Introduction

A Dark Spot in a Sea of Lights

WILLIAM F. PORTER

As we look at the Adirondacks at night from space, we see a dark spot in a sea of lights. Those who have a sense of the geography of eastern North America know that this is the Adirondacks, a remarkable mix of wilderness and small towns in the midst of one of the most heavily developed regions in the world. How could this dark spot still be here? More to the point, how did the Adirondack landscape moderate the influence of human activity with such dramatic results? Of course, the Adirondack region is not completely dark, so the complementary question is: how has human activity affected the Adirondack ecosystem? And in the end, what is working toward and against striking balance between economic development and environmental conservation?

The intent of part one is to begin to answer these questions. To the natural scientist, part one is a description of the biological and physical attributes of the natural ecosystem that first greeted Native Americans and, later, European immigrants. To the social scientist, part one is defining the *ultimate means* for human enterprise, the natural capital that enables human communities to prosper and form ties with larger national and international economies. To those interested in both nature and culture, part one is a look at how humans began to exploit this landscape, turning the ultimate means to *intermediate means,* and at which of these actions produced lasting environmental change.

This opening essay is an overview designed to give the reader a sense of the place and the issues. It is followed by a series of voices that enrich the story of the region as told by people who have spent their careers working in it. We first hear from James McLelland. He brings to this work more than forty years experience studying the geochronology and structural geology of the Adirondacks, and the evolution of rock and mineral resources making up this terrain. He collaborates with Bruce Selleck, who lends his expertise in geomorphology and glacial geology. Then, we hear from Christopher Cirmo. Cirmo conducted his doctoral work in the central Adirondacks and southwestern Adirondacks and has many years of experience studying the hydrology and biogeochemistry of the regions wetlands and streams.

Next we move to the soils and hear from one of the nation's foremost soil scientists, Russell Briggs. Charles Canham extends the story of soils to tell us about the changing faces of Adirondack forests. Canham, like Cirmo, conducted his doctoral work in the Adirondacks, and he has since spent more than twenty years investigating the dynamics of forest systems in the Adirondacks and throughout the world.

With this foundation of natural attributes in place, we begin to explore the dualism of nature and human culture as these forces interacted to shape one another over four centuries. We begin with two chapters on fish and wildlife and their attraction to humans. Here we get our first exposure to the exploitation of the region's natural resources. Roland Kays and Robert Daniels review the history of mammals and fishes inhabiting this region of lakes and forests, and they examine the role of humans in not only removing species from the system but adding exotic species to the region. Then I examine the resilience of the wildlife populations in the face of exploitation. In the short term wildlife proved vulnerable, and many species were quickly eliminated completely from the system, but the long-term picture is not quite so dark. Indeed, as we attempt to use wildlife as a measure of how far we may have moved the ecosystem from its natural state, we are seeing ongoing changes. We proceed through a sequence of human encounters with the region, hearing again from James McLelland and Bruce Selleck as they describe the mining in the region. I take on the challenge of relating the story of the exploitation of the Adirondack forest and draw on nearly thirty years of learning from extraordinary foresters and ecologists like Ralph Nyland, Dick Sage, and Jerry Jenkins.

Next we explore less direct but equally important human impacts. First is the influence of the acid and mercury pollution that rains down on forests and lakes. It is the story of an enormous amount of science that is nicely summarized by the multiple voices of Charles Driscoll, Kimberley Driscoll, Myron Mitchell, Dudley Raynal, and Karen Roy, who are among the world's top scientists on acid rain and mercury pollution. Their research, which was among the first efforts to quantify the effects of these pollutants, has been ongoing in the Adirondacks since the mid-1970s. Next is the influence of recreation. Chad Dawson examines the importance of recreation to the history of the region and the wilderness ethic that arose from it. Dawson offers the perspective of someone whose thirty years of research on recreation and contributions to wilderness issues has earned national respect. Peter Bauer then guides us through the numbers on residential development in the region. He is probably the person who has studied development in the park most over the past twenty years.

The debates over development are crystallized in the natural world by the debates over restoration of the large predators, and perhaps no one is better equipped to lead us through those debates than Rainer Brocke. He has spent more than thirty years examining the possibilities that the Adirondacks might once again be populated by lynx, cougars, and wolves, and he is among the few scientists in history to attempt the restoration of a major predator.

The most obvious and defining qualities of the Adirondack Park arise from its size and location. As a frame of reference, the park is about 100 miles by 100 miles. The 9,375 square miles, or 6 million acres, that constitute the Adirondack Park encompass an area that is greater than the size of the Commonwealth of Massachusetts and is three times the size of Yellowstone National Park, the largest of our national parks outside of Alaska. The southern boundary of the park lies just north of 43° N latitude and spans 73°30 W to 75°30 W longitude. Geographically, the Adirondack region is isolated by water courses: Lake Ontario and the large areas of lowland to the west, the St. Lawrence River and its broad valley to the north, Lake Champlain and Lake George to the east, and the Mohawk River on the southern periphery. These water bodies present important barriers and also travel corridors for wildlife. And, as we will see, they were crucial to shaping how both Native Americans and European immigrants used the region.

We begin with the geology of the region because in a real sense we can trace the origins of the black void on the satellite image to the geological history of the Adirondacks. Whereas Yellowstone National Park lies within an enormous and currently active volcanic caldera, the Adirondack Mountains represent a domical, deeply eroded remnant of a 1.3–1.0-billion-year-old mountain range of Himalayan scale that was created by the collision of massive tectonic plates. By 500 million years ago the range had been eroded to sea level, submerged beneath those ancient waters, and blanketed by flat-lying sedimentary strata. The neighboring Appalachian chain formed ~450–250 million years ago and, except for small inliers of billion-year-old Precambrian core, is much younger than the bedrock of the Adirondacks. The present-day Adirondack dome and mountain topography are perhaps no older than 20 million years and appear to be due to very recent, and relatively mild, crustal warping followed by erosion. McLelland and Selleck note that unraveling the origin of this ancient bedrock and younger dome has been a product of combining long-established geological methods with the tools of modern technology. The history that emerges, as they describe in more detail, is one of a region in which extreme pressure and heat created rock of a crystalline structure and mineral content that proved exceptionally resistant to weathering and erosion. As late domical uplift occurred, these resistant materials became especially prominent in the eastern portion of the region that underlies the High Peaks, where there are more than 100 peaks rising in excess of 3,500 feet above sea level and 42 mountains that reach above 4,000 feet elevation. Mount Marcy and Algonquin each exceed 5,000 feet. Many of these mountains appear less impressive to the casual observer because they rise from a plateau of 1,500 feet.[1] Elevations fall rapidly from the High Peaks down into the Lake Champlain valley to the east and more gradually to the west.

Today, if we look at the Adirondacks from space during the daylight, we see that the lakes and rivers, and also the principal ranges of the Adirondacks, are generally oriented in a southwest to northeast direction. Long Lake and Indian Lake, and the Gothic Mountain Range and MacIntyre Ranges, are good examples. McLelland and Selleck show that this orientation is a result of the faults and fractures that occurred during the uplift, which occurred along a southwest-to-northeast axis. Although the crystalline rock structure is resistant to erosion, once it fractures it becomes much more vulnerable. In contrast to the nearby Green Mountains of Vermont, the fractures did not result in any significant lowlands that traversed the dome from one side to the other. As we will see, the landform had profound influences on human activity in the region.

Christopher Cirmo talks of the aquascape, describing the hydrology we would expect for a region shaped like a dome. Precipitation is evenly spread throughout the year but the cold temperatures throughout winter mean that the snow accumulates to a depth that gives purpose to snowshoes. During the winter, areas of the western Adirondacks receive an average of 200 inches of snow per year, while the eastern periphery gets about 80 inches. Snowfall accumulates rapidly in early winter until Lake Ontario freezes over to the west. In average winters, snow depths in the geographic center of the Adirondacks reach 15 inches by about January 10, but that is highly variable. Snowpacks reaching 40 inches are common and persist 80 days on average. Snowmelt in the spring brings depths below 15 inches by April 1 with greater regularity.

Fourteen rivers drain radially from the center into five major watersheds. To the north and west a large region of wetlands drains into the St. Lawrence valley via the Grass and Raquette River systems. To the north and east, the Saranac and Ausable Rivers drain to the Lake Champlain basin from the High Peaks. To the southeast is the Hudson River system, the largest in the park, draining south to Albany and New York City. To the southwest is West Canada Creek flowing into the Mohawk River. Finally, to the west are the Oswegatchie and Moose Rivers flowing into the Black River and on to Lake Ontario. Except in the immediate vicinity of the High Peaks, the rivers tend to run slowly from the center of the dome, picking up the pace as they reach the periphery and drop down into the surrounding lowlands.

What is unexpected is the more than 10,000 lakes that dot the landscape. Indeed, the Adirondack region is unusual in its combination of mountains, lakes, and hardwood forests. As McLelland and Selleck and Cirmo relate, this combination is a product of glacial activity. The glaciers deposited rocks and soil at their margins as they retreated, leaving a thin veneer in most places and larger accumulations in the valleys. These larger accumulations dammed up water, producing many of the lakes, especially in the western Adirondacks. Many of the lakes are elongated because they occur in the original fractures produced as the dome uplifted. Where the topography is flatter, glacial moraines and eskers cause poor drainage, leaving lowland soils that have been perpetually waterlogged. Where the water drained more completely, melting glaciers washed the clay and silt particles, leaving behind sandy soils. The glacial lakes that surrounded the Adirondacks to the east, north, and west were recipients of significant depositions of sand, silt, and clay and formed much more fertile soils on their floodplain terraces.

Russell Briggs and Charles Canham pick up the story and show how the variation in the soils, the growing seasons, and natural disturbance events are central to understanding the forests of the Adirondacks. When we look down upon the Adirondacks from space during the daylight, we see a landscape covered primarily by temperate, broad-leafed deciduous forests known collectively as northern hardwoods. But we also find boreal species, the conifers or softwood. The Adirondack region contains this unusual diversity because it is located geographically on a transition zone between two major North American forests. The temperate forests to the south grade into the boreal forest of the north, and the variation in elevation creates climatic conditions common to both.

Growing seasons, those summer intervals that are frost free, vary with elevation. First frost occurs between September 10 and September 20 throughout much of the park; it comes later in the periphery, even to the north, as elevation drops down below 1,000 feet, and earlier in areas above 2,000 feet. In low elevations, the last frost is generally recorded before May 10. Average freeze-free intervals through the summer are 110 to 130 days throughout much of the park and 130 to 140 days at lower elevations.[2] July temperatures in 2002 averaged 63–65° Fahrenheit, and overall summer temperatures are about 2° warmer than in 1900. January temperatures average about 13–15° Fahrenheit, and winter temperatures are about 4° warmer than 1900.[3]

Over the Adirondack landscape, we find thirty-four species of trees, exceptionally diverse among mountainous regions of the world. The distribution of these species is dependent on soil depth and mineral content, moisture, and length of the growing season. The influence of these gradients is most obvious when we look at the forests in the northeastern Adirondacks, an area of the park known as the High Peaks because of the abundance of mountains whose elevation exceeds 4,000 feet. At the top of the mountains above 4,000 feet in the Adirondacks there are no trees at all. This is the *alpine zone,* where soil is so limited that there is little to capture moisture or make basic minerals available to trees. The wind scours these exposed areas so severely that soil cannot accumulate and, consequently, no forest can grow. By comparison to other mountains of the world, there is relatively little of this treeless alpine zone in the Adirondacks—only eleven mountain tops comprising about eighty-five acres.

In the sub-alpine forest are mountain paper birch, black spruce, and balsam fir, species able to grow in the organic duff that overlies thin soils. This organic duff is composed of dead vegetation that decays slowly in the cold climates of higher altitude. The trees growing at this altitude are stunted and misshapen unless protected from the wind. Farther down the mountain, at about 4,000 feet elevation, the soil is deeper though generally not fertile because it contains few clay and silt particles. Moisture seeps through almost continuously, and the growing season is a little longer. Red spruce and balsam fir begin to share the crevasses with paper and yellow birch. From 4,000 down to about 2,500 feet, the sandy and rocky soils are increasingly deeper and mixed with silt and clay, so fertility and moisture conditions of the soil improve. Growing season lengthens, and here the birches and spruce are mixed with sugar maple, American beech, and eastern hemlock.

The transition continues on the lower slopes, where sugar maple, birch, and beech grow alongside white ash, black cherry, red maple, white pine, and red spruce. Much of the Adirondack dome lies within this zone of 1,000 to 3,000 feet elevation, where hardwoods are abundant and conifer species (softwoods) are more scattered. It is these midslope forests that give the Adirondack region its rich array of fall colors. And this is the reason that our satellite view suggests a region dominated by hardwoods.

In the river valleys and lowlands, we encounter areas of glacial till and other areas of sandy outwash soils. The mineral-rich till soils that developed in the large valleys surrounding the Adirondacks–Lake Champlain, the Mohawk River and the St. Lawrence River—supported hardwood forests of great stature. In contrast, the sandy soils of the major river valleys lack the mineral richness and are prone to drought. These areas are typically dominated by pines, especially white, red, pitch, and jack pine. White pine reaches greatest abundance and its 130-foot stature in the southeastern Adirondacks. Jack pine occurs on the sand barrens of the northeastern Adirondacks and the St. Lawrence River valley and pitch pine on sandy outwashes north of the capital city of Albany. It is in these same peripheral regions of the park, where growing seasons are longer, that the only significant stands of oak occur.

In the lowest areas, where soils are frequently saturated with moisture, we find yet another transition. Sugar maple, beech, birch, cherry, and white ash drop out, and where hydrology produces moving water red spruce and balsam fir persist, mixed with red maple and hemlock. The floodplain areas of rivers that exist just a few feet above the water table produce the large areas of red spruce forest. As soils become completely saturated and water is stagnant, the forest grades into black spruce, white cedar, and tamarack. These are the forests most common in western regions such as the Raquette and Oswegatchie River systems.

We tend to think of these forests as unchanging. In fact, as Canham points out, they are continually undergoing change because trees are continually dying and new individuals are growing to take their place. The change becomes more obvious, though, when there is a significant disturbance. As much as the forests are a reflection of the kinds of soils on which they grow, they are a product of disturbance. Fire nearly always comes to mind as a disturbance factor, and certainly fire has been important in the Adirondacks, especially in the early 1900s. However, large-scale fire is not a common occurrence in the region. With 30 to 40 inches of annual precipitation supporting a forest dominated by hardwoods, the region is just too moist to permit large burns. More common to the Adirondacks is disturbance due to wind storms. To flatten large areas of Adirondack forest requires wind speeds of 100 to 200 miles an hour. These are winds of tornadoes or hurricanes. While hurricanes are associated with the southeastern United States and the Gulf Coast, they periodically reach into the Adirondacks. The last one occurred in the fall of 1950, and it blew down forests over 800,000 acres, mostly in the western part of the park. Smaller areas of forest are flattened by tornados or derechos (gusting straight-line winds) associated with summer storms. In 1995 a derecho blew down about 130,000 acres in half an hour.

More subtle, but of greater impact to forests, is disturbance caused by insect outbreaks and disease. The Adirondack region is not prone to large-scale insect outbreaks, in part because there are no large expanses dominated by one or two species of trees, like the spruce-fir forests of Maine and eastern Canada. Nevertheless, disease is an important player in the Adirondacks. Disease can completely eliminate tree species of great importance to the forest community. Beech scale disease, a combination of an insect, *Cryptococcus fagisuga*, and a fungus, *Nectria coccinea*, has attacked American beech since its arrival in the central Adirondacks in 1965. By the late 1990s, 90 percent of the trees six inches in diameter or larger were dying. The loss of beech has wide-scale implications because it comprised almost half of the mature hardwood trees in the Adirondack hardwood communities, which produced a nut crop that was important as a food for many forms of wildlife from grouse to squirrels to black bears.

Just as the tree species of the Adirondacks reflect the fact that the region lies on the transition zone of the temperate and boreal biomes, so too do the species of wildlife. Animals such as spruce grouse and moose represent boreal species and white-tailed deer and wild turkey the temperate species. Most species are not abundant because Adirondack land is either at the southern or northern edge of the ecological tolerance of boreal and temperate species. Spruce grouse and moose number a few hundred but are much more abundant to the north. White-tailed deer, perceived by many people to be truly at home in the Adirondacks, actually occur at relatively low densities in comparison to populations farther south. Some species, like the chipmunk, span both biomes and number in the tens of millions. Others, like the wild turkey, may actually be beyond their native range and probably number fewer than a thousand.

Thus biodiversity in the Adirondacks is a reflection of these countervailing ecological forces and, as Roland Kays and Robert Daniels argue, a lot of recent human intervention. Of 384 terrestrial species of wildlife, 55 are mammals, another 40 are reptiles and amphibians, and 197 are birds. The 92 fish species reflect the broad reach of the Adirondack Park, particularly the inclusion of Lake Champlain and Lake George. Our knowledge of the losses of species from the Adirondacks and invasion by exotics is limited to fish and wildlife, trees and flowers. This number is changing as we learn more about insects, lichens, and other forms of life. A total of 61 species are known to have been lost or purposely extirpated: 14 fishes, 1 reptile, no amphibians, 5 birds, 7 mammals, and 34 plants. A somewhat smaller number, 45 species not native to the Adirondacks have arrived or were consciously introduced: 25 fishes, perhaps 1 reptile, no amphibians, 3 birds, 1 mammal, and 15 species of plants.

Biodiversity is a common and important measure of the health of an ecosystem. However, the number of different species in a park such as the Adirondacks is only one measure, and ecologists recognize that it can be a misleading indicator. For instance, the presence of exotic species adds to the biodiversity but at the same time is indicative of degradation of the ecological system. In the Adirondacks, most exotic species are common in two of the five major private land-use classes, Hamlet and Rural, but still rare in Wilderness, Wild Forest, and Resource Management lands. Hamlet and Rural lands constitute about 21 percent of the park, so native populations are still largely intact.

A second important measure of the health of an ecosystem is resilience to human impacts. A resilient ecosystem is one in which populations of native species that have been severely reduced or extirpated are able to recover or return. This ability reflects the size of the region and its degree of connectedness to other ecosystems containing similar complements of species. Size is important because it increases the possibility for species to persist in isolated pockets and then rebound when conditions improve. Connectedness is important because greater connectedness increases the potential that a species will find its way back into the region.

With this sketch of geological base and biotic systems as a backdrop, we then begin to examine how European explorers, entrepreneurs, and settlers attempted to harness the resources of the Adirondacks. It is a history that is largely one of uncontrolled exploitation resulting in economic booms and busts but, interestingly, little permanent ecological damage. Mining, lumbering, and trapping begin the story, but contrary to expectation, prove not to be the undoing of the biological integrity of the Adirondacks.

Indeed, Canham observes that what makes the Adirondacks particularly interesting is that while harvest was extensive, the region escaped the fate of so much of the rest of eastern North America. Despite widespread disturbance in Adirondack forests, their composition today is largely the same as in presettlement times.

The impact of human settlement and natural resource exploitation was ameliorated early on by the harsh Adirondack environment. Much can be read into the observation that from the date of the first European encounter with the region, it was more than three centuries before the Adirondack Mountains were mapped.[4] Then, through much of the next 150 years to the present, only the wealthy or those providing direct service to the wealthy could afford to live in the region. Most communities in the Adirondacks were built around mining and forest industries, and came and went with the fluctuations of supply and demand and the cost of transporting the resources to urban markets.

Mining was among the first activities to attract large investments of capital. McLelland and Selleck point to the region as providing major iron ores to our war efforts from the American Revolution through World War II as well as fueling U.S. industry through the nineteenth century and up until the 1960s. Beginning in the early twentieth century, and continuing until the 1970s, titanium ore from Tahawus was utilized for both industrial and military purposes. Closely associated was the timber industry. The local impact of these industries was huge. As much as two million acres of the eastern Adirondacks were cleared, and operations penetrated the region. Mining was limited by lack of easy transportation, and much of it collapsed by the 1850s. With the exception of the large open-pit iron-titanium mine at Tahawus, few scars are evident to the casual observer. Those people who are more discerning can find the influence in relics now rapidly becoming overgrown and in the mix of tree species inhabiting a site. Even there, natural change continues to restore original conditions.

Timber harvest continued to grow owing to the demand for construction material following the Civil War. And as with mining,

the long-term impacts of lumbering were relatively small. The one lasting mark of these enterprises that is likely to affect the Adirondacks well into the future is the infrastructure of roads they created. Built initially to allow extraction of wood fiber, they facilitated other human pursuits, especially recreation and residential development, and became corridors for invasive species. Roads are a two-edged sword. On one side, they prove valuable because they enable the public to enjoy the Adirondacks, although at the same time they raise concerns about too much development. On the other side, they prove a harbinger, if not direct cause, of a downward trend in the biological integrity.

Still more subtle has been the change that has come from without, the pollution of acid rain and mercury. The Adirondack region is located downwind of a high concentration of coal-fired power plants in the Midwest and so receives doses of acid precipitation on a continuing basis. As Charles and Kimberley Driscoll, Myron Mitchell, Dudley Raynal, and Karen Roy relate, the ecological impacts of these airborne pollutants raise questions about the future of the very essence of the Adirondacks, the health of the ecological processes that support it.

One might argue that truly lasting effects have been those that brought permanent human presence to the landscape. Chad Dawson chronicles the importance of the Adirondacks to recreation and the emergence of a romantic image of wilderness as a source of renewal in the face of an industrializing society. Artists and writers promoted the Adirondacks, and entrepreneurs like William West Durant recognized the opportunity to bring the Adirondacks to the attention of those with wealth and time. Durant, the son of a railroad tycoon, was a visionary who saw the potential to push railroad lines to the interior of the Adirondacks to develop tourism. His initial clients were the economic elite of America's Gilded Age: the Vanderbilts, Whitneys, Morgans, Rockefellers, and Huntingtons.

Beginning near Raquette Lake, Durant built what would come to be known as Great Camps. Craig Gilborn suggests that in these initial recreational investments by the wealthy were the seeds of an American wilderness ethic. Summer homes of the rich brought politically connected people into contact with the pleasures of seclusion amid the beauty of the region. They became a manifestation of the cynic's definition of a conservationist: a person with *his* cabin on a lake to himself. At the pivotal points of the establishment of the Forest Preserve, and later the Adirondack Park, they wielded political and economic influence to favor protection.

The pace of development began to increase after World War II. The postwar years brought three dramatic changes that influenced the Adirondacks with increasing intensity. First was the movement of a large portion of society from rural environments to urban areas. These were people whose formative years had been spent outdoors and who had strong ties to the philosophy of self-sufficiency. So, while they earned a livelihood in the city, they sought recreation elsewhere in hiking, camping, fishing, and hunting.

Second was the rapid improvement and expansion of the transportation infrastructure. National security interests and expanding business persuaded the government to develop the Interstate Highway System and improve roads everywhere. This made it possible for people to leave the city and travel to the Adirondacks for a weekend. Completion of Interstate highways I-87 and I-90 meant that more than one third of the human population in the United States and Canada was within eight hours drive of the Adirondacks.

Third was the accumulation of wealth that permitted the ownership of second homes, which, since the late 1990s, has spurred the park's largest sustained period of residential growth. Peter Bauer laments the negative impacts on the social fabric of the community because the associated land speculation has priced many people out of the communities in which they grew up. The limitation to permanence remains the availability of jobs, and today that is the central issue confronting most communities. However, the internet and fax service, and the transition from manufacturing to a service economy, are enabling businesses to consider establishing themselves in more distant locations from urban centers. This is a park within which there are 103 communities.

The irony, and the challenge, is that the major attractions for residential development are the rural character of the communities, the clean air and water, and the beauty of the wild forest. The magnitude of development may change that vitality from within. A new limit may be imposed by economic costs of ownership. Peter Bauer observes that the Adirondack region is becoming a place where whole neighborhoods and even towns are dominated by second homes, and the large wild areas are increasingly surrounded by developed areas.

The Adirondack region has moved from a position where extractable natural resources were the main economic engine to one where conservation of those same natural resources is the engine of tourism. Private ownership that was once dominated by the forest industry is now moving to major conservation organizations, and eventually to the public, because of the value society places on open space. This recognition of the economic value of wild lands may not be new, but the scale of its impact is likely to be profound. Just as the Adirondack experience with unbridled exploitation set a cornerstone for conservation a century ago, so may the experiment with highly regulated regional land management provide another.

We come full circle to our original question of why the wilderness character of the Adirondacks is still there and realize that the question is not that simple. A reasonable person might ask, is it? A measure of wilderness is the presence of the top predators in the ecosystem, and the Adirondack region has lost all of those we associate with wilderness: the lynx, the cougar, and the wolf. Rainer Brocke takes a hard look at the prospects for restoring these species. People and roads, and all that they bring with them, are encircling the Adirondacks to the point of limiting the connectivity of wild areas to the north and east. The loss of connectivity can limit the natural return of predators. Active management efforts have tried to overcome these limits, and restoration programs have successfully reestablished the bald eagle and peregrine falcon. However, Brocke describes how an attempt to restore the lynx met with an uncertain fate and says that the prospects of restoring the cougar are dim. The wolf holds special interest because mere mention generates so much debate and because the story is complicated by the coyote.

The voices of the chapters that follow add important detail to the overview presented here. Geology, hydrology, and soils may sound esoteric, but the stories are as fascinating as they are important. And the history of how the natural environment shaped human enterprise in the region is as much about the soils and the weather as it is about the forests and the wildlife. But the great experiment is about the impacts of human activity, especially in the past two centuries, that motivated creation of a Forest Preserve, an Adirondack Park, and a stringent set of land-use regulations. In each case, the story is told by observers whose experience and exposure to the Adirondacks sets them apart.

1

Geology of the Adirondack Mountains

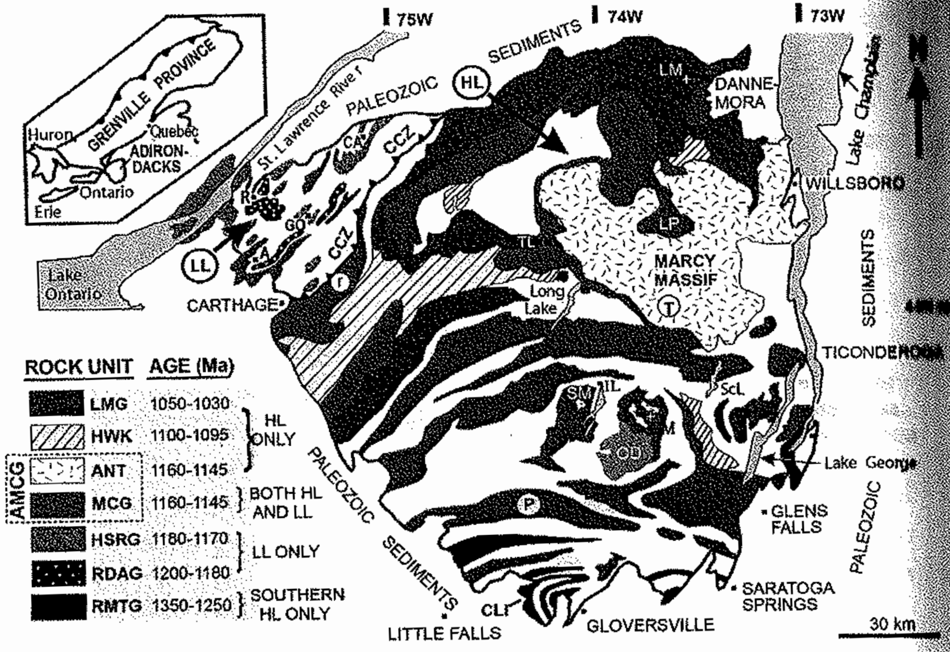
Like an Egg with Its Major Axis to the North

JAMES MCLELLAND AND BRUCE SELLECK

In his *Survey of the Second Geological District*, Ebenezer Emmons captured an Adirondack vision that holds today and poses questions that remain objects of scientific research:

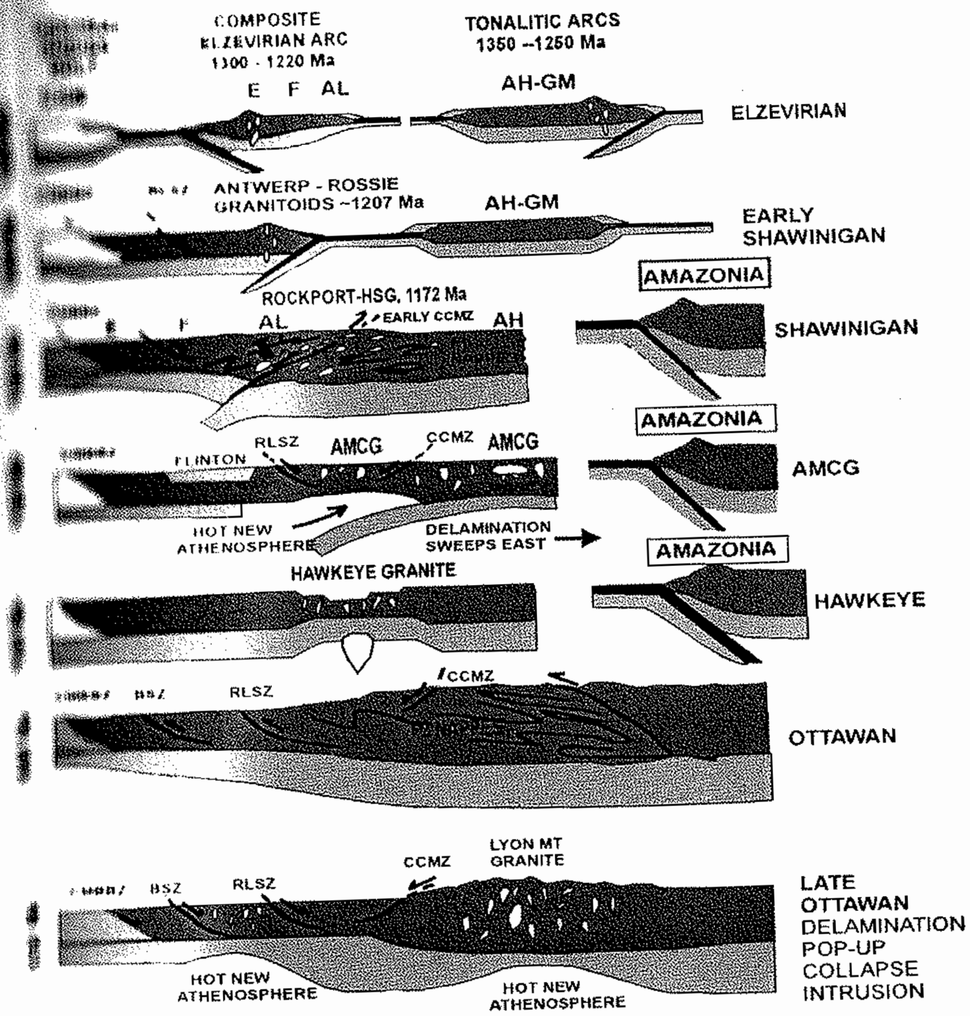
> That portion of New York which is north of the Mohawk Valley may be considered one of the great natural divisions of the state . . . [It] is a territory which is unsusceptible to farther [*sic*] subdivision; it may be considered as an insulated portion of the State, bordered by three great valleys; the valley of the Champlain on the east, that of the Mohawk on the south and the St. Lawrence on the west, northwest and north. . . . Geologically considered, it is one great uplift with gradual but unequal slopes on all sides, which, if we leave out of view minor irregularities, may be compared to an egg with its major axis to the north. [While] the Green Mountains of Vermont run onward through Lower Canada as far as the eye can trace them in the distant horizon, those of the Adirondack rise suddenly from the Mohawk and Hudson valleys, and terminate equally abrupt either upon the lakeshore or in the levels of Lower Canada. . . . We have indubitable evidence of this mighty and concentrated force in the magnificent cliffs and precipices, which are continually arresting to the attention of travelers.[1]

The Adirondack Mountains (fig. 1.1), although positioned in proximity to the Appalachian Belt, are clearly not part of that



1.1. Generalized geological and geochronological map of the Adirondacks. Published with permission of the Geological Society of America.

linear chain but belong to an older, deeper, and more profoundly deformed part of North America. Their insularity, ruggedness, and impenetrability remain as barriers to human development, just as when Emmons wrote his report on the first geological expedition to the Adirondacks almost 170 years ago. Since Emmons's pioneering work, the tools of modern geology have allowed us to know quite precisely the origins and ages of the rocks constituting the Adirondacks and to develop realistic explanations for the complex patterns in which the rocks occur. We now understand this ancient terrain as a product of global plate tectonic processes that gave rise to the continents and ocean basins of planet Earth. In this chapter we describe the current understanding of the geological origin and history of the Adirondacks. These findings are summarized in figure 1.2, which presents a series of age-designated, schematic NW-SE cross sections through the upper ~60 miles of the earth. The vertical sections are



Cross-sections of continental crust. Published with permission of the Geological Society of America.

anchored on the east by Rutland, Vermont, and on the west by Bancroft, Ontario, a distance of ~300 mi. The cross sections are subdivided into continental crust; oceanic crust; and cool, rigid upper mantle. Together, these three units compose the lithospheric plates that slide along the underlying hot, ductile athenosphere (A, fig. 1.2) thereby giving rise to plate tectonics. These and other subdivisions are identified on figure 1.2 where the heavy black arrows indicate the relative motions of plates and melts. New oceanic crust (gabbro/basalt) is added to oceanic lithosphere by volcanism at mid-ocean ridges, and old, cold oceanic lithosphere is consumed at subduction zones where new continental crust is created by arc volcanism.

As Emmons aptly described, the Adirondacks form a slightly elongate, domical uplift of 1,300–1,000 million-year-old (henceforth designated as Ma) Precambrian rocks that rises from an elevation of 100 feet along the Lake Champlain shore to the summit of Mount Marcy at 5,348 feet. An ancient fault zone known as the Carthage-Colton Shear Zone (CCZ, figs. 1.1, 1.2) separates the Adirondack Highland (HL, fig. 1.2) and the smaller Lowland (LL, fig. 1.2) topographic sectors. The Adirondack Park lies entirely within the Highlands, which are largely underlain by erosion-resistant igneous and metamorphic rocks. In contrast, the Lowlands are dominated by less-resistant marble (metamorphosed limestone) that yields a more subdued topography. Surrounding the Adirondacks are flat-lying, softer Paleozoic sedimentary marine sandstone and limestone deposited about 550–450 Ma. These younger rocks either lie on top of the older, deformed basement or are down-faulted against it along large faults (mostly NE-SW trending) that bound the eastern Adirondacks. The most important regional rock units are shown in figure 1.2 and are divided on the basis of composition and age.

The age and origin of the present-day Adirondack dome are enigmatic. However, the uplift is certainly younger than ~350 Ma, which is the last time that the region was beneath sea level. Fission-track dating that determines the time at which rocks have risen from deep in the crust to approximately 1.2 miles below the surface suggests that the High Peaks were uplifted to these levels about 150 Ma, whereas the southeastern Adirondacks were uplifted about 100 Ma. These ages are related to the breakup of the supercontinent Pangea and the opening of the modern Atlantic Ocean. Locally, the breakup resulted in steep NE-SW faults that are readily visible on satellite imagery and that define the orientation and shape of Lake George, Lake Champlain, Long Lake, Indian Lake, and the Ausable Lakes as well as the orientation of the major mountain ranges in the Adirondacks (e.g., Gothics, MacIntyre, and Great Ranges). A magnificent view of the Long Lake fault system can be seen from the summit of Ampersand Mountain.

A problem with sustaining the domical Adirondack uplift is the absence of a low-density crustal root extending into the upper mantle so as to buoy up the region like an iceberg. Accordingly, the topographic dome would not rise as its surface was eroded and would be rapidly reduced to sea level. We can calculate how long it would take to erode the current topography to sea level: approximately 18–20 million years, which is much younger than the fission-track ages. Two possible resolutions to this enigma are: (1) an upper mantle hotspot is holding up the dome, or (2) the dome is supported by broad crustal compression that arches up this sector of the North American continent. A difficulty with the hotspot model is that rocks beneath the Adirondacks today are cooler than normal, yet a hotspot would produce hotter than normal rocks. The compression model, however, is consistent with the numerous small earthquakes that occur in the Adirondack region, particularly in the Blue Mountain Lake and northeastern Highlands regions. Active, recent compression could also account for the region's radial drainage system, which is characteristic of young uplifts. This recent crustal compression could have produced the final mile of uplift in the region as well as its current topography.

Although the topography of the Adirondack region may be young, its bedrock is ancient and is best understood on a regional scale. The Adirondack Mountains constitute a southwestern outlier of the much larger Grenville Province that consists of approximately 1,750–1,000 Ma igneous and metamorphic rocks extending throughout southeastern Canada from Lake Huron to the coast of Labrador (fig. 1.1, inset). The region was affected by several mountain-building events that extensively deformed and metamorphosed the bedrock. Similar rocks with similar ages are found in eastern North America from Newfoundland to Alabama and westward through Texas to California, and even in Australia. The scale of this ancient belt of mountain building rivals the great Himalayan-Alpine chain of Eurasia and was surely equally as spectacular.

Early Evolution of the Adirondack Mountains

Unraveling the origin of complex ancient mountain belts requires knowing the ages of their constituent rocks, and modern geochronology has provided major advances in our understanding of the history of the earth. In the Adirondacks, the most important results have involved the mineral zircon, which is present in small amounts in most rocks. When zircon crystallizes, it incorporates tiny quantities of the radioactive element uranium but almost no lead. Uranium undergoes spontaneous radioactive decay into lead and does so at constant rates. When zircons are analyzed, they are found to contain lead that formed by the radioactive decay of uranium. Because the decay rates of the uranium/lead series are constant, and because zircon neither gains nor loses lead or uranium, the absolute age of the igneous rock can be determined by calculating the length of time required for the uranium to produce the quantity of lead found in the zircon. While this core strategy appears simple, the method requires highly expensive and sophisticated instrumentation and technology not available until about 25 years ago.

The oldest igneous rocks (1,350–1,250 Ma) in the Adirondacks are granites and granitelike tonalites in the southern and eastern Highlands (RMTG, fig. 1.1) that intrude garnetiferous metamorphosed sediments (originally shale and muddy sandstones). Similar assemblages characterize modern volcanic island arcs (e.g., Aleutians, Indonesia, Lesser Antilles), suggesting that the proto-Adirondacks originated as a sequence of volcanic island arcs with igneous material produced by melting of the upper mantle in the wedge overlying subducting lithosphere, including its thin skin of oceanic crust (Fig. 1.2, left). Assembly of this arc-derived crust occurred over a 200-Ma interval, and began to be accreted to what was then eastern North America by about 1,220 Ma (accretion along CMBBZ, fig. 1.2). Subduction then stepped eastward with the downgoing plate descending to the west beneath the Adirondack Lowlands and resulting in tonalites and granites that were emplaced into the overlying Lowlands continental margin (RDAG, H, HSRG, fig. 1.1). By ~1,200 Ma, the Adirondack–Green Mountain terrane collided with the subduction zone and the powerful Shawinigan Orogeny ensued (fig. 1.2). Accretion continued until about 1,160 Ma and resulted in metamorphism and strong deformation across the entire Adirondack region (Shawinigan Orogeny, fig. 1.2). Similar events occurring at the same time in the Blue Ridge of Virginia, in Texas, and in Australia document that this was a global-scale event.

At about 1,160 Ma (fig. 1.1), the Adirondack region had become thickened by collision, and a deep mass of relatively cool, dense lithospheric mantle (density about 3.5 gm/cm³) was driven down into warmer, less dense athenosphere (density about 3.3 gm/cm³). Density differences of this magnitude commonly lead to the breaking off and sinking of the denser rocks into the deeper mantle. This process is known as delamination and causes the overlying crust to rebound upward, just as a ship will float higher when its heavy keel is detached. As the rebounding mountain belt rises, its own weight causes it to collapse outward along gently sloping detachment faults. Similar delamination-related faults are currently causing large portions of the Himalayas to collapse outward as the range continues to rise following delamination. The process causes the deep, hot cores of active mountain belts to ascend rapidly to the surface, thereby preserving the high temperature rocks and mineral assemblages (about 1,475° Fahrenheit and 15 miles depth) such as those we now find in the Adirondacks. At the surface it is common for basins to form in the extending crust and then to receive erosional detritus that lithify into sedimentary rocks. This is the origin of the Flinton basin (fig. 1.2).

Delamination at about 1,160 Ma caused hot, deep athenosphere underlying the lithosphere to rise and fill the potential void at the base of the crust (fig. 1.2). As the buoyant athenosphere ascended, it underwent melting that formed gabbro, which is the intrusive equivalent of basalt lava flows such as those that erupt in Hawaii or Iceland. Owing to its high density, the gabbro was trapped at the base of the less dense continental crust. Upon crystallizing, it formed large gray crystals of plagioclase feldspar that floated in the denser melt and collected into crystal-rich mushes that eventually ascended to form large masses of the rock anorthosite (fig. 1.2) that underlie the entire High Peaks region (i.e., Marcy Massif, figs. 1.1, 1.2) as well as the Oregon dome (OD, fig. 1.1). Anorthosite consisting of ~95 percent plagioclase feldspar is magnificently exposed in a series of rock cuts along Route 3 from Tupper Lake to Saranac Lake. Heat derived from the crystallization of the deep gabbroic magmas melted large portions of the overlying continental crust, giving rise to a spectrum of granitic melts that rose together with the plagioclase-rich crystal mushes to form the 1,150-Ma anorthosite-granite suite (AMCG suite, figs. 1.1, 1.2d) that accounts for the greatest volume of Adirondack bedrock. AMCG rocks of 1,150 Ma age are found in large volume throughout the Grenville Province (fig. 1.1) and are thought to have formed by the same processes as those described for the Adirondacks.

The Adirondacks experienced quiescence until about 1,100–1,090 Ma, when small volumes of Hawkeye granite (HWK, figs. 1.1, 1.2) were intruded. At about this time Amazonia (fig. 1.2), an Australia-size continent that now underlies most of Brazil, drew close to North America, and a continent-to-continent collision ensued at about 1,090 Ma (fig. 1.2). The collision resulted in intense deformation and metamorphism that by 1,050 Ma yielded a Himalaya-style mountain range. Thick slabs of rock were stacked up to produce double crustal thicknesses of 37–44 miles (fig. 1.2). Temperatures of ~1,475° Fahrenheit and pressures corresponding to 15–19 miles depth resulted in intense deformation that generated large refolded sheets of rock and ribbonlike rock fabric and caused partial melting of many Adirondack rocks. This major collision is known as the Ottawan Orogeny, and it occurred throughout the Grenville Province, as well as in the Appalachians and west Texas. Outside of North America, evidence of the Ottawan is present in southern Scandinavia, Australia, and Antarctica, supporting the existence of a Late Proterozoic supercontinent known as Rodinia.

Late in the history of the Ottawan Orogeny a delamination event resulted in buoyant rebound of the mountain belt (fig. 1.2g). Large, low-angle detachment faults developed, and portions of the mountain belt collapsed outward under its own weight. The most significant of these faults in the Adirondacks is the Carthage-Colton Zone, along which the Lowlands were down-faulted to the west (CCZ, figs. 1.1, 1.2). To the northwest in Ontario, a series of similar collapse faults formed and dropped crustal blocks back to the southeast (fig. 1.2).

At the same time, the emplacement of hot new athenosphere at the base of the crust caused partial melting of older, deeply buried AMCG-rich crust. This melting produced pink granite intrusions referred to as Lyon Mountain Granite (LMG, fig. 1.1, 1.2) and are dated at 1,050–1,030 Ma. The map distribution of Lyon Mountain Granite (fig. 1.1) and its age relationships suggest that it may have locally intruded into and lubricated the detachment fault zones related to collapse of the mountain range. This granite event extends through the Precambrian core of the Appalachians at least as far south as the Blue Ridge Mountains and resurfaces in central Texas.

Following the Ottawan Orogeny, relative quiescence returned to the Adirondack Mountains, and they, together with related terranes to the northeast and south, were reduced by erosion until inundated by seas some 550 million years ago. The Adirondacks would remain subdued until uplifts at ~150 Ma and ~20 Ma brought them to near-surface and surface positions, respectively.

Glaciation and Recent Adirondack History

It is a commonly held misconception that glaciers formed the mountains. Glacial ice is a powerful mechanical agent but not nearly powerful enough to form significant mountains. During glaciation, ice sheets modify and round V-shaped water-carved valleys; this is a secondary effect and has little impact upon relative elevations, which are primarily determined by running water. However, ice certainly modifies the landscape by sculpting the final nuances of landforms. Thus glaciers round—but rarely deepen—the V-shaped valleys cut by running water. They pluck away at mountaintops to produce the converging amphitheater-like cirques that converge on Whiteface Mountain to form a classic horn (e.g., Matterhorn) at its summit.

Glacial meltwaters deposit sediment, including well-washed sand and gravel that accumulate in deeper, broader valleys and are sources of sand and gravel for construction and road building, as well as aquifers for domestic and municipal water wells. Many Adirondack lakes are the result of glacial deposits that dammed what otherwise would have been river valleys. For example, Long Lake exists as a lake because glacial sediments dammed the Raquette River at the north end of a long and wide stretch of its fault-controlled valley.

During maximum advances of the last ice age, the Pleistocene, glaciers extended as far south as Kansas and Nebraska, where their southerly advance is marked by piles of sedimentary debris known as terminal moraines. Although these earlier ice sheets passed through and covered the Northeast, the last great Pleistocene advance (i.e., Wisconsin glaciation) has largely obscured the effects of earlier advances. In fact, most of what we know about Wisconsin glaciation comes from features left behind during its retreat. The advance reached its maximum southerly terminus about 21,000 years ago and upon retreat left large terminal moraines whose eastern extent passed through central Pennsylvania and created both Long Island and Cape Cod. At its maximum the ice was about 1 mile thick and must have covered most of the Adirondacks, with the possible exception of the highest summits. About 21,000 years ago the ice began to melt northward, and meltwaters formed proglacial lakes (i.e., lakes in front of the glacier) that were dammed to the north by the glacier itself and to the south by earlier glacial deposits through which the impounded waters cut outlets to the sea.

One of these lakes occupied the Hudson Valley, and its size increased as the ice continued to melt back to the north. This lake, known as Glacial Lake Albany, ultimately extended through the Lake George region and into the Champlain Valley to form Glacial Lake Vermont, which extended to the Canadian border, where it was blocked by another large lobe of ice that extended eastward to the Atlantic. The latter glacial mass had dammed its own meltwater to the west, thus forming a large precursor of Lake Ontario known as Glacial Lake Iroquois (about 16,000–13,000 years ago) that submerged the St. Lawrence Lowlands almost to Lake Chateaugay and the present-day town of Ellenburg on the northeast and reached southward to present-day locations of Rochester and Rome.

When the Hudson Valley ice sheet retreated north of present-day Schenectady, the great mass of water to the west broke through ice and earthen dams near the area that is now the cities of Barneveld, Rome, and Little Falls. The water cut a channel that drained into the western Mohawk Valley and flowed eastward to join Glacial Lake Albany. Much of this outflow involved large bursts of water (called jokulhlaups) whose erosional effects were catastrophic, carrying huge boulders and cutting deep gorges.

By about 13,350 years ago, the northeastern arm of Glacial Lake Iroquois breached its ice impoundment north of present-day Ellenburg and debouched into Glacial Lake Vermont, whose northern terminus lay only a few miles to the east in the Champlain Lowland. As catastrophic floods rushed downhill, they scoured soil and overburden from the underlying Potsdam Sandstone, leaving clean, bare pavement and gave rise to the Flat Rock area (about 12 by 2 miles) that extends southeastward from Covey Hill, Quebec, to the Champlain Valley and is well exposed in the town of Altona.

The conjoined Glacial Lake Iroquois–Lake Vermont waters burst southward into the Hudson Valley system and broke through the terminal moraine at Hell's Gate and the Narrows near Staten Island. The immense volume of water carried huge boulders to the edge of the continental shelf, which was then exposed because of a lower global sea level. The flood also deposited enormous lobes of sediment on the shelf and carved much of the Hudson Submarine Canyon.

Subsequently, the ice lobe impounding the northern terminus receded into the St. Lawrence Lowlands (about 12,000 years ago) and then opened drainage to the Gulf of St. Lawrence. Enormous volumes of water rushed northward and into the Atlantic. The cold, fresh waters from these jokulhlaups interrupted flow of the Gulf Stream thermal conveyor belt, and that, in turn, resulted in brief repetitions of glacial climate (i.e., Inter-Allerod and Younger Dryas events). As the lake waters emptied, sea water moved in to take its place, forming the Champlain Sea about 13,000–12,900 years ago. Marine waters extended throughout the St. Lawrence Lowlands to Lake Ontario and north to Ottawa and persisted until about 10,000 years ago. A postglacial rebound led to an uplift of the crust and draining of the sea. Numerous fossils (e.g., whales) testify to this incursion by marine waters at the end of the Wisconsin glacial event.

As the Wisconsin-age glacier withdrew to the north it thinned, so that Adirondack summits became exposed at about 14,000 years ago. The first place that this happened was along the Hudson–St. Lawrence River Divide in the vicinity of Blue Mountain Lake. As the ice receded, a series of proglacial lakes formed in the easily erodable valley from Blue Mountain Lake through the Marion River, Raquette Lake, the present-day Fulton Chain of Lakes, and then on to the Moose River. During periods of slower retreat the ice dumped debris at its terminus and formed moraines that would serve to impound its meltwaters. The result was the series of eight partially connected lakes that extend from Old Forge to a few miles southwest of Raquette Lake.

By about 13,000 years ago, melting had removed all ice from the Chain of Lakes and the Moose River basin. At the same time that this ice lobe was retreating, lobes along the western margin of the Adirondack Mountains were also undergoing meltback. The result was that a sequence of proglacial lakes waxed and waned between Tug Hill and the western margin, sometimes reaching 20–30 miles farther east into the Adirondacks. Periodically these lakes broke out through low spots in rock and/or ice (e.g., Cedarville, Barneveld) and disgorged southeastward into the Mohawk-Hudson drainage system. During the lifetime of these lakes, they deposited significant thicknesses of sand and gravel in stream valleys, lake deltas, and shorelines, especially throughout the Black River drainage basin.

On the northeastern side of the Adirondack region, a lobe of glacial ice retreated northward (about 13,000 years ago) along the Keene Valley from St. Huberts to Ausable Forks and formed a

proglacial lake with numerous terrace deposits, deltas, wave-formed beaches, and outbreak channels. Ultimately, the Keene Valley proglacial lake connected with related bodies extending from Ausable Forks to Keeseville. During the incursion of the Champlain Sea, marine waters extended to St. Huberts, and marine fossils can be found there in local terrace deposits.

The highest peaks of the Adirondacks retain tundra ecosystems as vestiges of the former cold-climate ecology. The warming of the region following deglaciation is recorded in pollen buried in lake sediments. Pollen records indicate that the earliest postglacial forests were adapted to cooler climates, but that the climate warmed to nearly modern temperatures by 7,500 years ago and by 4,500 years ago may have been warmer than today. More subtle cycles of warming and cooling in the last 4,500 years likely caused shifts in the geographic boundaries of some plant and animal species.

Globally, the earliest vestiges of recognizable civilization appeared about 10,000 years ago, coinciding with emergence from the Wisconsin glaciation. The coincidence is no surprise, for the warming climate brought with it a far gentler and more abundant way of life. As sea level rose, valleys filled with water and commerce by watercraft became viable, thereby facilitating trade, commerce, and the emergence of civilization. On the other hand, the advent of farming, clearing of forests, and animal husbandry may have helped to reverse an otherwise decreasing temperature regime and thus prevented a slide back into the glacial icehouse.

Suggested Readings

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ape

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What catches the senses most upon entering the Adirondack region is the seeming superabundance of water! In the soils; on the foliage; covering the roads; in ponds, lakes, and streams; in wetlands and rivers; on the trees, and in the sky! In winter, it is difficult to look down on the Adirondacks and find a point not associated with water in the form of snow or ice. Any discussion of the resource means by which the Adirondack region fulfills its anthropogenic ends must include the water that drives the engine of recreation, development, industry, art, resource extraction, wealth, well-being, ethics, and, in the end, value. From wildlife resources and fisheries, to mining and industry, to human consumption and aesthetics, the Adirondack region of the past, present, and future depends on both water quality and water quantity for its human valuation. Water can be thought of as the fundamental template for such lightning-rod issues as wetland protection, shoreline development, air pollution control, stream bank erosion, fisheries viability, drinking water supply, recreation . . . the list includes almost all issues at the intersection of conservation and development. The interaction and abundance of water as a manifestation of geography allows us to combine the words *aquatic* and *landscape* into a resource called the *aquascape*. The base of critical food chains in the region is maintained directly by the aquatic conditions in wetlands, springs, streams, lakes, and rivers, and indirectly by the saturated conditions presented by soil water and groundwater. It is