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How Changing Climate Created Mount Desert Island

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> As the waves rise and fall in broken rhythm on the shore, as the tide flows and ebbs across the littoral belt, so the seas of former times have risen and fallen in uneven measure on the uneasy land; the rocks have grown and wasted; the ice of the North has crept down and melted away;--all shifting back and forth in their cycles of change. Only one scene lies before us of the many that have floated through the past.
>
> —William Morris Davis[1]

The earth began, again, to cool. It cooled so much that one year, when summer came, the winter snow did not melt. The next winter, more snow fell onto the old snowpack and did not melt. Annual layers of snow compacted into ice, and the ice grew into glaciers that spread south from the Arctic.

Along with tectonic shifts and eruptions of the earth's crust, climate change has had the greatest influence on the Mount Desert Island environment we experience today. Over the last two million years or so, cyclical changes in the earth's orbit, tilt, and spin caused changes in global climate, resulting in long periods of cold temperatures alternating with shorter warm or "interglacial" periods. The most recent cold phase began around 100,000 years ago.

When the leading edge of the continental glaciers first reached the coast of Maine, they were blocked by the east-west mountain range of Mount Desert. Ice piled up on the north side of Mount Desert and flowed around to the east and west, spilling into the low areas. It continued to build, thickening into a mile-high layer of moving ice, amassing into a giant sheet covering northeastern North America.

Today, it is common knowledge that the landscape of Mount Desert Island is the product of glaciers. We know that heavy ice smoothed granite mountains into rounded hills. We know the parallel lakes and valleys were formed by trapped tongues of ice that slowly melted. We know the erratic boulders perched on hillsides and summits were carried there from far away by ice and water. We know from the steep southeast cliffs and the direction of scratches in the rocks that the glaciers melted away from southeast to northwest, back in the direction from which they came. We know all of this.

Two hundred years ago, we knew none of this.

Charles T. Jackson, a young Boston physician, conducted the first scientific survey of Maine from 1835 to 1837, at the request of the Maine Legislature. Primarily in search of mineral resources, Jackson spent only a brief time on Mount Desert Island. He concluded from his work there and elsewhere in the state that,

> All the observations that have been made, tend to prove that a current of water has swept over the surface of the globe . . . and that the current swept along with it, the loose masses of stone and gravel and sand, carrying them from the north or northwest toward the south or southeast. Thus was formed the accumulation of rounded masses of stones and gravel and clay, which constitute what is called, by geologists, diluvial soil. It is supposed that this rushing of water over the land, took place during the last grand deluge, accounts of which have been handed down by tradition, and are preserved in the archives of all people. Although it is commonly supposed that the deluge was intended solely for the punishment of the corrupt antediluvians, it is not improbable, that the descendants of Noah reap many advantages from its influence, since the various soils underwent modifications and admixtures, which rendered them better adapted to the wants of man. May not the hand of Benevolence be seen working, even amid the waters of the deluge?[2]

Jackson's words reflected the intellectual consensus of his era.[3] Gravel deposits, erratic boulders, scratched rock, and eroded valleys were the products of moving water. A lot of water. *A great flood.* The earth, after all, was young, young enough to have been written about *in the beginning*, and so most of what had happened had been witnessed by man, and written down. No text said that *ice* had done this work, that the whole world had been colder and was still thawing out. The theory was *diluvian, Noachian*: Noah's Flood created the landscape.

Charles Jackson was only the first of many scientists to study the landscape of Mount Desert. The island's striking and obvious geology made it a destination for people in search of evidence to support their hypotheses about how nature came to be. Naturalists and scientists had been debating the causes of surficial geologic features and questioning the age and formation of the earth, challenging religious beliefs at a time when science was still emerging as an independent discipline.

Charles H. Hitchcock and Ezekiel Holmes expanded Jackson's work with a second state geological survey in 1861 and 1862.[4] They, too, tried (with difficulty) to explain Mount Desert's features in terms of the Noachian Flood.[5] Some geologists had come to acknowledge the role of frozen water, but in the form of floating icebergs. Hitchcock and Holmes corresponded with John Kimball De Laski, a local physician with an interest in geology who had been making observations around Penobscot Bay, including the "boulder phenomena" of Mount Desert. He shared his conclusions with the surveyors: "A glacier once occupied that margin of the state, of a magnitude sufficient to cover the highest hills of the region, and to extend far into the interior towards the north." The soil was made of gravels, clays, and sands crushed and ground out of the detached rocks by "the great denuding agent." He disregarded floating icebergs as an explanation, and thus was the first to suggest the historic influence of ice cover.[6]

Still, the Ice Age was not widely accepted in 1864, when Swiss scientist and Harvard zoology professor Louis Agassiz traveled to Maine.[7] Agassiz had first introduced the idea of an *eiszeit,* an Ice Age, in Europe in 1837. Not only were existing glaciers much bigger in the past, he proposed, but other areas currently without snow or ice were once covered by glaciers, too. For the next several decades, working with Oxford professor Reverend William Buckland and others, Agassiz assembled from his observations the glacier theory that would earn him credit as a co-discoverer of the Ice Age.

But in 1864, many still had their doubts.

Upon crossing the bridge to Mount Desert Island, Agassiz saw the same grooves and scratches he knew from studying glaciers at work in the Alps. He observed how the scratches always ran in one direction, south to north, ascending all the elevations and descending into all the depressions. Addressing his critics, he wrote, "If not openly said, it is whispered, that, after all, this great ice-period is a mere fancy, worthy at best of a place among the tales of the Arabian Nights."[8]

"How is it possible to suppose that floating icebergs would advance over such an uneven country with this steadfast, straightforward march?" he asked.[9] To Agassiz, the signature of ice was obvious. He could see the solid weight of it: "Every natural surface of rock is scored by its writing, and even the tops of the mountains attest, by their rounded and polished summits, that they formed no obstacle to its advance."[10]

Agassiz helped others to see it, too. In Britain, geologists had been walking over the mountains for many years, seeing the deluge, until Agassiz visited in 1840 and introduced the idea of glaciated landscapes and local evidence for ice cover.[11] And the same happened in Maine, where Mount Desert provided further evidence for his glacial theory. Agassiz visited Great Head and Sand Beach, and climbed Cadillac Mountain, noticing all the time polished and grooved surfaces and scratches. Agassiz estimated the ice sheet was more than 6,000 feet thick.

Agassiz believed that, like a great flood, ice, too, could be the work of a Creator. He described the ice as "God's great plow."[12]

The great plow began its work 25,000 years ago. The Laurentide Ice Sheet extended from its center near Hudson's Bay, eventually stretching to Long Island, Cape Cod, and out onto Georges Bank. Maine was buried beneath a mile and a half of ice.[13] The air was cold and dry everywhere; south of the ice sheet was a landscape of open boreal woodlands and tundra dominated by white spruce, jack pine, red pine, white pine, and paper birch.[14]

Twenty-one thousand years ago, the earth wobbled and tilted toward warming. The glacier began to melt, calving icebergs at its edge into the North Atlantic while growing thinner over land. When all the water was tied up in the ice, the edge of the sea was hundreds of feet lower; as ice turned to water, sea levels began to rise.[15]

Sixteen-thousand six-hundred years ago, the peaks of Sargent and Cadillac mountains emerged as nunataks—islands in the ice. A pond began to form in the granite bowl exposed on Sargent's summit.[16]

Hundreds of feet of ice still covered the rest of Mount Desert Island, and continued to grind the mountain range as it melted, creating long slopes and steep east and west sides.

By 15,500 to 14,000 years ago, southern New England, the Gulf of Maine, and southeastern Maine, including Mount Desert, were ice-free. Shrubby willows, birches, sedges, and herbs had taken root on the mountain slopes. Northern Maine remained under ice, but the rate of melting accelerated as the glacier shrank: from 30 feet per year to 130 feet per year to 500 feet per year.[17]

The weight of the ice had pushed the land surface down, and the rising Atlantic ocean flooded into Maine in the glacier's wake. This "DeGeer Sea," named for Swedish geologist Bernard De Geer, reached its highest extent 13,000 years ago, submerging two-thirds of Mount Desert Island beneath the water. This ancient shoreline can now be seen at 230 feet above sea level.[18]

Understanding of these complex interactions of climate, land, sea, ice, and water came slowly.

Nathaniel Southgate Shaler first visited Mount Desert in 1860, when he was a student under Agassiz at Harvard. He became a Harvard professor of paleontology and geology and continued to visit the Maine coast, first with the Coast Survey from 1870 to 1872, publishing a "Report on the Recent Changes of Level on the Coast of Maine" in 1874. Later, working under the U.S. Geological Survey, he conducted what is considered the first systematic study of Mount Desert's surficial and bedrock geology.[19] By this time, Agassiz had helped American scientists see the work of past climate changes on their home ground, and the Ice Age was no longer a mere whisper. So Shaler wrote. "There can be no question that ice covered the hills to their summits, and that it was deep upon the tops of the highest peaks."[20] Shaler spent much of this time with the Geological Survey documenting marine submergence, and Mount Desert provided plenty of evidence.

When the sea was higher, it created the same characteristics that can be seen on the shoreline today: cobble beaches, caves and sea walls, towering cliffs and sea stacks. The most famous sea stack, known as Pulpit, Tilting, or Chimney Rock, is on the side of Day Mountain, where a bedrock wall now hidden by beech and hemlock branches once faced the sea. As waves crashed against the wall, the rock fractured and split along weak spots and fault lines, breaking away and tumbling into the surf. Left behind was a twenty-foot pinnacle of more resistant rock—a sea stack, topped by a triangular block of granite. Shaler was so preoccupied with this theory of an ancient ocean that he could see nothing else, claiming sea-worn rock faces and cliffs as high as 1,300 feet.

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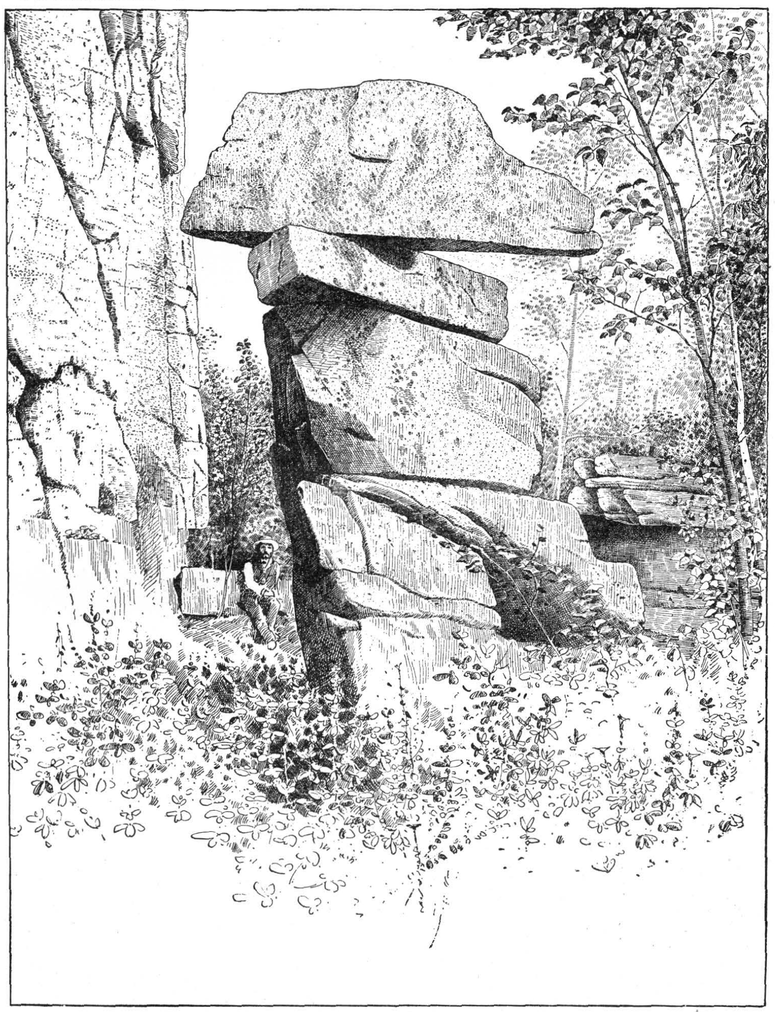


ROCK DETACHED BY WAVE ACTION ON 220-FEET BEACH.

Drawing of "Pulpit or Chimney Rock" on the side of Day Mountain.
From Nathaniel Southgate Shaler's article "Geology of Mount Desert," 1889

According to modern geologists, most of the rocks on the Maine coast have too many fractures to allow features like sea stacks to form or exist for very long, but the granite of Mount Desert Island "appears ideal for their formation."[21] Chimney Rock was well known to nineteenth-century ramblers on Mount Desert. The triangular block of granite on the top is loose, and today is in a different position than Shaler showed in his illustrations. The story goes that in the 1930s vandals toppled the uppermost stone, and John D. Rockefeller Jr. had a crane brought in on the nearby carriage road to re-position it.[22]

Shaler used notes and maps sketched by his Harvard colleague William Morris Davis. Davis had been studying the geology of Mount Desert since 1880, when he joined some of his students at their camp in Northeast Harbor. The students had spent a productive summer surveying the natural history of the island under the leadership of Charles Eliot, son of Harvard president Charles William Eliot. Davis spent a few weeks with the Champlain Society, as the young men called themselves, and later reported on their geologic findings to the Boston Society of Natural History. Citing Agassiz, Davis reported that glacial action was conspicuous over the whole island. "The mountain summits are all rounded, and when protected from weathering, sometimes show polishing or striation: boulders of foreign rocks are common even on the summits. Along the shore, the drift shows well scratched pebbles and boulders, and is therefore probably of original, unstratified, subglacial origin, somewhat modified in surface form by the sea during its former higher level."[23]

His full report appeared in 1894 in *The Flora of Mount Desert* by Edward Rand (also a member of the Champlain Society) and John Redfield. Davis noted that "during a time of colder climate, there was an invasion of the region from the north by a sheet of ice, such as that which still maintains possession of Greenland." He also described "beds of stratified clay bearing marine fossils" at various points on the lowland of the island and the mainland, up to about 200 feet above the present sea level. Davis reasoned that "at the closing stages of the ice invasion and for a time afterwards, the land must have stood lower than now."[24]

For in addition to the features formed by waves at the surface of the ancient ocean, the sea floor also left its mark, as Davis reported. Rock flour washed into the sea from melting ice and settled to the bottom, forming a layer of mud and silt that became home to mollusks such as macoma clams and astartes, wrinkled rock borer, nutclams, and Iceland scallops. (Where it settled in high-elevation lakes like Sargent Mountain Pond, this same rock flour allowed plants to grow since it contained minerals, such as phosphorus, from the surrounding granite.)

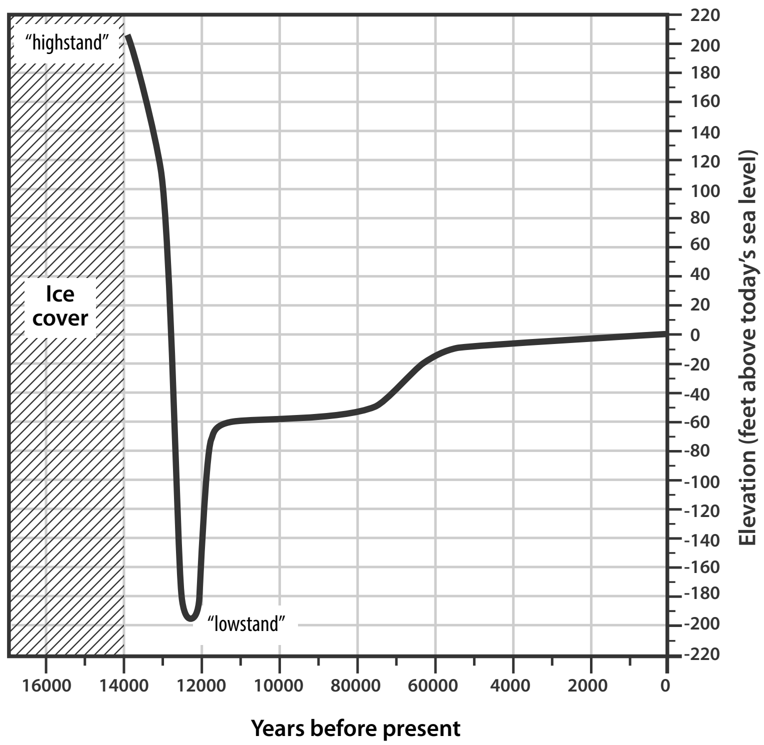
When, 13,000 years ago, the ice receded from northern Maine, the land rebounded, causing sea levels to drop dramatically—180 feet lower than present sea level. As the sea fell, it left behind the layer of marine mud or "cove clay" filled with fossils that suggested a past climate similar to that of southern Labrador and Greenland today. Geologists who visited after Shaler and Davis noted the clay's presence at the south end of Jordan Pond, along Hunter's Brook and other stream valleys, and beneath many wetlands. These geologists, including Stone (1899),[25] Bascom (1919),[26] and Raisz (1929),[27] continued to refine the post-glacial history of Mount Desert. But not until later in the twentieth century would the full picture come together.

Around the time of the sea level "lowstand," temperatures dropped as abruptly as they had warmed, plunging back to glacial conditions. The Younger Dryas cold event lasted for a thousand years.[28] Spruce trees scattered across the exposed summits of Mount Desert as the ancestors of today's Wabanaki peoples entered the region, hunting caribou, musk ox, mammoth.[29]

Substantial and rapid warming 11,600 years ago ended the Younger Dryas, but created dry conditions. Lake levels dropped. Shrub fens and spruce-tundra dried out into mixed forests of hemlock, white pine, birch, maple, and beech around 7,000 years ago. Jack pine and white pine became more abundant; growing forests restricted caribou habitat.[30]

Meanwhile the sea, swollen with meltwater, had begun to rise again, quickly at first, from 180 feet to 65 feet below present levels, then more slowly. Then, as now, the ocean influenced the climate of Mount Desert Island.

As sea levels rose, the shape of the semi-enclosed basin of the Gulf of Maine formed and twice-daily tides developed. Increasing tides mixed the warm surface layers with cold layers below, lowering surface water temperatures and causing the frequent formation of fog, which would have favored spruce and fir and discouraged pine and hemlock. The influences that permitted spruce to dominate the forest affected only a narrow band near the shore, and perhaps only on coastal islands and peninsulas.[31]



Sea levels in Maine, 16,000 years ago to present, relative to today's mean sea level. The sea reached a "highstand" immediately after the glaciers melted 14,000 years ago, dropped briefly, and has been rising ever since. *Figure by K. Tenga-Gonzalez, modified from J.T. Kelley et al., "Drowned coastal deposits," 2010. Courtesy of Joseph T. Kelley*

Swordfish, which inhabit warm surface layers and had been hunted by the Wabanaki, declined in numbers, while broad tidal flats formed and shellfish populations expanded. Native people adapted, shifting their diet to the abundant shellfish, as evidenced by large piles of discarded shells or middens.

The continued rise of global sea level brought the ocean close to its present position about 3,000 years ago. It has been rising ever since, with a recent acceleration due to warming caused by human activities that at once induces further melting of land-based glaciers and delivery of meltwater to the ocean, and expands ocean waters, increasing volume.

Five hundred years ago, the forests came to resemble present-day conditions. How might they change in the future? The same dramatic "coastal cooling" effect that allowed spruce to persist along the Downeast coast during past warm periods likely will continue into the future, allowing spruce-fir forests to remain on Mount Desert, in greater contrast to inland areas. Increased greenhouse gases and greater availability of some nutrients could favor fast-growing, competitive trees like red maple, along with weeds and invasive species.[32]

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In *The Ice Finders*, Edmund Bolles observed that scientists in 1850 could not comprehend the Ice Age, because it was so unlike anything else they knew.[33] Today, we cannot imagine—truly cannot picture in our minds—how humans can rival glaciers and volcanoes in the scale of our influence on earth. And, like Agassiz and others who *saw*, finally, that what they observed all around them was the result of glaciers, many of us need to see or experience change to accept that it is happening. Mount Desert is a reliable witness: when we admire the summits and marvel at the balanced rocks and ancient shorelines, we are all observers of climate change.

Notes

[1] "An Outline of the Geology of Mount Desert," in Edward L. Rand and John H. Redfield, *Flora of Mount Desert Island, Maine* (Cambridge: John Wilson and Son, 1894), 71.

[2] Charles T. Jackson, First Report on the Geology of the State of Maine (Augusta: Smith and Robinson, 1837).

[3] David R. Oldroyd, *Thinking About the Earth* (Cambridge, MA: Harvard University Press, 1996). For a comprehensive history of geologic work on Mount Desert, see George H. Chadwick's "Compendium of the Geology of Mount Desert Island in Maine," Fogler Library Special Collections, 1937.

[4] Ezekiel Holmes and Charles H. Hitchcock, in *Sixth Annual Report of the Secretary of the Maine Board of Agriculture* (Augusta: Stevens and Sayward, 1861) and *Seventh Annual Report of the Secretary of the Maine Board of Agriculture* (Augusta: Stevens and Sayward, 1862).

[5] David C. Smith and Harold W. Borns, Jr., "Louis Agassiz, the Great Deluge, and early Maine geology," *Northeastern Naturalist* 7 (2000): 157-77.

[6] John De Laski, "Ancient glacial action in the southern part of Maine," in *Seventh Annual Report of the Secretary of the Maine Board of Agriculture* (Augusta: Stevens and Sayward, 1862), 382-83. Smith and Borns wrote that De Laski's explanations are very similar to modern views.

[7] Louis Agassiz, "Glacial phenomena in Maine," *Atlantic Monthly* (February 1867): 211-87; E.C. Agassiz, *Louis Agassiz, His Life and Correspondence,* vol. 2 (Boston, MA:

Houghton, Mifflin and Company, 1885); Smith and Borns, "Louis Agassiz," *Northeastern Naturalist*.
[8] Louis Agassiz, "Glacial Phenomena in Maine I," *Atlantic Monthly* 19 (February 1867): 212.
[9] Louis Agassiz, "Glacial Phenomena in Maine II," *Atlantic Monthly* 19 (March 1867): 286.
[10] L. Agassiz, "Glacial Phenomena in Maine I," 216.
[11] Oldroyd, *Thinking About the Earth*, 150.
[12] L. Agassiz, "Ice-Period in America," in *Geological Sketches* (Boston: James R. Osgood and Company, 1876), 99.
[13] Harold W. Borns, "Maine Ice Age Trail" (Orono, ME: Climate Change Institute. http://iceagetrail.umaine.edu/maineice.htm).
[14] S.T. Jackson et al., "Vegetation and environment in Eastern North America during the Last Glacial Maximum," *Quaternary Science Reviews* 19 (2000): 489-508.
[15] Maine Geological Survey, "The Geology of Mount Desert Island: A Visitor's Guide to the Geology of Acadia National Park" (Augusta, ME: 2011).
[16] Catherine Schmitt, "Maine's first lake," *Friends of Acadia Journal* 15(2010): 10-11.
[17] H.W. Borns et al., "The deglaciation of Maine, U.S.A.," in Quaternary Glaciations – Extent and Chronology, Part II, eds. J. Ehlers and P.L. Gibbard (Elsevier, 2004), 89-109.
[18]J.T. Kelley, D.F. Belknap, and S. Claesson, "Drowned coastal deposits with associated archaeological remains from a sea-level 'lowstand'": Northwestern Gulf of Maine, USA," *Geology* 38 (2010): 695-98; D.A. Smith, "Late-glacial emerged shoreline features of Mount Desert Island, Maine, a report submitted to Acadia National Park" (Orono: University of Maine, 1966). While the general consensus is that the DeGeer Sea reached a height of 230 feet above current sea level, one unpublished report locates a sea stack on Champlain Mountain at 440 feet; P. Rubin, "The DeGeer Stack," copy of email in Acadia National Park library, 2002.
[19] N.S. Shaler, "Recent changes of level on the coast of Maine," *Memoirs of the Boston Society of Natural History* 2(1874): 321-40.
[20] N.S. Shaler, "Geology of Mount Desert" in *Eighth Annual Report of the U.S. Geological Survey to the Secretary of the Interior, 1886-1887, Part II* (Washington, DC: Government Printing Office, 1889), 993-1061.
[21] Joseph T. Kelley, "Sea-level change on Mount Desert Island, Maine, Geologic Site of the Month." (Augusta, ME: Maine Geological Survey, 2002).
[22] Joseph T. Kelley, "Sea-level change on Mount Desert Island, Maine, Geologic Site of the Month" (Augusta, ME: Maine Geological Survey, 2002); interview with Charlie Jacobi, National Park Service, 2009.
[23] W.M. Davis, "Remarks on the geology of Mt. Desert, Me.," *Proceedings of the Boston Society of Natural History* 21(1883): 117-18.
[24] W.M. Davis, "An outline of the geology of Mount Desert," in Edward Lothrop Rand and John H. Redfield, *The Flora of Mount Desert Island, Maine* (Cambridge, MA: J. Wilson and Son, 1894), 43-71.

[25] G.H. Stone, "The Glacial Gravels of Maine and their Associated Deposits," Monographs of the United States Geological Survey Vol. 34 (Washington, DC: Government Printing Office, 1899).
[26] Florence Bascom, *The Geology of Mount Desert Island* (Joint Path Committee of the Village Improvement Societies of Mount Desert Island), revised and reprinted from the *Bulletin of the Geographical Society of Philadelphia* 17 (1919).
[27] E.J. Raisz, "The scenery of Mt. Desert Island: its origin and development," *Annals of the New York Academy of Sciences* 31(1929): 121-86.
[28] H.W. Borns et al., "The deglaciation of Maine," 101.
[29] J.C. Lothrop, P.E. Newby, A.E. Spiess, and J.W. Bradley, "Paleoindians and the Younger Dryas in the New England-Maritimes Region," *Quaternary International* 242 (2011): 546-69.
[30] Ibid.
[31] M. Schauffler and G.L. Jacobson, Jr., "Persistence of coastal spruce refugia during the Holocene in Northern New England, USA, detected by stand-scale pollen stratigraphies," *Journal of Ecology* 90(2002): 235-50. Spruce did not expand through other parts of northern Maine until further cooling occurred 1,000 years later, allowing spruce to increase fourfold.
[32] M. Day, I. Fernandez, G. Jacobson, and R. Jagels, "Forests," in *Maine's Climate Future* (Orono: University of Maine, 2009), 26-29.
[33] E.B. Bolles, *The Ice Finders: How a poet, a professor, and a politician discovered the Ice Age* (Washington, DC: Counterpoint, 1999).