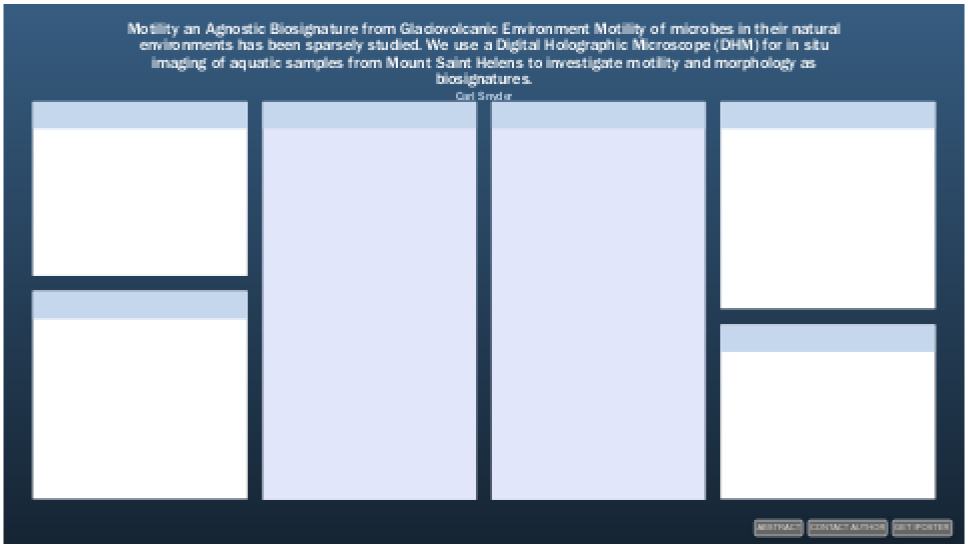
Motility an Agnostic Biosignature from Mount Saint Helens, a Glaciovolcanic Environment.



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PRESENTED AT:

WHY MICROBIAL MOTILITY

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1652835689/agu/38-07-FD-C1-BF-B1-40-D1-76-80-9D-30-54-F5-38-67/Video/2020.10.13_19-47_bolded_yumdkn.mp4

Video 1. Reocding of sample from Mount Saint Helens hot springs. One large Eukaryotic cell swimming in and out of frame while many smaller microbes are swimming through the frame.

NON-EARTH CENTRIC

- No assumptions of chemical make-up
- Evolutionarily advantageous for avoiding predators and toxicin[1] and finding nutrient patches[2]

INCREASED DETECTION

- Ability to identify and resolve smaller featureless objects as having a biosignature

UNAMBIGUOUS BIOSIGNATURE

- Regularly distinct from fluid flow and Browian motion

UBIQUITY ON EARTH

- Almost everywhere we have looked microbial motility has been observed. From hotsprings to glaciers and sea ice to deserts.

COMPELLING

- Upon discovering microbes Antoni Van Leeuwenhoek described the motion of the tiny 'animalcules'[3] and later wrote, 'Oh, that one could ever depict so wonderful a motion!'[4]
- Compelling for general audience

INVESTIGATION BEYOND LIFE DETECTION

- Predator/prey interactions, biofilm formation, taxis (chemoattractant or chemorepellent)

INTRO

Motility of microbes in their natural environments has been sparsely studied. We use a Digital Holographic Microscope (DHM) for in situ imaging of aquatic samples from Mount Saint Helens to investigate motility and morphology as biosignatures. Sites include:

- Glacial Ice Cave
- Hot Spring
- Mixed

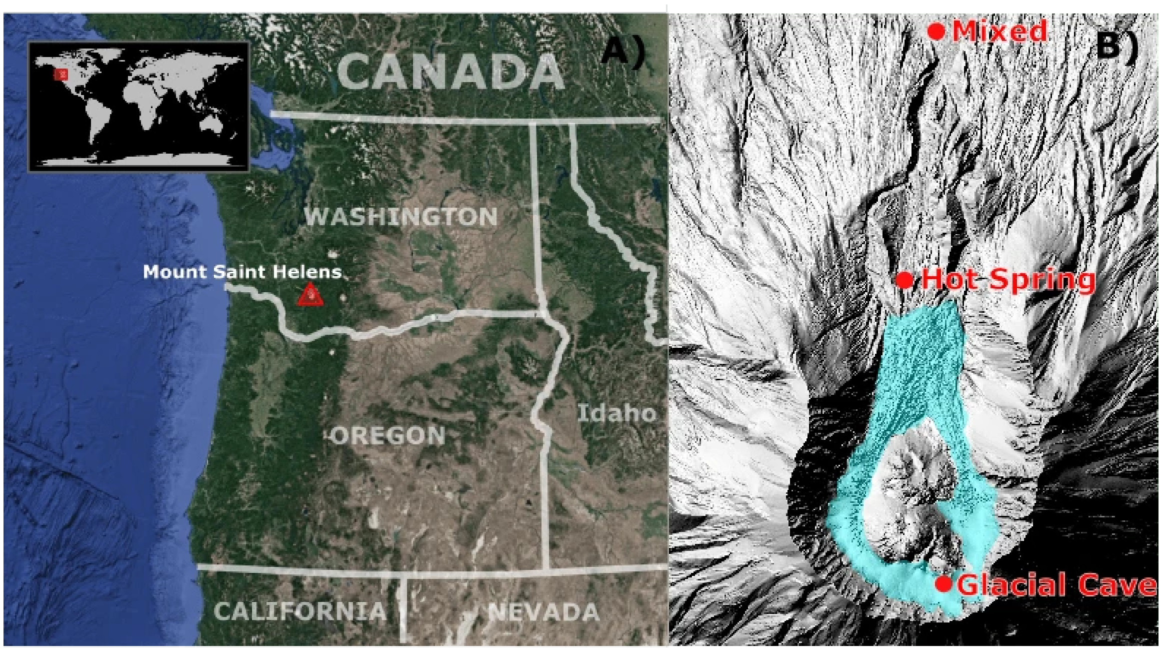


Figure 2. A) Map indicating location of Mount Saint Helens. B) The location of the three different sites collected and analyzed.

Goals:

- Demonstrate life detection tool in extreme environments and Enceladus analog
- Compare and characterize microbial motility and morpholoy present

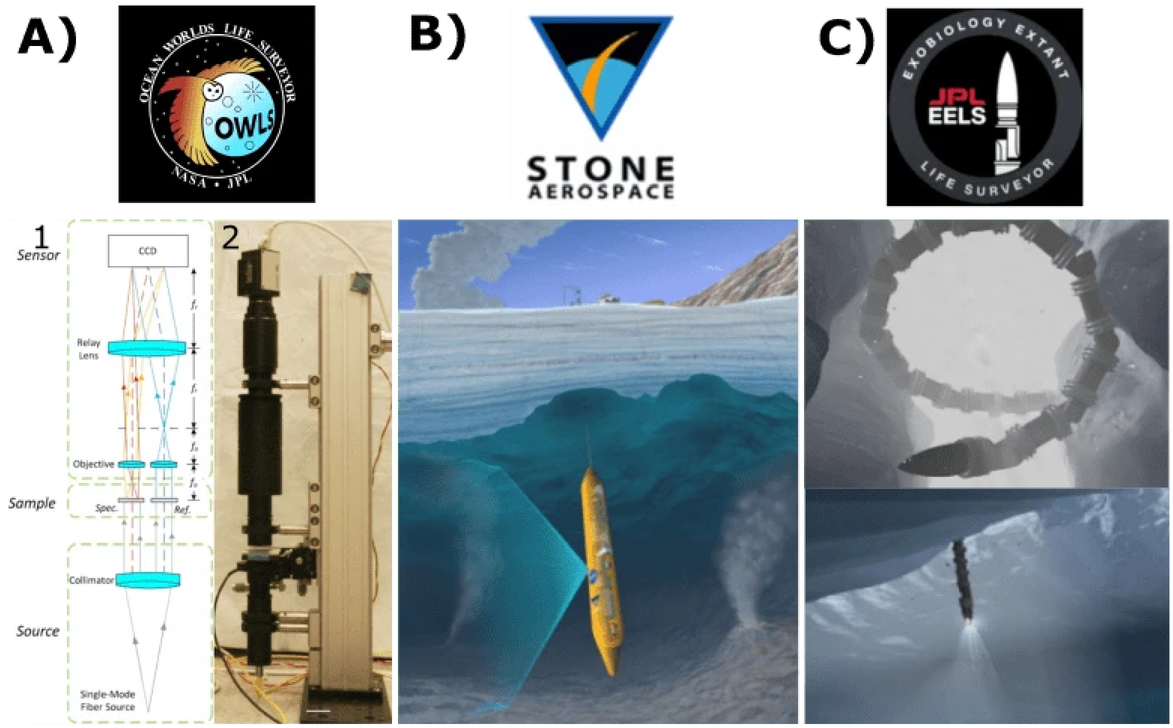


Figure 4. A) On top is the logo for Ocean World Life Surveyor (OWLS) , A1) is optical diagram of our benchtop DHM, and A2) is a photo of the benchtop DHM instrument. Stone aeroscpace is working on Thermal High-voltage Ocean-penetrator
Research platform (THOR), shown in B) above, as a underwater robot for investigation ocean worlds. Exobiology Extant Life Surveyor (EELS) are collaborators are JPL that are designing developing a robot, as shown in C) above, for investigating icy and ocean worlds in out solar system.

MATERIAL METHODS

Digital Holographic Microscopy:

- Sub-micron resolution
- Volume of view ~ 0.1-0.2 ml
- Robust no moving parts
- Compact design

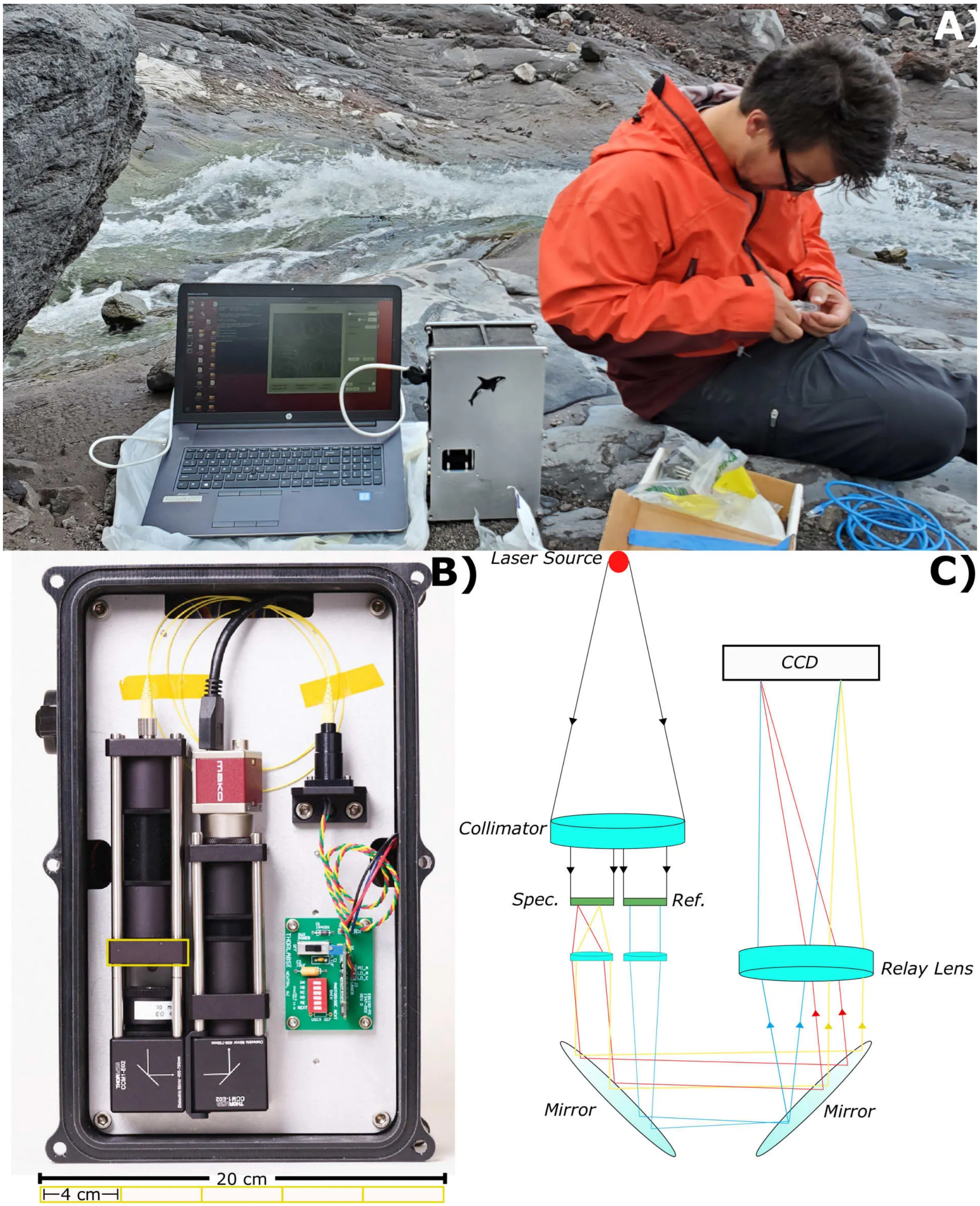
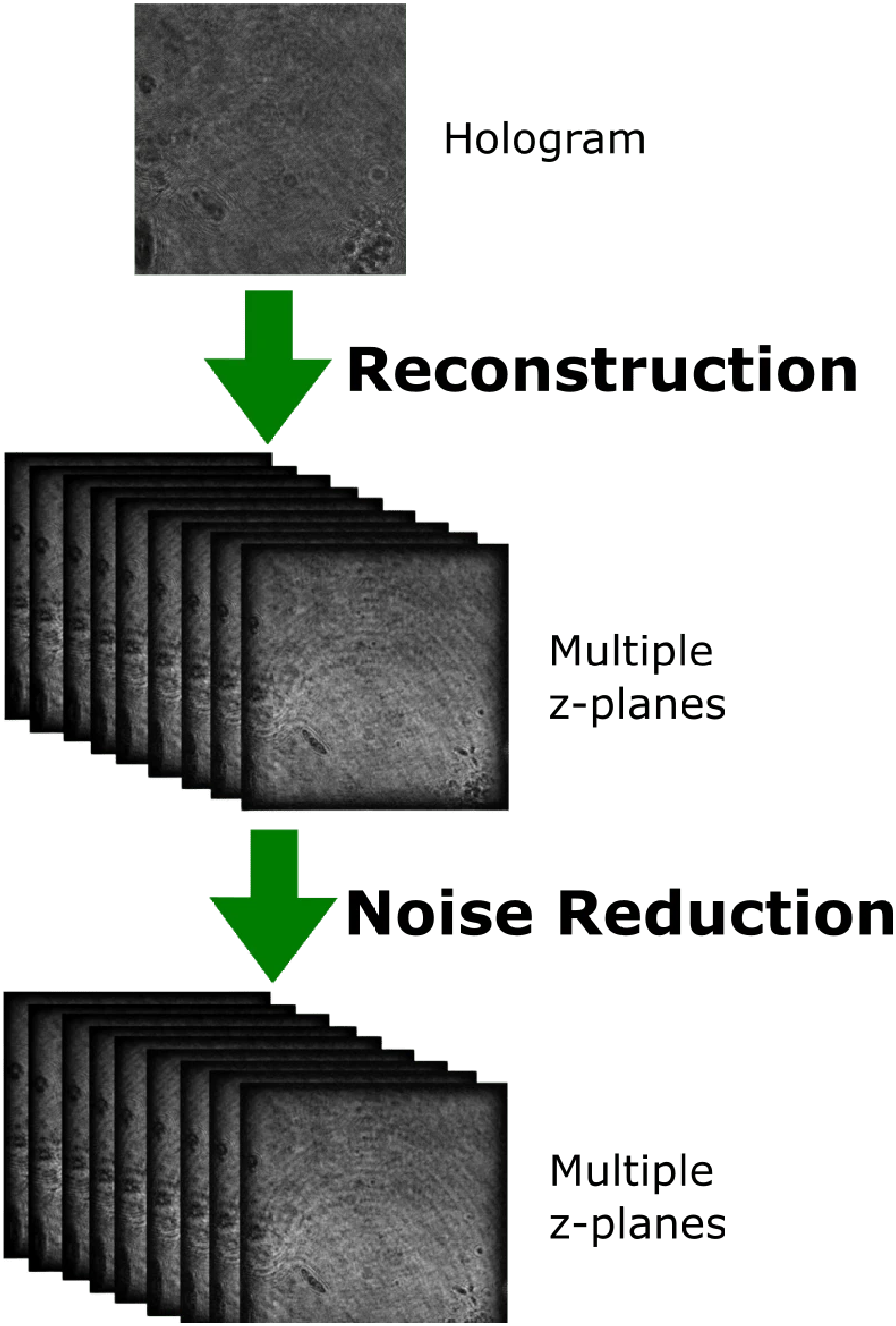


Figure 4. A) A photo of Son of Shamu (SoS) the field deployable DHM being used by Carl Snyder just below the Mount Saint Helens crater. B) Is a photo of a partially assembled DHM allowing use to see the optical train. C) A diagram of the optical components of SoS.

Manual Tracking Protocal



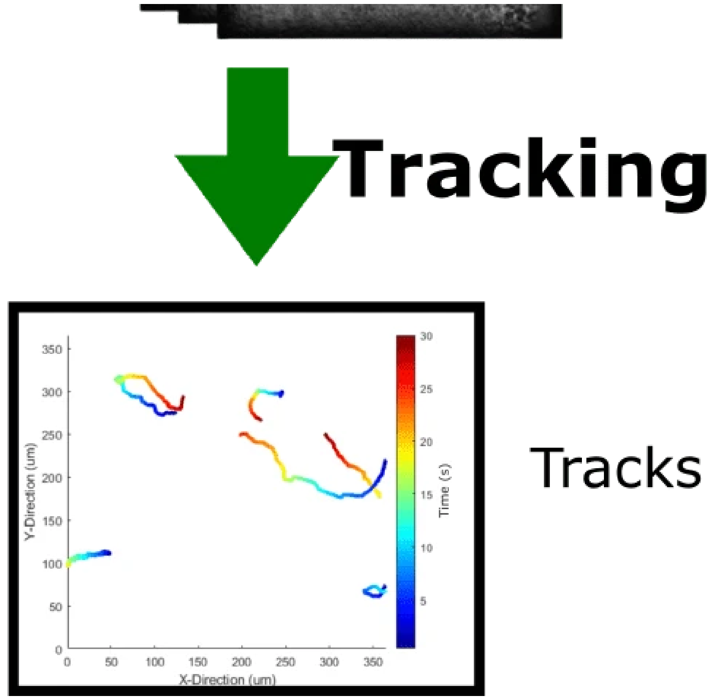


Figure 5. Visualization showing that the holograms when reconstructed can provide multiple z-planes as a form of 3D information and then what next steps are needed to get motility tracks.

RESULTS

Mixed: Dominated by larger eukaryotic cells demonstrating high velocity swimming.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1652823679/agu/38-07-FD-C1-BF-B1-40-D1-76-80-9D-30-54-F5-38-67/Video/StepBottom_1_bgtljl.mp4

Figure 6. A) A plot showing the maximum pixel change at each time point of the hologram recording. The pixel values correspond to the scale bar colors and are based off of which tiff the largest intensity value change occured. B) Shows the distribution of average velocity of individual tracks recorded. C) Median subtracted hologram video corresponding to plot A) & B). Photo of Carl Snyder collecting a sample from the mixed sample site.

Glacial: Samples observed to have low biomass. Motile organisms appeared to be solely prokaryotic and demonstrated slow swimming speeds.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1652845413/agu/38-07-FD-C1-BF-B1-40-D1-76-80-9D-30-54-F5-38-67/Video/Figure01_muz2od.mp4

Figure 7. A) A plot showing the manually tracked microbes from one of the glacial ice cave samples. B) Shows the distribution of average velocity of individual tracks recorded. C) Median subtracted amplitude video at z = -100 µm from the original focal plane. Photo of Carl Snyder collecting a sample from the ice cave wall.

Hot Spring: Mat Samples appeared to have high biomass. Both prokaryotic and eukaryokatic cells present and exhibiting high swimming speeds.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1652823974/agu/38-07-FD-C1-BF-B1-40-D1-76-80-9D-30-54-F5-38-67/Video/Figure003_gmp4no.mp4

Figure 8. A) Context photo of the hotspring area in Mount Saint Helens crater. B) Context image of green mats near the hotsprings. C) Hologram recording of green mats shown above.

CONCLUSION

At all sites motility was observed and useful as a tool for identifying extant microbial life forms.

Mixed: These samples were distinquished by their high velocity and high concentration of eukaryotic cells to prokaryotes.

Hot Spring: Samples from green mats exhibited high concentration of living motile organisms. Green mat samples showed both high levels of prokaryotic and eukaryotic cells.

Glacial: These samples were low biomass and appeared to only have prokaryotic cells present and swimming speeds were between 4-12 μm/s.

Further work includes:

- Automate identifying motile low SNR and sub-micron sized organisms.
- Developing field ready taxis and concentrating tools

Future Publications:

- "Prevalence and stimulation of motility in fresh field samples from diverse and extreme environments across North America"
- "Biogeochemical responses to mixing of glacial meltwater and hot spring discharge in the Mount St. Helens crater"

ABSTRACT

Self-propelled motion is an agnostic biosignature that is observed widely, yet motility of microbes in their natural environments is sparsely studied. In this study we use a Digital Holographic Microscope (DHM) for in situ imaging of aquatic samples in extreme environments to investigate motility and morphology as biosignatures. Samples were collected from glaciovolcanic ice caves, glacial runoff, hot springs, and mixed glacial and hot spring samples.The transport and deposition of materials and heat from the volcanic subsurface in glaciovolcanic caves may be similar in some respects to the eruption processes of the plumes of Enceladus. Through different tracking methods, we identified concentrations of organisms, morphologies, swimming patterns, speeds, and turn angles. In every type of sample we looked we were able to identify motile organisms. Methods for distinguishing active swimming from Browian motion and drift are considered. Field work was done over two deployments in collaboration with the Thermal High-voltage Ocean-penetrating Research platform (THOR) science team and EELS robotics team. This work and these collaborations intend to inform future off-world extant life detection missions of the utility of DHM and motility as an investigation tool and biosignature, respectively.

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