WORSWICK HOT SPRINGS:
A RADIOACTIVE HYDROTHERMAL FIELD SITE

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Introduction

We report on a systematic characterization of the radiation environment and water temperatures of Worswick Hot Springs, which is in support of companion biochemical and microbial investigations of iron respiration in the 'extreme' microbial systems found at the field site. We have discovered localized areas of elevated radioactivity that are approximately four to five times greater than background radiation. Additionally, we have observed that both the radiation environment and the temperature of the spring waters vary over time. Because localized "hot spots" of elevated radiation and biofilms are easily accessible, various biological studies of radiation resistance and biosignature formation are possible, making this field site relevant for analog field studies that consider microbiology, geochemistry, and ionizing radiation. In addition to Worswick being a natural radiation biology laboratory that may also be relevant for space biology applications, we assert that these unusual environmental conditions may inform us about locations on Mars that are also enriched in radioactive elements and their potential for hosting biosignatures.

Background

Radioactive hot springs are well documented in many locations around the world and radiation resistant microbes have been found in some as well. Examples of some of the earliest discoveries of radiation in and around hot springs in the United States were made on public lands, namely at Hot Springs National Park in 1904, and at Yellowstone National Park in 1906. Follow-on reports document the sources of radiation to be radon gas within the hot spring waters.

Field Site

Worswick Hot Springs is located at 1827 feet altitude in the southern Soldier Mountains of Idaho at GPS coordinates 43°33.869 N, 114°47.814 W. The field site is approximately 73 miles straight east of Boise, ID, or 15 miles straight north of Farfield, ID. The field site contains multiple small hot spring water sources that form two streams (Stream A and Stream B), which flow into Worswick Creek.

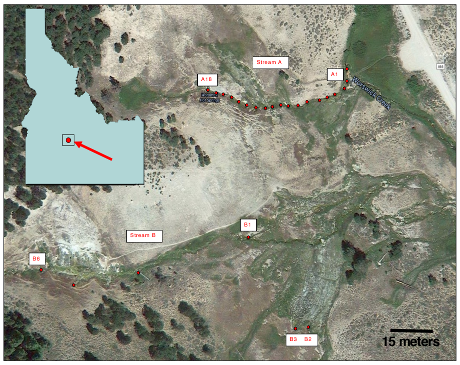


Figure 1. Red arrow on Idaho map denotes the location of this satellite image of the field site. Radiation and temperature data was collected from 25 locations along streams A and B at Worswick in 2011, 2013, 2015, 2016, and 2017. Radiation data was collected on every field visit; temperature data was collected on all field visits except in 2013. Parking lot at upper right is also seen in lower right of figure 2.

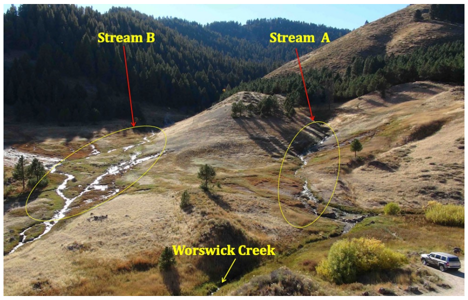


Figure 2. Streams A and B of the Worswick complex both flow into Worswick Creek, which empties into Little Smoky Creek, a tributary of the South Fork Boise River.

Methods

A Ludlum 19 micro-r-meter (Ludlum Measurements, Inc.) capable of sensing x-rays and gamma-rays (0-5000 µR/hr), was operated in the field to gather radiation data at twenty-five field locations denoted as red dots in Figure 1. The micro-r meter was held within 10 centimeters of flowing water at all locations and microroentgens per (µR/hr) were read from the instrument and recorded. A digital hand-held mini-infrared thermometer (Digi-Sense, 39642-00) was used to collected water temperatures (˚C) at every radioactivity measurement site. Data is presented in Figures 3, 4 and 5. We also deployed a radon detector (Corentium) in the highest radiation environment on Stream A to determine if radon was present. Evaporite/precipitate samples collected from rocks perched above flowing stream waters were analyzed by x-ray diffraction (XRD). Water samples were collected and analyzed by ICP-MS at the ISU Center for Archaeology, Materials and Applied Spectroscopy. Na, S, and Th results shown in Figure 6.

Radiation and Temperature Observations

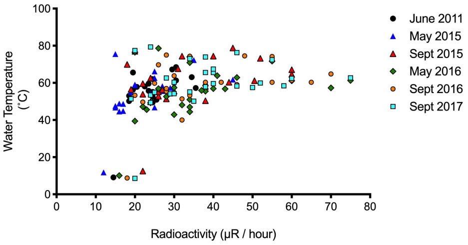


Figure 3. Radioactivity and temperature data from Worswick Hot Springs.

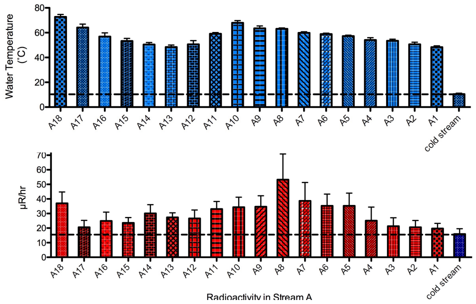


Figure 4. Mean water temperature and radioactivity of Steam A locations A1 through A18 for all years. Note that A1 is the lowest elevation of stream A, and A18 is the highest elevation of stream A. Cold stream was measured in Worswick Creek, 5 meters upstream of the mouth of Stream A.

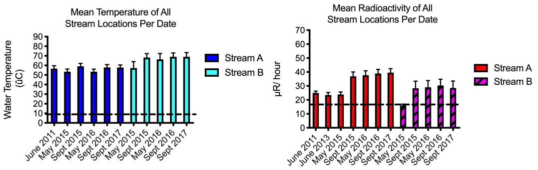
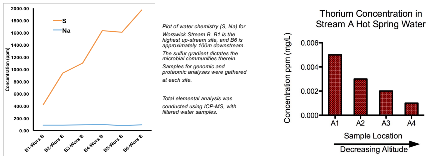


Figure 5. Mean water temperature and radioactivity of each stream per date of measure. The dashed line in each chart approximates the cold stream temp and background radioactivity respectively.



Plot of water chemistry (S, Na) for Worswick Stream B. B1 is the highest up-stream site, and B6 is approximately 100m downstream.

The sulfur gradient dictates the microbial communities therein.

Samples for genomic and proteomic analyses were gathered at each site.

Total elemental analysis was conducted using ICP-MS, with filtered water samples.

Figure 6. Water chemistry results from streams A and B .

Discussion

A correlation between temperature and radioactivity appears to exist, and the aqueous geochemistry ICP-MS analyses reveal the presence of thorium and uranium as being likely sources of radioactivity. Radon was also detected on two separate occasions at levels ranging from 0.78 to1.42 pCi/L. XRD analyses show Opal-A ($SiO_2•H_2O$), Anorthite, $(Ca, Na)(Si,Al)_4O_8$, and Quartz (SiO_2) minerals coat the rocks perched above the stream waters, providing additional context when comparing silica-producing hot springs on Earth and Mars. It is important to note that Worswick is also similar to other present-day Mars analog hydrothermal systems, such as those currently studied in El Tatio, Chile, which contain nodules of opaline silica sinter that are strikingly similar to those observed by the Spirit Rover on Mars, near "home plate" in the ancient volcanic hydrothermal systems in the Columbia Hills of Gusev crater. We have been unable to find a record that documents the presence of elevated radioactivity around Worswick Hot Springs, despite detailed characterization of its waters and local hydrothermal systems [1]. We believe our work represents the discovery of radioactivity at Worswick Hot Springs. Regarding radioactive hot springs as a model geomicrobiological system for exobiology studies, we assert that elevated radioactivity in a hot spring on Earth serves as an analog environment for hot springs on other planetary bodies with thinner atmospheres and elevated levels of radiation on their surfaces [2][3]. For example, thorium-enriched areas of Acidalia Planitia on Mars [4] (Figure 7) occur in an area that contains more than 40,000 circular mounds with associated lobate and flow-like features, which suggests possible widespread and extensive mud volcanism [5] (Figure 8). A study of the habitability of these features as it relates to in situ radionuclides is warranted and may prove useful regarding site selection criteria for future life detection missions.

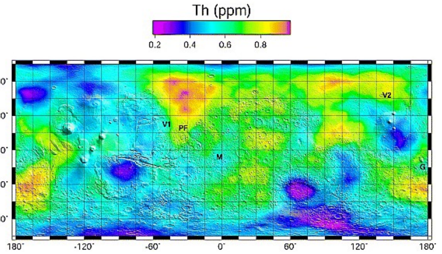


Figure 7. Thorium enriched areas on Mars (Adapted from Taylor, 2006).

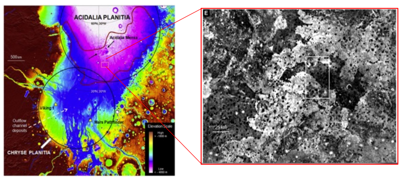


Figure 8. Possible mud volcanism in Acidalia Planitia (adapted from Oehler, 2010).

References

[1] Mariner, R.H., et. al. (2006) Geoth. 35(1):3-25. [2] Rask, J.C., et.al., (2016) Sixth Mars Polar Sci Conf, 6110. [3] Ruff, S. W., Farmer, J., (2016) Ncomms, 7:13554. [4] Taylor GJ, et.al., Journal of Geophysical Research: Planets. (2006) Mar 1;111(E3). [5] Oehler DZ, Allen CC, (2010). Icarus. Aug 1;208(2):636-57.

Acknowledgments

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