNNL-SA-133438.
https://doi.org/10.1007/s10967-018-6167-8

"Simulating the Effects of an Underground Nuclear Explosions with an Exploding Wire."
Liezers M.; A.J. Carman, and G.C. Eiden.
J Radioanal Nucl Chem, 318, 79-87 (2018) PNNL-SA-133439.
https://doi.org/10.1007/s10967-018-6047-2

“Remote sensing volatile elements for new signatures from underground nuclear explosions”
Liezers, M.; Eiden, G.C. & Carman, A.J.
J Radioanal Nucl Chem 318, 55–64 (2018)
https://doi.org/10.1007/s10967-018-6167-8

“Physicochemical Gas–Solid Sorption Properties of Geologic Materials Using Inverse Gas Chromatography”
Denis, E.H.; Fraga, C.G.; Huggett, N.L.; Weaver, W.C.; Rush, L.A.; Dockendorff, B.P.; Breton-Vega, A.S.; Carman, A.J.
Langmuir 2021, 37, 23, 6887–6897
https://pubs.acs.org/doi/10.1021/acs.langmuir.0c03676

“Rugged nanoparticle tracers for mass tracking in explosive events”
Hubbard, L.; Sumner, R.; Liezers, M.; Cell, T.; Reed, C.; Uhnak, N.; Allen, C.; Berry, B.; Currah, H.; Fuller, E.; Kinney, E.; Smith, N.; Foxe, M.; Carman, A.
MRS Communications, 1-6. (2020)
https://doi.org/10.1557/mrc.2020.70

This Low Yield Nuclear Monitoring (LYNM) research was funded by the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (NNSA DNN R&D). The authors acknowledge important interdisciplinary collaboration with scientists and engineers from LANL, LLNL, NNSS, PNNL, and SNL.

INTRODUCTION
OBJECTIVES
METHODS/DATA
RESULTS
CONCLUSION