Interpreting the history of Blood Falls and the terminus of Taylor Glacier, Antarctica through photographs and field observations

Chris Carr[1], Erin Pettit[2], and Andrew Fountain[3]

[1]Los Alamos National Laboratory
[2]Oregon State University
[3]Portland State University

November 24, 2022

Abstract

Taylor Glacier, located in the McMurdo Dry Valleys of Antarctica has piqued curiosity since the first observations in 1903. Episodic release of iron-rich brine at or near the glacier terminus rapidly oxidizes, forming a visually striking red stain on the ice and glacier forefield called 'Blood Falls'. The triggering mechanism behind these releases is unknown. The recent history of brine releases have been well documented since the 1993-94 summer season. To better understand the frequency and extent of brine releases over a longer time period we compile a detailed history of observations of the Taylor terminus from photographs, journals, field reports, oral histories, and published papers prior to the onset of more frequent monitoring in the 1990s. We developed a confidence assessment framework for our interpretation of the presence/absence of brine icing deposits. Results show that of the 30 summer seasons between 1903-1904 and 1993-1994 with interpretable observations, 21 seasons (70%) show evidence of brine flow events, and 9 seasons show no evidence of brine flow. At least two of these brine flow events are newly reported by our study. Concurrent observations of the glacier terminus over the same period showed a localized advance and collapse of a small portion of the southern terminus. We demonstrate a framework to fuse multiple data types and qualitatively assess the confidence level of our interpretations that could be applied to similar investigations of environmental history. We encourage other researchers to explore and contribute to the growing collection of open access historical archives.

Interpreting the history of Blood Falls and the terminus of Taylor Glacier, Antarctica through photographs and field observations

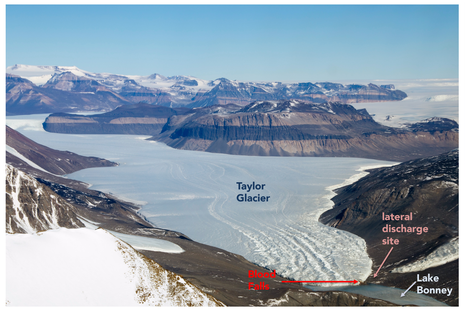
Chris G. Carr[1], Erin C. Pettit[2], Andrew G. Fountain[3] | [1]Los Alamos National Laboratory, [2]Oregon State University, [3]Portland State University

Session: Community Tools and Products for Cryosphere Discovery & Application
AGU Abstract #814865
LA-UR-21-31562

Blood Falls

EPISODIC DISCHARGE OF SUBGLACIALLY-SOURCED IRON-RICH BRINE

- We use publicly available archives to construct a record of activity & inactivity of Blood Falls
- Evidence of activity = icing deposits form if air temperatures are cold enough, but melt/sublimate away over weeks-months
- Discharge during warmer air temperatures leaves no icing deposit, but more likely to be observed as active outflow because of human presence during the summer field season
- Important for: understanding cold glacier hydrology & microbiology of Blood Falls
- **We compiled a record of people in the area from 1903-04 through 1993-94**, to provide a resource for other researchers using public photo archives



Taylor Glacier, an outlet glacier of the East Antarctic Ice Sheet, terminates in Lake Bonney.
Image: Michael Studinger, Operation Ice Bridge

DATA SOURCES

Data sources include: (a) Victoria Univ. of Wellington Antarctic Expedition Reports, (b) Japan's *Antarctic Record*, (c) New Zealand's *Antarctica*, (d) *Antarctic Journal of the US* and its predecessors, (e) Antarctica New Zealand Image Library, (f) USGS EROS Archive Aerial Photography Antarctic Single Frame Records (g) McMurdo Dry Valleys Historical Archive + prior compilations: Black (1969), Keys (1979, 1980), Lawrence (2017), and many more published papers & books

METHODS

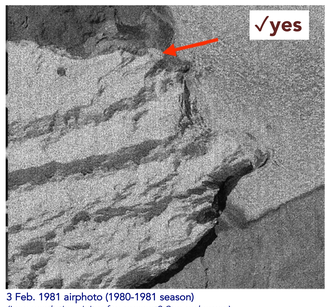
find data: photos, observations → brine outflow or icing deposit? ✓yes | x no

→ date reliability score: 0, 1, 2, 3
→ evidence quality score: 0, 1, 2, 3
→ Confidence assessment low/med/high

EVIDENCE QUALITY

evidence quality: 1

1959-1960 field season photo, John McCraw
(No photo with more context available)
Photo: MDV Historical Archives



3 Feb. 1981 airphoto (1980-1981 season)
(Low resolution, icing fan present? See red arrow)
Photo: USGS (2017) through the Polar Geospatial Center

18 December 1903
R. Scott's description of Taylor terminus area
(no mention of any red discoloration, icing, etc.)
Text from: Scott (1907)

x no

evidence quality: 3

5 November 1962, photo by Robert F. Black
(icing fan visible in this and other photos)
Photo in Black (1969)

✓yes

1990-1991 summer season
(clear description of summertime brine outflow)
Text from: Spigel & Priscu (1998)

associated with a saline intrusion of meltwater originating from the glacier. Surface discharges of salty water from the terminus of the Taylor Glacier, rich enough in iron oxides to have stained a section of the glacier face red, have been described in detail by Black [1969], *Black et al.* [1965], *Black and Bowser* [1968], and *Keys* [1979]. These discharges were no large during the summer of 1990-1991 that by January 1991 reddish-orange slush covered extensive areas of shoreline next to the glacier and was conspicuous from a distance of several kilometers. Water samples collected in the west lobe from depths between 20 and

x no

1989-1990 summer season painting by Jonathan White
(no red icing deposits in this or associated paintings from same season)
Accessed through the Antarctica New Zealand Pictorial Collection

Newly reported events

1969–70 field season photo by Lois Jones of Blood Falls
Obvious icing deposit (observation quality =3), photo title in archive: 'Taylor Red Melt'. Date listed in the source archive is 1969–70 field season; to our knowledge this is the only season Lois Jones was in Antarctica (date reliability =3).

Photo from: The Ohio State University Archives (Byrd Polar Center: Antarctica Expeditions 1969–1970).

1981-82 field season photo
A group of photos credited to Harold Neumann are listed with "unknown" dates in the MDV Archives; the photos show a brine deposit (observation quality = 3) which we interpret as originating from the lateral release site. We determined that all photos were taken during the same day based on features like clouds. We cross-referenced photos of the people in the photos with photos from the Antarctica New Zealand Image Library and lists of team members from the *Antarctic Record* to constrain the season (date reliability = 2).
Photo: Harold Neumann, MDV Archives

Earliest images

Plate LXX.—The Taylor Glacier from the top of the Bonney Riegel. (Looking S.W. up the glacier.)

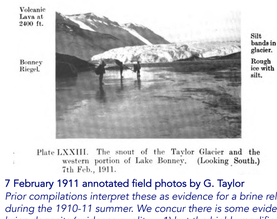


Plate LXXIII. The snout of the Taylor Glacier and the western portion of Lake Bonney. (Looking South.)

7 February 1911 annotated field photos by G. Taylor
Prior compilations interpret these as evidence for a brine release during the 1910-11 summer. We concur there is some evidence of brine deposits (evidence quality = 1) but the highly modified deposits may be remnants from an earlier year.

DATE RELIABILITY

score	selected examples
0	no reliable date (no date provided, or same photo attributed to many seasons by various sources)
1	date lists single year (1964 vs. 1964-1965), no month
2	date of photographer's field season circumstantially determined in our study and does not conflict with other published observations
3	multiple sources agree on date, or published date for single source from original observer

CONFIDENCE ASSESSMENT

Date reliability \ Evidence quality	1	2	3
3	MED	MED	HIGH
2	LOW	MED	MED
1	LOW	LOW	MED

Observations of brine deposits or outflow activity

FOR EACH SUMMER SEASON, WE REPORT YES or NO or NO DATA

Prior compilations did not usually distinguish between no data found in archives and data indicates no Blood Falls activity

confidence level: brine deposit or outflow?	high x no	medium x no	low x no	*(no data) ???*	low ✓yes	medium ✓yes	high ✓yes

Summer season						1956-57	57-58	58-59	59-60
1960-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70
1970-71	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	*79-80*
1980-81	81-82	82-83	*83-84*	*84-85*	*85-86*	*86-87*	*87-88*	*88-89*	89-90
1990-91	91-92	*92-93*	93-94	*94-95*	95-96	96-97	97-98	98-99	99-00
2000-01	01-02	02-03	03-04	04-05	05-06	06-07	07-08	08-09	09-10
2010-11	11-12	12-13	13-14	14-15	15-16	16-17	*17-18*	18-19	19-20

Additional seasons**: 1903-04 (no, low confidence), 1910-11 (yes, low confidence), *1946-47* (airphotos available, but were taken from an angle and distance that precludes interpreting Blood Falls activity)
***To our knowledge, no other seasons before 1956-57 had field parties or fly-overs. For seasons after 1956-57, "no data" means we have not yet found Blood Falls observations from these years, but they may exist.*

Changes in timing or frequency?

MORE BRINE RELEASE EVENTS HAVE OCCURRED IN THE HISTORICAL PERIOD THAN PREVIOUSLY REPORTED

Recurrence intervals for subaerial brine discharge at the glacier or lateral site are not known; however, data from our study and prior compilations indicate that discharge event time scales are on the order of weeks to perhaps a few months in duration and occur during the majority of years with observations available. The temporal resolution of observations in the pre-LTER era are not sufficient to comment on potential changes in seasonal timing of outflow events.

Is your research in the Dry Valleys?

OUR COMPILATION OF WHO WAS IN TAYLOR VALLEY PRE-1993/94 MAY HELP

For season-by-season lists of who was where and when, please see Chris's thesis:
- focused on Taylor Valley, see the Appendix for Chapter 2

Our compilation improves date control for the photos in public archives, to help researchers address glaciological, environmental, hydrological, and other questions using the rich historical archives.

We've successfully narrowed down the dates for several photos from 'unknown' field seasons, and hope it helps you do the same!

DO YOU HAVE BLOOD FALLS/TAYLOR GLACIER OBSERVATIONS TO SHARE?

We are especially interested in these summer seasons, please email Chris: cgcarr@alaska.edu
1960-61, '64-65, '79-80, '83-84, '84-85, '85-86, '86-87, '87-88, '88-89, '92-93
We're adding to the pre-1993-94 scope of the initial project (seasons prior to McMurdo Dry Valleys Long Term Ecological Research Project), observations from these years are also helpful:
1994-95, '2017-18, '20-21

ACKNOWLEDGEMENTS

We thank Robin Nicholson at the University of Alaska Fairbanks Geophysical Institute Mather Library, Max Sullivan at the Victoria University of Wellington Library, and staff at Archives New Zealand for their assistance tracking down historical records, original airfoils, and copyright use permissions. Adrian Howkins provided assistance with records through the McMurdo Dry Valleys Archive. We thank Paul Dayton and Paul Robinson for permission to use their photos, and Paul Dayton for the detailed and helpful correspondence. We thank Emilie Sinkler and Regine Hock for providing thoughtful feedback during the development of the methods for this paper. Thank you to Carl Tape, Martin Truffer, and Josh Carmichael for reviews of the related dissertation chapter written by CGC.
VUWAE reports were obtained through the New Zealand Electronic Text Collection, available at http://authority.nzetc.org/tm/scholarly/tei-corpus-VUWAnta.html. Geospatial support for this work, including access to the USGS airphotos, was provided by the Polar Geospatial Center under NSF-OPP awards 1043681 and 1559691. Financial support for this project was provided by NSF Award OPP 1144177 to E.C.P.

REFERENCES [in addition to resources listed under "Data Sources]

ANTARCTICA NEW ZEALAND PICTORIAL COLLECTION (2020) Antarctica New Zealand Image Library: https://adam.antarcticanz.govt.nz/
BLACK, R.F. (1969) Saline discharges from Taylor Glacier, Victoria Land, Antarctica. *Antarctic Journal of the United States*, 4(3), 89–90
BYRD POLAR CENTER: ANTARCTICA EXPEDITIONS 1969–1970. Lois M. Jones Papers, The Ohio State University Byrd Polar and Climate Research Center Archival Program. https://library.osu.edu/polararchives
MCMURDO DRY VALLEYS (MDV) HISTORICAL ARCHIVE: Howkins A., Chignell S.M., Gullett P., Fountain A.G., Brett M., and Preciado E. (2020) A digital archive of human activity in the McMurdo Dry Valleys, Antarctica. *Earth System Science Data*, 12(2), 1117-1122, doi: 10.5194/essd-12-1117-2020
KEYS, J. (1979) Saline discharge at the terminus of Taylor Glacier. *Antarctic Journal of the United States*, 14(5), 82–85
KEYS, J.R. (1980) *Salts and their distribution in the McMurdo region, Antarctica*. Ph.D. thesis, Victoria University of Wellington
LAWRENCE, J. (2017) *Evidence of subglacial brine inflow and wind-induced seiching from high temporal resolution temperature measurements in Lake Bonney, Antarctica*. Master's thesis, Louisiana State University
SCOTT, R.F. (1907) *The Voyage of the 'Discovery'*, volume II. Smith, Elder, & Co., London
SPIGEL, R.H. and PRISCU, J.C. (1998) Physical limnology of the McMurdo Dry Valleys Lakes. In J.C. Priscu (ed.), *Ecosystem dynamics in a polar desert: the McMurdo Dry Valleys, Antarctica*, volume 72 of Antarctic Research Series, 153-187, American Geophysical Union, Washington, D.C., USA, doi: 10.1029/AR072p0153
TAYLOR, G. (1922) *The Physiography of McMurdo Sound and Granite Harbour Region*. Harrison and Sons, Ltd., London, United Kingdom
US GEOLOGIC SURVEY (2017) USGS EROS Archive -- Aerial Photography -- Antarctic Single Frame Records, doi: 10.5066/F7MW2FDP