Geology of the Bonner Area with Bruce Baty

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https://www.youtube.com/watch?v=7XUODEpbK1w

(This program has been edited for clarity.)

First stop: at the Bonner Quartzite location above Weigh Station

Bruce Baty: [00:00:00] Okay, I'm Bruce Baty and I taught earth science at Hellgate High School for 30 years. Retired about 25 years ago, 24 years ago in 2000. And I've been working at Montana Natural History Center and doing some talks like this off and on and leading some field trips. I went to graduate school in geology at the University of Montana and kind of morphed into teaching high school and just stayed there and had fun.

Okay, the rocks here are part of the Belt series of rocks in western Montana. They're pretty unique in the sense [00:01:00] that they're slightly metamorphosed sedimentary rocks that are a billion years old and they're deposited the thickness of about five miles, 40,000 feet. And they extend from here to Helena. Those red rocks that you see in Wolf Canyon over there, extend to kind of the Idaho border from Canada to Darby and there's this kind of a sliver of them here. They're unique in the sense that they are sedimentary rocks, but they were deposited before there was any life on earth. And so there's no worm burrows through all the layers. And people [00:02:00] come to study the layers because it's one of the few places in the world where you can see a good sequence of sedimentary rocks without worm burrows and distortions within the layers.

And like I said, they're all about a billion years old. They were deposited in an ancient sea that gradually subsided because there are ripple marks and mud cracks throughout the whole sequence. And those are shallow water features and the only way you can get 40,000 feet of shallow water features is to have it shallow all the time and the basin keeps settling down and you have shallow water filling it in.

This unit is a quartzite which was a [00:03:00] sandstone, a quartz sand. It was deposited and there's some mud associated with it. That's been altered and changed into what's called an argillite. But the quartzite was buried so deep and got so hot that all the quartz grains fused together into one solid mass. And so you can't, - like in a sandstone, you can feel it's kind of gritty. This won't be gritty. All the sand grains are fused together.

So let's go up here and look at what the quartzite is like.

Question from group inaudible

Bruce Baty: Yeah. Almost vertical. Yeah, it is. It is from folding. Yeah.[00:04:00]

All of these rocks came from up there, but that's a good piece of the Bonner quartzite. As is this. (shows example) And then, there are some layers of really maroon stuff in here. That was a clay. (Bruce tosses out rock examples for the group to look at.) Okay, I'm done throwing. You can pick those up.

You can see that the layers are tilted. They run at an angle like this. (demonstrates slant) Originally they were deposited flat.[00:05:00] And earth movements have tilted them like this. There's a push from the south and it was an uplift push, at least three or four thousand feet of uplift on the fault that's all gone now. It's been eroded away, but there are three or four thousand feet of rock above here, probably three miles, two miles of rock up above here that's gone.

This was tilted by pressures from the south, coming this way. And I don't know if you've looked at the hillside over there. (gestures across the Blackfoot) That is tilted the same way as this. They match. That's the same stuff.

And rock layers are unique [00:06:00] in the sense that they're continuous. They don't stop. They go for miles and miles and miles. And these stop. They don't, can't terminate the rock layers. So that means there's a fault there. There's been erosion. Whatever was above there is gone because you just can't have vertical rock layers. So that in itself is pretty unique. Pardon?

Question from the group, inaudible.

Bruce Baty: Uh, it's not a dike. It’s a layer and it's a rock layer in here. It's a much younger rock layer. These rocks are about a billion years old and that's about 770 million years old. So no relation at all. Not even close. [00:07:00] But it was a layer that was deposited in the shallow sea that was here at that time that's just rich in phosphate.

Here's a band of this clay layer which is maybe about this thick. And yeah, it's all right here. Totally different. Totally different than the quartzite and it was essentially a mud. But during the pressures involved in the uplift it got compressed into what's called an argillite. If it was heated for a longer period of time, it would change into a slate and then into a phyllite and then into a schist. But this is a lower stage, but still, [00:08:00] it was buried two or three miles to get compacted the way it is. And you can't bend rocks, and the only way you can bend rocks really is if they're heated and warm. So at the time of this bending, these rocks were essentially red hot and kind of mushy like peanut butter would be. And they bent.

Did everybody pick up a piece of quartzite? Okay.

There's no fault between those rocks and these rocks. (indicates the bluff across the river and the bluff the group is standing near) The river cut down through all of this over the course of millions of years. And actually it cut down through all of this all the way up to Potomac. So there's a lot of rock that's missing. And then there's two miles of rock that was [00:09:00] above this that's missing, too. Time. It's hard to comprehend.

Comment from group member, inaudible.

That's good enough, yeah. One is a fourth of it, yeah. This was a billion years ago. Life on Earth started about five or six hundred thousand years ago, animal life.

Pardon? Oh, million. Million. Million. I do that every once in a while. Okay, I've got a bunch of rocks in that box down there that I want to show you and compare to these.

(Next comments interacting with group)

Take one of these with me.[00:10:00] Hey, yeah, take this. Okay. And they want to find another one like that. Not so much. I'll make somebody else find some others.

This is a rock that I got from another place, but it's a quartzite too. Very similar to this, but if you look at it, you can see sand grains in it. And the difference between this one and the Bonner Quartzite is, the Bonner Quartzite is so tightly fused that you can't see sand grains.

I'll pass this around. You might have to poke around at it a little bit.[00:11:00]

Given enough time, this red mudstone, which I'll call argillite, if it's heated longer and to a higher temperature, the mica flakes in it will start to grow, and they'll grow parallel to each other, and it'll tend to split in flat surfaces, like this. And this is called slate.

This was heated more than that was. And the difference between these, is these break real well in flat surfaces. Those, not so much. They're kind of rough, angular, flat surfaces. In some cases, it's kind of hard to tell [00:12:00] the difference. I'll start this one. I guess that one's going this way. Okay, this is slate, and it's the next stage in metamorphism.

If this was heated deeper, more pressure, a longer period of time, it would turn to this. And this breaks in flat surfaces because the mica flakes, although they're very small, they're all parallel to each other, they're pressure sensitive, and the compression causes the mica flakes to grow parallel to each other and enables the rock to split flat.

If it's heated even more for a longer period of time, it turns into a rock called phyllite. And [in] phyllite, the mica flakes are big [00:13:00] enough so that they have a shine to them, like a satin finish. Uh, but they aren't big enough to see. But it's been heated more than what the argillite has been.

And if it's heated even more, the mica flakes become larger. They're still parallel to each other and the rock is then called a schist. The ingredients for the mica are in the rock that just has to get to a certain pressure and a certain temperature before they'll grow. I'd like some able bodied people to poke around in here and see if you can find a rock like this that has parallel mica flakes in it.

In one of the red rocks, kind of look at this. And see if you can find a couple more. Pass that around. And see if you can find another one over here that has parallel mica flakes.[00:14:00] Yeah, that's a little bit. That's good. You're doing great. Now we have two.

(Question from group member, inaudible)

(interacting with the group members showing him rocks) Uh, I'm not going to say so. But it's a nice looking rock. That's different. Oh, that is. No, that's good. I see the sparkles. Yeah, these spots are different. So how we doing? We got three now. Okay.[00:15:00] I do have a rock hammer in my pickup. (comparing rocks) right here there's some of it. But it's not as good as what I wanted. This one, look at, look at this one.

Okay. The difference between these and the schist is these mica flakes were deposited when this was sand on the ocean floor. And waves came in and stirred up mica flakes and then they settled back down on this beach floor. So that's part of the evidence that this was a beach. And the ripple marks and mud cracks too show that.

(reacts to an example) Ooh, barely. Some, yeah. And there's [00:16:00] some rocks that you can pick up around here that you'll see more of that mica flake stuff. I've seen the whole surface covered with mica flakes to the point where I thought it was a schist, but it's not. It's mica settling between waves on the ocean floor, on the beach floor.

Alright. There's another feature here that is kind of prominent. You have to look really hard for it. In fault zones, there's a lot of force and pressure. And when rocks slide past each other, they tend to pulverize the surface or polish the surface that they slide over. And these are called slickensides. [00:17:00] And the motion either went that way or this way, but it went this way.

You can pass that around. And, if you take a paperback book and bend it, all the pages by the spine, stay close together or don't move. But the rest of them all slide past each other and it doesn't take much movement in a fault to create these slickensides. And the surfaces of the rock layers are called bedding planes.

And I've got a couple here that that came from bedding planes. (shows examples) This has slickensides on both sides. As does this one. These were picked up here close to that walking bridge. I was fishing and [00:18:00] was looking at the rocks I was walking over. (showing examples) Ah! Here's another one that's pretty cool. This is a sandstone. You can feel that it's sandy. But the movement causes slickensides. It's just totally different than what the rest of the rock looks like.

Pass that all the way around. And there's some slickensides here. And I can find you some. But we have to look and find a fault zone.

Group member: Did you want to add this to your collection, or?

Bruce Baty: I do not. I have actually have some better ones. I stopped at the Montana Natural History Center to pick some things up. I would have brought some of those, but I thought I would find a bunch here.

(looking at samples offered to him)Yep. Okay. In here? (puts in the box) In there. And this one? Yep. [00:19:00] I think there's some floating around yet. Okay. Oh yeah, I see some. Yeah. Well, we'll leave that right here.

Let's go this way. So, if you're brave enough to walk up to that surface, you can see the slickensides on it. It's been pointed out that there's a lot of white rock mixed in with this red rock. And this is a quartz vein that's squirted through. This is really hot. I'm going to use the word "hydrothermal." Hot water solutions, dissolved quartz, and this hot water solution went through the cracks in the rock during the faulting and left quartz behind.

As it cooled, it left the quartz. And so this, and down there [00:20:00] especially, since the rock is made totally of quartz, it was really hot, heated up. There's a lot of quartz in motion. Wherever there was a crack, quartz filled the cracks and left some quartz veins.

SiO_2. It's a mineral that is very, very common. Often forms in six sided crystals. But this is really fine grained. It melts it at fairly low temperatures. But it's a pretty standard common mineral.

(reacts to group members) Ooh, got another one. Yes, kind of.[00:21:00]

Around Butte, there were a lot of quartz veins, but there was also a lot of gold around Butte. And if you take all the rocks in the Missoula Valley and melted them, you'd have a couple thousand pounds of gold from all those rocks in the bottom of the basin, which is two or three thousand feet of gravel.

So, as you cool this all down, and you cool any magma down, gold is one of the last things to crystallize out. Also is quartz, one of the last ones to crystallize out. So everything crystallizes out and what's left is quartz with some gold in it and if there's a push on this pocket of liquid it squirts through the rock carrying the quartz and gold and so prospectors look for [00:22:00] quartz veins and if they were lucky enough they found gold in the quartz veins.

So primarily all those prospectors in the west that ran around with their mule and chipping rocks were looking for quartz veins. And if you could see gold in it, that's really pretty valuable ore. Mostly you can't see gold in it.

How you doin? Good job. Ah man, I came by here yesterday and put a rock out that had slickensides on it. But it disappeared. Somebody wanted it more than I did.

Kim Briggeman: I've got a question for you. We've got all these cool colored stones in the river, (inaudible) that kind of make Blackfoot what it is. And they're the [00:23:00] clay, the reds, the blues, the greens, I mean there's a whole bunch of them.

Bruce Baty: They came from upstream. They could have come from right here, but they could have come from Potomac, and they could have come from Rogers Pass. Off from rivers cutting down. There are two miles of rock here that the river cut through, and eroded a lot of it, and the residual rocks are left behind.

Tony Liane: So until the river cut through here, this was all one?

Bruce Baty: One solid mass of rock from that side to this side. (indicates the rocks across the river) And the river, as the land was uplifted, the river cut down along its course, wherever it was, the river cut down, and kept up with the uplift. And the Clark Fork did the same thing, and it cut through Mount Sentinel and Mount Jumbo at the point where it was, because [00:24:00] there's a fault there and the land was uplifted. And the river was flowing along a course and it cut down along its path, separating Mount Sentinel from Mount Jumbo. But that's 2,000 feet of erosion that you can see. There's another mile or two of rock above that that's gone. That's the amazing part.

Tony Liane: So what allowed the river to cut through here, was there a fault line?

Bruce Baty: Well, the river kind of picks its course. It's kind of true down there on the Clark Fork because there's a fault zone and the river follows that fault zone. But not entirely. The river, if it's established along a course, will cut down along that course. If it hits a fault zone on its way down, it may tend to follow that fault zone for as long as it can. [00:25:00]

Gary Matson: So the fossil mud cracks that we see around here and the ripple marks, Are those the same age?

Bruce Baty: The same age as this. A billion years old. That's the sea that was here. Deposited five miles of rock vertically, all in shallow water. It's really, really kind of weird. Yeah. There are some limestones in that, but there's just a lot of shallow water deposits.

Kim Briggeman: Back to the colored stones. Do we see those over in the Clark Fork? I don't see them as often in other rivers as the Blackfoot.

Bruce Baty: The red comes from this maroon. It depends on what layers there are. You know, if you go further up the Clark Fork, you'll find them. It depends on what [00:26:00] rocks are there. You need the red rocks in the hillside to make this.

Around Rock Creek, there's a lot of red rock up there. One of the problems is it's falling down the hillside and it's covered with lichens and it's black. If you hit it with a hammer and break it, it'll be red. There's a lot of red rock in Rock Creek. Up in Glacier Park, there's a lot of reds and greens and blues. And those rocks up there are the same as the rocks here. And it depends on the proximity, how close they are to where you are.

Unknown speaker: So that's where the greens and blues we see here came from?

Bruce Baty: Uh, they came from these rocks, which are the same rocks that are in Glacier Park. They're the same rock formation, the Belt Sequence. Which is a series of red and green and [00:27:00] blues, uh, for great thickness.

Unknown speaker: Does the color come from the relative oxidation of the clay?

Bruce Baty: Yes. The red is an oxidation state of iron. And the green is a different oxidation state of iron. So one's a plus two, and the other's a plus three, and they color the rock either reddish or greenish. And as that weathers, it may be orangish. Um, the greenish rocks were generally deposited below sea level and not exposed as much to oxygen. And the redder rocks were mudflat deposits and exposed to the air and the iron oxidized to red.

I think we better get going or [00:28:00] we're never going to get out of this place.

Second stop: Sha Ron Fishing Access site

Bruce Baty: (Showing rock with a fern pattern on it.) Okay. You can find these if you look in cracks in the rocks. There was a crack in the rock and mineral matter, in a water solution, worked into the crack. The water evaporated, leaving the mineral matter behind. The mineral matter is manganese dioxide, and it formed a pattern which is a dendritic pattern, branching of trees, and these are called dendrites. And although they look like ferns, they are just mineral matter. This is the crystal structure of the mineral that grows and it happens where [00:29:00] water does soak into a rock along a crack and the water evaporates leaving that mineral matter behind. And that's the crystal structure.

I'm gonna talk about rivers (speaking to Jan who is helping) and I'm going to pass some things over to you, just kind of keep them kind of in order.

(Illustration of a V shaped valley) Rivers start out in a steep slope cutting down and they make V shaped valleys. As gravity pulls the water down, the valley gets deeper and deeper, but it stays V shaped. And it just keeps cutting down. It cuts down until there's a point called base level. And the ultimate base level is sea level. The water cannot cut below sea level.

But you have temporary [00:30:00] base levels too. So when water hits base level, (illustration) let's call this sea level, can't cut below this point, then it starts to cut sideways and makes a flat valley floor with still kind of steep sides. The ultimate base level is sea level, but we have temporary base levels.

Like Rock Creek cannot cut any lower than the Clark Fork River. So the Clark Fork River is a base level for everything flowing into it. Rattlesnake Creek has a base level of the Clark Fork River, and it's a different level than what it is up there at Rock Creek.

(illustration) As time goes on, the valley gets wider, floodplain gets bigger. The floodplain only gets enlarged. [00:31:00] when the river is over on one side or the other side and it cuts the bank and the bank cascades down and it makes this floodplain at base level it just gets bigger.

I would have brought a blackboard. (illustration) And in some cases and this has happened around here and we're sitting at one of these levels. The river made a floodplain across here at this level. And then the land uplifted, something happened, the river changed slope, and it cut down to a new level, and started making a new floodplain at this new level.

And this is pretty common around here. We're on actually a floodplain, an old floodplain of the river, right now.

And [00:32:00] so this river starts to cut sideways. (illustration) And as it cuts down, each of these levels is called a terrace, river terrace, terrace level. And they generally match up on both sides, except in this case they don't match up on this side. Can you tell me why? (group offers answers) No, no. It got undercut by the river. These layers, these terraces which were over here were eroded away by the river when it got over here on this side. They're gone.

But, if you go through eastern Montana, the Madison River has excellent river terraces that are just huge. There's two that run all the way through Missoula. We're going to look at some right up here. 00:33:00] This level that we're on right now is the same river terrace level that Hellgate High School is on, and then there's one below it. If you go from Hellgate High School to the river, you go down the slope where Hellgate's practice field is. You go down a slope, or if you're on 3rd Street, going to Montana National History Center, you go down a slope and there's another flat area, but there's a higher flat area.

Almost all of Missoula is this floodplain surface. All the way through the whole town, and then there's a lower one, and then the present river surface. So, here we go. Little story about rivers. (illustration) So, again, this is possible if the river undercuts the terraces that used to be over here

At [00:34:00] Chico Hot Springs there's three or four terrace levels on the hillside as you look across at the hot springs.

(illustration) Okay, so rivers change course through time. The blue river is first, the green river is the same river later in time, and the red river … I'm going to reverse that. Red is first. Green is second. And blue is last.

So the river kind of meanders through an area. But the faster water goes around the outside of a corner. So the outside corners get eroded and deposition happens on the inside corners. So the river moves and makes its way across the valley leaving behind a flat valley floor which is the floodplain.

And that may have old channels in it and stuff but every time it floods those fill with mud and the mud gradually settles out and those essentially [00:35:00] will fill up to the level of the floodplain so the floodplain is relatively flat.

Okay, (illustration) in more extreme situations, the river will meander a lot. And red is first, green is second, blue is third. And in some cases, it'll cut through where the meanders touch. And it'll leave behind an oxbow shaped river, which is called an oxbow lake. And the river then flows this way, and water doesn't want to go around that long channel anymore, so it comes in here and it kind of slows down, deposits mud and gravel right here, and the same happens here, [00:36:00] as the river's going this way.

And so these get plugged right here at this point, and this ends up being a big lake. And that gradually fills in with mud with floods.

I might pass this one around. I think, yeah, I'll do this one first. This is the Flathead River north of Flathead Lake. (illustration) There's a big slough up there called Egan Slough, but that's an old meander. This is a river. That land was made flat by the river. The river flowing across all of it made all of that land north of the river flat.

So, and I'll have to pass this around so you can see it, but this is Missoula. Kelly Island is out here, [00:37:00] but all of this area in between here has been covered by the river. You can see old channels throughout all of this, and that's two or three miles across. Pass that one around.

(inaudible comment)

Bruce Baty: Right, right, yeah, it has excellent meanders in it. And another place is south of Missoula, right as you come out of Missoula and the railroad tracks are there. But there's a wide, flat area before you get to Fred's [00:38:00] Appliance. This whole area to Fred's Appliance is all meander scar. The river used to flow right around here and it's filled all this in with sediment as it moves sideways across here.

And I'll pass that one around. (illustration)

(inaudible question)

Within the last 10, 000 years. Yeah. Yeah. Before we got here. Yeah. And the same one. The river originally flowed through here. And all of this is totally flat. This is the same picture. I'll pass that one around from here. This is that Marshall Canyon area and that cliff right up the road here.

Here's the golf course. I don't know if you can see this but I can show [00:39:00] you some shadows and we'll be looking at it when we get up there and I'll pass some of these around. There's a row of trees right here and this is all flat. The whole golf course is pretty flat and then there's an increase in elevation right here and then there's another row of trees and an increase in elevation there and each one of those is a prehistoric floodplain.

(illustration) So these are black and white and do the same thing and this is colored and does kind of the same thing. So yeah, pass those. See if you can see the shadows of where the change in slope are. And we're going to go up there and look at that instead of looking at pictures.

Question: What's your source for your maps, Bruce?

Bruce Baty: Google. Somehow I was able to, at that time, copy Google Maps. And actually I found another way to do it is load [00:40:00] up the Google Map and take a picture of it. And then print the picture. Yeah, I couldn't do that 20 years ago.

(inaudible comment)

Bruce Baty: Yeah, it is. Yeah. I can take that clipboard back now that you've stored everything on there for me.

And so, right over here (points) is a road called Brickyard Lane. And what's the history of that? Brickyard. There used to be a brickyard there. Then they made the early bricks in Missoula. The bricks that were in the Mercantile and some of those older buildings [00:41:00] north on Higgins Avenue. It's really kind of a cruddy brick and it doesn't look nearly as pretty and uniform and square corners and everything as good bricks.

It wasn't a good clay. It didn't make good bricks. But if you had no clay at all, it worked pretty good with nothing else to use. So they used that in the early days of Missoula and it came from right here at Brickyard Hill. And Mount Jumbo School is built on top of those clays. Those clays are Glacial Lake Missoula sediments.

When the lake was here, sediment settled out of the lake and made a deposit on the valley floor. They exist at Nine Mile Ranger Station, the interstate goes right through a sequence of Glacier Lake Missoula sediments. Those existed everywhere in the Missoula Valley. [00:42:00] They've been eroded away by the river meandering back and forth since then.

The lake was here 12,000 years ago. And so in the last 12,000 years, the Clark Fork River has meandered back and forth across the whole valley and removed those sediments. The places where they still exist are at the airport, from the airport over towards Mullin Road, that whole El Mar Estates area is Glacier Lake Missoula sediments.

There's some right here at Brickyard Hill. Mount Jumbo School is built on top of the clay. There's a very little bit around Blue Mountain. Rollercoaster Road out by the Axmen has some on it. Other than that, they're totally gone out of the Missoula Valley and they should have been deposited everywhere [00:43:00] about 100 feet thick everywhere in Missoula Valley. In the last 12,000 years, the river has taken those all out. If you get up on top of Brickyard Hill and look down at this area, you'll see a big arc curve through here. That was the old river course. The river meandered through here, deposits behind erosion going this way.

It got into Mount Jumbo and really couldn't go any further. Kind of got stymied, but still was working away and eroding away. Uh, the land uplifted a little bit, the river changed course, and now the river's over here. And it's making a new flood plain at a different level. It's not this level. And it doesn't flood to this level. But this is an old river course, an old [00:44:00] floodplain of the river.

Okay, let's, let's go up to our next stop, which we'll park along the right side of the road, opposite this cliff.

Third stop: across from Marshall Grade

Bruce Baty: Okay, the way, the way the river cuts is the fastest water comes around the outside corner, and so this bank gets cut.

And the slow water goes on the inside corner. And deposition happens on that side. So the river stays the same width, but moves across the valley, cutting this side, depositing on the inside. And if you look at that inside corner, you'll see gravel bars. And on lower water, you'll see a bigger gravel bar.

So that's the present level of the river. If we go up on the golf course, that's the river level at the bottom part of [00:45:00] Sha Ron. And on the golf course, there's a car that's going across up above by those houses. It goes up a slope. That's a steep slope. That's one of the terrace levels. That terrace level matches this terrace level in the same terrace level the Hellgate High School is on and most of South Missoula and St.Patrick's Hospital also. And if you go further past where that car is, there's another shading and the houses are on a third level. So there are actually three different levels here. The present floodplain, if you look at this island down here, is at that level. That's the present floodplain. And then where that gas pipeline is, in that parking lot, is [00:46:00] actually the first historic floodplain level that matches the level of the golf course.

Those are the same, and that level is the level that Hellgate High School's playing field is on. And McCormick Park is at that level.

And then the river cuts down, makes a new floodplain, and tries to move sideways. So, this is just an example of everything we talked about back there. You can see it a little better here.

We're gonna cross the road. The Clark Fork fault goes through here following the Clark Fork River. Actually the Clark Fork River follows it, but it goes through the saddle in Mount Jumbo, and down this way.

The north side [00:47:00] went up 6,000 feet. This side went down 6, 000 feet. Well, either/or. That stayed the same and we went down 6, 000 feet, or we stayed the same and that went up 6,000 feet, or they both went up and one went up 6,000 feet more than the other. But something happened that went up 6,000 feet higher than this side And that's all of Bonner.

The difference isn't there now. Everything has been eroded back to normal. But we're going to go look at some rocks over here.

(Across the road to the base of Marshall Grade)

Bruce Baty: Can you tell which way these rocks are tilted? They're kind of buggered up because of the fault zone. Which way do the layers go? There are a lot of cracks here. Kind of look up in there. They're [00:48:00] kind of going through like this. (illustrates tilt)

Here you can see it pretty well. Different planes on these, the angles are different.

Unidentified speaker: Like up in the canyon there?

Bruce Baty: Yep. Right. Right. There's faults and earth movements that have gone on and so all of that changes the angle of the rock. And we're kind of right in the middle of the fault zone. This is the Clark Fork fault. And like those slickensides that we saw. It only takes like two or three inches of movement to create something like that. This had a mile of movement and it pulverized the rock. It pulverized the rock within a half a mile of the Clark Fork.

(uses rock hammer) And hopefully this works, [00:49:00] this never failed me, But the rocks break apart really easily. And that's because we're in a fault zone. The rocks are already fractured. And so there's some hammers here. What I want you to do is break a rock. Be careful when you hit the rock that you don't splash somebody with dust. You can put your foot here like that and hit it. And that keeps things from spattering.

But you can go up here. Those are better. That one doesn't break so well. So I brought these hammers so you could break some of these rocks. If there's a rounded rock along the roadside, it means the [00:50:00] highway department dropped it here. It doesn't belong. I cut myself a little bit.

(group member hammering) That's a hard one. If you get one out of the cliff, I'll guarantee you it'll break. Come over here and get one of those.

And at the Orange Street exit, there's a pull off for a hike up to those farm fields up there, but the fault goes right through there. If you pick any of those rocks out of that outcrop, [00:51:00] they'll do the same thing. It's the same fault zone. And once the Clark Fork River found the fault zone and realized that it was easier than anything else, it kind of stayed in the fault zone.

And the fault zone goes through the saddle in Mount Jumbo. When we came back on this highway, back in Milltown, you had a really good view of where the saddle is. And that's where the fault goes through. And it's pretty straight kind of all the way to Drummond. And the river wanders back and forth.

Unidentified speaker: When the river was a lot higher, did it go through the saddle?

Bruce Baty: It did not. It would have stayed through the saddle because that would have been the soft spot. And I've puzzled with that myself. But if it had been in the saddle, it would have stayed there. [00:52:00] And either uplifts or the movement of the land, it ended up being someplace else most recently and cut through solid rock versus soft rock. So it was there. And missed that saddle somehow. I don't know how it missed it.

Unidentified speaker: So, Bruce, historically, are Jumbo and Sentinel part of the same formation?

Bruce Baty: Right. Yeah. Yeah, the river cut through them and just like on both sides of the Blackfoot at the Bonner Quartzsite spot. Oh, and another thing, when the flood was here, when Glacial Lake Missoula was here, water was 2,000 feet deep here at the maximum.

And when it drained, it went out through Hellgate Canyon. Again, you have a corner there. The fastest water was on the outside edge. The Mount Sentinel side is all rocky. Any loose rocks were picked up and carried away. The Mount Jumbo side [00:53:00] is soft and smooth and has still a lot of soft rocks on it and a smooth slope, where that's a jagged slope from the aggressive force of the water as it went around the corner.

And the force of the water was so strong, it picked up rocks the size of me or bigger than me, the size of a Volkswagen, and carried them in a whirlpool in the water out into the Hellgate Valley, and then the whirlpool dissipated and the rock fell. There's a lot of very large rocks out at the mouth of Hellgate Canyon.

By Hellgate High School there are some apartments that they built 30 years ago. There's some rocks this size that were in the soil at that point, and they just pushed them up for landscape rocks. [00:54:00] Those were deposited from the rocks that got picked up in Hellgate Canyon and carried in water whirlpools and deposited in the valley.

Unidentified speaker: Can you explain the coloration differences on this (refers to the Marshall Grade bluff)?

Bruce Baty: Yeah, there are two different rock layers here. This purplish rock layer is a quartzite kind of thing like the Bonner Quartzite. And then above it is the Regina Formation which is made of more recent, very recent mudstones, volcanic ash and stuff deposited on top of what was here.

So it's two different rock layers. And this one goes up and has been eroded away, and that was deposited on top of it within the last 35 million years. Where this is a billion years old.[00:55:00] The yellow color is from iron that's in it, that weathers and turns orangeish, yellowish.

Unidentified speaker: They're part of the Belt that's a billion years old.

Bruce Baty: Right, yeah. And there's some on Mount Jumbo too. As you come up the trail, there's one that's the impression of a ripple mark, because the ripple mark's on the upper layer. But yeah, there's several there. Those are all ripple marks, indication that it was shallow water or sea. But it's 40,000 feet thick of shallow water. It's kind of hard to imagine. So the Gulf of Mexico is gradually subsiding. And so there's gravel, there's five miles of gravel in the Gulf of Mexico area of [00:56:00] relatively recent stuff. So it's not something that's unusual.

Okay. We're done here.

Unidentified speaker: No test?

Bruce Baty: No test. No test. Well, yeah, test yourself. How are we doing time wise? I'm going to go - the next stop will be the confluence.

Final stop: Confluence area pavilion in Milltown State Park

Okay, so this dark brown rock is really a black rock. So this is the black rock that it is, but the surface has been exposed to the elements and the weather and, water soaked into [00:57:00] it. And iron has been rusted, and so that gives it the rusty brown color. But if you break it, and that's why geologists carry hammers, you can really see what the rock looks like.

And if you look at this one really close, you'll see a, a two millimeter thick zone all the way around the outside of where the black has rusted pretty darn well.

And that rock is called a diabase. And although this one I picked up down the road yesterday. It could be very similar to that. Or similar to these. These are, are black and white spotted, mostly black, but some white spots in it. This was an [00:58:00] igneous rock that squirted in here and flowed as a lava flow. But it wasn't a lava flow, it came in between the layers. And so it kind of cooked the zone above and cooked the zone below. And it's called a sill. It's called a sill if it goes parallel to the layers. If it cuts across the layers, it's called a dike. And a lot of the mines around here are associated with that lava, sill or dike, depending on what it is in the hillside, because they're looking for igneous rock carrying gold or something into the countryside.

It's a pretty common rock. It exists in Glacier Park and scattered around through western [00:59:00] Montana through the Belt rocks. And it may also look like this. This is a little larger grained, and what I wanted to say, and I didn't, was that time determines the size of the grain size.

If the lava squirts in here and has a long time to cool, like a million years, the crystals get bigger. If it cools fairly quickly, there's not so much time and the crystals are much smaller. So that ends up determining the size of the crystals that are in the rock. If it cooled from the (inaudible) and the technical name for this rock is a diabase and this diabase sill or dike wherever it may be squirts through the hillside in a lot of different places.

There's [01:00:00] a mine shaft on Mount Jumbo, on Mount Sentinel, I'm sorry, on Mount Sentinel, that's associated with this same lava. And if you follow this up, well, if you walk all the way up Crazy Canyon and get to the Crazy Canyon saddle, the rock there is all brown and fractures and falls apart. That's this stuff. And it's exposed on the surface has been weathered and it weathers faster than the quartzite so it makes a low spot in the hillside and that's why the saddle is there.

Inaudible question.

Bruce Baty: Yeah, right, there's two miles of stuff above here at least. You can go three or four and that wouldn't be bad either. These are

Inaudible question asking where the sediment went.

Bruce Baty: Pacific, yeah, it filled up the valleys. The Missoula Valley.[01:01:00]

The Missoula Valley used to be filled all the way up with gravel. When the faults happened, the Clark Fork River was flowing above everything. It carried gravel and deposited into the Missoula Valley, filled the Missoula Valley up and then it continued on and filled the next valley up, and the next valley up, and then the next valley up.

Finally got to the Pacific, and then it started cutting down. And removing all those rocks that it put in these valleys so it had a path to follow. And so right now it's in the process of removing rocks. And it's done that over the course of the last 75 million years.

75 is the time frame for the uplift of the Rockies. So, that's why I picked that time. But that's all been going on. Uh, there's [01:02:00] a fault that runs along the base of Mount Jumbo and Mount Sentinel. And the Mount Jumbo-Mount Sentinel side went up. The University of Montana side went down.

That fault is a historic fault. It hasn't had any movement on it for many, many millions of years. So it's all pretty stable, but everybody in Missoula is living right on a fault. You're living right on a fault.

Unidentified speaker: Is that the Lewis and Clark fault?

Bruce Baty: Yeah. Yeah. And there are other faults that cross this way, across the Blackfoot, in different spots going up the valley. One of those is called Spring Creek fault, which matches with Spring Creek in the Rattlesnake and why the Spring Creek valley's there. Lolo Creek has a fault that runs up it.

Okay. This [01:03:00] pretty much all I had to say. Yes. Questions.

Unidentified speaker: [I'd like to] ask you to help us visualize [a] fault.

Bruce Baty: Okay. The easy one would be the San Andreas fault, and there are two different schools of thought about what happens with faults. And there's a group called Catastrophists that think things happen all at once. And you get 2,000 feet of movement. And the land is raised 2,000 feet.

And geologists looked at that and said, "no, no, no, no." It happens, small events over long periods of time. So the San Andreas fault moves, I don't know, maybe 10 feet, 15 feet, 30 feet at a time, but every 100 years. If you keep that up [01:04:00] for 3 million years, you got a lot of motion. So, these faults happened over a long period of time, maybe 5 feet at a time or 10 feet at a time.

The fault that's in Yellowstone Park, the Quake Lake fault, There's a marker that I like that says you're standing on ground that dropped 15 feet. And one of the rules of geology is the present is the key to the past. What's happening now probably happened in the past. So if the movements on faults are 15 feet at a time or 20 feet at a time or 3 feet at a time, that's probably how it happened in the past. Over long periods of time. And the kicker is time. So, does that answer your question? The gradual movements, the area stayed active for many millions of [01:05:00] years. Right.

Gary Matson: So both in this area and in Marshall Grade where we were before, there's all this gravel, uh, material that, I presume it's erosion, but, I guess my question is how hard, how stable is that bluff? (refers to the Bluff Overlook across the Clark Fork River) Is it going to continue to erode? And it has all those piles of gravel and the same thing down at Marshall Grade. Is that happening, you know, over a period of five years, ten years?

Bruce Baty: That's the width of the Clark Fork fault. This whole zone between where we were at Marshall Grade and to here is all Clark Fork fault zone and the rocks are all fractured and yes, that will continue to happen. That isn't stable rock, uh, but it'll erode faster than other rock and the closer you are to the Clark Fork River, the more fractured the rocks are. If you go back [01:06:00] 10 miles, 20 miles you can find flagstones that you can use in your fireplace. If you're close to the river, you can find flagstones this big. (indicates small size) Maybe.

Tony Liane: So, when was the last time there was an earthquake here?

Bruce Baty: Four years ago?

Mike Kustudia: 2017, July. Here. 5. 9. We had one in Missoula in 2017 in July. I remember clear as a bell because I made a beeline out here to see if the bluff was still standing. (laughter)

Bruce Baty: I'm just making the number up. There's a fault area through Montana that kind of centers around Big Fork and comes down the Mission Range into Helena and down into Yellowstone Park. And that's kind of the Rocky [01:07:00] Mountain fault zone, Northern Rocky Mountain fault zone. We have earthquakes here all the time. They've had some in Seeley that they felt. They're small. You do feel them and run out of bed to see if the cliff's still standing.

The big fault that was in Challis, Idaho in 1988. I was in Hellgate High School and Hellgate High School shook. The English teacher said the pine trees in front of the school touched each other. They got down to the first floor real quick. I was in a chair with casters on it and I looked down to see if one of my casters fell off because the floor did this. (indicates up and down motion) The door was rattling and it kept rattling and I said, "we're having an earthquake."

Yeah, that's continually going on. Many, many small [01:08:00] ones. The type of earthquakes we have now are adjustment earthquakes, where if you take a block of wood and float it in water and cut it off, then it rises up. If you cut it off again, it'll rise up again.

So as we erode rocks from this area, the rock base itself wants to raise up. And so as it does, it may raise a little bit more here than here. You get a fracture. So that's typical of what's happening now. The crust is floating on the mantle and is kind of in equilibrium and it's so thick and if you make it a little thinner it comes up a little bit.

Unidentified speaker: The Rockies are still rising, so it could be a major one or something.

Bruce Baty: Right, yeah, and, well, all the mountain ranges are still rising. [01:09:00] Early in my geology career, one of the statements a professor made about the Appalachian Mountains is they measured how much sediment was washed off the Appalachian Mountains.

And they figured it would take 50 million years for the Appalachian Mountains to be eroded to sea level at that present rate of erosion. But that's enough time for the Appalachian Mountains to be eroded to sea level four times because they started uplifting 200 million years ago. So, they started to come up with this idea of isostatic adjustment, or it's floating. And as you remove this sediment, this material, this rock, it rises a little bit. It's like cutting the top of an iceberg. It still keeps coming up. And there's a big root to all the mountains. As you have a fault and stack rocks on top of each other, it gets very thick. It sinks down a little bit.

And as it erodes, it [01:10:00] bounces back up. The base of the crust underneath the mountain range is maybe like 30 miles thick. The mountain, the crust here is 30 miles thick. On the coast, it's only 10 miles thick. And it's thick here because it's been compressed with all the faulting and folding that crunched up the Rocky Mountains.

The Himalayas are the same thing. India's moving north into Asia, and it's crumpled up all of Asia. There are sea fossils that they can find on top of Mount Everest. It just goes on and on and [01:11:00] on.