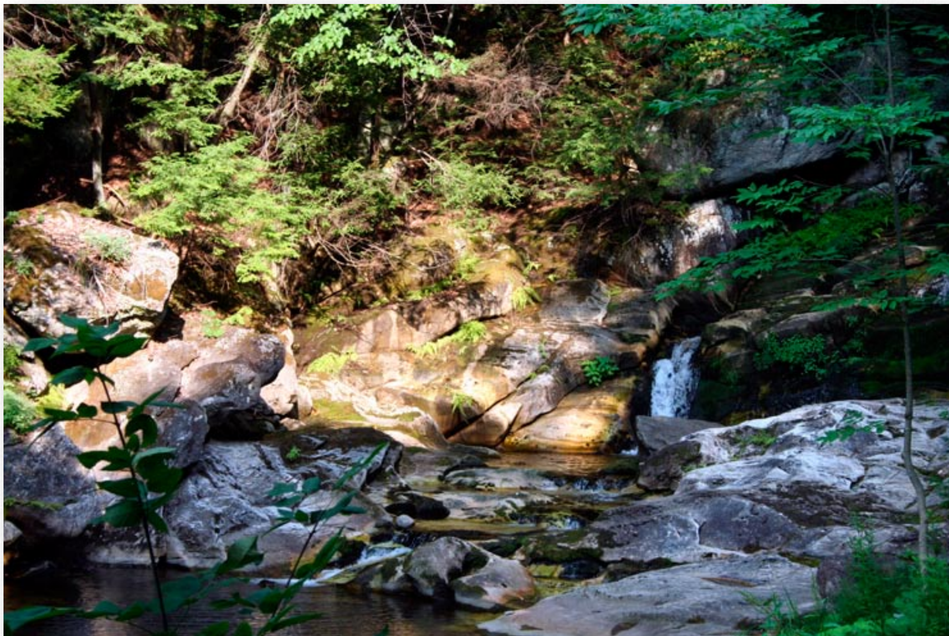

CHAPTER TWO

GEOLOGY

The geology of Kent reflects hundreds of millions of years of natural processes, all of which have left their identifying marks on the landscape. It is, to say the least, a complex tale. To read the sequence of dynamic, sometimes cataclysmic events that created the terrain of Kent, and ultimately the overlying soils as well, geologists begin by studying its bedrock.

Bedrock Fundamentals

Essential to reading Kent's history of geological cataclysms is a rudimentary knowledge of the bedrock underfoot. Bedrock is the rigid, stable rock crust that covers the Earth's hot, semi-solid interior. The part that is visible on the surface is commonly termed "ledge." It is formed of many different kinds of rocks, each of which is an aggregate of minerals of differing chemical composition, crystal form, color, hardness and other properties. The bedrock under Kent is at least three miles thick and may be many times thicker than that in some locations. Logically, older "basement" rock, in having been deposited first, should be found deeper in the earth and later formations should be located nearer the surface; occasionally, due to up thrusts and down thrusts caused when sections of the Earth's crust are subjected to massive tectonic shifts, the reverse may be true. All bedrock is classified as igneous, sedimentary or metamorphic according to the way it was formed.

Igneous (volcanic) rock was created deep in the Earth from semi-liquid molten rock or magma as it bubbled and seethed upward. It can have many different textures, determined by whether the bedrock cooled slowly at great depths (igneous of *intrusive* origin) or cooled rapidly on the Earth's surface (igneous of *extrusive* origin). Granites, which are igneous intrusives, cooled slowly at great depths and are characterized by large crystals, coarser grains and lighter colors; granites are revealed on the Earth's surface only after long periods of erosion. Basalts, which are igneous extrusives, are most often the result of lava flow that cooled and solidified rapidly upon reaching the surface and are characterized by finer grains and generally darker colors. Bedrock also varies in its chemistry and mineral composition.

Sedimentary rock generally forms from the breakdown of older rocks or the accumulation of skeletons and shells of organisms in a watery or oceanic environment. The breakdown occurs through weathering—chiefly physical erosion due to wind, water, ice and temperature extremes, but also chemical changes and other agents of disintegration and decomposition. The weathered material is transported from its point of origin and deposited elsewhere in more or less horizontal layers, often in a marine environment (i.e. beneath an ancient sea), but also on lake floors, river flood plains and deltas. The sedimentary layers gradually become lithified (compressed and cemented together into consolidated rock) by the effects of weight, pressure and chemical action. Sandstone, shale, limestone and gypsum are examples of sedimentary rock formations. Traces of fossilized organisms—the imprint of a leaf or a skeletal remain—are sometimes discernible in sedimentary rocks.

Metamorphic rock can be either igneous or sedimentary in origin, but in either case it has undergone additional physical and chemical alteration due to deformation and extremes of heat and pressure that the tectonic collisions cause. The mineral layers of metamorphic rock sometimes reveal a folded, wavy pattern. Granitic gneiss is the metamorphic form of granite. Marble is the metamorphic form of limestone. Slate is metamorphic shale. Schist is a general term for a family of metamorphic rocks characterized by coarse grains, often including mica and quartz, and a tendency to split easily. Gneiss is a severely metamorphosed rock of varying mineral composition. Amphibolite is a dark-colored gneiss rich in the minerals amphibole, hornblende and plagioclase. Metamorphic rocks dominate the landscape of Kent and the Western Highlands of Connecticut, an indication of the tremendous forces that played out here over millions of years.

Movement along fractures in what was originally a continuous bedrock formation is known as a *fault*. Different types of faults are produced by different compressional and tensional stresses, but once created they become focal points for repeated displacement. To the experienced eye, faults can be discerned in many locations in Kent. A particularly good example is at Kent Falls, where a fault runs from the top of the falls toward Dugan Rd. Another is the thrust fault that rises on the north side of Rte. 341 behind the Kent School's headmaster's house.

Seven primary bedrock types, most of them metamorphic due to the tectonic deformations that occurred here, are shown on the Bedrock Geology Map #4. Each bedrock type is identified on the map and in the text below according to the standard system of geological nomenclature. Capital letters such as Y, C and O, are used to indicate the geological age of the bedrock. The small letters that follow indicate the names of the primary rock types based upon their mineral aggregates and how the bedrock was formed.

A Glance Back in Geological Time

The physical landscape of Connecticut has undergone many changes over the eons. Most of what is reported here has been summarized from *The Geologic History of Connecticut Bedrock,* a book by Margaret Coleman (2005), and from the *Bedrock Geological Map of Connecticut,* a map and supporting documents compiled by John Rodgers (1985). The geological events in Connecticut's history are also presented in tabular form opposite, with the most recent era and period appearing at the top and the earliest at the bottom of the chart.

Kent is part of the Connecticut extension of New York's Hudson Highlands and Taconic Mountains to the west and of the Berkshire Mountains to the North. Known as the Northwest Highlands, its geology was created over more than a billion years of geologic time, as ancient proto-continents and oceans shifted in size and shape, in relationship to each other, and to their orientation on the surface of the earth (latitudes and longitudes). For example, what we know today as New England was once part of a topsy-turvy proto-continent located close to the Earth's Equator. And the familiar rounded peaks and valleys of today's Northwest Corner are mere remnants of far older mountain ranges that once stood here.

Connecticut's geological base was built from west to east. The oldest rock formations in Kent and in Connecticut are 1.3 billion years old, and are part of the Precambrian Grenville Massif that formed the eastern edge of the continental plate of Laurentia. Laurentia, with modifications, is the precursor of the North-American continent. About one billion years ago, most of the earth's tectonic plates collided to form one super continent called Rodinia. The eastern edge of the Laurentian plate crumbled in a major mountain building event called the Grenville Orogeny and the Grenville rocks were raised, deformed and metamorphosed. On the map, these rocks are indicated with the symbol Yg (Y stands for Proterozoic era). They include gneiss (Ygn), schist (Ygs), and amphibolite (Ygh), sedimentary rocks that have been metamorphosed, and granitic gneiss (Ygr), metamorphosed igneous rock. (See also the Bedrock Formations table below). Most of the uplands west of the Housatonic River, Treasure Hill and Sugar Loaf Hill on the southeast border of Kent, are built of ancient Grenville bedrock. Look for exposed segments of PreCambrian bedrock along the Appalachian Trail above Schaghticoke Rd., in broad bands along Fuller Mountain and Skiff Mountain roads, along St. John's Ledges, and in several locations along Ore Hill and Treasure Hill roads.

Over the next 400-500 million years the mountains gradually eroded. Eventually the super continent of Rodinia started to break apart and the new Iapetos Ocean formed. What would become western Connecticut was at the edge of the ocean and located somewhere south of the equator. Tropical white sand beaches during the early Cambrian epoch were lithified to sandstone, and later metamorphosed to quartzite of the Dalton formation (Cd). This quartzite is found in a narrow band along the west side of the Housatonic River valley and around Treasure Hill.

When the sea level rose during the middle and late Cambrian Periods (520-500 million years ago or MYA), the Laurentian continental shelf was covered by a shallow sea. Carbonate mud, consisting mostly of calcareous skeletons of marine micro-organisms, was laid down over the quartz sands. This lasted from about 520-470 MYA, continuing into the early Ordovician epoch. This mud solidified to limestone and later metamorphosed into the Stockbridge marbles (tagged as Csa ("C" for Cambrian), Csb and Ocs ("O" for Ordovician on our map). Because marble erodes and weathers more easily than most other rocks, the Stockbridge marbles were gradually carved into river valleys. In Kent large bands of marble are found along the Housatonic River, in Kent Hollow, and along Bull Mountain Brook and Merryall Brook.

Geologic Time Table

ERA	PERIOD	EPOCH	START IN MYA*	LIFE FORMS	GEOLOGICAL EVENTS IN CONNECTICUT
		Holocene	0.012	human societies	after last ice age
	Quaternary	Pleistocene	1.8	earliest humans	repeated glaciations
		Pliocene	5	appearance of hominids	cooling
		Miocene	24	grasslands spreading	
		Oligocene	34	first apes	warmer
		Ecocene	55		heavy erosion of mountains
Cenozoic	Tertiary	Paleocene	65	earliest large mammals	
			65	extinction of dinosaurs	
	Cretaceous		144	first flowering plants	Tectonic stability in Connecticut. Formation of Alps, Andes, Rockies and Himalayas.
	Jurassic		206	earliest birds and mammals	Atlantic Ocean forms. Shallow seas over much of N.America.
Mesozoic	Triassic		248	first dinosaurs, many deserts	Pangea starts breaking up. Hartford Rift Valley forms.
			248	widespread extinction	
	Permian		290	widespread glaciation	Large faults forming. Appalachian Mountains eroding.
		Pennsylvanian	323	first reptiles; amphibians dominant first conifers	Allegheniian orogeny: Appalachians formed as high mountain range, and metamorphosis of older rocks
	Carboniferous	Mississippian	354	large forests and swamps	Erosion of Acadian mountains
	Devonian		417	earliest amphibians	Acadian orogeny. Eastern highlands of CT formed. Older formations folded, fractured and metamorphosed.
	Silurian		443	first land plants and insects	Periods of calm. Central-CT on coastal plain/marine shelf. Western-CT rolling hills.
		late	458	first corals	Taconic orogeny: Manhattan shales (Cm+Cma) from Iapetos Ocean pushed over Stockbridge limestone.
		middle	470		W-CT continental shelf subsides. Deep-sea muds cover limestone, later lithify to dark shales, and evt. to Walloomsac schist Owm+Ow
	Ordovician	early	490		Last carbonate deposits (later Stockbridge marble Ocs). Iapetos Ocean begins to close. W-CT shallow sea
		late	500		More carbonate muds (Csb)
		middle	520	earliest fish	W-CT covered by shallow sea; deposits of carbonate muds, which lithify to limestone and later metamorphose to Stockbridge marble (Csa)
Paleozoic	Cambrian	early	543	many trilobites	Tropical beach sand deposits lithify to quartz sandstone (Cd)
				explosion of life in oceans	570-490 MYA Iapetos Ocean forms.
					~600 MYA supercontinent Rodina starts breaking up; continental rifting.
				first soft-bodied invertebrates	1000 MYA Grenville orogeny: Laurentia (proto N-America) collides with other continents; Grenville basement rocks deformed and buried.
				first multi-celled organisms	1300 MYA age of oldest rocks in CT: Grenville gneiss, schist, granitic gneiss and amphibolite (Ygn+Ygs+Ygr+Ygh on map).
	Proterozoic		2500		West edge of CT part of precambrian Grenville Massif.
	Archean		3800	first algae and bacteria	~4000 MYA oldest dated rocks in the world.
Precambrian	Hadean		4600?		Formation of the earth.

* Age in million years ago. From Geological Society of America, 1999

The marble bedrock stretched many miles southeastward, but during the Ordovician Period (490-443 MYA) the Taconic Orogeny took place. A narrow band of volcanic islands pushed up against the edge of Laurentia and over the Stockbridge marble. Deep sea muds were deposited atop this shelf and these later lithified to dark shales and eventually were metamorphosed to Walloomsac schistose marble (Owm) and schist (Ow). These rock formations can now be found on the lower slopes east of the Housatonic River, along Womenshenuk and Cobble Brooks and on much of The Cobble itself. (The iron ores so assiduously extracted from Kent's bedrock deposits for more than a century were also laid down as sediments in the mid-Ordovician Period when most of the region was under water. They are principally distributed along the contact line between the younger Stockbridge marble and the older Grenville gneiss, at such locations as the junction of Ore Hill and Geer Mountain roads in South Kent.)

The Taconic plate then pushed shales, formed much further out during the Cambrian period, over the younger Stockbridge marbles and Walloomsac schists, along fault surfaces. The area was significantly uplifted and deformed. Later erosion exposed the marbles again in the major valleys while the eastern uplands of Kent consist of those displaced shales. The shales were later metamorphosed to the Manhattan schistose gneiss (Cm) mixed with schistose gneiss rich in amphibolites (Cma). An isolated part of this formation sits on top of the schistose marble between the Housatonic River and Womenshenuk Brook. Part of Peet Hill, consisting of granitic gneiss, is a remnant of an underlying magma chamber, or pool of magma, that fed the overlying Taconic volcanoes (Og). So, while the bedrock formations of the eastern uplands are not that dissimilar from those in the west, they are much younger. Behind the Manhattan formation, another series of Iapetos Ocean sediments were pushed up against the continent along thrust faults.

The most significant of these faults is Cameron's Line, named for Eugene Cameron, the geologist who first described it. The line traces diagonally across the Western highlands, separating the formation of Connecticut's northwest corner from the rest of western Connecticut. Cameron's Line appears just east of Torrington and Litchfield to follow more or less the course of Rte. 202 until it eventually crosses the Housatonic River two miles south of New Milford's center. On the western side of Cameron's Line, Kent included, was deposited an abundance of marine-shelled creatures that in dying had lithified into deep beds of limestone. On the eastern and southern side is found a distinctly different geology.

The First Land Plants and Animals

The bedrock base of Kent was completed roughly 440 MYA. This marks the end of the Ordovician Period and the first appearance of land plants and animals. Subsequent tectonic events caused several phases of intense deformation, metamorphosis and fracturing of older formations, and periods of uplifting to high mountain ranges followed by long periods of erosion. But no bedrock formations occurred in Kent after the Ordovician Period, and the area west of Cameron's Line was relatively little impacted.

Further east, the situation was different. The Acadian Orogeny, which occurred during the Devonian Period (417-354 MYA), added another part to the North American continent, including the eastern half of Connecticut. At the same time the area east of Cameron's Line was severely compressed. During the late Carboniferous Period (323-290 MYA), the African, South American, and European plates collided with North America to form the super continent of Pangea. Known as the Alleghenian Orogeny, this collision compressed and broke apart Connecticut's crust. Estimated to have been anywhere from 500 miles to 3,000 miles across at the time, the crust was folded into the land mass that is today no more than about 100 miles across. In the process, our section of the Appalachian Mountain chain—the Berkshires and Taconics—was thrust up, the mountains' peaks reaching heights of 20,000 to 30,000 feet, equivalent in grandeur to those of the modern Himalayas.

About 220 MYA, during the Mesozoic Era, Connecticut, like its surroundings, was still covered with semi-tropical vegetation and dinosaurs roamed the region. A rift valley started to form in central Connecticut. But the breakup stopped and a new rift further east made the African continent break away from North America, separated by the beginnings of what would become the Atlantic Ocean. Also at that time North America finally drifted north across the Equator to its present location. The Hartford Rift Basin partially filled up with sedimentary brownstone, washed down from the surrounding eroding mountains during the Triassic and Jurassic Periods.

Volcanic intrusions left plates of basalt that later were tilted; after erosion of the softer bedrock around it, the basalt became exposed as the present trap rock ridges that form the north-south spine of the state. By 145 MYA, the whole of Connecticut was a stable part of North America's continental crust; eastern North America has remained tectonically quiet since.

By the late Cretaceous Period much of the bedrock under Connecticut was gradually worn down by erosion to become part of a large coastal plain that at times was flooded by the sea. Several times though, most recently about 40 MYA, upward arching of the inland area caused new river valleys to form. These valleys mostly followed the north-south fractures and cut deep into the less-resistant carbonate rocks, while the harder bedrock was shaped into ridges and hills. The flowing water gouged out the valleys, but it was during the last two million years that moving ice became the last great elemental force, polishing Kent's landscape to the terrain and textures we know today. The Geologic Time Table below gives a chronological summary of the geological events that played out in our part of the state.

Global Cooling and Glacial Geology

Beginning around three to five million years ago the generally warm, semi-tropical climate that prevailed for tens of millions of years changed. Long periods of dramatic cold led to a succession of advancing and retreating continental ice sheets that scoured the Earth's surface and killed off the semi-tropical biota that lived here.

In the eastern U.S. the Wisconsin Ice Age—75,000 to 12,000 years ago—was the last and had the greatest impact. The so-called Wisconsin Glacier or Laurentide Ice Sheet is estimated to have been as much as a mile deep at the latitude of Hartford, thinner as it approached the coast. At its peak so much water was locked up in ice across the globe that ocean levels fell to unprecedented lows, as much as 300 to 350 feet below present levels. A land bridge was revealed between Asia and North America permitting the ancestors of Native American peoples to migrate to the New World.

The Wisconsin Glacier scoured out the larger river valleys. Then, as the climate warmed once again and the glacier began its retreat about 19,000 years ago, it continued to transform surficial features. At the southern end of the retreating edge, a large amount of unsorted debris was left behind, creating the peninsula of Cape Cod and the chain of coastal islands from Nantucket to Long Island. The last remnants of the glacier disappeared from the Kent area around 14,000 years ago. Withdrawing in a generally south-to-north direction, it left marks still visible today—glacial striations and scrapes—on many exposed ledges and rocky balds.

The retreating glacier deposited two kinds of surficial materials atop the basement bedrock: glacial till and meltwater deposits. Both are important features of Kent's landscape, playing determining roles in creating the overlying soil and thus in determining the suitability of the land for various human and natural developments.

Glacial till is debris carried on top of the glaciers, collected at the edges of glaciers, or pushed before them. In physical form glacial till is an unsorted mix of gravel, sand, silt, clay and variable amounts of stones and large boulders. The debris can be more than 100 feet thick on lower concave slopes, in the valleys and on plateaus, such as the east flank of the Housatonic River valley north of the Flanders district. Similar deposits of glacial till are found in the Cobble Rd. area, Beardsley Rd. area, Spooner Hill and parts of Skiff Mountain. By contrast, it can be thin or absent on higher, steeper slopes.

Glacial till is further described in terms of specific physical formations, including *moraines*, which take the form of ridges usually deposited at the edges of glaciers, and *drumlins*, cigar-shaped mounds of glacial till formed under the glacier, usually of north-south orientation. Most drumlins are formed of till deposited during an earlier glaciation and shaped and compacted by the last glacier. They run NNW-SSE in the direction the ice sheet moved. Spooner Hill is an example of such a drumlin.

Erratics are another kind of glacial remainder. Unmatched to surrounding bedrock, they are large rocks that have been broken off and transported from parent bedrock elsewhere to be deposited in isolation in an area of differing geology. One notable erratic can be seen just off the Appalachian Trail and just above Numeral Rock above Kent School. Another erratic is the legendary Molly Fisher Rock atop Spooner Hill. As described in 1789 by Ezra Stiles, president of Yale University, who came through here on a land survey, he observed this rock "by itself and not a portion of a Mountain;

it is of White Flint. It ranges N & S & is about 12 to 14 feet long; eight to ten wide at base & on the top; … and of an uneven … surface."

A later visitor, Kent historian Clifford Spooner, added his own description in the 1930s: "It is one of several large boulders [that] lie right out on top of the ground … . Doubtless these large boulders came here during the glacial period as they are not the kind of rocks we usually see in the fields."


Molly Fisher Rock, a massive erratic atop Spooner Hill

Spooner went on to confirm Stiles' measurements, adding that it had a stripe of pure white quartz about four inches thick running lengthwise through it. The rock was so unusual, and so strangely scratched or inscribed, that locals attributed a story to it that involved buried gold, Captain Kidd, and a colorful medicine woman named Molly Fisher, who was said to be the only one who knew where the treasure lay. Whatever the truth of that story, the erratic is a reminder of the glaciers' one-time dominance in the area.

The second type of glacial debris, glaciofluvial or meltwater deposits, were laid down in front of the melting, retreating ice sheets, mostly in temporary lakes that formed in valley bottoms. Meltwater deposits appear as layers of well sorted to poorly sorted gravel, sand, silt and clay, giving them the alternative name of stratified drift deposits. Stratified drift can be up to 200 feet deep and, when coarse, forms very productive aquifers. (See Chapter Four and Map #8 for locations in Kent). Kames are small, compact knolls of stratified sand and gravel formed by meltwater at the edge of a retreating glacier. A kame terrace can be observed on the east side of the Housatonic River near Kent Falls.

Talus is often mentioned in connection with glacial alteration of the landscape; it is more precisely the result of other kinds of weathering. Talus is a steeply-sloped collection of usually angular rock that tumbles down from the face of steep rock faces, often from considerable heights; a gathering of talus can be seen beneath St. John's Ledges, below the steep escarpments of Segar Mountain at Club Getaway, and at the back side of the Lake Waramaug State Park camp grounds.

<u>Today's Landscape</u>

The advancing and retreating glaciers acted like gigantic bulldozers, scraping, leveling off and filling in the low areas of bedrock with rock, gravel and dirt, providing the raw materials for many of today's soil types. At the same time the constant flow of melting ice water altered the land, forming wide flood plains, lakes, ponds and rivers. By the end of the Wisconsin Ice Age the once V-shaped valley of the Housatonic River had been reshaped into to its present U-shaped profile as unimaginable amounts of meltwater drained seaward.

As meltwater slowed here and there due to more resistant land forms, and to ice dams and till ridges blocking its way, the larger particles settled out first, then the finer particles, and lastly the finest-grained. This sorting out gave rise to gravel and sand deposits as well as clay banks. Boulder fields were also left behind. Along the rivers fertile sediments (alluvium) were laid down in flood plains on either side, preparing the way for the agricultural activities that would eventually become so important to Kent.

A meander plain, caused as stream water traverses relatively flat land and wanders in evenly spaced side-to-side loops, is seen near the intersection of Macedonia Brook and the Housatonic River. This area is believed to have once been an arm of Lake Kent, the bed of a vast ancient lake that extended from the area of Housatonic Meadows on the Kent/Cornwall line southward to the pinch point at Bull's Bridge, the water trapped by a glacial dam several hundred feet thick. During periods of stronger erosion, the rivers would cut down deeper, leaving former floodplains as raised terraces. Kent has many such terraces, ranging from 20 to 100 feet above the Housatonic's present bed.

Other glacial effects are seen in the many existing lakes and ponds that formed in Kent's glacial depressions. Both Hatch and Leonard ponds are glacial ponds. Elsewhere, large ice blocks left behind were surrounded by thick deposits of debris that created raised earthen walls; these became what are known as "kettle ponds." Fuller Pond is a classic example. The shallowest depressions became wetlands.

Even before the last glaciers were fully gone, plants and animals began to repopulate the once-barren landscape. We can begin to fill in these gaps in our past from two archaeological finds in the vicinity of Kent. Many decades ago an amateur digger uncovered mastodon bones in a Sharon gravel pit; more recently, in 1999, using scientific excavation methods and dating techniques, the entire skeleton of a mastodon weighing up to 15,000 pounds and estimated to have lived c.11,500 B.C. was discovered in Hyde Park, NY, 25 miles west of the state line. It is reasonable to presume that other such prehistoric creatures passed through Kent as well before becoming extinct around 9,000 years ago.

In a sense, Connecticut is still "recovering" from glaciation as glacial ponds gradually fill in to become marshes and bogs, swamps become wet forests, rivers and streams continue to carry glacial sediments to the sea, and stones deposited by glaciers pop through the soil with every springtime frost-heave. The old stone walls that border countless fields and roads in Kent are also reminders of the glaciers' actions, as are the occasional erratics that stand out in the landscape like so much natural sculpture.

RECOMMENDATIONS

l. Keep strict limits on the extent to which landscape can be reshaped for development or resource extraction including mining. Promote the philosophy of working with the land, not against it.

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