

We would like to thank Florence Fetterer for her time and detailed review of the manuscript. In our response, the reviewer comments are shown in black while our answers are shown in blue. We also reference the relevant lines in the revised manuscript, in which changes are highlighted.

20-24: Various interest groups will be able to use the images for purposes beyond geophysical research. It's good to see that fact laid out clearly and prominently in these lines. The authors may want to reference Maness et al., 2017, doi:10.1016/j.grj.2017.10.002 because it stresses the importance of this kind of work through several examples, of which the NSIDC Glacier Photograph Collection is the most prominent.

This reference has been added – thank you for the suggestion.

A summary of the full collection is shown in Table 1.

It's not clear what the full collection referred to here is. It is the digitized collection of photographs, but those are part of a larger collection, and later it says

Due to budget constraints, we could not digitize all of the images, but focused on images of glaciers and glaciated landscapes from the Alaska and Greenland expeditions. There are still hundreds of other photographs in the RMC that were not digitized

Were all of the Alaska and Greenland expeditions photos digitized? Please clarify earlier in the manuscript (earlier than line 200) if this is so. "Collection" has a particular meaning in library archives, so referring to "full collection" can be confusing without some additional descriptive words.

We have clarified the wording by changing "full collection" to "digitized collection" (line 47 in the revised manuscript). The priority for digitization was Alaska and Greenland photos, then Ithaca region images. To the best of our knowledge, close to all of the Alaska and Greenland images with sufficient original material quality were digitized. We cannot guarantee that some images were not overlooked (some materials were not well organized). Some images were not digitized due to the original material being in poor shape, some others that were duplicates of already scanned images were also skipped over. We are working with Cornell library staff to obtain firm numbers of remaining, unscanned images. We have added more discussed of the remaining images (lines 208-213 in revised manuscript).

Over a forty year period (including 20 years at Cornell), Tarr accumulated images of glacial landforms ..

And he died at 48? This implies that he had been collecting photographs since he was 8, which is certainly possible, but if so, it is so remarkable that it would be good to add some comment about it!

This was a typo and has been fixed (line 190 in revised manuscript).

Section 3.1 on Original Material, lines 195-203: At NSIDC we have a similar situation. As of August 2018, the analog glacier photographs reside not at NSIDC, but in the University of Colorado at Boulder (CU) Library Archive. The Digital Library at CU and NSIDC collaborated on improving the digital portion of the collection, and both NSIDC and CU Library maintain interfaces to and identical copies of the digital portion of this large analog collection. These interfaces serve different user communities. The Background section of the User Guide, under <https://nsidc.org/data/g00472>, describes some of this and links to the CU Digital Library collection interface at <https://cudl.colorado.edu/luna/servlet/CUB>. At some point in the manuscript, it may be useful to link to the CU Library interface as well as to the NSIDC interface to the digital collection.

A link to the CU libraries has been added (line 359 in revised manuscript).

Master images were saved as 16B layered tiffs with curve adjustment layers. Uploaded access files are flattened, 8B, high quality compression, original sized jpegs.

Do the above lines mean that 16 bit images were digitally archived, but only 8 bit images are accessible/distributed? If so, perhaps some words on why 8 bit serve as well as 16 bit would be helpful.

The full resolution, 16 bit TIFF files are now available to download through the Cornell library interface. The standard policy for the Cornell libraries is to archive the full resolution images and make smaller files available for download, which is why only the smaller files were available initially.

221: Please list the range of file sizes, in MB, for the images, along with typical size.

There is not a simple way for library staff to assess the range of the file sizes, but the average size is 135 MB for the full resolution TIFFs.

224: Did you consider giving not only the entire collection but each individual photograph image a DOI?

We did not initially consider assigning individual DOIs. We are now exploring practicalities and options with library staff as adding ~2000 DOIs would be a non-trivial task. There are pros and cons to individual DOIs. If someone used a couple of the images, individual DOIs would be a benefit but if someone was using hundreds of the images it could become cumbersome.

Section 3.4 Metadata and Filenames

I found this section somewhat hard to follow. Adding some example filenames (e.g. "tve_lanternslide_0007.jpg") would help. Adding a listing of all the metadata fields that

were used, along with the range of possible values for each field, would be good. It would also be good to make the metadata for the collection available as a downloadable spreadsheet. Was this considered? As it is, the only way I see of using the metadata is to make selections from the user interface. That's adequate for most users, but having the ability to download all metadata would be a great way to get a complete and detailed picture of the collection for those who want to go further. Consider including a figure that is a screenshot of a page like this, <https://digital.library.cornell.edu/catalog/ss:9417838> , so that the discussed metadata fields are shown with a photograph, as it would appear to a data collection user.

[A spreadsheet with all the metadata fields was available as part of the supplemental information \(which was in a separate file from the manuscript\). An updated version of this spreadsheet \(with additional metadata fields, including approximate coordinates\) is included in the supplemental information to this revised submission. The spreadsheet \(Table S1\) includes a listing of all the metadata fields as well as the full range of values for each field. We have moved the first mention of S1 to the first sentence of the section to make the table more prominent to the reader.](#)

[An example filename is given \(line 258 in revised manuscript\).](#)

[We have also reorganized parts of the discussion of the metadata and filename section to make it clearer.](#)

In some cases, the envelope includes some “additional notes” that have not been included in the digital published metadata through the Cornell Library, but that are included in Table S1. For example, some images included a letter grade for the quality of the image (A+ being the highest and D being the lowest), presumably assessed by Tarr or von Engeln. In some other images, these notes include the name of the photographer, or if the photograph is duplicated as a lantern slide set, the number of the lantern slide is given (see above). Table S1 also includes the appropriate USGS Quadrangle topographic map or Natural Resources Canada topographic map for the images when available

This (above) is the first mention of Table S1. Please define it and put it in context. I am guessing it is a table of supplemental metadata. Is it accessible?

Lines 267 – 285: The detail is great, and it helps readers understand how complicated it can be to assign metadata consistently. But again, I had trouble following this section, and think a listing of all metadata fields, in a table with example rows, would help.

[See above.](#)

283: “Twenty-four photographs from Martin’s trips...”. Searching now, I find 35 attributed to L. Martin, and 15 to an E.R. Martin, all from Alaska in the early 1900s.

We have corrected our numbers (line 354 in revised manuscript).

Would you please cite the NSIDC collection somewhere in this section as “National Snow and Ice Data Center (2015)” and then have this, below, in the reference section? National Snow and Ice Data Center (comp.). 2002, updated 2015. Glacier Photograph Collection, Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: <https://doi.org/10.7265/N5/NSIDC-GPC-2009-12>. [Date Accessed].

Done.

294: I am happy to report that the NSIDC glacier photo collection now has more than 24,000 glaciers on line. More were digitized and described thanks to a grant to the CU Library (see Maness et al. 2017)

We have changed our mention of the NSIDC holdings to reflect the updated number (line 355 in revised manuscript).

295 ...The NSIDC also holds and has scanned Martin’s field notebooks from the 1904, 1905, and 1906 Alaska expeditions.

Are you able to give me a source or a link for the scanned Martin notebooks? NSIDC has not had an archivist for more than five years now, and I am not able to find the scans you reference. I believe the physical notebooks are safe with CU Library.

This is correct – the notebooks are in the CU Library. We have changed the mention in Section 4 to reflect this (lines 356 – 358 in revised manuscript).

Finally, I agree with RC1, who writes “ From you figures it shows that many of your images have already been geolocated – this information is not transferred to the meta-data. I recommend that this location data is added to the metadata, or alternatively a supplementary file with image coordinates is attached to the manuscript.

From the response to RC1: The locations used in the maps and based on the image descriptions and images themselves are approximate locations – exact locations would require further ground trothing. Some images allow fairly precise determination of location while others only allow for a general location. With those caveats, we have included coordinates for major features in the images in the supplemental metadata table. Further discussion of how we chose which coordinates to use can be found in lines 270 – 277 in the revised manuscript.

Technical corrections

28: correct typo and formatting in Hill et al.

Done (line 28 in revised manuscript).

102: think it needs a paragraph break after this line.

Done.

108: missing a close paren.

Done.

221: typo “originally size”

Corrected to “original size”.

Response to RC #1

We would like to thank Anders Anker Bjørk for his time and thoughtful review of the manuscript. In our response, the reviewer comments are shown in black while our answers are shown in blue. We also reference the relevant lines in the revised manuscript, in which changes are highlighted.

1) It is not clear to me why the images need to be in two different online archives – each with different level of metadata and (apparently also) different file sizes. I will recommend that you only link to the archive with the most metadata and the largest file sizes/original scans.

We now link to the Cornell library archive, which will be the archive of record. We have removed discussion of the ARTSTOR archive in the manuscript to avoid confusion. As noted below, the Cornell archive now have the full sized TIFF images as the default download option, while the ARTSTOR archive has only the downsampled jpg files.

2) I was not able to find the original scan sizes in ARTSTOR, here the images were also c. 1.5 mb as in the Cornell Library. For a 4x5 inch glass plate scanned at high resolution this is very downsized. It would be great with a link or DOI for the high resolution images.

The full resolution TIFF images are now available as the default download through the Cornell archive. The average size of the TIFF images is 135 mb.

3) From you figures it shows that many of your images have already been geolocated – this information is not transferred to the metadata. I recommend that this location data is added to the metadata, or alternatively a supplementary file with image coordinates is attached to the manuscript.

The locations used in the maps and based on the image descriptions and images themselves are approximate locations – exact locations would require further ground trothing. Some images allow fairly precise determination of location while others only allow for a general location. With those caveats, we have included coordinates for major features in the images in the supplemental metadata table. Further discussion of how we chose which coordinates to use can be found in lines 270 – 277 in the revised manuscript.

4) In your manuscript you call it the R.S. Tarr Collection – in the online archives it is called “Historic Glacial Images of Alaska and Greenland”. I find this title misleading as there are images from other locations and other subjects than glaciers too.

We agree that this is not the most descriptive title – it was chosen before the full extent of the digitized images was known. We have begun a conversation with the Cornell archives about modifying the name, but any changes will be in the longer term. Any modification of the name will not impact the access link to the collection.

5) The historical images in your figures do not appear to do the material justice. I would like to see a better processing of the photos with more contrast, also the cropping and set-up of the photos can be improved.

Processing the images proved to be a challenge as a number of the originals were degraded after being neglected for a century. The archive staff in charge of digitization tried a number of strategies, including scanning at multiple exposures. We have added additional discussion of this in the manuscript (lines 216 – 222). The master layered images could be reprocessed. We plan to pursue this option, but we will have to secure additional funding before the processing can be performed.

6) Lastly, I am looking more for information on the completeness of the Tarr collection. Are there other images/material from the expeditions in other archives?

We have expanded our discussion in Section 4 (lines 300 – 319) about complimentary collections. Previously, we had mentioned materials from the expeditions housed at the University of Alaska and the National Snow and Ice Data Center. We have now found materials from the expeditions at the University of Colorado, the Anchorage Museum at Rasmuson Center, and the National Geographic Image Collection.

Historic photographs of glaciers and glacial landforms from the R. S. Tarr collection at Cornell University

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Abstract.

Historic photographs are useful for documenting glacier, environmental, and landscape change and we have digitized a collection of about 1949 images collected during an 1896 expedition to Greenland and trips to Alaska in 1905, 1906, 1909, 10 and 1911, led by Ralph Stockman Tarr and his students at Cornell University. These images are openly available in the public domain through Cornell University Library (<http://digital.library.cornell.edu/collections/tarr>; *Tarr and Cornell University Library* (2014), <http://doi.org/10.7298/X4M61H5R>). The primary research targets of these expeditions were glaciers (there are about 990 photographs of at least 58 named glaciers) but there are also photographs of people, villages, and geomorphological features, including glacial features in the formally glaciated regions of New York state. Some of the 15 glaciers featured in the photographs have retreated significantly in the last century or even completely vanished. The images document terminus positions and ice elevations for many of the glaciers and some glaciers have photographs from multiple viewpoints that may be suitable for ice volume estimation through photogrammetric methods. While some of these photographs have been used in publications in the early 20th century, most of the images are only now widely available for the first time. The digitized collection also includes about 300 lantern slides made from the expedition photographs and 20 other related images and used in classes and public presentations for decades. [The archive is searchable by a variety of terms including title, landform type, glacier name, location, and date.](#) The images are of scientific interest for understanding glacier and ecological change, of public policy interest for documenting climate change, of historic and anthropological interest as local people, settlements, and gold-rush era paraphernalia are featured in the images, and of technological interest as the photographic techniques used were cutting-edge for their time.

25 1 Background

In recent decades, glacier retreat has become symbolic of climate change, but the relationship between climate and glacier response is complex. While global trends indicate significant ice loss throughout the 20th and early 21st centuries, glaciers are not losing ice at the same rate and a small fraction are continuing to gain mass (e.g. *Larsen et al.*, 2007; *Larsen et al.*, 2015; *Hill et al.*, 2017). A variety of factors control whether an individual glacier is advancing or retreating and how it will

30 respond to regional climate change (e.g. *Post et al.*, 2011; *Larsen et al.*, 2015). To better understand the link between
climate and glacier behaviour, long-term records beyond the relatively short temporal limits of satellite observations are
essential. Historic photographs can significantly expand the time span of observations, leading to both qualitative and
quantitative evaluations of glacier fluctuations and their possible causes (e.g. *Molnia*, 2007; *Bjork et al.*, 2012). [In recent
years, historic photographs have been used in applications as diverse as studies of human history in Glacier Bay, Alaska,
television documentaries, and education materials](#) (e.g. *Maness et al.*, 2017; *Conner et al.*, 2009).

Here we describe a newly digitized collection of photographs from a series of expeditions undertaken in the late 19th and
early 20th centuries to study glaciers and other geographical features in Greenland and Alaska led by Professor Ralph
Stockman Tarr and his students from Cornell University. Tarr was a professor of physical geography with particular
interests in glaciology and geomorphology. In pursuit of these interests, he led or participated in expeditions to western
Greenland in 1896 and to various regions of Alaska and western Canada in 1905, 1906, 1909, and 1911. His former student
and frequent collaborator, Lawrence Martin, joined Tarr on the expeditions of 1905, 1909, and 1911 and made trips to
Alaska without Tarr in 1904, 1910, and 1913 (*Tarr and Martin*, 1913). The collection presented here includes images from
the 1905, 1906, 1909, and 1911 expeditions and the 1896 Greenland expedition. The expeditions are discussed further
below. In addition to the images from expeditions, the collection includes digitized images of lantern slides (glass slides used
in magic lanterns, an early version of a projector) that were used in teaching at Cornell and public lectures. These lantern
slides duplicate a few of the original images from the expeditions but also include images from other scientific expeditions
as well from commercial teaching collections. A summary of the [digitized](#) collection is shown in Table 1. Approximate
image locations are shown in Figs. 1 and 2 (Alaska) and Fig. 3 (Greenland).

Counting the expedition images and lantern slides together, there are images of at least 49 named glaciers in Alaska and
eight in Greenland in the collection (Tables 2 and 3). These glaciers featured in these images are of global importance as
glaciers in coastal Greenland and Alaska are significant contributors to current sea-level rise because of their rapid loss of ice
mass (e.g., *Gardner et al.*, 2013). Of these 49 glaciers, 34 have photos that clearly show the majority of their terminus,
which will allow the position to be mapped and compared to modern terminus positions. Roughly half of the glaciers have
images in which the vertical extent of ice is easily distinguished against valley walls and other features that can serve as
benchmarks for modern comparisons. Eight of the glaciers in Alaska have photographs of the terminus region taken from at
least three different viewpoints, which may make the images suitable for ice volume estimation through photogrammetric
methods. About 20% of the glaciers, either through single photographs or a combination of photographs, have imagery
covering at least 5 km of their length, measured from their terminus. Tables 2 and 3 list which glaciers fall into each of these
categories.

In addition to the glaciers themselves, Tarr was very interested in the landforms formed and left behind by the glaciers. The collection includes images of alluvial fans, various types of moraines, outwash plains, eskers, kettles, fosse, and other glacial features (Fig. 4). In Alaska and Greenland, the images show active and recently active features. The collection also includes images of features developed during the last glacial maximum in the Finger Lakes region of upstate New York. Moraines are the most frequently featured glacier landforms in the images. In many images, the moraine appears alongside other features, such as mountains or shorelines, that are easily located in modern maps and imagery. This is especially true in Alaska, where moraine locations in images from Prince William Sound (Columbia, Spencer, and Shoup glaciers), the Wrangell Mountains (Kennicott Glacier), and the Yakutat Bay/Russell Fjord region (Hubbard, Orange, Hidden, Variegated, Atrevida, and Hidden Glaciers) can be mapped and compared to present day landscapes. Other types of geological changes are also documented in these photographs. One goal of the expeditions to Alaska was to document changes caused by a series of earthquakes in the area (e.g., *Tarr*, 1909; *Martin*, 1910; *Tarr and Martin*, 1912a) that caused significant, abrupt uplift and subsidence (Fig. 5). These observations have been used in modern tectonic studies (*Plafker and Thatcher*, 2008) and can be useful in separating instantaneous tectonic motion from the effects of glacial isostatic adjustment that have accumulated over the past century. For all of the regions Tarr visited, the collection includes images of people, towns, and smaller settlements that provide a glimpse into life at the turn of the 20th century (in particular, [gold rush era](#) interior Alaska, the Yukon, and British Columbia).

Historic photographs have been used for decades to observe glacier change (e.g., *Molnia*, 2007; 2008; *Meier et al.*, 1985), but the digitized photographs described here are a significant addition as they have been little studied and include glaciers with few historic photographs. Although most of the photographs in this collection have been publically available in the Division of Rare and Manuscript Collections (RMC) of the Cornell University Library for decades, only a fraction have been published in articles (e.g., *Tarr and Martin*, 1914). In particular, photographs from the 1911 expedition were not used extensively in publications (although see, e.g., *Tarr and Martin*, 1912b; 1913; *Martin* 1913a), because Tarr died suddenly in March, 1912 at age 48 and the collaborators moved on to other projects (e.g., *Brice*, 1985; 1989). Thus, many of the photographs have not been otherwise published or catalogued and have been seldom viewed over the past 100 years.

In the following sections, we describe the purposes and context of the expeditions, the types of photographs and the subjects, and how they were digitized.

2. The Expeditions and Photography

2.1 Photographers and Equipment

The photographs were taken by a variety of photographers. Tarr and Martin both took photographs. During the 1906 and 1909 expeditions, many of the photos were taken by Oscar D. von Engeln. A keen photographer, von Engeln worked with
95 Tarr as an undergraduate and graduate student at Cornell and later become a professor in the Department of Geology and
Geography there. James Otis Martin, a Cornell student who accompanied Tarr to Greenland in 1896, took a number of the
photographs during that expedition (*Tarr, 1897a; Tarr, 1897i*). Photos in the collection were also taken by members of the
U.S. Geological Survey, engineers of the Copper River and Northwestern Railway, members of the Canadian Boundary
Survey, and several unnamed Alaskan photographers (*Tarr and Martin, 1914*). The lantern slides include photos taken by
100 members of other well-known expeditions, including William Libbey, a Princeton geographer who participated in a trip to
explore Mount St. Elias in Alaska in 1886, Peary's 1894 expedition to Greenland, and a 1899 Princeton-funded trip to
Greenland (*Koelsch, 2016*); F. Jay Haynes, a professional photographer who visited Alaska, Yellowstone, and other parts of
the American West; Henry Fielding Reid, a professor at Johns Hopkins who performed pioneering studies of glacier
dynamics in southeast Alaska in addition to ground breaking work on how faults related to earthquakes; and Israel Russell, a
105 USGS scientist who explored the regions of Mount St. Elias and Yakutat Bay in Alaska.

Equipment varied depending on the trip and the most detail is known about the equipment used in the 1906 and 1909 Alaska
expeditions as von Engeln published articles on techniques he used to take and develop photographs in the challenging field
conditions (*von Engeln, 1907b; 1910*). During those expeditions, he used a Rochester Optical Company Pony Premo self-
110 casing folding plate camera (which is preserved in the Cornell RMC, see Fig. 6a,b) as well as several other cameras
including multiple Kodak film cameras (*von Engeln, 1907b*). Exposures were made on glass plates and film negatives
(typically standard 4 x 5 inch size, with a few of larger size). Several lenses were used, including a long-focus lens that was
custom made by Bauch and Lomb for the Alaska work (*von Engeln, 1907b*). At least one camera had a mount system that
allowed the capture of panoramic images on film (Fig. 6e,f). As shown in Fig. 6c-e, some of the images capture the process
115 and difficulty of taking photographs in the rugged field environment. The cameras, lenses, shutter, and plate holders were
packed into a leather case with straps so that it could be more easily carried along with a tripod, plates and film, and
containers for changing plates and protecting exposed film from the excessive humidity of southeast Alaska (*von Engeln,*
1907b). Although the camera system was designed to be compact, setting it up and making the exposures often took
considerably more time than scientific observations and notes at a site (*von Engeln, 1910*).

2.2 The Expeditions

We briefly describe the expeditions that are summarized in Table 1 and Figs. 1, 2, and 3.

125 2.2.1 1896 Greenland

In 1896, Tarr, along with other faculty and students from Cornell travelled to Greenland as part of Robert Peary's expedition that attempted (and failed) to remove the largest of the three Cape York meteorites (*Tarr, 1896; Huntington, 2002*). The Cornell group was one of three scientific parties along on the expedition; after stops along the coast of Labrador and at Baffin Island, Disko Island, Vaigat Strait, and Umanak, they were landed on the Nugsuak Peninsula along the Upernavik Archipelago (Fig. 3) where they stayed for several weeks making studies of the geology, plant life, birds, and invertebrates (*Tarr, 1896*). While there, they described and assigned names to a number of geographic features including Cornell glacier, Wyckoff glacier (after an Ithaca businessman who provided financial backing for the expedition), and Mt. Schurman (after the President of Cornell University) (e.g., *Tarr., 1896; Tarr 1897a,b*). Tarr wrote extensively of his field observations on the trip (*Tarr, 1896; Tarr 1897a-i*). The digitized photographs are from a variety of locations (but mostly from the Nugsuak Peninsula) and show glaciers, geological features, local people, and some of the day-to-day activities and challenges of the expedition (Fig. 7).

2.2.2. 1905 Alaska

In the summer of 1905, Tarr and Martin went to Yakutat Bay (Fig. 2a). Tarr was in charge of a USGS party charged with a general geological survey of the region while Martin was funded by the American Geographical Society (e.g. *Tarr and Martin, 1905*). The scientific party made observations of surface changes that occurred after a series of M8 earthquakes that occurred in the region in 1899 (e.g. *Plafker and Thatcher, 2008*), general descriptions of glaciers in the Yakutat Bay area and evidence for the extent of past glaciation, and noted the return of vegetation to areas in which glaciers had recently retreated. The work done during this trip was the primary focus of *Tarr and Martin (1905) Tarr and Martin (1906a-c)* and featured in a number of other publications (e.g. *Tarr 1907a-e; Tarr 1909; Tarr 1910; Tarr and Martin, 1907; Tarr and Martin, 1912a; Tarr and Martin, 1914*). Digitized photographs from this expedition include images of the area's glaciers, faults and other features related to the 1899 earthquakes, and glacial landforms (Figs. 4 and 8).

2.2.3. 1906 Alaska

150 Tarr again led a USGS-sponsored party to Yakutat Bay in the summer of 1906. One of the party's objectives was to cross the Malaspina Glacier, but they discovered that the normally navigable tributary glaciers east of the Malaspina had

advanced and created impassable crevasse fields (*Tarr, 1907 d-e*). At least two other glaciers in the Yakuat Bay area had also advanced since the summer of 1905 (*Tarr and Martin, 1912a*). Scientific findings of the expedition are described in *Tarr 1907a-e; 1909; Tarr 1910; Tarr and Martin, 1907; Tarr and Martin, 1912a; Tarr and Martin, 1914; von Engeln, 1911..*

155 Popular accounts of the expedition include *von Engeln (1906, 1907a)* and *Alley (2012)*. In the collection, the 1906 digitized photos are primarily images of the glaciers along the eastern edge of the Malaspina Glacier and within Yakutat and Disenchantment Bays and Russell Fjord (Fig. 9).

2.2.4 1909 Alaska

160 With funding from the National Geographic Society, Tarr and Martin returned to Alaska with a scientific party including a dedicated photographer and topographer in 1909. Most of their time was spent in Yakutat Bay, but the group also travelled further west and made observations at Valdez, Columbia, and Shoup glaciers in eastern Prince William Sound, and Miles, Childs, and Allen glaciers along the lower Copper River (Fig. 1). The primary purposes of the trip were to make detailed maps of the glaciers of the southern Alaska coast and to make additional observations concerning the sudden

165 advance of glaciers noted in 1906 (*Tarr and Martin, 1910a*). During the trip, the party found that the glacier advances noted in 1906 had slowed or stopped while two additional glaciers around Yakutat Bay showed signs of advance. Glaciers within Prince William Sound and the Copper River did not show evidence of significant change from earlier observations (e.g. *Tarr and Martin, 1910a-b*). Based on these results, Tarr and Martin proposed what they referred to as the earthquake advance theory or the glacial flood hypothesis: an earthquake causes an avalanche of snow and other material onto a glacier, causing

170 deformation that is transmitted down the glacier and eventually results in crevassing and an advance at the front of the glacier (e.g. *Tarr, 1910; Tarr and Martin, 1910a*). Later work in Alaska showed that the observed glacier surges are periodic and likely due to characteristics specific to the individual glacier system, not external factors such as earthquakes (e.g. *Post, 1965; Meier and Post, 1969*). Additional descriptions of the fieldwork and scientific work are found in *Tarr and Martin (1912a; 1914)* and *von Engeln (1911)*. Within the collection, the 1909 expedition contributes more digitized images than any

175 other trip. The images show glaciers and glacial landforms in the Yakutat Bay, Prince William Sound, and Copper River regions as well as construction camps and waypoints along the route of the Copper River Railroad (Fig. 10).

2.2.5 1911 Alaska

The 1911 expedition, funded again by the National Geographic Society, was the most wide ranging of the Alaska

180 expeditions. While, Tarr, Martin, and the rest of the scientific party returned to a few previously visited sites around Prince William Sound, the overwhelming majority of locations had not been visited by Tarr or Martin. Members of the party spent time in Glacier Bay (Fig. 2), the Kenai Peninsula, and Prince William Sound before moving inland to the Wrangell Mountains. They then moved north into Interior Alaska, with stops at Fairbanks and other locations involved with gold mining. The group travelled up the Yukon River through Alaska and the Yukon (with a variety of stops including Dawson)

185 before reaching the headwaters of that river in British Columbia (Fig. 1). Scientific observations are presented in *Tarr and*

Martin (1912b; 1913). The digitized images also have the most variety of any of the expeditions: glaciers in southeast and southcentral Alaska, railways, mining operations, roadhouses in Interior Alaska, city streets in Fairbanks and Dawson, and small settlements along the Yukon River (Fig. 11).

190 2.2.6 Ithaca and Upstate New York

The collection also includes images from closer to Tarr's home in Ithaca, New York. Over [his](#) 20 years at Cornell, Tarr accumulated images of glacial landforms and other geological features (including waterfalls) from Ithaca and upstate New York. Tarr used his observations in a number of publications on glacial erosion, the development of glacial landforms, and the geology of New York including *Tarr* (1904), *Tarr* (1905a-d), and *Tarr* (1906a-b). Examples of digitized images
195 from upstate New York are shown in Fig. 12.

3 Description of Dataset

3.1 Original Material

The original photographs are in the form of prints, glass plates, lantern slides, or negatives. The photographic material was
200 placed by Tarr and his associates in individual paper envelopes with handwritten notes on the outside of the envelopes. As these envelopes were fragile due to age and not acid-free, the materials were re-housed in acid-free paper and stored with copies of the original envelopes. These materials are stored and publically accessible through the Cornell University Library Division of Rare and Manuscript Collections (RMC) as part of the Ralph Stockman Tarr Papers (collection number 14-15-92, 21 boxes) and the Oscar Diedrich von Engeln Papers (collection number 14-15-856, 18 boxes). Due to budget constraints,
205 we could not digitize all of the images, but focused on images of glaciers and glaciated landscapes from the Alaska and Greenland expeditions [as well as the materials that would produce the highest-quality images](#). There are [several hundred](#) other photographs in the RMC that were not digitized along with thousands of lantern slides housed at the Department of Earth and Atmospheric Sciences at Cornell University. [Not all of this material is suitable for digitization as the original materials in some cases have significantly degraded over the past century. Some of the remaining materials are prints or
210 duplicates of already scanned material. Most of the lantern slide subjects are not directly related to the topics covered by this paper.](#)

3.2 Digitization

215 The photographs were digitized at the Cornell University Library. Transparencies (positives, negatives, film and glass) were scanned on Epson 10000xl flatbed scanners outfitted with transparency units using custom negative holders. Scan resolution varied depending on the size of the original (900 - 1800 dpi). The images were scanned to 16B, Grayscale, uncompressed

tiff files. [Choosing optimal parameters for scanning was difficult as a number of the originals had degraded in quality over the years.](#) Care was taken to capture the white and black endpoints so as not to clip those values. Curve and level adjustments were made within the scan software at the time of scanning (epsonscan software, version 3.49A). After scanning there were additional curve adjustments made in Photoshop CS6 or CC2015 (version updated during project.) [Performing more of the initial curve adjustments within the scanner software reduced loss of the density range of the negatives during contrast adjustment.](#) A few images were scanned with multiple exposures [due to the poor condition of the](#) original image material and required more than one processing version to adequately show details of different parts of the negative or glass plate. Several of the original film negatives and glass plates have been smudged or cracked over the years. In these cases, no corrective image processing has been attempted, so these artifacts appear in the digitized versions. [Master images were saved as 16B layered tiffs with curve adjustment layers. The average file size of images in the collection is 135 MB. Uploaded access files are the full resolution tiffs.](#)

230 3.3 Data Availability

The digitized files (original size, [full resolution tiffs](#)) were uploaded [and](#) made available through the Cornell University Library digital collections in the collection called “Historic Glacial Images of Alaska and Greenland” (<http://digital.library.cornell.edu/collections/tarr>). The collection includes 1948 images with metadata, has a digital object identifier (<http://doi.org/10.7298/X4M61H5R>), and can be cited as Tarr and Cornell University Library (2014)). The photographs are believed to have no known U.S. copyright or other restrictions. The Library does not charge for permission to use such material and does not grant or deny permission to publish or otherwise distribute public domain material in its collections. As a matter of good scholarly practice, we recommend that patrons using Library-provided reproductions cite the Library, the doi, and this article as the source of reproductions.

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3.4 Metadata and Filenames

[All of the metadata for the images is compiled in Table S1 in the Supplemental Materials.](#) For each digitized image, the assigned filename follows a specific convention: a prefix (“tve” for Tarr and von Engeln), then either the expedition year (e.g. “exp1911”), the phrase “lanternslide”, or “Ithaca”, and finally the sequential photograph number. For example, the 18th photo from the 1911 Alaska Expedition would have the filename “tve_exp1911_018.tif”. For images scanned with multiple exposures, the duplicates have filenames with numerical suffixes but otherwise identical information. Most of the photographs had descriptions (titles or captions) written on the original envelopes and these have been transcribed as the title of each digitized images. For the lantern slides, the captions were written on the slide itself instead of the envelopes. In cases in which there was no title available, the image was given the title “No Label”. For a few cases where we had other

255 knowledge of the image subject, information on the likely location of the image was added. Besides the titles, a variety of other metadata is available for the images. For most photographs, the location or glacier name was included on the envelope or lanternslide. We were able to assign dates (either specific dates recorded on the envelopes or more general dates based on expedition diaries) to many of the images. The “work type” of the original image media is also recorded (film negative, glass plate, or print). [For most photographs, the location or glacier name was included on the envelope or lanternslide. In the metadata, we list both a general location \(e.g. Alaska, Canada, Greenland\) and a more specific location \(e.g. Glacier Bay\) as well as the name of the glacier \(if applicable\).](#) A very few of the envelopes or lantern slides included the name of the photographer – for example, several of the Greenland photographs have “(Martin)” in the title referring to J. O. Martin 260 (discussed above) and some of the lantern slides taken from other collections have the photographer’s name in the title (e.g., Reid, Haynes, Libbey). This information is retained in the title in the metadata when available. [The appropriate USGS Quadrangle topographic map or Natural Resources Canada topographic map for the images was assigned when available.](#)

265 [Beyond the metadata described above, which is listed with each image in the digital collection, additional information was compiled for some of the images. All of this information is included in Table S1 and brief descriptions of the additional fields can be found below.](#) The lantern slides had a systematic naming convention (e.g., most images fall into the “North America” or “Glacier” categories) and numbering system that was indexed in a hand-written ledger in the RMC that was used to find the slides for teaching and public presentations. In some cases, the envelope includes [additional notes about the images](#) that have not been included in the digital published metadata through the Cornell Library. For example, some 270 images included a letter grade for the quality of the image (A+ being the highest and D being the lowest), presumably assessed by Tarr or von Engeln. In some other images, these notes include the name of the photographer, or if the photograph is duplicated as a lantern slide set, the number of the lantern slide is given. [The approximate geographic \(in longitude and latitude\) location of the images is also given when possible. These positions could be taken as approximate locations only; in many cases a precise location is not possible without additional ground truthing. For example, some detailed descriptions of images \(e.g. “NE side Russell fiord, opposite Marble Point”\) allow more precise locations while others \(e.g. “Glacier Bay”\) only allow general locations. We do not attempt to precisely tag which part of a particular glacier is in an image; we assign one set of coordinates for each glacier and use those coordinates as the location for each occurrence of that glacier. For images that contain multiple points of interest, we assign coordinates based on the dominant feature.](#) Table S1 also includes a direct link to each image.

280 We have not edited the glacier names in the metadata – it is possible that some photos labelled to show a certain glacier do not actually include that glacier and it is also possible that photos that do not include the name of glacier could include one. In several instances, names of glaciers used by Tarr and his colleagues were either not official names or were names that were subsequently changed. In these cases, the glacier is indexed by the name used by Tarr and the currently accepted name 285 is listed in the tables and the supplemental metadata. For Greenland glaciers, our choice of accepted name was guided by

Bjork et al. (2015). [As noted above](#) each image was assigned a general region (designated a “region” in the metadata - e.g. Canada) and a more specific area (designated a “sub-region” in the metadata - e.g. Yukon) when possible (for some images, location information was too vague to assign a more specific area). Several issues arose while assigning place names. One concerned the fact that multiple locations (sometimes separated by significant distances) shared the same name. As an example, there were Serpentine Glaciers in Prince William Sound and Yakutat Bay in Alaska. In Greenland, there are multiple Nugsuak Peninsulas and Devil’s Thumbs. To make accurate location designations, we relied on locations of images taken within the same time frame, publications discussing the images and expeditions, and, in a few cases, field diary entries. For these locations, we have added information to clarify which place is being referred to in the image (e.g. Nuussuq Peninsula (Upernavik Archipelago). Another issue concerned spelling of place names. Image subjects and locations recorded by Tarr and his colleagues had variable spellings for the same place (e.g. Nugsauk, Nugssauk) that in some cases differ from the current commonly accepted spelling (e.g. Nuussauq). We did not standardize or otherwise change the spellings of the transcribed titles. For instances where a designated sub-region tag contained a variably spelled name, we used the current common spelling. Image titles also contained variable spellings of other words (e.g. fjord/fiord, canyon/canon); we left the spelling as it was transcribed.

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4. Complimentary Collections

The images discussed in this paper represent a unique addition to publically accessible imagery of glaciers and glacier landforms in Alaska and Greenland that are not available elsewhere, but there are other collections that provide complimentary imagery and information. Along with the expeditions discussed above, Lawrence Martin went on expeditions to Alaska without Tarr in 1904 (e.g., *Tarr and Martin*, 1906), 1910 (*Martin*, 1911; 1913b), and 1913 (*Martin*, 1913c). Photographs and field notebooks from these trips are part of the William O. Field Papers in the Alaska and Polar Regions Collections at the University of Alaska, Fairbanks. [Photographic prints from Tarr and Martin’s work are included in the Dora Keen Collection at the Anchorage Museum at Rasmuson Center.](#) [Thirty-five](#) photographs from Martin’s trips are part of the ~24,000+ images the National Snow and Ice Data Center (NSIDC)’s Glacier Photograph Collection (https://nsidc.org/data/glacier_photo/index.html, [National Snow and Ice Data Center, 2015](#)). The [University of Colorado at Boulder Libraries](#) (<https://www.colorado.edu/libraries/>) also have digitized versions of those 35 images and hold Martin’s field notebooks from the 1904, 1905, and 1906 Alaska expeditions [in the Roger G. Barry glaciology collection.](#) [The National Geographic image collection includes 22 images of Alaska taken by Oscar von Engel.](#) Tarr’s field notebooks from the 1896 Greenland expedition are in the RMC at Cornell. The RMC also includes a hard copy of the 1896 Greenland trip diary published by *Hoppin* (1897) that includes Tarr’s hand-written notes in the margins. Tarr’s field notebook from the 1905 Alaska expedition and his field notebook and personal diary from the 1906 Alaska trip are housed at the RMC. Von Engel’s 1906 trip diary and letters to his parents are also in the RMC. Field notebooks from Tarr and von Engel written during the 1909 Alaska expedition are at the RMC. None of these notebooks, letters, or diaries were digitized as part of this project. The NSIDC has scanned 19 pages of Tarr’s field notebook from August 1909 as well as the second half of Tarr’s

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320 field notebook from the 1911 Alaska expedition. In addition to the collection discussed in this paper, Cornell University
previously digitized about 20 images related to Tarr and von Engeln which are available [through the Digital Collections](https://digital.library.cornell.edu/)
(<https://digital.library.cornell.edu/>) as part of the [Images from the Rare Book and Manuscript Collections Oscar von Engeln](#)
[holdings](#).

325 **4 Conclusions**

The newly digitized dataset will have a variety of uses for researchers. The images are of scientific interest for
understanding glacier dynamics and ecological change, of public policy interest for documenting possible effects of climate
change, and of historic and anthropological interest for capturing daily life in remote regions at the turn of the 20th century.
The glacier images provide documentation of terminus positions and ice elevation and offer the possibility of ice volume
330 estimates. Most the glaciers featured in the digitized images have undergone significant change over the past century and
comparison of the information in the images to modern data will provide new or more robust estimates of the extent of this
change.

Data availability

335 The digitized files are available through the Cornell University Library digital collections in the collection called “Historic
Glacial Images of Alaska and Greenland” (<http://digital.library.cornell.edu/collections/tarr>) and can be cited as *Tarr and*
Cornell University Library (2014), <http://doi.org/10.7298/X4M61H5R>.

Author contributions

340 J. E. conceived of this project, and both [J.E. and M.P.](#) worked to collect the metadata, supervise undergraduate student
workers, secure funding, interact with Cornell Library staff to digitize the images and make them available online, and write
the article.

Competing interests

345 The authors declare that they have no conflict of interest.

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References

- 380 Alley, B.: Rivers of Ice: The Yakutat Bay Expedition of 1906, Outskirts Press, 93 pp., 2012.
- Anonymous: The National Geographic Society Alaskan Expedition, The National Geographic Magazine, June, p. 581-584, 1909.
- Bjørk, A. A., Kruse, L. M., and Michaelsen, P. B.: Brief communication: getting Greenland's glaciers right – a new data set of all official Greenlandic glacier names, *The Cryosphere*, 9, 2215-2218. <https://doi.org/10.5194/tc-9-2215-2015>, 2015.
- 385 Bjørk, A. A., Kjær, K. H., Korsgaard, N. J., Khan, S. A., Kjeldsen, K. K., Andresen, C. S., Box, J.E., Larsen, N.K. and Funder, S. V.: An aerial view of 80 years of climate-related glacier fluctuations in southeast Greenland, *Nature Geoscience*, 5, 427-432. <https://doi.org/10.1038/ngeo1481>, 2012.
- 390 Brice, W. R.: Ralph Stockman Tarr: Scientist, writer, teacher, Geological Society of America, Centennial Special Volume 1, p. 215-235, 1985.
- Brice, W., R.: Cornell Geology Through the years, College of Engineering, Cornell University, 230 pp., 1989.
- [Conner, C., G. Streveler, A. Post, D. Monteith, and W. Howell, The Neoglacial landscape and human history of Glacier Bay, Glacier Bay National Park and Preserve, southeast Alaska, USA, *The Holocene*, 19\(3\), 381-393, 2009.](#)
- 395 Gardner, A.S., Moholdt, G., Cogley, J.G., Wouters, B., Arendt, A.A., Wahr, J., Berthier, E., Hock, R., Pfeffer, W.T., Kaser, G. and Ligtenberg, S.R: A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009, *Science*, 340(6134), pp.852-857, 2013.
- 400 Hoppin, B.: A Diary Kept While with the Peary Arctic Expedition of 1896, (New Haven: n.p.) 80 pp., 1897.
- Koelsch, W.A.: William Libbey of Princeton: A Forgotten Geographer, *Middle States Geographer*, 49,1-8, 2016.
- Hill, E.A., J.R. Carr, C.R. Stokes, and G.H. Gudmundsson: Dynamic changes in outlet glaciers in northern Greenland from 1948-2015, *The Cryosphere*, 12, 3243-3263, doi:10.5194/tc-12-3243-2018, 2018.
- 405 Huntington, P.A.M.: Robert E. Peary and the Cape York Meteorites, *Polar Geography*, 1, 53-65, doi:10.1080/789609353, 2002.

- 410 Larsen, C. F., R. J. Motyka, J. T. Freymueller, K. A. Echelmeyer, and E. R. Ivins: Rapid viscoelastic uplift in southeast Alaska caused by post–Little Ice Age glacial retreat, *Earth Planet. Sci. Lett.*, 237, 548–560, doi:10.1016/j.epsl.2005.06.032, 2005.
- Larsen, C. F., R. J. Motyka, A. A. Arendt, K. A. Echelmeyer, and P. E. Geissler: Glacier changes in southeast Alaska and northwest British Columbia and contribution to sea level rise,
- 415 *J. Geophys. Res.*, 112, F01007, doi:10.1029/2006JF000586, 2007.
- Larsen, C. F., E. Burgess, A. A. Arendt, S. O'Neel, A. J. Johnson, and C. Kienholz: Surface melt dominates Alaska glacier mass balance, *Geophys. Res. Lett.*, 42, 5902–5908, doi:[10.1002/2015GL064349](https://doi.org/10.1002/2015GL064349), 2015.
- [Maness, J., R. Duerr, M. Dulock, F. Fetterer, G. Hicks, A. Merredyth, W. Sampson, A. Wallace, Revealing our melting past: Rescuing historical snow and ice data, *GeoResJ*, 14, 92-97, <https://doi.org/10.1016/j.grj.2017.10.002>, 2017.](https://doi.org/10.1016/j.grj.2017.10.002)
- 420 [Maness, J., R. Duerr, M. Dulock, F. Fetterer, G. Hicks, A. Merredyth, W. Sampson, A. Wallace, Revealing our melting past: Rescuing historical snow and ice data, *GeoResJ*, 14, 92-97, <https://doi.org/10.1016/j.grj.2017.10.002>, 2017.](https://doi.org/10.1016/j.grj.2017.10.002)
- Martin, L.: Alaskan earthquakes of 1899, *Bull. GSA*, vol. 21, pp. 339-406, 1910.
- Martin, L.: The National Geographic Society researches in Alaska: *The National Geographic Magazine*, v. 22, no. 6, p. 537–561, 1911.
- 425 Martin, L.: Alaskan Glaciers in Relation to Life. *Bull. Am. Geographical Soc.*, Vol. XLV, p. 801-818, 1913a.
- Martin, L.: Some features of glaciers and glaciation in College Fiord, Prince William Sound, Alaska: *Zeitschrift für Gletscherkunde*, v. 7, no. 5, p. 289–333, 1913b.
- 430 Martin, L.: "Juneau-Yakutat Section," *Guide Books of Excursions in Canada*, No. 10. (Twelfth International Geological Congress, Toronto, 1913.) Ottawa: Canadian Geological Survey, Pp. 121-76, 1913c.
- Meier, M., and A. Post: What are Glacier Surges?, *Canadian Journal of Earth Sciences*, 6:807-817, <https://doi.org/10.1139/e69-081>, 1969.
- 435 Meier, M. F., L. A. Rasmussen, R. M. Krimmel, R. W. Olsen, and D. Frank: Photogrammetric determination of surface altitude, terminus position, and ice velocity of Columbia Glacier, Alaska, *U.S. Geol. Surv. Prof. Pap.*, 1258-F, 41 pp., 1985.

- 440 Molnia B. F.: Late nineteenth to early twenty-first century behavior of Alaskan glaciers as indicators of changing regional climate. *Global Planet. Change*, **56**(1–2), 23–56 doi: 10.1016/j.gloplacha.2006.07.011, 2007.
- Molnia, B. F.: *Glaciers of North America – Glaciers of Alaska*, U.S. Geological Survey Professional Paper 1386-K, 2008.
- [National Snow and Ice Data Center \(comp.\). *Glacier Photograph Collection, Version 1*. \[Indicate subset used\]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: <https://doi.org/10.7265/N5/NSIDC-GPC-2009-12>, 2015.](#)
- 445 Plafker, G., & Thatcher, W.: Geological and geophysical evaluation of the mechanisms of the great 1899 Yakutat Bay earthquakes. *Active Tectonics and Seismic Potential of Alaska*, 215-236, 2008.
- Post, A.: Alaskan Glaciers: Recent Observations in Respect to the Earthquake-Advance Theory, 148, 3668, 366-368, DOI: 450 10.1126/science.148.3668.366, 1965.
- Post, A., S.O'Neel, R. J.Motyka, and G.Streveler: A complex relationship between calving glaciers and climate, *Eos Trans. AGU*, 92(37), 305, 2011.
- 455 Tarr, R. S.: The Cornell Expedition to Greenland, *Science*, v. 4, no. 93, 520-523, 1896.
- Tarr R. S.: Former extension of Cornell Glacier near the southern end of Melville Bay, *Bull. Geol. Soc. America*, 8, pp. 251-268, pls. 25-29, 1897a.
- 460 Tarr R. S.: The margin of Cornell glacier (Greenland) *Am. Geol.* 20, p. 139-156, pls. VI-XII, 1897b.
- Tarr R. S.: Former extension of ice in Greenland, *Science*, 5, pp. 804-805 (see also pg. 344), 1897c.
- Tarr. R. S.: The Arctic sea ice as a geological agent. *Am. J. Sci.*, 3(15), p. 223-229 (Also: Supplement 44, pp. 17,941-465 17,942), 1897d.
- Tarr R. S.: Difference in the climate of Greenland and American sides of Davis Strait and Baffin Bay, *Am. J. Sci*, 3, pp. 315-321, 1897e.
- 470 Tarr R. S.: Evidence of glaciation in Labrador and Baffin Land, *Am. Geol.*, 19 pp. 191-197., pl. X, 1897f.

- Tarr R. S.: Valley glaciers of the upper Nugusak peninsula, Greenland, *Am. Geol.* 19, pp. 262-267 pl. XV, 1897g.
- Tarr, R. S.: The glaciers of Greenland, *Sci. Am.* 76, pp. 216-217, 1897h.
- 475
- Tarr. R. S.: Rapidity of weathering and stream erosion in the Arctic latitudes. *Am. Geologist*, 131-136, 1897i.
- Tarr, R.S.: The Yakutat Bay region. U. S. Geol. Survey, Bull. No. 284, pp. 61-64, 1906a.
- 480 Tarr, R.S.: Second expedition to Yakutat Bay, Alaska. *Phlla. Geog. Soc. Bull.*, vol. 5, No. 1, Jan., pp. 1-14. Glacial erosion in Alaska. *Pop. Sci. Mon.*, vol. 70, No. 2, Feb.. 1007, pp. 09-110, 1907a.
- Tarr R. S.: Glacial erosion in Alaska, *Pop. Sci. Monthly*, 70, pp. 99-110, 1907b.
- 485 Tarr, R.S.: Recent advance of glaciers in the Yakutat Bay region, Alaska. *Bull. Geol. Soc. Am.*, vol. 18, pp. 257-286, 1907c.
- Tarr, R.S.: The Malaspina Glacier. *Amer. Geog. Soc. Bull.*, vol. 3, No. 5, May. 1007, pp. 273-285, 1907d.
- Tarr, R.S.: The advancing Malaspina Glacier: *Science*, v. 25, no. 627, p. 34-37, 1907e.
- 490
- Tarr, R.S.: Some phenomena of the glacier margins in the Yakutat Bay region, Alaska. *Zeitschr. Gletscher-Kuude*, Bd. 3, Heft 2. Dec., pp. 81-110, 1908.
- Tarr, R.S.: The Yakutat Bay region. Alaska. U. S. Geol. Survey. Professional Paper 64, 190. 183 pp., 1909.
- 495
- Tarr, R.S.: Oscillations of Alaskan glaciers. Abstract : *Science*, new ser., vol. 32, Aug. 5, pp. 185-186. Abstract and discussion : *Bull. Geol. Soc. Am.*, vol. 21, No. 4, 1010, pp. 758-759, 1910.
- Tarr, R. S.: The theory of advance of glaciers in response to earthquake shaking. *Zeitschrift fur Gletscherkunde*. Band V. p. 1-35, 1910.
- 500
- Tarr, R. S.: The glaciers and glaciation of Alaska, *Science*, 35, pp. 241-258. (Same title in *Annals, Assn. Amer. Geog* 2, pp. 3--24), 1912.

- 505 Tarr, Ralph Stockman & Cornell University Library: Historic Glacial Images of Alaska and Greenland from the Ralph Stockman Tarr expeditions (1896; 1905-1911). Cornell University Library. doi.org/10.7298/X4M61H5R, 2014.
- Tarr, R.S., and Martin, L.: Recent change of level in Alaska, *Science*, v. 22, n. 574, pp. 879-880, 1905.
- 510 Tarr R. S., and Martin, L.: Recent Changes of Level in the Yakutat Bay Region, Alaska. *Bull of GSA*, Vol. 17, p. 29-64, 1906a.
- Tarr, R.S., and Martin, L.: Recent change of level in Alaska. *Geog. Jour.*, July, pp. 30-43, 1906b.
- 515 Tarr, R.S., and Martin, L. Glaciers and glaciation of Yakutat Bay, Alaska. *Am. Geog. Soc. Bull.*, vol. "8, 1906, pp. 145-167, 1 plate, figs. 24. Abstract : *Ibid.*, vol. 38, No. 2. Feb., pp. 99-101, 1906c.
- Tarr, R. S. and Martin, L., Position of Hubbard Glacier front in 1792 and 1794. *Am. Geog. Soc. Bull.*, vol. 39, No. 3. March, 520 pp. 129-136, 1907.
- Tarr, R.S., and Martin, L.: The National Geographic Society's Alaskan Expedition of 1909: The National Geographic Magazine, v. XXI, no. 1, p. 1-53, 1910.
- 525 Tarr, R. S., and Martin, L.: The earthquakes of Yakutat Bay, Alaska in September 1899, *U.S. Geol. Surv. Prof. Pap.*, 69, 135 pp., 1912a.
- Tarr, R.S., and Martin, L.: An Effort to Control a Glacial Stream, *Annals of the Association of American Geographers*, Vol. 2, pp. 25-40, 1912b.
- 530 Tarr R. S., and Martin, L.: Glacial Deposits of the Continental Type in Alaska, *J Geology*, Vol. XXI, No. 4., 289-300, 1913.
- Tarr, R.S., and Martin, L.: Alaskan glacier studies of the National Geographic Society in the Yakutat Bay, Prince William Sound and lower Copper River regions: Washington, D.C., National Geographic Society, 498 p., 1914.
- 535 Tarr, R. S. and Cornell University Library: Historic Glacial Images of Alaska and Greenland from the Ralph Stockman Tarr expeditions (1896; 1905-1911), Cornell University Library, doi.org/10.7298/X4M61H5R, 2014.

von Engeln, O. D.: Some Alaskan Days -- and nights: Cornell Era, Dec., p. 122-124, 1906.

540

von Engeln, O. D.: An Alaskan wonderplace: Outlook, v. 86 May 25, p. 169-180, 1907a.

von Engeln, O. D.: The photographic equipment of a sub-arctic exploring party, Photo-Era, October, 1907.

545 von Engeln, O.D.: Photography in glacial Alaska: The National Geographic Magazine, v. 21, no. 1, p. 54-62, 1910.

von Engeln, O.D.: Phenomena associated with glacier drainage and wastage with especial reference to observations in the Yakutat Bay Region, Alaska, Reprinted from Zeitschrift für Gletscherkunde, Band VI, Heft 2, 1911.

550 Wessell, P., W.H.F. Smith, R. Scharroo, J.F. Luis, and F. Wobbe, Generic Mapping Tools: Improved version released, *EOS Trans. AGU*, 94, 409-410, 2013.

555

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565

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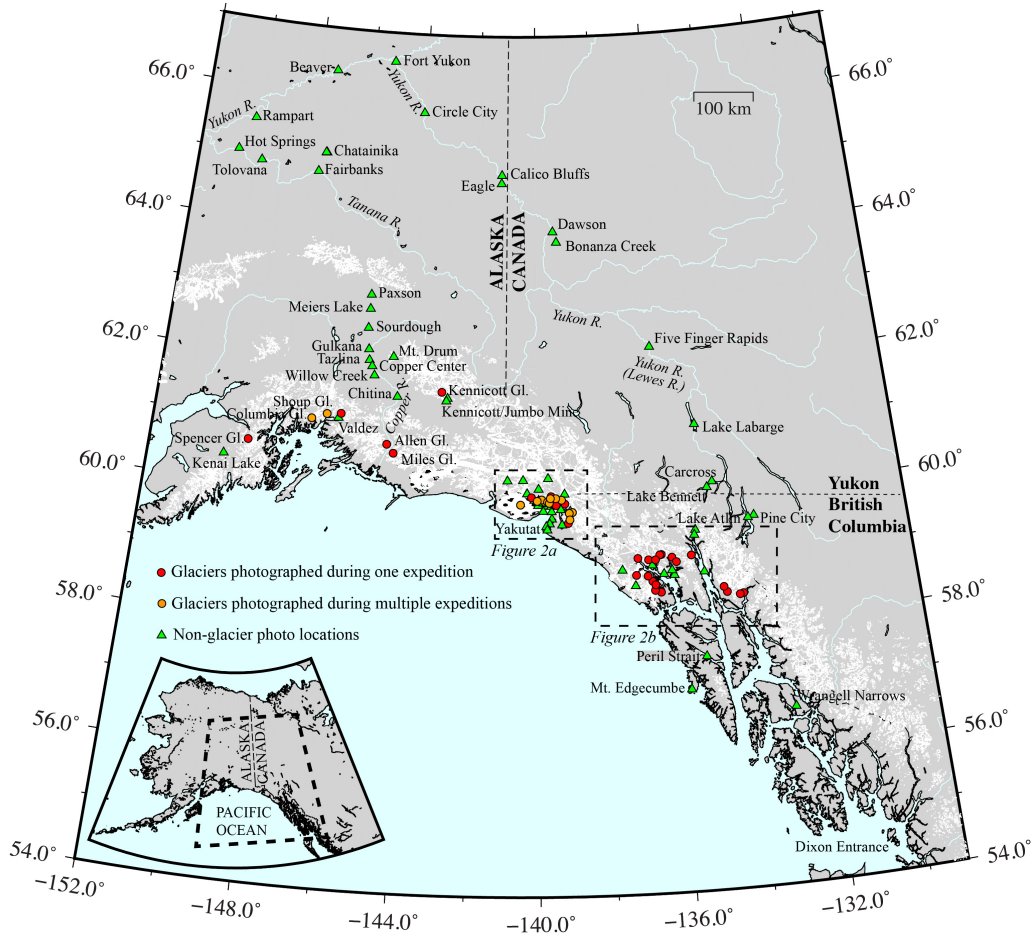
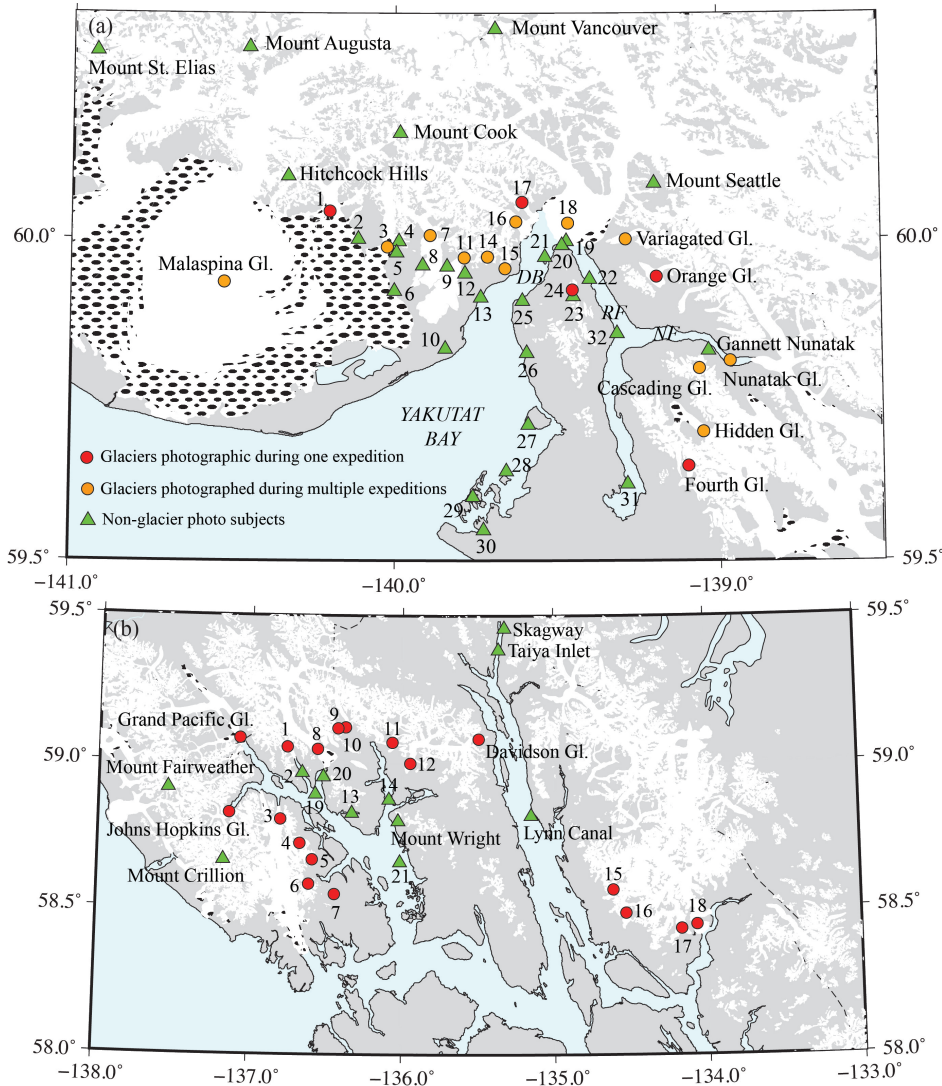


Figure 1. [Locations visited during expeditions to Alaska between 1905 and 1911.](#)



590 Figure 2. Sites visited in southeast Alaska. (a) Sites visited in Yakutat Bay. DB is Disenchantment Bay, RF is Russell Fjord, and NF is Nunatak Fjord. Numbered locations are: 1. Marvine Gl. 2. Blossom Island 3. Hayden Gl. 4. Floral Hills 5. Floral Pass 6. Kwik Stream 7. Lucia Gl. 8. Lucia Stream 9. Terrace Point 10. Strawberry Island 11. Atrevida Gl. 12. Amphitheater Knob 13. Esker Stream 14. Galianao Gl. 15. Black Gl. 16. Turner Gl. 17. Haenke Gl. 18. Hubbard Gl. 19. Osier Island 20. Gilbert Point 21. Haenke Island 22. Marble Point 23. Mt. Alexander 24. Alexander Gl. 25. Indian Camp 26. Logan Beach 27. Knight Island 28. Otmeloi Island 29. Khantaak Island 30. Yakutat 31. Cape Stoss 32. Cape Enchantment (b) Sites visited in Glacier Bay. Numbered locations are: 1. Rendu Gl. 2. Rendu Inlet 3. Reid Gl. 4. Hugh Miller Gl. 5. Charpentier Gl. 6. Geike Gl. 7. Wood Gl. 8. Carroll Gl. 9. Morse Gl. 10. Muir Gl. 11. McBride Gl. 12. Casement Gl. 13. Tidal Inlet 14. Muir Inlet 15. Herbert Gl. 16. Mendenhall Gl. 17. Norris Gl. 18. Taku Gl. 19. Russell Island 20. Triangle Island 21. N. Marble Island

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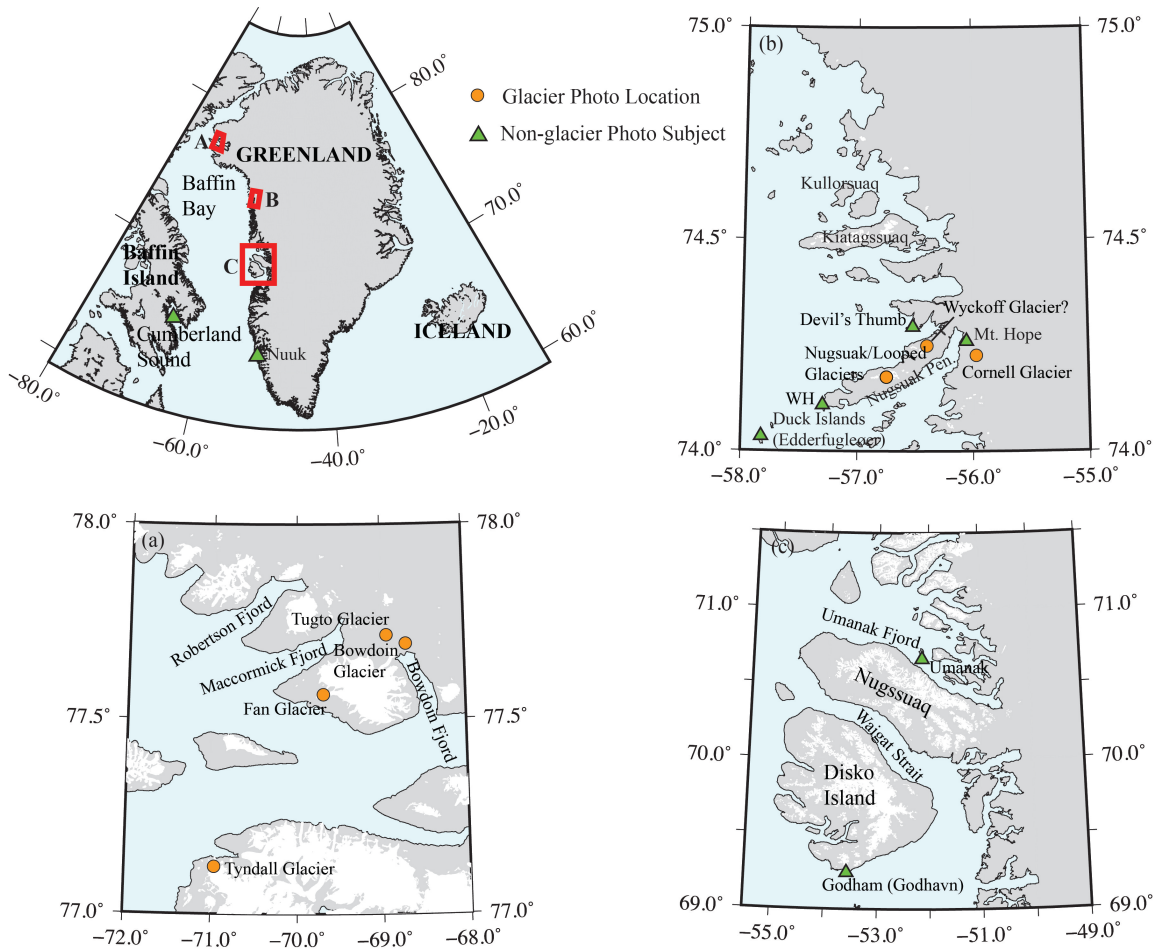
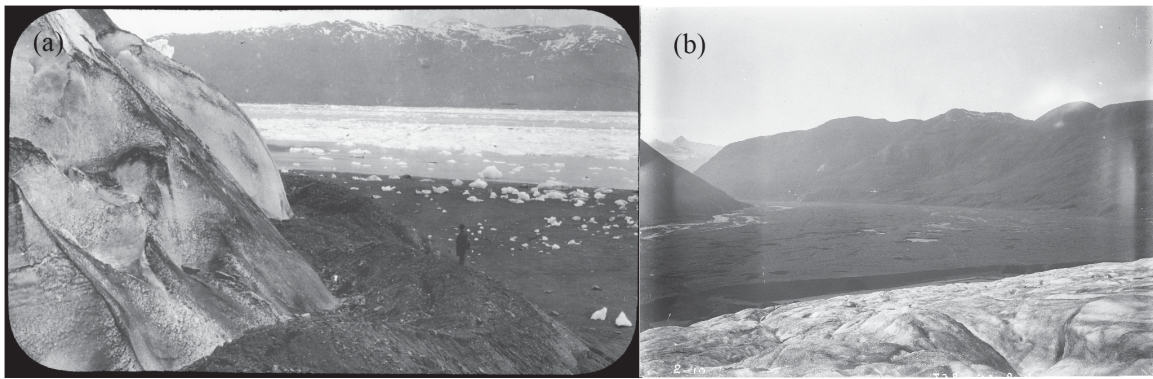


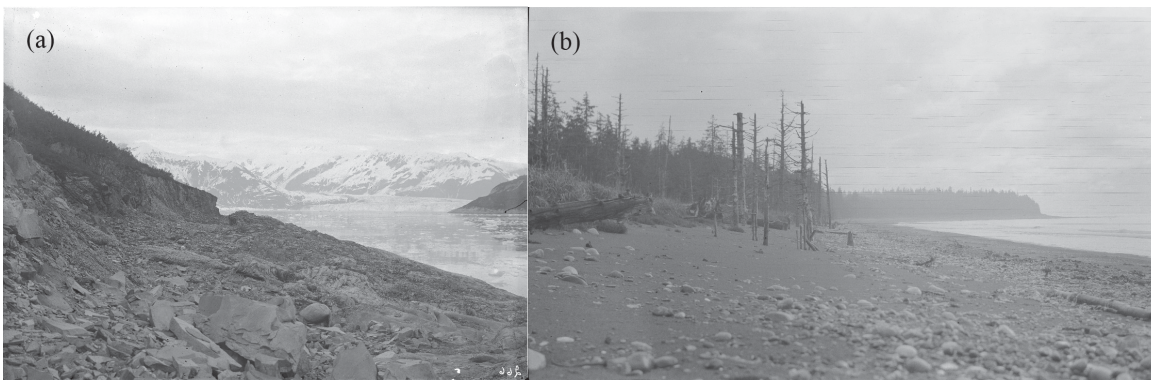
Figure 3. [Sites visited in Greenland.](#) (a) [Site locations in the Qaanaaq region.](#) (b) [Site locations in the Upernavik Archipelago region.](#) (c) [Site locations in the Disko Bay region.](#)

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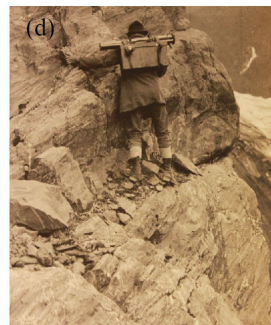
615 [Figure 4. Examples of photographs of glacial features. \(a\) Push moraine at front of Columbia Glacier \(note person for scale\)](#)
 (ID: [tve_lanternslide_0004](#)). (b) [Kettles in outwash plain of Hidden Glacier \(ID: tve_exp1905_162\)](#).

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625 [Figure 5. Photographs showing effects of 1899 earthquakes. \(a\) Wave cut bench and sea cliff on east shore of Haenke Island](#)
 uplifted during earthquakes. (ID: [tve_exp1906_183](#)). (b) [Trees on Khantaak Island killed by submergence in salt water due](#)
 to earthquakes (ID: [tve_exp1909_325](#)).

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660 **Figure 6.** [Figure 6. Equipment and field conditions. \(a\) Camera used in the Alaska expeditions. \(b\) Close up of camera front. \(c\) Expedition party traversing glacier in Alaska. \(d\) Expedition member with photography gear traversing cliff. \(e\) Scientific party and camera set up, Russell Fjord, Alaska. \(ID: tve_exp1909_002a\). \(f\) Example of panoramic image, Columbia Glacier, Alaska \(ID: tve_exp1909_035\).](#)

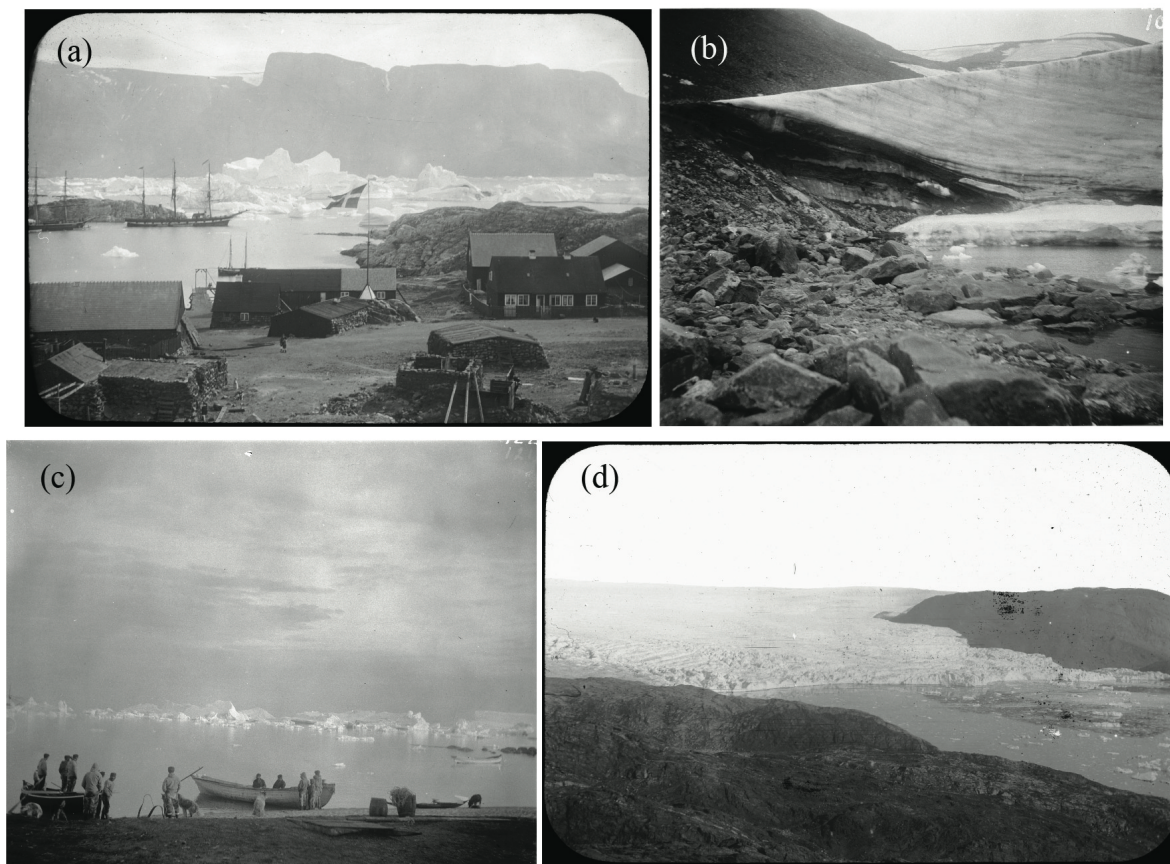
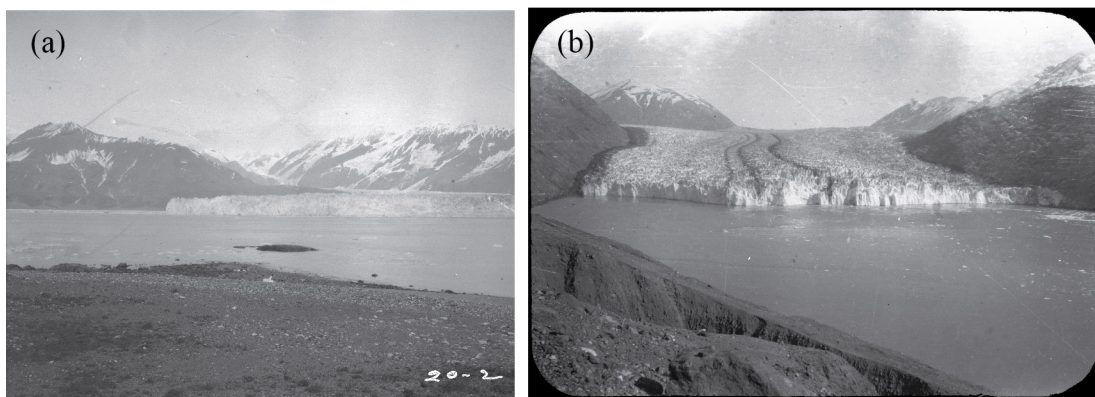


Figure 7. [Digitized images from Greenland. \(a\) Icebergs in harbor of Umanak \(Uummannaq\) \(ID: tve_lanternslide_0173\).](#)
[\(b\) Terminus of Nugsuak Glacier. \(ID: tve_exp1896_147\).](#) (c) [Icebergs in Waigat Strait. \(ID: tve_exp1986_186\).](#) (d) [North](#)
 670 [Cornell Glacier. \(ID: tve_lanternslide_0090\).](#)

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685 | Figure 8. [Digitized images from the 1905 Alaska expedition.](#) (a) [Hubbard Glacier from Osier Island \(ID: tve_exp1905_100\).](#)
(b) [Terminus of Nunatak Glacier \(ID: tve_lanternslide_0264\).](#)

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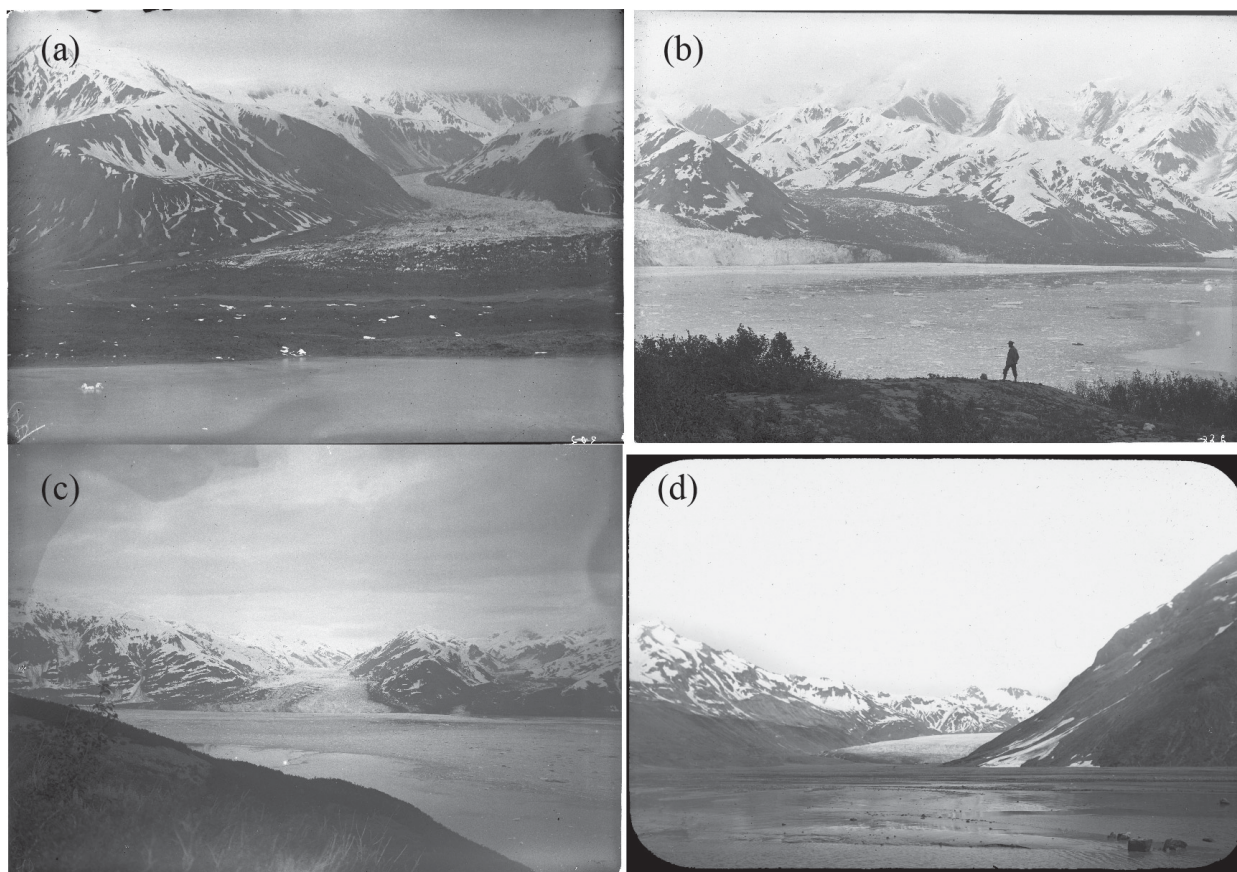


Figure 9. [Digitized images from the 1906 Alaska expedition](#). (a) [Variegated Glacier from Gilbert Point \(ID: tve_exp1906_219\)](#). (b) [Turner and Haenke Glaciers from Haenke Island \(ID: tve_exp1906_205_02\)](#). (c) [Turner Glacier from Gilbert Point \(ID: tve_exp1906_213\)](#). (d) [Hidden Glacier and outwash plain \(ID: tve_lanternslide_0267\)](#).

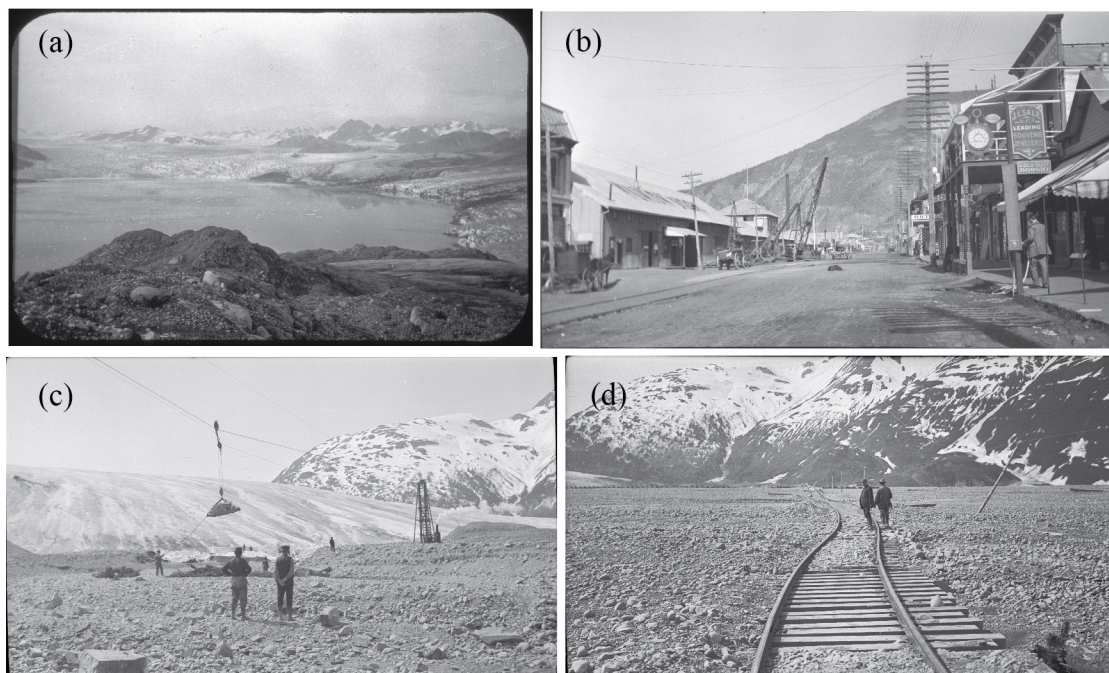
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720 Figure 10. [Digitized images from the 1909 Alaska Expedition. \(a\) Shoup Glacier terminus. \(ID: tve_exp1909_032\).](#) (b) [Miles Glacier and Copper River Railroad. \(ID: tve_exp1909_041\).](#)

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735 Figure 11. [Digitized images from the 1911 Alaska expedition. \(a\) Muir Glacier. \(ID: tve_lanternslide_0025\).](#) [\(b\) Street in Dawson, Yukon. \(ID: tve_exp1911_042\).](#) [\(c\) Effort to build diversion dam for Spencer Glacier Stream. \(ID: tve_exp1911_030\).](#) [\(d\) Tracks displaced by Spencer Glacier outlet stream. \(ID: tve_exp1911_020\).](#)



Figure 12. Figure 12. Digitized images from the Ithaca area. (a) Ridge of an esker, McLean, NY (ID: tve_ithaca_07). (b). Taughannock Falls in 1888. (ID: tve_ithaca_02).

Expedition/Year	Approximate number of photos	Examples of key geographic locations
1896	374	Labrador and Baffin Land, Canada; Nugsuak Peninsula, Waigat Strait, Disko Island, and Umenak Fjord, Greenland
1905	198	Yakutat Bay and steamer ride from Seattle
1906	264	Yakutat Bay and steamer ride from Seattle
1909	582	Yakutat Bay, eastern Prince William Sound, Kenai Peninsula, lower Copper River, coastal southeast Alaska , Inside Passage to Seattle
1911	356	Prince William Sound, Kenai Peninsula, Wrangell Mountains, Interior Alaska (including Fairbanks and several mining towns), Yukon Territory, northern British Columbia, Glacier Bay, Inside Passage to Seattle
Lantern slides/ various years	308	Alaska, Canada, Greenland, Antarctica.
Ithaca/ 1888- 1928	54	Waterfalls and glacial landforms around Ithaca, New York

Table 1. Summary of digitized photographs.

Glacier	Region	Years of Photos in Collection	# of Photos in Collection	# of Photos of Terminus**	Multiple Viewpoints^^	Large Area###
Columbia	Prince William Sound	1909, 1911	79	12	Yes	Yes
Spencer	Prince William Sound	1911	40	5	No	No
Shoup	Prince William Sound	1909, 1911	33	6	Yes	Yes
Valdez	Prince William Sound	1909	30	5	No	No
Catspaw*	Prince William Sound	1909	1	-	-	-
Miles	Chugach Mts.	1909	17	4	No	No
Allen (Baird)^	Chugach Mts.	1909	13	-	-	-
Kennicott	Wrangell Mts.	1911	15	-	-	Yes
Hubbard	Yakutat	1905, 1906, 1909	105	28	Yes	Yes
Turner	Yakutat	1905, 1906, 1909	66	16	Yes	No
Haenke	Yakutat	1906	1	1	No	Yes
Galiano	Yakutat	1905, 1906, 1909	16	-	-	-
Atrevida	Yakutat	1905, 1906, 1909	51	2	No	Yes
Variiegated	Yakutat	1905, 1906, 1909	44	4	No	No
Cascading	Yakutat	1905, 1906, 1909	6	-	-	-
Nunatak	Yakutat	1905, 1906, 1909	82	28	Yes	Yes
Hayden	Yakutat	1905, 1906, 1909	27	-	-	-
Malaspina	Yakutat	1905, 1906, 1909	24	2	No	Yes
Lucia	Yakutat	1905, 1906, 1909	30	5	No	Yes
Hidden	Yakutat	1905, 1906, 1909	79	26	Yes	Yes
Marvine	Yakutat	1906	31	-	-	-
Alexander	Yakutat	1906	1	-	-	-
Orange	Yakutat	1906	7	1	No	No
Fourth (Beasley)#	Yakutat	1909	18	5	Yes	No
Black	Yakutat	1905, 1909	2	-	-	-
Haenke	Yakutat	1909	4	2	No	No
Flat*	Yakutat	1905	4	-	-	-
Serpentine*	Yakutat	1905	3	-	-	-
Fallen†	Yakutat	1905	1	-	-	-
Muir	Glacier Bay	1911	28	6	Yes	Yes
McBride	Glacier Bay	1911	4	1	No	No
Casement	Glacier Bay	1911	1	-	-	-
Morse	Glacier Bay	1911	1	1	No	No
Rendu	Glacier Bay	1911	11	4	No	No
Wood	Glacier Bay	1911	2	2	No	No
Davidson	Glacier Bay	1911	4	2	No	No
Hugh Miller	Glacier Bay	1911	8	3	No	No
Carroll	Glacier Bay	1911	3	2	No	No
Grand Pacific	Glacier Bay	1911	2	2	No	No
Johns Hopkins	Glacier Bay	1911	3	-	-	-
Reid	Glacier Bay	1911	2	2	No	No
Charpentier	Glacier Bay	1911	6	3	No	No
Geikie	Glacier Bay	1911	2	1	No	No
White§	Glacier Bay	Not listed	1	1	No	No
Favorite	Glacier Bay	1911	3	-	-	-
Girdled§	Glacier Bay	Not listed	1	-	-	-
Taku	Juneau	1911	7	4	No	No
Norris	Juneau	1911	3	-	-	-
Herbert	Juneau	1911	1	-	-	-
Mendenhall	Juneau	1911	1	-	-	-

* Location and identification uncertain

^ Tarr referred to this glacier as Baird; the later accepted name is Allen

Tarr used both names for this glacier in the photos; the accepted name is Fourth

‡ Tarr and Martin (1914) reported that this glacier slid into the Disenchantment Bay on July 4, 1905, causing a local tsunami

§ Glacier only appears in a photo by H. Reid on a lantern slide

** To be counted in this category, the photo had to show the majority of the terminus region

^^ At least three viewpoints of terminus region (e.g. front view and angled from each side)

Photos (either as a single photo or collectively) show at least 5 km of the glacier from the terminus region

Table 2. Alaska Glacier Photographs in Collection

Glacier*	Region	Year of Photos	# of Photos	# of Photos of Terminus**	Multiple Viewpoints^^	Large Area##
Cornell <i>(Ikissuup Sermersua)</i>	Nuussuaq Peninsula - Upernavik Archipelago	1896	88	11	No	No
Wyckoff	Nuussuaq Peninsula - Upernavik Archipelago	1896	3	-	-	-
Nugsuak [#] <i>(Sermikavsak?)</i>	Nuussuaq Peninsula - Upernavik Archipelago	1896	12	-	-	-
Bowdoin [^] <i>(Kangerluarsuup Sermia)</i>	Qaanaaq	1894 or 1899	10	1	No	Yes
Tuktoo (Tugto) [^] <i>(Tuttu)</i>	Qaanaaq	1894 or 1899	1	-	-	-
Fan [^] <i>(Fan)</i>	Qaanaaq	1894 or 1899	1	-	-	-
Robertson [^]	Qaanaaq	1894 or 1899	1	1	No	No
Tyndall [^] <i>(Tyndall)</i>	Qaanaaq	1894 or 1899	1	1	No	No

* Regular type gives name of glacier as known to the photographer at the time the image was acquired. Italic type gives Greenlandic name or name it is commonly known as today.

[#]Variably spelled as Nugsuak or Nugssuak in collection materials

[^] Only appears as photos by Libbey on lantern slides

^{**} To be counted in this category, the photo had to show the majority of the terminus region

^{^^} At least three viewpoints of terminus region (e.g. front view and angled from each side)

^{##} Photos (either as a single photo or collectively) show at least 5 km of the glacier from the terminus region

Table 3. Greenland Glacier Photographs in Collection