The Creation
Monumentality and Place

the stories buried in the mountains
give out to the sea
and the sea remembers
and sings back
from the depths
where nothing is forgotten

DAVID WHYTE
Where Many Rivers Meet

Of all the terrestrial expressions of the changing nature of the earth's surface, mountains are the most dramatic. The hotter, molten rock of the interior mantle of the earth is less dense than the colder rock of the hardened crust above it. As it is less dense, the hot rock of the mantle rises. As it rises it cools, becomes denser. As it becomes dense it sinks. This continuous circulation of molten material creates huge currents in the earth's mantle, which in turn cause the great plates on the planet's crust to wander, a phenomenon known as continental drift.

Some of the world's most spectacular mountain ranges have been created by plate movement during continental drift. The Himalayas arose when the Indian subcontinent met Asia. The Andes were created when a down-going slab of oceanic crust melted and sent hot rock upward in a process called subduction. The hot rock then melted the overlying continental crust to send huge volcanic mountains skyward. While still very much a product of continental drift, the Canadian Rockies were formed in yet another way.

THE CONTINENT SHUDDERS AND MOUNTAINS ARE FORMED FROM COAST TO COAST TO COAST

North America has not always been where it is now. It moves slowly, jostling the other continents on its way across the spinning world. When the eastward-tending North American plate reversed direction about 200 million years ago, the oceanic crust off the west coast of the continent slid beneath it. Island arcs on the surface of the subducted oceanic plate rode up onto the advancing North American plate and were added to the continental land mass. This process is called accretion and the land masses added to a continent in this way are called terranes.

Over the past 200 million years, the North American continent acted as a wedge, peeling terranes from the underlying oceanic plate. As many as 50 different terranes have been added to the northwestern edge of North America through accretion, most from the southwest. Some terranes may have moved three to five thousand kilometres northward before being captured by our wandering continent.

The North American continent has grown wider over time. Much of British Columbia was not originally part of North America and arrived as an accumulation of terranes. This accumulation also caused horizontal compression of the sedimentary rock that already covered the surface of the North American plate. This horizontal compression created the mountains of Western Canada.

The first period of mountain building, known as the Columbian Orogeny, took place about 175 million years ago. Compression continued into the early Cretaceous, a period that began about 144 million years ago. The mountains of British Columbia kept piling upward and mountain-building advanced slowly eastward; 120 million years ago, the western ranges of the Rockies began to pile up too, and the main ranges began to rise. About 85 million years ago, North America "docked" with the massive Vancouver Island and Queen Charlotte terranes, causing the last major horizontal compression across Western Canada. It was this last great compression, the Laramide Orogeny, which created the

MOUNT KITCHENER, JASPER NATIONAL PARK
The Rockies have been carved by rivers and glaciers out of the thrust-up sediments of an ancient seafloor. Over time, a four hundred million year-old sea floor has been pushed three kilometres into the air. Now these mountains are being worn down and carried away into distant seas. The rocks of ages cycle like water but over much longer periods of time.
Photograph by R.W. Sandford.

foothills and front ranges of the Rockies. Thereafter, plates slid along the west coast of North America rather than ramming into it. Horizontal compression of this kind resulted in the deformed and thrust-faulted ocean sediments we now know as the Rocky Mountains.[1]

AS THEY GO UP, THEY COME DOWN

Even as the primordial mountain ranges of the West were being born, they came under the same multiple forces of erosion that created the sediments of which they were composed. The rising Rockies were worn away by the mechanical action of rain, running water, and the alternate freezing and thawing of frost and ice. Relatively soft sedimentary rock eroded, through the mechanical and chemical breakup of readily dissolvable minerals and through natural breakdown by plants. By the time the Rockies stopped rising, they were already hip-deep in their own debris.

If the geology of the Canadian Rockies could be summarized into a single brief statement it would be this: they have been carved by rivers and glaciers out of the thrust-up sediments of an ancient seafloor.

VERTICAL ARCHIPELAGOS

Regardless of how mountains are formed and later shaped, their most striking contemporary feature may be the fact that the conditions created by altitude and steep slopes organize life into what have been described as "vertical archipelagos" of biological and cultural diversity.

As the retreating ice revealed the scraped and torn surface of the land, plants and then animals followed the swollen rivers, reclaiming the scarred and empty valleys. Fish swam upstream to newly forming lakes; seeds fell on new soil created in the great grinding down of the rock of ages. In the lengthening summers lichens kissed bare rock into life. Glaciated landscapes were transformed by the miracle of the seed. In time, the white world of the glacial peaks turned brown, then green. Animals followed the upward advance of the plants. But not all life can be upwardly mobile, and there are limits to how high life can go.

Mountains are islands of uniquely adapted life forms surrounded by seas of lowlands. Plants and animals that inhabit these regions are not always able to cross hostile lowlands to reach other peaks. Isolation means that species develop quickly and, as a result, the mountainous places of the world are home to many unique and highly specialized plants and animals.

At altitudes where the trees thin out and then disappear into the cold, communities of extraordinarily adapted plants continue to assert themselves against the short seasons and the eternal frost. This narrow zone of life is called the alpine. It is the last bitter margin of life's upward march toward the cold stone of the peaks.

The toughness of alpine species notwithstanding, ours is a period of great biological disruption. The growing presence and expanding activities of humans have marked the beginning of a prolonged period of landscape change. To understand this change and why the Canadian Rocky Mountain Parks World Heritage Site is so important, we need to trace the circumstances of life on Earth through geological records preserved within the strata forming the mountains. In examining these strata we learn how the geological record has been defined by mass extinctions. In the process we are introduced to the most famous fossils and what they tell us about the progression of life through time and, finally, we arrive at recent time where we confront an established pattern of biological diminishment and loss that seems to characterize life on the planet since the end of the last ice age.

THE BURGESS SHALE
Trilobites are only one of the nearly 200 species of early life fossilized in this remarkable formation.
Photograph by R.W. Sandford.

THE SEA: WHERE NOTHING IS FORGOTTEN

In order to make it understandable, the planet's history has been broken down into periods of time that represent major changes in conditions. These periods are represented by different rock types and often distinguished by changes in the dominant life found as fossils within them. Today's geological time scale consists of huge blocks of time called eons. The eons are divided into eras; eras into periods and epochs – in much the same way we divide human time into years, days and hours.

As the Rockies are composed of marine limestone laid down during earlier periods in our planet's history, they tell us much about what has happened in the past. We don't have to go to the ocean floor to study evolution. In the Rocky Mountains the ocean has – very conveniently – come to us. To understand the direction life has taken, all one has to do is stand on a mountain peak in Yoho National Park and listen to what the seas say.

The Precambrian eon is the oldest and most difficult geological period to understand because most rock from this eon has been so much changed by heat and pressure that its age and origin are difficult to determine. This period begins with fossil forms that are as alien to what exists today as what we might expect to find on other planets. There are very few places on the planet where this history can be read. One of them is the Burgess Shale, which is located above Emerald Lake in Yoho National Park.

THE CAMBRIAN EXPLOSION AND THE MOST FAMOUS FOSSILS IN THE WORLD

We know from what the rocks say that over a period of only 5 million years, between 543 and 538 million years ago, the handful of animal body plans that existed at the time suddenly exploded from 4 to 38 different platforms upon which creation could build life. This rapid expansion in life forms is seen to be evidence of what is often referred to as the Cambrian Explosion. The Burgess Shale, the first World Heritage Site designated in the mountain West, is one of the best places on Earth to witness evidence of this explosion.

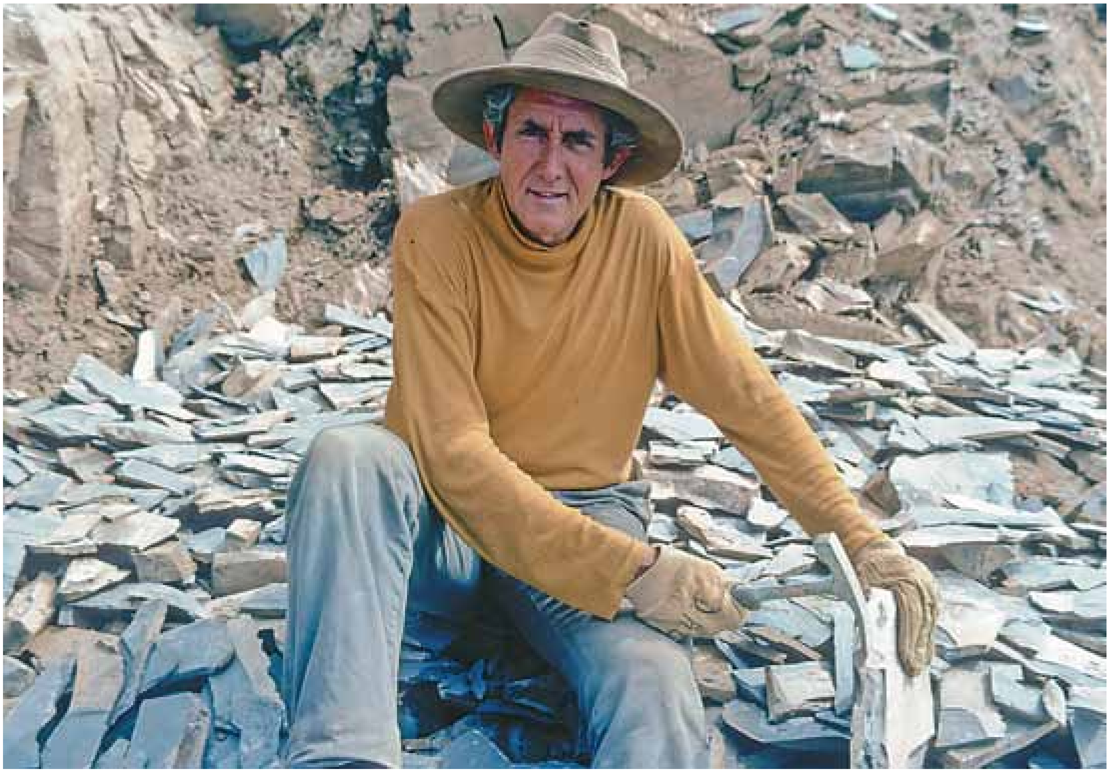
The first to understand the significance of the fossils in the Burgess Shale was Dr. Charles Doolittle Walcott, the Secretary of the Smithsonian Institution, who literally stumbled upon them during a visit to the Rockies in 1909. Between 1909 and 1911, Walcott collected and exported to Washington D.C. some 65,000 specimens from a quarry on the shoulder of Mount Field, representing some 170 species of plants and animals.

Over the next century, four generations of palaeontologists studied the nearly perfectly preserved creatures. One of the greatest of these was Desmond Collins, a palaeontologist from the Royal Ontario Museum. Dr. Collins and his colleagues and students mined the Burgess quarry for nearly 20 years. Based on his testimony on the value of this treasure trove to our understanding of Cambrian life, the Burgess Shale was nominated as a World Heritage Site.

For the first 20 years after the Burgess site was designated in 1981, everyone seemed satisfied that the rare creatures discovered there had been fully appreciated for what they told us about the evolution of life. Then in 2003, British palaeontologist Andrew Parker caused the Cambrian to explode all over again. Using an electron microscope to examine the fossil remains of particularly well-preserved Burgess fauna (*Wiwaxia, Canadia* and *Marrella*) Parker discovered the remnants of diffraction gradients. Their presence suggested to Parker that these animals were iridescent. If there was light and colour, Parker surmised, then animals could "see." The capacity to see meant the existence of an eye.

What Andrew Parker discovered was that the "Big Bang of Evolution" that took place between 544 and 543 million years ago apparently was the result of the new ability to see. The eye allowed the rise of a whole new kind of creature: the active rather than the passive predator. With the evolution of the predatory hunter, new defences were urgently required. "In the blink of an eye," armour was invented. The number of creatures with shells exploded and life filled all the seas in the Cambrian ocean.

The Burgess Shale is of inestimable value to us today because it is one of only a tiny number of places on our planet where fossils tell the tale of how nature turned the light switch on. These fossils represent a turning point in the history of life on Earth.



DR. DESMOND COLLINS
Since the discovery of this amazing fossil bed by the Secretary of the Smithsonian, Charles Doolittle Walcott in 1909, the Burgess Shale has attracted some of the world's leading paleontological researchers to the Rockies. Dr. Desmond Collins and his colleagues at the Royal Ontario Museum in Toronto affirmed to the world the importance of Yoho National Park through a series of important new discoveries in the 1970s and 1980s.
Photograph by R.W. Sandford.

With the rise of the eye, evolution got out of first gear. A new sense demanded adaptive strategies for prey seeking escape from animals with eyes. New musculature appeared. So did jaws, teeth and shells. The eye led to the rise of armament and ornament in nature. By way of evolution, adaptive colouration appeared in the world. In a world where animals could see, there was an explosion of new niches that life could fill. A broader food web came into existence, which led to creation of the first true ecosystems and to early animals with backbones: chordates like *Pikiai*. The chordates led to the first vertebrates, which led to us.

The eye caused a rapid advancement of evolution. In only a million years, the world was changed forever. Close your eyes. Keep them closed. Now open them. The world became ours the moment the first eye recognized light. That eye may have first opened above a seafloor that was since pushed three kilometres into the sky to form the Rocky Mountains.

THE NORTH SASKATCHEWAN RIVER
Because of their elevation, the Rocky Mountains play an important role in the hydrological cycle of the North American continent. Fed by rain and snow, rivers in the Canadian Rocky Mountain Parks World Heritage Site have been flowing without interruption for more than 10,000 years. As the glaciers in the Rockies continue to melt, however, that may change.
Photograph by R.W. Sandford.

THE BURGESS SHALE AND MASS EXTINCTIONS

Desmond Collins, who worked on the mysteries of the Burgess Shale fossils for much of his life, contended that one of the deeply disturbing lessons offered in our time by the Burgess record relates to the precariousness of life: existence is a gamble. Chance plays a huge role in determining what survives and what does not. "If you re-wound and replayed the video tape of time," he was fond of saying, "you might not get *Pikai* – and you might not get us."[2]

The Burgess Shale offers other sobering lessons on the history of earthly life. Its layers were laid down during a long period of stability. The geological time scale is founded upon the presence throughout history of such long periods of stability, followed by massive extinctions caused by horrific natural catastrophes. There are no guarantees against disasters from within or without. In other words, contingency is a fact of existence. During the past 570 million years, the span of time that hard-bodied creatures have lived on Earth, there have been as many as fifteen major periods of extinction. Five mass extinctions involved as many as half of the species then alive on Earth. Two major catastrophes were even more devastating.

The first extensive extinctions occurred about 245 million years ago at the close of the Paleozoic, or Age of Primitive Life. The end of the Permian Era is defined by something that caused more than 90 percent of species to vanish. Geologists examining the Permian-Triassic boundary have found an abundance of fossils that suddenly interface with a lifeless black mudstone, which upon analysis reveals a period during which there was little oxygen as billions of bodies decayed at the bottom of the sea.

Research has suggested that the catastrophe that caused the great Permian extinction was the explosion of a chain of Siberian volcanoes that introduced enough CO_2 into the atmosphere to heat the oceans sufficiently to force methane out of salt-water solution. The combined temporary impacts of increased atmospheric concentrations of these two gases may have caused a runaway greenhouse effect that eliminated much of life on Earth. Geologists are now able to model the extent of the temperature rise that brought about the loss of 95 percent of life on this planet. It is interesting to note that the sudden temperature rise that occurred in the Permian was on the order of about 6°C, which – interestingly enough – is about the upper limit at which the United Nations Intergovernmental Panel on Climate Change has projected for mean annual temperature rise if we do not curb greenhouse emissions in our time.[3]

Life on this planet underwent yet another cataclysm 180 million years later, at the end of the Cretaceous. In *The End of Evolution: On Mass Extinctions and the Preservation of Biodiversity,* geologist Peter Ward describes the scene.[4] An asteroid or the nucleus of a comet at least 10 kilometres across and travelling approximately 40,000 kilometres an hour approached the earth. Its huge velocity rammed a hole through the atmosphere. Moments later it slammed into the earth, causing an explosion more powerful than the detonation all of the modern world's nuclear weapons, creating a crater nearly 300 kilometres across. Rock in the impact zone, as well as the entire mass of the asteroid itself, blasted upward through the hole in the earth's atmosphere created by its entry. Some of this rocky debris was flung into orbit around the earth. The heavier material re-entered the atmosphere but fell back as blazing fireballs that set fire to many of the earth's forests. Over half of the vegetation on the planet burnt in the ensuing fires. Stratospheric winds carried the impact debris around the world. Debris and the smoke of the burning forests blocked out the sun for months. Shock heating of the atmosphere caused atmospheric oxygen and nitrogen to combine into nitrous oxide, which fell as poisonous acid rain. The acid concentration in the rain dissolved the calcareous shells of all the creatures in the upper 100 metres of the world's seas. After months of darkness, the "impact winter" gradually ended. But radical increases in the concentrations of carbon dioxide and water vapour in the atmosphere permanently altered the weather. No wonder the dinosaurs died.

We remain both fascinated and troubled by evidence of disasters of a planetary scale, with good reason. Scientists are concerned that a die-off could be occurring that might rival the impacts of the astronomical event that brought the Cretaceous to a close. Many experts believe that the period during which humans came to dominate the earth may mark a period of extinction in which more actual species disappear than during the two great die-offs of the Permian and Cretaceous periods combined. That dark view, however, supposes we don't do anything to slow or stop the massive extinctions we are causing.

What we have done as a society in the Rocky Mountains suggests other more positive possibilities. Hope for the future invites us to carefully examine the most recent periods in our planet's geological history and the earliest chapters of human presence on the North American continent, with the goal of determining what we might do in our time to slow this diminishment and loss and to allow current biodiversity to sustain us in the future.