Evidence for Subsurface Streams on Heard Island and a Preliminary Interpretation

Robert W. Schmieder
Cordell Expeditions
schmieder@cordell.org

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Introduction

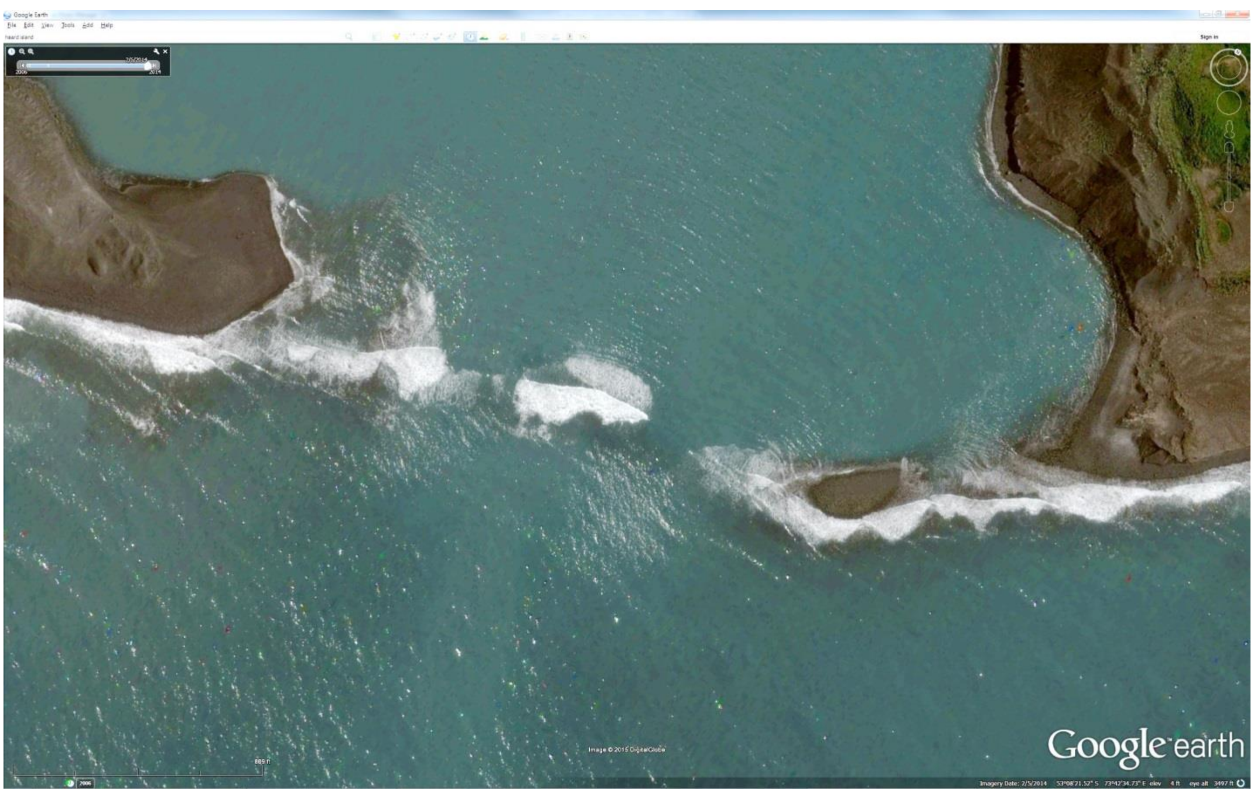
During a detailed examination of satellite images of Heard Island, I have found what appear to be evidence of numerous subsurface streams. Because the images are single-point, single date, and limited resolution, the evidence is not completely conclusive. It is, however, sufficiently suggestive to motivate an onsite examination during the March/April, 2016 Cordell Expedition to Heard Island. In this note I present some of the images that seem to provide rather strong evidence for these streams, and other images that are suggestive, but perhaps not as compelling.

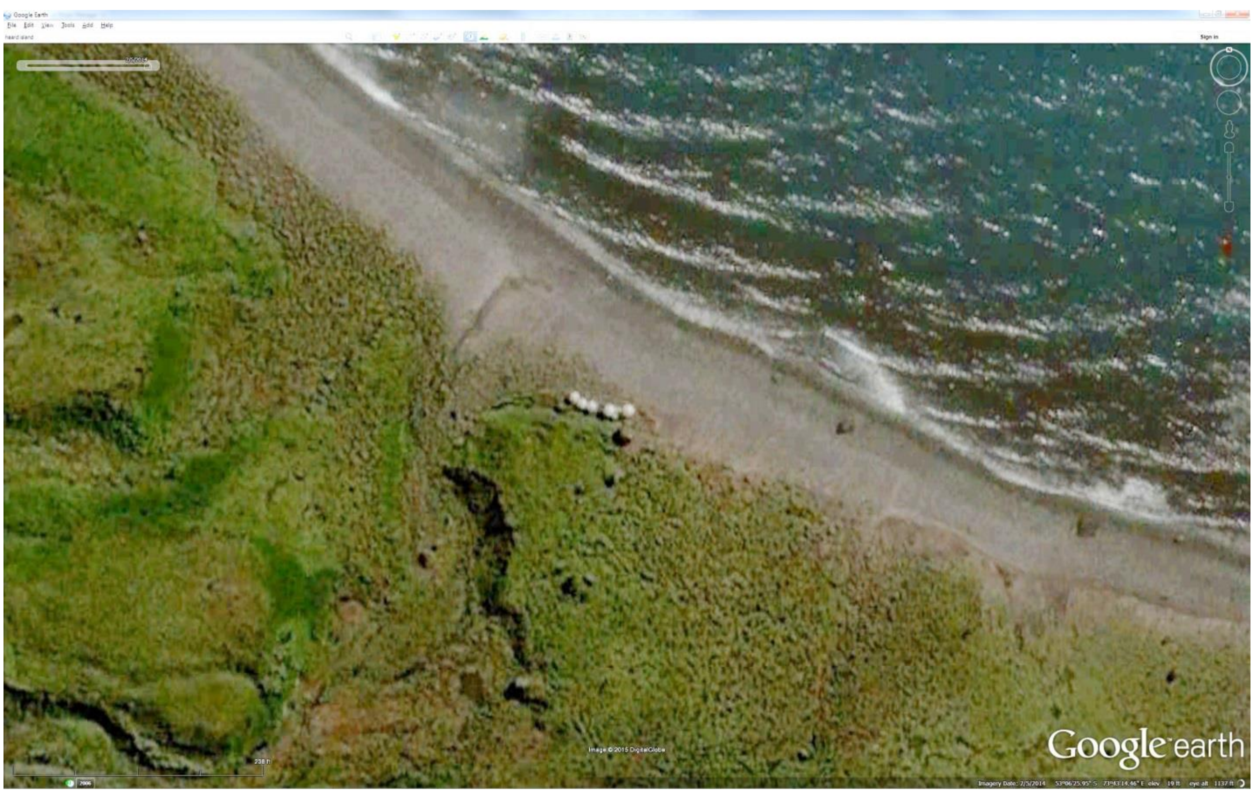
The images are taken from Google Earth, although they were generated by DigitalGlobe. The most recent images are dated 5 Feb 2014; some images on Google Earth have earlier dates. The dates of these images don't seem to be completely consistent. The resolution of the DigitalGlobe image is about 1 m. The images are not a uniform set; the exposure, cloud cover, scaling, and other aspects are not uniform over the entire island, although they are good enough for local examination. The 2014 image as presented is grossly underexposed; crops taken from that image have been adjusted, and to the extent possible, optimized in brightness, contrast, fill light, color balance, and focus, to enhance specific features. Hence, these images should be regarded as processed, although in most cases the processing is minimal–mostly an increase in brightness and minor contrast enhancement.

The Google utility for tilting provides a perspective image, making use of the associated elevation of the pixels. The perspective may be valid for large-scale images, but it may fail to give accurate images for small areas.

Spit Bay

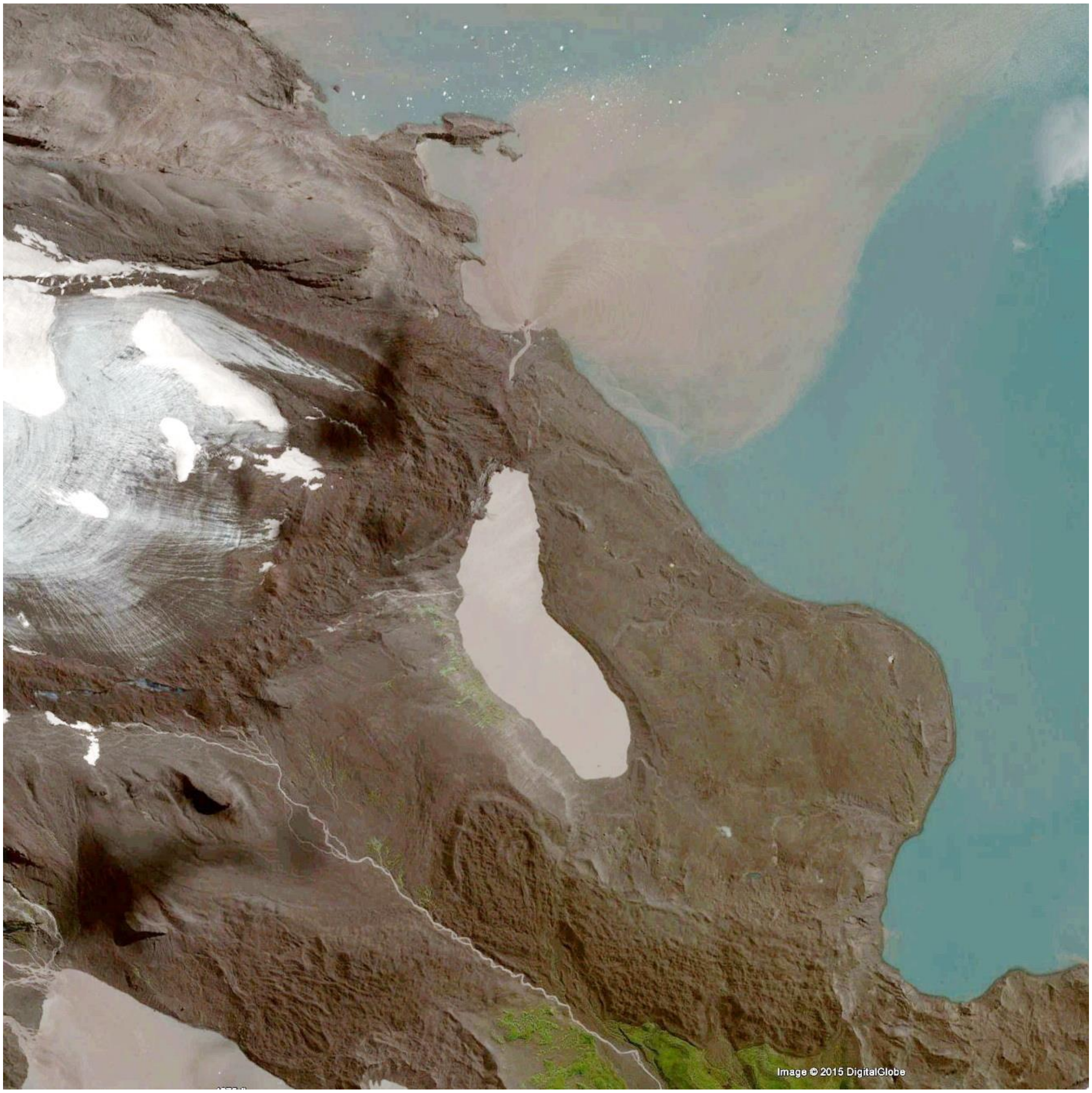
Kiernan and McConnell (2002) provided extensive documentation of the Stephenson Glacier and several lagoons in 2000. In comparison, the 5 Feb 2014 images (next 4 figures) shows that in the past 15 years this area has undergone a major change, principally the major melting of the Stephenson Glacier and consequent spread of Stephenson Lagoon to merge with Doppler Lagoon. The combined Stephenson-Doppler (SD) lagoon has an opening on the southern side, which could make the entire area accessible by small boat when we arrive in 2016. On the northern side, the lagoon communicates with the ocean in several apparently shallow passages 100–400 ft. wide. Ability to cross this isthmus by foot or small boat is uncertain. Slightly over 1 km to the SE is the group of five AAD tank shelters.



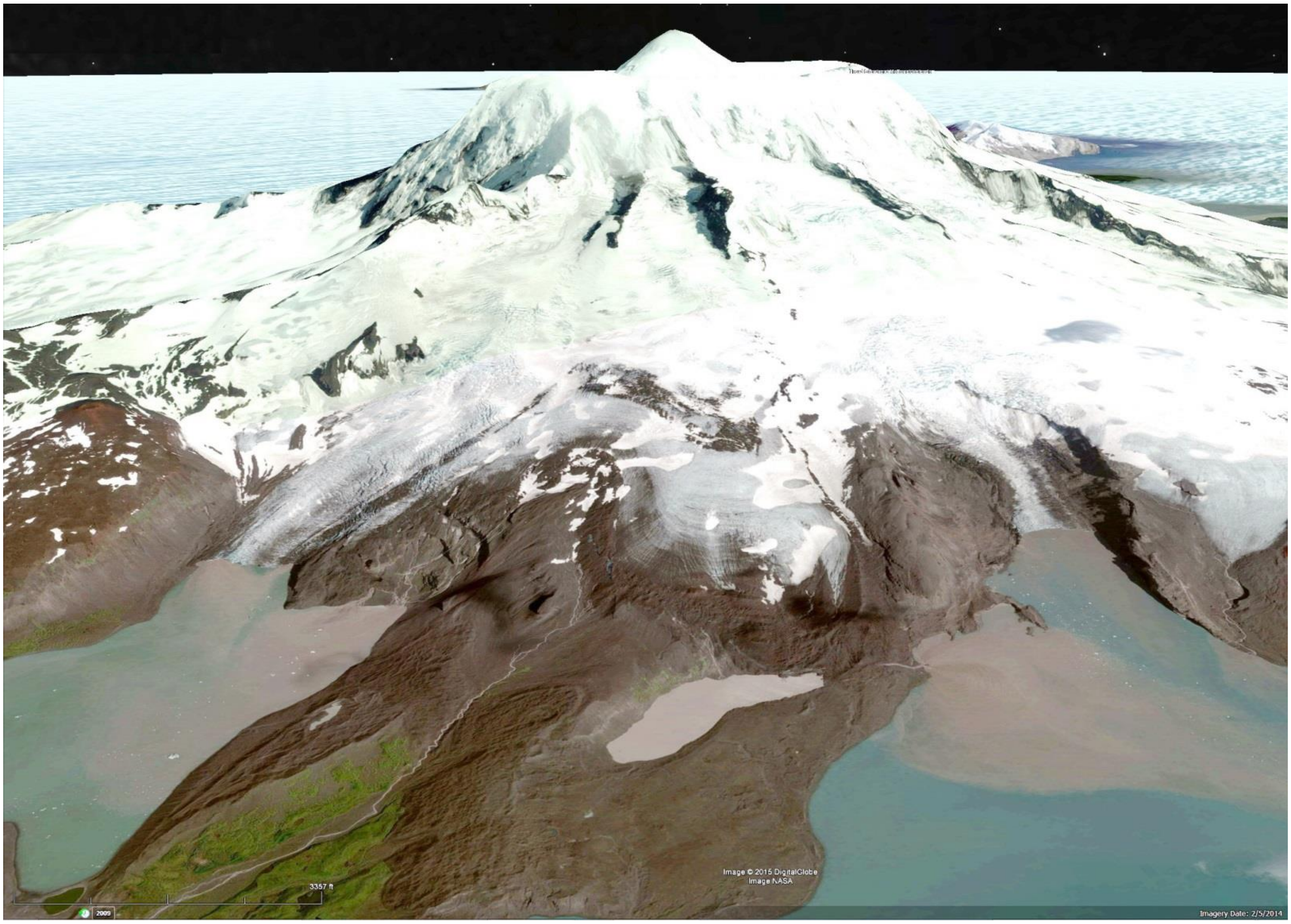


The Spit Bay Tarn

Above the east side of the SD Lagoon is a relatively shallow tarn. It is about 1 km long, and (as of this 2014 image) was at about 105 ft. elevation. The image shows clearly that the tarn supplies a major sediment-laden inflow into the SD Lagoon. Presumably the tarn is supplied by runoff from the retreating glaciers upslope toward the west.



An oblique view of the tarn is shown in this Google Earth image:



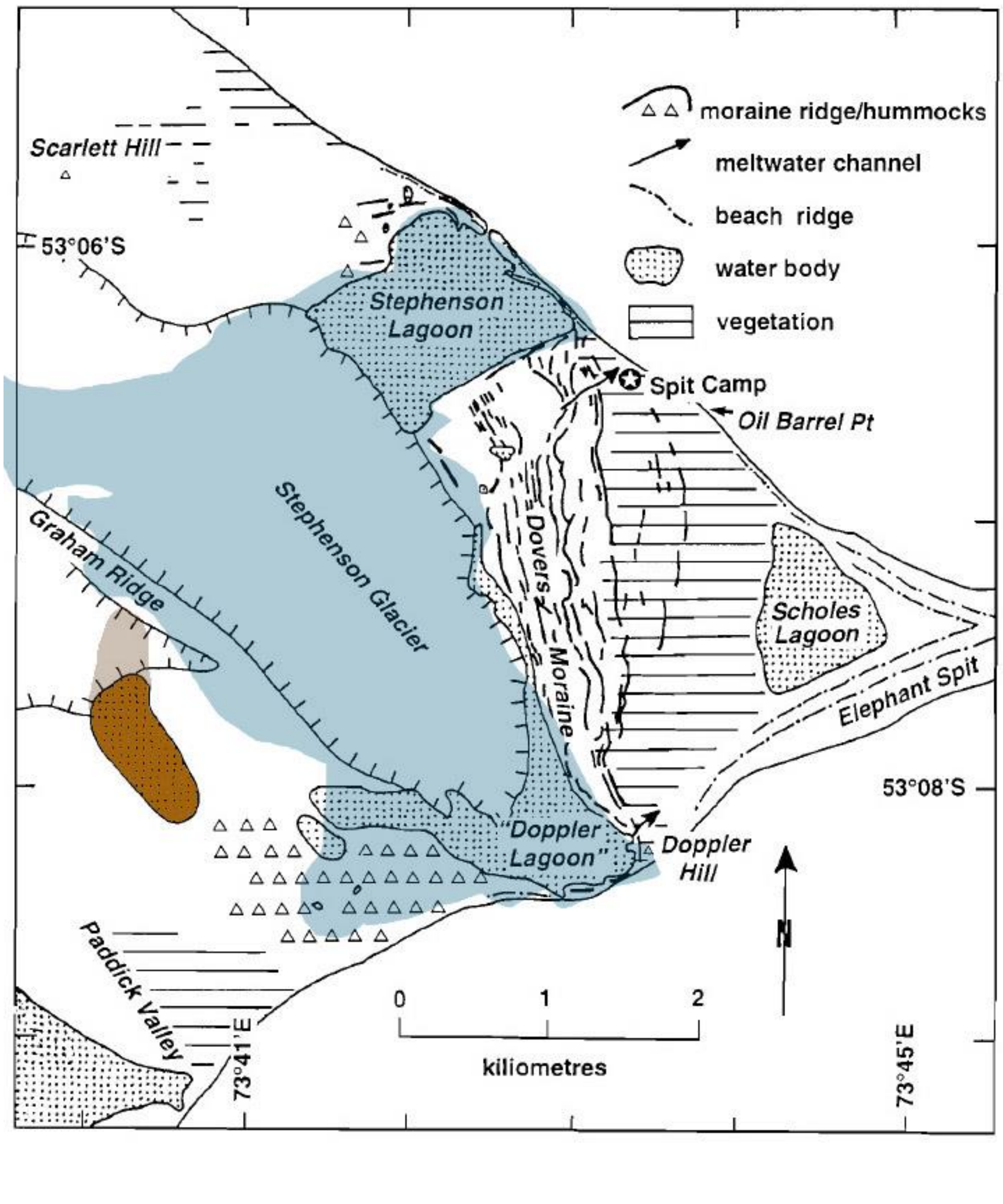
The photograph at shows the tarn from the south. The red circle is centered on a feature discussed below. The exit of the tarn into SD Lagoon is at the far distance. There is some evidence in other photographs of the small pond at right center, but during 2014 it was considerably smaller.

Photo: AAD 2012 Katie Kiefer

The drawing below was made as an overlay to the map published by Kiernan and McConnell of observations made in 2000. The dark brown tarn, its northern third covered by the glacier, has now been exposed. The waterline is confined at the northern end of the tarn by the Graham Ridge.

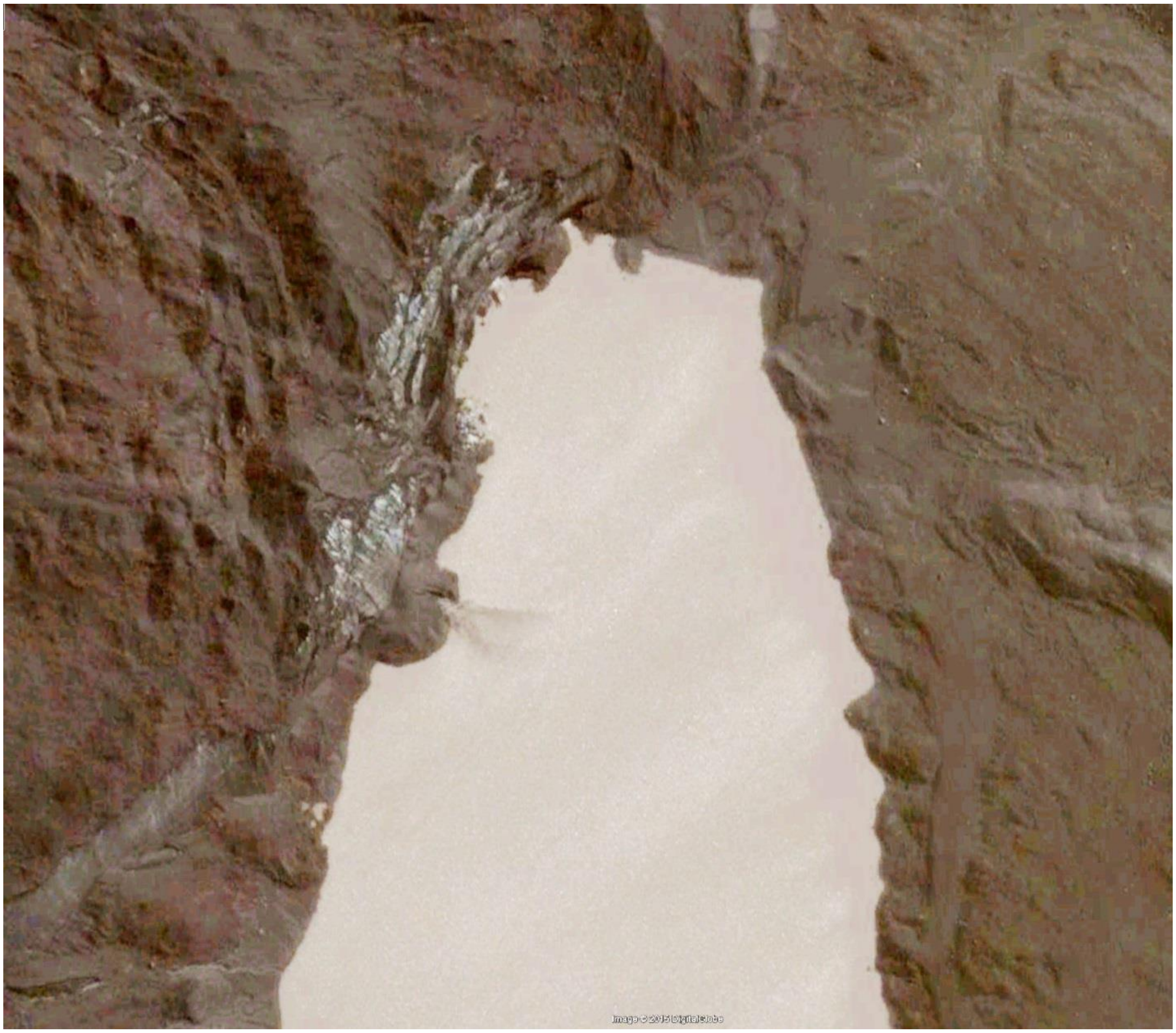
Since this map was made, the lower part of the Stephenson Glacier has essentially disappeared, filling the area (colored bluish) between the Stephenson and Doppler Lagoons.

Because of the merging of the lagoons to form one (SD) lagoon, the sea can flush the entire area, which means that the entire lagoon is seawater and probably supports an extensive marine community. Because this area is protected from storm seas, the community may differ substantially from the usual nearshore marine communities.



The Spit Bay tarn plume inlet

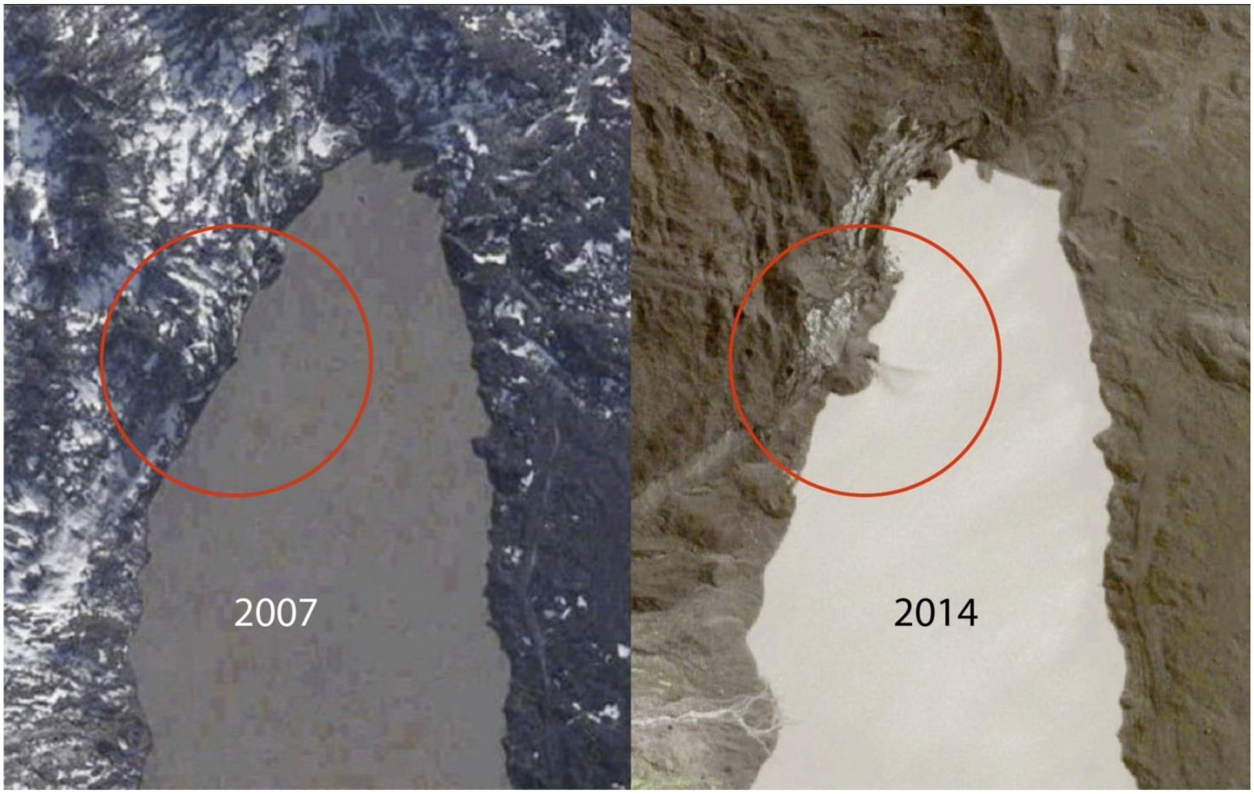
An enlargement of the image of the upper (northern) part of the tarn shows an unusual feature:



The image seems to show protuberance from the cliff, out of which issues a high-velocity plume exiting an opening above the water level. The formation is about 150 ft. long and 75 ft. wide. The plume appears to extend about 120 ft. Because the plume may be sediment-laden, and therefore would produce an image of the outflow of the sediment away from the opening, it is not obvious how to measure the arc of the plume, although it seems reasonable that it appears to exit the opening of about 5 ft. perhaps 20 ft. above the water, and arc out at least 30 ft. From elementary physics, we calculate that it take about 3 second to fall, implying that the exit velocity is about 15 ft./s.

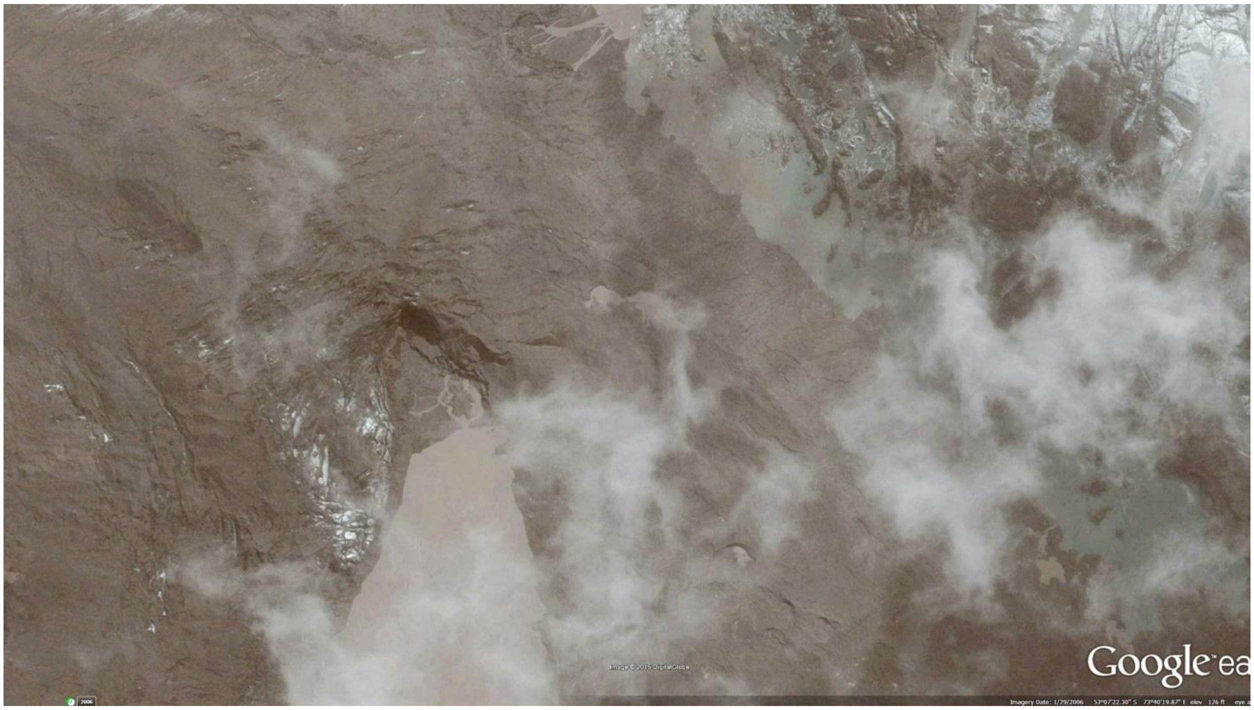
This image raises the question of the path of the stream. There appears to be no evidence of a stream above the opening, although there is a possible steep channel cut in the cliff. Even if the stream follows such a channel, it seems clear that it does not cascade over the protuberance, but emanates from an opening. Hence, this seems to be evidence of a large subsurface channel.

The protuberance was not present in the previous imaging set (2007).

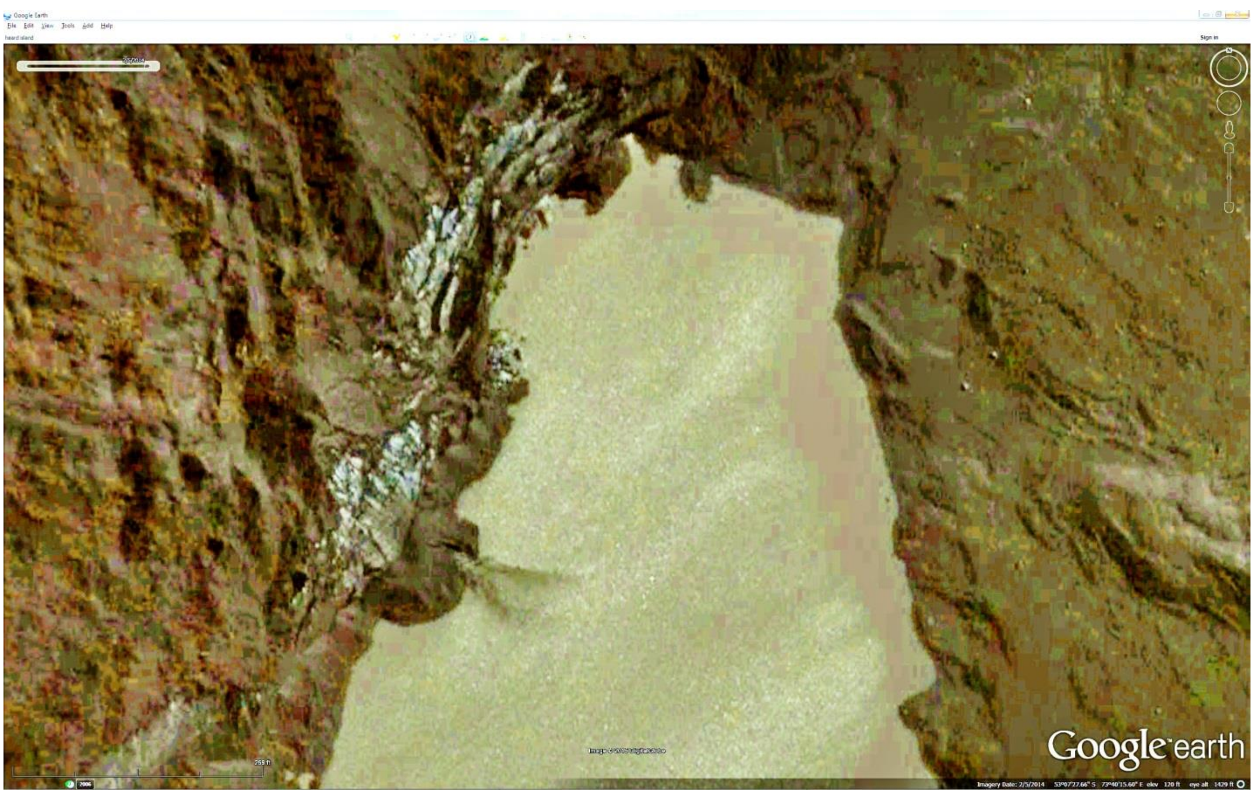


The left image below is an overlay of the 2007 and 2014 images, to emphasize the recent change. The false-color image below right is enhanced to emphasize the geometry of the plume.

The following image, taken in 2006, provides some evidence that the rockslide did not occur in 2006, but apparently

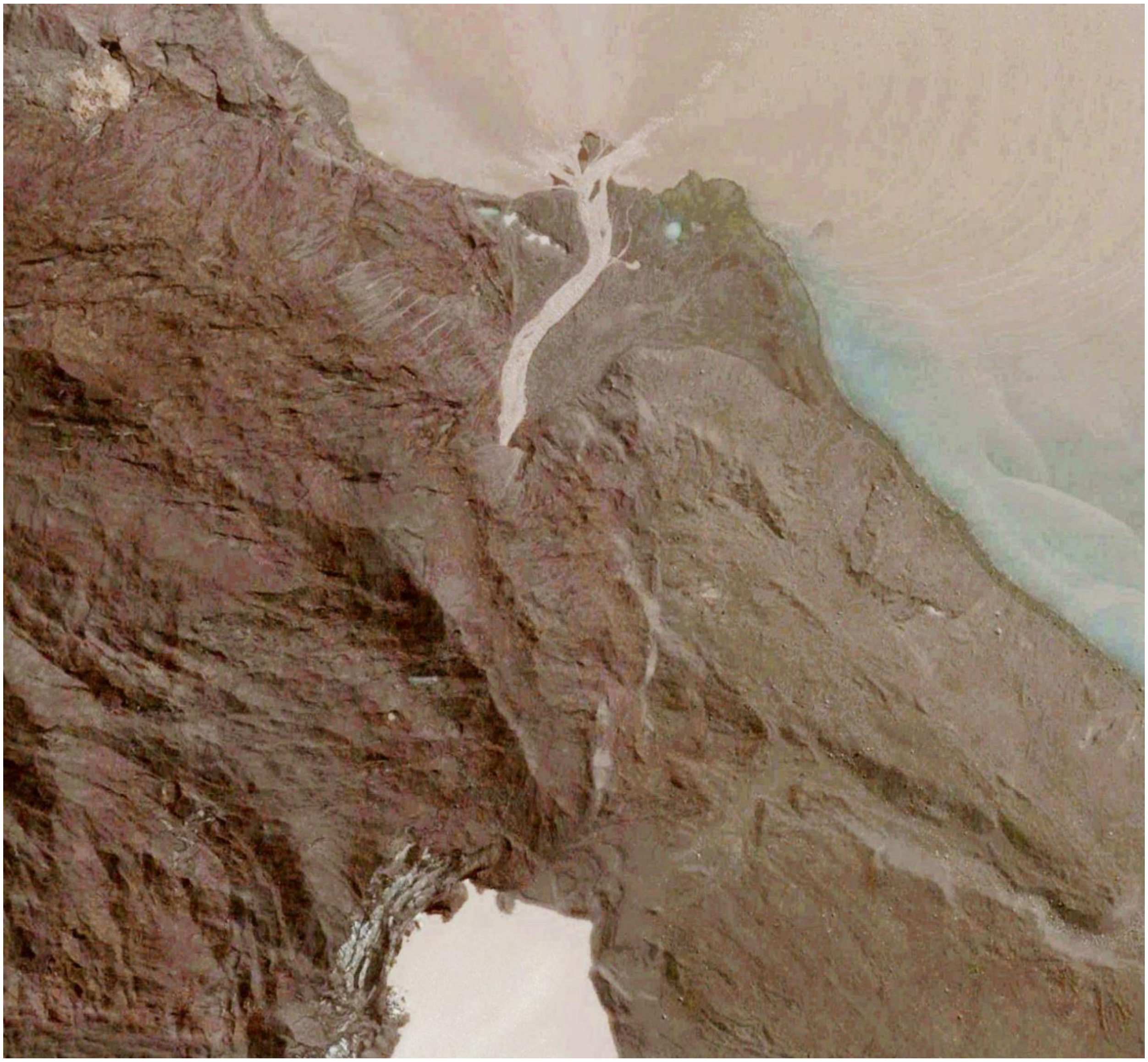


The following image is enhanced to show the waterline at the north end of the tarm, discussed in the next section.



The Spit Bay tarn outlet

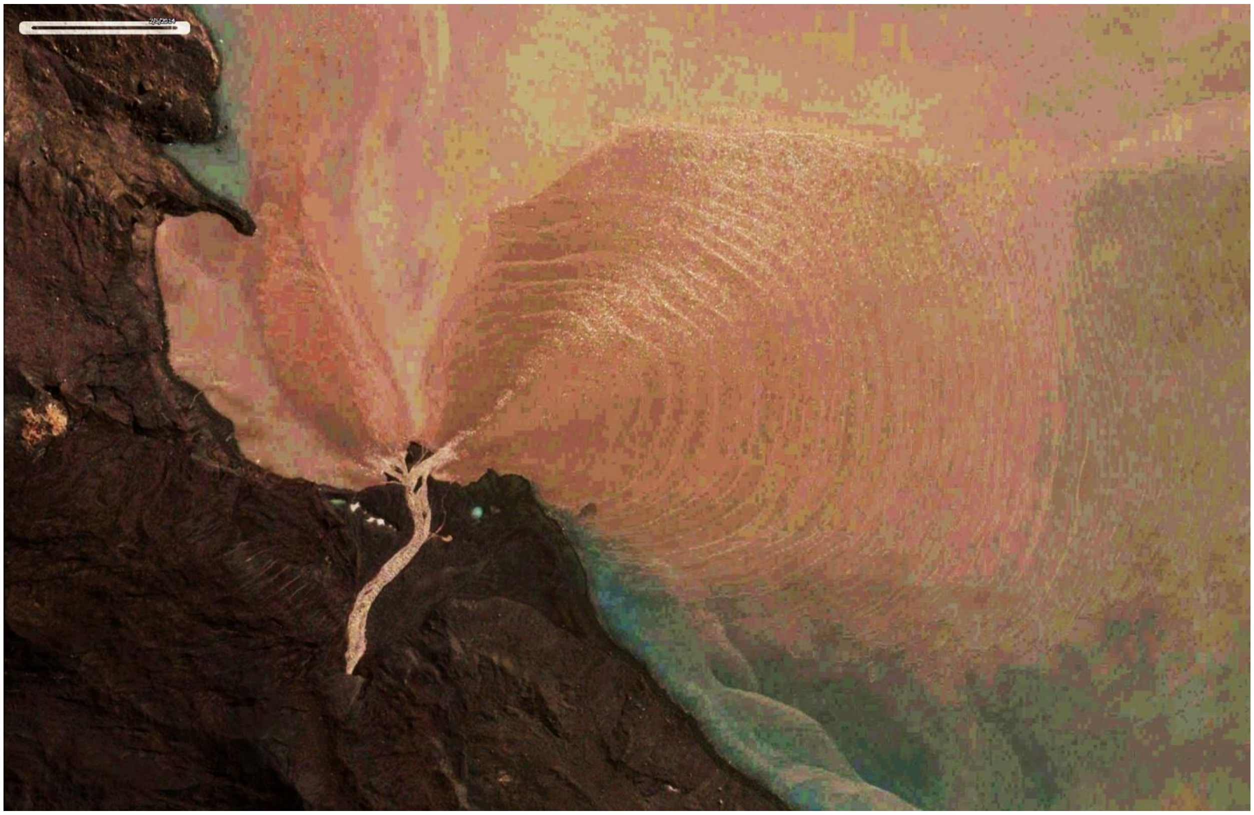
An enlargement of the northern end of the tarn and its adjacent ridge is shown here. The interesting aspect of this image is that there is no obvious channel for the stream. Indeed, it appears to emanate from the rocks as a relatively narrow stream about 500 ft. long, cascading about 50 ft. wide.

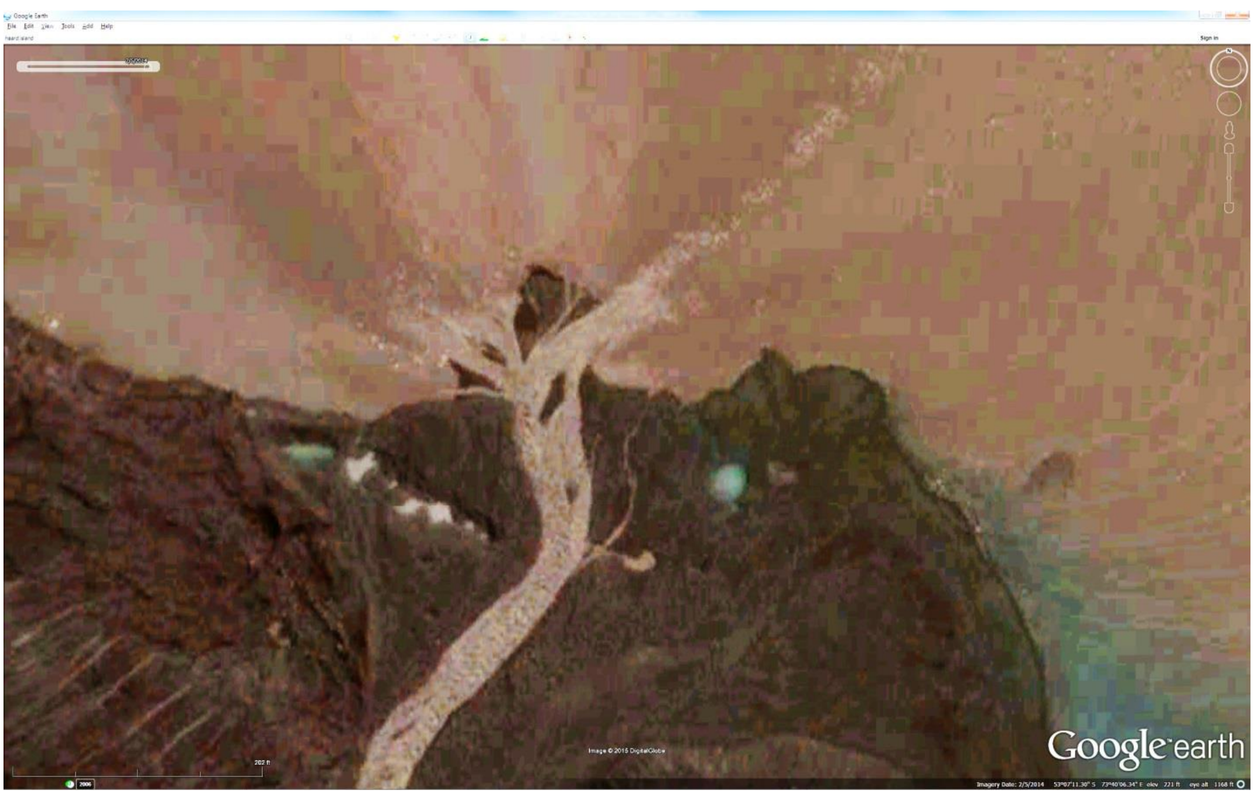


In interpreting this image, it should be remembered that, while the stream obviously flows downhill, the rocks at the waterline do confine the tarn, hence must be higher than the stream. That is, the stream cannot be as high as the rocks. If there were an erosional channel for the stream to follow as it exits the tarn, we would expect this vertical image to show some indication of it. On the contrary, the rocks seem to have coherent structures that extend across and above the stream, i.e., the stream apparently is subsurface before it emerges into the cascade.

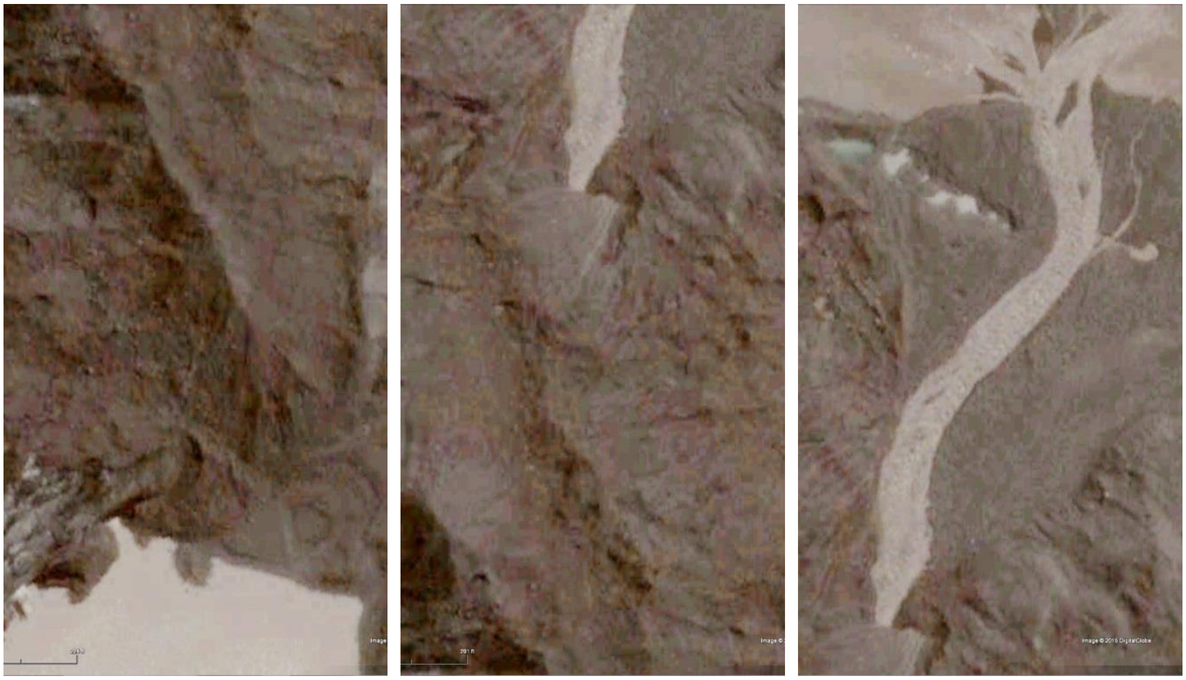
There is another possible interpretation, namely that the narrowing of the stream at it "emergence" is nothing more than the screening by an overhanging cliff above, and that the stream actually originates out of sight below the cliff, merely emerging into view. I cannot discount that possibility, although it does seem difficult to account for the absence of the stream between the tarn and the lagoon.

Enhancement of the image where the cascade enters the lagoon shows it is falling over a complex outcropping that breaks it into several braids. The width of the "delta" is about 150 ft. The persistence of the sediment in the lagoon shows that sediment is very fine, e.g., glacial flour.



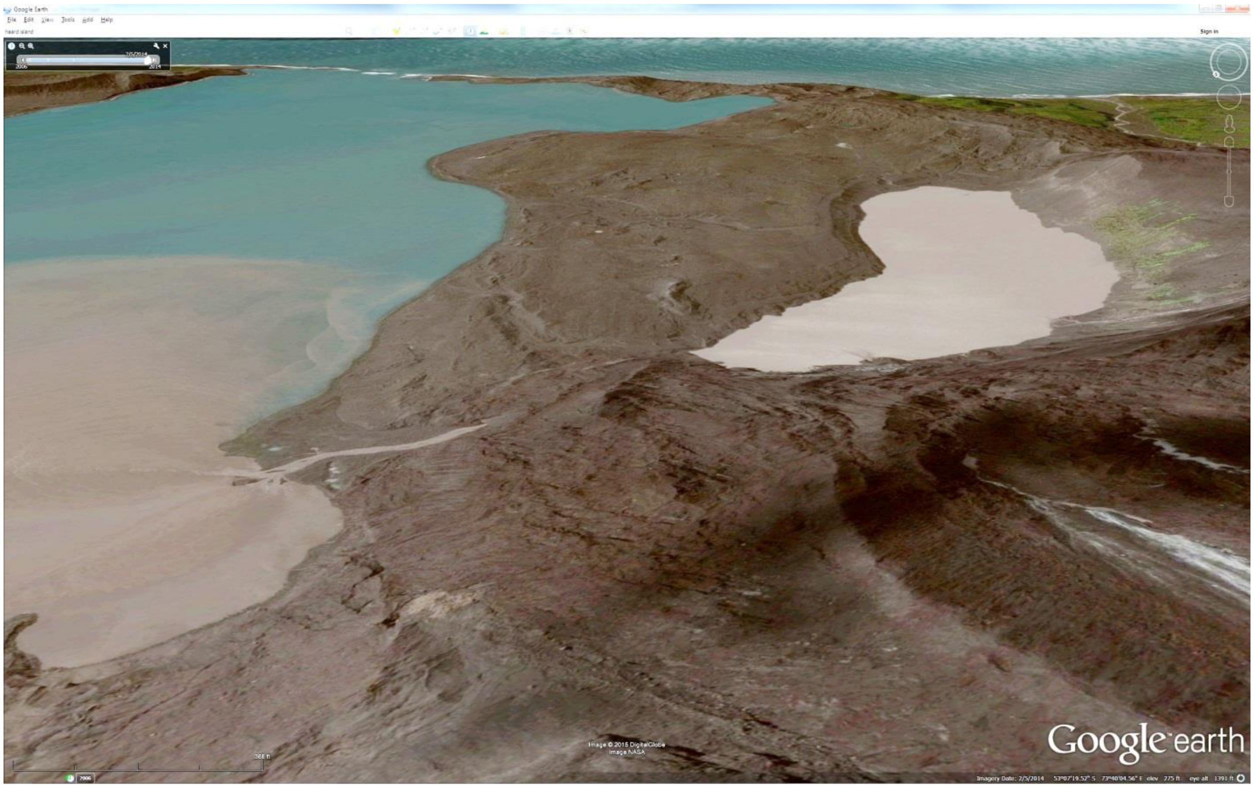


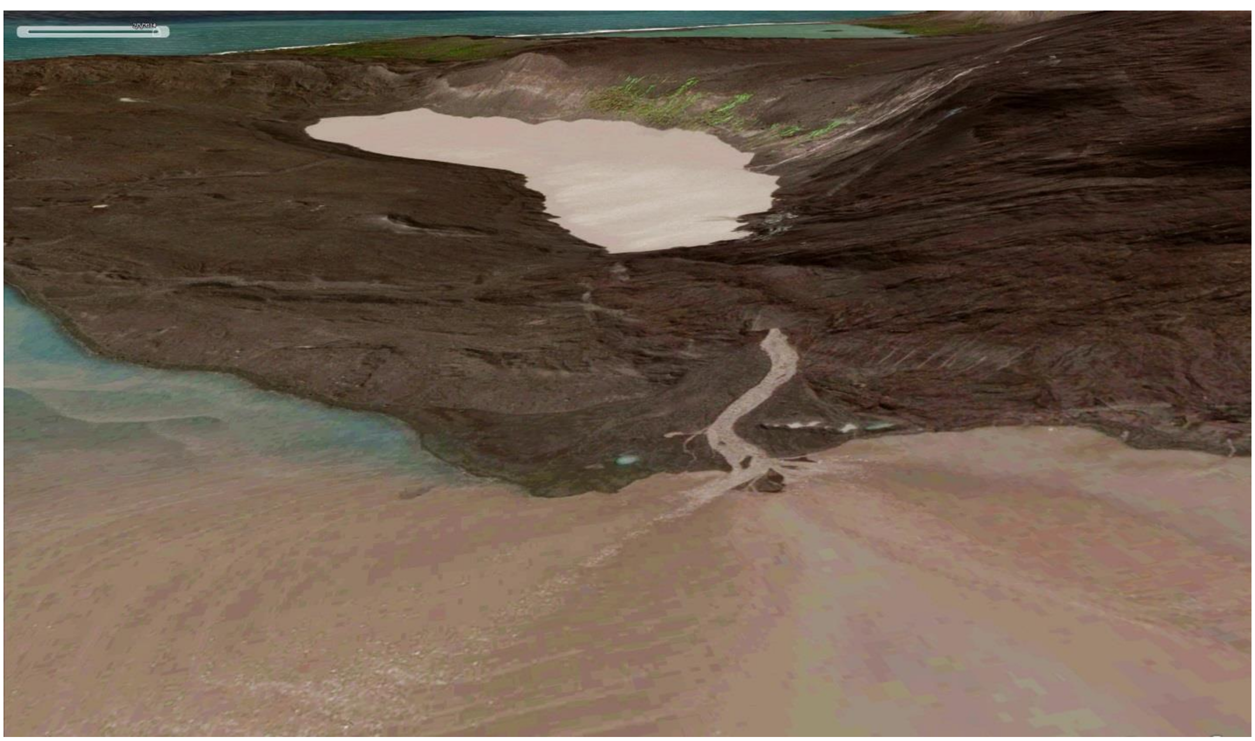
The following three panels , moving from the upper edge of the tarn to the lagoon, show this area in more detail.



The “exit” of the stream seems to show no obvious inlet. On the contrary, it appears to emanate from a relatively steep, or overhanging rock.

Here is are two tilted images that give some sense of the perspective view of the tarn and stream. However, as remarked before, the tilting provides limited new information; the elevations are coded into the images, but the accuracy of these elevations within small areas may not be high.





The next two photographs show SD Lagoon, taken in 2012. We do not know the current water level.

Source (both): Doug Thost

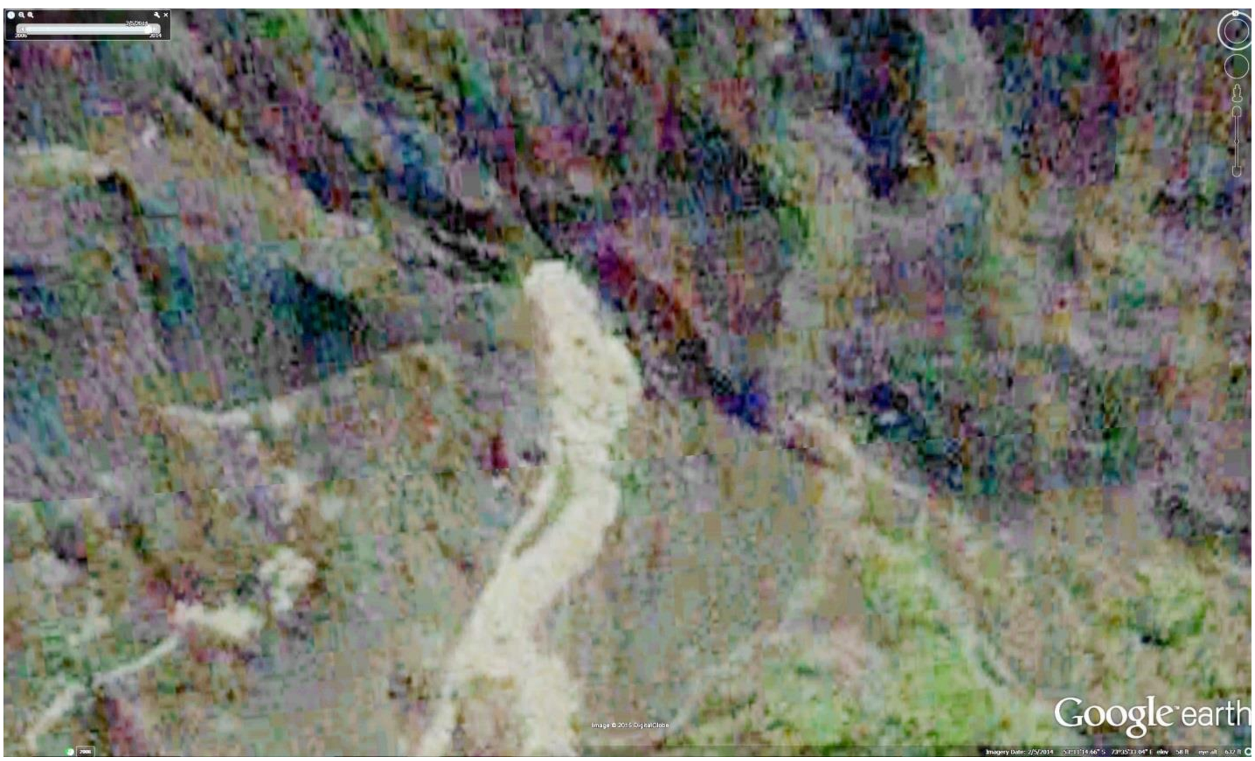
Additional candidates for subsurface streams

In examining the 2014 satellite image of Heard Island, I have found numerous additional candidates for subsurface streams. Some of these images are presented here (magnification pairs).

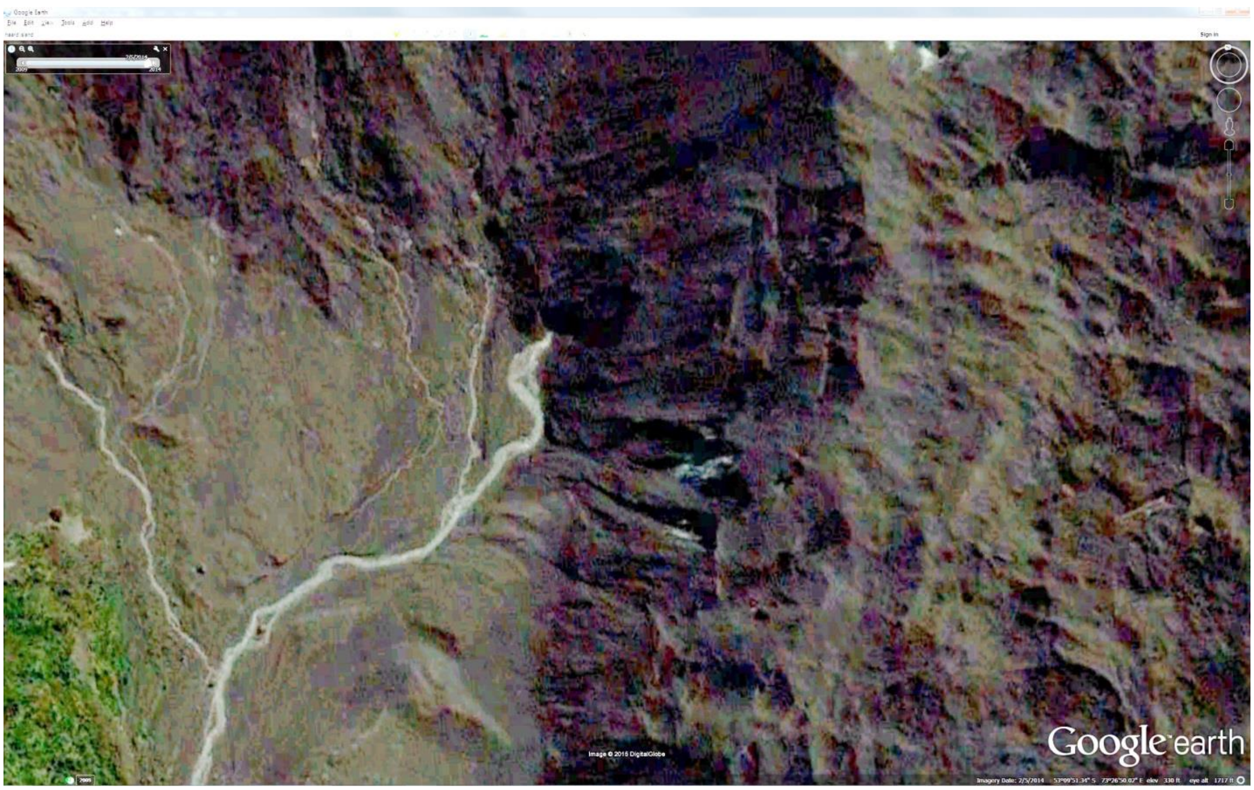
Lavett Bluff. 2009 images.

Lavett Bluff. 2014 images.

Lavett Bluff. 2014 images.

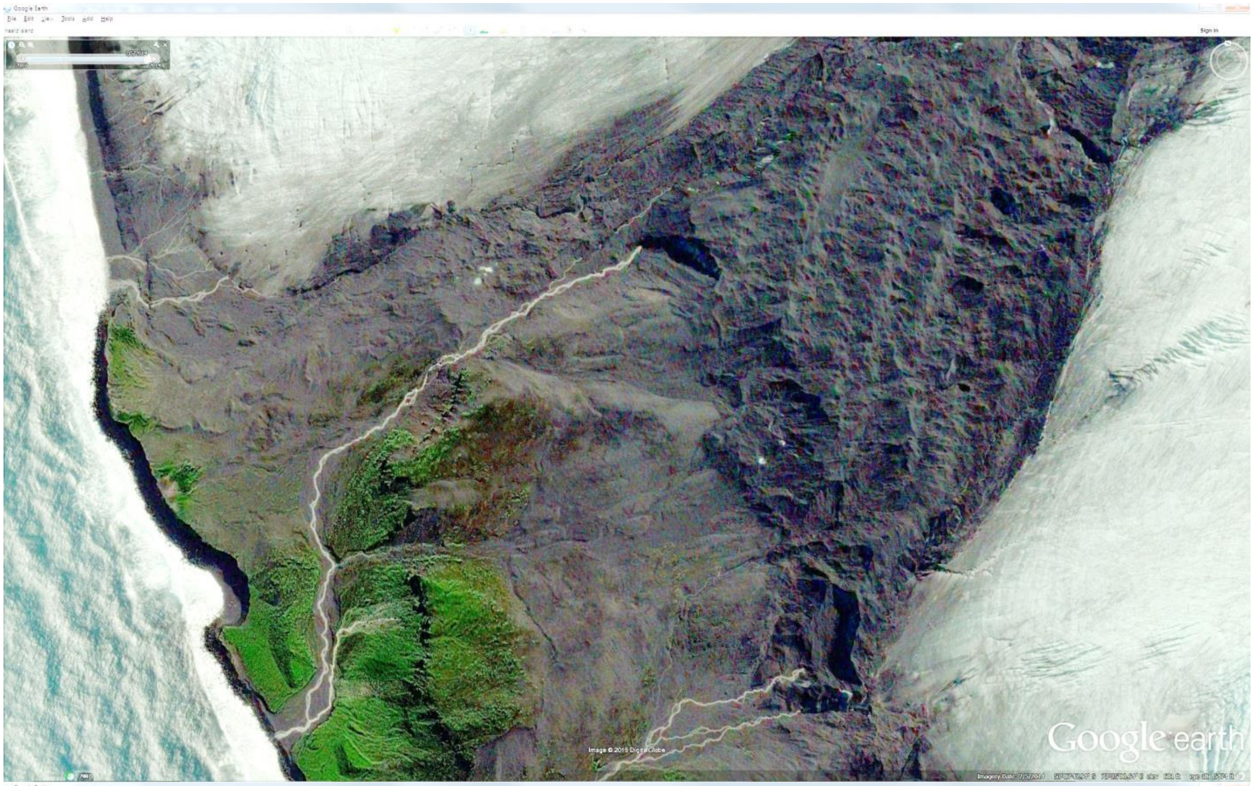


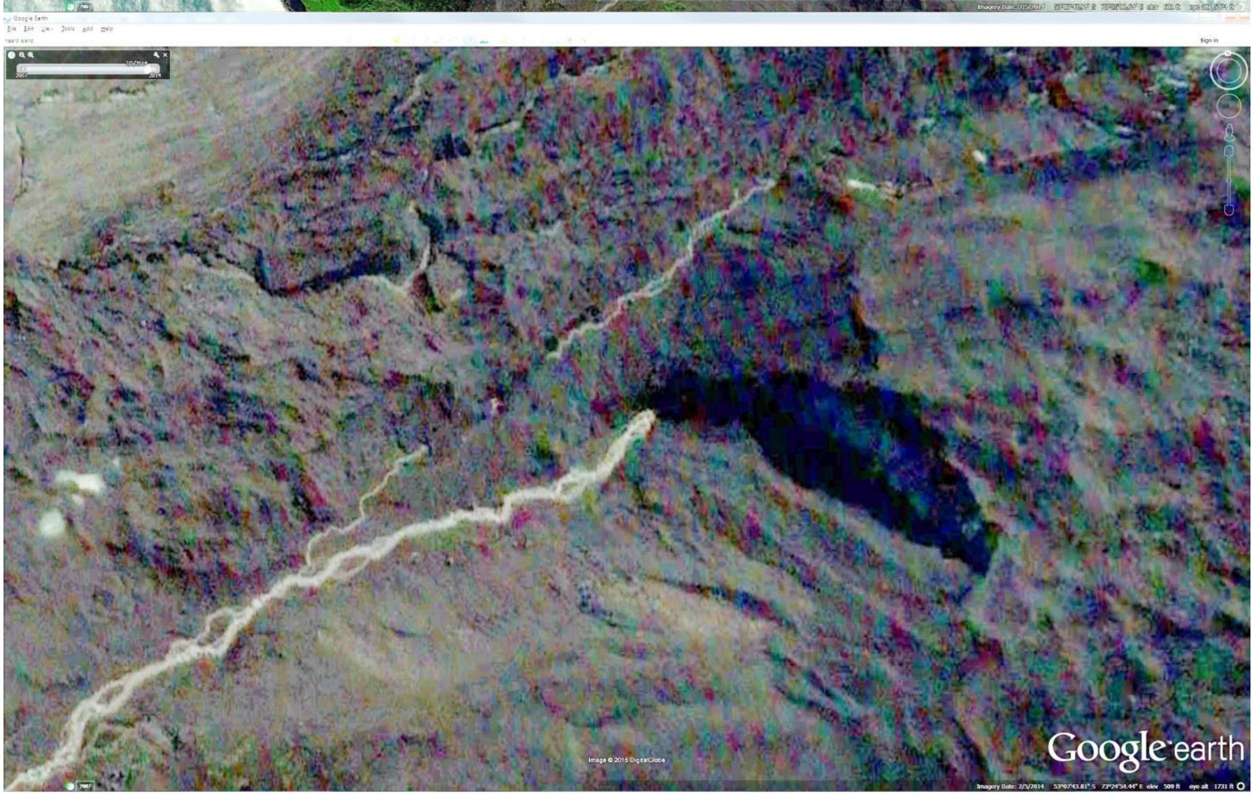
This stream might originate in the small lakes beyond the steep ridge, center vertical.



This stream appears to emanate from a very large ridge, a possible lava tube.

This stream may be a shunt associated with the(smaller) stream flowing down the gully. The latter also appears to disappear into the rocks and emerge later.





These two images show what appear to be streams with beginnings and ends. These could be merely artefacts of the camera position, or they might be images of a stream exiting and entering a subsurface channel. The photos seem persuasive that the streams do indeed go underground.

Interpretation

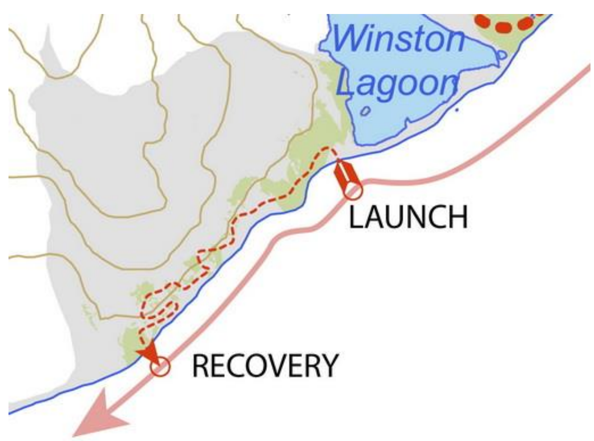
The simplest interpretation of these images is that the apparent streams are real–they actually do issue from openings in the cliffs. I suggest that until about 20 years ago, many lava tubes and other major drainage channels were filled with ice. As the temperature rose with global warming, this ice melted, providing channels through which the increasing runoff can easily drain. This drainage would also hasten further melting of the high glaciers, due to wind and sunlight. Thus, we may be seeing runoff that significantly exceeds that at the lower margins of the glaciers which are melting in warmer atmosphere.

Another effect that could be important is heating from active eruptions. The prominent stream on Lavett Bluff appeared in images taken in 2009. Possibly not coincidentally, Big Ben had erupted extensively in 2007-2008. Perhaps the release of heat from the flowing lava caused melting of the ice blockages, resulting in sudden opening of shunt passages for draining the meltwater from the glacier above. If so, the flow probably would enlarge the channel, and the violence of the flow may help to keep it open. The flow in 2014 appears to be significantly higher than in 2009, although that might be due to the latter image being take at the end of summer, while the former was at the beginning of summer.

Thus, in order to account for the observed runoff we may well have to include numerous additional nonlinear dynamic processes.

Proposal

The highest density of candidate subsurface streams appears to be on the steep southern wall of Big Ben, between Winston Lagoon and Long Beach. We propose to make a concerted effort to clarify the nature of the streams seen in these images. Unfortunately, most of the apparent streams are not accessible without extreme effort and some danger. However, we believe that good-quality photography would be sufficient to resolve whether they actually issue from underground sources.



We propose to use a multi-copter launched from the main vessel during the 2016 visit to obtain still images and video of some of the proposed subsurface streams. A typical quad-copter is shown above right.

We propose to fly the 'copter during one or more near-shore passes, shown schematically in the figure at right. In fact, we probably would carry out the flight in multiple steps, in order to get as much detail as possible of individual sites. One strategy would be to start at the lower end of each stream and follow it upwards until the stream origin is reached.

APPENDIX – Quotation from the paper by Kiernan and McConnell, 2002

Glacier retreat and melt-lake expansion at Stephenson Glacier, …

Conclusions

Rates of both glacier retreat and melt-lake enlargement have increased by about one order of magnitude during the last two decades. Precise ice-volume loss cannot presently be calculated, but about 30% of the cross-sectional area of the terminal zone of Stephenson Glacier above sea level has vanished in the past three decades. That accelerated melting of older ice-cored moraines is contributing so significantly to melt-lake expansion rather than it being the product solely of glacier recession perhaps emphasizes the significance of temperature increases in causing environmental change on Heard Island. The resulting transformation of the landscape implies there have been some fundamental alterations to the nature, rates, and relative contributions of the various geomorphological processes that are shaping eastern Heard Island. .Fluvial and other non-glacial processes are likely to play an increasingly significant role. Because atmospheric warming should also be accompanied by atmospheric moistening (Sun and Held 1996; Simmonds and Keay 2000), there may also be significant changes in glacial processes that could trigger further changes in glacial, glaciofluvial, and glaciolacustrine sedimentation and its interaction with coastal processes.

These changes in geomorphological processes and ongoing landscape evolution are having a pronounced impact on the character of this World Heritage Area, which is now a vastly different place to that experienced by the sealers and earliest ANARE expeditioners. In addition to impacts upon geodiversity, these changes also have implications for biodiversity, such as shoreline and other habitats, and by facilitating expansion of terrestrial vegetation. There are also implications for cultural heritage, notably archaeological sites dating from the nineteenth-century sealing days that are now subject to accelerated erosion due to changed interactions between glacial and coastal processes. Hence, this transformation has important implications for management of the Heard Island Wilderness Reserve.

Heard Island is uninhabited, infrequently visited, and about as remote from centres of direct human disturbance as any place on Earth, but there is increasing evidence of the pervasiveness of human impacts in southern polar latitudes (Liguang and Zhonqing 2001). If the climate changes responsible for glacier recession are of anthropogenic origin (Jones and others 1999; IPCC 2001), then the wilderness values and natural-process values upon which listing of this World Heritage property was partly based have in one sense been compromised. Heard Island remains about as wild and untouched as any place can be. But the changes that are occurring raise the philosophical question of whether any place on an artificially warming planet can be regarded with any validity as an untouched wilderness. These changes present the managing authority with difficult philosophical and practical issues regarding the desirability and level of any on-ground intervention for management purposes.

REFERENCES

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