

A Geological Study of the McKenzie Conservation Area, Spokane County, Washington

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INTRODUCTION

The McKenzie Conservation Area consists of 421 acres located along the northwestern shore of Newman Lake in eastern Spokane County. The area is administered by the Spokane County Parks and Recreation Department and became a Spokane County Conservation Futures property in 2005. The site is moderately forested with diverse topography including rocky knolls and ridges, ravines and lowland wetlands. Project goals included, mapping of the bedrock geology (and creation of a geologic map) along with a summary report highlighting field observations. The report will also include “sites of interest” that represent easily accessible geologic features that are characteristic to the park.

The McKenzie area has a long-lived and complex geologic history. The park occurs in the southern part of the Spokane Dome of the Priest River metamorphic complex (PRMC), (Doughty, et al. 1997). The bedrock geology here is composed primarily of Newman Lake Gneiss, a Mesozoic-aged granitic orthogneiss (Derkey, et al., 2004b, Armstrong, et al., 1987). Bedrock exposure consists of less than 10% of the total land area. Throughout the park, the Newman Lake Gneiss exhibits strong foliation, mineral lineation, and pervasive mylonitization. The mylonitization (blastomylonite) is characteristic of the upper part of the PRMC within the Spokane Dome mylonite zone. Bedrock knobs and adjacent gullies have a consistent NNW-trend suggesting possible structural control to topography. Scattered throughout the park are pegmatite veins and ice-rafted glacial erratics. There are also several seasonal streams and seeps, which ultimately drain eastward into Newman Lake.

The park area has numerous exposures of basic to complex geology that are easily accessible by the existing trail network. Findings from this undergraduate service-learning research project could be utilized by the public that visit the park for the purposes of earth science education.

MAPPING

Field mapping of the park was done during four separate field visits in October and November of 2013, and in March of 2014. Approximately 20 hours were spent walking the various trails as well as off trail documenting the bedrock geology. The original base map used to develop the site map was the U.S.G.S. Newman Lake 7.5 Minute Quadrangle (1:24,000), which was enlarged to a scale of 1 inch (on the map) equals 500 feet. Individual bedrock sites were located onto a topographic map and GPS coordinates were taken at each site. Where possible, foliations and lineations were taken and recorded. A generalized geologic map is seen in Figure 1 and GPS site locations are shown in Figure 2. Data from the individual stations is in Appendix A.

LANDMARKS

Numerous landmark names are used throughout this report for location purposes and include:

- *Hill 2450* is the prominent hill labeled in the central portion of the study area.
- *Eagle Ridge* is the NW-SE trending ridge along the eastern portion of the area.
- *The Ridge* is the main NW-SE trending ridgeline along which an established hiking trail occurs.
- *The Gully* is a prominent drainage north of *Hill 2450* and has a seasonal stream.
- *Turtle Rock* is a local name for the bedrock knob along the lake near the McKenzie boathouse.

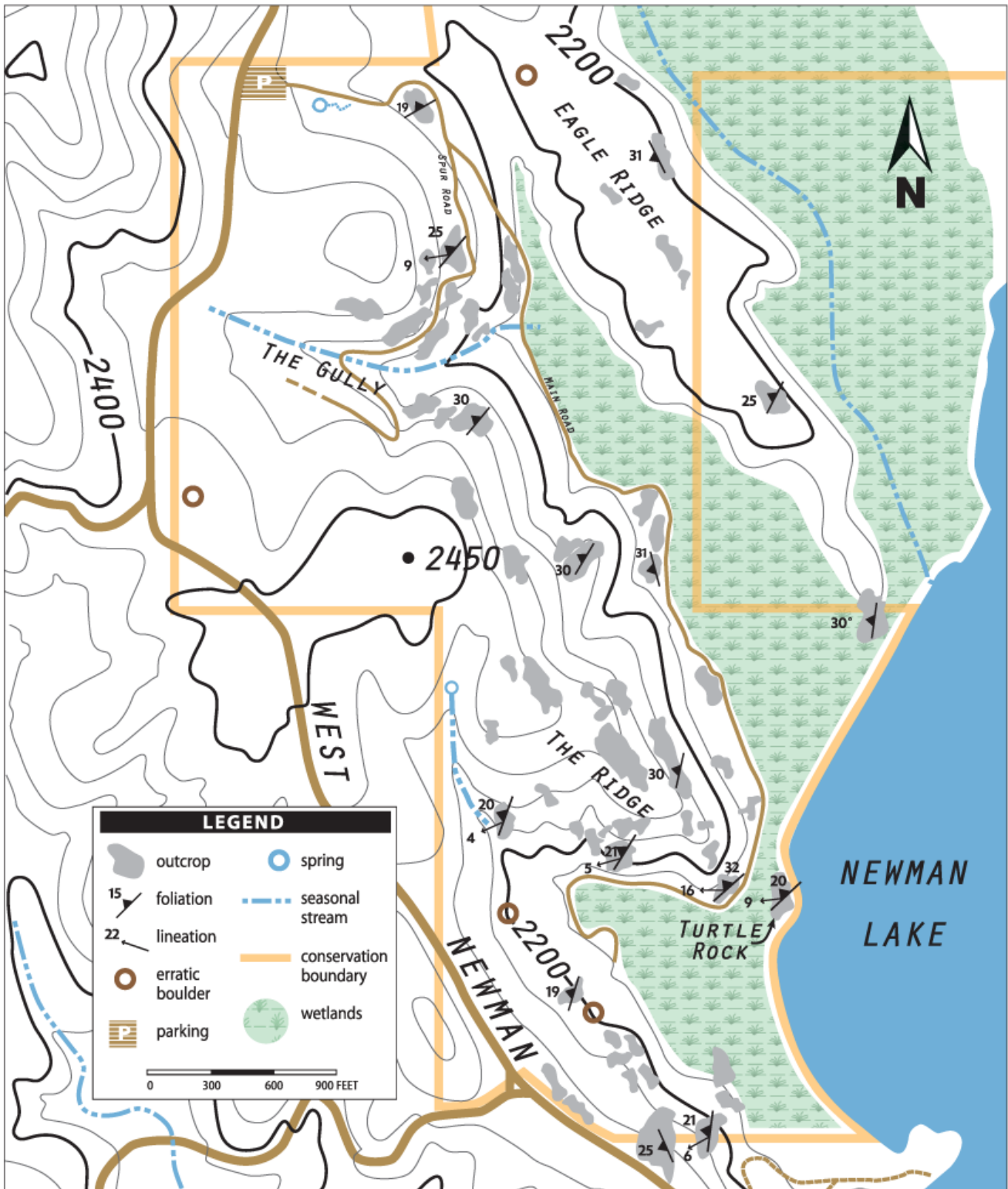


Figure 1: outcrop geology map of the McKenzie Conservation Area.



Figure 2: Google Earth map of the McKenzie CA with GPS station locations.

BEDROCK GEOLOGY

The major bedrock type throughout the McKenzie CA is the Newman Lake Gneiss (Fig. 3). The Newman Lake Gneiss is a light-colored, coarse-grained megacrystic, moderately to well-foliated orthogneiss of granodiorite composition. Orthogneiss is the term given to high-grade (pressure-temperature) metamorphic rocks that formed from the recrystallization of an igneous parent (protolith). In the case of the Newman Lake Gneiss, the original parent rock before metamorphism was an igneous granodiorite. Characteristic minerals found within the Newman Lake Gneiss include quartz (gray, glassy), orthoclase (milky white), plagioclase (white to gray), and biotite mica (shiny, black). Large megacrysts (crystals up to 10 cm.) of orthoclase appear throughout the unit.

Occurring sporadically throughout the study area are light-colored pegmatite masses (Fig. 4, 5). Pegmatite is a very coarse-grained crystalline rock of granitic composition. Pegmatite within the study area consists of large crystals (> 2 cm.) of quartz, orthoclase, plagioclase, and muscovite (mica). The pegmatite masses occur as veins (<20 cm. wide) or as truncated pods.



Figure 3: foliated Newman Lake Gneiss with Kspar megacrysts, coarse quartz and biotite. Note that fractures and weathering patterns are parallel to foliation (Site #34).



Figure 4: large Kspar megacrysts in Newman Lake Gneiss; a pegmatite vein is in the upper left (Site #45).



Figure 5: close-up of pegmatite with coarse crystals of white Kspar, gray quartz, and silvery-clear muscovite (Site #40).

ROCK TEXTURES, FABRICS, and STRUCTURE

The dominant bedrock unit, the Newman Lake Gneiss, exhibits a coarse-grained, crystalline texture. In most outcrops, the original igneous “megacrystic” texture with large, well-formed crystals of orthoclase feldspar can be seen. The dominant fabric element observed is foliation resulting from metamorphic recrystallization. Foliation is a rock fabric in which mineral crystals show a preferred parallel alignment or planar pattern. Throughout the park, the Newman Lake Gneiss exhibits pervasive foliation as seen by aligned biotite crystals. So, the original igneous plutonic texture of the Newman Lake Gneiss has been affected (recrystallized) by later high pressure and high temperature regional metamorphism creating a pervasive foliated fabric. The average strike of foliation is 210° , with dips ranging between 20° - 45° NW. A good location to observe the foliation and megacrysts within the Newman Lake Gneiss is at Turtle Rock.

Another fabric element observed, but less obvious, is a pervasive mineral and stretching lineation. Lineation is defined as a linear orientation (vs. planar) pattern of minerals or features within a rock. Mineral or stretching lineations are most often associated with shearing or shear zones related to faulting. The mineral lineations in the Newman Lake Gneiss are defined by elongated quartz (+/-feldspar-biotite) aggregates, and rare quartz ribbons. Lineations plunge gently (4° - 16°) with an average trend of 252° . A plot of the poles to foliations along with lineations is shown in Figure 6.

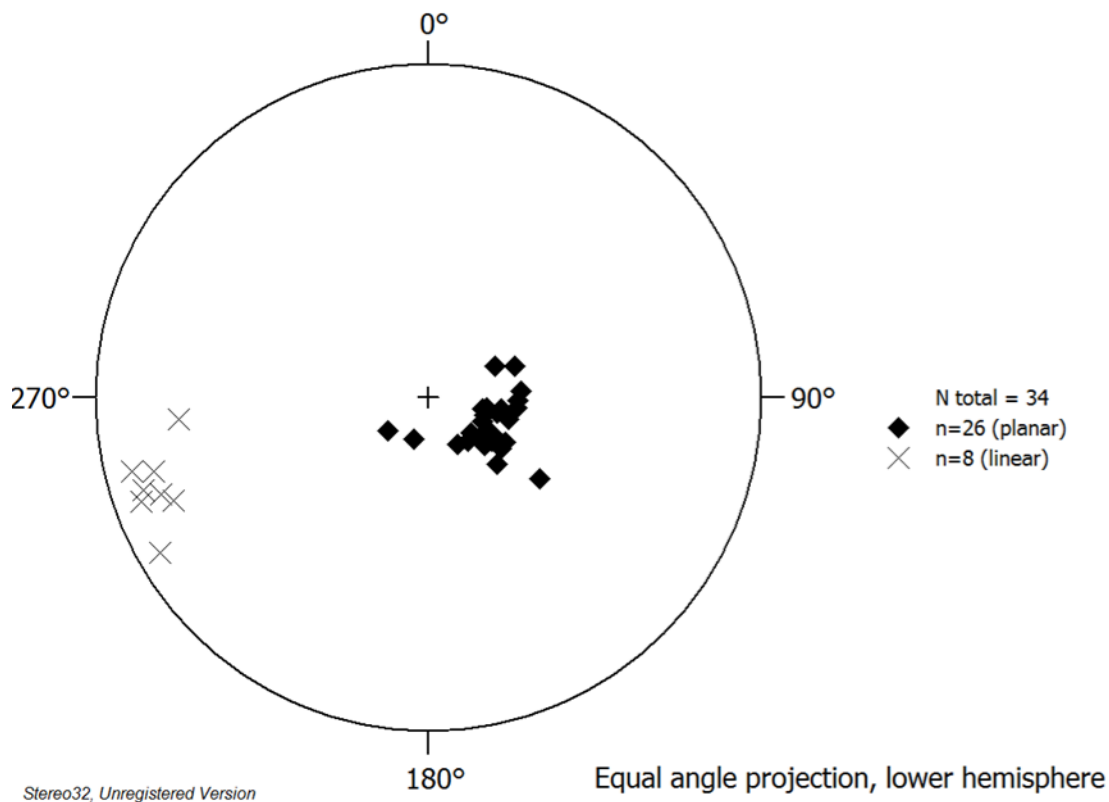


Figure 6: lower hemisphere plot of the poles to foliation (diamonds), and lineations (X) from the McKenzie Conservation Area. Poles to foliation are consistent and show a northeasterly strike with gentle dips to the northwest. Lineations are consistently plunging gently to the west-southwest.

Throughout the park, the Newman Lake Gneiss exhibits variable degrees of mylonitization (Figures 7, 8, 9). Mylonite is a rock fabric that results from significant shear-related deformation due to squeezing and flattening. At McKenzie, the original igneous texture is still somewhat observable, but due to shearing-related cataclasis (grinding and crushing) and metamorphism (recrystallization), moderately developed blastomylonite fabric is dominant. Locally, zones of very intense mylonitization occur as bands of ultramylonite.

Ultramytonites are typically fine-grained and somewhat glassy in their appearance. They can be light to dark-colored depending on the mineral make-up. At McKenzie, ultramytonite is fine-grained, milky white to dark gray in color and occurs in narrow bands (<30 cm). One unusual occurrence of strongly mylonitic rock contains a high percentage of biotite (phyllosite) and is almost black in color with small, highly deformed porphyroclasts of feldspar. This occurrence is along the gravel road just WNW of Turtle Rock.



Figure 7: close-up of moderately mylonitized (blastomylonite) Newman Lake Gneiss. Note the moderate amount of grain size reduction, especially of the white feldspars. The Kspar megacrysts have been reduced significantly in size by pulverization during mylonitization. Also note the pods of gray quartz.



Figure 8: close up of strongly mylonitized Newman Lake Gneiss. Note the significant grain size reduction where Kspar megacrysts and the original igneous texture are no longer recognizable.



Figure 9: close-up of ultramytonite where all original texture has been destroyed during mylonitization. Note one remaining Kspar megacryst in the upper part of the rock.

No obvious folds or faults were observed directly at the McKenzie area. However, based on characteristic surface topography, it appears that the area may be the result of some kind of structural control. At McKenzie, there are several defined ridge lines of bedrock and parallel and adjacent gullies or ravines. The general trend of these ridges and gullies is in a NNW orientation (Fig. 1). This pattern has been observed in several other areas within the Spokane region (Derkey, et al., 2004, Vaughn, et al., 2013). This trend has been interpreted as a series of bedrock fracture zones (or possible faults) where weathering and erosion is concentrated (in the fracture zones) causing gullies or ravines to form.

TEXTURE AND FABRIC: DISCUSSION

The combination of well-developed foliation and lineation along with mylonitic fabric indicates that the rocks at McKenzie have undergone a significant amount of deformation as a result of being subjected to intense stresses. The lineated and mylonitic fabric seen here is typical of rocks from other parts of the Spokane Dome mylonite zone, which is part of the Priest River metamorphic complex (McCallum and Buddington, 2009, Derkey, et al., 2004, Doughty, et al., 1997). The foliation and lineation data are consistent with studies done from other parts of the Spokane Dome mylonite zone and the Priest River complex in general. Our study indicates that lineations are plunging to the WSW but that kinematics show that movement was to the ENE (up-plunge).

The mylonite at McKenzie represents part of a large shear (fault) zone that occurred at depth within mid-levels of Earth's crust (Doughty, et al., 1997). This shear zone resulted as portions of the deep crust were being uplifted and sections of the upper crust began to detach causing intense squeezing and sliding pressures. The original Newman Lake granodiorite was caught up in this deep shear zone metamorphosing it into gneiss and causing it to become mylonitized (blastomylonite). The less common, narrow ultramylonite zones represent more localized, high intensity strain zones within the overall shear zone. Studies indicate that this process occurred between 40 to 50 million years ago (Doughty, et al., 1997). Eventually the entire portion of the Priest River complex (including the McKenzie area) was uplifted and eroded by surface processes to expose what we see today.

SURFICIAL GEOLOGY

Surficial geology represents all the non-bedrock geological features or surface processes examined at the McKenzie Conservation Area. Surficial geology includes soils, weathering patterns, glacial features, and hydrology. In this report, we will discuss the surface weathering features along with glacial and hydrological relationships; soils and soil development is excluded.

Spheroidal Weathering

Spheroidal weathering is a dominant surface weathering pattern observed throughout the park area (Figures 10, 11, 12). Spheroidal weathering is the result of chemical weathering of rock that occurs at or very near the surface. Rock masses that have undergone spheroidal weathering typically exhibit a characteristic rounded or spherical shape. Chemical weathering by water will occur more rapidly along the corners or edges of an initially angular rock mass. With time, the chemical attack along the corners and edges causes the rock to develop into a rounded shape. In many cases, spheroidal weathering of rock can be confused or misidentified as glacially or water transported (and abraded) erosion features. For example, some spheroidally weathered rock masses have been misidentified as glacial erratics. Spheroidal weathering occurs "in place" and is not a form of transport-related erosion.

At the McKenzie CA, the primary bedrock unit is the well-foliated Newman Lake Gneiss. Spheroidally weathered rock masses at the McKenzie CA are foliated gneiss and the foliation orientations are parallel to and consistent with adjacent in-place bedrock. This indicates that the spheroidally weathered masses have not

been transported, but rather have weathered in-place. In other words, the many numerous rounded boulder masses seen throughout the park are not the result of glacial or flood-related transport.

The best place in the park to examine spheroidal weathering is along the trail segment that traverses “*The Ridge*”. Along this trail section are rounded, in-place masses of Newman Lake Gneiss that have undergone variable levels of spheroidal weathering.



Figure 10: spheroidal weathering of bedrock gneiss along “The Ridge” area.



Figure 11: spheroidal weathering of bedrock along “The Ridge” area. Note that the foliation is parallel to and consistent with underlying bedrock.

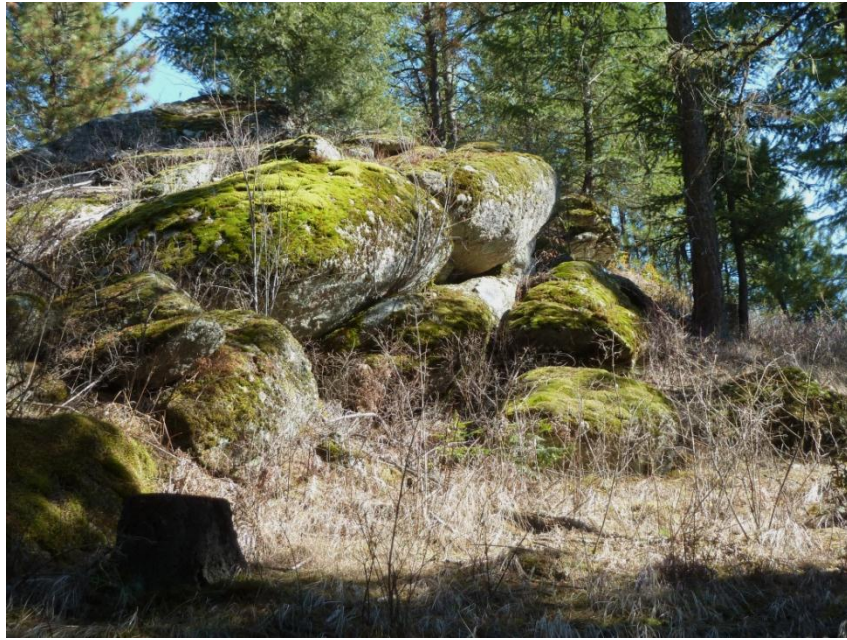


Figure 12: typical outcrop of spheroidally weathered bedrock gneiss (Site #28).

Glacial Erratics

Although the majority of rounded or spherical shaped rock masses at the park are the result of spheroidal weathering, there are several isolated occurrences of erratic boulders (Fig. 13, 14). Glacial erratics are rounded rock masses that have been transported significant distances from their original source location and are typically composed of a different rock type than the surrounding local bedrock. In this study, three occurrences of rounded, erratic boulders (0.5 to 2.0 meters in diameter) were identified. The compositions of the boulders range from non-foliated granite to non-foliated, medium-grained diorite. Interestingly, several small, well-rounded cobbles of quartzite and granite were found along the trail of the northern park boundary of “*Eagle Ridge*” (Fig. 15). Granite, diorite, and quartzite are common bedrock types found in northern Idaho and western Montana. The erratic boulders and cobbles are of igneous and sedimentary origin and are not composed of Newman Lake Gneiss.



Figure 13: ice-rafted erratic boulder of non-foliated granite from Eagle Ridge area (Site #41).



Figure 14: ice-rafted erratic boulder of non-foliated diorite (Site #22).

Throughout the Spokane and Inland Northwest region, countless examples of “transported” rock boulders or masses occur. There are at least three possible mechanisms for the transport and deposition of these erratic boulders. One possible transport mechanism could have been by the massive glacial outburst floods, the Great Missoula Floods, where boulders of rock were moved and abraded directly by the floodwaters. This would be similar (but on a much greater scale) to the way flooding streams transport and erode boulders. A second possible transport mechanism would involve direct movement of boulders by glacial ice. Many glacial erratics in the Midwestern U.S. have been transported and deposited this way during the last major glacial advance during the Pleistocene ice age. A third transport mechanism would involve the rafting of boulders within glacial icebergs and then later deposited as dropstones (ice rafted erratics) as the icebergs melted.

Since this study has not positively identified any glacial till or moraines, the mechanism for direct deposit by a glacier is not likely. In general, glacial ice transport and deposition results in the accumulation of glacial till in the form of moraines. No moraines were recognized at the McKenzie CA. Likewise, if the erratics found at the park were the result of Missoula floodwater transport, we would expect to find stratified drift exposures. No stratified drift was identified. Our favored hypothesis for the erratics identified would involve the transport by icebergs and the deposition as dropstones.



Figure 15: rounded cobbles of quartzite, granite. These are interpreted as ice-rafted erratics from source rocks in northern Idaho and western Montana (on road between sites #41-42).

A recent study just west of the park suggests that the Newman Lake area was once part of a large, glacial lake, glacial Lake Columbia (Kienke and Buddington, 2007). Glacial Lake Columbia was the result of an ice dam at Grand Coulee that caused water to back up the Spokane River drainage all the way to the eastern end of the Spokane Valley and possibly as far north as the Rathdrum Prairie. The Kienke and Buddington study establishes that lake sediments occurred at elevations of 689 meters (2235 feet). This suggests that much of the Newman Lake area would have been under water and in essence would have been a large bay or inlet to the greater Lake Columbia. The Kienke and Buddington study also found the presence of glacial dropstones within the lake bed sediments. So, it appears that icebergs calved from the terminus of the glacier occupying the Sandpoint-Lake Pend Oreille area, and likely carried the erratics found at the McKenzie CA. Hence, we believe that the numerous erratics found at McKenzie are indeed ice rafted erratics.

Hydrology: Seasonal Streams, Seeps, and Wetlands

The McKenzie Conservation area is situated on an eastward-sloping hillside and all surface drainages ultimately flow into Newman Lake. This study identified three seasonal stream systems within the park and these streams typically flow during the wettest, springtime months of the year. The largest system occurs in the northern portion of the park and originates from two seasonal tributaries north (Shady Lane) and northwest of the park boundary. This seasonal stream flows to the southeast via culverts under West Newman Lake Drive and then along the eastern side of Eagle Ridge, eventually flowing into Newman Lake north of Turtle Rock. The second seasonal stream originates from a manmade pond just to the west of the park boundary along West Newman Lake Drive. The pond is part of the privately held Pettibone property and a culvert under West Newman Lake Drive drains overflow from the pond into this drainage. This system drains in an easterly to southeasterly direction eventually ending in the wetlands southeast of the parking area and just west of Eagle Ridge (Fig. 16). The third and smallest of the drainages originates from a seep/spring within the defined gully just south of Hill 2450. This stream flows southeasterly and ends within the wetlands due west of Turtle Rock (Fig. 17).

There are several extensive wetland areas throughout the park and although this study does not address wetland dynamics, these geomorphic and important biologic areas are worthy of brief discussion. The largest wetland tract occurs in the northernmost portion of the park south of West Newman Lake Drive. The second



Figure 16: seasonal stream from *The Gully* drainage. This photo was taken from the main road looking east into the wetlands. The photo was taken in May, 2014.



Figure 17: small seasonal stream draining the gully south of *Hill 2450* and west of *The Ridge*. The photo was taken in April, 2014. This stream drains into the wetlands south and west of *Turtle Rock*.

wetland is located west of Eagle Ridge all the way down to the shore of Newman Lake (Fig. 18). During much of the winter and spring, this wetland is partially submerged in water although no obvious flowing channel was observed. Drainage of this wetland is to the southeast into Newman Lake just north the boathouse and Turtle Rock. The third wetland occupies the southern portion of the park and drainage through this area comes from the seasonal stream to the northwest and hillslopes to the west. The water table in each of these wetlands fluctuates by season. In the southernmost wetland, a pit that had been dug by previous owners, filled with water in February and March of 2014 and we interpret this to represent the water table in this area (Fig. 19).



Figure 18: extensive wetland area southwest of *Eagle Ridge* along the main road from the parking area to Turtle Rock. This view is to the east.



Figure 19: groundwater filled trench in the low-lying wetland area along the main trail west of *Turtle Rock*. Note that when this photo was taken (March, 2014), the water table in the wetlands is very shallow.

Turtle Rock and Prehistoric Lake Levels

Turtle Rock is an obvious bedrock feature along the shore of Newman Lake in the southeastern portion of the park. It is composed of foliated Newman Lake Gneiss and is an erosional remnant of “The Ridge” to the northwest. Although Turtle Rock exhibits moderate degrees of spheroidal weathering, along its east face is a defined erosional undercut (Fig. 20). We interpret this undercut to be the result of wave erosion during a time when lake levels were higher. During higher lake level periods, presumably post Lake Columbia time, the low wetland areas throughout the park and surrounding Turtle Rock were inundated by the higher lake levels. This study was unable to establish the timing of when the lake was higher, however a future sediment coring study of the wetlands could test this hypothesis and establish a date for lake level changes.



Figure 20: Turtle Rock is a knob of bedrock gneiss that exhibits spheroidal weathering (rounded shape) and erosional undercutting. Note the distinctive “undercut” on right side (western); Newman Lake is to the right (Site #8).

GEOLOGIC HISTORY OF THE MCKENZIE AND NEWMAN LAKE AREAS

The known geologic history of Newman Lake area and its immediate surroundings can be traced back to about 1.1-1.4 billion years ago. Along the southern portions of Newman Lake is the Hauser Lake Gneiss. Geologists that have studied this metamorphic rock formation believe that it was once a sedimentary rock that was deposited in an ancient ocean approximately 1.4 billion years ago (Doughty, et al., 1997). The Hauser Lake Gneiss has been correlated to the Prichard Formation, which is part of the thick sequence of Proterozoic-aged (Precambrian) sediments of the Belt Supergroup of northern Idaho and northwestern Montana. This area was part of a massive basin that became a large inland sea. During this time sea levels rose enough to inundate large portions of northeastern Washington, northern Idaho, and western Montana. Within this large inland sea, known as the Belt Sea, thick layers of sediment were deposited over a very long period of time. These sediments were then lithified (cemented) into sedimentary rock. The Prichard Formation was part of this sedimentary sequence.

Fast forward to about 140-200 million years ago, during Earth’s Mesozoic time period, a large magma chamber intruded (invaded) the sedimentary layers deep underground. As it cooled, the magma turned into a coarse-grained igneous rock called granodiorite, which is very similar to granite, a rock commonly used for countertops. This granitic intrusion would one day become the rock that occurs as the bedrock formation underlying the McKenzie CA and the northern portion of Newman Lake all the way to just south of Mt. Spokane.

Approximately 100 to 150 million years ago, during Mesozoic time, collision of the plates beneath Earth’s crust caused the deep burial of the sedimentary layers and granodiorite. This tectonic activity led to metamorphism of the rock here at the park. Metamorphism occurs when minerals in a rock are changed due to contact with high amounts of heat and pressure. The change from one type of rock to another occurs without melting the original rock. There are two basic types of metamorphism, regional and contact. Contact metamorphism occurs at high temperatures, with no pressure. Regional metamorphism also occurs at high temperatures; however, this type of metamorphism is characterized by immense pressure when tectonic plates of crust collide. This pressure causes the visible parallel alignment of minerals (foliation) in the rock. Locally, the deep burial of the granodiorite caused it to be regionally metamorphosed into gneiss, the well-foliated metamorphic rock we see throughout the park. In 1968, a geologist named Paul Weiss identified and named this particular

unit of rock the “Newman Lake Gneiss” (Weiss, 1968). Later work by local geologists has confirmed much of what Weiss proposed (Derkey et al., 2004a & 2004b).

Eventually, the collision of the plates ceased, and about 40 million years ago, a very interesting thing happened. The plates began to relax and extend apart! This is the very nature of plate tectonics. The plates, miles beneath our feet, are constantly moving, shifting course, and reshaping our Earth. This change in tectonic activity led to a regional uplift of Earth’s crust, including the Newman Lake Gneiss. Extensive faulting (fracturing and displacement) of the uplifted crust began to occur at that time. A large fault, termed a detachment fault, developed deep in the crust as it was being uplifted (Fig. 21). The detachment fault allowed the crust to separate and slide during uplift, with the upper portion of the crust detaching and sliding off the rising lower, deeper crust. This detachment and the shearing motion (and stress) caused the mineral lineations and mylonites we see at the McKenzie CA to form. This detachment fault is part of the large uplifted area in northeast Washington and northern Idaho known as the Priest River complex (Doughty, et al., 1997). This “core” complex represents the deep crust that domed up during this period of crustal extension. The Newman Lake area is part of what geologists call the Spokane Dome mylonite zone, which is a zone of intense mylonite development and uplift.

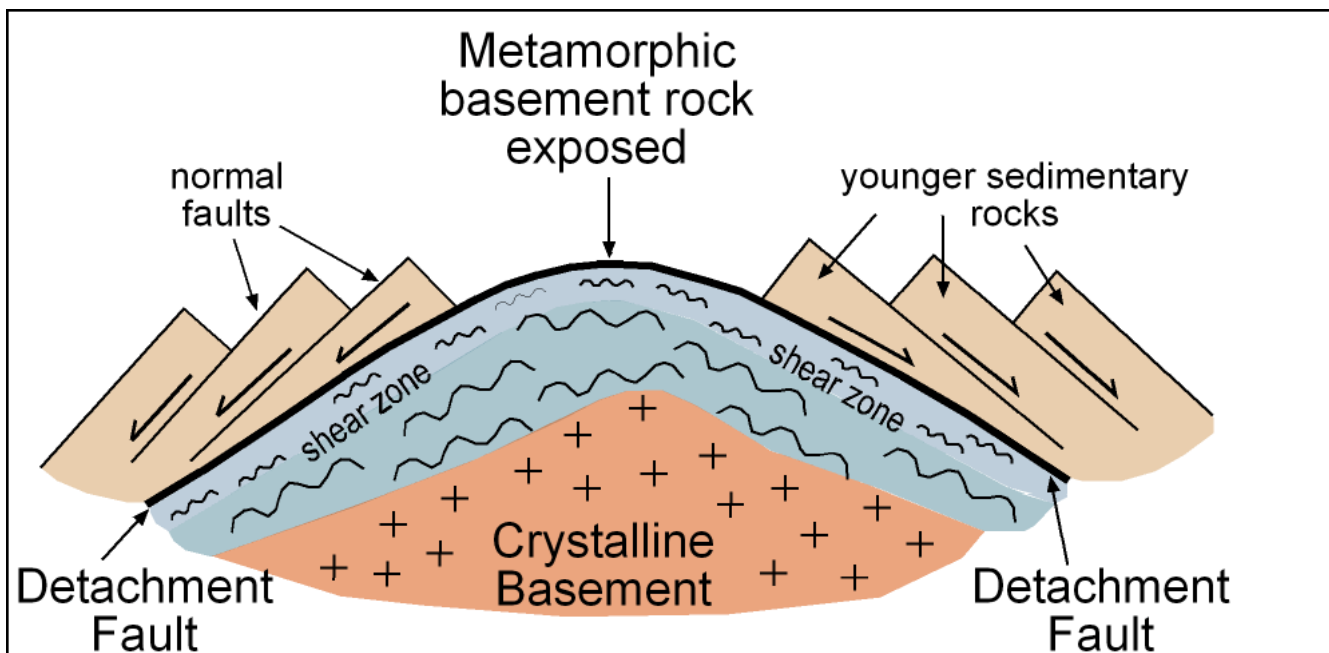


Figure 21: Simplified cross section of a metamorphic core complex with domal internal “core” and detachment fault and associated shearing (mylonite zone). The McKenzie CA is part of the Spokane Dome, which is part of the greater Priest River metamorphic core complex. The McKenzie area exhibits rocks and textures that are typical of the mylonitic shear zone directly below the detachment fault. (from Link, 2006)

Close to 17.5 million years ago, during the Miocene Epoch, huge amounts of lava erupted and flowed over much of the Pacific Northwest, including the Spokane Valley. The lavas, referred to as “Columbia River Basalts”, cooled into a fine-grained, dark-colored igneous rock called basalt. Thick layers of this basalt can be observed throughout Spokane and eastern Washington. However, no Columbia River basalt was observed within the McKenzie CA during this study. Why? To understand this, we must examine the most recent geological events to affect our region.

In more recent times, approximately 15-20 thousand years ago, numerous massive floods marked the end of the last ice age. These floods are thought to be some of the largest floods ever in Earth’s history. The floods were caused by the periodic emptying of glacial Lake Missoula, a 3000 square mile lake in Montana that held about 500 cubic miles of water. These catastrophic “outburst” floods resulted when the lake waters of Lake Missoula became so high, the ice dam holding back Lake Missoula collapsed. When the flood waters reached

this area, they were traveling at about 60 miles per hour, and were several miles wide and 300 to 400 feet deep! The raging torrent scoured out the valley we see here today, eroding it into a much deeper and wider valley than had been here before the floods. These “Missoula Floods” were slowed somewhat by the fact that this area was at the bottom of another glacial lake, Lake Columbia. As this towering force of nature met Lake Columbia, it dropped a lot of its bedload, sediment consisting of coarse sands, gravels, and boulders. The combined mass of water then sped off to the west and southwest as one herculean flood, ripping apart the landscape in a frenzy of torrential violence on its way to the ocean. The Columbia River basalt that presumably once covered the Newman Lake area was likely ripped up and eroded away.

The present-day McKenzie Conservation Area is located right on top of a 421 acre section of the Newman Lake Gneiss. The gneiss is exposed in numerous outcrops throughout the park. This durable metamorphic rock has withstood the forces of millions of years of violent tectonic activity, and several thousand years of catastrophic flooding, weathering, and erosion. Today, the park appears as a peaceful place where geologic change is hardly observable. Yet, when we look closer at the rocks and the various surface features and process, what we can see is a dynamic, yet slowly evolving landscape, which today is but just a snapshot in a long history of geologic development.

SITES OF INTEREST

The following “Sites of Interest” are sites identified that may be of interest to users of the park. We have picked sites that would be easily accessible from the existing trail network at the McKenzie CA.

Ice Rafted Erratics

There are several occurrences of ice rafted erratic boulders throughout the park. In this section, we’ll describe two occurrences that are easily accessible via the hiking trails in the park.

Erratic-1: this ice rafted erratic is located east of the walking trail along the far western part of the park on the northwest side of Hill 2450. This erratic is a medium-grained, non-foliated igneous rock of intermediate composition, presumably a diorite. It is a rounded, moss covered boulder that is approximately 1.0-1.5 meters in diameter and has been split in half to expose its interior. This has been interpreted as an ice rafted erratic because of its rounded form and its composition is unlike any of the bedrock seen throughout the park.

Erratic-2: this large (2.0 meter diameter) semi-rounded erratic is located just above and west of the walking trail from the Peninsula Trailhead. It is almost entirely covered with moss and small trees and can be easily missed. This boulder is composed of coarse-grained, non-foliated granite containing the mineral hornblende (black color). The non-foliated nature and the presence of hornblende indicate this rock is not part of the local bedrock, but has been transported as an ice rafted erratic.

Turtle Rock: this large bedrock remnant is just south of the boathouse along the shore of Newman Lake. It is comprised of well-foliated gneiss and along several of the exposed faces, the foliation is obvious, and large orthoclase feldspar megacrysts can be easily observed. Upon close examination, one can see white pegmatite veins that have been stretched and deformed (lineated). The pegmatite veins are composed of coarse white feldspar and gray quartz with muscovite mica. At the base of the east side of Turtle Rock is a well-defined undercut approximately 1.5 meters in height. This undercut was likely the result of prehistoric wave erosion.

Mylonite

Mylonite occurs at numerous locations throughout the park. The most accessible sites will be described here.

Mylonite-1: this location of mylonite occurs within the banks of the main road just before the boathouse. The mylonite can be recognized as a creamy white-colored rock to strongly foliated gneiss that has a flat, “slate-like” appearance and because it breaks into relatively flat slabs. Although the exposure here is poor, rubble (float) exhibits excellent mylonite characteristics. The light colored mylonite is highly deformed (stretched and flattened) pegmatite and the darker grey mylonite is highly deformed gneiss. Upon close examination, lineations can be seen as faint, cryptic parallel lines within the rocks. This mylonite represents a high strain zone within the bedrock that resulted from intense shearing when the rocks were at significant depths within the crust as the Spokane Dome detachment zone developed.

Mylonite-2: this site is along the main road just around the point from Mylonite-1 and northwest of the boathouse and Turtle Rock. This low-lying outcrop directly adjacent to the road contains strongly mylonitized (well-foliated and lineated), biotite-rich Newman Lake Gneiss. One notable characteristic of the outcrop is its relatively dark color, and this is because of its very high biotite (black mica) content. Upon close examination, the strong foliation is obvious and there are lenticular zones or stringer-like pods of white feldspar that have formed due to shearing of the rock. The pattern of shearing is demonstrated by the parallelism of the pod-shaped feldspar and foliated biotite. As with Mylonite-1, this is the result of intense shearing during the uplift and detachment of the Spokane Dome mylonite zone.

The Ridge and Spheroidal Weathering: spheroidal weathering is a dominant feature seen in most of the exposed bedrock throughout the McKenzie CA. The best and most accessible places to see spheroidal weathering is along the trail that traverses the main ridge southward to the main road near the boathouse. All along this ridgeline are excellent exposures of spheroidally weathered bedrock including rounded to semi-rounded masses as well as boulder-like forms. Upon close examination, the rock masses are all composed of foliated gneiss that have been weathered in place. In other words, these should not be confused with flood or ice transported boulders. This section of trail would make for an excellent teaching opportunity of K-12 students learning about weathering, erosion, and landform development.

Seasonal Stream: an excellent example of a seasonal stream can be seen along the spur trail that connects the main road to the western trail. The stream flows within what we have called “The Gully” and the spur trail crosses this seasonal stream near the upper portions of The Gully. This small stream is approximately 1.0 meter wide and only flows during the wet season of late winter and early spring. Another location where this stream can be examined is along the main road at the lower end of The Gully where it passes under the road via a culvert into the wetlands to the east.

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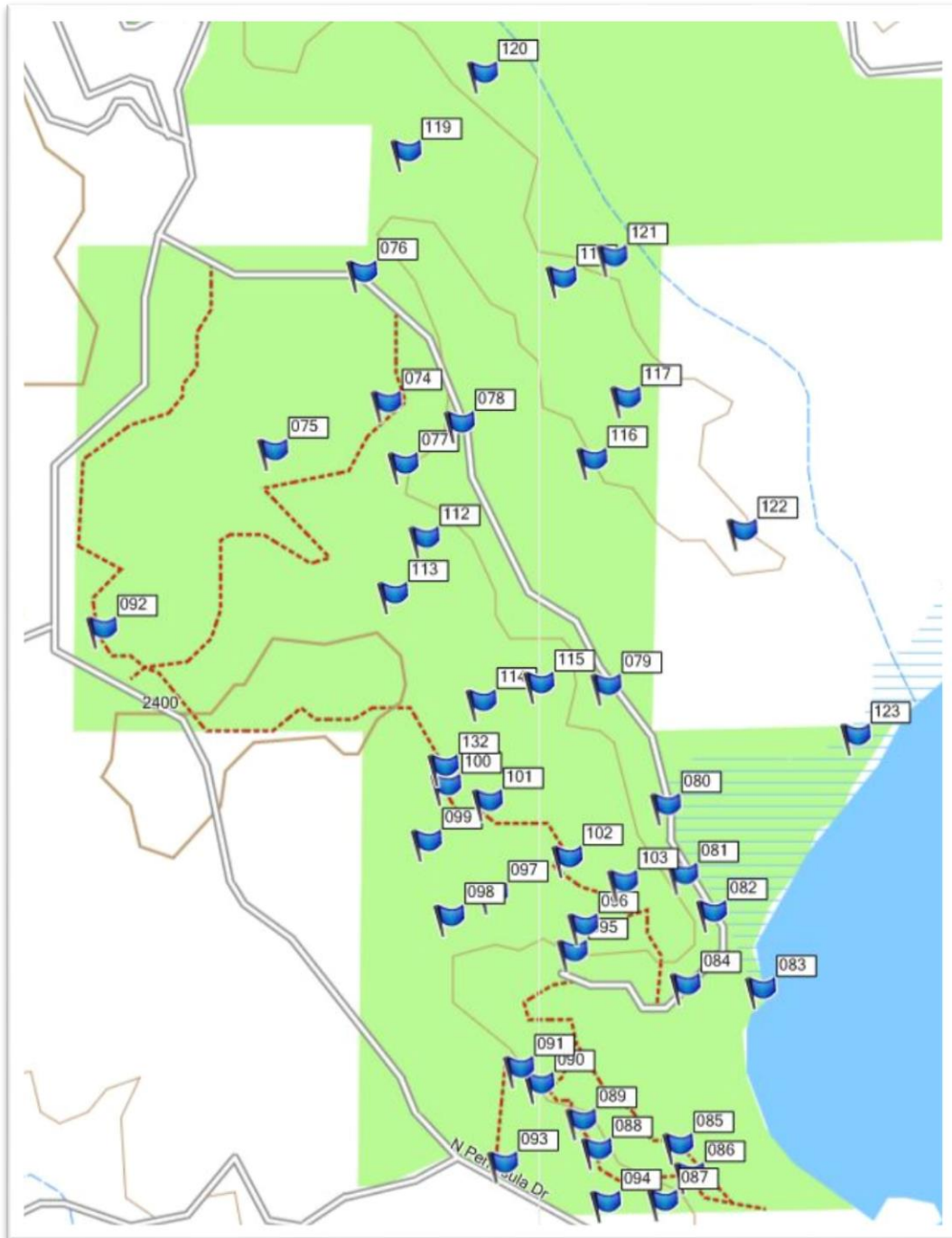
APPENDIX A: table of site/station information.

Site #	GPS #	Lat/Long	Rock Type	Foliation			Lineation		Misc.
				Strike	Dip		Plunge	Trend	
1	74	N 47° 47' 55.6" W 117° 07' 01.2"	Orthogneiss	220	25	NW	9	250	megacrysts of Kspar appx 1-3 cm
2	75	N 47° 47' 53.0" W 117° 07' 08.6"	Orthogneiss	216	45	NW			
3	76	N 47° 48' 02.6" W 117° 07' 02.8"	Orthogneiss	238	19	NW			
4	78	N 47° 47' 54.5" W 117° 06' 56.4"	Orthogneiss	220	19	NW			
5			Orthogneiss	193	24	NW			
6	79	N 47° 47' 40.5" W 117° 06' 46.9"	Orthogneiss	176	31	W			
7	80	N 47° 47' 34.1" W 117° 06' 43.0"	Orthogneiss	214	22	NW	5	256	Good lineations at this site
8	83	N 47° 47' 24.2" W 117° 06' 36.8"	Orthogneiss	228	20	NW	9	255	Turtle Rock has good lineations and good lineated pegmatite veins
9			Orthogneiss						
10			Orthogneiss	189	25	NW			
11	77	N 47° 47' 54.5" W 117° 07' 00.1"	Orthogneiss						Large moss covered out cropping above main road.
12	81	N 47° 47' 30.3" W 117° 06' 41.9"	Orthogneiss						This site appears to be a high strain zone, with float of creamy colored ultramylonite
13	82	N 47° 47' 28.3" W 117° 06' 40.0"	Orthogneiss	321	18	W			Poor outcrop of weathered rock
14	84	N 47° 47' 24.4" W 117° 06' 41.7"	Orthogneiss	224	32	NW	16	265	Strongly foliated, biotite rich Gneiss Good mylonite
15	85	N 47° 47' 15.9" W 117° 06' 42.2"	Orthogneiss						Moss covered
16	86	N 47° 47' 14.3" W 117° 06' 41.4"	Orthogneiss	215	26	NW	4	240	Good lineations at this site
17	87	N 47° 47' 12.8" W 117° 06' 43.2"	Orthogneiss	190	20	NW	6	252	Narrow zone 6-8 inches thick of strong mylonitic to ultramylonite. Possible shear zone.
18	88	N 47° 47' 15.6" W 117° 06' 47.5"							Moss covered

Site #	GPS #	Lat/Long	Rock Type	Foliation			Lineation		Misc.
				Strike	Dip		Plunge	Trend	
19	89	N 47° 47' 17.2" W 117° 06' 48.5"	Orthogneiss						Scattered outcrop along trail, below and at trail.
20	90	N 47° 47' 19.2" W 117° 06' 51.2"	Granite						This is an igneous rock, semi rounded edges. Non-foliated ice rafted erratic
21	91	N 47° 47' 20.0" W 117° 06' 52.6"	Orthogneiss	192	19	NW			Small outcrop
22	92	N 47° 47' 43.5" W 117° 06' 19.8"	Diorite						Fine grained to medium grained; Intermediate to mafic; Igneous ice rafted erratic
23	93	N 47° 47' 14.9" W 117° 06' 53.6"	Orthogneiss						Rounded, moss covered sm outcrop; megacrysts of Kspar, rusty red, weathered pegmatite.
24	94	N 47° 47' 12.7" W 117° 06' 46.9"	Orthogneiss	155	25	W			Lg outcrop
25	95	N 47° 47' 26.2" W 117° 06' 49.1"	Orthogneiss	215	21	W	5	250	Lg series good outcrop, semi rounded, good lineations, Lg megacrysts
26	96	N 47° 47' 27.6" W 117° 06' 48.4"	Orthogneiss	290	15	N			Lg megacrysts 3-5cm in length
27	97	N 47° 47' 29.3" W 117° 06' 54.3"	Orthogneiss	195	28	NW			Truncated veinlet of pegmatite w/pinch swelling
28	98	N 47° 47' 28.1" W 117° 06' 57.1"	Orthogneiss	198	20	NW	4	254	
29	99	N 47° 47' 32.1" W 117° 06' 58.6"	Orthogneiss						Poor outcrop
30	100	N 47° 47' 35.1" W 117° 06' 57.3"	Orthogneiss						
31	101	N 47° 47' 34.3" W 117° 06' 54.6"	Orthogneiss						Long shelf outcrop facing lake; off trail
32	102	N 47° 47' 31.3" W 117° 06' 49.4"	Orthogneiss	215	29	W	11	248	
33	103	N 47° 47' 30.0" W 117° 06' 45.8"	Orthogneiss	182	30	W			The cliffs, strongly mylonitic zone 3-4 in thick
34	112	N 47° 47' 48.4" W 117° 06' 58.7"	Orthogneiss	215	30	NW			
35	113	N 47° 47' 45.4" W 117° 07' 00.8"	Orthogneiss						
36	114	N 47° 47' 39.6" W 117° 06' 55.0"	Orthogneiss						

Site #	GPS #	Lat/Long	Rock Type	Foliation			Lineation		Misc.
				Strike	Dip		Plunge	Trend	
37	115	N 47° 47' 40.6" W 117° 06' 51.2"	Orthogneiss	210	30	W			
38	116	N 47° 47' 52.2" W 117° 06' 47.8"	Orthogneiss						
39	117	N 47° 47' 55.8" W 117° 06' 45.6"	Orthogneiss						
40	118	N 47° 48' 02.3" W 117° 06' 49.8"	Pegmatite						Subcrop, foliated
41	119	N 47° 48' 09.0" W 117° 06' 59.9"	Granite						Ice rafted erratic, west side of ridge
42	120	N 47° 48' 13.2" W 117° 06' 54.9"	Orthogneiss						
43	121	N 47° 48' 03.4" W 117° 06' 46.5"	Orthogneiss	160	31	SW			
44	122	N 47° 47' 48.7" W 117° 06' 38.0"	Orthogneiss	210	25	NW			
45	123	N 47° 47' 38.7" W 117° 06' 30.6"	Orthogneiss	187	30	NW			At end of eagle rock ridge, very foliated coarse grained megacrystic gneiss.

APPENDIX B: map showing GPS stations by number.



APPENDIX C: additional photos of documented geologic features at the McKenzie Conservation Area.



C-1: close-up of Kspar megacryst in Newman Lake Gneiss (Site #8).



C-2: deformed, disarticulated pegmatite vein (white) in mylonitic Newman Lake Gneiss. Note sporadic white Kspar megacrysts (Site #27).



C-3: dark band (2 cm.) of ultramylonite (or deformed mafic xenolith) in Newman Lake Gneiss (Site #33).



C-4: lineated pegmatite; lineations are parallel to the long direction of the pocket knife (Site #44).



C-5: tree and moss-covered ice-rafted glacial erratic (Site #20).



C-6: close-up of medium-grained, non-foliated diorite broken from the ice-rafted erratic at Site #22.



C-7: abandoned water well head near the eastern boundary, WSW of *Hill 2450*.



C-8: seasonal stream in *The Gully*, March 2014.



C-9: small seep along the western bank of the main road just below the parking area.