MONTANA GEOLOGY

Montana Centennial 1889·1989

"FROM THE MOUNTAINS TO THE PRAIRIES"
Rocky Mountain front near Augusta—George Wuerthner

January

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Layers of Sediment Shuffled Like Cards . . .

The Rocky Mountain Front*

From the general vicinity of Helena north through Montana and on for many hundreds of miles into Canada, the front of the Rocky Mountains rises like a wall, abruptly ending the long westerly sweep of the high plains. That high mountain barrier separates two geographic regions as unlike in their geologic foundations as their differing landscapes suggest. The geologic boundary between the regions lies a few miles east of the mountain front, between it and the lines of highways 287 and 89 through Wolf Creek, Augusta, Choteau, Dupuyer and Browning.

Layers of rock exposed in roadcuts and stream banks in the high plains east of those highways lie almost flat. They are sedimentary rocks that originally accumulated as layers of sand and mud on the floor of a shallow sea. Eastern Montana, as well as much of the central region of North America, were under a few hundred feet of salt water while the Rocky Mountains were forming to the west—between about 150 and 50 million years ago. The events that made the mountains left the rocks beneath the plains virtually undisturbed, so their layers lie as flat today as they did when they were originally laid down.

Layers of sedimentary rock exposed in the towering cliffs of the Sawtooth Range west of the mountain front are much older than those to the east. They accumulated as sediments in shallow seas that flooded the region off and on for hundreds of millions of years as the continent slowly rose and fell above and below sea level. They were already ancient rocks long before the geologic events that built the Rocky Mountains shuffled their layers as though they were cards in a fast game.

The narrow zone between the actual mountain front and the geologic boundary a few miles east of it contains rocks like those beneath the plains to the east, shuffled like those in the mountains to the west. Those rocks are much softer than the older ones in the mountains, so they don't stand up against the processes of erosion to make mountains.

Visitors to the Bob Marshall Wilderness Area in the Sawtooth Range soon notice that the landscape there consists essentially of a series of long and remarkably straight ridges and valleys. They run on for mile after undeviating mile, consistently trending in a generally north-south direction. Each long ridge and each valley follows the outcrop of the upturned edge of a formation of sedimentary rocks. The valleys trace the outcrops of the softer formations which are now scooped out by erosion and the ridges are the outcrops of the harder rock formations that resist erosion. The layered rock formations in the Sawtooth Range are stacked as though they were a row of books standing on edge on the floor and then shoved slightly so they all tilt steeply downward to the west.

Landscapes consisting of long, straight ridges and valleys are fairly common and develop wherever erosion attacks a tilted sequence of hard and soft sedimentary formations. However, the rocks in the Sawtooth Range are extraordinary in that the layers are often stacked in an unusual order.

Geologists very carefully observe and measure the sequences of layered sedimentary rocks they work with so they can recognize the individual formations wherever they see them. Each rock formation is distinctive enough to make that possible, and they generally occur stacked on top of each other like the layers in a cake in the same predictable order. Geologists expect to find the oldest rock formations at the bottom of the pile, because they were deposited first, with the youngest ones on top.

The Madison limestone, for example, is a thick section of layered sedimentary rock that people who travel in the western half of Montana see fairly regularly because it so often makes high ridges and bold cliffs. It exists in eastern Montana too, but there it lies buried beneath several thousand feet of younger rocks well hidden from everyone not in the business of drilling oil wells. The Madison limestone usually outcrops as big masses of very pale gray or white rock which are often streaked with bold splashes of red. The high cliffs of pale gray rock that form the eastern front of the Sawtooth Range are composed largely of Madison limestone.

One of the best ways to see the unusual arrangement of rock layers in the Sawtooth Range is to drive west from Augusta through the Sun River Canyon to Gibson Dam. The road enters the mountains through a narrow gorge the river has cut through the Madison limestone. Then it passes across a valley eroded into some softer rock formations that lie on top of the Madison limestone. The road then passes through another narrow gorge cut through still another ridge of Madison limestone! And then another! And another! Four ridges of Madison limestone occur between the mountain front and Gibson Dam. The road likewise passes through the softer formations above the Madison limestone over and over again.

The U.S. Geological Survey has worked for years in the Sun River Canyon area, patiently unraveling the rocks there outcrop by outcrop. Their work showed that the four ridges of Madison limestone and the associated formations that make the valleys are actually four big slabs of the same section of rocks laid on top of each other and slightly overlapping like shingles on a roof. Exactly the same kind of structure continues for many miles west of the dam and beyond the end of the road, except that the Madison limestone finally disappears and layers of older rocks form the ridges. In fact, the layers of rock get progressively older to the west, and they continue to lie on top of, and overlap, the slabs of younger rocks to the east. That is exactly the reverse of the usual order—the younger rocks should lie on top of the older ones, in the same order in which they formed.

So there are two major questions: how did slab after slab of the same formation get stacked on top of each other and how did the slabs of the older formations wind up on top of the younger ones? Geologists can't answer those questions as definitely as they would like to, but they do have some interesting theories.

Before the Rocky Mountains began to form, those layers of rock that now make the Sawtooth Range must have been stacked in their proper order some place tens of miles west of where they are today. And the rock layers must have lain flat, just as they do beneath the plains today. Imagine them as a sort of giant layer cake with soft icing between the layers representing the softer rock formations. The problem is how to shuffle that flat stack into the complicated arrangement we see today.

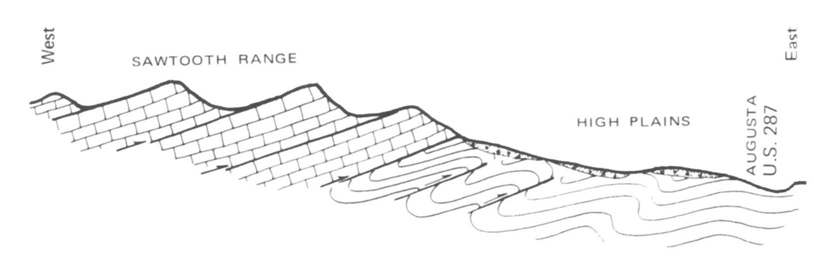
Formation of the Rocky Mountains involved a complex set of events, one of which raised the western edge of the continent so that it tilted very gently downward to the east. When that happened, the uppermost and youngest sedimentary formations began to slide eastward, gliding on the softer formations within the stack just as the layers in cake will slide on the icing between them if it is tilted. As the layers of rock slowly slid eastward, they broke into great slabs which continued to slide eastward. No one knows how fast they moved but most geologists assume that the entire process must have taken some several million years. If so, then the rate of movement would have been almost imperceptibly slow.

The slowly gliding slabs of rock reached the eastern limit of their movement where the front range is now and piled up there, slab after slab, to make a new stack of sedimentary formations. Several slabs of the same formation stacked on top of each other, thus explaining the multiple ridges of the same rock unit. As each successively older layer of rock peeled off the original stack to the west and slid eastward, it piled onto those that had arrived earlier. That explains why the rocks get older to the west. And since the youngest rocks moved first and the older ones slid in on top of them, we now have a stack with the youngest layers on the bottom and the oldest on top. Therefore, the present arrangement reflects the sequence in which the formations slid eastward into the positions where we now find them, which is the reverse of the sequence in which they originally accumulated.

Geologists use the term *overthrust faulting* to refer to the kind of movement that slides an older rock formation over a younger one along the surface of their layering. The geologists who have worked in the Sawtooth Range have found dozens of such faults, which explains why the formations appear in ridge after ridge and why they are stacked in the wrong sequence. That is why the ranges along the mountain front are referred to as the *overthrust belt.*

Until recently the term *overthrust belt* was just another item of jargon among geologists and hardly a subject for street-corner conversation. But the energy shortage has now made the term a household word in Montana, because the *overthrust belt* is a potential source of new oil and gas deposits. A few of those may lie within the great slabs of old rock that slid eastward, but the most promising prospects are in the younger rocks that undoubtedly lie buried beneath them—rocks like those beneath the great plains to the east, which are already producing oil and gas.

The complex arrangement of the rocks in the *overthrust belt* will make it difficult to find those new oil and gas reservoirs, if they exist. Developing them would be very expensive too, because it would entail drilling through the slabs of older rock in the mountains to get into the younger and more promising rocks beneath. It will also become very important to figure out exactly how far east the sliding slabs actually moved, because that will determine how far west potentially productive rocks lie buried beneath the mountains.



West-east cross section from the Sawtooth Range across the High Plains to U.S. 287 at Augusta. Large slices of Paleozoic sedimentary rock slid eastward and stacked on top of one another to form the ridges of the Sawtooth Range.

***Reproduced from Profiles of Montana geology by David D. Alt, Montana Bureau of Mines and Geology Special Publication 89, 1984.**

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Charter, Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a public service agency and research entity of the Montana College of Mineral Science and Technology. The Bureau Director serves as the State Geologist and represents Montana in the Association of American State Geologists.

Enacted by Legislative Assembly of the State of Montana (Section 75-607, R.C.M., 1947, Amended), the scope and duties of the agency are summarized as follows:

- To collect, compile, and publish information on Montana's geology, mining, milling, and smelting operations, and ground-water resources.
- To maintain collections of geologic and mineral specimens, photographs, models, and drawings of mining and milling equipment, and literature on geology, mining, and ground water.
- To conduct investigations of Montana geology, emphasizing economic mineral resources and ground-water quality and quantity.

In accordance with the enabling act, the MBMG conducts research and provides information, but has no regulatory functions. To carry out its duties most effectively, the Bureau operates in five divisions: Geology and Mineral Resources, Hydrology, Administration, Analytical and Information Services.

Selected Publications on Montana Geology

Bulletin 126—Directory of Montana mining enterprises for 1986, compiled by D. C. Lawson, *with a section on* the Sapphire deposits of Montana, Lester Zeihen, 1987, 56 p., 7 figs., 1 table, 1 appendix, 1 sheet. $3.00

Special Publication 89—Profiles of Montana: A layman's guide to the treasure state, David D. Alt, 1984, 168 p., 180 figs. $12.00

Special Publication 94—Belt Supergroup: A guide to Proterozoic rocks of western Montana and adjacent areas, Sheila M. Roberts *(ed.)*, 1986, 311 p., 175 figs., 11 tables, 10 color plates. $25.00

Special Publication 95—Guidebook of the Helena area, west-central Montana, compiled by Richard B. Berg and Ray H. Breuninger, 1987, 64 p., 20 figs., 1 table. $5.00

Reprint 6—Gold placers of Montana (2nd edition, *revised*), Charles J. Lyden, 1987, 120 p., 23 figs., 22 maps. $10.00

Open-File Report 191—Iron and iron bacteria in Montana ground water, Joseph J. Donovan, 1987, 28 p., 4 figs., 6 tables, 1 appendix. . . $5.00

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