# The Valley of Fire and Ice

VOLCANOES AND GLACIERS HAVE SHAPED BC'S WELLS GRAY PARK

*Article and photography*

*by Trevor Goward*

Campers at Clearwater Lake, in British Columbia's Wells Gray Provincial Park, seldom guess that buried beneath their camping pads lies the business end of a river of lava.

Seventy-six hundred years ago that lava flow was an incandescent flood of steaming basalt. Having erupted from the throat of the Dragon Cone, a volcano to the northeast, it flowed some 18 kilometres to dam the mouth of Clearwater Lake. The thunder and commotion of its advance would have been awesome: the serpentine hiss of gases suddenly released from pressures deep within the earth; the rattle of rock cakes tumbling forward off the advancing front; the creak and groan of the cooling lava; and, above it all, the sustained, jet-engine roar of the volcano itself.

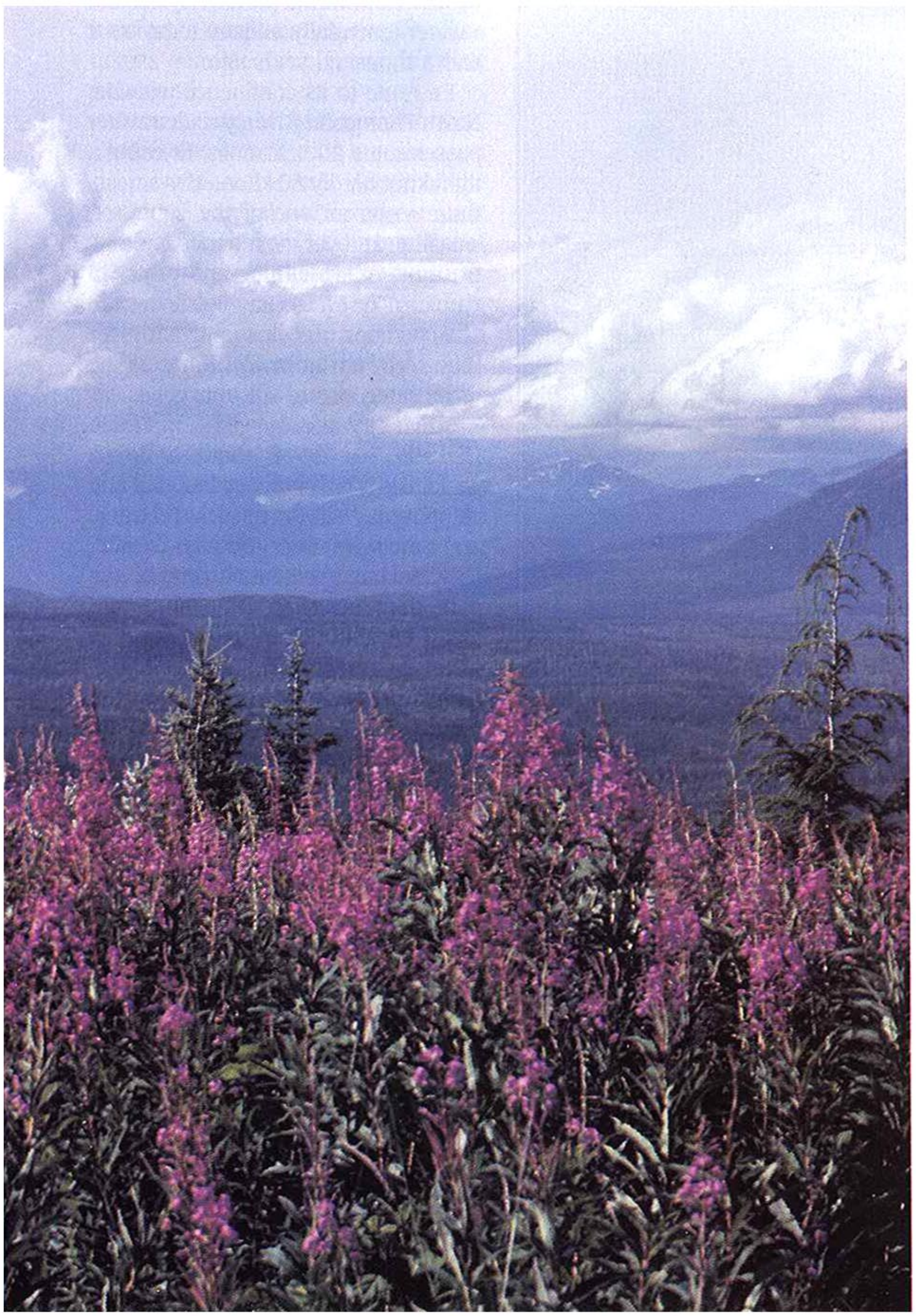
Nowadays, sights and sounds such as these are probably more familiar to the inhabitants of Hawaii than they are to Canadians. Yet Canada is not without a few volcanoes of its own. At least five regions of geologically recent volcanic activity can be identified in Canada – all of them in the west. They have developed under widely differing sets of geologic circumstances, and collectively they provide a thumbnail sketch of the genesis of volcanoes worldwide.

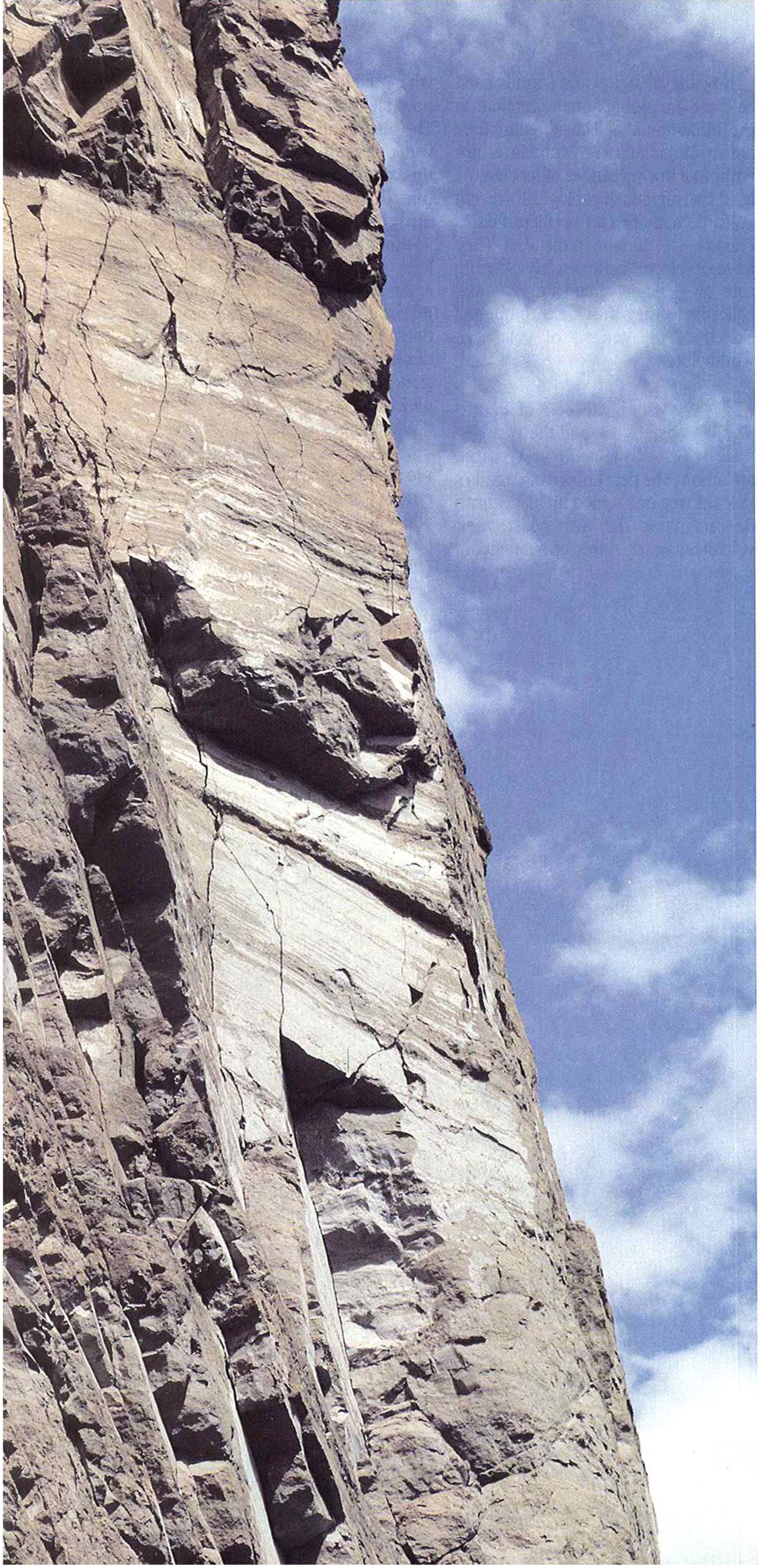
The Garibaldi Belt of southwestern BC, and the Wrangell Belt of the southwest Yukon, are among the best known of Canada's volcanic regions. Lined up like cancan dancers along the west coast, their volcanoes mark zones of subduction, where the floor of the Pacific Ocean is now sliding beneath North America. The descending ocean floor injects water beneath the earth's crust, and this combines with increasing temperatures to melt the adjacent rocks. In time, the molten rock – called magma – either hardens below the surface to form granitic plutons like the (now exposed) Coast Mountains of western BC, or erupts at the surface as volcanoes. Mount Garibaldi is an artifact of the latter process – and so, by extension, is the spectacular 200,000 hectare park that bears its name. Volcanoes and parks go well together.

Other volcanoes, like those along the Stikine Volcanic Belt of northwestern BC, mark regions of extension where the earth's crust is slowly being pulled apart. As the crust thins like pulled taffy, magma may force its way upward to the surface and there explode into action. Mount Edziza, one of Canada's largest volcano at 2800 metres, formed in this way – whence also Mt. Edziza Provincial Park.

Yet another volcanic region, the Anahim Belt, stretches like a toothy grin across the western half of BC, east almost to Quesnel. Here volcanoes have formed above a localized thermal upwelling from deep within the earth's mantle. Such upwellings are called hotspots; visualize them as stationary laser beams focussed upward on the bottom of the earth's crust. The heated crust buoys upward, weakens, and eventually allows magma to reach the surface. The volcanoes thus generated tend, at any one geological period, to form a tight, circular cluster above the more or less circular hotspot.

Why, then, the Anahim "Belt"? The reason seems to be that North America has been gradually sliding westward over the stationary Anahim hotspot during the past 15 million years; a string of ever-younger volcanoes has been the result. Eight million years ago this hotspot lay beneath (and created) what is now the kaleidoscopic Rainbow Range of Tweedsmuir Provincial Park. Twenty million years hence, it may well be generating new volcanic eruptions on the outskirts of Grande Cache.





As it happens, volcanoes have already begun erupting within 200 kilometres of Grande Cache, though apparently these have nothing to do with the Anahim hotspot. The scene of action is the Clearwater Valley, alias Wells Gray Provincial Park, and the easternmost of Canada's volcanic regions. On the BC road map, Wells Gray is a large green spot lying about 160 kilometres north of Kamloops. On the ground, at 515,301 hectares, it is among the province's largest wilderness parks, of a size to swallow one in every five nations on earth. The park's boundaries are defined primarily by the drainage of the Clearwater River and its major tributary, the Murtle. These flow with a combined volume which, in freshet, moves approximately a thousand cubic metres of water out of the park every second –water essentially as pure today as it was a thousand years ago.

En route to its confluence with the North Thompson River, the Clearwater passes some 20 volcanoes. Forming a tight knot hardly 60 kilometres across, these represent one of the youngest, smallest, and yet most varied concentrations of volcanic landforms in Canada. The Wells Gray volcanoes are also, perhaps, the most enigmatic, for they seem not quite to fit any of the usual categories of volcanic genesis.

So, at any rate, suggests Dr. Cathie Hickson – one of about a dozen geologists who have been banging and chipping at Wells Gray's rocks (volcanic and otherwise) over the past decade. Hickson has spent more time in the park than most; in 1986 she completed her Ph.D. thesis on its volcanic history – at the same time revolutionizing our understanding of its fire mountains. Now a volcanologist with the Geological Survey of Canada, Hickson has moved on to projects in other areas, but she still admits to a special fondness for the valley of the Clearwater, which she refers to as "a puzzle in the making."

Geologists are not the only people to be perplexed by Wells Gray's volcanoes. Because the park's volcanic features tend to be cloaked in dense Columbian forests, or else buried beneath thick deposits of glacial till, visitors are likely to notice only bits and pieces of them – a canyon here, a lava flow there.

Indeed, many of the thousands who visit Wells Gray each year are scarcely aware that the park has been a focus of volcanic eruption at all.

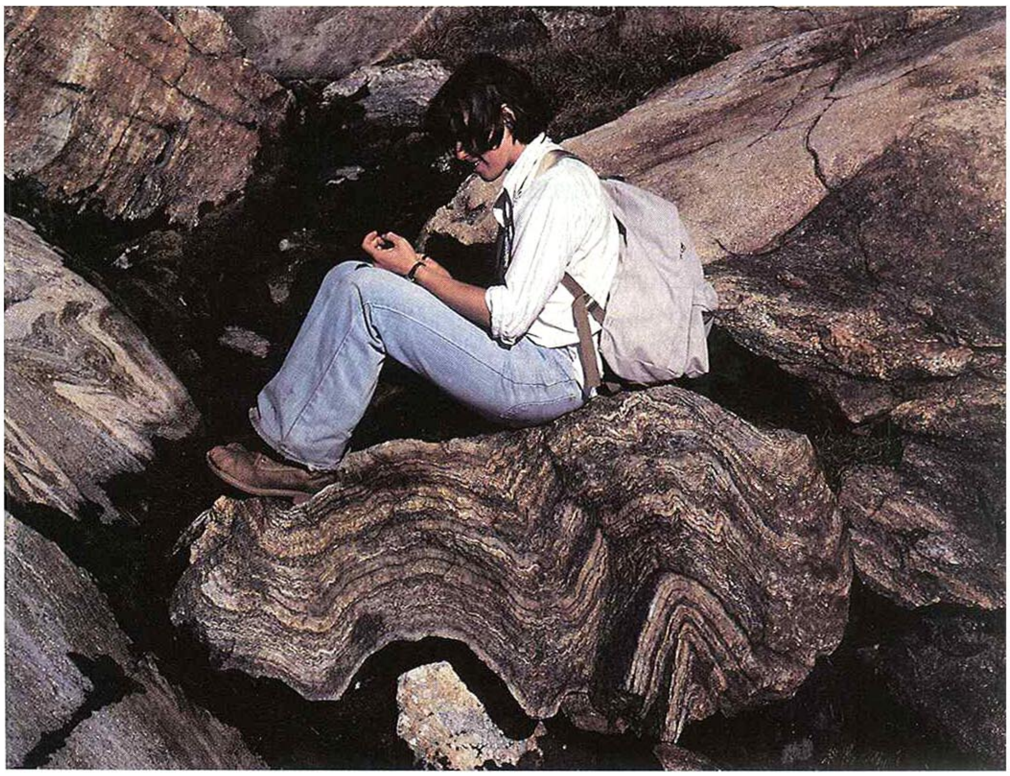
Some volcanic artifacts, however, are hard to overlook and, of these, the Dragon's Tongue is among the most accessible. Less than 30 minutes away from the tents and motorhomes of Clearwater Lake Campground, the surface of this lava flow has buckled, cracked, crimped, and cluttered into enormous piles of broken crockery. Standing on one of these piles, it is easy to imagine how, during eruption, the solidifying surface of the flow was continuously jostled from below by the still-liquid lava and, thereby, broken and piled into rafts, like ice floes in a fast-flowing river. Such rock is technically called aa – a name supposedly derived from the sound uttered by barefoot Hawaiians as they walked across similar lava flows in their homeland.

Near the edge of the Dragon's Tongue, visitors are often startled to come upon deep wells in the rock. Some of the wells are vertical, while others slant upward from below like the imprints of buried cannons. These are tree casts, known locally as the Dragon's Teeth. They have formed where moisture in the trees quickly cooled the lava, solidifying it to a thin, protective skin. Because lava begins to crystallize at about 1100° C – four times hotter than the hottest household oven – the trees would have been quickly killed. By the time they burned away, permanent castings marked the place where they had stood.

Some of the imprints measure nearly a metre across; they tell geologists that a sizable forest stood here at the time of eruption. Other remnants of that forest were buried by the lava – only to be exposed again by downcutting streams. Such charred remains have helped Cathie Hickson, using the radiocarbon dating method, to place the eruption at about 7600 years ago.

The Dragon's Tongue is one of three volcanic eruptions to have occurred in the Clearwater Valley subsequent to the retreat of the Ice Age glaciers, about 11,000 years ago. Accordingly, its Columbian forests are now gradually creeping in from the edges. For the park's older lava flows, however, things are otherwise; they have been subjected to the polish of up to three separate glacial advances and retreats.

One of the gifts to mankind of modern earth science has been a perception that landforms are continually changing, and are, in fact, often less enduring than lifeforms. To be alive today, and to be geology-literate, is to inhabit a planet quantitatively different from the one we inhabited only 20 years ago. Gone forever are the rocks of ages; in their place are the rocks of perpetual change.



On a clear day from the viewing tower on the summit of Green Mountain, near the south entrance to Wells Gray, you can survey quite a lot of that perpetual change. East and north, the rugged Cariboo Mountains encapsulate about 100 million years of geologic upheaval. The Cariboos are a subset of the Columbia Mountains and nextdoor neighbours to the Rockies. In summer, thunder rumbles over their peaks. In winter, avalanches tumble down their slopes. And in the gaps that separate the summits, lie massive icefields and glaciers – remnants of an Ice Age past.

Today the park's rivercourses are loaded with the meltwaters of the snowfields and glaciers of the high Cariboos; not long ago they were charged with the glaciers themselves. Geologists suspect that during the past two million years, glacial ice has come and gone at least 17 times. Given that British Columbia has probably spent more time during this period beneath the ice than above, it is not surprising that some of Wells Gray's volcanic episodes occurred against a glacial backdrop.

Eleven thousand years ago, those Ice Age glaciers were retreating northward from the broad circular basin – the Murtle Plateau – which fans outward from the base of Green Mountain. As they melted, the glaciers left behind a thick mantle of debris which has ever since obscured the volcanic origins of the Murtle Plateau. Notwithstanding, its surface is still punctuated by the domes and low ridges of volcanoes, though most would scarcely be identified as such by the average visitor.

There are two reasons for the confusion. One of them is water. Water does strange things to erupting volcanoes, and nowhere is this better illustrated than at Whitehorse Bluff, jutting westward from the west flank of Green Mountain. More resembling a breached hydro dam than a volcanic cinder cone, Whitehorse Bluff juts out clear into the middle of the Clearwater Valley. Meandering serenely past its base, 250 metres below, is the Clearwater River.

The Bluff formed about 600,000 years ago when a lake occupied this part of the valley. Just why a lake filled the valley at that time may never be known. Perhaps it formed when lava flows downstream temporarily dammed the Clearwater River. Or maybe it backed up behind a tongue of glacial ice. What is certain is that the lake water had a spectacular effect on the erupting magma.

When cold water manages to enter the dykes that feed an erupting volcano, huge explosions result. At Whitehorse Bluff, the explosions shattered the lava, sending billowing clouds of steam and debris high into the air. When the particles eventually steeled, they formed a layer of shattered basaltic glass over the lake bottom, only to be blasted upward again by another explosion, as yet more magma was erupted. That process -- eruption, shattering, deposition – was repeated many times, building layer upon layer of sandstone-like basalt, called tuff breccia.

The eruption continued, and now the rising magma cut dykes through the newly deposited breccia. Because the breccia was relatively cold, it caused the margins of the dykes to harden into small basaltic columns. Eventually glaciers and water would cut through the centre of the volcano, and thus expose these columns – its internal plumbing – to public view.

As a high, wall-like promontory, Whitehorse Bluff is unusual. As a volcanic remnant, it is unique. Though some twenty underwater volcanoes are thought to erupt each year on the ocean bottoms of the world, these tend to be rather difficult to view – both during eruption, and afterward. At Whitehorse Bluff, by contrast, geologists have a rare instance of an underwater volcano that was later left standing high and dry.

The unusual texture of the basalt which comprises the bluff illustrates a fundamental property of lava: its final appearance is controlled largely by the circumstances under which it was erupted. Though basalt represents a fairly narrow chemical "recipe" of volcanic rock (high in iron, high in magnesium, and comparatively low in silica), it nevertheless comes in a wide assortment of colours, forms and textures.

Basalt that has cooled slowly and in the open air tends to crack vertically into polygonal columns, called columnar basalt. Should, however, the lava flow into water (rather than the other way around, as at Whitehorse Bluff), it acquires a very different form. The water abruptly chills the surface of the lava, causing it to skin over with a hardening crust. The underlying lava is of course still molten and eventually it breaks through this crust, creating numerous rounded lobes. In their turn, the lobes, likewise, skin over and the process repeats itself. So the lava advances through the water in small steps, as though on tiptoe. Each of the "toes" is technically called a pillow, and the whole mass is known as pillow lava.

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Pillow lava also forms when volcanoes erupt under glaciers. And glacial ice is the other reason that so many of Wells Gray's volcanoes are scarcely recognized as such by the average visitor. Because the ice acts as a barrier, it prevents the lava (and the water from the melting ice) from flowing away. Trapped, the lava pours out into the icy water and so builds into a platform made up of pillows and pieces of pillows. Eventually the erupting vent may protrude through the surface of the ice. Here, the lava cools to the more usual columnar basalt which becomes, as Hickson puts it, "the icing on the cake made of pillow lava." The end product is a flat-topped, steep-sided mound called a tuya.

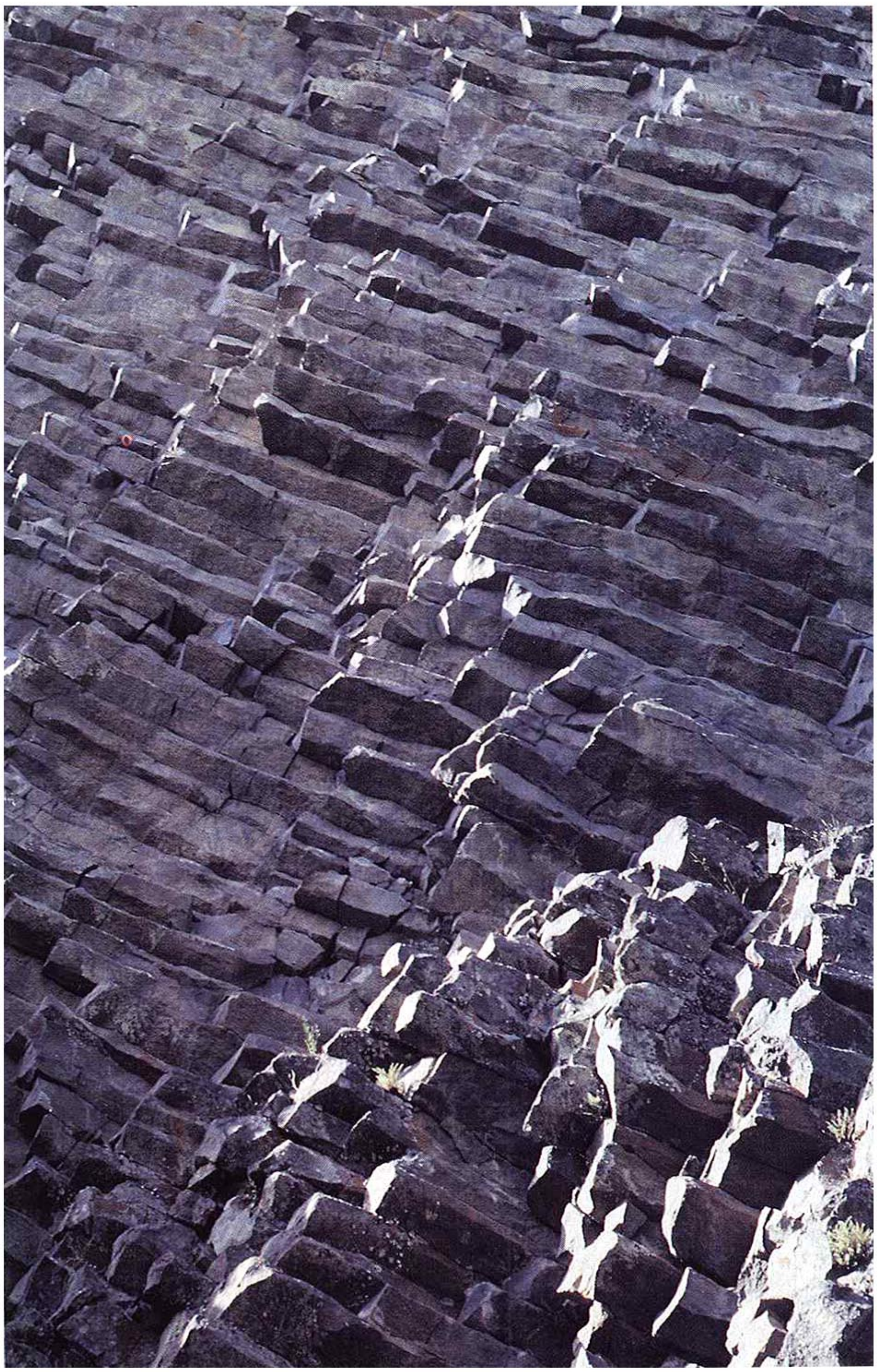
It is well known that the gods prefer to perform their strangest topographic tricks in regions remote from man. And so it is with subglacial volcanoes. Don't bother looking for them in Hawaii, or Italy, or Japan, or any other populous place. Look instead in the Far North, where the glacial history lies thickest. In Europe, you'll have to search the remotest corners of Iceland. In North America, check the far distant recesses of northwestern BC and the adjacent Yukon. In Wells Gray, however, you can peer at a tuya from over the steering wheel of your car; the view from Green Mountain reveals no fewer than five of them.

Among the better preserved of Wells Gray's tuyas is 52 Ridge, perched high on the slopes of Battle Mountain. Though itself only 125 metres tall, its broad summit lies at about 2000 metres, and so apparently escaped the worst of the glacial grinding of the last Ice Age. The 20 deep, conical pits that pock its summit are craters, and the frothy, reddish-coloured rocks that line the craters are called scoria – yet another incarnation of lava.

The scorias formed when gas-charged magma rose to the surface and fire-fountained into the air. Its existence suggests that the ice through which the eruption occurred was thick enough to confine the flows, yet too thin to cap them. Still, Hickson maintains there must have been plenty of water around: coming into contact with the erupting magma, it caused the vents to explode, thus forming the craters. Some of the scoria which lines the bottoms of the craters is so full of holes that it actually floats in water like pumice.

Not all the park's under-glacier volcanoes have acquired the table mountain profile typical of tuyas. Pyramid Mountain, for example, is a tuya that looks for all the world like a replica-in-miniature of the classic volcano, Mt. Fuji. But Mt. Fuji is a 3780-metre strato volcano, composed of alternating ash and lava flows. By contrast, Pyramid Mountain, at only 250 metres tall, really ought to be a cinder cone: a loose, rubbly heap of scoria blown from the vent at the time of eruption Yet the flanks of Pyramid are solid, and closely resemble sandstone. Here, apparently, is a tuya that simply did not build tall enough to poke out above the surface of the glacier beneath which it erupted. Rather than building outward in the open air, this little volcano was confined to a tight cone by the meltwaters that surrounded it.

Elsewhere, lava has erupted from vents lying above the upper surface of the ice; at Sheep Track Bench on the slopes of the Trophy Mountains, the glacial ice hemmed in the lava flows against the valley wall. As the lava melted the ice, a slurry of freshly hardened bits and pieces flowed down the slope, mixed with granitic boulders that had been released from the glacier. When the whole mess finally hardened, it formed a sort of volcanic Christmas cake called pillow breccia. Today this applique still clings to the mountainside: an upright, pie-shaped wedge across whose surface visitors now steer their motor homes en route to the park entrance.



But these are just details: the latterday ramifications of processes that were set into motion 180 million years ago. The real story involves not just the volcanoes themselves, but all the landmasses of western North America, stretching from southern California north to Alaska. As viewed against this larger picture, the Clearwater Valley is just a small – but pivotal – piece in a geologic jigsaw puzzle of continental proportions. And the frame which makes that puzzle whole is the theory of plate tectonics.

First proposed by the Canadian geophysicist Tuzo Wilson in 1963, plate tectonics postulates that the earth's crust is composed of about a dozen rigid plates. At the surface, moreover, these plates are made up of essentially two kinds of basaltic rock, 10 to 20 kilometres thick. Visualize the plates as enormous rafts floating above the semi-molten upper mantle of the earth. Because the granitic portions of the plates are lighter, they tend to buoy up as continents above the heavier basaltic rocks, which thus comprise the ocean bottoms of the world.

The plates are not static, but move about ponderously over the earth's mantle. Their movements are thought to be powered by the heat of decaying radioactive elements deep within the earth. Rising as convective upwellings, most of this heat is vented along the edges of the plates, especially along oceanic ridges like the one running down the middle of the Atlantic Ocean. Collectively, the mid-oceanic ridges make up the greatest mountain system on earth, measuring a total of 60,000 kilometres in length.

Year after year, volcanic eruptions along these ridges add two and one-half square kilometres of new basaltic rock to the ocean floor. At the same time, the adjacent plates heave apart (or are drawn apart) in a process called seafloor spreading. As they move outward from the ridges, the plates cool, become denser and eventually get sucked beneath the edges of other, more buoyant plates, especially the continents. In this way all the ocean floors of the world turn over at least once every 200 million years.

The disappearance of an oceanic plate beneath the edge of a continental one is not without incident. As the

former slides downward, layers of sediment are scraped off the ocean floor – only to be plastered against the continental margin. At times, embedded bits and pieces of continental material, called terranes, also come ashore and these cause the continent to grow outward even more.

One hundred and eighty million years ago, the western edge of North America lay some 500 kilometres inland of its present margin. In those days, the Pacific rollers broke on beaches just to the east of what is now the Clearwater Valley. Ever since, British Columbia has been growing incrementally westward as terranes have docked, one by one or in preassembled packages, against its shores. Today the western two-thirds of the province is a geological jigsaw puzzle comprised of some 200 of these terranes.

Prior to the arrival of the terranes, western North America was a region of low relief, probably similar in topography to the Atlantic coast of today. By 85 million years ago, however, the stresses associated with the docking terranes had worried it – the terranes included – into a vast, wrinkled brow of mountains. The Cariboo Mountains of northern Wells Gray formed from ocean sediments that were squeezed into rock during this wrinkling process. On their summits you can still find marble pods, marking the place of prehistoric reefs.

None of this seems to say very much about the genesis of Wells Gray's volcanoes. But as Hickson points out, there is a connection: faulting. Because the Clearwater Valley is underlain by the contact zone between two quite different landmasses – the original North American plate to the east, and the crazy quilt of accreted terranes to the west – its bedrock has been repeatedly faulted as the landmasses have continued to shift and jostle. One of the products of this process has been the Clearwater Valley.

Faults are just deep-set cracks in the earth's crust. The Rocky Mountain Trench of eastern BC, for example, records a fault that extends over hundreds of kilometres. By contrast, the stresses that led to the creation of the Clearwater Valley appear to have tugged in two directions at once, creating a fishnet of crisscrossing faults. The result has been a zone of extension, where the middle portions of the valley have been pulled asunder and, at the same time, caused to drop almost 1000 metres relative to the adjacent land. This has created a pull-apart basin – a mini rift valley – which Hickson has christened "the Clearwater Depression."

The same pressures which initiated the Clearwater Depression apparently also thinned and weakened the earth's crust here. As a result, cracks have formed, and through these magma has pulsed to the surface, propelled in part by its own expanding gases. At the time of eruption, much of this magma had a thin, syrupy consistency; it flowed out across the Clearwater Valley, filling it layer by layer with hardening basalt. In time, some 25 cubic kilometres of basalt would be extruded, and the Clearwater Depression would be partially infilled, creating a rolling landscape now called the Murtle Plateau.

The eruptions, it should be stressed, did not happen all at once, but have continued intermittently over the past million years. The question is why: what has provided the trigger for this repeated volcanic activity. Could it have been a renewed stretching of the earth's crust? Or perhaps it was the increased alkalinity (and therefore lower melting point) of the later magmas? Or might it, again, have been the earth-rending weight of the Pleistocene glaciers?

This last possibility – the press of glaciers – is especially intriguing. Lying at the zone of contact between two very different landmasses, the Clearwater Valley would have been particularly susceptible to the stresses associated with ice loading. The thinner crust to the west would have downwarped much farther than the thicker continental crust to the east. If it is true that the press of up to two kilometres of glacial ice reactivated the old Wells Gray vents, then a kind of poetic justice resides in the fact that the resulting lava flows and other volcanic features have preserved evidence of the very ice which initiated them.

Whatever the truth of the matter, the fact is that the Pleistocene glaciers have been both a bane and a boon to our present understanding of Wells Gray's geologic past. A bane because they have eroded many of the earlier volcanic features, and buried much of what is left with a thick blanket of glacial till. Yet also a boon because, at the end of the Ice Age, here about 11,000 years ago, the meltwaters released by the retreating glaciers carved deep canyons into the lava, thereby opening a public archive to the underlying volcanism. Intercalated with the lava flows are the tills of no fewer than three glaciations – one of the most complete Pleistocene records in North America.

When the Clearwater Valley was set aside as a park 50 years ago in November 1939, no one, and certainly not the BC legislature, knew exactly why. Obviously it had something to do with the valley's narrow canyon, its 20 major waterfalls, and the Murtle Plateau: home of one of Canada's great moose herds. Until the arrival of geologists like Cathie Hickson, however, no one saw that all of these attractions owe their existence, directly or indirectly, to some 25 cubic kilometres of erupted basalt. It is the geologists who are finally bringing Wells Gray's tumultuous past into focus; and in doing so, they are winning for it a permanent place in the Canadian imagination. The valley of fire and ice.