Aqueous Geochemistry in Norris Geyser Basin: Using ArcGIS to Enhance Sampling for a Master's Thesis

Lindsey Sydow

INTRODUTION

One of the most widely known theories for the origin of life at hydrothermal vents is dependent on the presence of abiotically synthesized organic sulfur gases. These gases are key to the "surface metabolism" proposed by this theory to be the precursor to life as we know it (Wachtershauser 1990). My main field site for researching the presence of these gases and the associated chemistry is Cinder Pool, a hydrothermal feature with some unique properties that increase the likelihood of finding organic sulfur compounds. Cinder Pool has sulfur spherules (called cinders, hence the name) floating over much of the surface (see Figure 1). The source for the cinders is a molten layer of sulfur at the base of the pool (interface is approximately 20 meters down), which gas bubbles up through, creating the bubbles in the cinders (Xu et al. 2000). I have hypothesized that the reactions occurring near the base of this pool are relevant to Wächtershäuser's origin of life theory.

Figure 1: Cinder Pool. Note the cinders floating on the surface.

In this project, I will utilize the power of ArcGIS to evaluate other hydrothermal features in Norris Geyser Basin that may be similar enough to Cinder Pool to warrant additional sampling. Cinder Pool's temperature ranges from ~85^{o}C at the surface to 113^{o}C at the water/sulfur layer interface (Xu et al. 2000), so I only want to look at features with recorded temperatures above 70^{o}C. These temperatures are important for catalyzing reactions, and even though this threshold is substantially cooler than Cinder Pool, higher temperatures are likely at depth. Cinder Pool's pH is ~4, so I am also only selecting features with a pH of <5. It is unlikely that there is enough dissolved hydrogen sulfide (H_2S) in the water for this reaction to be favorable if the pH is much higher. Temperature and pH are the two firm requirements for selection, but I am also going to observe the location of the features in terms of the geologic unit where they occur. Cinder Pool springs from the alluvium in the One Hundred Springs Plain, so that will be an interesting parameter to examine as well. I do not expect to find a huge number of features to sample using these constraints.

METHODOLOGY AND RESULTS

Gathering and processing data for this project required a lot of trial and error. Initial searches for geospatial and hydrothermal data using ArcGIS online were confidence-inspiring in that they turned up 500+ results, but on closer inspection, I found that these maps were not detailed enough for my purposes. Geologic maps were for regions much larger than my study area and could not convey the heterogeneity of outcrops in a place as dynamic as Norris Geyser Basin. The only map I found with hydrothermal features displayed about 50 hot springs all across Wyoming, which is insignificant when compared with the estimated 10,000 features in Yellowstone National Park alone.

These holdups led me to the National Geologic Map Database available on the USGS website. Here I found a data series (Flynn et al. 2008) that contained the geologic units of Norris Geyser Basin as well as the associated thermal features. I created a "water_features" layer by selecting springs from the point features and converting polygon pool features to points, then merging the two (see Figure 2).

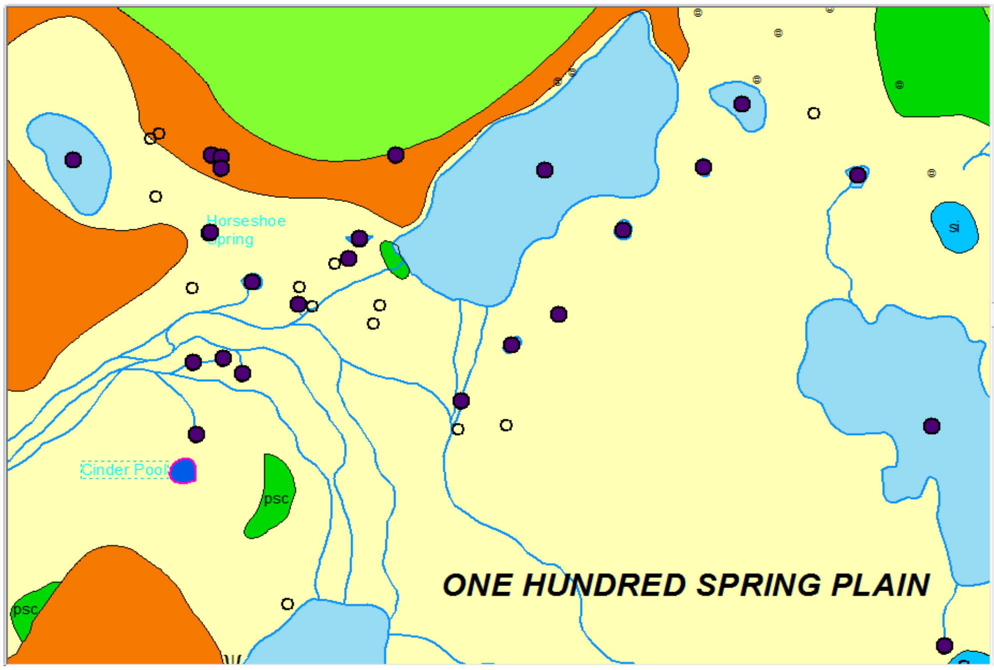

Figure 2: The purple circles represent the constituents of "water_features" which was not used in analysis due to the lack of a common field for joining with chemical data.

Although no geochemical data was associated with this dataset, I was able to acquire the necessary information from a paper about the chemistry of select hydrothermal features in the park (Ball et al. 2010). This required copying data from a pdf into a text file, then tab delimiting it for import into Microsoft Excel and ArcMap, as well as entering temperature data by hand. Ball et al. had noted the site locations using GPS in degrees/minutes/seconds format, which I converted to decimal degrees for UTM projection in ArcMap (see Table 1). However, because there was not a USGS sample number associated with any of the "water_features" points in my original dataset, I was unable to join the geochemical table with this layer. I chose to abandon "water_features" and use "Display XY Data" and "Project" to project the geographic coordinates from the sample sites in UTM coordinates on my map (see Figure 3).

Name	sample #	latitude			y	longitude			x
Cinder Pool	07WA113	44	43	57.2	44.73256	110	42	.6	-110.71
Realgar Creek at mouth	06WA106	44	44	16.8	44.738	110	42	32.7	-110.709
Realgar Creek at mouth	06WA139	44	44	16.8	44.738	110	42	32.7	-110.709
Tantalus Creek at weir	06WA107	44	44	2.7	44.73408	110	42	54.6	-110.715
Tantalus Creek at weir	06WA158	44	44	2.7	44.73408	110	42	54.6	-110.715
Tantalus Creek at weir	08WA105	44	44	2.7	44.73408	110	42	54.6	-110.715
Unnamed hot spring northeast of Cinder Pool	06WA109	44	43	59.1	44.73308	110	42	29.3	-110.708

Table 1: A few of the features sampled by Ball et al. Latitude and Longitude are given in degrees, minutes, and seconds, then converted to decimal degrees in the y and x columns.

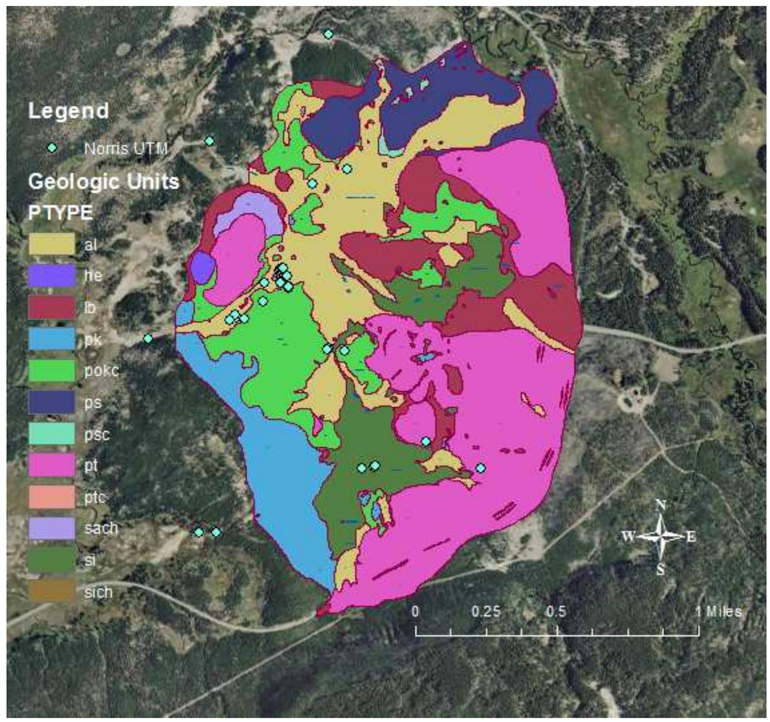

Figure 3: Projected locations of features (Norris UTM) evaluated by Ball et al. and the geologic units outcropping in Norris Geyser Basin.

From here I began the steps to find the features I may want to sample on future trips to the field. Using the select by attributes tool, I created an "alluvium" layer and a "temp&ph" layer for the hydrothermal features that met my initial constraints. I then used a select by location query to find any of the "temp&ph" features that also occurred in the alluvial deposits (see Figure 4).

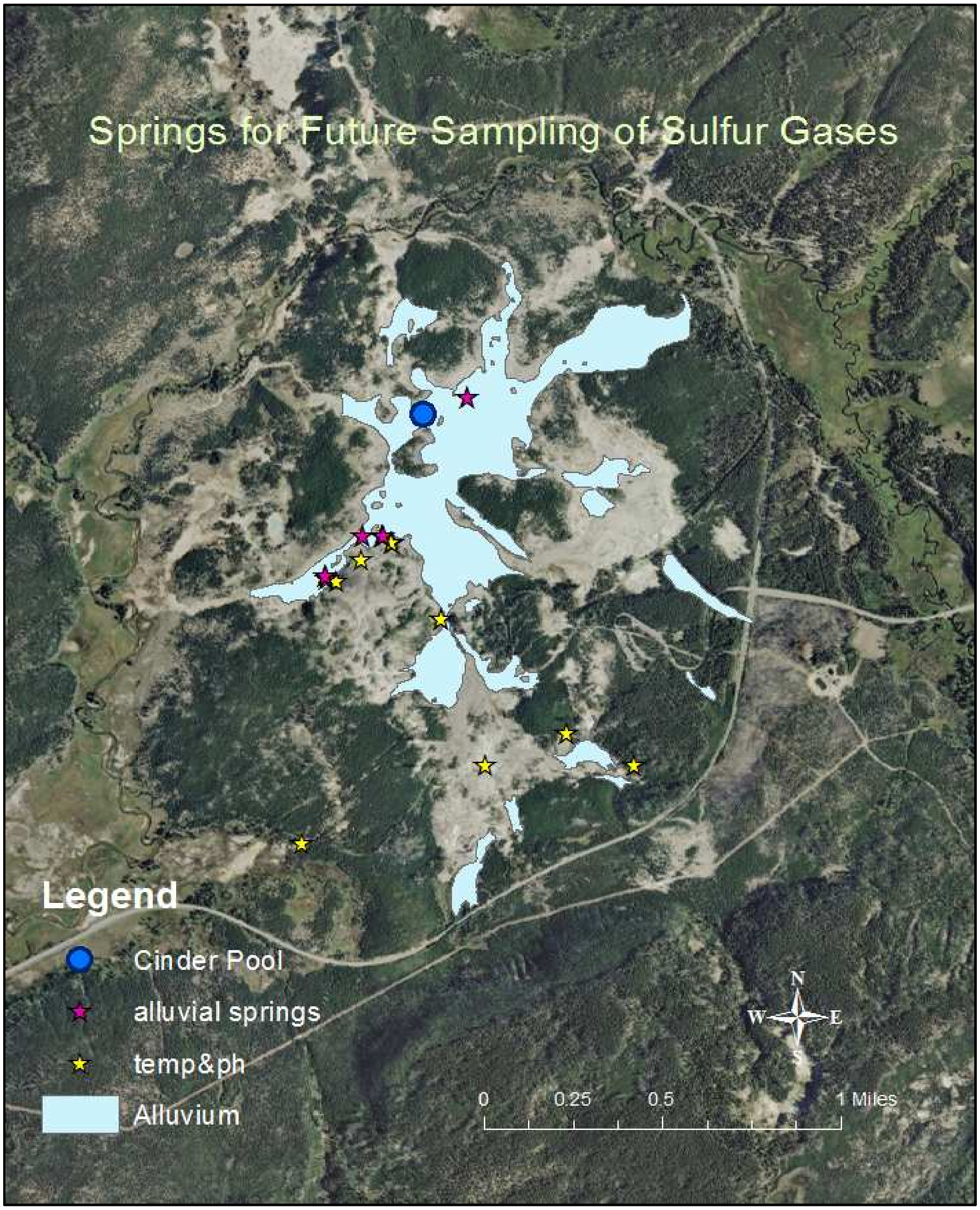

Figure 4: Cinder Pool and optimal springs for future sampling plotted against satellite imagery of Norris Geyser Basin and the alluvium unit. Yellow stars denote features meeting temperature and pH specifications, and pink stars denote those features that fall within the alluvium.

DISCUSSION

After creating Figure 4, I exported the attribute tables to examine the features identified by my queries. A number of the points were actually repeat samples at the same locations so I ended up with fifteen features that met the criteria I imposed for pH and temperature. Of those, six were within the same alluvial unit as Cinder Pool (See Table 2).

Feature	sample__	pH	temp C
Cinder Pool	07WA113	3.96	86.8
Unnamed hot spring northeast of Cinder Pool	06WA109	3.56	74
Cistern Spring	07WA116	4.3	81.1
Cistern Spring	08WA127	4.25	79.5
Echinus Geyser	08WA126	3.52	77.1
Porkchop Geyser	07WA143	4.47	86.1
Unnamed acid spring next To Perpetual Spouter	06WA133	2.95	89
Unnamed acid spring next To Perpetual Spouter	07WA145	2.92	93
Unnamed hot spring, north end of Elk Park near 07WA140	07WA141	4.14	91.4
Appendage side spring to Lifeboat Spring	08WA124	2.52	89.3
Crystal Spring - eastern side	07WA147	1.96	77
Crystal Spring - western side	06WA111	3.77	80.3
Crystal Spring - western side	07WA146	1.94	82.9
Crystal Spring - western side	08WA120	2.15	80.8
Hot Spring next to Orpiment Puddle 2	07WA107	3.12	90
Kaolin Spring	07WA106	2.37	73.8
Lifeboat Spring	06WA118	3.49	70.4
Persnickety Geyser	06WA119	3.81	87.1
Persnickety Geyser	07WA105	3.39	89
Unnamed pool near The Gap	08WA121	3.24	91.2
Unnamed pool near Succession Spring	06WA125	4.7	84

Table 2: Features with a pH<5 and temperature>70^{o}C. Those in blue fall within the alluvium unit.

There are a couple of items of particular interest among these features. First is that Porkchop Geyser, although listed on this table with a pH of 4.47, was sampled a year later with an alkaline pH of 8.4 (Ball et al. 2010). This is just one example of the highly variable chemistry occurring in this most active geyser basin. Also of note is that the unnamed hot spring northeast of Cinder

Pool is only 211.6 meters from Cinder Pool as measured in ArcMap (see Figure 5). This increases the likelihood that it is hydrologically connected to Cinder Pool.

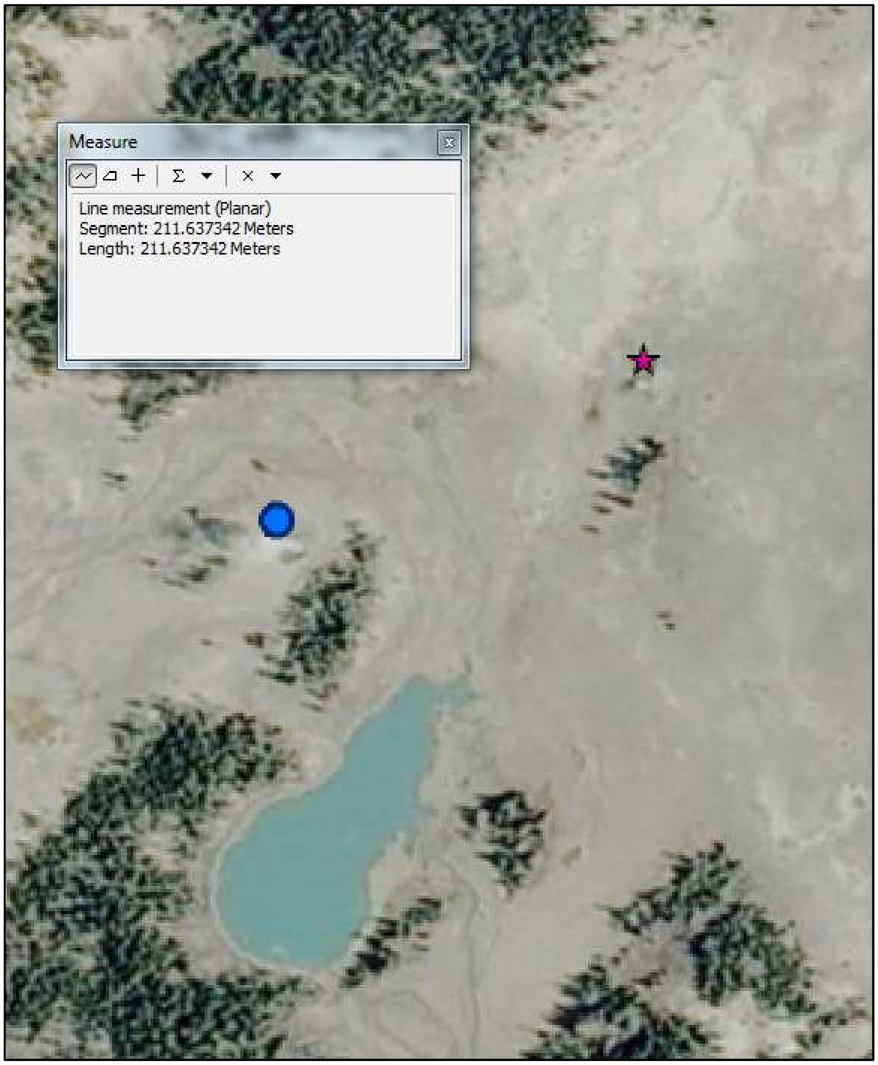

Figure 5: Cinder Pool and the unnamed feature to the northeast sampled in 2006.

CONCLUSIONS

ArcGIS proved useful for finding other hydrothermal features in Norris Geyser Basin that may be worthwhile options for future gas sampling. In particular, I will definitely sample the unnamed feature near Cinder Pool depicted in Figure 5. I would also be interested in sampling all of the other features in the "alluvial springs" layer, and any of those in the "temp&ph" layer I had time to visit, specifically Porkchop Geyser because of its large swing in pH.

This project was made more difficult by the lack of readily available data. If the USGS were to create a geospatial database of geochemical data for the thermal features at Yellowstone National Park, I am sure I am not the only person who could benefit from it.

REFERENCES

Ball, James, R. Blaine McCleskey, and D. Kirk Nordstrom, 2010, Water-Chemistry Data for Selected Springs, Geysers, and Streams in Yellowstone National Park, Wyoming, 2006-2008, *U.S. Geological Survey Open File Report 2010-1192.*

Flynn, Kathryn et al., 2008, Database of the geology and thermal activity of Norris Geyser Basin, Yellowstone National Park: *U.S. Geological Survey, Data Series DS-324*, scale 1:2400.

Wächtershäuser, G., 1990a, The Case for the Chemoautotrophic Origin of Life in an Iron-Sulfur World, *Origins of Life Evol. Biosphere*: 20.

Xu, Y. et al., 2000, Sulfur geochemistry of hydrothermal waters in Yellowstone National Park, Wyoming, USA. II. Formation and decomposition of thiosulfate and polythionate in Cinder Pool, *Journal of Volcanology and Geothermal Research*: 97.