Cliff hanging Science

By KATHRYN HOPPE

Sheer cliffs protect a unique ecosystem

While scientists pursue new knowledge to the ends of the Earth and beyond, some of nature's most amazing creations remain hidden within sight of our busiest cities.

Only in the last few years have researchers discovered the cliffhanging natural mysteries of Ontario's Niagara Escarpment. "This cliff is like a world apart," says botanist Douglas W. Larson, one of the first scientists to climb over the edge in order to study this rocky ecosystem. Although he and his co-workers from the University of Guelph in Ontario first began to focus their attention on the Niagara Escarpment in 1985, they "are just beginning to figure out how wonderful and different this cliff ecosystem is," Larson says.

For hundreds of kilometers, from Niagara Falls northwest to the islands of northern Lake Huron, the Niagara Escarpment runs through Canadian countryside populated by more than 7 million people, Larson says. Yet the escarpment has remained largely untouched by human civilization or scientific curiosity.

Small wonder: This is not a habitat to be entered lightly.

Larson and his associates had to learn the ups and downs of rock climbing in order to traverse the average 30 vertical meters of cliff face. Safety ropes, helmets, and harnesses have joined their more traditional notebooks.

But the dangers are worth the rewards, says Larson, who calls himself privileged to work in an environment still pristine, despite its proximity to such large cities as Toronto. Fellow Guelph researcher Peter E. Kelly agrees, but a bit more colorfully. "There are people out there who would kill for an office window [with the view from this cliff]," he says.

One of the group's most surprising discoveries involves the small cedars found growing out of cracks in the cliff face: These trees may well form the most extensive old-growth forest in eastern North America.

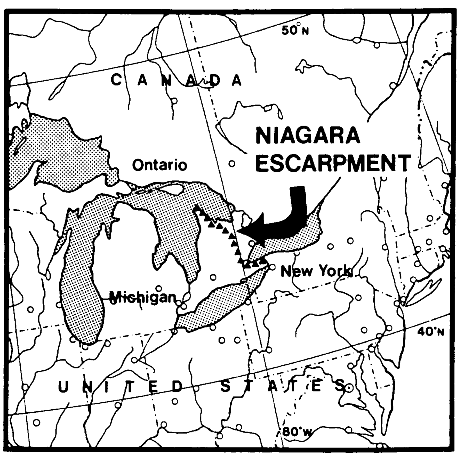
Commonly known as the eastern white cedar – taxonomically called *Thuja occidentalis* – these cliff-clinging trees grow small and scrubby, yet some of them manage to survive for more than 1,000 years. "Nobody had any idea prior to [our study] that these little twisted trees were so old," Larson says.

The species' better-placed members give little indication that such longevity runs in the family, says Larson, noting that in highly productive environments eastern white cedars seldom live longer than 400 years. Mature trees grow to large sizes – up to 25 meters tall and 2 meters in diameter – thus becoming vulnerable to high winds. Because eastern white cedars produce a relatively weak wood, these taller trees are often blown down, Larson explains.

On cliff sides, however, this same species forms only twisted trunks, typically less than 3 meters long. Their small size keeps these cedars from being blown down. Further protected from most forest fires by the barren rock that surrounds them, many individuals survive for over 500 years. The oldest eastern white cedar dated by the Guelph team still grows after 1,032 years of rocky life.

Since the bare rocks provide few nutrients and little room for roots to expand (see sidebar), these trees may grow more than 1,000 times slower than their larger counterparts, the researchers have found. The Niagara Escarpment thus supports a forest of natural bonsai trees, they say.

These cedars grow at one of the slowest rates yet recorded for a woody plant, says Larson. They may have an average radial, or outward, growth rate of only 0.05 millimeter per year. Researchers must use a microscope to distinguish between their annual growth rings, which can be



Above: A line of triangles traces the Niagara Escarpment. Right: The variation in vegetation between the cliff face and the surrounding forest becomes more obvious in winter because the cedar trees maintain their green foliage.

Larson

thinner than a human hair.

The slowest-growing specimen found by the Guelph team lived for almost 600 years yet reached only the size of a half dollar in diameter and less than 25 centimeters in height. It weighed approximately 140 grams, giving it an average rate of growth estimated at less than 0.26 gram per year.

Such characteristics may make these cedars an eastern analog of the better-known bristlecone pine trees of the western United States, says Larson. The similarity extends not only to their growth rate, but also to their habitat and shape, he adds. The oldest members of both species grow only in very rocky environments, which supply only small amounts of nutrients. These harsh conditions so limit growth that the older trees of both species lose extensive amounts of their cambial layer, the cell layer that produces new tissue and bark. Mature trees may retain less than 10 percent of their original bark and thus grow asymmetrically, producing irregularly oblong trunks instead of the familiar round ones.

The comparison between these two species is not exact, however, since the oldest bristlecone pines grow only at high elevations in an arid desert, notes Thomas P. Harlan, a bristlecone researcher with the Tree Ring Lab of the University of Arizona in Tucson. And even the most venerable eastern white cedar looks young next to the oldest bristlecone pine, which has grown for approximately 4,800 years, he adds.

From such ancient trees, researchers can produce a dendrochronology: a timeline constructed from the seasonal variations recorded in tree trunks. Each growing tree annually produces a new ring of cells, which consists of a relatively wide, light ring grown during the productive seasons of spring and summer, and a thinner, darker ring grown during the harsher months of autumn or winter. The width of each year's growth ring depends on yearly changes in the weather. By comparing the various rates of growth recorded in annual rings, researchers can construct a year-by-year timeline that reveals long-term trends in precipitation rates or temperatures.

Larson

This cryptoendolithic community, here exposed to daylight, inhabits the white dolomite rocks of the Niagara Escarpment. These green organisms grow in a 2-millimeter-wide strip, which starts approximately 2 to 4 mm away from the exposed surface.

Living and dead specimens of the bristlecone pine provide the basis for a continuous dendrochronology that stretches more than 8,000 years into the past, Harlan says. Additional samples have enabled scientists to construct a discontinuous record to approximately 12,000 years ago.

The Guelph research team hopes to produce a similar, although shorter dendrochronology based on the eastern white cedar. Some initial details of this work appeared in the March INTERNATIONAL JOURNAL OF PLANT SCIENCES.

To date, the researchers have constructed a continuous chronology from the present to approximately A.D. 500, Larson told SCIENCE NEWS. They hope to extend this chronology farther back, since they have found well-preserved cedar logs from trees that lived and died more than 2,000 years ago. Their oldest log started growing around 1,300 B.C. and died around 600 B.C. In order to extend their continuous chronology back this far, the team must fill a gap in their records from approximately A.D. 200 to A.D. 500.

While the researchers use the remains of ancient logs, they puzzle over the logs' preservation. Dead wood from bristlecone pines may remain in good condi-

Bonsai cedars: No room to grow roots

Larson

Looking like a tree surgeon with her patients, researcher Sarah Owen checks on an innovative cliff-side sprinkler system constructed from hospital intravenous feeding equipment.

Curious about how trees manage to live on solid rock, University of Guelph researchers set up shop on the face of an abandoned quarry that supports a 40-year-old community of eastern white cedars. (They know when these trees started growing because they know the date when the quarry closed.)

By selectively watering or fertilizing individual trees, the researchers hoped to determine what factors control growth rate. The root of the problem: how to get nutrients through solid rock so the plants can absorb them. The solution: providing a slow but steady flow of nutrients via intravenous tubes extending through small holes drilled in the cliff face.

After two years of study, the scientists harvested 60 trees this summer in order to examine in detail their relative rates of growth.

Easier said than done. Each tree's root system wound through cracks in the cliff, so researchers had to break through solid rock in order to harvest the entire tree. And these trees can extend long roots. While the largest trees in the community had tiny trunks – only slightly longer than a new pencil and smaller around than a dime – their roots stretched for up to 2 meters parallel to the face of the cliff. Fortunately for the harvesters, these roots were relatively shallow: None penetrated more than 15 centimeters into the rock.

While the study remains incomplete, preliminary results indicate that the size of the crack in which a tree takes root controls its rate of growth: An excess of nutrients does not seem to speed a tree that cannot expand its roots.

This abandoned quarry provides the Guelph researchers with a rare opportunity to conduct invasive experiments without damaging a pristine ecosystem. When climbing the Niagara Escarpment, they take great care not to harm either the organisms or the cliff. Thus, the cryptoendolithic microorganisms that live inside this cliff remained hidden until the team first began to break through rock in order to harvest the quarry trees. *– K. Hoppe* tion for thousands of years, but this appears to be due largely to the arid conditions of the high deserts in which the trees grow and die, says Larson. In the relatively wet climate of southern Ontario, even decay-resistant woods seldom last more than a few hundred years. Yet many eastern white cedar logs remain in pristine condition more than 1,000 years after their death. The unusual durability of this wood intrigues Larson. He views the question of why these particular logs remain free of rot and fungal attack as "a microbial biologist's dream come true—a project sitting here waiting to be done."

Regardless of the reasons for such preservation, these cedars, living and dead, give scientists a rare opportunity to study past climatic variations in eastern North America, Larson says. Few previously published dendrochronologies from the East Coast go back more than 300 years, and only one chronology — which uses the bald cypress tree — goes back farther than 1,000 years, he explains. If the eastern white cedar can provide a continuous chronology to approximately 3,000 years ago, it would be a considerable advance, says Edward R. Cook, a dendrochronologist with Columbia University's Lamont-Doherty Geological Observatory in Palisades, N.Y. "It is very unusual to find situations where one can construct a tree ring chronology back for 2,000 years. . . . For studies of past climate, it would be very, very significant," Cook says.

To reconstruct past climates accurately, researchers need chronologies from many different regions. "Climate is not consistent all the way across the U.S., the northern hemisphere, or the world. The records that we have for . . . one area may have very little bearing on what is going on anywhere else," Harlan explains.

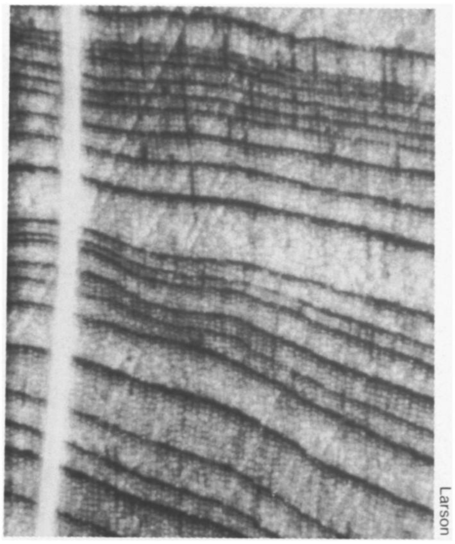
In addition, different trees record different climatic variables, such as precipitation or temperature, says Cook. In order to understand long-term weather patterns like global warming, scientists need to construct dendrochronologies not only from different species, but also from different regions. Thus, even a relatively short chronology derived from the eastern white cedar would contribute to our knowledge of past climatic conditions.

Other findings have underscored the differences between the ecosystem found on the Niagara Escarpment and life in the surrounding countryside. In June, Larson and his coworkers discovered cryptoendolithic (meaning hidden inside rocks) organisms living within these cliffs.

Previously found only in extremely harsh environments, such as the deserts of the Middle East and Antarctica's ice-free Dry Valleys, these organisms grow as a thin line of color several millimeters below the surface of translucent rocks. Researchers believe that these communities, which may include lichens, algae, or fungi, evolved to live inside rocks in order to escape the conditions at the surface.

The presence of these organisms within the rocks of the Niagara Escarpment may reflect extremes in cliff face temperatures, which can range from −30°C in winter to 58°C in summer, says Larson. Such extremes in temperature, the general scarcity of nutrients, and the lack of snow cover in winter combine to produce a cliff-side environment closer to that of arctic tundra than to the productive climate found in the rest of southern Ontario, says Larson.

While the discovery of cryptoendolithic organisms emphasizes the escarpment's environmental distinctiveness, it also raises many new questions. The researchers have yet to identify what species are present, their range, or the exact role they play in the escarpment ecosystem. Larson speculates that they might help convert atmospheric nitrogen into a form the cliff-growing cedars can use as a fertilizer. Larson says that this most recent "discovery opens a door we didn't know existed," one he plans to investigate thoroughly in the future.



Larson

A human hair (bright vertical line) provides the scale for tiny tree rings that record past climatic variations. The seasonal variation of one year is represented by each pair of light and dark rings.

While the ecosystem of the Niagara Escarpment is unusual, it probably is not unique. Larson has received reports from a dozen researchers around the world describing similar cliff-side ecosystems. He believes that these open, exposed habitats may compose a series of "parallel universes" consisting of closely related organisms that interact in similar ways.

The ecosystem that most closely resembles that of the Niagara Escarpment may exist in the steep valleys of the Appalachian Mountains. Dolomite cliffs in these valleys support many small, isolated populations of eastern white cedar, says Gary L. Walker, a population ecologist with Appalachian State University in Boonę, N.C. Although he has not dated samples of the cliff-dwelling trees, he notes that they appear very similar in form to the cedars on the Niagara Escarpment.

In the Appalachians, however, these cedars remain relatively rare, because the species generally grows best in the cooler climates to the north. Also, early settlers often harvested cedars, so only a few inaccessible populations remain undisturbed in the southern part of their range, which stretches to Kentucky and Tennessee, Walker says.

His studies have shown that such isolated populations often display unusual genetic variations not found in the main population. Walker speculates that since they have remained undisturbed, the cliff-hanging cedars of Appalachia may preserve ancient genes that would otherwise have been lost. Starting in the spring of 1993, Walker and researchers at the University of Tennessee plan to examine this possibility in a genetic study of these trees.

While researchers have just begun to uncover a few of the amazing aspects of this cliff-clinging ecosystem, human civilization has already adversely affected these previously protected organisms. The same techniques and technology that have allowed researchers to discover the special characteristics of this environment also contribute, in some places, to its destruction.

The popularity of recreational rock climbing threatens the ancient life on the Niagara Escarpment, as climbers sometimes break trees off during a traverse. Since the discovery of the ancient age of these cedars, however, many climbing groups have changed their ways, Larson notes. Instead of deliberately clearing away obstructing plants, most people now actively avoid disturbing these trees.

While the work of the Guelph researchers has already helped to preserve the ecosystem of the Niagara Escarpment, Larson hopes that future studies will help scientists understand the factors that control the health of a broad range of ecosystems.

This cliffhanging ecosystem seems to have an unusually fast restoration rate, Larson says. By studying the fundamental properties that control the natural reconstruction of this ecosystem, his team hopes to improve understanding of what controls reconstruction rates in general. Larson believes that such information could help worldwide efforts to restore an increasing number of damaged ecosystems. □