Okanogan Highlands Alliance ~ Geology Tour 2014
With Karl Lillquist, Ralph and Cheryl Dawes
A Highland Wonders Educational Event

Introduction:
Two hundred million years ago, what is now the Okanogan Highlands was ocean floor dotted with volcanic islands off the west coast of North America. Since that time, four major geologic processes have formed the Highlands and left their marks in the geologic record. These processes were: subduction, terrane accretion, Eocene extension, and glaciation.

Between 200 and 170 million years ago, tectonic forces generated deep within the earth caused the oceanic crust to converge toward the continent and move beneath the edge of North America in a process called subduction. When subduction started, the volcanic islands and uppermost oceanic crust that lay offshore were shoved into the continent. Rocks added to a continent in this manner are called accreted terranes. The largest accreted terrane in the Okanogan Highlands is known as Quesnellia. Some of the rocks and fossils in Quesnellia are over 200 million years old.

Once accreted, Quesnellia had become part of the North American continent. After 170 million years ago, continuing subduction of the oceanic plate caused a mountain range to uplift along the edge of the continent. Slabs of rock were shoved up along thrust faults, thickening the crust; molten rock intruded deep within the crust, further thickening it and forming granitic rock; and a chain of volcanoes, similar to the present-day Cascade Mountains, erupted at the surface. Rocks deep in the hot, thickened crust recrystallized into new sets of minerals, a process known as metamorphism. The geologic record indicates that this process continued through two or three cycles between 170 and 70 million years ago.

Between 60 and 40 million years ago (roughly a period of time geologists call the Eocene Epoch), the tectonics in the region switched from convergence and thickening of the crust to extension and thinning of the crust. The crust was stretched and broken apart at the same time as volcanic ash and lava erupted from cracks and vents at the surface. The stretching and breaking apart of the crust that occurred at this time created the definitive geologic structures of the Highlands, known as metamorphic core complexes and grabens. The Okanogan metamorphic core complex forms the heart of the Highlands between the Okanogan River, on the west side, and the Toroda Creek and Sanpoil River basins, on the east side.

Between 2.6 million and 12,000 years ago, continental glaciers repeatedly advanced from the north over the region, reshaping the surface of the Okanogan Highlands. The glaciers smoothed the ridges and peaks, caused flat layers of sediment to accumulate on valley bottoms beneath temporary lakes, and deposited terraces of sediment along the sides of valleys. “Erratics,” boulders brought from elsewhere by the flowing glacial ice, were left strewn throughout the Highlands.

The unique combination of bedrock, geologic structures, and glacial features create the wondrous landscape of the Okanogan Highlands.

Stop 1: View of Mt Hull (from Gene’s gas station parking lot along Hwy 97)
11.8 miles from Tonasket School District; 9:15-9:45 a.m. (48°51'47.73"N, 119°24'32.03"W)

This is a good place to consider the big picture of geology in our area, starting with the geology of the core complex that forms the main uplifted area of the Okanogan Highlands. A metamorphic core complex is a zone of granitic and metamorphic rock that was stretched sideways and domed upward at the same time as the colder part of the Earth’s crust above it broke into slabs and slid off to the side. The type of fault along which upper crustal rocks slide down to the side is called a detachment fault.

The lower slopes to the east of us, at the base of Mt. Hull, consist of gneiss. Gneiss is metamorphic rock that recrystallized under high temperature, pressure, and stress into layers of minerals. The higher slopes of Mt. Hull, including the peak, consist of granite. The granite of Mt. Hull is solidified magma that began intruding into the crust around 60 million years ago and continued to intrude for about 10 million years.

At about 50 million years ago, the crust of the Highlands underwent a "tectonic upheaval" as the core complex went through its climactic stage of formation. Hot, partly molten rock inside the complex lifted up and spread out. Slabs of upper crustal rock slid off to the side along detachment faults. Volcanic ash and lava spewed from cracks and vents at the Earth's surface.

Stop 1 is on top of the Okanogan detachment fault. A fault is a surface along which rocks break and move in opposite directions. The Okanogan fault is buried beneath glacial and river sediments here, so we cannot see it directly. The fault slopes down, or dips, inside the earth to the west.

The nearest slopes we can see to the east of us, at the foot of Mt. Hull, were deformed by motion along the fault. Stress from movement on the Okanogan fault sheared some of the gneiss, rendering into layers of broken and deformed minerals. This type of rock, with layers of broken and deformed minerals, is called mylonite.

At our last stop today, Stop 8, we will be on the other side of the Okanogan fault, inside the Okanogan metamorphic core complex, looking at the granite, metamorphic rock, and mylonite.

From Stop 1, one can imagine the glaciation of the Okanogan Highlands and Okanogan Valley.

Stop 2: Chesaw Grade, Glacial Lake Sediments
19.3 miles from Tonasket School District; 10:00-10:45 a.m.
Stop 2a: 48°56'51.49"N, 119°23'12.87"W -- Stop 2b: 48°56'50.80"N, 119°23'15.46"W

There are two stops located across from the pullout, the uphill light-colored fine sand and silt outcrop, and the downhill darker-colored mineral rock outcrop. The uphill location contains fine glacial sediments laid down in a lake, with drop stones berg-rafted in. A coarse band of gravel tells the story of a stream running through the lake, depositing a larger diameter sediment load with its faster moving waters. The downhill outcrop will be interpreted during the event.

Stop 3: Molson drainage
11:00-11:45 (48°58'46.06"N, 119°12'5.69"W)

Standing in the back field of the Molson Schoolhouse Museum is a great place to envision the big picture of glaciation in the region, including the origins of Molson and Sidley lakes. Glaciers sometimes have highly unusual impacts on drainages, as evidenced here with the Baker Creek reverse drainage. You can also see some examples of *roche moutonnée*, a rock formation caused by the movement of the glacier across the bedrock, creating an asymmetrical landform in which rock has been smoothed on one side and plucked on the other. Literally translated from French, the term means "sheep rock" and was first applied to landforms like this in the European Alps.

(**Stop 4: Lunch in Chesaw**, 12:15 pm)

Stop 5: Myers Creek Valley from Byers Road
Arrive at spot by 1:00 p.m. (48°56'51.32"N, 119° 3'13.36"W)

This location offers a view of the Myers Creek valley, with its alluvial fans and "underfit" stream. It is a large valley, but has a relatively small stream – have you ever wondered why? We will discuss this question in the context of a theory about the old pathway of the Kettle River, as well as aspects of the landscape that may have been different before glacial till was deposited, and while the land was covered in ice (e.g. the isostatic effect of the weight of the ice on the land). Big picture bedrock and structural elements will also be discussed.

Note: We are looking at the outside of these landscape features, but wouldn't it be neat if we could look inside a terrace or an esker? Hold that thought during the drive and for the next stop…

(Walk back down to Chesaw, bathroom break; try to leave Chesaw by 2:00 pm or sooner. Note that we will be driving by: 1. marble outcrop, 2. interior of a kame terrace, and 3. on Hungry Hollow road, watch for mounds in the landscape and observe them closely as we drive by.)

Driving by Location 6: **Interior of a Kame Terrace**, along Chesaw road near MaryAnn Creek (48°56'18.11"N, 119° 4'43.19"W) This site of interest provides a view into a kame terrace, and community members may want to stop on their own time in the future. Stop 7 text below also pertains to this location.

Stop 7: Hungry Hollow
2:15-3:00 or 3:15 p.m. (48°54'48.91"N, 119° 6'48.13"W; interesting eskers also can be viewed from 48°55'18.24"N, 119° 6'25.53"W, along the way)

Starting as much as 2.6 million years ago, the Okanogan Highlands were covered several times by an ice sheet that flowed out of western Canada. The most recent ice sheet glaciation of the Highlands ended about 12,000 years ago and left many of the landscape features we see today. As the most recent ice sheet that covered the Okanogan Highlands stagnated and melted, remnant glaciers were left occupying the major valleys. Between the sides of the remnant glaciers and the valley walls, glacial meltwater deposited sand, gravel, and boulders, forming kame terraces. Kames are landforms deposited by flowing water adjacent to and partly in contact with glacial ice. Terraces at more than one elevation along a valley suggest that the glacier melted in stages.

The landscape we are looking at is associated with glacial meltwater and is known as "kame and kettle topography." Kames and associated kame deltas and eskers form from glacial meltwater and associated sediments being deposited within, and at the base of, glacial ice, and indicate downwasting glaciers. This occurs because meltwater atop a glacier thermally and mechanically erodes moulins (i.e., vertical shafts) that deliver sediment to the interior or base of a glacier. This sediment accumulates in thermally and mechanically eroded hollows in the ice. When the ice melts, a variety of topographically positive features appear depending on the original shape of these hollows. Conical hills reflecting roughly circular ice voids are kames while sinuous ridges known as eskers develop in sinuous former meltwater channels. Kame deltas are roughly circular but flat-topped deposits formed when subglacial meltwater channels emptied into subglacial lakes. As such, eskers are often associated with kame deltas. Finally, the depressions seen on kames and kame deltas are kettles, formed by the melting of chunks of glacial ice once buried in glacial drift. From the ground (but much better from the air via Google Earth), we can see an esker in the foreground and kames, kame deltas, and kettles in the background. While it does not appear to be true of these features, kames, eskers, and kame deltas are often the sites of quarries because of the associated well-sorted sands and gravels. Google Earth shows such a quarry or borrow pit north of our stop and just north of the Chesaw Road. There is also sculpted bedrock to view from this location.

These features formed during ice stagnation in the area, near the end of the Pleistocene probably 15,000-11,000 years before present.

Due to the construction of Turner Homestead road and the excavation of gravel, we are able to look into the interior of a glacial landform. Take a close look at the different rock types inside this landform, and the sorting and bedding that occurred. We will discuss the variety of minerals represented here, and the closest bedrock source for some of them. Compare and contrast what you see here with the glacial lake sediments of Stop 2.

Potential Stop 8: Nealy/Havillah Glacial Landscape Vista
Location: at the Nealy/Havillah Road Junction (48°51'25.15"N, 119°10'1.62"W)

This site provides a visual overview of Havillah and surrounding areas, including a view of Mt. Bonaparte and the headwaters of Antoine Creek. From here, glacial cirques can be seen on the north face of Mt. Bonaparte. This site will be interpreted during the event if time allows.

Stop 9: Gneiss Outcrop and Antoine Creek Gorge Overlook
3:45-4:15 or 4:30 p.m. (48°46'29.57"N, 119°19'4.43"W)

Since the last glacial ice melted away (or possibly starting before then), Antoine Creek incised a steep gorge within a broader glaciated valley. Features that can be seen from here include terraces, a flat lake basin, and an old drainage path toward Tonasket for water that flowed east of the glacier. The glacier that filled Okanogan Valley remained for a while after the ice sheet had melted from the Highlands.

Tonasket gneiss crops out along the road. The Tonasket gneiss consists of several types of metamorphic rock, ranging from dark rocks that may have once been igneous rock with the composition of basalt to light-colored rocks that were once granite. Around 50 million years ago, during the Eocene epoch, when the Okanogan metamorphic core complex was lifting up and stretching out and the colder slabs of rock above it were sliding off to the west, stress from the active Okanogan detachment fault sheared the metamorphic and granitic rock into layers of mylonite. See if you can recognize and distinguish gneiss, granite, and mylonite in the outcrop here.

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2014 Route Map