The Geology of the Mid-Columbia Basin

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Introduction

The Mid-Columbia region is a large, arid land mass in central Washington State. If you live here, you pretty much know the boundaries as they correspond closely to the Shrub-Steppe ecosystem. Where you see sagebrush, rabbit brush and exposed basalt and, unfortunately, tumble weeds and cheat grass, you are in the Mid-Columbia (MC). The extent of this region will become clearer as we explore the geology of this area. The MC geology garners a lot of attention because of the massive basalt flows that cover our area and the massive ice age floods that scoured much of the region right down to and into the underlying basalt. There are many sources of information from road-side geology books to the Ice Age Floods Institute.

Of much less interest, but much more importance, to the general public are the gravely soils that support our highly productive farmland. While the hydrology and ecology of this area is of interest to farming and many other aspects of our economy, we will concentrate here on where and how these gravely deposits formed.

Caveat

I am neither a professional geologist or hydrologist and have not spent years studying the local landscape except through extensive climbing, hiking and paddling in the MC. I found most of the material focused towards public consumption to be interesting with often spectacular specifics, but lacking any relevance that helps us understand our current geology and hydrology. The professional/scientific literature on the subject is enormous and again somewhat focused on specific technical questions. Geologic studies and hydrologic studies remain somewhat disconnected even though the desired objective is to merge the two fields. It was difficult to put together an overall time and spatial view of the geology and hydrology of this region. This is my attempt to interpret my readings and many will and should take objection to the specifics of this interpretation. Be happy to discuss this over a glass of beer.

A Hop, Skip and Jump Through Geological Time

Below I describe the geological timeline of the MC region. However, in brief summary we are concerned primarily with how lava flows combined with the Missoula floods left behind a discontinuous overburden referred to as the Ringold Formation. These deep, gravely soils are further separated into the largest Pasco Basin in the south and the smaller Quincy and Othello basins further north. There are also related gravely formation such as the Ellensburg and Umatilla Formations.

The Basalt Flows

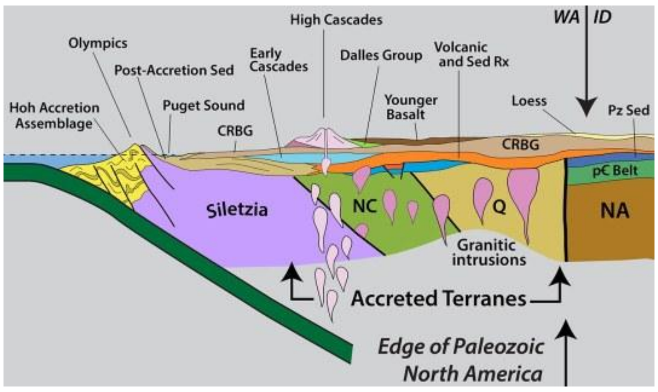

Figure 1. Marli Miller [Summarizing Washington State's Geology –in 19 photo out-takes | geologictimepics](https://geologictimepics.com/wp-content/uploads/2017/08/nw-x-sxn6-2017lr1.jpg)

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Fig. 1 created by Marli Miller provides a useful cross section of Washington state from west to east. As the Juan de Fuca plate smashed into and sank beneath the North American (NA) plate various layers of assorted crud piled up against NA plate whose boundary is basically the Washington-Idaho border. So, us "Warshintonans" might ponder over a glass of beer if we even live in North America. The "Terranes" labeled Q, NC and Siletzia form the underlying structure of most of Washington State. I imagine this process being something like scraping ice off a windshield. This particular plate tectonics phenomena originated roughly 50 Million Years Ago (MA) and continues to this day. This is undoubtably a great oversimplification but the mechanism is not critical to our main objective

Over the same period the Yellowstone Hot Spot was originally located west of Oregon out in the Pacific Ocean and, as the NA plate moved slowly westward, that hot spot is now quite conveniently located beneath Yellowstone National Park. See Fig. 2

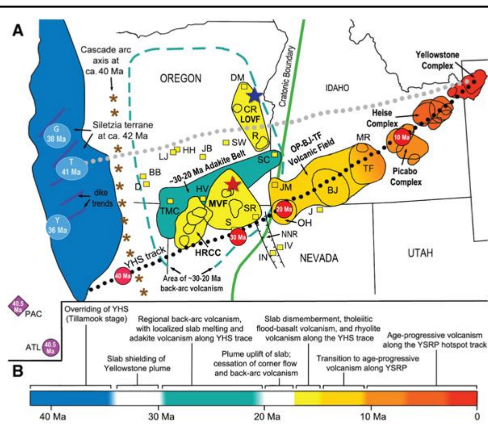

Figure 2. Victor E. Camp and Ray E. Wells, The Case for a Long-Lived and Robust Yellowstone Hotspot, GSA Today, 2020.

https://www.geosociety.org/GSA/GSA/GSAToday/science/G477A/article.aspx

Around 16 MA this magma hotspot was located in southeastern Oregon below what is now the Steens mountains. And thus, begun a series of lava flows that formed the Columbia Basin Basalt Group. These basalt flows came to the surface along a series of cracks or dikes running from SSE to NNW somewhat west of the Washington-Idaho border. There are dozens of named, basalt flows but for our purpose we can group these into the Imnaha, Steens, Grand Ronde, Wanapum and Saddle Mountain basalt flows. The Imnaha and Steens basalt flows are located in east and southeastern Oregon and are not of keen interest for our purpose. The Grande-Ronde basalt flow covers a huge area and underlies most if not all of the MC region. The Wanapum and Saddle Mountain flows are smaller but geologically relevant to our purpose.

Burns, et al. published an article entitled "Three-Dimensional Model of the Geologic Framework for the Columbia Plateau Regional Aquifer System, Idaho, Oregon, and Washington" whose purpose was to provide the geographical information in a form that can be used for hydrological modeling of the MC region. They also provided the appropriate GIS information to recreate their maps and explore selected aspects. I have taken this data as well as other data such as county boundaries, the Columbia River and its tributaries and created a series of regional maps using the QGIS mapping program.

Fig. 3 shows the extent of the more important basalt flows to the MC region. For our purposes we are interested in the region outlined in Red. A link to an interactive version of this map is also available. It should be on the same web page as the link to this article.

The Grande-Ronde flow (shown in Black) is largest in terms of both volume and area and underlies most of the region. This flow occurred between 17 and 16 MA. Basalt is heavy (or rather dense) and what goes up must come down. Hence the basalt flows sank down creating new low lands where the next layers accumulate on top of the old flows. Near Pasco, the Grande-ronde flow is some 17,000' thick and hundreds of miles wide. In comparison, Mt. Rainier is quite puny. While the figure shows the black around the edges it actually is underneath all the other layers. This is more apparent in the interactive map where the various layer visibilities can be toggled.

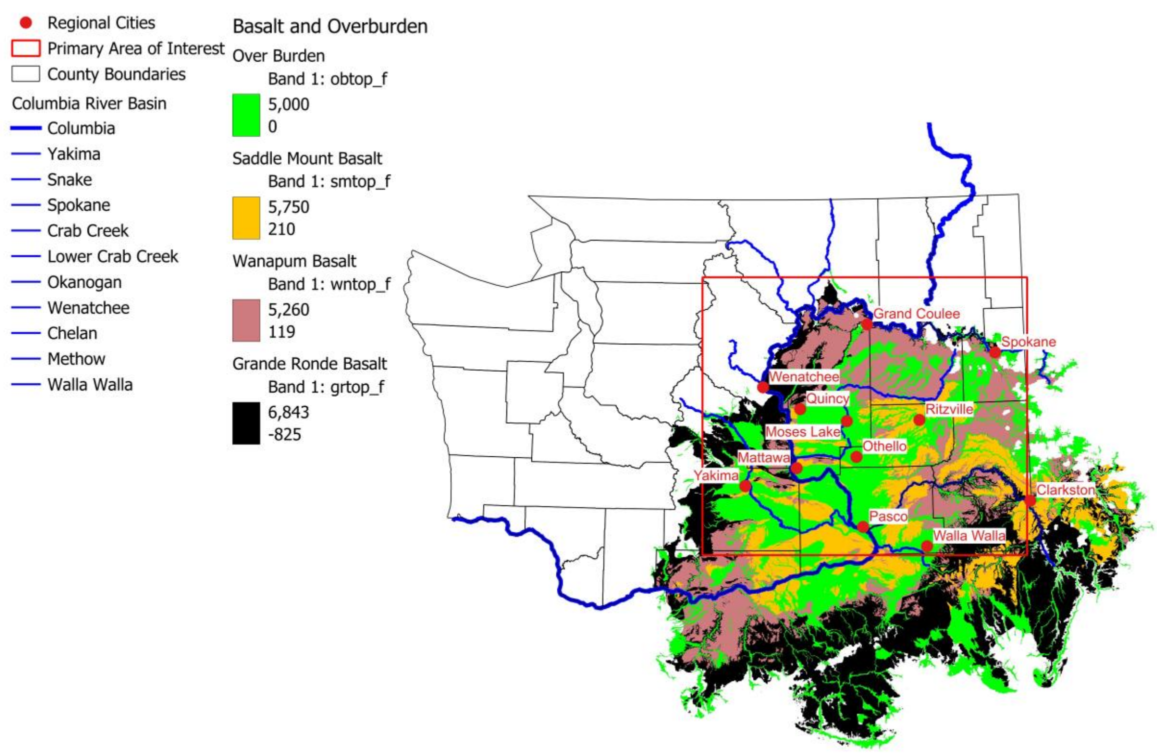

Figure 3. The three major basalt flows of importance to the Mid-Columbia region as well as the overburden layer consisting of sedimentary formations.

The Wanapum Basalt (shown in brown) came next from about 16 to 15.5 MA and covered a smaller area with significantly less volume. The Saddle Mountain flow (shown in orange-yellow) is the top most basalt layer as well as the most recent flow. It occurred between 15.5 and 15 MA.

These flows were not contiguous and consisted of many smaller flows. Meanwhile the rivers system was constantly changing and depositing considerable masses of gravel and stone. The Mabton and Vantage interbeds are alluvial (river) deposits between these basalt layer. As these layers are buried beneath basalt flows their extent and distribution are not well known and are likely intermittently distributed. The general story suggests the basalt flows pushed the Columbia River quite far west even past present-day Cle Elum.

The Lost Millions

Between about 15 MA and 2.6 MA the region was relatively quiet. That's a long time. Both the basalt flows and the coming ice age lasted only a couple of million years. There was considerable uplifting, folding and rotation of the accretion layers shown in Fig. 1 to form major ridges that extend out into Eastern Washington. Example include the Horse Heaven Hills, the Saddle Mountains, Frenchman Hills, Umptanum Ridge and Manatash Ridge. These pushed the Columbia River system back as far east as Othello and Moses Lake and finally to its present-day location. Indeed, the Columbia, Yakima, Snake and Umatilla Rivers were not really recognizable as the entities they are today. The area rivers changed paths significantly sometimes being blocked by rising ridges causing the formation of large lakes. Nick Zentner of Central Washington University refers to the lakes collectively as Ringold Lake. The important point is that much of the MC was covered by alluvial deposits most of which originated from points north of Grand Coulee and are non-volcanic, granite and quartzite in the form of gravels, silts and clays. This makes for soils with little nutrient content but varying degrees of porosity.

Shown in Fig. 3 are what remains of these alluvial deposits which Burns et al. refer to as the overburden layer (shown in green). The map shows the overburden layer where it is greater than 100 feet thick. These overburden deposits are given various names that describe their general location. The Umatilla Formation is the most southern deposit and probably came from ancient rivers flowing out of southern

Idaho. The Ellensburg Formation tracks along the current day Yakima River and was probably a combination of sediments from the Cascade Range and the Columbia River.

We are most interested in the Ringold Formation and this was deposited by the Columbia River as it wafted it way across the underlying basalt plains as well as the associated lakes that presumably repeatedly formed and drained. The Ringold lies between Pasco and Grand-Coulee Dam. This formation is composed of the Pasco Basin which is the largest and most southern portion and extends on the south end from the Pasco area and terminates on the north end at the Saddle mountains. North of that is the narrow Othello Basin extending up to the Frenchman Hills. And finally, there is the Quincy Basin extending north to about halfway between Frenchman Hills and Grand-Coulee Dam. As we will see the Ringold Formation corresponds closely to the Columbia Basin Irrigation Project.

Presumably these "formations" were at some point more or less contiguous. They may have been deposited over some 13 million of years but were not as disjoint and distinct as we see now. As basalt ridges rose up the river was blocked forced to a different path causing alluvial erosion and redeposition. Large lakes formed and disappeared.

The Palouse

One might reasonably ask "where the heck is the Palouse Region, Fig. 3 shows mostly basalt where we observe rich soils supporting dry-land wheat farming". The Palouse was formed during this time frame by windblown deposits originating from these overburden areas. The map shows only where the overburden is greater than 100 feet thick and the Palouse is generally less than 10 feet thick although the *literal* dust is up to 250 feet thick at selected sites.

Below we discuss the Palouse using a modified surface geology map of Washington. This clarifies in more detail the sediments deposited by aeolian and alluvial processes

The Ice Age and the Lake Missoula Floods

The Quaternary glaciation or Pleistocene glaciation began about 2.6 MA of which the "Last Glacial Maximum" (LGM) occurred about 110,000 years ago and reached down into the northern parts of Washington State and created the now famous Lake Missoula. My impression is that this ice age began slowly and reached the above mentioned LGM relatively recently. The ice then retreated in a hurry. Hence during this initial period, the advancing glaciers would have created fine scoured sediments that contributed to the Ringold formation. But as the ice age grew moving south but not into the MC, the weather in the MC was probably cold and dry and major erosional water flows might have decreased in intensity. Much remains to be understood about the geology of the Ringold Formation.

Beginning about 20,000 YA, during a series of glacial advances and retreats, Lake Missoula repeatedly (as many as 40 times) burst through the ice dams and flooded eastern Washington.   In the northern eastern reaches of the MC, it scoured the aeolian deposits on the northern edge of the Palouse deposits. This erosion formed the majority of the scablands now found in that region. The sediments, being relatively small, traveled south down to the Snake River and in part west cutting through the Ringold Formation. Some of the floods took a more westward path along the current Columbia River and scoured the western edge of the Ringold Formation. These alluvial deposits, probably measuring 100's of feet thick, were scoured down to the underlying basalt in the north and this debris was transported to the Pasco Basin. Local farmers still refer to these as the "Pasco Gravels." Because the Wallula Gap constricted flow a series of enormous lakes were formed in the Pasco basin. This ancient lake or lakes are commonly referred to as Lake Lewis. Much of the Pasco region is covered by 100-200 feet of these coarse flood deposits but underlying this are finer less permeable silts from the pre ice age Ringold Formation.

It was probably during this period that the Ringold formation became distinct from the Ellensburg formation. The floods scoured two main paths. One pathway was through the relatively thin Palouse deposits and created what we now call the Scablands. A second pathway followed closer to the existing Columbia River and scoured a section between the Ellensburg and Ringold formations. In addition, as the ice retreated further north back into Canada, the meltwater would have had a major erosive action along the current Columbia River. As this was the thicker alluvial deposits, this is the materials that was deposited in the Pasco Basin. However much of the Ringold formation was untouched or lightly scoured by the Lake Missoula floods. The unscoured areas primarily in the north and the associated deposits primarily in the south form the distinct overburden shown in Fig. 3. As we shall see this region correlated closely with the CBIP and is now a highly productive agricultural region.

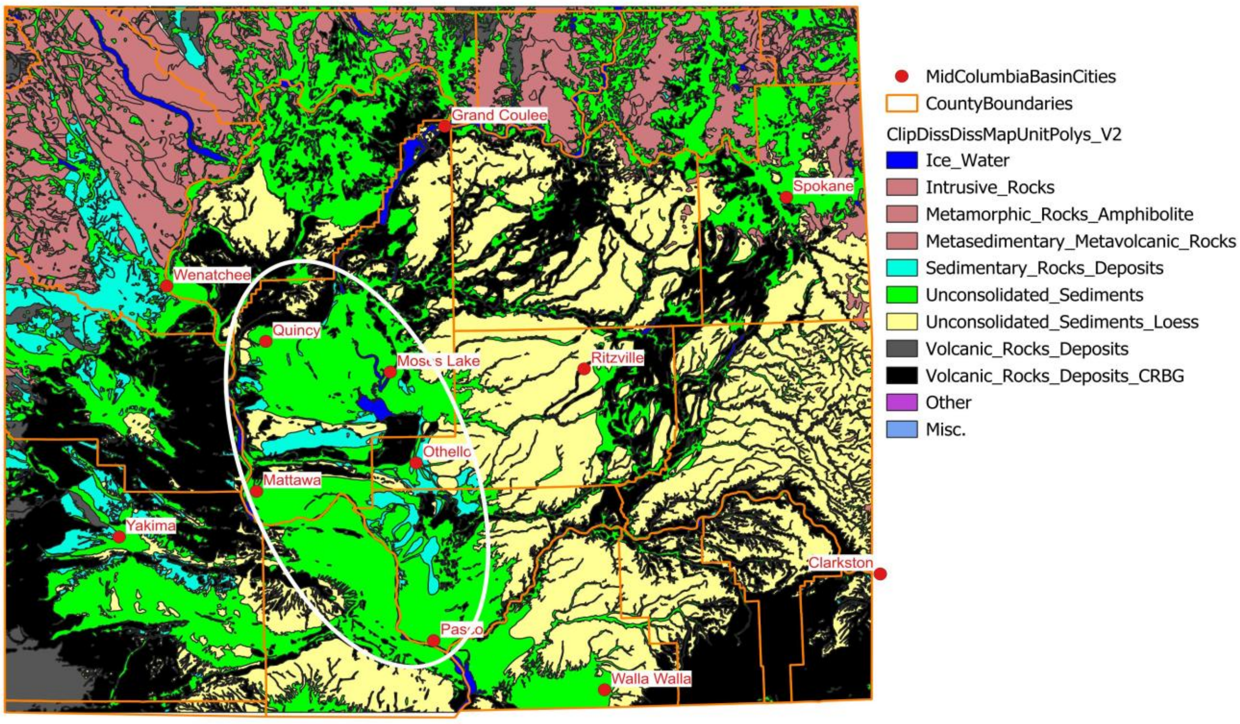

Fig. 4. Simplified Surface Geology Map of Mid-Columbia. The white ellipse identifies the general extent of the Ringold Formation.

Figure 4 is adapted from the Surface Geology Map of Washington. The raw data can be found at the DNR site Geology GIS Data and Databases | WA - DNR. Appendix A is a summary of the key found on the surface geology map and corresponds roughly to the categories use to create Figure 4. A similar map can be found at the Washington Interactive Ecoregions Map

The Black areas are the Columbia Region Basalt Group and are a combination of the individual basalt flows shown in Figure 3. On the norther edge of this map are nonvolcanic, metamorphic rocks, shown in Brown, that were scoured by the ice-age glaciers. The Green and Yellow regions overlie the basalt and the Green corresponds closely to the “Overburden” layer of Figure 3 and is primarily alluvial deposits. The white ellipse roughly identifies the Ringold Formation as well as the Hanford Formation on the southwest portion of the ellipse. The Yellow region is primarily Loess and now the Palouse region becomes clear. The area northwest of Clarkston is often referred to as the Palouse Hills as the elevation begins to rise in this region. Some consolidated sedimentary rocks, shown in Cyan, pop up on occasion. I suspect these are very old deposits laid down after the end of the basalt flows and have undergone millions of years of compaction.

The exposed areas of basalt in Black that are north and east of Ritzville correspond to the classic Scablands. A major portion of the Missoula Floods flowed south down to the Snake River while other floods took a more westerly flow and cut across the Ringold Formation.

However, note the large exposed basalt west of Mattawa and Quincy but south of Wenatchee. The region across from Mattawa is the U.S. Army’s Yakima Firing Range while that across from Quincy is the Quilomen Wildlife area. This area was probably part of the Ringold Formation prior to the floods and may have connected with the Ellensburg Formation further west. Much of this material was gravel and sand and after the floods, the material was deposited primarily in the Pasco Basin portion of the Ringold Formation. Thus, the Pasco Basin is composed of two general deposits. The bottom is hydrologically a relatively impervious layer. It is a remnant from the preflood Ringold Lake deposits and appears to be 100-300 feet thick. The top layer is the classic “Pasco Gravels” deposited by the Missoula floods and is relatively porous and is also 100-300 feet thick. As one move north the Pasco Gravels decrease in thickness and the older Ringold formation dominates.

This sets out the basic geology process that produced the Ringold Formation as we know it today. I have taken many liberties in extrapolating how I interpret the maps and literature. If you disagree, I will be willing to buy you as much beer as necessary to ween the truth from your poor drunken soul. Seriously, the mechanisms of geological processes are of importance to real geologist and apparently the geologic time between the basalt floods and the Missoula floods has not been of keen interest to the geology community. It certainly isn't of popular interest. Our purpose is to make the reader aware of the Ringold geology and then to move on to the hydrology and ecology of this region about which I know as little as I do of the geology.

Appendix A. Groupings of Surface Geology

Unconsolidated_Sediments	
Qd	Holocene dune sand
Qa	Quaternary alluvium
Qls	Quaternary mass wasting deposits
Ql	Quaternary loess
Qf	Pleistocene outburst flood deposits
Qgd	Pleistocene continental glacial drift
Qad	Pleistocene alpine glacial drift
Sedimentary_Rocks_Deposits	
QTc	Quaternary–Tertiary continental sedimentary rocks and deposits
Tc	Tertiary continental sedimentary rocks
Mzc	Mesozoic continental sedimentary rocks
Tn	Tertiary nearshore sedimentary rocks
Mzn	Mesozoic nearshore sedimentary rocks
Tm	Tertiary marine sedimentary rocks
Mzm	Mesozoic marine sedimentary rocks
Volcanic_Rocks_Deposits	
Qv	Quaternary volcanic rocks
QTv	Quaternary–Tertiary volcanic rocks
Tvcr	Tertiary volcanic rocks, Columbia River Basalt Group
Tv	Tertiary volcanic rocks
Tvc	Tertiary volcanic rocks, Crescent Formation
Mzv	Mesozoic volcanic rocks
Qvt	Quaternary fragmental volcanic rocks and deposits (includes lahars)
Tvt	Tertiary fragmental volcanic rocks
Intrusive_Rocks	
Qi	Quaternary intrusive rocks
QTi	Quaternary–Tertiary intrusive rocks
Ti	Tertiary intrusive rocks
TKi	Tertiary–Cretaceous intrusive rocks
Mzi	Mesozoic intrusive rocks
Pzi	Paleozoic intrusive rocks
pCi	Precambrian intrusive rocks
MzPzu	Mesozoic–Paleozoic ultramafic rocks
Metasedimentary_Metavolcanic_Rocks	
Mzms	Mesozoic metasedimentary rocks
Pzms	Paleozoic metasedimentary rocks
PzpCms	Paleozoic-Precambrian metasedimentary rocks
pCms	Precambrian metasedimentary rocks
Mzmt	Mesozoic metasedimentary and metavolcanic rocks
MzPzmt	Mesozoic–Paleozoic metasedimentary and metavolcanic rocks
Pzmt	Paleozoic metasedimentary and metavolcanic rocks
Mzmv	Mesozoic metavolcanic rocks
Pzmv	Paleozoic metavolcanic rocks

pCmv	Precambrian metavolcanic rocks
Metamorphic Rocks (Amphibolite Facies and Higher)	
Mzhm	Mesozoic heterogeneous metamorphic rocks
MzPzhm	Mesozoic–Paleozoic heterogeneous metamorphic rocks
pChm	Precambrian heterogeneous metamorphic rocks
Mzam	Mesozoic amphibolite
MzPzam	Mesozoic–Paleozoic amphibolite
TKgn	Tertiary–Cretaceous gneiss
Mzgn	Mesozoic gneiss
Pzgn	Paleozoic gneiss
Tkog	Tertiary–Cretaceous orthogneiss
Mzog	Mesozoic orthogneiss
Mzmi	Mesozoic migmatite and mixed metamorphic and igneous rocks