THE SANDY GLACIER CAVE PROJECT: THE STUDY OF GLACIAL RECESSION FROM WITHIN

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Abstract
The Sandy Glacier Cave Project is a National Speleological Society (NSS) sponsored study on the unique system of glacier caves located on the Sandy Glacier on the western flank of Mt Hood, Oregon. While the study primarily targets the structure, layout and ice volume change of the ever moving cave system by conducting annual grade 5 surveys, numerous tangential observations and trends have been recorded that are of great interest to the study of glacial recession, watershed hydrology, micro-biology and astro-biology, as well as the study of organic specimens and remains being thawed out of the ice mass by the expanding cave. Water analysis of the three cave streams involved show significant differences, despite their close proximity, which could indicate differences in the speed of glacier movement along the span of the glacier. Annual cave surveys are revealing massive volumes of ice melting from within the glacier, a figure not obtainable via traditional surface observations. Biological specimens and remains have been located, perfectly preserved, that were previously encapsulated in the glacier, and thus serve as a time capsule for subsequent study.

Introduction
The project began in July 2011, when 3 NSS members – Brent McGregor, Eddy Cartaya, and Scott Linn– located and surveyed a previously unmapped glacier cave under the Sandy Glacier on the west flank of Mt Hood in the Mt Hood National Forest. For several years, the cave was visited sporadically by summer day hikers who ventured a short way into the massive tube. There were no maps, GPS coordinates, or study records on the unnamed cave, which apparently opened up each year in the July timeframe and was reburied by snow by late November. The 3 researchers became aware of the cave’s existence from a You Tube video.

In July 2011, Brent, Eddy, and Scott used the hikers’ internet photographs to locate the elusive glacier cave at 1950 meters (6400 feet) elevation. It had just opened in the form of a crevasse. After a short rappel, the three realized they had found the titanic cave and completed a grade 5 survey of the upper section, which bored over 550 meters up the mountain under the hard, blue glacier ice. They named the cave Snow Dragon, after a common analogy to avalanche dangers. Brent and Eddy returned a few weeks later with wet suits to survey the wet lower section of the cave. It travels mostly through firn, a highly compacted, pre-glacial, form of snow that melts off in large sections during late summer. The two discovered a rushing torrent of icy water entering the system from an unexplored side tube. The volume of water indicated that a significant cave was joining there.

A few weeks later, Brent discovered another previously unrecorded glacier cave just 150 meters from the opening to Snow Dragon. The interior was coated with ice, making the rock climbs inside untenable for a solo explorer. Eddy returned with Brent 2 weeks later and the two climbed to the back of the cave. The crown jewel of the new cave was a towering pit entrance traveling over 40 meters straight up through the ice to the surface. This glacial feature is called a moulin, a vertical conduit through which surface melt waters of the glacier used to flow and drill down to the original underlying lava bedrock. The shaft had been abandoned by the water, which had since found a new passage higher up the mountain. They named this cave Pure Imagination (Fig. 1, Fig. 2, and Fig. 3). Brent and Eddy returned again on

Figure 1. Cerebus Moulin of Pure Imagination Cave as discovered on 11-09-2011.
January 4, 2012, braving vicious winter conditions (and frostbite!) to rappel and climb the huge moulin for the first time.

Later that month, Eddy and Brent met with Mt Hood National Forest (MHNF) science staff to propose a study expedition. The scope of these caves was too massive to keep secret, and they were clearly significant caves as defined by the Federal Cave Resource Protection Act (FCRPA). Given the receding glacier issue on Mt Hood, the caves offered a unique and short-lived opportunity to study 40 meter cross-sections of the ice and record glacial melt changes from WITHIN the glacier, as opposed to the traditional surface studies. The proposal was ambitious and obviously required a huge amount of equipment. While Mt Hood NF declined to be the lead agency, they did grant the NSS a research permit to conduct the expedition in July 2012. Geary Schindel, Vice President of the NSS, signed the permit for the expedition and insured the mission.

In July 2012, with the assistance of over 50 sherpas, the expedition moved over 680 kilograms (1500 lbs) of caving, medical, survival, and science gear up the mountain and established a base camp near Snow Dragon, at the toe of the glacier. Over the next 9 days, NSS teams surveyed Pure Imagination, made geology collections for the US Geologic Survey (USGS), conducted water quality and composition tests, took atmospheric readings, and collected ice samples for ash deposition tests. Deschutes National Forest geologist Bart Wills managed the rock collections for the USGS. Gunnar Johnson, a Portland State University Ph.D. Student in Environmental Science, conducted the water and sediment collections. The team succeeded in accessing the 3rd tube joining Snow Dragon via a low airspace flooded passage, and later completed a survey of this 3rd cave in the system, naming it Frozen Minotaur, due to its maze-like layout. Over 2133 meters (7000 feet) of passage was subsequently documented in 3 maps, including a 3-dimensional, wire mesh moving image.
In July 2013, the Sandy Glacier Cave Project conducted another 9-day expedition to resurvey Snow Dragon and most of Pure Imagination. In the Cerebus Moulin alone, a size increase of over 400% was measured, marking a HUGE amount of ice lost. Once again, local Mountain Rescue Association teams came up to assist with the complex rigging to facilitate these surveys, which sometimes involved dangling the surveyor 40 meters in the air over a pit, or belaying an ice climber up a 10 meter ice wall to access a new passage.

Special events of note during the 2013 expedition included a site visit by prominent Portland State University glaciologist, Dr. Andrew Fountain. Fountain inspected the Pure Imagination Moulin and the first third of Snow Dragon, concurring that these caves are extremely unique, large, and rare in the lower 48, and indicative of the dying throes of the glacier. Fountain explained the mechanical structure of the cave’s formation and why we are seeing such radical changes. He also suggested more snow melt studies, which were immediately established. Also of note was a film crew from Oregon Public Broadcasting (OPB), who braved arduous logistical challenges to get their crew and equipment to base camp and document the team as it conducted its studies. Their efforts culminated in a 30-minute special that aired on Oregon Field Guide and an interactive website that provided priceless documentation of this year’s conditions of the Sandy Glacier Caves. (Check out the link: http://www.opb.org/glaciercaves/)

The use of cave surveys to record ice volume lost

The initial goal of the project was simply to survey and photo-document the caves. The Paradise Ice Caves of Mt Rainier, formerly the longest glacial cave system in the lower 48 of the United States, are completely melted. As such, the most urgent focus of the project was to memorialize the cave system with a detailed 3 dimensional map and photograph as much detail as possible.

In cave mapping, there are several grades of surveys. A grade 5 survey is one of the most detailed formats, with an inclinometer used to record floor slope, and hence generate not only a floor plan view of the cave, but a profile view (ant farm view) as well. Each survey station records the width of the passage as well as the floor to ceiling height at that point. Distances between survey points are recorded using a Bosch laser ruler with a 500 foot range. Slope between points is measured with a Brunton inclinometer to within ½ degree. Bearing between survey points are recorded with a Brunton survey compass to within ½ degree. Significant cave features, to include isolated domes and waterfalls, are measured with the Bosch laser and plotted on the map. A surface survey of the ice over the caves is also completed in order to compute the thickness of the ice at any given point over the passage. All data are then entered into a cave mapping software called Compass, and the local NSS cartographer, Matt Skeels, then drafts in the details recorded by the surveyors in their sketch book (Snow Dragon Cave map, Fig.4).

Within 4 months of the first survey of Snow Dragon in 2011, significant changes in the cross sectional dimensions were noted. By the 2012 expedition, the cave had increased in volume tremendously, although on the surface, very little appeared to have changed.

Likewise, the dimensions of Pure Imagination were also noted to have increased significantly, again with little surface indication. The only surface indications of glacial recession or melting were gradual crumbling of the entrances up the mountain, maybe 8 meters a year.

During a site visit by Portland State University glaciologist Doctor Andrew Fountain, it was discussed to record and track the changes in ice thickness over the caves, snow melt rate over caves, and specifically the concept of using annual surveys, which effectively capture the air volume of the cave, to calculate an approximate volume of ice lost each year. To do this, the survey data of each year is used to generate an approximate volume of air (cross sectional data averaged over each leg of the survey), and then compare the volume differences with each subsequent survey. The volumetric difference in cubic meters can then be used to calculate an approximate ice volume, or ice mass, lost annually in that section of glacier.

For example, using the dimensions of the Cerebus Moulin in Pure Imagination Cave as recorded in July 2012, the air volume of the vertical passage was 2259.6 m³. The volume calculated using the 2013 survey of this same passage almost exactly 1 year later was 9613.9 m³. This results in a volumetric change of 7354.3 m³, or well over a 400% increase in passage size.
Glacial ice has a density of about 850 kilograms per cubic meter (kg/m³), somewhat lower than pure ice at 917 kg/m³, due to air bubbles. In the Cerebus Moulin, this equates to about 6,251,155 kilograms of ice lost in about a year. 1 metric tonne of water equals 1 cubic meter of water. So in this context, we can approximate that this one length of passage has liberated about 7300 tonnes of water into the cave and subsequent watershed over a period of one year. (Fig. 5)

Granted, this vertical passage most certainly exhibits a greater rate of melt due to its exposure to the sun and the passage of warm air through the cave and out, what is essentially a warm air chimney. This process of warm air movement, however, is occurring throughout all the caves and contributes greatly to the increasing height and girth of the passages. Water flow, boring its way down through fissures and smaller passages, is also speeding the melting process by flowing laminarly along the walls and ceilings, melting the ice which is barely at freezing level as it is.

Following this summer’s survey expedition of 2014, 3 layers of survey will be available for volume comparison. A detailed calculation of volume will be done with a resulting ice lost volume and water mass liberated figure generated for each cave and the system as a whole. Observations to be noted will also include a comparison in rates of melt in the 3 caves.

It is of interest to note that aside from entrance feature differences, there is little indication of rate of change or melting in the glacier as viewed from the surface.

**Figure 4.** Snow Dragon Cave Map. Profile view on top, plan view on bottom.

**Figure 5.** Cerebus Moulin of Pure Imagination Cave. As seen on 09-19-2013.
The caves as a time capsule

During the above discussed surveys, numerous organic specimens were located that had been melted out of the ceiling as it constantly melts back and delaminates.

Seeds from trees long past, birds that died on the glacier long ago, and other items that landed on the glacier were buried by snow pack above the firn line (in the accumulation zone) and subsequently became part of the ice pack. As these items flowed downhill with the glacier and got deeper in the ice, they eventually got low enough to be freed from underneath by the cave passages, as their ceilings melted up into the ice. Exactly how long it takes for a seed or feather to travel the thickness of the ice and then rain down onto the cave floor is still unestablished, but preliminary figures based on initial studies of a seedling located in the 2012 expedition indicate it to be approximately 100 years.

Seeds contain enough stored energy to sprout and produce a few leaves to start the food making process of photosynthesis until there is enough green surface area to sustain the tree on its own. It is not uncommon to see sprouted plants deep inside limestone caves, where the seeds have been washed in one entrance and then sprouted in the cave. These sprouts are, of course, short lived, albeit well watered.

In this case, there is no through passage where water flows in one way and out the other. The water flow in the glacier caves starts as small rivulets and seepages along the contact surface of the ice with the underlying bedrock, although it is still possible some seeds could be washed into the cave via tiny, pencil width channels.

Several seedlings from noble firs were located in the caves, and a couple had started to sprout (Fig. 6). Several were collected. Gunnar Johnson with PSU had one such sample analyzed, identifying it as an Abies procera, or Noble Fir, with a resulting approximate age of about 100 years. Constance A. Harrington, Research Forester and Team Leader for the US Forest Service Pacific Northwest Research Station in Olympia, Washington, advised that seeds frozen in ice for a long period, and then thawed to sprout, frequently exhibit growth pattern anomalies due to their DNA being somewhat “confused” following such a long hibernation. Seeds will frequently sprout abnormally and continue developing with a pattern distinctly different from normal specimens. As such, grant monies and additional permits have been solicited to further these collections and studies to this lab.

Near the very back of Snow Dragon, a fully intact feather was located and collected (Fig. 7). The lab analysis done by Doctor Carla J. Dove of the Smithsonian Institute’s Feather Identification Lab revealed this to be a feather of Anas platyrhynchos, or a mallard duck. Again, funds are not yet available to have the feather dated, but the location of its find is not such that it could have entered the cave via any other route than being thawed from the roof ice. The floors of the caves stay almost constantly covered with water flow, thus items such as these will not remain on the floor long before being washed away or buried by collapsing ice, which occurs annually due to ceiling delamination.

This unexpected occurrence of items frozen in the ice being “rained” down onto the cave floor as the caves melt and expand upward provides a unique opportunity...
to collect and study specimens after a long period of preservation. Future dating of these items may also shed light on the rate of glacial recession and melting.

References