Geology of the Canadian Rockies and Columbia Mountains

Notes on lecture by Ben Gadd

1. Basic geological history of western Canada

First phase: deposition of most of the rock. About 1.7 billion years ago, part of what is now North America was imbedded in a supercontinent called "Columbia." At about this time, the oldest sedimentary rock in the Rockies was deposited in an inland sea on Columbia. This rock is mostly argillite—very hard mud—and it is now found at the northern end of the Rockies. It is not found in the Columbia Mountains (no relation to Columbia, the supercontinent) or the other ranges immediately west of the Rockies farther north—the Ominecas and the Cassiars—which otherwise have a history rather like that of the Columbia Mountains.

Columbia broke up about 200 million years later, and while North America was drifting free some 1.5 billion years ago a second batch of ancient argillite was deposited in another inland sea, this time at the southern end of the Canadian Rockies (in the Waterton area) and to the west in what are now the Purcell Mountains. These are the oldest sedimentary layers in the Columbia Mountains. I think of these layers, plus the Columbian-supercontinent rock at the northern end of the Rockies, as western Canada's **ancient sediments.**

The fragments of Columbia had drifted back together by 1.0 billion to become the supercontinent of Rodinia. But by 800 million years ago Rodinia was splitting up. One of the pull-apart zones lay pretty much where the Rockies and Columbias are now, and a lot of coarse sedimentary rock—mostly gritstone, sandstone and shale—was deposited in it. I think of this next great rock unit as the **old clastic unit.** ("Clastic" just means rock made of particles eroded from one place and transported to another by water, gravity, glacial ice or wind.) The world was undergoing its greatest ice age during this time, with all the continents covered by glaciers, so some of these deposits are glacial.

Over the next 625 million years North America drifted slowly southeastward. As the great ice age ended, the glaciers melted and sea level rose. By 513 million years ago the shore had moved thousands of kilometres inland, and the Rockies/Columbias area became a continental shelf under shallow seawater. This shelf was like the Grand Banks of Newfoundland, but it was on the western side of North America instead of the eastern side, and it was much wider. A lot of limestone, dolomite (similar to limestone but with magnesium in it as well as calcium) and shale were deposited on the shelf. I think of this next great layer as the **middle carbonate unit.** ("Carbonate" refers to CO_3, the chemist's "carbonate ion," found in both limestone and dolomite.) Carbonate rock forms in place mainly from accumulation and intergrowth of tiny lime crystals produced inside cyanobacteria, also known as "blue-green algae."

Meanwhile the world's continents were slowly drifting together to form yet another supercontinent: Pangea. Pangea was fully assembled by 300 million years ago. It straddled the equator and was home to the dinosaurs.

Second phase: mountain-building. Around 210 million years ago Pangea began to break up. The Atlantic Ocean opened. North America reversed its direction of drift and began to move northwestward, over-riding the denser rock making up the floor of the Pacific Ocean, which was moving northeastward. The oceanic floor had large chains of islands riding on it, most of them made of relatively light volcanic rock. Rather than slipping under the edge of the continent, the islands stuck themselves onto North America. Much of western British Columbia is made up of these "terranes." The force of the collisions built the mountains of western Canada, beginning with the Columbias, the

Ominecas and the Cassiars at about 180 million. The Rockies are the easternmost, youngest part, above sea level by 100 million. (The Coast Mountains, like all the mountain ranges west of the Columbias, Ominecas and Cassiars, are on the terranes and thus younger.)

Out in front of the growing Rockies, along their eastern edge, lay a long, shallow seaway that connected the Gulf of Mexico to the Arctic Ocean. Coarse sediment—mostly sand and gravel— eroded from the Rockies, Columbias, Ominecas and Cassiars eastward was carried into the seaway by rivers. Later on, these deposits were themselves caught in the mountain-building as it kept working its way northeastward. They became the rest of the rock in the Rockies, an upper and last great layer I think of as the **young clastic unit.**

By 60 million years ago the mountain-building period was winding down. At 55 million, compression was replaced by stretching and San-Andreas-style faulting. The result was the Rocky Mountain Trench. This long valley now divides the Rockies on the eastern side of the trench from the Columbias, the Ominecas and the Cassiars on the western side. Were it not for the Rocky Mountain Trench, the entire region would still be one continuous mountain range.

2. Key concepts of Canadian Rockies and Columbia Mountains geology

Here are the three main things to keep in mind about this great mountain region:

1. Old rock. Overlying the basement (the ancient metamorphic rock of our continent, 2.8 billion years old and buried deep beneath Jasper and Banff but exposed farther west in the Columbia Mountains), are the four great sedimentary layers of the Rockies and Columbias: the ancient sediments (age 1200–1700 million, thickness 9 km), the old clastic unit (age 513–780 million, thickness 9 km), the middle carbonate unit (251–513 million, 6.5 km) and the young clastic unit (1.8–251 million, 5 km).

2. Middle-aged mountains. A simple analogy for mountain-building in western Canada is to imagine a rug lying on a hardwood floor. If you push on one side of the rug, it wrinkles up. The wrinkles represent mountain ranges.

Imagine that the flat-lying sedimentary rock of western Canada is the rug, and the underlying gneiss ("nice") of the continental plate—the metamorphic basement rock, visible at the surface in eastern Canada as the Canadian Shield—is the hardwood floor. Shoved northeastward by terrane collisions, the rug-like sedimentary layer slides along over the floor-like basement. The sedimentary layer wrinkles into folds. In places it breaks ("faults"), and thick slabs of rock many kilometres in size slide up and over one another, a process known as **thrust-faulting.** The basement under the Rockies is generally not folded or thrust-faulted. Under the Columbia Mountains it is.

The Columbia Mountains and the Rockies were built from west to east, beginning about 180 million years ago in the western Columbias and ending about 60 million years ago in the eastern foothills of the Rockies. The basement was upthrust extensively in the Columbia Mountains. You see the gneiss along the Trans-Canada Highway around Revelstoke, for example, and along Highway 5 southwest of Valemount. But in the Rockies the basement is exposed at the surface only at a few spots along the Rocky Mountain Trench. In the Columbia Mountains you also find younger gneiss and granite produced during the plate collision.

In contrast, within the American Rockies large areas of basement gneiss and granite moved upward along thrust faults, carrying the overlying sedimentary rock up with them. These sediments were stripped away by erosion, leaving the granite and gneiss exposed. This is what you see in the Rockies of Colorado, for example. Another difference is that the American Rockies were built twice: once from 325 million to 280 million (the ancestral Rockies, worn down flat) and again to form the modern Rockies from 90 million to the present. But the essential mountain-building mechanism—terrane collision—was similar.

The three main east-west divisions of the central Canadian Rockies, meaning the section between Crowsnest Pass and the Peace River, correspond roughly to the distribution of three of the four great layers: the old clastics are found mostly in the main ranges, above sea level by 100 million; the middle carbonates are found mostly in the front ranges, present by 75 million; and the young clastics are found mostly in the foothills, present by 70 million. North of the Peace River, the ancient sediments are found at the far northern end of the Canadian Rockies. The ancient sediments also form the southern end, in the Waterton area and along the eastern wall of the Rocky Mountain Trench south of Radium.

The Columbia Mountains have four sub-ranges: Cariboos, Monashees, Selkirks and Purcells. The Cariboos are nearly all old-clastic-unit rock. Basement rock makes up the northern part of the Monashees, while the old clastic unit makes up most of the southern part. The Selkirks have a lot of young-granite areas, plus some middle carbonates in the northern part. Ancient-sediments rock and the old clastic unit make up much of the Purcells, plus some young granite areas with impressive spire-like peaks such as the Bugaboos. What you don't see in the Columbia Mountains are the young clastics. The Rocky Mountain Trench, though, is filled with them.

Mountain-building in the Rockies and neighboring ranges was mostly finished by 60 million, but block faulting (this occurs when land is stretched) and sideways slippage still continue today west of the Rockies.

3. Young landscape. It is unlikely that the Columbias and the Rockies once reached Himalayan heights, but they might have stood six kilometres above sea level. It's important to understand that erosion occurred during mountain-building as well as after. (The rate of mountain-building must exceed the rate of erosion, or no mountains will be built, right?) In all, a thickness of up to 10 km of rock has been eroded away in the region during and after its 125 million years of mountain-building activity. So the landscape we see now—the positions of the ridges and the valleys, the heights of the peaks, the depths of the valleys—is quite different than it was 60 million years ago. At that time the area probably resembled today's Tibet: a huge, hilly highland elevated three or four kilometres above sea level.

The modern landscape developed through **differential erosion.** The rock lay in parallel bands of hard and soft layers. The soft layers were worn down more quickly than the hard layers. So the hard layers became the ridges, and the soft layers became the valleys. The valleys deepened faster than the ridges could be eroded, producing greater topographic relief (elevation difference between ridges and valleys) and more ruggedness as time went by.

Today's landscape is glacial, carved during the worldwide ice advances of the last 1.8 million years. The most recent major glacial-sculpting episode began about 25,000 years ago and ended about 14,000 years ago. That's not very far in the past, when you consider the great lengths of time we have been considering. In geological terms, this is a very young landscape.

A minor glacial advance called the "Little Ice Age" began about A.D. 1200 and reached its maximum in the mid-1840s, building the fresh-looking moraines seen at higher elevations all over the Rockies and Columbias today. Another minor advance should be occurring now, but global warming from rapidly increasing levels of CO_2 in the atmosphere (main cause: burning of fossil fuels) is rapidly melting the glaciers of the Rockies and the Columbias.

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