3. The Geologic Foundation

The Story Behind the Landscape

If any one feature defines the Crown of the Continent, it is the mountains along the rugged ridge of the Continental Divide. Geology is the oldest, most fundamental story here, setting the stage for all stories to come. Events that occurred millions of years ago continue to control what goes on today.

The mountains of the Crown of the Continent divided aboriginal tribes of the region into cultures and subcultures. Geology dictated whether the Crown's early prospectors would find gold, coal, or oil. Geology left some mountain passes suited for railways and highways. The drama of the uplifted mountains prompted early conservationists to create Waterton Lakes and Glacier national parks and stalled the commercial development of areas like the Bob Marshall Wilderness. Today, geologic forces make some mountains suitable for ski resorts and leave some as rugged refuge for hibernating grizzly bears. The mountains split the ecosystem into a lush western half and a dry eastern half. The nutrients leached from bedrock to water dictate the life that can exist in the streams, rivers, and lakes of the Crown of the Continent. The rocks provided the basic building materials for the soils that determine the area's capability to support plant life. The ancient and dynamic history of sedimentation, uplift, and mountain building provide the basic physical framework for today's landscape. Underneath everything is the story of the stone.

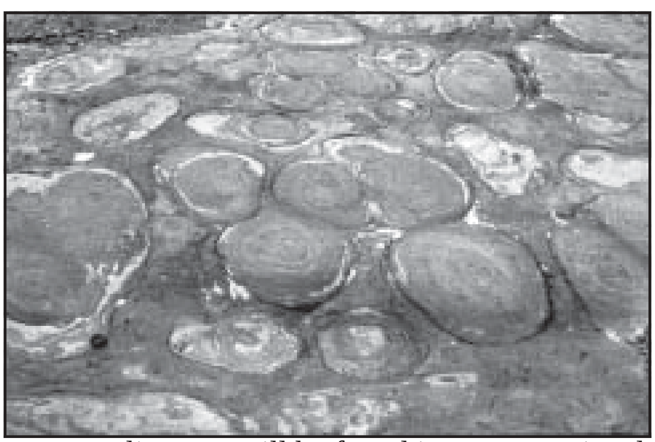
The Story in Stone

Rocks found throughout the Crown of the Continent, even on some of the highest peaks, have a wavy pattern on their flat surfaces. These are ancient ripple patterns

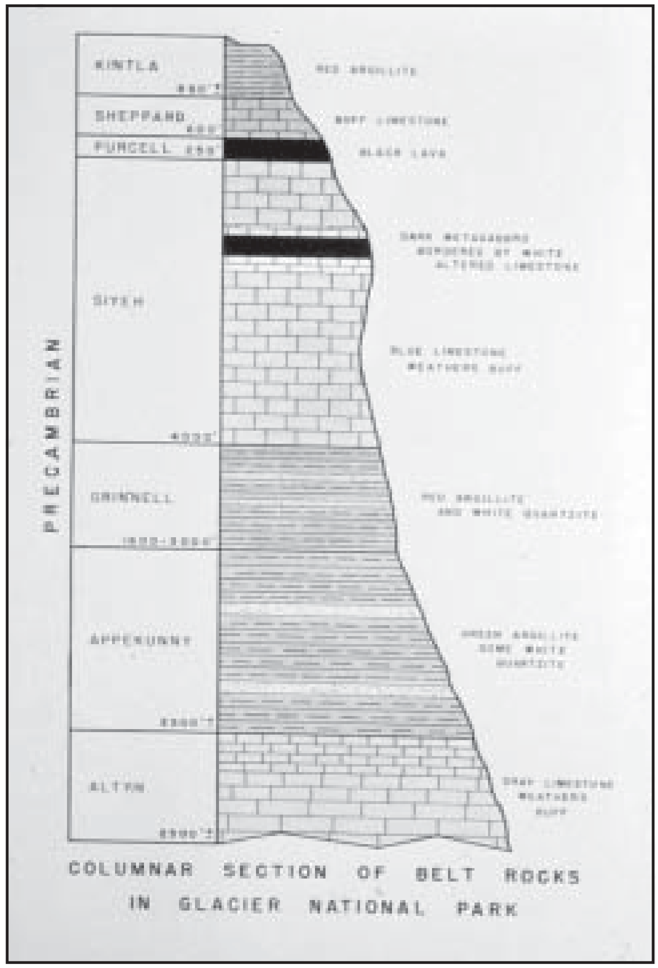
formed in currents hundreds of millions of years ago, when the rocks were soft sediments at the edges or bottom of a shallow sea. These and other clues reveal how this place used to be, long before there were mountains. Geologists and astronomers calculate Earth formed about 4.6 billion years ago, one of nine planets in our Solar System. For our story, imagine a time about 1.5 billion years ago, a long time ago in human standards, but relatively recent in the history of the planet.

Instead of mountains, imagine a huge basin, largely devoid of terrestrial life. This basin was roughly the size of Arizona and was comprised of rolling uplands surrounding a saltwater bay, somewhat similar to today's Gulf of Mexico. Rains fell from the sky and, because there were no land plants to hold back the soil, erosion of weathered rock material was dramatic. Water washed silt and sand from higher portions of the landscape into the shallow sea.

Sediments gradually filled the basin, stacking up like layers in a cake. Over hundreds of millions of years these layers hardened into rock, through compaction and deposition of mineral matter between the grains. Geologists call these sandstones, argillites, and limestones, depending on the particles that make up the rock. Geologists identify distinct layers of these ancient, hardened sediments that were deposited between 900 million and 1.5 billion years ago. Collectively, they are called the Belt/Purcell Supergroup. One fascinating feature in these layers are fossilized stromatolites, dome-shaped colonies of algae that lived in this sea hundreds of million years ago. (Living stromatolites can still be found in some restricted ocean coastal areas on earth.)



The rocks of the Belt/Purcell Supergroup total about 15,000 meters (50,000 feet) in thickness and are the foundation of the Crown of the Continent. These are the bands of rock

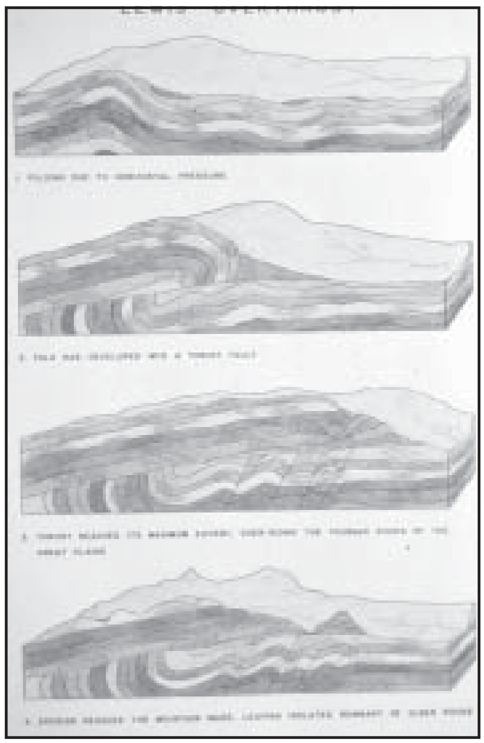


we see along the east front of Waterton and Glacier national parks. The most striking of these layers are the red and green argillites. These colors reflect the presence of a small amount of iron. The red rock appears when the iron combined with oxygen, the green when the iron combined with silicon.

After the Belt/Purcell sediments were deposited and consolidated, this region was a relatively shallow continental shelf, off the western shore of the still-developing North American continent.

During the Paleozoic Era (from 525-225 million years ago), ocean levels alternately rose and fell, leaving the land inundated or exposed. When the land was exposed, dense vegetation grew along the coast. These plants died and were covered in layers of sediment. Today, the Paleozoic layers are predominately limestones, sandstones, and shale. Some layers contain fossilized coral and clamlike shells. These limestones are particularly visible in high outcrops, called *reefs*, along the Rocky Mountain Front.

The layers of the Belt/Purcell formation are very old. In fact, they are among the oldest, best-preserved sedimentary rocks on earth. However, the mountains themselves are relative newcomers to this scene. The mountain building started in the Mesozoic Era.



All continents ride on tectonic plates. During the Mesozoic Era (225-65 million years ago), the North American Continent moved westward. During this era, the North American plate separated from the European plate. This separation formed the Atlantic Ocean.

Tectonic pressures began compressing the western margin of North America. For the next 100 million years, the western edge of North America buckled and was uplifted, accompanied by earthquakes and volcanic activity. The primary result was the creation of the Rocky Mountains, much in the same way as the active forces today are creating the South American Andes.

Sediment was eroded from those new, uplifted mountains and was deposited in lower elevations, both to the east and west. This eventually hardened into layers of sandstone, shale, and coal, which are visible today in many road cuts and stream channels east of the mountains. During much of this time, lowland portions east of the rising mountains were muddy swamps and peat bogs. The dense vegetation growing in these swamps was the source of some of the shallow coal fields found today in eastern Montana and Alberta. These layers of sediment also contain the remarkable fossilized dinosaur bones and eggs found in Montana and Alberta.

Some of the most dramatic mountain building occurred about 75 million years ago, all along the mountainous western margin of the continent. Compressive forces in the earth's crust moved great masses of rock, pushing the old "basement" rocks over much younger material. This formed what is known as the North American Overthrust Belt, which stretches from Alaska to the Yucatan Peninsula of Mexico.

Rock originating west of today's Flathead Valley moved as much as 60-70 kilometers (approximately 40 miles) to the east. One textbook example of this is the Lewis Overthrust, the evidence of which is clearly visible at Marias Pass and on the eastern side of Glacier and Waterton Lakes national parks. The lowermost layers of the stack of rocks immediately above the Lewis Overthrust Fault reveal some of the oldest exposed sedimentary rock in North America, at 1.5 billion years old. The fault zones tend to be more complex south of Marias Pass, where numerous thick sheets of rock have been piled one upon another like roof shingles. The mountains formed by this overthrusting process make up the Crown of the Continent. If any one geological structure defines the Crown of the Continent, it is probably the Lewis Overthrust and associated faults.

Beginning 40-50 million years ago, these forces ended. Due to changes occurring on the western edge of North America, the crust was stretched along major north-south fault lines. Portions of the high, mountainous landscape reacted by dropping to form the relatively broad valleys seen today. This faulting produced the Swan, Mission, and Flathead ranges and the extensive parallel valleys we see today. The most dramatic of these valleys is the Rocky Mountain Trench, the long valley that runs northerly from St. Ignatius to the Yukon. The Flathead Valley lies near the southern end of this major, down-dropped portion of the earth's crust. Many of these valleys now contain major rivers, such as the Kootenay, the Swan, and the three forks and main stem of the Flathead.

The landforms we see today were shaped much more recently, during the Pleistocene Period, starting roughly 2 million years ago. The great carver of this landscape was ice. During the Pleistocene, the global temperature dropped. About 30% of the earth's land surface, including much of North America and Europe, was covered in ice. As global temperatures fell and rose, ice advanced and retreated, producing glacial and interglacial periods. During the icy periods, only sporadic mountain peaks, called *nunataks*, were exposed above the frozen white expanse. Ice was thousands of meters thick over most valleys and hundreds of meters thick over most of the mountains.

During the Pleistocene, northern North America was covered in ice. This ice took two forms. Mountains were covered in "alpine" glaciers, while the lower elevations were covered in vast ice sheets called "continental" glaciers.

Central and eastern Canada, and the northeastern and north central United States, were covered by a continental glacier called the Laurentide Ice Sheet. The Laurentide Ice Sheet lapped up against the eastern edge of the Crown of the Continent.

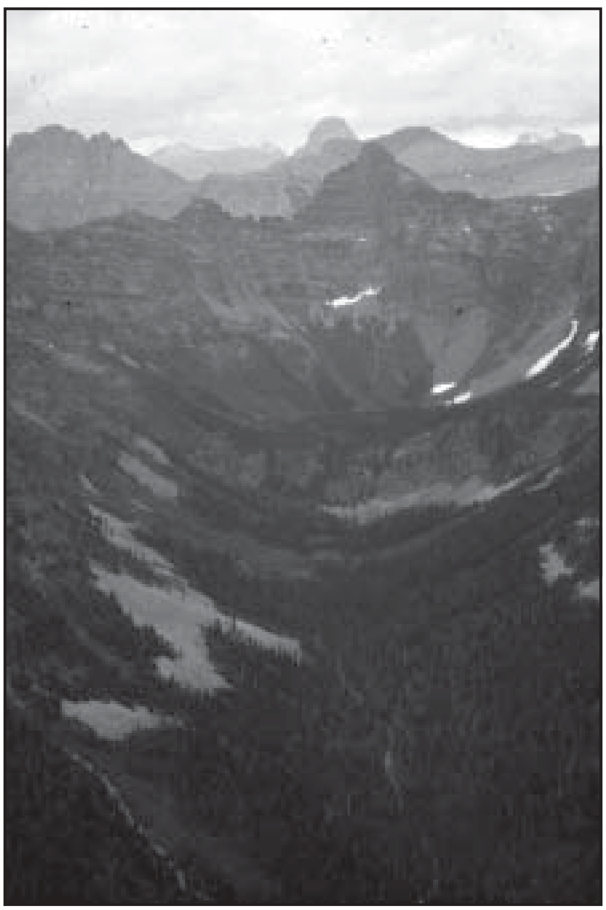
Meanwhile, the mountains of western North America were primarily covered by glaciers known as the Cordilleran Ice Sheet. In addition, smaller alpine glaciers formed fingers of ice which flowed along existing topography.

With so much of the earth's water locked up in ice, ocean levels dropped, connecting Siberia and Alaska by a strip of land called the Bering Land Bridge, or Beringia. Many scientists believe this land bridge allowed plant and animal species, including human beings, to pass back and forth between North America and Asia.

When gaps occurred between the Cordilleran and Laurentide glaciers, large mammals were able to migrate between Asia and North America. Late in the Pleistocene Ice Age, people probably also followed this route from Asia to North America, and eventually on to Central and South America. The last great ice sheet retreated about 10,000 years ago.

The classic features of the Crown of the Continent are chiefly the result of glacial erosion. As the ice retreated, it left behind a dramatic landscape formed by glacial sculpting of the underlying rock. The ice left behind such features as U-shaped valleys, knifelike ridges, hanging valleys, waterfalls, cirques, and steep cliffs. Ice also carved depressions that were filled with lakes such as Waterton, Cameron, Swiftcurrent, St. Mary, and Two Medicine.

Along with erosion comes deposition. While erosion, the removal of rock, occurs in portions of an area, deposition of that rock occurs in another, typically lower, area. That is, rock eroded from one place is deposited someplace else.



Where the glaciers deposited loose rock, it formed features such as lateral and terminal moraines. Terminal moraines are essentially the debris (called *till*) left at the toe of a glacier, while lateral moraines are left along the sides of a glacier. Prominent examples of lateral moraines are Snyder and Howe ridges, alongside the length of Lake McDonald. Terminal moraines often serve as natural dams that retain lakes. For example, the moraine near Polson is the southern boundary for Flathead Lake. Similar terminal moraines dammed McDonald, Kintla, and Bowman lakes.

The east side prairies of the Crown of the Continent are pockmarked with kettle lakes and gravel deposits which were formed by the deposition from continental glaciers.

Perhaps a more apt name for Glacier National Park would be Glaciated National Park. Eventually, the glaciers of the Pleistocene disappeared altogether. It’s a common misconception that the thirty or so small glaciers in the high country today are remnants of the great ice fields that carved this land. Rather, today’s mini-glaciers date from a recent cool period, the Little Ice Age, which began about 1200 A.D. These glaciers reached their maximum extent late in the nineteenth century and have been retreating ever since.

Not all the Crown of the Continent’s

landforms were created by glaciation. While the role of glacial ice is crucial to understanding the present topography of the Crown, running water is universally the most important agent of erosion. Water deposits sediment along rivers and in lakes, eventually carrying it to the oceans. Running water creates another important example of deposition called an *alluvial fan*. Alluvial fans are created when sediment is washed off a steep slope and is deposited on more level terrain. These depositions form a fan-shaped bed of gravels, fine sediments, and even organic materials that create favorable conditions for plants and wildlife.

Blakiston Fan is an example of a large alluvial fan. The large, open, flat area on the east end of St. Mary Lake is also an alluvial fan, deposited by Divide Creek, and is important winter range for deer and elk. Similar alluvial fans are found throughout the Crown of the Continent. In fact, Waterton townsite itself sits on a large alluvial fan formed by Cameron Creek.

Even after the Pleistocene, geologic events continued to have tremendous repercussions for the Crown of the Continent. Coastal volcanoes of the Cascade Range erupted, coating portions of the region with layers of rock fine rock called *loess*. One of the most noted of these explosions was the eruption of Mt. Mazama, in what is now Oregon. This mountain blew its top 6,600 years ago, in an explosion that dwarfed the Mt. St. Helens explosion of 1980. Such ash is an important ingredient in the soil that allowed trees to take root, leading to the coniferous forests of today.

The Crown remains a very active landscape, where weathering and erosion occur at a brisk pace. Earthquakes are signs of continuing mountain building and movement in the earth's crust. Streams are steep and can move huge amounts of soil and rock, particularly during spring runoff. Even seemingly solid rock faces gradually crumble in a constant pattern of freezing and thawing. Sometimes, massive amounts of earth move literally overnight. In 1992, a large slab of rock separated from the northeast face of Chief Mountain. Columbia Mountain, on the east side of the Flathead Valley, is another site of a large, post-glacial landslide. Another is the Frank Slide, northwest of Waterton Lakes National Park, where in 1903, a huge portion of Turtle Mountain collapsed and buried the mining town of Frank. Major landslides are fairly common occurrences in the Crown, although none since have proven so deadly.

Soil: Icing on the (Layer) Cake

Soil is a crucial asset for plant life and therefore the entire terrestrial food chain. That

thin, but all-important, layer of soil is the product of a combination of physical, chemical, and biological processes. Along with climatic characteristics, these dictate the kind of vegetation a place can support.

Only the upper several inches of soil contain much in the way of organic matter. The major portion of any soil is composed of the small mineral or rock fragments that result from the breakdown of the underlying parent rocks.

Five factors determine what kind of soil an area supports: climate, parent material, living organisms, topography, and time. Soil-building processes occur all around us, all the time. Because of cool temperatures, lack of available water, and steep slopes, soils on the Crown of the Continent tend to be immature or poorly developed. Much of the alpine environment is devoid of soil altogether and is comprised of bare rock.

Overall, the Crown of the Continent has lots of rock, but relatively little soil. Soils are deepest and most fertile in low, flat valleys. Periodic floods deposit very fine sediments over these flatlands, leaving fertile soils behind. The warmer valley microclimates and lack of downslope movement provide the best conditions for soils to develop.

Places like the Creston area in the Flathead Valley, while limited, are the best locations for farming because of deep, easily cultivated soils, adequate water, and a favorable climate. Subsequently, these areas are where towns and cities have developed. Conversely, areas with the harshest, driest climates and poorest soils tend to be uninhabited.

While spans of geologic time are so immense they defy the imagination, evidence of ancient geologic forces is all around us today.

Paleontology on the East Front of the Rockies

In the foothills of the Continental Divide, from southern Alberta south into Montana, lies one of the richest treasure troves of dinosaur paleontology. Meltwater from retreating glaciers of the last ice age stripped away younger sedimentary layers, exposing the Upper Cretaceous rocks on the east front of the Rocky Mountains. These rocks record sediment deposited in an ancient floodplain environment that existed in Alberta and Montana from about 80 to 75 million years ago.

The Cretaceous Landscape

During the final phase of the dinosaur era, a vast floodplain opened between the Rocky Mountains to the west and an inland sea to the east. The Western Interior Seaway extended from the Gulf of Mexico to the Arctic, splitting North America into a western and eastern land mass. Sea levels rose as the ice caps melted, and the climate grew warm and temperate. Close to the mountains, a rain shadow effect resulted in a more seasonal wet and dry climate compared to coastal areas 150 miles to the east. When the rains came, flooding rivers carried vast amounts of sediments shed from the mountains and deposited it on the floodplain. In Montana, repeated eruption of one of the largest volcanic centers that ever existed on earth, the Elkhorn Mountains volcanic field, contributed voluminous amounts of ash and volcanic debris to the floodplain sediments.

Dinosaur Habitats

The rocks that record this deposition on the floodplain are known as the Two Medicine Formation in Montana. The same rocks in Alberta are called the Old Man Formation. Both represent an ecosystem that supported diverse and abundant dinosaur groups towards the end of the dinosaur era. These include various duckbill dinosaurs, large tyrannosaurs such as *Albertosaurus,* and horned dinosaurs similar to Triceratops. Although notable for its abundant dinosaurs, the two formations are perhaps most famous for their fossil eggs and dinosaur embryos.

Egg Mountain, Montana

Juvenile duckbill dinosaurs were discovered in the badlands west of Choteau, Montana in 1978. In the years that followed, crews lead by Jack Horner of the Museum of the Rockies in Bozeman found the first dinosaur eggs in North America and the first dinosaur embryos in the world at this site called the Willow Creek Anticline. A small, inconspicuous hill in this area, known as Egg Mountain, has produced a wealth of information about dinosaur nesting and biology. The eggs belong to a small carnivore called Troodon, a dinosaur considered by many to represent the closest relative of modern birds. Eggs and nests of the duckbill dinosaur, Maiasaura, and abundant skeletal remains of a previously unknown plant-eating dinosaur named Orodromeus also occur within the two-square-mile area of the Willow Creek Anticline.

Devils Coulee, Alberta

A trident-shaped drainage system feeding the Milk River in southwestern Alberta provides this fossil egg locality its name. Devil's Coulee was the first dinosaur nesting site discovered in Canada. In 1987, a crew from the Royal Tyrell Museum of Palaeontology found a nest containing beautifully preserved eggs with embryonic skeletons of duckbill dinosaurs. Bones from this site range from embryo to nestling size and provide information on possible herding behavior, dinosaur growth rates, and nesting biology. Other fossils collected from the locality include two new mammals, a new bird, turtles, and amphibians.

Fossil Resources

In Alberta, as elsewhere in Canada, paleontological resources belong to the public trust and are protected and conserved under the Alberta Historical Resources Act. This law applies equally to private and public lands. In contrast, fossil protection pertains only to specimens discovered on state and federal land in the United States. The increasing commercial pressure and monetary value placed on dinosaur fossils represents a significant concern to paleontologists internationally. Educational access for future generations and potential loss of scientific information is of growing concern and represents a significant threat to the Crown of the Continent's fossil resources.

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Bozeman, Montana

Geologic Time Scale
for the Crown of the Continent

Era		Time	Summary of Geologic Events in the Crown of the Continent
Precambrian		4800 m.y.*	Earth and other planets formed as solar system.
		4800 m.y.	Oldest known rocks on earth.
		3500 m.y.	Oldest evidence of life found in rocks - single-celled organisms.
		800-1200 m.y.	Possible breakup of ancient continent - Belt/Purcell rocks begin traveling to present locations in the U.S./Siberia/Australia.
Paleozoic		300-400 m.y.	Deposition of limestone found in North Fork and Sawtooth Range.
		300 m.y.	North America/Europe/Africa/South America come together to form Pangea. Formation of Appalachian mountains as suture zone. Major biological extinction.
Mesozoic		125-150 m.y.	Breakup of Pangea - Westward drift to North America. Mountain building activity (orogenesis) begins along entire western margin of North America from Alaska to Mexico. Accretion of exotic terrains along western edge.
		100 m.y.	Uplift of broad region of Western Montana, British Columbia and Alberta. Folding, faulting, mountain building and volcanic activity. Inland Sea exists north-south from Gulf of Mexico. Deposition of sandstone and shale found east of the Rocky Mountains. Abundant marine life forms - dinosaurs.
Cenozoic	Tertiary	50 m.y.	Sliding of upper slab of rock west to east. Extinction of dinosaurs and much other life. Completion of “sliding” (overthrusting) of thick slabs of rock (5-10 miles thick) as much as 50-60 miles from west to east to form surface rocks for present northwest Montana.
		20-40 m.y.	Crust pulled apart and crustal blocks dropped down to form major valleys. Deposition of sediments into down-dropping valleys - Kishenehn Formation (North Fork, Middle Fork, etc. - modern fish fossils).
	Quaternary	2-3 m.y.	Alternate advance and retreat of glaciers. Glaciers cover mountanous areas, carve alpine glacial features, spill onto plains to the east and into major valleys in the west, deposit rock material (glacial till) as moraines, drumlins, etc. Meltwater rivers deposit outwash materials. Winds carry sand and form dunes. Human occupation of North America.
		Present	Rivers rework and deposit glacial materials as sand and gravels in major valleys. Landslides occur along valley margins.
		Future	???

* Million years before the present.

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