CHAPTER 6

DARWIN'S WORLD—SPECIES, VARIETIES, AND THE AGE OF THE EARTH. EVIDENCES OF GLACIATION

When Louis Agassiz came to Harvard from Switzerland in 1846, he brought with him not only his considerable expertise in biology, but also a lifetime experience in the Swiss Alps. In the Alps, he had often observed the workings of glaciers and had speculated that the glaciers had once been much more massive. Glaciers form when more snow accumulates each winter than can melt in the spring. The snow continues to pile up until it compresses the snow below into a dense form of ice, so dense that it has a blue color. (The ice is blue for reasons very similar to the reasons why the sky is blue and why the ocean under sunlight is blue. It has to do with the way that water transmits and reflects light. But that is a different story.) As anyone who has ice-skated knows, at appropriate temperatures ice, when compressed, will melt. The ice skate puts the weight of your body on a very narrow surface, compressing the ice and causing it to melt. Thus the skate glides easily along the ice. It does not work if the ice is too cold or the weight is not enough. Try it!

Glaciers do the same thing. With all the weight of the glacier above, the ice at the bottom melts, allowing the glacier to slide down the mountain. Glaciers slip down mountainsides at rates from a few feet to hundreds of feet per year, as has been documented by objects such as abandoned climbers' tents being moved down the mountain. At the upper end, the glacier is renewed by the continuous accumulation of snow. See Fig. 2.1. Underneath the glacier, the movement rolls or pushes rocks and often breaks them; and the glacier often breaks apart small structures such as uneven parts of the earth. The glacier expands in the winter and retreats in the summer, leaving piles of the rubble it produced. The glacier as a whole moves like a river: The glacier is always there, but the water in it changes constantly.

The movement of the glacier produces characteristic marks, very similar to those that would be produced if you scoured a dirty pot with cleanser or a soft stone such as a pumice stone. The uneven surface (the remnant food) would be ground away, and the pot, if it were soft metal, would be scratched by the cleanser. The remnant food would accumulate at the edge, where the scouring stopped. Glacial valleys look very much like those shown in Figs. 6.1 and 6.2, whether the glacier is still there or not. The walls are steep and give the appearance of having been gouged

Figure 6.1. Termination of a glacier in Alaska. The glacier extends much farther into the sea in the wintertime and previously was much larger. Note the characteristics of the land through which it has come: steep-walled carved and scored valleys (arrows) and piles of rubble, mostly stones, boulders, and pebbles, along the sides of the glacier. The rubble along the side is called lateral moraine. At the front of the farthest extension of the glacier is the terminal moraine

Figure 6.2. Edge of a fjord, or valley carved by a glacier (Norway). Note that the physical characteristics are the same, allowing its identification long after the glacier has disappeared

out; the stones at the base are scratched or polished; and there is considerable rubble piled up at the sides and at the front of the glacier. These piles of rubble are called moraines, from the French dialect word meaning referring to the types of hills formed by rubble.

You can imagine Agassiz' bewilderment, astonishment, and finally sense of wonder as he toured the US and began to realize that the characteristics of the landscape that he was viewing—the rocky terrain of New England and farther north, compared to the deep soil of land south of New England; the Great Lakes and Finger Lakes; the scratched appearance of rocks and odd placement of huge boulders—were similar to the characteristics of the Swiss glacial valleys that he knew, but on a vastly larger scale, rather like Jack and the Beanstalk, where Jack encounters a world of giants on a much greater scale of measurement than he is. The glacial valleys of the Alps are not more than a few miles long, and much less than a mile across. (Glacial valleys are typically much longer and deeper than they are wide. This also is a characteristic of the fjords of Norway, and is how a fjord is defined (Figs. 6.3 and 6.4). Fjords were formed by glaciers, though this association

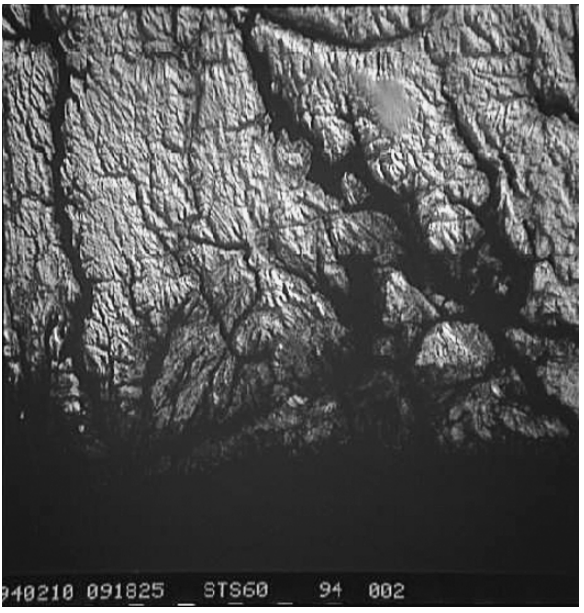


Figure 6.3. Satellite view of fjords in Norway Note the long, narrow, straight channels. Part of the definition of a fjord is that it is deeper than it is wide, characteristic of valleys carved by glacial tongues. Credits: Image Science and Analysis Laboratory, NASA-Johnson Space Center. 25 Sep. 2006. "Astronaut Photography of Earth - Quick View." <http://eol.jsc.nasa.gov/scripts/sseop/QuickView.pl?directory=ISD&ID=STS060-111-3> (6 Dec. 2006). Image Science and Analysis Laboratory, NASA-Johnson Space Center

Figure 6.4. Satellite view of Finger Lakes District, New York. The long, narrow, deep lakes are characteristic of fjords. Though less visible by satellite, the entire Lake Champlain-Hudson River valley system is also a fjord. Credits: Image Science and Analysis Laboratory, NASA-Johnson Space Center. 10 Jul. 2006. "Astronaut Photography of Earth - Display Record." <http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS010&roll=E&frame=23284&QueryResultsFile=116542430891802.tsv> (6 Dec. 2006). Image Science and Analysis Laboratory, NASA-Johnson Space Center

was not realized until Agassiz recognized it. What Agassiz saw, though, suggested glaciers the width of continents, and tens of miles thick!

There were many features that Agassiz identified, most of which can be readily observed throughout the northern parts of the US and in Canada. First, there were fjord-like lakes, most notably the Finger Lakes of upstate New York. Then there were the scooped-out areas resembling the water-beds at the front of a receding glacier, but much more vast: the basins of the Great Lakes. The mountains of New England were often smooth and polished on their north sides, but rough and steep on their south sides. And then there were the scratch marks. On embedded rocks throughout the north, there were scratch marks—glacial striations—mostly in a north-to-south direction. They are very prominent in Central Park (Figs. 6.5 and 6.6). Only something very massive and universal could have done all this. Finally, there were huge boulders, much larger than could be moved by humans, animals, or floods, sitting randomly on mountain tops, in valleys, and in various locations. They had two characteristics in common: They showed no relationship to the land or the stones in their neighborhood, but they did resemble the rocks of land hundreds of miles to the north. These are called erratics, more correctly glacial erratics, and we now know that they were, indeed, carried to their current location by riding piggy-back on glaciers (Fig. 6.7).

There were three other characteristics that could be noted. First, the vegetation of New England and upstate New York is very different from that of areas immediately to the south, and not just because of climate. North of Long Island Sound, in Connecticut, there is very little topsoil, and the trees are consequently shallow-rooted, light trees like birch and aspen. Ten miles away, on Long Island, there is much more soil, and deep-rooted heavy trees like maple and oak are prominent. This

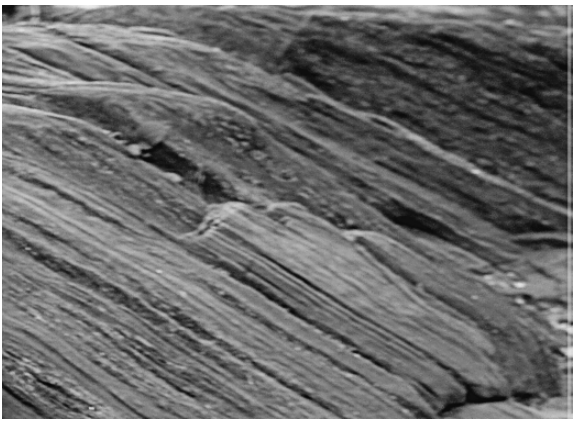


Figure 6.5. Glacial striations visible on rocks in New York City. Many rocks are scored in this fashion, as is this boulder in Central Park. Most of the gouges are in a north-south direction, and some are much deeper. Such marks are found wherever the glaciers scraped the soil to bedrock. There is a Glacial Striations State Park in a small island in Lake Erie off the Ohio shore. Striations are not found south of a line running roughly from Long Island, New York through the flat area surrounding the Great Lakes

is very visible in the amount of light that reaches the floor of the forest (Fig, 6.9). Second, the soil of the north shore of Long Island is rather peculiar. It is rather sandy, filled with small pebbles of various sizes. Third, the north shore of Long Island is very hilly, with the hills separated by deep north-to-south ravines (Fig. 6.8).

All of these different observations could be accommodated by one overall hypothesis, shocking for the time but perhaps the only reasonable interpretation. Long

Figure 6.6. Smaller scale glacial gouging visible on rocks in New York City

Figure 6.7. Shelter Rock, a glacial erratic, Long Island, New York

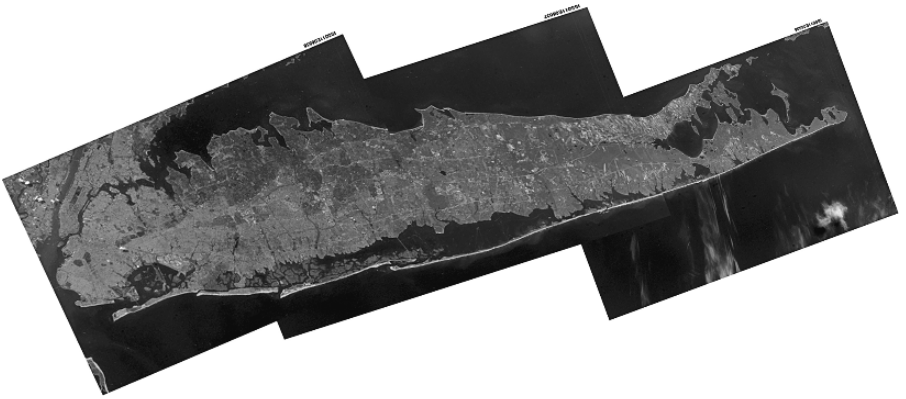


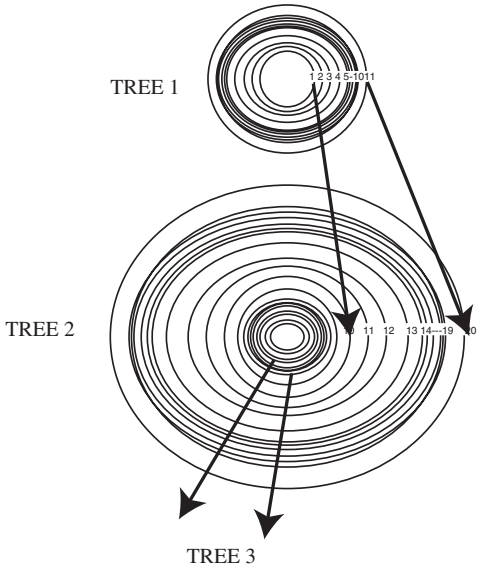
Figure 6.8. The terminal moraine of Long Island, seen in a satellite view. The end of the moraine is marked by the transition between the hilly region to the north (darker color) with deeply carved north-south valleys ending in bays in Long Island Sound. These valleys were the last fingers of the glacier. North of the Sound, the land is heavily scarred in a north-to-south direction. To the south of the hills is flat sandy soil, the outwash from the glacier. (At the western end of the island, neighborhoods in Brooklyn have names such as “Flatlands” and “Flatbush”.) Credits: http://eol.jsc.nasa.gov/sseop/clickmap/ image ESC_large_ISS011_ISS011-E-8036 and 8037

Figure 6.9. Left: The Long Island forest, which is typical for this latitude and elevation. Deep-rooted large-leaf trees such as maple and oak predominate, leaving the undersurface quite dark and with little vegetation. Right: Forest in Westchester County, New York, less than 30 miles north of the forest pictured on the left, but north of the terminal moraine and Long Island Sound. This forest consists of slender, shallow-rooted trees such as birch, poplar, and aspen, and light penetrates to the floor, allowing substantial undergrowth. Contrary to the moraine and areas south of the moraine, which have topsoils one to several feet deep, north of the moraine the topsoil is only two or three inches deep before yielding to bedrock, and the forest reflects this difference. The pictures were taken during the same week

Island was a giant terminal moraine, and many of the features of northern US and Canada could be best explained by the existence at a previous time of huge glaciers that covered most of the territory, tens of miles thick. Of course, the possibility of the existence of massive glaciers carried several implications, none of which were compatible with the Biblical description of the origin of the earth. The first concern, of course, was that Genesis neither described a period of ice nor a situation in which the climate was substantially different from the current climate. Second, it was evident that ice of this order of magnitude would take an extremely long time to form and to melt, and the state of the remnants, including sediment on top of them, erosion such as river cuts into the remnants, and estimates of the age of the remnants, suggested a time span well beyond the calculated six thousand years. To estimate the age of the remnants, one had merely to look at the land. The area immediately to the south of the Great Lakes, perhaps three times the surface area of the lakes themselves, is very flat and sandy, and aquatic fossils such as fish can be found throughout the region. In Indiana, starting immediately south of Lake Michigan, there are sand dunes that clearly seem to be related to the lake bottom. The farther one is from the lake, the more settled and mature the forest is: the topsoil is thicker, and the trees are more like the rest of the region. In these and other areas, if one can count tree rings on current and fossil trees, one can get a lineage that goes back into the thousands of years (Fig. 6.10; see also Chapter 8, page 95).

Even the plants of the New World supported the argument of glaciation. Glaciers covered Europe as well as North America, but in Europe the glaciers drove the flowering plants off the continent. To return to Europe after the glaciers melted, they would have to cross the rapidly drying Sahara desert and the Mediterranean

A



B

Figure 6.10. A: Tree rings seen on a felled relatively young sequoia tree. B: Principle of counting tree rings. Where there are many fossils of trees, it is possible to recognize similar patterns depicting years of abundant growth (presumably with adequate water) and years of very poor growth (see inset on photograph). These can be compared on different trees and a sequential record built. Sequences have been covered for a few thousand years

Sea. In North America the plants were driven to the southern part of the United States and Mexico, and as the glaciers melted they spread northward again. Ponce de Leon's choice of a name for what is now Florida ("Land of flowers") was not simply a publicist's gimmick. To the Europeans, the Americas had far more varieties and numbers of flowers, including far showier flowers, than Europe did. As is described in Chapter 8, many of these were eagerly collected for cultivation in Europe.

All of these observations suggest that the Great Lakes were once much more massive, as if they were a giant reservoir for melting ice, and that they have retreated considerably.

There is also biological evidence for an Ice Age (actually several successive Ice Ages). Most animals and plants live in a preferred characteristic climate. We do not expect to see palm trees in Maine or spruce trees (one of the common Christmas trees) in Florida. Coral reefs are characteristic of warm water, while moose and caribou are common in colder climates. There are many indications from the fossils of the types of animals and plants that during the period in which these geological formations were created, the living organisms were characteristic of climates colder than the current climate in the region. This conclusion can also be reached by penetrating into more subtle analysis: pollen grains, for instance, are preserved in many locations, and the type of plant that gave rise to them identified. Also, many chemical and biochemical reactions proceed differently at different temperatures, and all of the remnants of these reactions indicate a colder climate.

It was not only astonishing but, because of the many converging sources of evidence it soon became incontrovertible that many thousands of years ago much of the earth had been much colder than present. At the very least it suggested that Genesis was incomplete and that efforts to calculate the age of the earth from Genesis were most likely wrong. In more general terms, as is explained in Chapter 8, these results were congruent with the emerging analyses of geologists such as Lyell in that they indicated a much greater age for the earth. When other sciences developed, the several lines of evidence led to the conclusion that the universe was roughly one million times older, and that even the continents were at least 100 times older, than Bishop Ussher's calculation.

There were several other biological considerations as well. The creatures that live in the northern part of North America are very different from those that live in the southern part. The moose-spruce forests of Canada and Alaska are very different from the oak-maple forests of Virginia and Tennessee, the alligator-infested cypress swamps of Florida, the live oaks and pitch pine of southern United States, or the palms of Mexico. If, for instance, Kentucky once had a climate like northern Ontario, many animals and plants would not have been able to live there, so the distribution of living organisms would have been quite different. Even those that managed to hang on through the climate changes would have either to be very resourceful or be modified to deal with the severely changing climate. As the slogan goes, "adapt or die". Over the time scale of generations, the changing climate must be very stressful for all organisms.

An obvious example is how humans adapt to different climates. As we will discuss in Chapter 29, all fossil evidence suggests an origin for humans in east central Africa, and our physiology also reflects this origin. Unlike many mammals, we sweat through our skins to get rid of excess heat, and have become almost hairless, presumably to allow the sweat to evaporate and cool us. All animals have what is called a "neutral temperature": one at which they are comfortable. The neutral temperature can be recognized as the temperature at which the animal's energy consumption is lowest, because it neither has to shiver or move to keep warm or sweat or pant to keep cool. The neutral temperature for cold-weather animals such as polar bears and wolves is much lower than that for tropical animals such as monkeys. The neutral temperature for humans is identical to that of a tropical animal. Furthermore, we adapt to heat by sweating and altering our metabolism much more effectively than we adapt to cold. So how is it that humans live in all continents except Antarctica? We simply move our tropical climate wherever we go. We build houses that we can keep warm by using fire, and we use the skins of cold-weather mammals to keep our bodies at tropical temperatures. An unprotected human in a blizzard can lose enough heat in 20 minutes to die. Without these abilities, humans could never have left the tropics and, if for any reason, the climate had turned colder, we would have perished. Our closest relatives, the great apes, which have a physiology extremely similar to ours, do not know how to kindle or control fire, and they do not clothe themselves. They are therefore confined to central Africa and Asia, while humans, while humans cover the earth.

We can assume that the same demands are placed on all animals and plants. Thus the fact that the climate of the earth has fluctuated strongly means that species have been pushed from one location to another and that they have frequently been under severe stress, which perhaps forced them to change. Also, interpreting the evidence for glaciation in a consistent manner implies an extended history of the earth, which is a further issue to address. This understanding is growing in the early 19^{th} C. For European and American science, it is almost an awakening: If the world is not what we thought it was, what is this world in which we live? And how did it come to be? It was this atmosphere that Darwin encountered in college, and of which he was thinking when he joined the Beagle for its trip around the world.

REFERENCES

http://www.amnh.org/exhibitions/expeditions/treasure_fossil/Treasures/Giant_Sequoia/sequoia.html?acts (Site from American Museum of Natural History, New York, image of giant sequoia tree rings)

STUDY QUESTIONS

1. Is there evidence in the region in which you live for a previous ice age? What is the evidence? What other interpretations can you give for what is claimed to be your evidence? What other hypotheses might there be?

2. Is there any way to assess the age of the evidence that you can identify?
3. What might you expect would happen to the animal and plant life in your region if the climate got noticeably colder or warmer? Can they all migrate, or can the species spread elsewhere?
4. What would happen if the climate in your region got noticeably colder or warmer and a species of plant or animal could not move? For instance, fish in a lake might not have a means of moving; or animals and plants within a mountain valley might not be able to cross the barrier; or there might not be suitable climate at a different elevation on the mountain.
5. Would the amount of rainfall be likely to change if the climate got colder or warmer?