PRIEST RIVER COMPLEX
Pend Oreille Rock & Gem Club Field Trip

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The discussions and field stop descriptions below are taken from the 2006 field guide by Doughty, Cheney, and Buddington, for the Northwest Geological Society's, Priest River Complex field trip.

Geology of the Priest River Complex

The Priest River complex is a large Eocene metamorphic core complex that extends from southern BritishColumbia to east-central Washington. The eastern boundary of the Priest River complex is defined by the Purcell Trench fault (Rehrig et al, 1987; Doughty and Price, 2000), which is an east-dipping and east-verging detachment fault concealed by Pleistocene, catastrophic flood deposits that fill the Purcell Trench valley (see below). The western edge of the Priest River complex is marked by a diffuse, west-dipping homocline along the southern two-thirds of the complex. At the northern end of the complex, the infrastructure bifurcates around a southward closing U-shaped detachment fault system; the Newport fault (Harms and Price, 1992). The portion of the Priest River complex south of the Newport detachment fault is referred to as the southern Priest River complex in this report and it terminates to the south against strike-slip faults of the Lewis and Clark Line (e.g., Reynolds, 1979). These faults link extension in the Priest River complex with the Boehls Butte metamorphic complex and Bitterroot metamorphic complex to the southeast (Foster et al., 2003; in press). Metamorphic rocks exposed along the eastern side of the southern Priest River complex are composed of the Hauser Lake Gneiss (Weis, 1968; Weissenborn and Weis, 1976). These paragneisses were metamorphosed at peak pressures of 8-11kb and above the breakdown reaction of muscovite and quartz (Rhodes, 1986; Doughty, 1995). A low pressure retrograde metamorphism accompanied mylonitization in the core of the Priest River complex and is expressed by the growth of andalusite after kyanite and the formation of muscovite after sillimanite and orthoclase (Rhodes, 1986). It records the rapid, nearly isothermal decompression that accompanied detachment faulting and tectonic unroofing during exhumation.

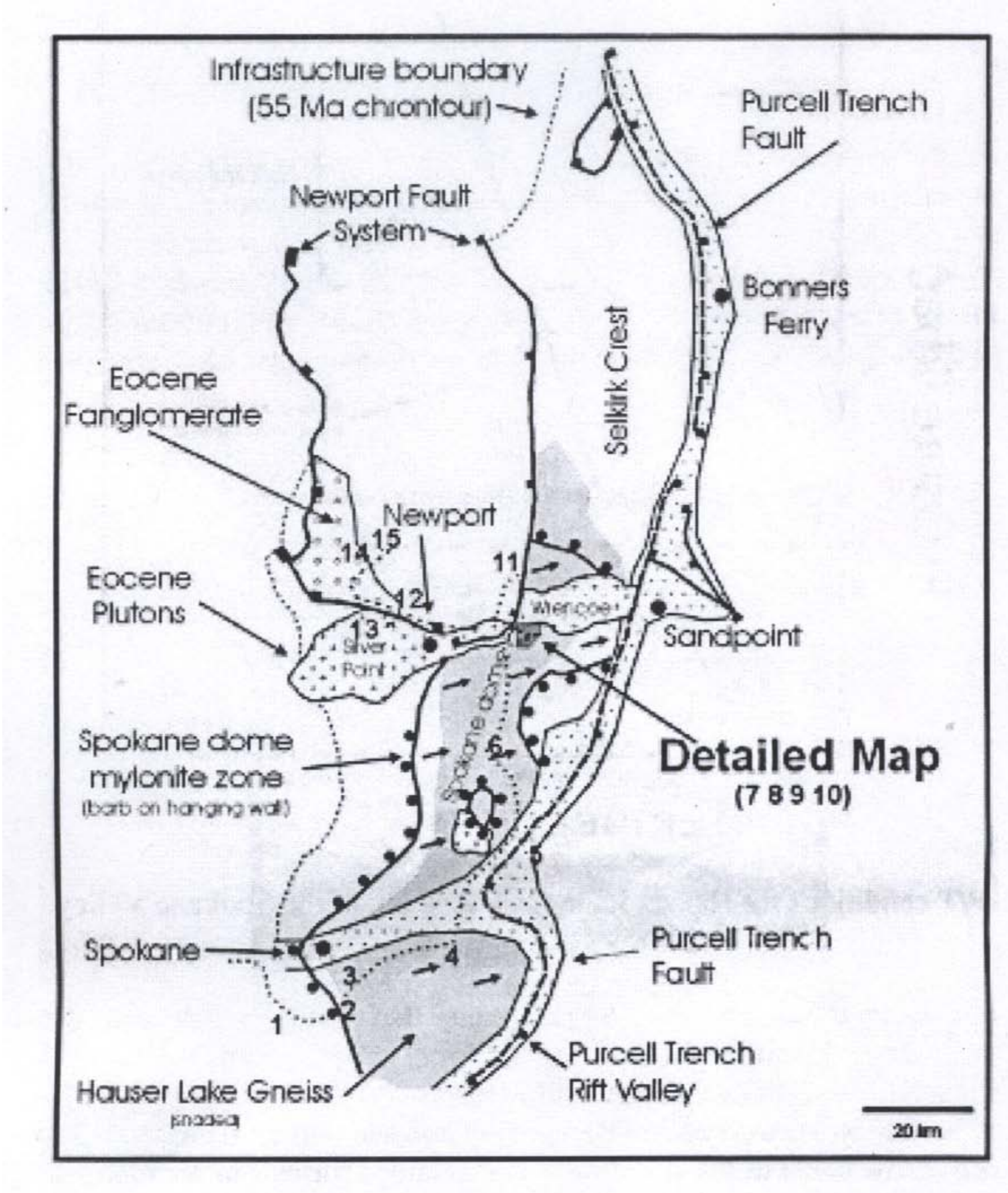
Overlying the Hauser Lake Gneiss to the west, is a thick sheet of megacrystic granitic orthogneiss (Newman Lake Gneiss) and farther to the west, a large body of two-mica granite informally referred to as the Mount Spokane granite (Weissenborn and Weis, 1976; Joseph, 1990). Armstrong et al. (1987) reported poorly defined crystallization ages of 94-143 Ma for these igneous rocks. In the southern Priest River complex, the rocks are folded into a north-trending antiform that follows the crest of the tectonically denuded core of the complex. Cheney (1980) referred to this structure as the Spokane dome. The Spokane dome plunges northward beneath the Selkirk Crest, near the town of Sandpoint, and extends to the south across the Spokane Valley. The Spokane dome is interpreted as a footwall flexure that formed in response to tectonic unroofing and subsequent isostatic rebound of the infrastructure during extension (e.g., Spencer, 1984; Wernicke and Axen, 1988). Arched across the Spokane dome is a 4 km thick zone of mylonitization named the Spokane dome mylonite zone (Rhodes and Hyndman, 1984). The Spokane dome mylonite zone is truncated on the east by the Purcell Trench fault, whereas the top of the mylonite zone coincides with the transition from the infrastructure to the suprastructure along the west side of the complex. Kinematic indicators yield a consistent top-to-the-east sense of shear along an azimuth of 070-074, regardless of the dip of the mylonite zone. Rhodes and Hyndman (1984) provide detailed descriptions of these mylonitic rocks. A characteristic feature of the Spokane dome mylonite zone observed by others, (Rehrig et al.,1987; Rhodes and Hyndman, 1984) is the dearth of brittle structures, such as chloritic veins and minor faults, that typically overprint ductile mylonitic fabrics. This is taken as evidence that the Spokane dome mylonite zone ceased moving before being uplifted to the surface by the ounding detachment faults. Similar mid-crustal mylonite zones occur within the Valhalla complex in southeastern B.C. and were active during the early phase of crustal extension (Carr et al., 1987; Schaubs et al., 2002).

The timing of formation of the Priest River complex is constrained by U-Pb crystallization ages and K-Ar and Ar40/Ar39 mica cooling ages. Synkinematic stocks and plutons, like the Silver Point Quartz Monzonite and the Rathdrum Mountain granite, yield 52 Ma crystallization ages (Bickford et al., 1985; Whitehouse et al. 1992) which demonstrate that the Spokane dome mylonite zone and the bounding detachment faults were active during Eocene extension.. K-Ar and Ar40/Ar39 dating of micas across the metamorphic infrastructure reveal a progressive west to east pattern of younging in the cooling ages of muscovite and biotite (Miller and Engels, 1975; Doughty and Price; 1999). This is consistent with progressive quenching of the metamorphic infrastructure as it was tectonically exhumed along the east-verging Spokane dome mylonite zone, western limb of the Newport fault, and the Purcell Trench fault (Doughty and Price, 1999).
*a complete reference list is available upon request

What is Mylonite?

Mylonite is typically a fine-grained rock that generally forms during intense shearing and ductile deformation. Mylonites will commonly exhibit a foliation (banded-like) and lineation as a result of shearing and/or flattening in localized zones often associated with large-scale faulting. Mylonites are rocks that have undergone significant grain size reduction due to grinding (granulation), cataclasis (pulverization and rounding), and dynamic metamorphism (recrystallization). The term mylonite is derived from the Greek word meaning **mill**. Several mylonite types exist and are based on % of matrix (crushed grains) vs. original minerals:

- *Blastomylonite* = medium to coarse mylonite with minor recrystallization (+/-banding). Original rock type & character often discernible. In general, less than 50% matrix (new or crushed grains)
- *Mylonite* = medium to fine-grained with 50-90% matrix (crushed grains). Original rock type may/may not be discernible. Moderate to high amount of recrystallization.
- *Ultramylonite* = extreme grain size reduction, hard, cherty-like, may look glassy or obsidian like. May be banded and original rock type and character often indistinguishable.



Generalized map of the Priest River Complex and Newport Fault system.

Stop 1: Hauser Lake Gneiss Amphibolite

What you will see: Spectacular garnet amphibolite with metamorphic coronas. This outcrop is an incredible exposure of a coarse-grained garnet amphibolite interleaved with the Hauser Lake gneiss (east end of outcrop). The Hauser Lake gneiss contains metamorphosed mafic (basalt-diabase) sills that contain the mineral assemblage: garnet-hornblende-plagioclase-quartz-rutile+/- biotite. Locally, clinopyroxene joins the assemblage and is symptomatic of the granulite facies. The spectacular coronas in this outcrop contain symplectic intergrowths of hornblende and plagioclase resorbing embayed garnet porphyroclasts. These are classic decompression reactions that record the tectonic exhumation of the Priest River complex.

Stop 2: Pend Oreille Gneiss

What you will see: The oldest rocks north of the Snake River Plain in the Cordillera. This exposure is of a biotite gneiss, named the Pend Oreille Gneiss, that occurs in the core of a northeast-trending antiform at the northern end of the Spokane dome. The antiform is subparallel to the mylonitic lineation and is interpreted as a turtle-back structure within the core of the Priest River complex. This is the deepest level of the Spokane dome and Spokane Dome mylonite zone exposed.

Just beyond the north end of the main outcrop, a megacrystic phase indicates that at least some of the Pend Oreille Gneiss was derived from a tonalitic protolith. High precision TIMS U-Pb dating reveals that these are Archean rocks (2651 Ma) that are a rare exposure of the crystalline basement beneath the Cordillera. The uplift of the crystalline basement here is due to tectonic exhumation along both the Spokane Dome mylonite zone and the eastern limb of the Newport fault. This is the most highly denuded part of the complex.

Stop 3: Gold Cup Quartzite

What you will see: Orthoquartzite, locally pebble-bearing, that is the basal Belt Supergroup. It separates the Archean basement from the Hauser Lake Gneiss. The Archean Pend Oreille Gneiss in the core of the antiform is flanked on all sides by an orthoquartzite that locally contains stretched pebbles and small flecks of graphite. The contact between the two rock types is mylonitized and it is difficulty to discern the original relationship between the two. Detrital zircons demonstrate that the Gold Cup Quartzite can be no older than 1.7 Ga and support the interpretation that there was originally a nonconformity between the two rock bodies. Clean, coarse-grained sandstones do not occur in the Middle Proterozoic Belt Supergroup, with exception of a basal quartzite exposed along the eastern margin of the basin.
This quartzite, known as the Neihart Quartzite, has been interpreted as a sand sheet deposited on the nonconformity between the basement and the overlying Belt Supergroup. This sand sheet continues to the west beneath the allochthonous rocks of the Cordillera and is exposed again in the tectonically denuded core of the Priest River complex. The spectrum of detrital zircon ages also support a correlation between the Gold Cup Quartzite and Neihart Quartzite.

Stop 4: Laclede Augen Gneiss

What you will see: Mylonitized augen gneiss with spectacular mafic boudins. This is an outcrop of a mylonitized augen gneiss with a well documented crystallization age of 1576 Ma. It is older than the Hauser Lake Gneiss and a “window” into the nature of pre-Belt basement that underlies the Rocky Mountains. In the late Precambrian, western Idaho was part of the supercontinent of Rodinia, which broke apart >550 Ma and formed a passive margin in west-central Washington. 1576 Ma rocks are absent from western Laurentia and the Laclede Augen Gneiss and the Pend Oreille Gneiss are a critical piercing point for identifying the continent that broke away from Laurentia during the disintegration of Rodinia ca. 550 Ma. One possible link is with Australia where Archean basement is overlain by a suite of granitic intrusions and volcanics (Hitalba Suite) that are the same age as the Laclede Augen Gneiss. Other reconstructions place Siberia adjacent to Idaho and Washington at that time.

The Laclede Augen Gneiss occurs as two folded lozenge-shaped masses within the Hauser Lake Gneiss. It is pervasively mylonitized and the contacts between the two rock units are structural (well exposed in the next road cut to the east). These bodies were tectonically emplaced into the Hauser Lake Gneiss within the lower part of the Spokane Dome mylonite zone.

Mylonitization is expressed by a strong gently east dipping mylonitic foliation with a lineation trending to the northeast at about 72-74 degrees. Asymmetric augen indicate a top-east sense of shear along the dominant mylonitic foliation. This fabric is crenulated by west-dipping and west verging macro-scale crenulations. These are interpreted as large antithetic extensional crenulations (see below). A mafic dike has been boudinaged during mylonitization and back-rotated along the macro crenulations. Note that in places the dike is also isoclinally folded. Inside the pressure shadows between the boudins and along pull-aparts are small masses of granitic aplite. These formed during high-temperature mylonitization and boudinage as partial melt was injected into the pull-aparts from the host rock (Laclede Augen Gneiss). U-Pb dating of one of these masses yields an age of 48 Ma for this high-temperature top-east mylonitization. These new dates show that while Cretaceous deformation is likely along the Spokane Dome mylonite zone, most of the fabrics seen on this trip are Eocene in age. Look closely at the outcrop and you will see thin east-dipping shear surfaces that contain slickenlines and chlorite and quartz pods along releasing bends. These surfaces record topeast shear at relatively low temperatures. Thus the outcrop shows top-east shear during progressively lower metamorphic conditions as the Priest River Complex was unroofed.

Most extensional crenulations are synthetic to the shear direction, but antithetic crenulations do occur. Earlier workers interpreted the west-dipping crenulations as a overprinting of the Spokane Dome mylonite zone by the west-dipping Newport fault zone that occurs to the west. The presence, however, of progressively shallowing top-east kinematics in the augen gneiss argues for a simple uplift during a single event rather than overlapping shear in different directions.

Newport Fault Zone

Discussion: The Newport Fault is a brittle-ductile detachment fault system that records the upper levels of the detachment fault system responsible for tectonically exhuming the Priest River complex. Compared to the recrystallized deep-seated shear zones seen earlier in the trip, extension exhumed these rocks to shallow levels during the Eocene and there is little recrystallization and extensive overprinting by brittle deformation. The Newport Fault system is a complex detachment fault system that can be subdivided into three segments.

The eastern segment is west-dipping and west-verging. The western segment is east-dipping and east-verging. At its southern end, it turns to the east and becomes a gently northdipping fault zone with top-oblique slip. These two segments merge with the Spokane Dome mylonite zone and together form a master top-east detachment fault that was responsible for unroofing most of the Priest River complex. The eastern segment is west-dipping and west verging. It is slightly younger than the other two segments and is interpreted as an antithetic fault to a predominately top-east detachment fault system. All three segments of the Newport Fault system display evidence for slip along an azimuth of either 254 or 74 degrees. This direction is identical to the direction of slip observed in the Spokane Dome mylonite zone and supports a linkage between the two fault systems. This outcrop is a poorly exposed section across the eastern segment of the Newport Fault. It juxtaposes Prichard Formation on the west against the Hauser Lake Gneiss and related intrusive rocks within the core of the Priest River complex. If one starts at the eastern end of the outcrop, the Hauser Lake Gneiss and associated pegmatites exhibit well-formed topwest mylonitic fabrics. In places they have been back-rotated and dip to the east. As one proceeds to the west, the mylonitized rocks become progressively overprinted by brecciation, chloritization, and silicification. Directly beneath the fault surface (difficult to see in the small swale), the footwall rocks have been transformed into microbreccia and cataclasites. The change from ductile to brittle deformation is common beneath detachment faults and records the exhumation of the footwall to shallower levels during extension.

STOP 5: Prichard Formation

What you will see: The Prichard Formation, the dominant formation found within the lower portion of the Belt Supergroup. The Belt Supergroup is a thick Middle Proterozoic (Precambrian) sedimentary sequence deposited approximately 1.4 to 1.47 billion years ago. The total thickness of the Belt sequence is up to 18 km's (10.8 mi) and the Prichard Fm. is up to 6 km in Idaho. The Prichard consists of dark to light gray fine sediments that have been interpreted as a deep water (facies) depositional sequence. The basin in which the Belt sediments were deposited has been interpreted as a "restricted" inland ocean basin on the North American continent. The basin was enclosed on three sides but open to the ocean. The main source of sediment came from large rivers draining the continental interior (to the east) but paleocurrent studies indicate a sediment source also being derived from a landmass to the west. Some detrital zircons in the Prichard indicate a non-North American source, possible Australia or Siberia. The younger sedimentary formations that sit above the Prichard indicate a filling of the basin and an increasingly shallower sedimentation environment.

The Belt Supergroup is comprised of four main groups and Prichard is the oldest occurring at the bottom of the sequence:

Group	**Formations (ID - NE WA)**	**Rock Types**
Missoula Group	Snowslip, Mt. Shields	qtzites, siltites
Middle Belt Carbonate Group	Wallace Fm.	dolomitic qtzites
Ravalli Group	Burke, Revett, St. Regis	qtzites, silt, argillite
Lower Belt Group	Prichard	qtzites, silt, argillite

At this outcrop we will be looking at dark gray, rusty weathering, bedded quartzites and siltites. The rusty weathering is very characteristic of the Prichard and is the result of weathering (oxidation) of moderate amounts of pyrrhotite (Fe-sulfide) found throughout the unit. A key thing to observe here is the fact that original sedimentary features are obvious and the amount of metamorphism is relatively minor (compared to the previous stops). Geologists that have studied the Priest River Complex argue that the Prichard Formation was the precursor parent (protolith) to the Hauser Lake gneiss seen in earlier outcrops. So, here we see relatively undeformed Prichard Formation within the hangingwall of the Newport Fault.

Stop 6: Newport Fault System

What you will see: Chloride breccia in the upper part of the Newport fault zone. This outcrop is located along the upper part of the southern segment of the Newport Fault system. In this area, the 52 Ma Silver Point Quartz Monzonite intruded the Newport Fault during slip and was deformed within and adjacent to the fault zone. The outcrop displays mylonitized SPQM that has been extensively brecciated and altered into a chloride breccia. The fault surface, now eroded, was only a few 10’s of meters above ground level.

Stop 7: Manresa Grotto, Tiger Formation

What you will see: Syntectonic Eocene fanglomerates in the hanging wall of the Newport fault. This outcrop is an exposure of a west-dipping fanglomerate (Tiger Formation) of Eocene age that was shed off of the footwall to the western segment of the Newport Fault. Clasts consist of Belt Supergroup quartzites, granites, and Eocene volcanics. Apparently, the Paleozoic rocks were completely eroded from the rising core complex by the time the Tiger Formation was deposited in this location.

The Tiger Formation was deposited in an asymmetric 1/2 graben that formed above the listric western segment of the Newport Fault. As slip progressed, the hanging wall was progressively rotated to the west forming a roll-over anticline. The Tiger Formation shows progressively steepening dips from horizontal on the west to very steep on the east. This records deposition during movement and rotation along the listric normal fault; i.e., the older sediments on the east have been rotated the most. Directly underneath the Tiger Formation lie Eocene andesite flows and tuffs correlated with the Sanpoil volcanics. They are the eruptive phase of the Silver Point Quartz Monzonite. These volcanics and underlying Prichard Formation dip steeply to the west (60 degrees) and demonstrate that the Newport Fault has a nearly horizontal attitude at depth.

The caves that make up the grottos are relicts of a Pleistocene glacial lake that formed in front of the retreating Cordilleran ice sheet. The fetch on the lake created waves that eroded the grottos into the exposed cliffs of the Tiger Formation. As well, the current northward flow of the Pend Oreille River is due to stream reversal as isostatic rebound could not keep pace with melting of the ice sheet and for a time, the river drainage sloped north rather than south. To date, the Pend Oreille River has been able to keep pace as the land surface rebounded to its former southerly slope.

Stop 8: Folded & Faulted Prichard Formation

What you will see: intensely folded and faulted metasediments of the Prichard Formation. This long series of outcrops along the Flowery Trail Rd. east of the 49^o North ski area exhibits variable amounts of low-grade metamorphism along with isoclinal, recumbent folds with intermittent faults. Note here that the original sedimentary bedding is for the most part, still visible. Folding on both the large scale and small (micro) scale is common along this section. Preliminary investigation of the folds indicates that compression from the west (toward the east) resulted in the overall pattern and orientations of the folds seen here.

Upon closer inspection of the rocks, abundant biotite and muscovite (metamorphic) is visible. Also note that the rocks show a distinctive cleavage (planar fabric) that is cuts across the bedding orientations. The cleavage is obvious in the finer-grained, silty-mud beds but apparently absent in the sandy beds. Why? Also note that on the cleavage surfaces there is an obvious crenulation pattern that looks like small scale ripples r folding. This crenulation is the result microfolds developed in the rock. This is an area of moderately ductile strain.

Unresolved questions for this outcrop include:

1: what (and when) was the main cause of the folding seen here?
2. are the folds seen here related to the Colville Fold & Thrust Belt to the west?
3. is there more than one episode of deformation recorded in the rocks here?
4. what is the relationship of the metamorphism seen here to the metamorphic core complex to the east?