THE COORDINATED UTILIZATION OF HANDHELD GEOCHEMICAL INSTRUMENTS AT KILBOURNE HOLE, NM, TO INVESTIGATE VOLCANIC DEPOSITS. C. A. Knudson[1,2,3], C. N. Achilles[1,2,3], Z. R. Morse[1,4], A. Baldridge[5], B. Harte[5], A. D., Rogers[6], B. Wolfe[7], R. Hopkins[6], L. A. Edgar[8], P. Whelley[1,2,3], C. Honniball[1], K. Young[1], A. C. McAdam[1], T. D. Glotch[6]. [1]NASA Goddard Space Flight Center, Greenbelt, MD; Christine.a.knudson@nasa.gov, [2]Univeristy of Maryland, College Park, MD, [3]CRESST II, Greenbelt, MD, [4]Howard University, Washington DC, [5]Saint Mary's College of California, Moraga, CA. [6]Stony Brook University, Stony Brook, NY. [7]Spectrum Photonics Inc., Honolulu, HI. [8]USGS Astrogeology Science Center, Flagstaff, AZ.

Introduction: In support of the Solar System Exploration Virtual Research Institute (SSERVI) Remote In Situ Synchrotron Studies for Science and Exploration 2 (RISE2) objectives, a suite of handheld geochemical instruments were deployed for *in situ* field measurements of explosive volcanic deposits and underlying paleosols at Kilbourne Hole and Hunts Hole in the Potrillo Volcanic Field in Southern New Mexico. The goals of the RISE2 field expeditions are to develop scientific field methods for human exploration by conducting field research at a lunar analog volcanic site. These goals include evaluating the eruptive history of the region, establishing field exploration protocols, and developing a concept of operations and data management strategy for field portable instruments. Our group used four handheld geochemical instruments to obtain coordinated *in situ* fine-scale measurements of the same vertical exposures of volcanic deposits to be paired with hyperspectral imaging, and LiDAR [1,2]. This coordinated effort provides an opportunity to develop efficient and effective science operations through the development of intermediate data products for real time decision making for future missions on the Moon or Mars [3].

Fieldwork: Kilbourne Hole and Hunts Hole are both the result of explosive volcanic eruptions, generated when magma came in contact with groundwater [4]. The resulting maars expose underlying stratigraphy of the sedimentary Camp Rice Formation, Afton basalt, and associated paleosols. At Kilbourne Hole these eruptive events deposited up to ~70 m of pyroclastic material adding to the crater walls [5]. Not only is this location geologically interesting, but it is one of the many places used by Apollo astronauts for field training, and is being considered for future Artemis field exercises.

Two handheld instruments, a SciAps handheld Laser Induced Breakdown Spectrometer (hLIBS) and a SciAps handheld X-ray fluorescence (hXRF) spectrometer provide elemental data which are then converted into oxide weight percentages to characterize samples by mineral or rock type. Additionally, an Analytical Spectral Devices Inc. (ASD), Malvern Panalytical TerraSpec Halo visible/near-infrared (VNIR) spectrometer, and an ASD FieldSpec spectroradiometer (0.3-2.5μm) were deployed to identify primary and secondary minerals and/or mineral groups.

Outcrops were selected based on multiple factors: 1) geologic importance (e.g., evidence for variability in deposition), 2) accessibility for the handheld instruments and instrument operators, 3) exposures and visibility for the standoff instruments and 4) accessibility and utility of the area for future extravehicular activity (EVA) concept of operations field testing. Once standoff instruments completed their measurements, markers were placed on the outcrop to identify specific locations within sections for handheld analyses to allow for all measurements to be taken on the same parts of the outcrop Figure 1). Photos were acquired of each measured sample and stratigraphic relationships and sedimentary observations were noted. In addition to the instrument measurements, select samples representative of the studied outcrops were collected for detailed laboratory analyses. These comparisons will largely complement the handheld data, as well as inform the effectiveness of the handheld instruments during planetary surface exploration.

Figure 1. Outcrop of pyroclastic deposits selected for *in situ* measurements with handheld and standoff instruments on the North rim of Kilbourne Hole. Flags

and pins indicate layers selected for handheld measurements.

Data Acquisition: The focus of this particular expedition for our group was on data collection for site characterization; all data acquired during the Fall 2021 field expedition are being evaluated and processed. These data include ~500 LIBS spectra and 153 XRF measurements as well as ASD/Halo and FieldSpec spectral data. Establishing effective processing methods and summary data products are key tasks prior to the next field deployment in Spring 2022. Before the next field expedition, data will be reformatted so that *in situ* measurements are displayed in units that allow for more intuitive sample comparison (e.g., weight percent oxide rather than element weight percent), and can be displayed in a way that will provide contextual comparisons, and inform sample collection [6]. Testing the effective display of data in real-time during the next field expedition will serve as a trial run for tactical implementation of these types of data products for crew and enable us to evaluate alternative data products for use by support scientists.

Future Work: Improvements and modifications will be made to the data products generated with handheld instruments in the field after input from the scientist instrument operators and lessons learned while using these data products during the next field expedition are taken into consideration. These changes can then be incorporated for use during training in simulated EVAs at Kilbourne Hole (a major goal of this portion of the RISE2 work).

The coordination of data sets from both the handheld instruments and the standoff instruments allows for ground truthing and provides examples of features or structures that may be missed by standoff instrumentation but identified on a smaller scale through handheld analyses. Operating in this way also acts as a rover-like suite of instrumentation and provides additional data sets that may be helpful in informing a hypothesis made with a different but complementary data set.

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References: [1] Rogers, A. D., et al. (2022) *LPSC, this conference.* [2] Whelley, P. F., et al. (in review) *Journal of Volcanology, Geothermal Research.* [3] Young, K. E. et al. (2020) *Lunar Surface Science Workshop, LPI Cont. No.2241,* id.5143. [4] Lorenz, Y. (1973) *Bulletin Volcanologique,* v.37, 183-204. [5] Reiche, P. (1940) *American Journal of Science,* v.238, 212-255. [6] Achilles, C. N., et al. (2021) *Joint NESF and ELS 2021.*