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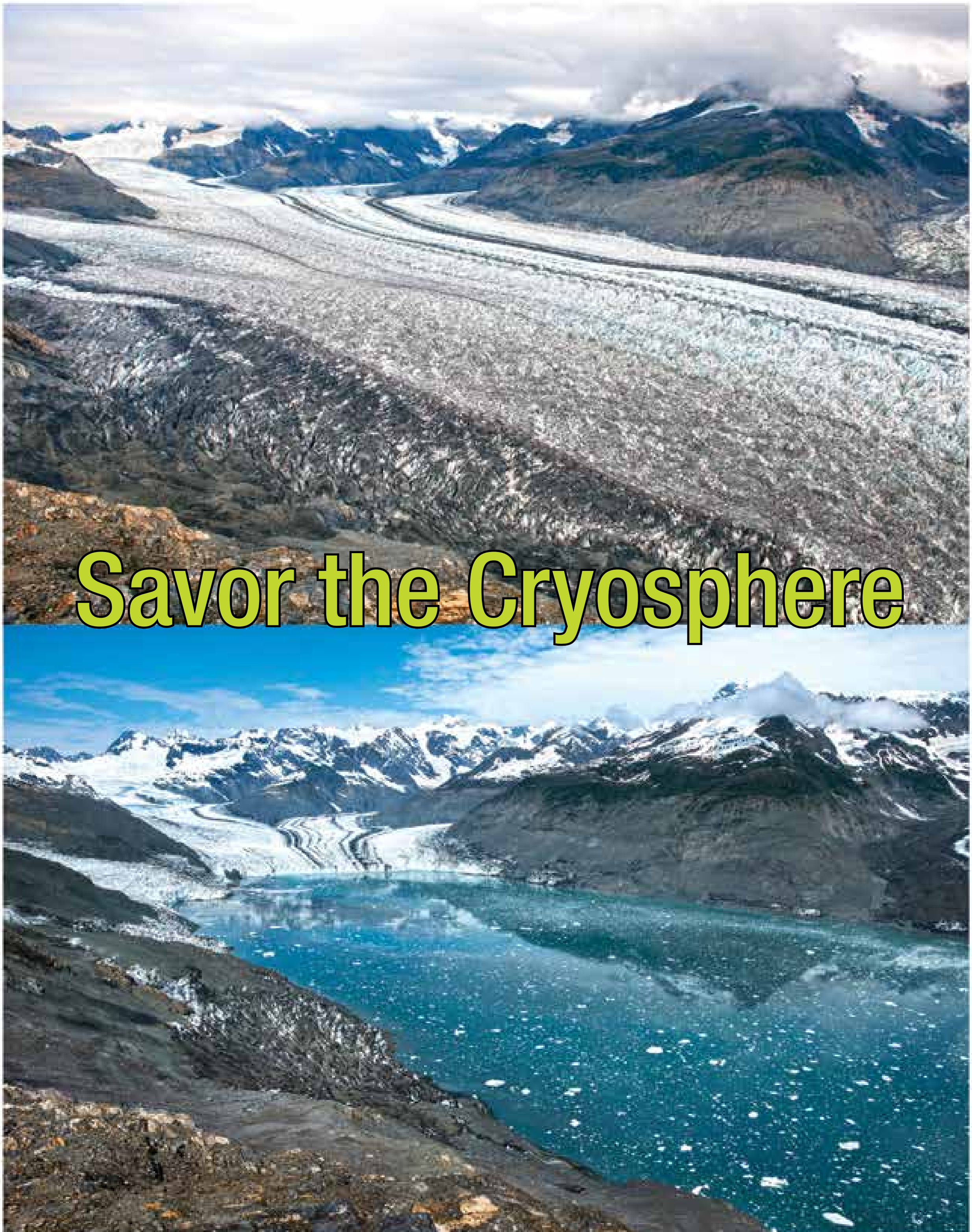
Savor the Cryosphere



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SCIENCE

Cover: Retreat of the Columbia Glacier, Alaska, USA, by ~6.5 km between 2009 and 2015. Photo credit: James Balog and the Extreme Ice Survey. See related article, p. 4–11.

GSA 2017 Annual Meeting & Exposition

GSA News

Cover inset image: Seattle Art Museum, 1300 1st Ave., Seattle, Washington, USA.

Savor the Cryosphere

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ABSTRACT

This article provides concise documentation of the ongoing retreat of glaciers, along with the implications that the ice loss presents, as well as suggestions for geoscience educators to better convey this story to both students and citizens. We present the retreat of glaciers—the loss of ice—as emblematic of the recent, rapid contraction of the cryosphere. Satellites are useful for assessing the loss of ice across regions with the passage of time. Ground-based glaciology, particularly through the study of ice cores, can record the history of environmental conditions present during the existence of a glacier. Repeat photography vividly displays the rapid retreat of glaciers that is characteristic across the planet. This loss of ice has implications to rising sea level, greater susceptibility to dryness in places where people rely upon rivers delivering melt water resources, and to the destruction of natural environmental archives that were held within the ice. Warming of the atmosphere due to rising concentrations of greenhouse gases released by the combustion of fossil fuels is causing this retreat. We highlight multimedia productions that are useful for teaching this story effectively. As geoscience educators, we attempt to present the best scholarship as accurately and eloquently as we can, to address the core challenge of conveying the magnitude of anthropogenic impacts, while also encouraging optimistic determination on the part of students, coupled to an increasingly informed citizenry. We assert that understanding human perturbation of nature, then choosing to engage in thoughtful science-based decision-making, is a wise choice. This topic comprised "Savor the Cryosphere," a Pardee Keynote Symposium at the 2015 Annual Meeting in Baltimore, Maryland, USA, for which the GSA recorded supporting interviews and a webinar.

INTRODUCTION

The cryosphere is the portion of Earth that is frozen, which includes glacial and periglacial environs on land, where ice, permafrost, or snow cover dominate, as well as ice-covered sea. Geographically, arctic regions and the higher elevation portions of alpine regions at lower latitudes are included. We assert that the retreat of glaciers—the loss of ice—is emblematic of the recent, rapid contraction of the cryosphere. Because relatively few people visit such places due to their remoteness, we note the difficulty that many non-specialists have in recognizing the scope of this issue. Our response is to explain ice loss in tangible terms that feature multimedia, as well as to provide geoscience educators with information for doing so themselves. We presented this topic as "Savor the Cryosphere," a Pardee Keynote Symposium at the 2015 Annual Meeting of the GSA in Baltimore, Maryland, USA. Archival interviews are available at https://www.youtube.com/watch?v=d1-jzYuea9E, and a webinar is available at https://attendee.gotowebinar.com/recording/5467381313092358658 (no charge to register to see the information). Our approach here is to document glacial retreat, noting that rising air temperature is the principal cause of it (coupled with warming sea water and changes in ocean currents in areas with tidewater glaciers), then to review the implications of ice loss, and finally to present the legacy that the loss of ice will pass to the future. The extent of ice can be measured by satellites or by ground-based glaciology. While we provide a brief assessment of the first method, our focus on the latter is key to informing broad audiences of non-specialists. The cornerstone of our approach is the use of repeat photography so that the scale and rate of retreat are vividly depicted. Science is grounded in observation, so science education will benefit from displaying the recently exposed landscapes. We close by prompting people to value the cryosphere and to recognize the consequences of fossil fuel consumption.

RETREAT OF GLACIERS

Earth is losing ice. The instances of glacial retreat far exceed those of advance. Zemp et al. (2015) reported glaciological and geodetic observations of over 5,200 glaciers from nineteen regions around the world, showing that the rates of early twenty-first–century ice mass loss are without precedent, at least for the few-century observational period. The compilation of Zemp et al. (2008) shows that, since 1900, retreating glaciers have been more common than advancing ones (see http://www.grid.unep.ch/glaciers/img/5-1.jpg). These inventories are based upon a variety of different approaches to measurement; hence, we present both remote and close observation.

Space-Based Observation

Satellites are useful for studying glaciers for many reasons. Ice loss can be assessed by repeat gravimetry, which quantifies changes in ice mass, or by altimetry, which contributes to measuring changing surface elevation, coupled together with repeat

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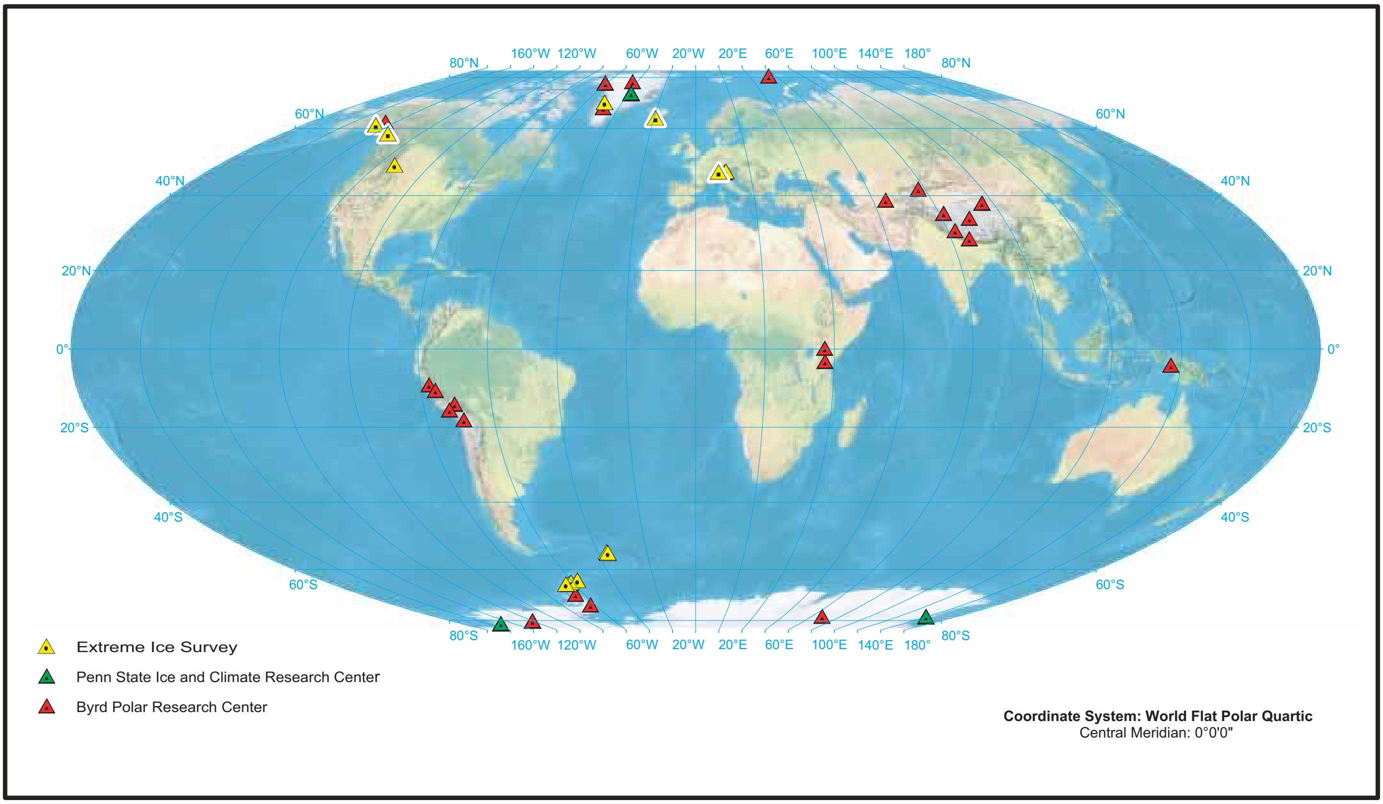

Figure 1. Global distribution of glaciers studied by the co-authors.

imagery that displays changes in coverage area (Gardner et al., 2013). As we shall see, comparison between results determined by various tools lends confidence to the findings. Remote sensing is advantageous because glaciated terrain is remote and difficult to access (Luthcke et al., 2008). Kääb (2008) also notes that spaceborne techniques are sustainable for global-scale monitoring of glaciers because satellites can remain operational for decades.

These observations provide robust documentation of ice loss. Arendt et al. (2013) reported a mass-balance for glaciers in the Gulf of Alaska of −65 ± 11 Gt/a from 2003 to 2010 from the Gravity Recovery and Climate Experiment (GRACE), which compared well with their determination of −65 ± 12 Gt/a from the Ice, Cloud, and land Elevation Satellite (ICESat) based upon glacier elevation changes. Kääb (2008) compared a digital elevation model from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite optical stereo to elevation data from ICESat and an earlier topographic map to report elevation change at two ice caps in eastern Svalbard of −0.55 or −0.61 m/a between 1970 and 2002 (ASTER) and 2006 (ICESat), respectively. Kääb et al. (2012) used satellite laser altimetry and a global elevation model to report widespread loss of ice in the Himalayas. While one recent study suggested slight growth of the Antarctic ice sheet as an ongoing response to the increase in snowfall at the end of the last ice age (Zwally et al., 2015), a study using a wider range of analytical techniques (Shepherd et al., 2012) indicates shrinkage at both poles. Several additional studies as summarized by Scambos and Shuman (2016) support and extend the record of Antarctic mass loss. Jacob et al. (2012) used GRACE results to calculate global ice change of −536 ± 93 Gt/a between 2003 and 2010 by summing the mass balance of twenty glaciated regions around the planet. Thus, satellites are very useful for assessing changes in glaciers, both regionally and over time.

Land-Based Glaciology

Our documentation of ice loss, like that of other groups working on this problem, integrates art with science, by focusing upon glaciologic study that is enriched through photography. Figure 1 displays the global network of monitoring completed by the co-authors' collaborators. The authors assess findings from six continents, where inquiry spans the study of ice sheets, ice caps, and mountain glaciers. The researchers at the Byrd Polar and Climate Research Center (BPCRC) and Penn State Ice and Climate Exploration have extracted, or helped to extract, ice cores at the sites indicated. The ice cores provide histories of annual net balance and of precipitation chemistry. The Extreme Ice Survey provides extensive archives of time-lapse photography for a multitude of glaciers, which reveal changes in the lateral extent and thickness of ice.

Examples of ice loss are abundant and well documented. Since 1974, investigators at the BPCRC have monitored glaciers in South America, Africa, and Asia. In Tanzania, the total surface area of the ice fields on top of Mount Kilimanjaro decreased by 88.3% from 1912 to 2013; however, the rate of retreat has recently accelerated—from 2000 to 2013, they decreased by 40%. The three remaining ice fields on its summit and slopes are also losing volume vertically at a rate of 0.5 m/a (Thompson et al., 2009, 2011). In Papua, New Guinea, several small glaciers exist in the vicinity of Puncak Jaya. From 1850 to 2005, their total surface area decreased from 19.3 km^2 to 1.72 km^2, representing a 91% loss (Kincaid, 2007). From 2000 to 2002 alone, surface area decreased from 2.326 km^2 to 2.152 km^2, or by 7.48% (Klein and Kincaid, 2006). The rate of retreat accelerated from 1988 to 2005, even while precipitation (partly as rain) actually increased (Kincaid, 2007). When ice contracts in area and thickness, the ice within the glacier can also be affected by melting. Snow pits and cores at the Quelccaya ice cap in southern Peru reveal that since the late 1970s the seasonal oxygen isotopic ($\delta^{18}O$) variations have been homogenized by meltwater percolating through the top 20 to 30 m of firn. This homogenization compromises the long-term seasonally resolved record of past climate variations. This finding is consistent with analyses of shallow cores throughout the Cordillera Blanca of northern Peru (Davis et al., 1995). Radiocarbon dates from wetland plants exposed by the retreating margins of Quelccaya ice demonstrate that, for >~6,300 years, this ice cap has not been smaller than it is today (Thompson et al., 2013). Rapid retreat of the ice margin continues to expose such evidence.

Photography

Our collaboration features the work of the Extreme Ice Survey (EIS), a non-governmental organization founded to photograph the retreat of glaciers. Photo couplets of ice retreat have been both coincidentally and intentionally collected. Ernest Shackleton's expedition on HMS *Endurance*, for example, collected historic photos of the extent of ice on South Georgia that can be compared to modern photos (see https://vimeo.com/125634374). Figure 2 presents photo couplets of glacial retreat in Alaska, Iceland, Switzerland, and Peru, where lateral retreat and thinning are apparent. In a similar vein, the EIS has amassed >1.1 million images recorded by 43 cameras observing 24 glaciers in Alaska, the Rockies, the Andes, South Georgia, Antarctica, the Alps, Iceland, and the Himalayas. *Ice: Portraits of Vanishing Glaciers* (Balog, 2012) provides graphic evidence in print form. Such time-lapse imagery has also been assembled into videos that display ice retreat, such as "Extreme Ice" (https://www.youtube.com/watch?v=6scs-Q-Ut_E). The film *Chasing Ice* is critically acclaimed for its portrayal of glacial retreat. The film captured spellbinding imagery of perhaps the largest calving event ever witnessed, when Greenland's Ilulissat glacier discharged a section of its terminus that measured ~5 km wide, 1 km thick, and 1.5 km long.

CAUSES OF ICE LOSS

Extensive literature shows that the ongoing loss of mass from glaciers is being caused primarily by warming over those glaciers and that this warming is, in turn, being caused primarily by the rising CO_2 concentrations in the atmosphere. The reports of the Intergovernmental Panel on Climate Change (IPCC) provide useful starting points for understanding the linkage between temperature and the mass balance of a glacier (e.g., Lemke et al., 2007), and IPCC (2013) examines the history and causes of warming. Glaciers can respond to changes in accumulation of snowfall, seasonality of temperature, cloudiness, and other factors. The advance or retreat of a single glacier may be difficult to interpret without targeted studies, but literature summarized in these sources shows that for a large suite of glaciers ending on land, retreat is primarily driven by atmospheric warming.

Paleoclimate information contributes in fundamental ways to the strong evidence that warming temperature is the primary driver of the recent acceleration of ice retreat (Thompson et al., 2011, 2013). For example, evidence for warming is associated with ice retreat in the tropical Andes (Rabatel et al., 2013). Arendt et al. (2013) found that mean summer temperatures derived from ground and lower troposphere records were good predictors of GRACE-derived summer mass balances in Gulf of Alaska glaciers, capturing 59% and 72% of the variability. In the context of the ice retreat in New Guinea from 1972 to 1987, mean monthly atmospheric temperature was the only climate variable that changed in a statistically significant way (+0.24 °C; Klein and Kincaid, 2006). Warming is also seen throughout the Tibetan Plateau (now sometimes characterized as the Third Pole [TP]), where meteorological data show that surface temperatures are rising faster at higher elevations than at lower elevations (Liu and Chen, 2000). On average, the temperature on the TP has been increasing at a rate of 0.16 °C annually and 0.32 °C per decade during winter.

On decadal and longer time scales, climate models project that greenhouse-gas–forced warming will drive temperatures to rise faster with elevation, with this vertical amplification being greatest in the tropics due to feedbacks involving upper-tropospheric humidity, as well as snow albedo and surface-based and water-vapor feedbacks (Ramaswamy et al., 2006; Randall et al., 2007; Pepin et al., 2015). Results from general circulation models indicate that the combined water-vapor/lapse-rate feedback provides the largest positive radiative reaction and that this effect alone roughly doubles the warming in response to forcing by greenhouse gases. As a result, the projected changes in mean annual free-air temperatures show twice as much warming at higher elevations in the tropics as is predicted at Earth's surface generally (Bradley et al., 2006). These projections are consistent with the recently documented rise of the free-air 0 °C isotherm in the tropical atmosphere (Bradley et al., 2009). Furthermore, as more dark land surface is exposed, absorption of the intense higher-elevation radiation increases, thus accelerating the melting (Bradley et al., 2006).

Low- to mid-latitude glaciers are extremely susceptible to such warming. In accord with model predictions of warming, high-elevation tropical glaciers appear to be responding with an accelerating rate of glacier loss (Coudrain et al., 2005; Thompson et al., 2006). Smaller glaciers respond more rapidly to climate changes, and these mountain glaciers are generally much smaller than their polar counterparts. These ice masses are also particularly sensitive to small changes in ambient temperatures, because they already exist very close to the melting point.

We again emphasize that many environmental factors affect glaciers, and one glacier may change for many reasons. As glaciers shrink, the insulating effect of a debris cover that slows further melting may become more important, joining other factors influencing glaciers, some of which are mentioned above. Thus, proper characterization of ongoing trends requires monitoring of many glaciers in many places, together with targeted studies of selected glaciers to better characterize controls. Taken together, though, the full scholarship as summarized above gives high confidence that warming caused primarily by human release of greenhouse gases is causing the retreat of glaciers.

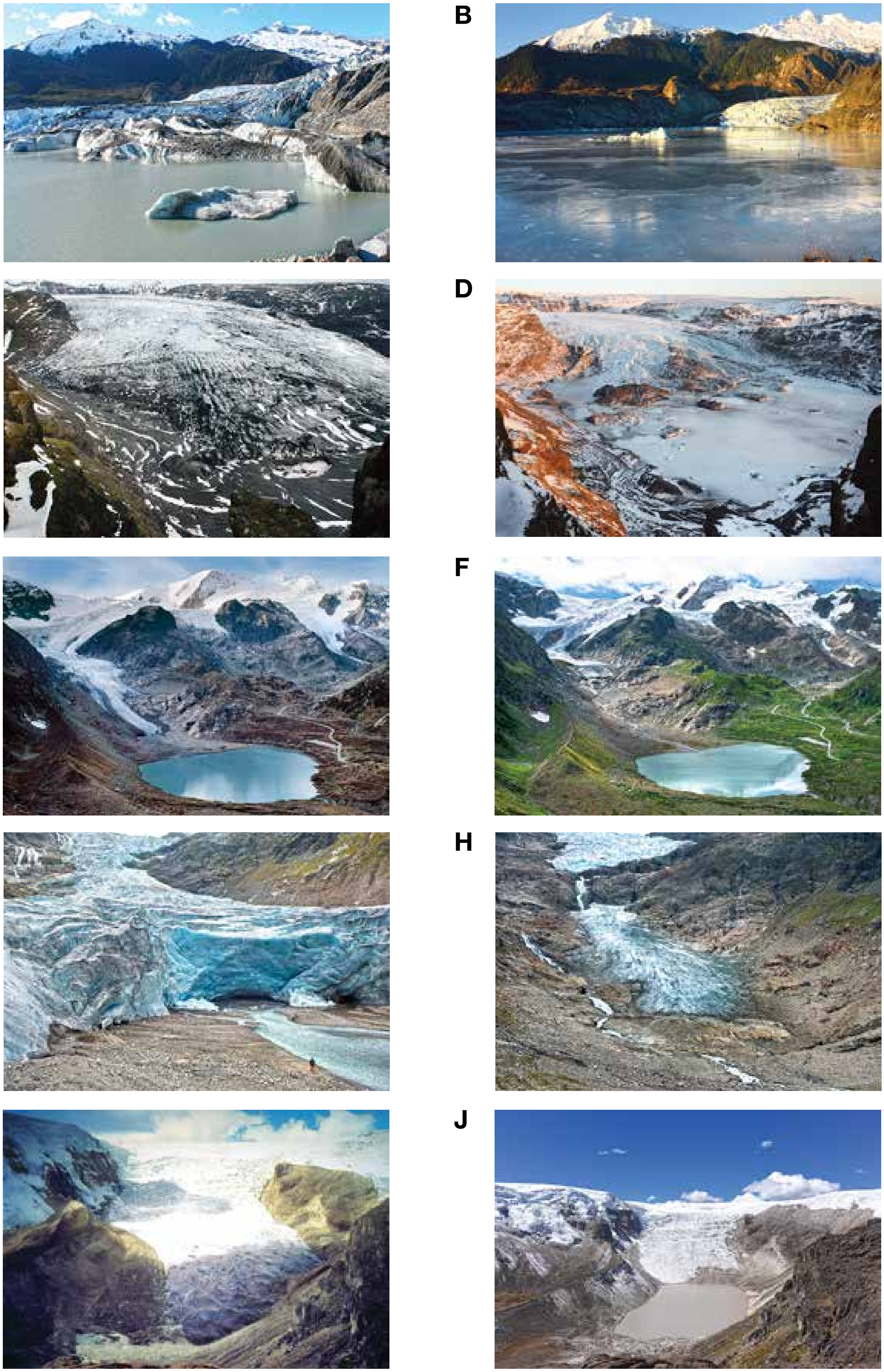

Figure 2. Time-lapse photo couplets of glaciers revealing retreat. (A–B) Mendenhall Glacier, Alaska, retreat of ~550 m from 2007 to 2015. (C–D) Solheimajokull, Iceland, retreat of ~625 m from 2007 to 2015. (E–F) Stein Glacier, Switzerland, retreat of ~550 m from 2006 to 2015. (G–H) Trift Glacier, Switzerland, retreat of ~1.17 km from 2006 to 2015. (I–J) Qori Kalis Glacier, an outlet of the Quelccaya Ice Cap, Peru, retreat of ~1.14 km from 1978 to 2016. Photo credits: (A–H) James Balog and the Extreme Ice Survey; (I–J) Lonnie Thompson.

IMPLICATIONS OF ICE LOSS

Global Sea Level

The most widespread and economically important global impact of ice loss is sea-level rise. As summarized by the IPCC (2013), sea level has recently been rising at just over 3 mm/year. A longer view shows that this rise has accelerated and that further acceleration is likely with continuing warming. Recent contributions to ocean volume have come from a combination of the expansion of ocean water due to its warming, retreat of mountain glaciers, shrinkage of the Greenland and Antarctic ice sheets through faster flow of land-originated ice into the ocean, and, primarily in Greenland, increasing surface melting and runoff. Relevant studies show accelerated flow in coastal regions in response to warming ocean waters that reduce the buttressing of ice shelves (IPCC, 2013). The Shepherd et al. (2012) synthesis estimated that sea-level rise from the ice sheets accelerated between 1992 and 2011, with an average over that interval of 0.59 ± 0.20 mm/yr. Complete loss of the ice sheets would raise sea level ~60 m, so at this average rate, more than 100,000 years would be required for complete ice-sheet removal. As discussed below, however, much shorter time scales may be involved.

Some studies estimate the costs of sea-level rise to be relatively small. These estimates are, in part, based upon using the most-likely IPCC projections of a slow, small, and well-anticipated rate, as well as the assumption of an efficient response to the rise (e.g., Darwin and Tol, 2001). Growing knowledge about the ongoing evolution and behavior of the primary outlet glaciers in Greenland and Antarctica, however, raises the possibility that future increments of sea-level rise may not, in fact, be slow, small, or well-anticipated (e.g., Joughin et al., 2014; Pollard et al., 2015; DeConto and Pollard, 2016).

As reviewed in Alley et al. (2015), the distribution of possible rates of sea-level rise includes values with slightly slower, slightly faster, or a much faster rise than the central IPCC projections. Of particular concern is marine instability in West Antarctica, especially the drainage through Thwaites Glacier into the Amundsen Sea (National Research Council, 2013). Extensive retreat may already have been triggered or may be imminent (Joughin et al., 2014; Parizek et al., 2013). In cold environments, ice flowing into the ocean typically forms attached, floating ice shelves. Friction between ice shelves and fjord walls, or local sea-floor highs, slows ice-shelf flow, in turn slowing the flow of non-floating ice into ice shelves. Warming ocean waters thin shelves, reducing this ice-shelf buttressing, allowing faster flow of non-floating ice into ice shelves. Beyond some warming threshold, ice shelves typically break off completely, leaving tide-water cliffs (reviewed in Alley et al., 2015). Material strength limits the height of cliffs (e.g., Fig. 3); ice cliffs much taller than ~100 m are likely to be unstable and break rapidly (Hanson and Hooke, 2003; Bassis and Walker, 2012). Retreat of Thwaites Glacier, West Antarctica (Joughin et al., 2014; DeConto and Pollard, 2016), could generate a cliff much higher than this limit, suggesting that very rapid retreat could follow. Implementation of a parameterization for these processes in a well-characterized ice-flow model produced ice-sheet collapse more than one century after initiation of rapid retreat, with >3 m of sea-level rise from this one source alone (Pollard et al., 2015; DeConto and Pollard, 2016). The full parameter space for such cliff instability has not been extensively explored, and faster collapse cannot be eliminated (Alley et al., 2015). Even if such rapid cliff collapse is not triggered, warming during the next one to a few centuries could commit the world to a very much larger long-term rise of sea-level (Pollard et al., 2015), possibly including complete loss of the ice sheets (Winkelmann et al., 2015). Uncertainties remain great, with potentially very large impacts upon human society and economies. The importance of this topic was highlighted by the recent studies from the National Research Council/National Academies (2013, 2015).

Figure 3. Ice that enters the ocean typically forms cliffs that then fracture, as shown for this iceberg with an approximate 60 m cliff face, in Scoresby Sound, Greenland. Higher cliffs have larger stress imbalances and so are more likely to break rapidly. Ice cliffs of ~100 m height appear to be near the highest that can support themselves. Retreat in West Antarctica, particularly at Thwaites Glacier, could produce taller cliffs that would fail rapidly, accelerating the retreat and its contribution to sea-level rise.

Water Supply

The loss of ice will have direct impact on local populations through changes in water availability, particularly during dry periods. The glacial-fed streams in the Andes, and elsewhere, are essential for hydroelectric production, irrigation, and municipal water supplies. Indeed, the glaciers across the TP are sometimes referred to as the "water towers" for southern Asia, where >100,000 km^2 of glaciers contain one of the largest glacial stores of fresh water outside of the Greenland and Antarctic ice sheets (Yao et al., 2012; Bolch et al., 2012). These glaciers discharge meltwater into the largest rivers in south Asia (Fig. 4), which are critical water resources in the populous regions surrounding the Himalayas. In 2009, the Third Pole Environment (TPE) program was launched in part to study the response of this remote region to climate change (http://www.tpe.ac.cn). The TPE program includes a strong educational component, as well as an integrated study of paleo-records to develop the context essential to assess and address the impact of anthropogenic activities. Beside the larger-scale impacts that are yet to unfold, people who live in areas affected by glacial retreat are already experiencing the consequences. For example, in 2006, a lake that had grown from the melting of Quelccaya's Qori Kalis outlet glacier (see Fig. 2J) breached its moraine dam after an avalanche and flooded the valley below, drowning herds of grazing alpacas. Emblematic of these concerns, the National Research Council of the National Academies also conducted a study to assess the role of Himalayan glaciers within the context of climate

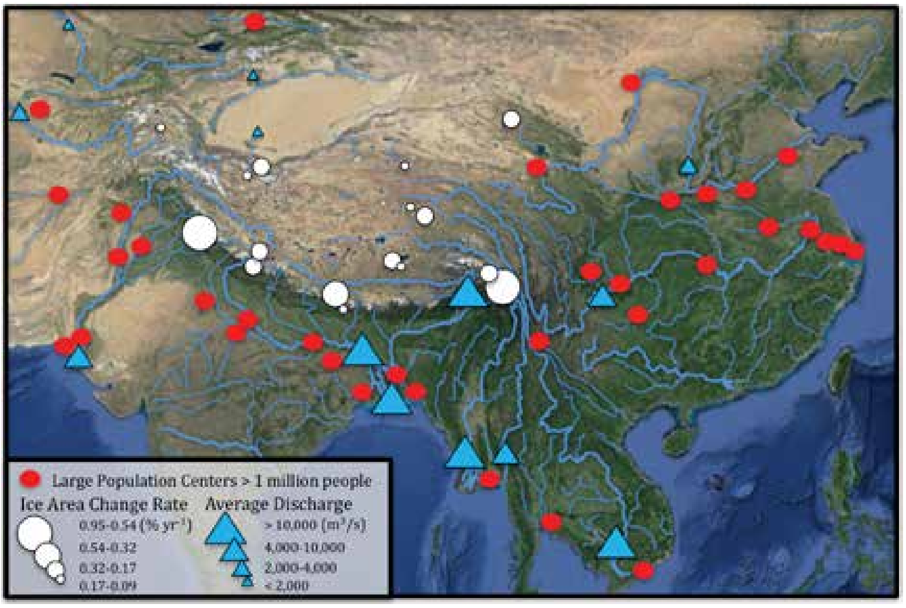

Figure 4. Earth's "Third Pole" (TP, also known as the Tibetan Plateau). Melted snow and ice from the TP generates major river systems including the Indus, Ganges, Salween, Mekong, Yangtze, and Huang He. Red dots—population centers with > 1,000,000 people that are served by these major river systems; white dots—areas of glacier loss as measured on 7,090 glaciers across the TP from the 1970s to 2000s (modified from Yao et al., 2012); blue triangles—average discharge of rivers. The base map and population centers are modified from Google Earth and the river drainages are modified from International Rivers database.

change, water resources, and water security (http://www.nap.edu/catalog.php?record_id=13449).

Loss of Natural Environmental Archives

Glaciers serve as both recorders and indicators of climate change, as the ice contains archives of environmental conditions that prevailed throughout their existence. Ice-core paleoclimatology plays an important role here, because the chemical and physical properties preserved within the glacial ice provide an essential long-term context for twentieth- and twenty-first–century changes. The history of links between climate change and humans, and indeed the rise and fall of entire civilizations, is well documented in low latitude ice cores (e.g., Thompson and Davis, 2014). Snowfall that accumulates to metamorphose into ice incorporates dust, volcanic ash, smoke, and other atmospheric constituents, as well as isotopic variations. Changes in the concentration of these constituents can reveal changes in the distribution of land mass, ocean currents, deserts, wetlands, and human activity. As the snow accumulates into annual layers that add mass to a glacier, a record of all these environmental conditions is preserved. Alley (2000) discussed the array of analyses that reveal the natural and anthropogenic history contained within the ice, which in the Greenland ice cap extends back over 100,000 years. The EIS film *Chasing Ice* and the multimedia production *Earth: The Operators' Manual* (Alley, 2011) vividly display the preservation of paleo-atmospheres within a glacier, as well as the loss of that archive that occurs during melting.

SUMMARY, LEGACY, AND CHALLENGE

Both satellite measurements of ice mass and ground-based observations indicate that Earth is losing ice; related studies show that warming temperatures are triggering this dramatic response in the world's ice cover. The characterization of rapid retreat of glaciers across Earth is well documented. Melting ice is contributing to sea-level rise, with concomitant disruption of shoreline communities. It is apparent that feedback mechanisms, such as loss of buttressing near calving faces, can rapidly accelerate this rise in human timeframes. Since glaciers are reservoirs for frozen water, the retreat of ice has other powerful implications. As glaciers are lost, rivers receiving meltwater will increasingly be susceptible to low flows during dry seasons and drought, stressing societies that rely upon those resources. Ice loss is also destroying environmental archives, much to the disadvantage of our scientific understanding of natural history.

In some places, the legacy of ice loss may be one of barren landscapes, as terrain that witnessed the passing of thousands of years during burial by advancing glaciers is now being rapidly exposed by substantially accelerating rates of retreat. It is likely that these recently deglaciated landscapes will not be re-occupied by ice during foreseeable human timeframes. In other places, forests or other vegetation may rapidly colonize such landscapes. Photographic records, such as those included here, provide an outstanding avenue for education, because they display a record of ice that may never be seen again.

This project has focused upon conveying captivating imagery of ice loss to the public, through which we highlight the forcing that the human combustion of fossil fuels is exerting upon terrestrial systems. Society is committed to additional warming, perhaps moving well past the 1.5–2 °C target from the recent Paris Agreement, unless strong actions are taken, perhaps growing from that accord. The rate at which glaciers are retreating provides one of the clearest indications that time is of the essence if human impacts are to be limited. As geoscience educators, we attempt to present the best scholarship as accurately and eloquently as we can to address the core challenge of conveying the magnitude of anthropogenic impacts, while also encouraging optimistic determination on the part of students, coupled to an increasingly informed citizenry. We assert that understanding human perturbation of nature, then choosing to engage in thoughtful science-based decision making, is a wise choice. Let us endeavor to tell the story better. Savor the cryosphere.

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REFERENCES CITED

Alley, R.B., 2000, The Two Mile Time Machine: Ice Cores, Abrupt Climate Change, and Our Future: Princeton, New Jersey, Princeton University Press, 229 p.

Alley, R.B., 2011, Earth: The Operators' Manual: New York, W.W. Norton, 496 p.

Alley, R.B., Anandakrishnan, S., Christianson, K., Horgan, H.J., Muto, A., Parizek, B.R., Pollard, D., and Walker, R.T., 2015, Oceanic forcing of ice-sheet retreat: West Antarctica and more: Annual Review of Earth and Planetary Sciences, v. 43, p. 207–231, doi: 10.1146/annurev-earth-060614-105344.

Arendt, A., Luthcke, S., Gardner, A., O'Neel, S., Hill, D., Moholdt, G., and Abdalati, W., 2013, Analysis of a GRACE global mascon solution for Gulf of Alaska glaciers: Journal of Glaciology, v. 59, no. 217, p. 913–924, doi: 10.3189/2013JoG12J197.

Balog, J., 2012, Ice: Portraits of Vanishing Glaciers: New York, Rizzoli, 288 p.

Bassis, J.N., and Walker, C.C., 2012, Upper and lower limits on the stability of calving glaciers from the yield strength envelope of ice: Proceedings of the Royal Society of London, Series A, v. 468, p. 913–931, doi: 10.1098/rspa.2011.0422.

Bolch, T., Kulkarni, A., Kääb, A., Huggel, C., Paul, F., Cogley, J.G., Frey, H., Kargel, J.S., Fujita, K., Scheel, M., Bajracharya, S., and Stoffel, M., 2012, The state and fate of Himalayan glaciers: Science, v. 336, p. 310–314, doi: 10.1126/science.1215828.

Bradley, R.S., Vuille, M., Diaz, H.F., and Vergara, W., 2006, Threats to water supply in the tropical Andes: Science, v. 312, p. 1755–1756, doi: 10.1126/science.1128087.

Bradley, R.S., Keimig, F.T., Diaz, H.F., and Hardy, D.R., 2009, Recent changes in freezing level heights in the tropics with implications for the deglacierization of high mountain regions: Geophysical Research Letters, v. 36, doi: 10.1029/2009GL037712.

Coudrain, A., Francou, B., and Kundzewicz, Z.W., 2005, Glacier shrinkage in the Andes and consequences for water resources [editorial]: Hydrological Sciences Journal, v. 50, no. 6, p. 925–932.

Darwin, R.F., and Tol, R.S.J., 2001, Estimates of the economic effects of sea level rise: Environmental and Resource Economics, v. 19, p. 113–129, doi: 10.1023/A:1011136417375.

Davis, M.E., Thompson, L.G., Mosley-Thompson, E., Lin, P.N., Mikhalenko, V.N., and Dai, J., 1995, Recent ice-core climate records from the Cordillera Blanca, Peru: Annals of Glaciology, v. 21, p. 225–230.

DeConto, R.M., and Pollard, D.M., 2016, Contribution of Antarctica to past and future sea-level rise: Nature, v. 531, p. 591–597.

Gardner, A.S., Moholdt, G., Cogley, J.G., Wouters, B., Arendt, A.A., Wahr, J., Bertheir, E., Hock, R., Pfeffer, W.T., Kaser, G., Ligtenberg, S.R.M., Bolch, T., Sharp, M.J., Hagen, J.O., van den Broeke, M.R., and Paul, F., 2013, A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009: Science, v. 340, p. 852–857, doi: 10.1126/science.1234532.

Hanson, B., and Hooke, R., 2003, Buckling rate and overhang development at a calving face: Journal of Glaciology, v. 49, p. 577–586, doi: 10.3189/172756503781830476.

IPCC, 2013, Summary for Policymakers, *in* Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and Midgley, P.M., eds., Climate Change 2013: The Physical Science Basis: Cambridge, Cambridge University Press, 1535 p.

Jacob, T., Wahr, J., Pfeffer, W.T., and Swenson, S., 2012, Recent contributions of glaciers and ice caps to sea level rise: Nature, v. 482, p. 514–518, doi: 10.1038/nature10847.

Joughin, I., Smith, B.E., and Medley, B., 2014, Marine ice sheet collapse potentially underway for the Thwaites Glacier Basin, West Antarctica: Science, v. 344, p. 735–738, doi: 10.1126/science.1249055.

Kääb, A., 2008, Glacier volume changes using ASTER satellite stereo and ICESat GLAS laser altimetry, a test study on Edgeoya, Eastern Svalbard: IEEE Transactions on Geoscience and Remote Sensing, v. 46, no. 10, p. 2823–2830, doi: 10.1109/TGRS.2008.2000627.

Kääb, A., Berthier, E., Nuth, C., Gardelle, J., and Arnaud, Y., 2012, Contrasting patterns of early twenty-first–century glacier mass change in the Himalayas: Nature, v. 488, p. 495–498, doi: 10.1038/nature11324.

Kincaid, J.L., 2007, An assessment of regional climate trends and changes to the Mount Jaya glaciers of Irian Jaya [M.Sc. thesis]: College Station, Texas A&M University, 101 p.

Klein, A.G., and Kincaid, J.L., 2006, Retreat of glaciers on Puncak Jaya, Irian Jaya, determined from 2000 and 2002 IKONOS satellite images: Journal of Glaciology, v. 52, no. 176, p. 65–79, doi: 10.3189/172756506781828818.

Liu, X., and Chen, B., 2000, Climatic warming in the Tibetan Plateau during recent decades: International Journal of Climatology, v. 20, no. 14, p. 1729–1742, i:10.1002/1097-0088(20001130)20:14<1729::AID-JOC556>3.0.CO;2-Y.

Lemke, P., and 54 others, 2007, Observations: Changes in snow, ice and frozen ground, *in* Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., and Miller, H.L., eds., Climate Change 2007: The Physical Science Basis: Cambridge, UK, Cambridge University Press, p. 337–383.

Luthcke, A.B., Arendt, A.A., Rowlands, D.D., McCarthy, J.J., and Larsen, C.F., 2008, Recent glacier mass changes in the Gulf of Alaska from GRACE mascon solutions: Journal of Glaciology, v. 54, no. 188, p. 767–777, doi: 10.3189/002214308787779933.

National Research Council/National Academies of Sciences, Engineering, and Medicine, Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts, 2013, Abrupt Impacts of Climate Change: Anticipating Surprises: Washington, D.C., National Academies Press, 222 p.

National Research Council/National Academies of Sciences, Engineering, and Medicine, Committee on the Development of a Strategic Vision for the U.S. Antarctic Program, 2015, A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research: Washington, D.C., National Academies Press, 154 p.

Parizek, B.R., Christianson, K., Anandakrishnan, S., Alley, R.B., Walker, R.T., Edwards, R.A., Wolfe, D.S., Bertini, G.T., Rinehart, S.K., Bindschadler, R.A., and Nowicki, S.M.J., 2013, Dynamic (In)stability of Thwaites Glacier, West Antarctica: Journal of Geophysical Research Earth Surface, v. 118, p. 638–655, doi: 10.1002/jgrf.20044.

Pepin, N., and 19 others, 2015, Elevation-dependent warming in mountain regions of the world: Nature Climate Change, v. 5, p. 424–430, doi: 10.1038/nclimate2563.

Pollard, D., DeConto, R.M., and Alley, R.B., 2015, Potential Antarctic ice sheet retreat driven by hydrofracturing and ice cliff failure: Earth and Planetary Science Letters, v. 412, p. 112–121, doi: 10.1016/j.epsl.2014.12.035.

Rabatel, A., and 27 others, 2013, Current state of glaciers in the tropical Andes: A multi-century perspective on glacier evolution and climate change: The Cryosphere, v. 7, p. 81–102, doi: 10.5194/tc-7-81-2013.

Ramaswamy, V., Hurrell, J.W., Meeh, G.H., Phillips, A., Santer, B.D., Schwarzkopf, M.D., Seidel, D.J., Sherwood, S.C., and Thome, P.W., 2006, Why do temperatures vary vertically (from the surface to the stratosphere) and what do we understand about why they might vary and change over time? *in* Karl, T.R., Hassol, S.J., Miller, C., and Murray, W., eds., Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences: Washington, D.C., U.S. Climate Change Science Program. Subcommittee on Global Change Research, p. 15–28.

Randall, D.A., and 85 others, 2007, Climate models and their evaluation, *in* Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M.M.B., Miller, H.L., Jr., and Chen, Z., eds., Climate change 2007: The Physical Science Basis: Cambridge, UK, Cambridge University Press, p. 589–662.

Scambos, T., and Shuman, C., 2016, Comment on Zwally et al., 2015, Mass gains of the Antarctic ice sheet exceed losses: Journal of Glaciology, v. 61, no. 230, p. 1019–1036, doi: 10.3189/2015JoG15J071.

Shepherd, A., and 46 others, 2012, A reconciled estimate of ice-sheet mass balance: Science, v. 338, p. 1183–1189, doi: 10.1126/science.1228102.

Thompson, L.G., and Davis, M.E., 2014, An 1800-year ice core history of climate and environment in the Andes of Southern Peru and its relationship with highland/lowland cultural oscillations, *in* Meddens, F., Willis, K., McEwan, C., and Brancg, N., eds., Inca Sacred Spaces: Landscape, Site and Symbol in the Andes: London, Archetype, p. 261–268.

Thompson, L.G., Mosley-Thompson, E., Brecher, H., Davis, M., León, B., Les, D., Lin, P.-N., Mashiotta, T., and Mountain, K., 2006, Abrupt tropical climate change: Past and present: Proceedings of the National Academy of Science, v. 103, no. 28, p. 10,536–10,543, doi: 10.1073/pnas.0603900103.

Thompson, L.G., Brecher, H.H., Mosley-Thompson, E., Hardy, D.R., and Mark, B.G., 2009, Glacier loss on Kilimanjaro continues unabated: Proceedings of the National Academy of Science, v. 106, p. 19,770–19,775, doi: 10.1073/pnas.0906029106.

Thompson, L.G., Mosley-Thompson, E., Davis, M.E., and Brecher, H.H., 2011, Tropical glaciers, recorders and indicators of climate change, are disappearing globally: Annals of Glaciology, v. 52, p. 23–34, doi: 10.3189/172756411799096231.

Thompson, L.G., Mosley-Thompson, E., Davis, M.E., Zagorodnov, V.S., Howatt, I.M., Mikhalenko, V.N., and Lin, P.N., 2013, Annually resolved ice core records of tropical climate variability over the past ~1,800 years: Science, v. 340, no. 6135, p. 945–950, doi: 10.1126/science.1234210.

Winkelmann, R., Levermann, A., Ridgwell, A., and Caldeira, K., 2015, Combustion of available fossil fuel resources sufficient to eliminate the Antarctic ice sheet: Science Advances, v. 1, no. 8, p. 1–5, doi: 10.1126/sciadv.1500589.

Yao, T., Thompson., L., Yang, W., Yu, W., Gao, Y., Guo, X., Yang., X., Duan, K., Zhao, H., Xu, B., Pu, J., Lu, A., Xiang, Y., Kattel, D.B., and Joswiak, D., 2012, Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings: Nature Climate Change, v. 2, p. 663–667, doi: 10.1038/nclimate1580.

Zemp, M., Roer, I., Kääb, A., Hoelzle, M., Paul, F., and Haeberli, W., 2008, Global glacier changes: Facts and figures, *in* Zemp, M., and van Woerden, J., eds., UNEP/Earthprint: Zurich, Switzerland, http://www.grid.unep.ch/glaciers/ (last accessed 18 Jan. 2017).

Zemp, M., and 38 others, 2015, Historically unprecedented global glacier decline in the early 21st century: Journal of Glaciology, v. 61, p. 745–762, doi: 10.3189/2015JoG15J017.

Zwally, H.J., Li, J., Robbins, J.W., Saba, J.L., Yi, D., and Brenner, A.C., 2015, Mass gains of the Antarctic ice sheet exceed losses: Journal of Glaciology, v. 61, no. 230, p. 1019–1036, doi: 10.3189/2015JoG15J071.

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Education, Careers, and Mentoring

Washington Geology Presentations for the Public and the Geocaching Community

▶ Sunday, 22 Oct., 1–4 p.m.

At the GSA 2017 Annual Meeting in Seattle, GSA and its EarthCache program are hosting a series of presentations about the geology of Washington state. These presentations are designed for the Geocaching and EarthCaching communities, as well as other members of the public, particularly local teachers.

A list of presentations and their times will be listed on the GSA 2017 Annual Meeting website (**community.geosociety.org/gsa2017/home**) and the EarthCache homepage (**www.geosociety.org/earthcache**).

TM

For more information, contact Matt Dawson (mdawson@geosociety.org).

BE A PART OF THE MOVEMENT—ON TO THE FUTURE (OTF)

Since 2013, GSA has supported 435 students from underrepresented groups to attend their first GSA Annual Meeting. Support from members is instrumental in shaping careers and changing lives. Join us as we look forward to another successful year by mentoring an OTF student at the meeting and/or donating to support a student at **https://www.gsafweb.org/fund/on-to-the-future-fund/.** Learn more about this program or how you can get involved at **http://bit.ly/2r1EwZ1.**

SHORT COURSES

Don't forget to sign up for a Short Course. Course prices go up US$30 after 18 Sept., **community.geosociety.org/gsa2017/courses.**

JUMPSTART YOUR CAREER AT GSA's ANNUAL MEETING

If you are interested in a career in government or industry, you won't want to miss the GeoCareers Day on Sun., 22 Oct. You can interact with professionals from government and industry sectors and ask them career-related questions. This program includes a career workshop, booths highlighting careers and career opportunities, a lunch panel of professional representatives, and 30 mentors with varying careers to speak with in a small group setting, **community.geosociety.org/gsa2017/careers.**

MAKE AN IMPACT—BE A MENTOR

GSA is recruiting mentors to provide real-world information and insight to students and early career professionals at GSA's Annual Meeting. Mentoring can range from one-on-one mentor pairs for the duration of the meeting to short-term mentoring opportunities. Learn more about becoming a mentor and sign up at **http://bit.ly/2r3mW7Z.**

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LUNCHTIME ENLIGHTENMENT

SEATTLE

2017 MICHEL T. HALBOUTY DISTINGUISHED LECTURER

John (Jack) Shroder, Senior Research Scholar, Center for Afghanistan Studies, University of Nebraska–Omaha

Afghanistan Resources: Rapacious Extraction, Ruined Environments, and Chaos Continuation?

▶ Tuesday, 24 Oct., 12:15–1:15 p.m.

The rich minerals, hydrocarbons, and waters of Afghanistan have been known for more than half a century, yet some have only belatedly realized that trillions of resource dollars might enable hard-pressed Afghanistan to rebuild the war-destroyed infrastructure. This could enable withdrawal of the foreign militaries, a strong desire of those who struggle greatly against the Taliban and ISIS insurgencies. Other critics think Western powers and multinational companies are in this Longest War not to help Afghanistan recover normalcy but rather to exploit the beleaguered country and run off with cheap resources. The reality is that a corrupt and kleptocratic governmental elite of only marginal technical capability has been incapable of providing transparency in the mineral tender processes or adequate licensing and royalty production for the extractive industries. Pressure from the International Monetary Fund and others to open up the mining in haste, without sound vision, a proper legal framework, or well-functioning management institutions, has greatly limited any success. Simultaneously, armed mining oligarchies have dug in to extract profits in league with the insurgencies to use minerals as revenue generators. Wise ideas and plans for transparent mineral extraction and development of resource corridors have run aground on bureaucratic incompetence and lethargy. In the "Wild-West" mining environment of Afghanistan, rampant excitement over get-rich-quick schemes has drawn in companies with variable foreign-government support, as well as Afghan insiders looking to make quick profits. China and India are expected to benefit most, along with a host of the new mining oligarchs and insurgents, but not the legitimate government of the country unless suggested strong changes are successful. A second wind for the mining sector has been promoted recently, however, by a revolving door of ministers of mines to get the Ministry of Mines and Petroleum correctly focused, coupled with the possible moderate success of the new Afghanistan Extractive Industries Transparency Initiative. It remains to be seen whether or not the resources can be extracted with minimal environmental damage to help the local people, or if they should be left untouched to keep the profits away from the mineral mafias.

Neighborhood Spotlight: Pioneer Square

A neighborhood defined by its colorful past: Pioneer Square was the original heart of the city in Seattle's early days. Now more than a century later, the historic neighborhood is bustling once again with historic brick buildings, notable restaurants, and more.*

Intrigue Chocolate Co. Photo by Olivia Brent.

Drygoods Design. Photo by Lauren Stelling.

Occidental Square. Photo by Olivia Brent.

▶ Eat

The on-trend culinary scene offers something for every craving and culinary desire. **The London Plane** is an airy, elegant oasis. Meet friends for a sit-down lunch or dinner featuring a rotating menu of seasonal ingredients. Pick up fresh breads and pastries from its bakery before selecting a bouquet from the on-site florist. For a heartier lunch, break out the napkins at **Rain Shadow Meats.** The butcher shop and lunch spot offers piled-high sandwiches such as the Pigfall and Lambwich. Then go satisfy that sweet tooth at **Intrigue Chocolate Co.** Take home a tarragon or mocha artisan truffle or sip made-to-order chocolate milk mixed with the flavoring of your choice.

▶ Shop

The neighborhood is a literary playground. Take a spin around **The Globe Bookstore** to enjoy its selection of vintage Northwest and children's titles. **Arundel Books** entices with its brick, ivy-covered storefront, antiquarian gems, and on-site art gallery. Put your best foot forward at **Clementines,** which is known for unique, comfortable, and sophisticated women's shoes in addition to apparel and jewelry. For unexpected finds, **Bon Voyage Vintage** is a treasure trove, stocking everything from retro dresses to Beatles t-shirts. And both kids and the young at heart can't resist **Magic Mouse Toys.** The shelves burst with everything from puppets to Star Wars memorabilia and a charming collection of Seattle-themed books and playthings.

▶ Play

Bill Speidel's Underground Tour has uncovered Seattle's history since 1965. Today's Pioneer Square is built atop the remnants of pre-1889 Seattle. Tours wind through the underground nooks and crannies of the old city. Urban town square **Occidental Park** provides a breath of fresh air thanks to rotating outdoor art installations. Winter activities include ice sculpting and professional carolers beginning with December's **First Thursday Art Walk** and every Friday thereafter that month. Come spring, people may very well be dancing in the streets at the first **Upstream Music Fest,** featuring more than 200 Northwest artists performing at more than 25 Pioneer Square locations.

*Text copy credit Visit Seattle, www.visitseattle.org/neighborhoods/pioneer-square/.

COMMENTARY

The Geology of Capitol Hill

Paul K. Doss, GSA Visiting Scholar, Past Chair, GSA Geology and Public Policy Committee

Spring "fieldwork" with Kasey White, GSA's Geoscience Policy Director, took us to more than 40 offices on Capitol Hill, targeting members of congressional Appropriations Committees and communicating the societal benefits of the geosciences.

What is geoscience on Capitol Hill today? It is largely perceived as climate change research. Of course this is a generalization; many legislators know the role of geoscience in natural hazards, resources, and energy development, and a few even respect the role of geoscience in understanding climate change. But in today's Congress, ignorance about the breadth of the geosciences dominates.

Public lands are an important resource for many geologists. For me, they've included Indiana Dunes National Lakeshore, Everglades, Acadia, and Yellowstone National Parks, and Manistee National Forest, where "Michigan water wars" pitted resource advocates against bottled-water producers in courts and protest lines. These, plus efforts in local government (Doss, 1994; Doss, 2000) provided my understanding that public policy must be informed by Earth science. GSA leadership has recognized GSA's role in these efforts; GSA President Claudia Mora wrote in support for the March for Science, "It is the role of GSA to directly and positively engage policy makers across the political spectrum and at national to local levels" (www.geosociety.org/GSA/News/Releases/GSA/News/pr/2017/17-13.aspx).

Also, my two terms as member and chair of GSA's Geology and Public Policy Committee (GPPC) illuminated a persistent reality. Geologists, largely, do not engage well in the policy process. If we've improved, it's clear from today's policy "climate" we waited too long.

In the 1990s, House Speaker Newt Gingrich crafted his "Contract with America" that included abolishing the U.S. Geological Survey. That proposal, introduced by Representative John Kasich (R-OH), once came within six votes of passing. From Kasich's office, "We haven't heard a single voice" speak for the Survey, only media inquiries (www.paloaltoonline.com/weekly/morgue/cover/1995_Feb_1.USGS0001.html). In GPPC talking points then were the importance of the USGS, the agencies it served, and programs it fulfilled. For example, not a single congressional staffer contacted knew that the USGS conducted stream-gaging.

A quarter-century later, here we are with higher stakes. In the U.S. alone, 50 million more people depend on fewer non-renewable resources, more urbanized and fragmented land, an aging water-supply infrastructure, more eroded soils, and an increased international supply of necessary minerals. All while natural systems are responding in unpredictable ways to global climate change.

In his 2011 GSA Presidential Address, John Geissman (2012, p. 13) said, "We cannot deny that several activities and factors are presently conspiring to make what we describe, and take for granted, as life on our only home more and more unsustainable."

Our nation's need for what geoscience offers is at its highest. I suggest that geology is under siege within the public-policy sphere. Attempts in Congress to reduce funding for geosciences due to its role in climate science research threatens the entire spectrum of benefits our science provides.

Elected officials work for you and make impactful decisions on your behalf. Although geologists differ on matters of resource use, environmental protection, energy "policy," or land use—that's OK. Any time an elected official hears "geology" with respect to societal importance, everyone benefits. We must inform decision makers and educate policy developers. They will make decisions; it's our responsibility to help them understand the data needed to make *informed* decisions.

Your representatives must hear what NASA Earth Science does—it's more than climate science; what NOAA does—it's more than sea-level rise; what NSF geoscience funding provides to their district; and what the Department of the Interior supports (USGS, NPS, EPA, BLM).

The geoscience community knows Earth is in flux. Societies also evolve. Demographics change, exposing populations to new, previously unforeseen hazards. Technological advancement demands new mineral resources. Energy consumption sustains the search for non-renewable energy reserves. Infrastructure degrades in response to earth movements and weathering agents. Geoscience understands these things. Individual citizen geoscientists must show our policy makers the elegance of that understanding, over and over again.

REFERENCES CITED

Doss, P.K., 1994, Constructed wetlands: Can and will we engineer a viable ecosystem?, *in* Fleming, J.R., and Gemery, H.A., eds., Science, Technology and the Environment: Multidisciplinary Perspectives: Akron, Ohio, Univ. of Akron Press, p. 173–196.

Doss, P.K., 2000, Geology and community planning: An Earth Scientist in City Hall, *in* Schneiderman, J., ed., The Earth Around Us: Maintaining a Livable Planet: New York, W.H. Freeman & Co., p. 244–253.

Geissman, J., 2012, The importance of the global professoriate in the geosciences—The students we are teaching, and learn from, today may represent the last great hope: GSA Today, v. 22, no. 1, p. 12–16.

The Geological Society of America®

GEOCAREERS

Mentoring Tomorrow's Geoscience Leaders at the 2017 Section Meetings

The Geological Society of America (GSA) is proud to provide mentoring and career pathway events at all meetings. At Section Meetings, students are invited to participate in the Roy J. Shlemon Mentor Program in Applied Geology and the John Mann Mentors in Applied Hydrogeology Program. These popular events, supported by the GSA Foundation through gifts from Roy J. Shlemon and John Mann, are designed to extend the mentoring reach of individual professionals. Together, mentor volunteers and students meet in a relaxing, informal setting, to discuss careers in geology over lunch.

This past spring, 280 students and 33 mentors participated in the Shlemon Program and 195 students and 25 mentors attended the Mann Program. With additional financial assistance from GSA's South-Central, Northeastern, North-Central, and Southeastern Sections, both mentors and students left the events expressing feelings of personal and professional growth. As a result of these programs, new friendships were made and professional contacts were established that will last well into the future.

In addition to mentoring, GSA also provided three career workshops for students, designed to help them plan and prepare for their job search. The workshops covered career planning and informational interviewing, career exploration, and cover letters, résumés, and CVs. Working professionals from academia, government, and industry were invited to answer questions and help attendees maneuver the career exploration process.

GSA gratefully acknowledges the following mentors for their individual gifts of time and for sharing their insight with students. To learn more about these programs, or to be a mentor at a future Section Meeting, please contact Jennifer Nocerino at jnocerino@geosociety.org.

The Roy J. Shlemon Mentor Program in Applied Geology

Helping Mentor Students Since 1996

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Richard Gray, DiGioia Gray

Jim Hamel, Hamel Geotechnical Consultants

Heather Houlton, American Geosciences Institute

Charlie Martin, KEMRON Environmental Services Inc.

Kyle Metz, Ohio Department of Natural Resources–Division of Geological Survey

Katherine Neff, American Geotechnical & Environmental Services

Connor O'Loughlin, Hazardous Site Cleanup Division

David Russ, U.S. Geological Survey

David Saja, The Cleveland Museum of Natural History

Greg Walsh, U.S. Geological Survey

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Diane Murbach, Murbach Geotech

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Diego Davis, Xylem/YSI

Jeff Sloan, U.S. Geological Survey

ROCKY MOUNTAIN SECTION

Gregory Hartman, Alberta Geological Survey

Dale Leckie, University of Calgary

Geosphere and *Lithosphere* to be Open Access in 2018

At its spring 2017 meeting, GSA Council approved a plan to make *Geosphere* and *Lithosphere* 100% open access beginning in January 2018. GSA Council remains committed to making all GSA journals 100% open access in the future.

Manuscripts submitted to *Geosphere* or *Lithosphere* on or after 1 Sept. 2017 that are ultimately accepted for publication will be assessed an article publication charge (APC) of US$1,750. GSA members will receive a US$100 discount on this APC. There will be no other color or page charges, and a waiver system will be in place. No manuscript will be rejected for an inability to pay. (More details on journal fees and options are posted on the publications pages at www.geosociety.org.)

Papers in *Geosphere* and *Lithosphere* will continue to undergo the rigorous peer review and editing processes that uphold the quality of the journals.

As part of GSA's transition to open access, the GSA Foundation is seeking endowment funds to cover publications fees for those who cannot afford to pay (e.g., authors from countries or institutions with little funding). If you are interested in supporting GSA's transition to open access, please contact the GSA Foundation at info@gsafweb.org.

GSA MEMBER BENEFIT CONTINUES

GSA members will continue to have free online access to *Geology* in 2018. Paid print subscriptions to *Geology* will continue to be available in 2018.

Related articles: "Open Access," p. 50, July 2016, *GSA Today*; "Changes Coming to Geology," p. 36, August 2016, *GSA Today*.

Total solar eclipse 1999 in France. Additional noise reduction performed by Diliff. Original image by Luc Viatour.

A total solar eclipse will take place on Monday, 21 Aug. 2017. The path of totality will pass from Oregon to South Carolina, and the rest of North America will see a partial solar eclipse. This rare event (see https://eclipse2017.nasa.gov/when-was-last-solar-eclipse-seen-north-america-and-when-will-next-one-happen) is an exciting educational opportunity for GSA and its members. GSA's partner, the NSF-funded EclipseMob, provides a hands-on citizen-science project that can be performed anywhere in the United States.

Learn more about the eclipse: **https://eclipse2017.nasa.gov/**

Participate in the EclipseMob project: **www.eclipsemob.org**

GSA Divisions

GSA's specialty Divisions help you stay connected with your colleagues worldwide and receive specific information related to your area of interest. Divisions provide opportunities for leadership and service, specialty meetings, awards, student support, and development of the GSA meeting technical program.

Division membership costs between US$3 and US$12 annually. Join one or more Divisions when you renew your 2018 membership (opens 16 Aug.) at www.geosociety.org/members or by calling +1-888-443-4471.

The **Archaeological Geology** Division (est. 1977; ~496 members) provides a forum for the presentation and discussion of papers on archaeological geology in order to stimulate and promote research and teaching within this field. Division awards include the Rip Rapp Archaeological Geology Award, the Richard Hay Student Paper/Poster Award, and the Claude C. Albritton, Jr., Award memorial fund. Learn more at **community.geosociety.org/archgeodivision/.**

The **Energy Geology** Division (est. 1954; ~698 members [formerly the Coal Geology Division]) encourages energy research and disseminates information about energy geology to all interested parties by actively participating in thought-provoking symposia and technical sessions at GSA's meetings and through scientifically pertinent publications. The Division sponsors a major award for outstanding contributions to the field of coal geology, the Gilbert H. Cady Award, and also recognizes the volunteered contributions of its members through its Distinguished Service Award. For students, the Division offers the Antoinette Lierman Medlin Scholarship, the Antoinette Lierman Medlin Laboratory and Field Awards, and a Best Student Paper Award. Learn more at **www.uky.edu/KGS/coal/GSA/.**

The **Environmental and Engineering Geology** Division (est. 1947; ~2,000 members) seeks to advance the ability of geologists to identify, characterize, and mitigate adverse geological and environmental conditions and hazards affecting human safety and the built environment. To do so, the Division promotes research, education, and dissemination of information relevant to members. Each year, the Division honors an outstanding recent publication with the E.B. Burwell, Jr., Award and, along with the Assoc. of Environmental and Engineering Geologists, commissions the Richard H. Jahns Distinguished Lecturer. Other Division awards include the Meritorious Service Award, the Distinguished Practice Award, and, for students, the Roy J. Shlemon Scholarship Awards. Learn more at **community.geosociety.org/eegdivision/.**

The **Geobiology & Geomicrobiology** Division (est. 2001; ~561 members) promotes interdisciplinary research focusing on the interplay between the biosphere, lithosphere, hydrosphere, and atmosphere. More specifically, geobiologists and geomicrobiologists examine the effects of biological activities on geological processes and the influences of geological settings on biological processes—both at the macro- and micro-biological scales and in the past through the present. Members are invited to the yearly lunch banquet where winners of the annual Outstanding Contributions to Geobiology & Geomicrobiology Awards are celebrated. Learn more at **www.geosociety.org/gsa/division/gbgm/home.aspx.**

The **Geoinformatics** Division (est. 2006; ~182 members) advances "Data to Knowledge," providing GSA members with an opportunity to participate in the emerging field of cyberinfrastructure. The Division actively promotes and sponsors short courses, symposia, and books that emphasize information-technology–supported discovery and integration of geoscience data leading to a more comprehensive understanding of Earth and the planets as complex systems. Each year, the Division presents the Outstanding Contributions in Geoinformatics Award. Learn more at **community.geosociety.org/geoinformaticsdivision/.**

The **Geology and Society** Division (est. 2003; ~373 members) advances the concept of "geology working for society" by providing GSA members with opportunities to bring together multiple fields of geoscience to address important societal issues. This Division actively hosts interdisciplinary symposia at national and regional meetings, provides forums to help its members effectively communicate with decision makers and the public, encourages student achievement in helping to inform public policy by sponsoring a Best Student Presentation Award at the national meeting, and honors professional achievement in enhancing public policy by presenting a Distinguished Lecture at the annual meeting. The Division also works closely with the Geology and Public Policy Committee to develop and distribute GSA position statements. Learn more at **community.geosociety.org/gsocdivision/.**

The **Geology and Health** Division (est. 2005; ~196 members) focuses on the intersection of natural or anthropogenic geological conditions with health, disease, pathology, and death in modern and fossil humans, animals, and plants. This Division fosters communication and collaboration among scientists and health practitioners with an emphasis on the interdisciplinary relationship of geology to medicine, biology, chemistry, and other sciences. Division awards include the Meritorious Service Award, the Distinguished Service Award, and—to students—the Best Publication Award. Learn more at **community.geosociety.org/geologyhealthdivision/.**

The **Geophysics Division** (est. 1971; ~582 members) facilitates the presentation and discussion of the ideas of scientists interested in geophysics, fosters communication among geophysicists and other earth scientists, and promotes research and publication. This Division sponsors the George P. Woollard Award and lecture for outstanding contributions to geology through the application of the principles and techniques of geophysics. For students, the Division offers the Allan V. Cox Student Research Award and the GSA Geophysics Division Student Research Award. Learn more at **community.geosociety.org/geophysicsdivision/.**

The **Geoscience Education** Division (est. 1991; ~804 members) fosters the active participation of GSA members in all aspects of earth-science education. The Division complements and expands on the contributions of the National Earth Science Teachers Association (NESTA), the National Association of Geology Teachers (NAGT), the National Science Teachers Association (NSTA), and other similar organizations. It sponsors the Biggs Earth Science Teaching Award and a Distinguished Service Award. Learn more at **community.geosociety.org/gedivision/.**

The **History and Philosophy of Geology** Division (est. 1976; ~332 members) works to encourage the study and communication of the philosophy and history of geology. The Division sponsors technical sessions at GSA meetings and honors geologists for their research, writing, and historical work through the Mary C. Rabbitt History of Geology Award, the Gerald M. and Sue T. Friedman Distinguished Service Award, and the History & Philosophy of Geology Student Award. It is also responsible for *GSA Today's* Rock Stars series. Learn more at **community.geosociety.org/histphildiv/.**

The **Hydrogeology** Division (est. 1959; ~1,400 members) focuses on the geologic aspects of hydrogeology, the role of geology in the hydrologic cycle, and the importance of hydrogeology to society and science. The Division has a well-established mentor program (John Mann Mentors in Applied Hydrogeology) for students looking at careers in this field. The Birdsall-Dreiss Distinguished Lecturer honorees are named by this Division, along with the O.E. Meinzer Award, the George Burke Maxey Distinguished Service Award, the Kohout Early Career Award, and the Hydrogeology Division Student Research Grant Awards. Learn more at **community.geosociety.org/hydrodivision/.**

The **Karst** Division (est. 2014; ~309 members) is GSA's newest. The study of karst terranes necessarily involves a wide variety of subjects and specialties, spanning almost every division in GSA and scientific disciplines outside of GSA's purview. These include geology, biology, microbiology, soils, environmental geology, engineering, geology, geochemistry, geophysics, structural geomorphology, archaeology, urban planning, climatology, paleoclimatology, meteorology, hydrology, speleology, and even planetary studies. Comprehensive karst studies also can require the assistance of cave explorers and mappers, cave divers, mathematicians, modelers, and computer programmers. In all cases, practitioners in each discipline bring with them their own experiences, perspectives, insights, tools, and scales of reference. Learn more at **community.geosociety.org/karstdivision/.**

The **Limnogeology** Division (est. 2002; ~250 members) encourages research on both ancient and modern lakes around the world, the collaboration of scientists from all disciplines on lake research, and the fostering of student research and careers in lake studies. The Division sponsors the Israel C. Russell Award and the Kerry Kelts Student Research Award. Learn more at **community.geosociety.org/limnogeologydivision/.**

The **Mineralogy, Geochemistry, Petrology, and Volcanology** Division (est. 2009; ~1,900 members) promotes awareness, teaching, and research in these fields, and stimulates discussion about the knowledge, ideas, research results, and problems regarding these fundamental areas of the earth sciences. Annually, the Division sponsors both a Distinguished Geologic Career Award and an Early Career Award, as well as six student research grant awards. Learn more at **community.geosociety.org/mgpvdivision/.**

The **Planetary Geology** Division (est. 1981; ~773 members) fosters interactions among planetary scientists, facilitates the presentation and discussion of their research and ideas, stimulates communication with other earth scientists, and promotes planetary geology to a broad audience. Awards sponsored by the Division include the G.K. Gilbert Award, the Ronald Greeley Award for Distinguished Service, and, for students, the Eugene M. Shoemaker Impact Cratering Award, the Stephen E. Dwornik Awards for best student presentations at the annual Lunar and Planetary Science Conference, Student Travel Grants, and (jointly with the Meteoritical Society) the Pellas-Ryder Award for the best student-authored paper in planetary science. Learn more at **http://rock.geosociety.org/pgd/.**

The **Quaternary Geology and Geomorphology** Division (est. 1955; ~1,400 members) facilitates communication among scientists in these fields and the presentation of their research and ideas to the wider scientific community. Several awards are given by this Division, including the Distinguished Career Award, the Kirk Bryan Award, the Gladys W. Cole Memorial Award, the Farouk El-Baz Award for Desert Research, and the J. Hoover Mackin, Arthur D. Howard, and Marie Morisawa student research awards. Learn more at **community.geosociety.org/qggdivision/.**

The **Sedimentary Geology** Division (est. 1985; ~1,400 members) works to ensure the presentation of sedimentary-related topics and sessions at GSA meetings and actively nurtures the work of students by offering the Sedimentary Geology Division Student Research Grant Award and Student Poster Awards and by providing financial aid for students to attend Division-sponsored short courses and field trips. It also offers the Laurence L. Sloss Award for outstanding accomplishments in sedimentary geology and contributions to GSA and cosponsors the Stephen E. Laubach Research in Structural Diagenesis Award (alternating with the Structural Geology and Tectonics Division). Learn more at **community.geosociety.org/sedimentarygeologydiv/.**

The **Structural Geology and Tectonics** Division (est. 1980; ~1,800 members) focuses on the geometry and mechanisms of natural and experimental deformation at all scales and works to promote the research of scientists in these fields and to facilitate communication and discussion at all levels of the earth sciences. The Division offers a Career Contribution Award for advancement of the science of structural geology and tectonics, an Outstanding Publication Award, and a Division Student Research Grant Award. It also cosponsors the Stephen E. Laubach Research in Structural Diagenesis Award (alternating with the Sedimentary Geology Division). Learn more at **http://rock.geosociety.org/sgt/.**

Ads (or cancellations) must reach the GSA advertising office no later than the first of the month, one month prior to the issue in which they are to be published. Contact advertising@geosociety.org, +1.800.472.1988 ext. 1053, or +1.303.357.1053. All correspondence must include complete contact information, including e-mail and mailing addresses.
Rates are in U.S. dollars.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
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Positions Open

PETROLEUM GEOSCIENTIST (2 POSITIONS AVAILABLE) KANSAS GEOLOGICAL SURVEY UNIVERSITY OF KANSAS, LAWRENCE

Full-time, faculty-equivalent, sabbatical-eligible positions at Assistant or entry-level Associate Scientist rank. Complete announcements/application information at www.kgs.ku.edu/General/jobs.html.

Positions are expected to conduct, publish, and present the results of fundamental and applied research in petroleum geology and related areas that is of national stature and relevant to Kansas. Ph.D. in the geosciences or related field is required. Review of applications will begin Sept. 1, 2017. For further information contact Eugene Holubnyak (eugene@kgs.ku.edu) or Tandis Bidgoli (tbidgoli@ku.edu). For other questions contact Annette Delaney, KGS Human Resources, adelaney@ku.edu.

KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

HYDROGEOCHEMIST GEOHYDROLOGY SECTION KANSAS GEOLOGICAL SURVEY UNIVERSITY OF KANSAS, LAWRENCE

Full-time position to lead KGS hydrogeochemical investigations. Faculty-equivalent, sabbatical-eligible position at Assistant or entry-level Associate Scientist rank. Requires Ph.D. with emphasis on aqueous geochemistry related to groundwater resources, and scientific leadership potential. Background in hydrogeochemistry applied to regional-scale groundwater investigations is desired. The Geohydrology Section has 6 full-time professionals with additional support personnel. Emphasis on state-of-the-science field studies and complementary theoretical research. Complete announcement/application info at www.kgs.ku.edu/General/jobs.html. Review of applications will begin Sept. 30, 2017. Apply online at http://employment.ku.edu/academic/8718BR. For further information contact Geoff Bohling (geoff@kgs.ku.edu) or Don Whittemore (donwhitt@kgs.ku.edu). KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

ASSISTANT PROFESSOR OF GEOLOGY, BELOIT COLLEGE

The Beloit College Department of Geology invites applicants for a tenure-track position in the area of Earth History and Climate (Paleoclimatology) to begin August 2018. The successful applicant will teach courses in climate and historical geology for geology majors and non-majors. Additional courses taught will reflect the applicant's area of specialty, and might include paleontology, sedimentology, geochemistry, and geoarchaeology. We seek candidates that can contribute to the departments' commitment to increasing access and opportunities for populations under-represented in the geosciences. The successful candidate will develop a research program that engages undergraduates, contribute to all-college programs such as first-year seminars, interdisciplinary studies, and international education, and serve in leadership roles in campus governance. An ability to contribute to an interdisciplinary Environmental Studies program is considered an asset.

Because equity and inclusion are central to our students' liberal education and vital to the thriving of all members of our residential learning community, Beloit College aspires to be an actively anti-racist institution. We recognize our aspiration as ongoing and institution-wide, involving collective commitment and accountability. We welcome employees who are committed to and will actively contribute to our efforts to celebrate our cultural and intellectual richness and be resolute in advancing inclusion and equity. We encourage all interested individuals meeting the criteria of the described position to apply.

Located in a diverse community close to Madison, Milwaukee, and Chicago, Beloit is a selective undergraduate liberal arts college that attracts students from across the United States and the world. The college emphasizes excellence in teaching, learning beyond the traditional classroom, international perspectives, and collaborative research among students and faculty. It is recognized as one of the Colleges That Change Lives.

Inquiries may be addressed to Susan Swanson, department chair (swansons@beloit.edu). Interested individuals may submit a letter of interest, curriculum vitae, statements of teaching and research interests, graduate transcripts, and contact information for three references to geologysearch17@beloit.edu. To ensure full consideration, please submit all materials by November 15, 2017. The search will remain open until the position is filled.

VISITING ASSISTANT PROFESSOR OF GEOLOGY, BELOIT COLLEGE

Beloit College invites applications for a one-semester Visiting Assistant Professor of Geology beginning in January, 2018. The successful candidate will teach two laboratory courses: introductory evolution of the earth and oceanography.

Because equity and inclusion are central to our students' liberal education and vital to the thriving of all members of our residential learning community, Beloit College aspires to be an actively anti-racist institution. We recognize our aspiration as ongoing and institution-wide, involving collective commitment and accountability. We welcome employees who are committed to and will actively contribute to our efforts to celebrate our cultural and intellectual richness and be resolute in advancing inclusion and equity. We encourage all interested individuals meeting the criteria of the described position to apply.

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GSA FOUNDATION Update

John W. (Jack) Hess, *GSA Foundation President*

The Value of Corporate Partnerships to GSA Programs, Students, and Beyond

GSA and the GSA Foundation have long partnered with corporations in both support and programmatic involvement. While contributed funds are vital to the existence of many programs, so is the hands-on, engaged participation of companies and their employees.

Our partners are highly committed to the next generation of geoscience talent. Newmont Mining Corporation is one of those, supporting programs through both funding and interaction with GSA students through committed employees who volunteer their time and share their experience directly. For more than 20 years, Newmont has contributed to GSA's education programs, annual meeting, and student-specific initiatives in career development and diversity. The company is supportive of the Society's work to engage industry, and also of its employees' dedication to emerging scientists. Terry Briggs, Senior Director of Corporate Development for the company, has attended a number of Annual Meetings to interact with student attendees. During the meeting's Sunday morning career program, it has become a common sight to walk by an eager, attentive group of aspiring geoscientists captured by Terry's engaging knack for relaying his experience:

> Having worked in the minerals sector for the past 20 years, one of the things that I most look forward to every year is the opportunity to engage with the geoscientists of tomorrow, through the GeoCareers program that GSA offers at their Annual Meeting. It is a real pleasure to be able to share my experience from working in greenfields exploration, project development, and operations across the globe with those who are just about to embark on their journeys. As much as I get to provide words of wisdom, every year I leave these sessions learning from the students and feeling that the geosciences are in good hands. Many are ready to challenge conventional wisdom and improve understanding for the benefit of industry and society.

Terry has been involved additionally by helping shape the GeoCareers program during its formative stage along with other corporate partners, and bringing Newmont support to GSA's On To the Future diversity initiative with funding for one student to participate in the program each year. He also collaborated with GSA and organizational partners on a proposal to develop a professional training program that would include his service on the program's advisory board if accepted.

This partnership represents a depth and breadth of collaboration between GSA and corporations that reaches far beyond a one-time financial contribution to a program. We value the support of our partners and the devoted time of their employees to GSA students and efforts. Together, we can maximize the collective ability to foster current and future leaders in the geoscience community. We strive to engage business and industry as a positive force to advance science, stewardship, and service, joining with corporations to have a meaningful impact. If you want to learn how you or your employer can join these efforts, please contact Debbie Marcinkowski at +1-303-357-1047 or dmarcinkowski@geosociety.org.

Terry Briggs addressing students from the GeoCareers lunch panel, 2015, Baltimore, Maryland, USA.

Roger Cooper talking to students at the Newmont Booth during GeoCareers Day 2016, Denver, Colorado, USA.

Student attendees at the GeoCareers lunch panel.

www.gsafweb.org

Earth-Science Outreach Using an Integrated Social Media Platform

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INTRODUCTION

Public outreach is an important aspect of every scientist's job description, but, unfortunately, it is often the aspect that is most neglected. Barriers that prevent scientists from engaging in effective public outreach include the pressing demands of administrative responsibilities, a lack of training, misaligned incentives, and/or a lack of administrative support (Andrews et al., 2005). However, funding agencies still often require evidence for the broader impacts of research results for continued access to public funds. New approaches are needed that encourage participation, provide a greater return on time invested, and offer quantifiable metrics on their impact.

In response to these challenges, many people use the Internet to communicate science to a wider audience (Fig. 1). Web-based science outreach efforts often struggle without a focused goal and/or well-defined audience, or suffer from low visibility within a particular platform (e.g., blog, Facebook, Twitter). If one desires to have an impact on public discourse and opinion, it is essential to engage in multiple outlets, given the fractured and diverse nature of the information ecosystem (Bik et al., 2015; Bik and Goldstein, 2013). This means expanding beyond blogs and websites, and including social media sites like Twitter, Facebook, Instagram, and other digital media (e.g., viral videos, mobile apps, podcasts). When used effectively, social media engagement doesn't replace scholarly output or "dumb down" science; rather, it boosts awareness, increases curiosity, builds community, and points readers to in-depth research of which they may not otherwise have been aware. In this article, we present a

		Participation: Low	Participation: High
Reach	High	popular media	integrated social media platform e.g. TravelingGeologist
Reach	Low	individual Twitter/ Instagram accounts specific research programs	academic conferences

Figure 1. The impact-participation matrix illustrates the goals of science outreach (i.e., high "impact" and wide "participation"). TravelingGeologist provides an open platform for anyone to contribute (and therefore maximizing participation from scientists) and has broad reach by utilizing an ISMP that spans the online ecosystem (thereby maximizing audience size/diversity).

five-year multi-national case study using "TravelingGeologist" (TG), an integrated social media platform (ISMP) focused on inspiring new scientists using field-based research narratives. Garnering >50,000 followers across multiple web-based platforms and >100 contributors, we conclude that lessons learned from TG can help scientists broaden their impact and participation in outreach efforts.

EXAMPLE OF A SUCCESSFUL ISMP: TRAVELINGGEOLOGIST

TG is an example of a successful, not-for-profit, web-based ISMP serving as a public outlet for earth scientists engaged in field-based research. TG allows researchers to give a high-level synopsis of research goals and findings, publish photographs of field locales, and tell "behind the scenes" stories about the fieldwork of their research project, all with the expressed purpose of (1) attracting and inspiring budding scientists; (2) sharing results of research to the public; and (3) fostering scientific communication and interdisciplinary collaboration. TG leverages social media for dissemination and as a springboard for generating discussion; e.g., using Twitter to point readers to new and interesting papers, using Facebook to prompt a discussion on a controversial scientific topic, and using Instagram to provide in-the-field photographs and discussions of ongoing research.

Currently, TG has >100 contributors from >70 institutions and 14 countries. Its blog platform has >50,000 readers with average posts gaining >1000 page views. Readership currently comes from >180 nations and encompasses a wide range of education levels and employment status (Fig. 2). Over 50% of the followers on Instagram and >30% on Facebook come from lower/middle-income countries (Fig. 2). We highlight the relationship between different social media platforms and engagement with different countries and education levels in Figure 2. Reaching a wide audience beyond national and socio-economic borders elevates and strengthens the scientific community.

Survey results collected from TG readers (n = 172; see Fig. 2) found differences in platform preference, engagement level, and impact of interactions. Undergraduate students (n = 47) were more likely to follow Instagram (45%) and, together with high school students (n = 3), were least likely to visit the website, suggesting a preference for learning in a social context. Students and researchers (n = 54) wanted to participate in future fieldwork after engaging with TG. Female respondents (n = 82) felt more connected in finding role models than male respondents (n = 90). University-employed individuals (n = 25) were more likely than government/industry-employed individuals

GSA Today, v. 27, https://www.doi.org/10.1130/GSATG333GW.1. Copyright 2017, The Geological Society of America.

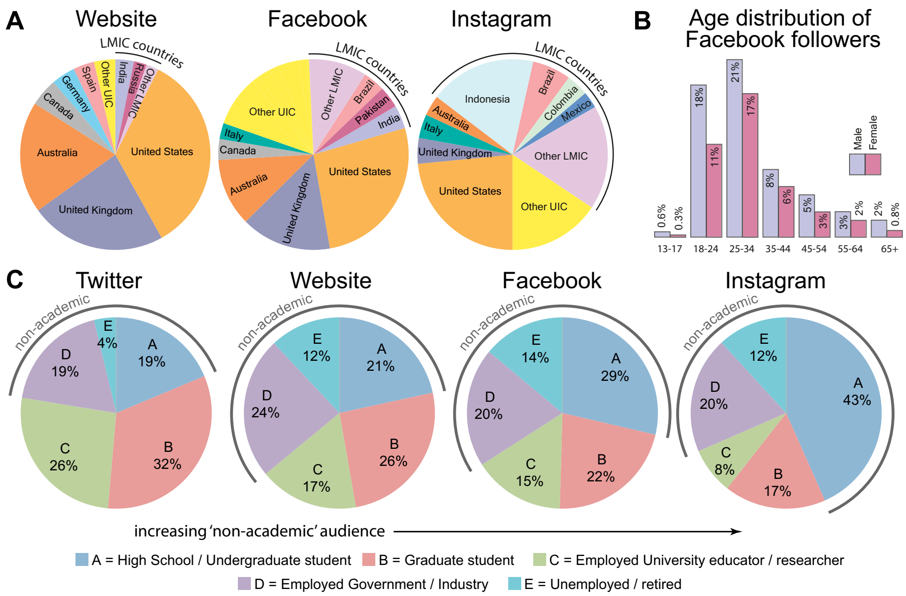

Figure 2. (A) Geographic distribution of website traffic and Facebook/Instagram followers. LMIC—lower-/middle-income countries (as defined by the World Bank); UIC—upper income countries. (B) Age/gender distribution of followers of TravelingGeologist on Facebook; e.g., 11% of females and 18% of males are 18–24 years old. (C) Chart of the current education/employment situation for survey respondents made up of TravelingGeologist readers.

($n = 43$) to report greater gender diversity at TG than in their institution, suggesting an important role for social media in supporting gender diversity in academia.

We attribute the success of TG to some key principles that should be employed by any group wishing to use social media as a successful outreach tool:

1. TG has a **focused goal**; i.e., inspiring the next generation of scientists by targeting young people interested in adventure travel and science. Field-based research and teaching is an effective way to recruit students to the geosciences (e.g., Moore, 2015). Additionally, adventure and travel narratives inherent to field-based science, when shared effectively, offer an alternative, low-cost approach to boosting the visibility of and interest in science careers. This is a specific audience niche, and focus enables building a recognizable social media brand (e.g., Bik et al., 2015).
2. TG is a **single unified platform** that uses multiple web-based platforms: Twitter, Facebook, Instagram, and TravelingGeologist.com. These platforms offer different levels of outreach. Twitter offers links to external sources, pithy commentary, or simple announcements, but each post/comment is limited in length. Facebook can expand conversation to lengthy discussions with photos and videos. Instagram offers quick, ephemeral outreach using photographs requiring minimal engagement ("double tap"). TravelingGeologist.com is less socially interactive but offers a permanent and in-depth outreach presence through contributor-produced georeferenced articles. These articles are short and non-technical. While not neglecting the science, articles delve into the human stories behind the research. By using multiple platforms, TG is able to reach a wider audience.
3. With TG, **content is not generated by a single researcher,** therefore lessening pressure for content generation. This lightens the load for any one person and providing more diverse content.

Earth scientists are invited to participate by submitting an article (500–2000 words) and photographs (with captions) from field-based research (recent or historical). Submitted material is reviewed and edited by volunteer staff and queued for publication.

ASSESSING ENGAGEMENT IMPACT FROM OUTREACH EFFORTS

A final key aspect of using an ISMP to enhance outreach is measuring success easily. Followers, readership, downloads, and engagement are quantifiable with accessible and transparent metrics (see GSA Data Repository Fig. DR1[1] for statistics and growth from 2012 to 2017). The ultimate challenge of any ISMP is evolving as new technologies and media emerge that change the landscape of social interactions.

CONCLUSION

Science outreach with an ISMP provides an opportunity to more efficiently engage with a diverse body of students and aspiring scientists around the world in order to foster a global network of current and future scientists. TG provides a case study on diversifying outreach efforts across a variety of social media platforms. This model is not unique to TG and can be applied to any scientific subdiscipline. Our hope is that funding agencies and sponsoring institutions will see value in this type of public outreach and incentivize social media outreach among scientists.

ACKNOWLEDGMENTS

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REFERENCES CITED

Andrews, E., Weaver, A., Hanley, D., Shamatha, J., and Melton, G., 2005, Scientists and public outreach: Participation, motivations, and impediments: Journal of Geoscience Education, v. 53, p. 281–293, doi:10.5408/1089-9995-53.3.281.

Bik, H.M., and Goldstein, M.C., 2013, An introduction to social media for scientists: PLoS Biology, v. 11, no. 4, e1001535, doi:10.1371/journal.pbio.1001535.

Bik, H.M., Dove, A.D.M., Goldstein, M.C., Helm, R.R., MacPherson, R., Martini, K., Warneke, A., and McClain, C., 2015, Ten simple rules for effective online outreach: PLoS Computational Biology, v. 11, e1003906, doi:10.1371/journal.pcbi.1003906.

Moore, S.L., 2015, GeoFORCE: Inspiring the geoscientists of tomorrow through field experiences: The Leading Edge, v. 34, p. 1210–1212, doi:10.1190/tle34101210.1.

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[1]GSA Supplemental Data Item 2017209, growth statistics of the TravelingGeologist integrated social media platform, is online at www.geosociety.org/datarepository/2017/.