Geologic Map of the Potlatch 30 x 60 Minute Quadrangle, Idaho

Compiled and Mapped by
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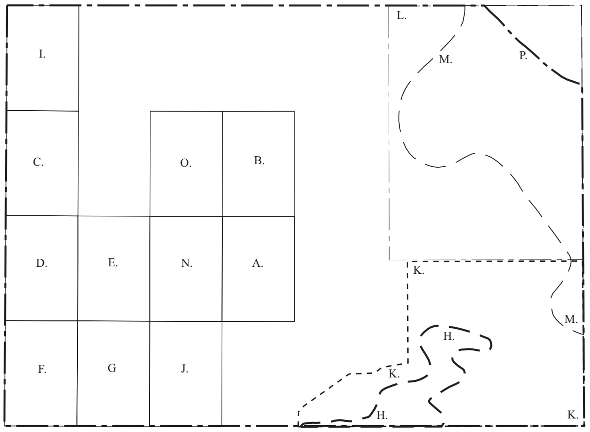
INTRODUCTION

Geology depicted on the 1:100,000-scale Potlatch 30' x 60' quadrangle is based partly on previous mapping, principally the 1:48,000-scale map of Hietanen (1963) and numerous 1:24,000-scale maps of John Bush and his students at the University of Idaho (Figure 1). We supplemented that with secondary sources (Figure 2) and extensive field work in 2000 (Figure 3). Basalt stratigraphy, chemistry, and magnetic polarity are from Wright and others (1973) and Swanson and others (1979a, 1979b). Chemical types and polarity were verified by field sampling. Whole-rock XRF analyses were done at the Washington State University GeoAnalytical Laboratory. K-Ar dating was done by Geochron Laboratories Division of Krueger Enterprises, Inc., and ^{40}Ar/^{39}Ar dating by the New Mexico Bureau of Mines and Mineral Resources and the College of Oceanic and Atmospheric Sciences at Oregon State University. Magnetic polarity was measured by a fluxgate magnetometer in the field or a spinner magnetometer at the Idaho Geological Survey.

The oldest and most abundant rocks in the Potlatch quadrangle are Precambrian. These include low-grade Mesoproterozoic metasedimentary rocks of the Belt Supergroup and high-grade (amphibolite facies) metamorphic rocks whose protolith is suspected to be the Belt Supergroup. Other high-grade rocks mapped as the Syringa metamorphic sequence in the southern part of the area are probably Neoproterozoic age and thus postdate the Belt. Precambrian rocks in the eastern part of the area may be correlative with the Syringa sequence, the lowermost Belt Supergroup, or the basement to the Belt. South of the Syringa sequence are metamorphosed rocks of the Orofino series, a carbonate-rich clastic (or volcaniclastic?) sequence of Mesozoic age. Deformed granitic rock (orthogneiss) of probable Cretaceous age is more extensive in the northeast than previously



A. Bush and others, 1999a
B. Bush and others, 1999b
C. Bush and others, 1998a
D. Bush and others, 2000
E. Bush and Priebe, 1995
F. Bush, 2001
G. Bush and others, 2001
H. Davidson, unpublished mapping, 1987-1988
I. Duncan and Bush,1999b
J. Garwood and others, 1999
K. Hietanen,1962
L. Hietanen,1963
M. Jenks, unpublished parent material maps, 1998
N. Potter and others, 1999
O. Priebe and Bush, 1999
P. Swanson and others,1979a

Figure 1. *Index of previous geologic mapping used as primary sources of data.*

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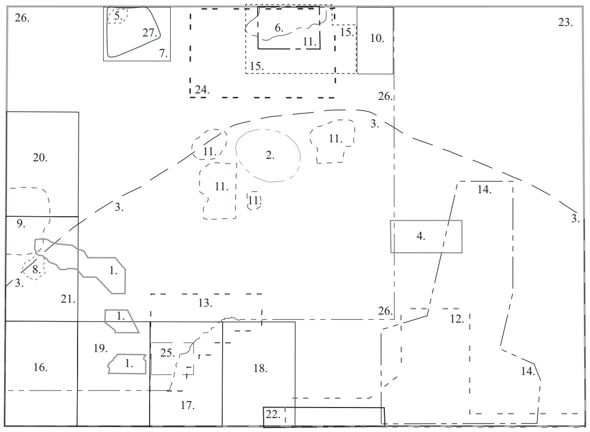


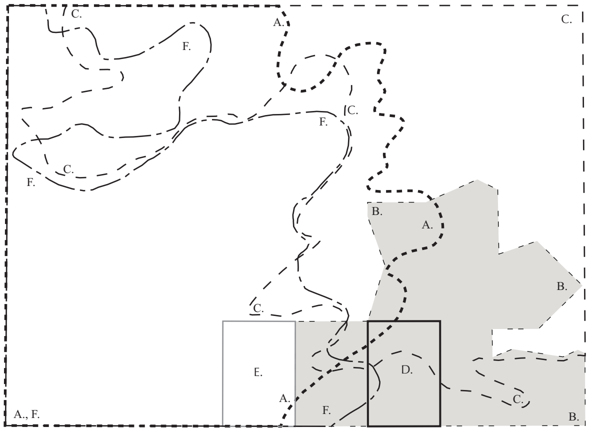
1. Anderson, M.A., 1991
2. Bitten, B.I., 1951
3. Bond, J.G., 1963
4. Boyd, A.E., 1985
5. Butterfield, P.J., 1998
6. Cunningham, Cynthia, unpublished mapping
7. Faick, J.N., 1937
8. Hammerand, V.F., 1936
9. Hosterman and others, 1960
10. Kemple, H.F., 1979
11. Kinney, V.L., 1972
12. Kopp, R.S., 1959
13. Lynch, M.B., 1976
14. McNary, S.M., 1976
15. McNeill, A.R., 1971
16. Othberg and others, 2001a
17. Othberg and others, 2003a
18. Othberg and others, 2003b
19. Othberg and others, 2001b
20. Othberg and Breckenridge, 2001b
21. Othberg and Breckenridge, 2001a
22. Peterson, D.W., 1951
23. Rember, W.C., and E.H. Bennett, 1979
24. Shively, M.V., 1977
25. Smith, D.A., 1984
26. Tullis, E.L., 1940
27. Wong, J.S., 1980

Figure 2. *Index of previous geologic mapping used as secondary sources of data.*

mapped. Deformed plutonic rock of Cretaceous age also is in the south-central part where rocks of continental affinity are in fault contact with upper Paleozoic to lower Mesozoic rocks of oceanic affinity. Much less deformed to undeformed Cretaceous granitic intrusions and pegmatite-aplite complexes are present throughout the map area. Undeformed Eocene igneous rocks are exposed as plutons and rhyolite dike swarms in the central part of the area and as volcanic rocks north of Deary. Oligocene basalt flows and alkali-rich pyroclastic rocks are in the northwest. Flows of Miocene Columbia River Basalt Group cover much of the southern and western part, although in places these flows are covered with Miocene sediments. Pleistocene loess deposits cover the basalt in the west and thin eastward.

DESCRIPTION OF ROCK UNITS

Intrusive rocks are classified according to IUGS nomenclature using normalized values of modal quartz (Q), alkali feldspar (A), and plagioclase (P) on a ternary diagram (Streckeisen, 1976). Oligocene and older volcanic rocks are classified by chemical composition (total alkalis versus silica) according to IUGS recommendations (LeMaitre, 1984). The Columbia River Basalt Group contains basalt, basaltic andesite, and andesite by this classification, but the term basalt is applied here, as it has been historically. Mineral modifiers are listed in order of increasing abundance for both igneous and metamorphic rocks. Grain size classification of unconsolidated and consolidated sediment is based on the Wentworth scale (Wentworth, 1922).



A. Bush, 1990-2000 field mapping
B. Kauffman, 2000 field mapping
C. Lewis and Burmester, 2000 field mapping
D. Myers, Burmester, and Lewis, 2000 field mapping
E. Garwood and Bush, 2000 field mapping
F. Othberg, 2000 field mapping

Figure 3. *Index of areas of mapping responsibility.*

YOUNG SURFICIAL DEPOSITS

Qal—Alluvial deposits (Holocene)—Primarily channel and flood-plain deposits of the Clearwater and Potlatch rivers and their major tributaries, but includes local slope wash and debris-flow deposits from canyon slopes. Most alluvium is composed of laterally discontinuous beds of pebbles, cobbles, sand, and silt. Gravel clasts are predominantly basalt. Locally, sediment derived from the Latah Formation is abundant. In plateau areas, alluvium is finer grained (silt dominated) and, in the western part, grades laterally into loess (*Qp*). In canyon floors, poorly sorted cobbly and bouldery alluvium grades into debris-flow deposits near junctions with tributaries.

Qls—Landslide deposits (Pleistocene and Holocene)—Poorly sorted and poorly stratified angular basalt cobbles and boulders mixed with silt and clay. Clay is derived from liquified sedimentary interbeds or deeply weathered pre-Tertiary rocks. Landslides include rotational and translational blocks and earth flows. Slump blocks are primarily composed of intact to broken sections of basalt and Tertiary sediments. Earth flows are mainly composed of unstratified, unsorted gravel rubble in a clayey matrix derived from liquified fine-grained sediments. Scarp and headwall areas of landslides are excluded because those features provide some of the best exposures of basalt units. The largest landslides occur where valley incision has exposed sedimentary interbeds to steep topography. Thick, fine-grained sediments, when saturated by ground water moving toward the valleys, can fail and produce slumps, slides, and debris flows. The sediments can be traced by locating landslides along the valley sides, demonstrating that the primary control of landslides is the stratigraphy and hydrogeology of fine-grained sedimentary interbeds. The landslides range from relatively stable Pleistocene features to those that have been active within the past few years. In most places, the stratigraphic, lithologic, and hydrologic conditions are the same today as in the past. Landslide debris is highly unstable when modified, either through natural variations in precipitation or through artificial modifications such as cuts, fills, and changes in surface drainage and ground-water infiltration. Even small landslide activity on the upper parts of canyon slopes can transform into high energy debris flows that endanger roads, buildings, and people below.

Qp—Palouse Formation (Pleistocene and Holocene)—Loess composed of massive silt and clayey silt of the Palouse hills in the eastern Columbia Plateau and shown only as an overlay pattern on the map. Consists of many layers that record periods of rapid loess deposition followed by long surface exposure and soil development. Depositional and soil units within the Palouse Formation have complex surface and subsurface patterns that are discontinuous and difficult to map. Thick, welded, clayey B horizons of paleosols are locally exposed through erosion, especially on steep amphitheater-shaped slopes with northerly aspects, and form low knobs below the high ridge crests of the Palouse hills. Early work restricted the Palouse Formation to Pleistocene loess deposits (see Newcomb, 1961; Keroher, 1966; Richmond and others, 1965; Ringe, 1968; Griggs, 1973; Foley, 1982; Schuster and others, 1997), but more recent work included Holocene loess in the Palouse Formation (Hooper and Webster,1982; Hooper and others, 1985). The soils developed in the loess form a pattern that reflects the complex interaction of erosion and deposition of loess throughout the Quaternary. The Palouse Formation overlies a Miocene-Pliocene surface developed predominantly on Columbia River basalt. The loess is as much as 60 m (200 feet) thick in the western edge of the area but thins eastward where the plateau surface is characterized by low rolling hills of dissected, weathered basalt (see *Tsap*).

Qg—Glacial deposits (Pleistocene)—Poorly sorted till containing quartzite boulders. Present only west of White Rock in the northeast part of area.

OLDER SEDIMENTS AND SAPROLITE

Ts—Sediment, undivided (Oligocene and Miocene)—Deeply weathered (saprolitic) yellow to orange silt and clay, sand, and quartzite pebbles and cobbles exposed on flat upland surfaces. Clasts derived primarily from the Belt Supergroup. Sediment northeast of Harvard was deposited upstream from basalt of Onaway flows and is probably Oligocene. Some may be as old as Eocene; others may be distal high-level equivalents of the Miocene Latah Formation. Typical thickness is 10 m (30 feet).

Tsap—Saprolite (Oligocene? and Miocene)—Clayey residuum weathered in place mainly from granitic and basaltic parent rock and shown only as an overlay pattern on the map. Clay mineralogy and depth of weathering reflect conditions of chemical weathering that date back to Miocene and earlier climates that were warmer and wetter than today. Evidence from fossil plant assemblages and paleosols support this paleoclimatic interpretation (Smiley and Rember, 1979; McDaniel and others, 1998). Saprolite on granitic parent rock forms a border zone between areas of less weathered bedrock and Tertiary sediments. The composition of granitic-source saprolite reflects the leaching conditions of intense weathering and is high in kaolinite and halloysite with lesser amounts of fine-grained quartz and muscovite. Biotite and fresh feldspars are absent or uncommon but increase in amount with depth. Thickness can exceed 30 m (100 feet; Hosterman and others, 1960). Basalt saprolite is thickest and most widespread in plateau remnants of the eastern parts of the Clearwater embayment (eastern part of area). In the Grangemont area in the southeast part of the map, brown and reddish brown silt and clay compose the upper part of the saprolite. Below that, gray, subround remnants of spheroidally weathered basalt are present. At greater depths, original joint patterns that have controlled paths of weathering become visible. Toward the west, the basalt saprolite thins, is more discontinuous, and is ultimately buried by Miocene Latah sediments (*Tls*) and thick loess deposits (*Qp*). In the plateau area of Southwick and Cameron in the south-central part of the map, the saprolite is thick only on the highest parts of the rolling, dissected landscape, and spheroidally weathered basalt and relatively fresh basalt are commonly exposed in valleys. It is difficult to distinguish between basalt saprolite and fine-grained Tertiary alluvium, which is common along the borderlands between plateau basalt and the pre-Tertiary rocks of foothills.

Latah Formation

Clay, silt, sand, and gravel deposits associated with the Columbia River Basalt Group. Related to high base levels formed when the Miocene Columbia River basalts blocked and diverted stream drainages. These sediments both overlie and are overlain by the basalt flows; those between basalt flows are referred to as interbeds. Several interbeds have been given local names, but terminology is inconsistent from locality to locality. However, interbeds between the uppermost Grande Ronde Basalt and the lowermost Wanapum Basalt – widely recognized as the Vantage horizon, interbed, or member – have been correlated from central Washington into the Pullman and Moscow subsurface (Bush and others, 1998a; Bush and Provant, 1998). The uppermost Latah unit, which typically overlies the Priest Rapids Member or the uppermost Grande Ronde flow, has been mapped across ten quadrangles in Latah County at a scale of 1:24,000. Locally, this unit exceeds 75 m (250 feet) in thickness but is typically much thinner; it has been referred to informally as the sediments of Bovill (Bush and others, 1998b; Provant and Bush, 1998).

Regional maps commonly include the interbedded sediments in the Columbia River Basalt Group because the sediments are too thin, not continuous, or not well enough exposed to map as separate units. Composition and fossil content are so varied that stratigraphic position generally can only be defined by the bounding basalt units. Locally, basalt flows burrowed into sediments and formed invasive sills with chilled upper and lower margins. Invasive basalt also occurs as pods, dikes, glassy breccias, and isolated pillowlike forms. These invasive features are common, especially in the Juliaetta-Texas Ridge and Dent-Elk Creek Falls areas, but are best exposed in the Grande Ronde units in the lower reaches of Bethal Canyon in the southwest corner of the Little Bear Ridge quadrangle northwest of Juliaetta (Potter and others, 1999).

Tls—-Latah Formation sediment (Miocene)—Upward-fining sequences of clay, silt, sand, and minor gravel adjacent to or overlying the Columbia River Basalt Group. Clay was both transported and formed in-situ by intense chemical weathering, which probably reflects relict conditions of chemical weathering during Miocene and earlier climates that were warmer and wetter than today. Evidence from fossil plant assemblages and paleosols supports this paleoclimatic interpretation (Smiley and Rember, 1979; McDaniel and others, 1998). Clays are white, yellow, red, and brown, are kaolinite-rich, and range from about 1 m to several meters in thickness. The sands and gravels are typically poorly sorted with a clay matrix. Common lithologies include poorly rounded quartz and basalt granules and pebbles in a micaceous matrix of silt and clay. Locally, iron-oxide cementation forms discontinuous, thin ironstone layers and lenses. Where the unit is eroded, a lag gravel of vein quartz and quartzite pebbles and cobbles commonly mantles the surface. The unit grades laterally into thick colluvium or residuum of pre-Tertiary rocks, perhaps on old pediment surfaces.

Tli—Latah Formation interbed (Miocene)—Sand, silt, clay, and minor amounts of gravel in interbeds between flows of Columbia River Basalt Group. Interbeds that are too poorly exposed or too thin to show at this map scale are included with basalt. Laterally, abrupt thickening and thinning of interbeds is common. Some interbed units exceed 60 m (200 feet) in thickness. The thickest sequences occur near the plateau margin such as along the Deary grade in southern Latah County (Bush and others, 1999b), in the subsurface beneath Moscow (Bush and Provant, 1998), and along Whiskey Creek in the southeast part of the area. Overall, older units are coarser grained and contain more feldspar than stratigraphically younger units. Muscovite is common on bedding planes throughout. Upward-fining sequences capped by kaolinite- and halloysite-rich clay are common. Plant fossils are locally abundant at most stratigraphic horizons.

COLUMBIA RIVER BASALT GROUP

The stratigraphic nomenclature for the Columbia River Basalt Group follows usage of Swanson and others (1979b). In the Potlatch quadrangle, the four formations, from oldest to youngest, are Imnaha Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. The Grande Ronde Basalt, from oldest to youngest, includes the R_1, N_1, and R_2 magnetostratigraphic units. No basalt from the N_2 was identified in the area. Flows from two units of the Wanapum Basalt, the Priest Rapids Member and Icicle Flat Member were identified, although the Icicle Flat Member is too thin to show at the map scale and is included in the Priest Rapids Member. Saddle Mountains units, from oldest to youngest, are the undivided flows of the Wilbur Creek Member and Asotin Member; the basalt of Lewiston Orchards, Weissenfels Ridge Member; the basalt of Weippe; the basalt of Feary Creek; the basalt of Swamp Creek; and the basalt of Craigmont. Marginal to and interbedded within the basalt sequence are sediments of the Latah Formation.

Saddle Mountains Basalt

Tsm—Saddle Mountains Basalt, undivided (Miocene)—In some areas of the southeastern part of the quadrangle, the individual Saddle Mountains Basalt units described below were not mapped or sampled in sufficient detail to define their limits adequately. Although these units have previously been separated (Camp, unpub. field data, 1978-1980; Swanson and others, 1979a), buttress, erosional, and invasive contacts complicate the stratigraphy. Camp's and our sample locations are noted on the map, and chemical types for the samples are tabulated in Kauffman (2004b). In general, the areal extent of these units is small compared to that of Wanapum and Grande Ronde flows.

Tcsc—Basalt of Craigmont and basalt of Swamp Creek, undivided (Miocene)—In some areas, we have combined these units on the geologic map because of the similarity in chemical signatures, their close physical association, and the scarcity of outcrops. Although the dates noted below indicate that Swamp Creek is younger than Craigmont, Craigmont was found overlying Swamp Creek east of the quadrangle near Weippe. The basalt of Swamp Creek is mapped separately (*Tsc*) in the eastern part of the quadrangle where it is the only unit present.

The basalt of Craigmont is fine- to medium-grained phyric basalt with common plagioclase phenocrysts 2-5 mm or rarely 7-10 mm long, scattered to uncommon olivine about 1 mm in diameter, and some manganese(?) oxide (or siderite?) cavity filling. Normal magnetic polarity, although fluxgate magnetometer readings are commonly inconsistent. Outcrops uncommon; commonly weathers to red-brown saprolite. Thickness estimated at 15-45 m (50-150 feet), possibly thicker locally. Forms local capping unit in southeast corner of map. First identified and named by Camp (1981) who gave it informal member status. A dike sampled by Camp east of Kooskia yielded a K-Ar whole-rock date of 11.9 ± 0.7 Ma (unpub. data, Department of Energy, Rockwell Hanford Operations).

The basalt of Swamp Creek, where mapped with the basalt of Craigmont, is light to medium gray and medium to coarse grained with scarce to common plagioclase phenocrysts as much as 5 mm in length and olivine phenocrysts a few millimeters in diameter. Normal magnetic polarity, although fluxgate magnetometer readings are commonly inconsistent. Poorly exposed; commonly weathers to red-orange or red-brown saprolite. Forms local capping unit and probably fills structural and erosional depressions on older units. To the east, it directly underlies the basalt of Craigmont at one exposure a few kilometers north of Weippe. At another location to the southeast on the north side of Jim Ford Creek, the Swamp Creek overlies the basalt of Weippe and is overlain by a Craigmont flow. Thickness not determined, but probably less than 23 m (75 feet). Camp (1981) gave informal member status to the Swamp Creek.

Tsc—Basalt of Swamp Creek (Miocene)—Light to medium gray, coarse-grained basalt exposed southeast of Elk River. Occurs in the Swamp Creek area northeast of Dent. Coarsely diktytaxitic with scattered plagioclase phenocrysts 5-10 mm long and abundant olivine phenocrysts or clots as much as 5 mm in diameter. Normal magnetic polarity. Caps other basalt flows, sediments, or basement rocks in the southeastern part of the quadrangle. Commonly weathers to a deep red or red-orange saprolite. Maximum thickness is estimated at 45 m (150 feet). A sample collected by Camp (sample VC79-317) yielded a K-Ar whole-rock age of 11.4 ± 0.8 Ma (unpub. data, Department of Energy, Rockwell Hanford Operations).

Tfc—Basalt of Feary Creek (Miocene)—One sample (sample 00JK038, map no. 29) most closely matches the chemistry of the basalt of Feary Creek (Camp, 1981), although the hand sample does not match Camp's description. It overlies Grande Ronde north of Dent in secs. 15 and 16, T. 38 N., R. 2 E., and has normal polarity. The flow is dense and dark gray with common plagioclase microphenocrysts and a few plagioclase phenocrysts as much as 4 mm. Camp reported plagioclase phenocrysts as much as 10 mm and common olivine, although none was noted in the flow at this site.

Camp (1981) designated the basalt of Feary Creek as an informal unit of the Frenchman Springs Member, although he indicated its relative stratigraphic position was uncertain and its chemical signature was similar to a Saddle Mountains flow of Frenchman Springs chemical type. K-Ar ages of two samples collected near Headquarters are 11.9 ± 0.7 and 11.2 ± 0.7 Ma (unpub. data, Department of Energy, Rockwell Hanford Operations). Likewise, we have no conclusive evidence of its stratigraphic position in the Potlatch quadrangle other than that it overlies Grande Ronde Basalt. To the east, in the John Lewis Mountain 7.5-minute quadrangle, the Feary Creek is closely associated with *Taw* and *Twe* units, but there, too, its stratigraphic position is unclear. We have included it in the Saddle Mountains Basalt because of the age and also chemical similarity to the Swamp Creek and Craigmont members.

Twe—Basalt of Weippe, Pomona Member (Miocene)—Medium to dark gray, medium- to coarse-grained basalt; olivine and plagioclase phyric. Reverse magnetic polarity. Appears to be in erosional contact with underlying units locally. Probably filled depressions and valleys formed on older basalt units and sediments, or on basement units. Occurrence at elevations of 600-800 m (1,930-2,580 feet) along Dworshak Reservoir may be either large intact slump blocks or, as suggested by Camp (1981), valley fill. In places, weathers to a red-brown saprolite.

Camp (1981) included the basalt of Weippe in the Pomona Member because of the similarity in chemistry, although a physical connection of the two was not confirmed. We also found the major and trace element chemistry of the Weippe to be nearly identical to the Pomona. However, paleomagnetic directions recently determined for the basalt of Weippe from two sites near Grangemont (Kauffman, 2004a) are somewhat different from those determined for Pomona flows by Reitman (1966) and Choiniere and Swanson (1979), indicating that the two units may not be coeval. A whole rock K-Ar age for sample 00JK054 (map locality 41) is 12.9 ± 0.8 Ma. This is slightly older than the Pomona, but within the margin of error range, which was reported by McKee and others (1977) as "about 12" Ma.

Twe$_d$—Basalt of Weippe dikes (Miocene)—Camp's field work (1978-1980) documented several dikes of Weippe chemistry in the Dworshak Reservoir area (Swanson and others, 1979a).

Twl—Basalt of Lewiston Orchards, Weissenfels Ridge Member (Miocene)—Medium- to coarse-grained basalt with microphenocrysts of plagioclase and olivine in an intergranular groundmass with minor glass (Hooper and others, 1985). Normal magnetic polarity. Four distinguishable flows of the Weissenfels Ridge Member occur in the Lewiston basin. One of these, the basalt of Lewiston Orchards, has been identified in small isolated outcrops in the Genesee area as well as west of the Potlatch quadrangle (Hooper and Webster, 1982; Bush and Provant, 1998; Bush, 2001; Bush and others, 2000). One sample collected by Camp (sample VC78-105, map no. 302; Kauffman, 2004b) on the Potlatch 7.5-minute quadrangle also has Lewiston Orchards chemistry, but the outcrop is too small to show at the 1:100,000 scale.

Taw—Asotin Member and Wilbur Creek Member, undivided (Miocene)—Medium- to fine-grained basalt with scattered to common plagioclase phenocrysts 1-5 mm; rare to common olivine phenocrysts 1-3 mm. In general, the Asotin tends to be denser than the Wilbur Creek. South of the map area in the Lewiston basin, the lowermost basalt, generally the Wilbur Creek, overlies the Sweetwater interbed of Bond (1963). Includes the basalt of Lapwai, Wilbur Creek Member. Upper part of flows are commonly very vesicular with abundant small spherical vesicles, commonly with a pale bluish lining. All three units have normal magnetic polarity. Thickness of individual flows ranges from about 30 m (100 feet) to more than 90 m (300 feet). These units and local underlying sediments fill structural lows developed on Wanapum and Grande Ronde basalt and thin or pinch out on structural highs.

Where more than one unit is present, the stratigraphic sequence, from oldest to youngest, is as follows: Wilbur Creek, basalt of Lapwai, and Asotin, although the complete sequence was not documented at any one location. To the west in the Pasco Basin, the basalt of Lapwai and the Asotin Member mix to form the Huntzinger flow (Reidel and Fecht, 1987). Some mixing of these same units likely occurred in the Lewiston basin (Garwood, 2001). The units have been combined on the map because of their close relationship and because extremely detailed sampling would be required to separate them. However, analyzed samples are noted on the map, and the individual units are identified in chemical tables in Kauffman (2004b).

Wanapum Basalt

Tpr—Priest Rapids Member (Miocene)—Dark gray, fine- to coarse-grained, dense to diktytaxitic phyric basalt with scattered equant crystals and laths of plagioclase as large as 5 mm and common olivine crystals 1-3 mm in diameter. Reverse magnetic polarity, although a thick unit in Swamp Creek canyon commonly gave normal polarity readings. Commonly in erosional contact with older basalt units or sediments, or overlies basement rocks. Flows tend to coarsen near the eastern margin of the plateau. Hyaloclastic deposits, common near contact with basement rocks, contain glassy lapilli-like fragments, small bombs, basalt inclusions and invasions, and rarely sediment wedges; typically yellowish brown, probably as a result of alteration of glass to palagonite. Unit is invasive into fossiliferous sediments in quarry on Swamp Creek Road at east edge of sec. 26, T. 39 N., R. 2 E. Also invasive into a sedimentary interbed within the Grande Ronde R$_1$ along Whiskey Creek (Whiskey Creek sill of Bond (1963) and McNary (1976)) where it is mapped as *Tpr$_s$* (see description below). A single flow of basalt of Icicle Flat, too thin to show at map scale, is included in the *Tpr* unit at one locality 8 km (5 miles) south of Juliaetta on the slope north of the Clearwater River (southeast of sample locality 177). The flow is about 15 m (50 feet) thick and underlies the Priest Rapids.

Over much of the western part of the Potlatch quadrangle, the member ranges in thickness from less than 30 m (100 feet) to more than 75 m (250 feet) and is the uppermost unit in most areas, forming the plateau surface. Measured sections and well data show that it consists of one to three flows or flow units. Pillow basalts and hyaloclastic breccias are abundant locally (Bush and Priebe, 1995). Contacts between flows and flow units reveal little evidence of erosion or deposition between emplacement of separate flows. Chemical data indicate that in southern Latah County the basalt is the Lolo chemical type of Wright and others (1973). In the northern part of the map, both the Lolo and the Rosalia chemical types are present (Duncan and Bush, 1999b). Mapping for this project shows that both types are also present in the eastern part of the map area. Palagonitic breccia deposits described by Bush and Priebe (1995) were examined and reinterpreted to be hyaloclastic rather than near-vent breccias as was suggested by Bush and others (1995). Priest Rapids dikes within the hyaloclastic units are interpreted as intraflow dikes and not source dikes.

Tpr_d—Priest Rapids Member dikes (Miocene)—One dike is associated with the sill along Whiskey Creek. Another (sample 00JK046, map no. 34) cuts Grande Ronde R_1 south of Dent in sec. 28, T. 38 N., R. 2 E. The basalt is medium grained with plagioclase phenocrysts as much as 5 mm in length and small olivine grains. Reverse magnetic polarity.

Tpr_s—Priest Rapids Member sill (Miocene)—Whiskey Creek sill of Bond (1963) and McNary (1976) invasive into a sedimentary interbed within the Grande Ronde R_1 along Whiskey Creek. The invasive flow breaks through the overlying unit of Grande Ronde in a quarry along Wells Bench Road (SE¼ sec. 22, T. 37 N., R. 2 E.). Thin glassy selvage zones border the contact of the Priest Rapids with the Grande Ronde. Above the sill, the Grande Ronde has been displaced upwards at least 9-12 m (30-40 feet). An outcrop of Priest Rapids along Indian Creek (SW¼ sec. 20, T. 37 N., R. 2 E.) may also be a sill.

Grande Ronde Basalt

Tgr_2—Grande Ronde R_2 magnetostratigraphic unit (Miocene)—Dark gray, fine- to very fine-grained, aphyric to plagioclase-microphyric basalt. Uppermost unit or units typically contain abundant microphenocrysts. Hackly to blocky entablature common. Reverse magnetic polarity. Consists of two or three flows. Unit appears to pinch out toward the east-northeast near Juliaetta. Westward towards the Lewiston basin near Green Knob, the unit thickens to over 60 m (200 feet; Bush and others, 2001). According to Garwood and others (1999), the flows are tentatively correlated to the Wapshilla Ridge unit of Reidel and others (1989).

A small, isolated exposure of basalt with reverse polarity and Grande Ronde chemistry (sample 00JK016, map no. 13) is present along the South Fork of Dicks Creek (sec. 28, T. 38 N., R. 1 E.). It is at an elevation of 870 m (2,850 feet), equivalent to nearby exposures of Priest Rapids, and apparently above an interbed that overlies Grande Ronde N_1. The exposure is too small to show at the map scale, but the location is noted by the sample number. The basalt is dark gray and fine grained with abundant microphenocrysts of plagioclase.

Tgn_1—Grande Ronde N_1 magnetostratigraphic unit (Miocene)—Dense, dark gray, fine- to very fine-grained basalt. Microphyric with abundant plagioclase laths and needles <1 mm. Normal magnetic polarity. Consists of as many as five flows. Blocky to hackly entablature commonly forms cliffs. Invasive into sediments east of Oviatt Creek. The uppermost N_1 flow typically has a well-developed saprolite. Maximum thickness is about 75 m (250 feet).

The basal contact with the underlying R_1 member is difficult to determine in places because of inconsistent magnetic readings at the top of the R_1. Northeast of Kendrick, stratigraphic problems are also caused by the invasion of N_1 basalt beneath sediment that elsewhere separates N_1 and R_2 units. Chemically, the flows are similar to the intermediate to high MgO and relatively low TiO_2 flows of Reidel and others (1989) and are tentatively correlated with their China Creek unit (Garwood and others, 1999). Near Juliaetta and Texas Ridge, the flows are commonly separated by a sedimentary interbed of the Latah Formation, which is best exposed along the grade between Kendrick and Deary. Chemical data from N_1 flows on the grade do not correlate well with data for N_1 units in the surrounding areas.

Tgr_1—Grande Ronde R_1 magnetostratigraphic unit (Miocene)—Dense, dark gray basalt. Microphyric but also contains a few scarce plagioclase laths up to 5 mm. Reverse magnetic polarity, although uppermost unit locally gives conflicting readings. Hackly to blocky entablature commonly forms cliffs 6-12 m (20-40 feet) high. Consists of as many as four flows, locally separated by sediments, or possibly invasive into the sediments. Along Potlatch Creek between Juliaetta and Kendrick, the unit is more than 120 m (400 feet) thick with little evidence of flow-top features. Chilled contacts at the top of this unit indicate that it is a sill. To the west and southwest, the same sequence contains interbeds and flow-top features. The base is rarely exposed; however, along the Clearwater River 8 km (5 miles) south of Juliaetta the basal *Tgr$_1$* is invasive into an interbed that rests on the Imnaha Basalt. Garwood and others (1999) suggest the R_1 in Latah County is correlative to the Center Creek unit of Reidel and others (1989) and Bond (1963).

Imnaha Basalt

Tim—Imnaha Basalt (Miocene)—Flows are typically fine to medium grained with scattered to abundant plagioclase phenocrysts and glomerocrysts as large as 2 cm. At least one flow is medium to coarse grained with scarce plagioclase phenocrysts as much as 5 mm. Erosional contact with basement rocks exposed along the Clearwater River at the southern edge of the map. Normal magnetic polarity. Well data from the Juliaetta area and exposures north of the Clearwater River and east of Big Canyon Creek indicate that the Imnaha is at least 120 m (400 feet) thick.

A thick hyaloclastite or tuff breccia is present at top of the Imnaha in Cranberry Creek, Elk Creek, and south of Dent along the north shore of Dworshak Reservoir. Different in appearance and character from the hyaloclastic deposits associated with the Priest Rapids Member; varies from crudely bedded arkosic sediments with glassy lapilli fragments to a crystal-lithic tuff breccia also crudely bedded in places. Inclusions of large basalt fragments or zones of invasive basalt are common. Contains wood fragments and randomly oriented plagioclase crystals commonly 2 cm in length. Crude columnar structure present locally; weathers to gray-brown grus-like detritus, although commonly resistant to weathering because of zeolite(?) cement. Probably as much as 60 m (200 feet) thick in places along Elk Creek; in erosional contact with overlying Priest Rapids Member in Cranberry Creek and probably in Elk Creek.

POTLATCH VOLCANICS

Basalt and subordinate amounts of trachyte tuff compose the herein informally named Potlatch volcanics. Columbia River basalt abuts or overlies these volcanic rocks. The basaltic part was previously mapped as the Onaway Member of the Columbia River Basalt Group (Swanson and others, 1979a; Camp, 1981), but field relations and dating indicate that these rocks are about 10 million years older than the oldest flows of the Columbia River basalt. In the Hatter Creek area south of Potlatch, the basalt is closely associated with trachytes, described below, that have a similar age. However, the field relation between the two units was not determined.

Ton—Basalt of Onaway (Oligocene)—Dark gray to black, fine-grained, sparsely to moderately plagioclase-phyric basalt. Phenocryst content is as much as 20 percent plagioclase; locally pyroxene phyric. Plagioclase phenocrysts are typically 1 cm or less, but rarely as much as 5 cm in length (Duncan and Bush, 1999b). These crystals are commonly embayed and may be xenocrysts. Flow-aligned plagioclase laths in the groundmass define a moderately developed fabric at several localities. Other minerals include opaque oxides, olivine, clinopyroxene, and minor potassium feldspar. Unit typically has brown weathering rinds and at some localities weathers to gray or purplish clay that is difficult to recognize as basalt. These deeply weathered zones may exceed 6 m (20 feet) in thickness and have been mined for commercial clay. Drill hole data from the Potlatch area indicate that the basalts are at least 150 m (500 feet) thick in places. One dike too small to show at map scale has been identified southwest of Deary (Potter, 2001), where the basalt cross-cuts schist and gneiss in Big Bear Creek (sample LB1030, map no. 205). Several outcrops near Harvard were cored and found to have normal polarity. Fluxgate magnetometer readings of the flows along the Dent road also indicate normal polarity. However, the number of flows in this unit is unknown, and it has not been verified that all known units have normal polarity.

Camp (1981) originally named these flows the basalt of Potlatch, Onaway Member of the Columbia River Basalt Group, and placed the unit at the top of the Wanapum Basalt. Later, Bush and others (1995) thought the Onaway was likely part of the Saddle Mountains Basalt, until two $^{40}Ar/^{39}Ar$ dates indicated the basalt was older than Columbia River basalt and Oligocene in age (25.6 ± 0.2 Ma and 26.2 ± 0.2 Ma; samples H1-9 and H1-6, respectively, from the Harvard quarry, map letters A and B). These are similar to a K-Ar whole-rock age of 25.3 ± 1.2 Ma (VC79-003, map letter C) from one of Camp's Onaway samples near Princeton (unpub. data, Department of Energy, Rockwell Hanford Operations). Camp's sample and others he collected in the Potlatch-Troy area have a similar chemical signature (Wright and others, 1980) to those collected recently. In addition, a flow along the Dent road south of Elk River (SE¼ sec. 23, T. 39 N., R. 2 E.), collected during this mapping project, has the chemical signature of Onaway basalt and a whole-rock K-Ar age of 25.9 ± 0.8 Ma (sample 00JK068; map letter D). Recent mapping east of Troy, in conjunction with the age data, has confirmed that the Onaway clearly underlies and is older than Columbia River basalt.

When compared chemically to most Columbia River basalt flows, the basalts of the Potlatch volcanics are generally lower in SiO_2 and higher in Al_2O_3, TiO_2, Na_2O and P_2O_5. Trace elements also show distinctive differences from most Columbia River basalts, with generally lower Cr and higher Ba, Sr, Nb, and Ce. Duncan (1998) compared Nb-TiO_2 and Zr-TiO_2 ratios from samples collected on the Potlatch 7.5-minute quadrangle and concluded that there are at least three chemical types.

Tth—Trachyte of Hatter Creek (Oligocene)—Predominantly pyroclastic trachyte and minor trachyte lava flows(?) exposed mainly in the Hatter Creek area 8 km (5 miles) south of Potlatch. Includes light-colored trachyte crystal tuff and trachyte crystal-lithic tuff. Crystal tuff contains 1 to 3 mm sanidine. Microprobe data indicate that at least some of the groundmass is anorthoclase. Crystal-lithic tuff has sparse sanidine, flattened pumice, and clasts of quartzite and crystal tuff. Chemical analyses indicate high total alkalies and trachyte composition (John Wolfe, 2000, written commun.). Hornblende from tuff sample PR-1 (map letter E) has an $^{40}Ar/^{39}Ar$ plateau age of 26.32 ± 0.17 Ma.

POTATO HILL VOLCANICS

Rhyolitic and dacitic volcanic rocks exposed on Potato Hill north of Deary and in isolated masses near Bovill are probably Eocene in age and equivalent to the Challis Vocanics in south-central Idaho. Dated Eocene hypabyssal rocks (*Tpd* unit) are present 12 km (7 miles) southwest of Potato Hill. Welded tuff and other pyroclastic rocks have been noted in the Potato Hill area and its circular outline suggests it may be a small caldera (John Wolfe, oral commun., 1998; Bill Bonnichsen, oral commun., 2000). Vertical flow banding and contacts in the northwest part of Potato Hill along with abundant clast-rich units were used as evidence to suggest that that area was the primary vent (Bush and others, 1999b).

Trdv—Rhyolitic and dacitic volcanic rocks (Eocene)—A complex group of slightly porphyritic and nonporphyritic, rhyolitic to dacitic volcanic rocks that are locally clast rich and flow banded. In places, the volcanics are in complex contact with shallow intrusive rocks. Colors range from very dark gray and black to white, light gray, and pinkish gray. Best exposed in the Potato Hill area near Deary. The clasts range in size from under a millimeter to several meters in diameter, but 5-10 cm is common. Clast-rich (>20 percent) units are intercalated with units that contain less than 1 percent lithic fragments. Volcanic fragments are the most common, but granitoid clasts are more apparent because of their light color in the darker matrix. The granitoid fragments are presumed to be Cretaceous (*Kgu* unit) and Eocene (*Tggd* unit). The former contain quartz, plagioclase, orthoclase, muscovite, and minor biotite. The Eocene clasts lack muscovite and typically are darker with amphibole and biotite. Rare fragments of fine-grained quartzite and pegmatitic clasts of quartz, muscovite, and feldspar also are found.

Porphyritic volcanic rocks tend to underlie units that are less porphyritic and more clast rich. Some of these porphyritic units are poorly exposed at low elevations along the west end of Potato Hill and in outcrops in the NE¼ sec. 12, T. 40 N., R. 2 W. They are light in color, typically lavender or gray. They weather dark red-brown and are locally stained with iron-oxides. Phenocrysts constitute 3-10 percent and are set in a dense aphanitic devitrified groundmass. Tan to white elongate feldspars as much as 3.0 mm in length are the predominate phenocryst. Bitten (1951) reported that plagioclase, typically oligoclase, is slightly more abundant than orthoclase. Quartz, the second most abundant phenocryst, occurs as rounded anhedral grains ranging from 0.25 to 2.0 mm in diameter. Magnetite, hornblende, apatite, and zircon also have been reported (Tullis, 1940). Chemical analyses from Tullis (1940) and Bill Bonnichsen (written commun., 1997) indicate rhyolitic to dacitic composition.

INTRUSIVE ROCKS

Tb—Basalt dikes, undivided (Miocene)—Dark gray basalt dikes present along Dworshak Reservoir east of Dent Bridge. Probable feeder dikes for undetermined flows of the Columbia River Basalt Group.

Ttr—Trachyte dikes (Oligocene?)—Dark gray, aphyric trachyte dikes exposed east of Sand Mountain. Rocks contain about 60 percent plagioclase, 15 percent brown glass(?), 10 percent prismatic pyroxene(?), and 5 percent opaque oxides. Most similar chemically to alkaline rocks of the Potlatch volcanics, but not as rich in alkalies (8.1-9.2 versus 9.6-13.7 percent K_2O+Na_2O).

Tr—Rhyolite dikes (Eocene)—Light gray rhyolite dikes. Locally contain phenocrysts of quartz, andesine, and biotite. Probably related to the Potato Hill volcanics.

Tpd—Porphyritic dacite dikes and plugs (Eocene)—

Porphyritic dacite with a gray aphanitic groundmass and phenocrysts of plagioclase, quartz, biotite, and hornblende. Potter (2001) reported a biotite $^{40}Ar/^{39}Ar$ date of 51.29 ± 0.26 (preferred age) from a sample collected in Dry Creek.

Ta—Andesite dikes (Eocene?)—Intermediate to mafic dikes, typically andesitic, but including diabase and lamprophyre.

Tgg—Granophyric biotite granite (Eocene)—Pale pink, fine-grained biotite granite with a micrographic (granophyric) texture. Exposed in one small intrusion southeast of Bovill where it forms massive, resistant outcrops. Has 1-2 mm plagioclase phenocrysts and miarolitic cavities. Contains roughly 22-30 percent quartz, 40-42 percent potassium feldspar, 25-35 percent plagioclase, and 3 percent biotite.

Tggd—Granite and granodiorite (Eocene)—Small stocks composed primarily of granite and granodiorite but including minor quartz monzodiorite and monzodiorite. Typically massive, medium-grained, and seriate to porphyritic. Most contain hornblende in addition to biotite and have pale pink potassium feldspar in the groundmass. Biotite and hornblende are euhedral; phenocrysts of euhedral potassium feldspar are present locally. Elk River stock (quartz monzonite of Hietanen, 1963) has a faint subhorizontal flow(?) foliation on the northeast side. It contains perthitic interstitial orthoclase; single grains of plagioclase are strongly zoned (An_{40} to An_{28}; Hietanen, 1963). Elk River stock has relatively low initial $^{87}Sr/Sr^{86}$ ratios (0.706; samples 818-09G and 818-09J, Criss and Fleck, 1987). Small stock northeast of Spring Valley Reservoir consists of hornblende-biotite quartz monzodiorite to the north and porphyritic biotite granite to the south. Hornblende in the quartz monzodiorite has pyroxene cores.

Kap—Aplite and pegmatite (Cretaceous)—Areas of abundant granitic aplite and pegmatite dikes and sills east-northeast of Elk River and north of Hemlock Butte.

Kgu—Granitic rocks, undivided (Cretaceous)—Primarily weakly foliated to massive, equigranular to weakly porphyritic, biotite- and muscovite-biotite granodiorite and granite. Includes lesser amounts of foliated biotite tonalite and biotite quartz diorite. Granodiorite and granite are exposed on East and West Twin, northeast of Moscow, and east of Beals Butte north of Bovill. They typically contain 1-3 percent muscovite and locally as much as 7.5 percent (Tullis, 1940). Biotite content is 0.1-6.8 percent (Tullis, 1940). Plagioclase is oligoclase (An_{25}) that either is unzoned or has a thin outer sodic-rich zone; myrmekitic intergrowths of quartz and oligoclase common (McNeill, 1971). Foliated biotite tonalite and biotite quartz diorite with 0.5-14.2 percent biotite are present 2.4 km (1.5 miles) south of West Twin, and at several other localities in the western part of the area (Tullis, 1940). Contact relations between these rocks and the granodiorite and granite have not be determined. Initial $^{87}Sr/^{86}Sr$ ratios are greater than 0.708 (Criss and Fleck, 1987). Minimum age of 69.8 ± 0.2 Ma based on biotite K-Ar date from granite collected in a roadcut 8 km (5 miles) north of Moscow (recalculated from McDowell, 1971).

Kbgd—Biotite granodiorite (Cretaceous?)—Weakly foliated to massive, fine- to medium-grained biotite granodiorite. Subdivided from *Kgu* only in the area northeast of Park. Contains 4-5 percent biotite and 1 percent or less muscovite.

Kgdg—Granodiorite gneiss (Cretaceous)—Strongly foliated (mylonitic) flaser gneiss of granodiorite composition exposed along the west side of Dworshak Reservoir 1.6 km (1 mile) north of Dworshak Dam and along Cedar Creek northeast of Kendrick. Dworshak exposure contains about 15 percent potassium feldspar in l-cm-long porphryoblasts, 5 percent biotite, and 2 percent garnet. Initial $^{87}Sr/^{86}Sr$ ratios at that location are about 0.708 (sample 837-24C, Criss and Fleck, 1987). Cedar Creek exposure contains about 20 percent potassium feldspar, 15 percent biotite, and trace amounts of garnet. A sample from Big Eddy Marina, 1.6 km (1 mile) north of Dworshak Dam, produced a 96 ± 1 Ma U-Pb zircon age (single grain TIMS analysis by D.M. Unruh, U.S. Geological Survey; Karen Lund, written commun., 2004).

Kbt—Biotite tonalite (Cretaceous)—Foliated to massive biotite tonalite. Biotite 3-10 percent. Contains 1-2 percent muscovite in exposures immediately north of Dent Bridge in T. 38 N., R. 2 E. Described in more detail by Hietanen (1962).

Ktt—Biotite tonalite and hornblende-biotite tonalite (Cretaceous)—Moderately foliated biotite tonalite and lesser amounts of hornblende-biotite tonalite. Exposed only in the southeast part of the map. Exposures immediately south of the map area contain 7-15 percent biotite and 0-10 percent hornblende. Initial $^{87}Sr/^{86}Sr$ values there are transitional between low (<0.704) and high (>0.706) from west to east along Orofino Creek (Criss and Fleck, 1987).

Khgd—Hornblende granodiorite (Cretaceous?)—Medium-grained, massive to weakly foliated and weakly lineated, equigranular hornblende granodiorite and minor pyroxene-quartz-plagioclase rock (granofels?). Exposed only west of Troy. The granodiorite is unusual in that it lacks biotite. The granofels has equant grains with numerous 120 degree intersections (i.e., crystalloblastic texture) yet has the composition of pyroxene tonalite. Unit may represent granodiorite that has intruded and partially assimilated calc-silicate country rocks. Alternatively, the granodiorite magma may have brought granulite-facies basement rocks (granofels) to higher crustal levels.

Kqdg—Quartz diorite gneiss (Cretaceous)—Foliated, medium- to coarse-grained, hornblende-biotite quartz diorite gneiss. Initial $^{87}Sr/^{86}Sr$ ratios are about 0.707-0.708 (Criss and Fleck, 1987; R. Fleck, written commun., 2002). Minimum age for quartz diorite gneiss 2.4 km (1.5 miles) north of Freeman Creek along Dworshak Reservoir is 76.3 ± 0.2 Ma (hornblende $^{40}Ar/^{39}Ar$ plateau age; Davidson, 1990). Same body contains about 7 percent biotite, 3 percent hornblende, and 1 percent primary epidote with allanite cores.

Kqd—Quartz diorite (Cretaceous)—Massive to foliated, medium- to coarse-grained, hornblende-biotite quartz diorite and minor tonalite and granodiorite. Includes the Hemlock Butte stock, which contains 10-12 percent biotite, 1-5 percent hornblende, and a few percent primary(?) epidote. The plagioclase is moderately zoned andesine (An_{30-39}), some with bent twin lamellae. This stock is sharply discordant (Hietanen, 1963). Other stocks contain as much as 15 percent hornblende. Stock in Bedrock Creek contains foliated granodiorite in the south, possibly related to the *Kgdg* unit. Initial $^{87}Sr/^{86}Sr$ ratios are typically 0.707-0.709 with the exception of an exposure in the southern part of Bedrock Creek which is 0.713 (Criss and Fleck, 1987; Fleck and Criss, 2004). Age is probably similar to Kqdg unit. Minimum age of Hemlock Butte stock is 60 Ma based on $^{40}Ar/^{39}Ar$ dating of biotite (Timothy Grover, written commun., 2002).

Kog—Orthogneiss (Cretaceous)—Gray, moderately to strongly foliated, biotite tonalite gneiss and subordinate hornblende-biotite quartz diorite gneiss. May include granodiorite gneiss at the southernmost exposures along Middle Potlatch Creek. Biotite is the primary mafic mineral (10-15 percent). Anderson (1991) reported unzoned andesine (An_{32}) and garnet, and a crystalloblastic (metamorphic) texture from tonalite along Middle Potlatch Creek. Initial $^{87}Sr/^{86}Sr$ ratios are 0.712-0.713 in this same area (Fleck and Criss, 2004). Age is poorly known, but orthogneiss is considered to be Cretaceous based on similarities with approximately 94 Ma orthogneiss near Lowell (Toth and Stacey, 1992).

Kam—Amphibolite (Cretaceous)—Black to dark gray, fine- to medium-grained, foliated to lineated hornblende-plagioclase rock. Associated with *Kog* unit and interpreted here as Cretaceous mafic intrusions. Otherwise similar to *KYam*.

Ksy—Syenite (Cretaceous)—Medium- to coarse-grained pyroxene-hornblende syenite and quartz syenite, and lesser amounts of monzonite, quartz monzonite, and pyroxene syenite. Syenite and quartz syenite in the Gold Hill stock northeast of Potlatch contain 0.1-5 percent quartz, 49-57 percent potassium feldspar, 9-22 percent plagioclase, 9-31 percent hornblende, and 0.1-9 percent pyroxene (Wong, 1980). The pyroxene syenite is similar but contains 8-13 pyroxene and only 1-3 percent hornblende; the quartz monzonite contains as much as 14 percent quartz (Wong, 1980). The Gold Hill stock hosts several small gold mines and prospects (Faick, 1937) and is locally layered. Green Knob stock is a poorly exposed, light-colored, medium-grained syenite body northeast of Genesee (Bush and others, 2001). It consists largely of microcline microperthite accompanied by a small amount of plagioclase, trace amounts of muscovite and opaque oxides, and minor amounts of unusually large zircon. Anderson (1991) reported an anhedral granular to crystalloblastic texture with evidence of metamorphism. U-Pb analyses of zircon provided a 74 ± 1 Ma age from the Green Knob stock (Bush and others, 2001).

Kpx—Pyroxenite (Cretaceous)—Coarse-grained and lesser amounts of fine-grained pyroxenite exposed only in Gold Hill area northeast of Potlatch. Aggregate of augite, biotite, epidote, oligoclase, albite, microcline, and orthoclase; minor hornblende, titanite, and magnetite (Faick, 1937). Wong (1980) reported up to 95 percent augite and cumulate textures. Augite largely altered to hornblende, actinolite, biotite, and chlorite (Faick, 1937).

KJbtg—Biotite tonalite gneiss (Jurassic or Cretaceous)—Foliated, light gray, medium-grained, equigranular biotite tonalite gneiss. Contains about 7-13 percent biotite and 1-2 percent primary epidote. Initial $^{87}Sr/^{86}Sr$ ratios are <0.704 (Criss and Fleck, 1987; Fleck and Criss, 2004). Intermixed with but overall less deformed than the *KJqdg* unit.

KJqdg—Quartz diorite gneiss (Jurassic or Cretaceous)—Foliated, medium- to coarse-grained, hornblende-biotite quartz diorite gneiss. Mylonitic texture is typically recrystallized, forming blastomylonite. Contains 5-10 percent biotite, 5-15 percent hornblende, and primary epidote. All sampled bodies have initial $^{87}Sr/^{86}Sr$ ratios <0.704 (Criss and Fleck, 1987). Quartz diorite from the Dworshak Dam quarry yielded a 116.7 ± 1 Ma U-Pb zircon age (single grain TIMS analysis by D.M. Unruh, U.S. Geological Survey; Karen Lund, written commun., 2004). The quartz diorite at the dam yielded younger ^{40}Ar/^{39}Ar plateau ages on hornblende (81.9 ± 0.4 Ma and 82.2 ± 0.4 Ma; Davidson, 1990) indicating that cooling was protracted.

KJqd—Quartz diorite (Jurassic or Cretaceous)—Massive to foliated, medium- to coarse-grained, hornblende-biotite quartz diorite. Exposed only at the southern map boundary. A hornblende ^{40}Ar/^{39}Ar plateau age of 121.9 ± 0.5 Ma obtained by Davidson (1990) from quartz diorite sample collected 1.2 km (0.75 mile) east of the Peck Junction on Highway 12, immediately south of the map area, is a minimum age for the quartz diorite southwest of the Ahsahka thrust; nearly concordant hornblende and biotite ^{40}Ar/^{39}Ar plateau ages from a quartz diorite at Peck, 3 km (2 miles) farther south, suggest an implacement age of 135 Ma (Davidson, 1990).

KJdg—Diorite and gabbro (Jurassic or Cretaceous)—Dark gray, massive to foliated and lineated, hornblende diorite and gabbro. Minor amounts of hornblendite, ultramafic rocks, and other mafic-rich (hypersthene-augite-hornblende-cummingtonite) rocks. Discrete mylonitic zones common. Relict clinopyroxene; abundant hornblende (typically 40 percent of rock; Hietanen, 1962) and lesser actinolite. Minor epidote, quartz, magnetite, biotite, and chlorite. Epidote is euhedral and likely metamorphic in origin. Plagioclase laths typically aligned and bent lamellae common; composition An_{46-55}. See Hietanen (1962) for more detailed descriptions. ^{40}Ar/^{39}Ar data indicate a likely emplacement age of about 145 Ma and a minimum age of about 130 Ma (Davidson, 1990).

KYam—Amphibolite (Proterozoic or Cretaceous)—Black to dark gray, fine-grained, foliated hornblende-plagioclase rock. Similar to *Kam*, but present in metasedimentary units. Age highly uncertain, but those in *Ysgp* may be metamorphic equivalents of Proterozoic sills in the less metamorphosed Prichard Formation north of the area.

Yag—Augen gneiss (Proterozoic)—Coarse-grained, porphyritic, garnet-muscovite-biotite augen gneiss. Present as numerous sills both east and west of the Dent Bridge in T. 38 N., R. 2 E.; most are too small to show at map scale. Also includes larger masses south of Bovill, south of Moscow, and northeast of Kendrick that are similar mineralogically and chemically to those near Dent and which are tentatively assigned to this unit. Granite and granodiorite in composition. Potassium feldspar augen locally as much as 12 cm in length; typically 4-6 cm. Abundant myrmekitic and perthitic textures. Contains 10-20 percent biotite, 0-2 percent muscovite, and 0-1 percent garnet. Localities near Dent Bridge first recognized by Kopp (1959), who noted two exposures that occupy hinges of tight folds. U-Pb zircon SHRIMP age of zircon cores from a sill west of Dent (map letter WD) indicate an intrusive age of 1379 ± 12 Ma (William McClelland, written commun., 2004). Zircon rims in the same sample give ages of 82-87 Ma; these are interpreted to reflect the approximate age of metamorphism.

ISLAND ARC(?) ROCKS

JPg—Gneissic rocks (Permian to Jurassic?)—Mixed metavolcanic(?) and metasedimentary unit consisting of biotite-quartz-plagioclase gneiss, amphibolite, and muscovite-quartz schist. Gneiss contains subequal amounts of quartz and plagioclase, lesser biotite, and minor muscovite, garnet, and cordierite(?); possible protoliths are andesitic and dacitic tuffs. Schist contains quartz and lesser plagioclase and muscovite; likely protolith is clastic sedimentary rock. Unit exposed only in the extreme southern part of the area. May be part of the Orofino series.

OROFINO SERIES

Amphibolite-facies metasedimentary (and metavolcanic?) rocks first recognized near Orofino (Anderson, 1930; Hietanen, 1962). Commonly sulfide-rich with iron-stained exteriors. Lithologically varied at outcrop scale. Includes marble commonly associated with dark-colored fine-grained garnet-diopside-quartz-plagioclase-hornblende gneiss of fairly uniform appearance. The series appears to belong to the Wallowa accreted terrane assemblage, but straddles the initial ^{87}Sr/^{86}Sr 0.704-0.706 line (Criss and Fleck, 1987; Fleck and Criss, 2004) from Orofino to Kooskia. May be equivalent to parts of the Riggins Group (upper part of Squaw Creek Schist?), 100 km to the south, described by Hamilton (1963). It must be older than its metamorphic age of about 80 Ma (Davidson, 1990). Detrital zircons collected from a quartzitic interval near Orofino yielded Permian to Cretaceous (280-80 Ma) ages (Schmidt and others, 2003). Grains with ages less than 117 Ma have Th/U ratios <0.15 (Paul Link, writtten commun., 2003) and may have a metamorphic origin.

Mzgo—Gneiss and schist of the Orofino series (Mesozoic)—Fine- to medium-grained hornblende-biotite gneiss and schist consisting primarily of plagioclase, hornblende, and quartz with subordinate and various amounts of biotite along with minor garnet and magnetite.

Mzco—Calc-silicate rocks of the Orofino series (Mesozoic)—Calc-silicate gneiss, amphibolite, and calc-silicate quartzite. Minerals include quartz, diopside, biotite, plagioclase (An_{37-40}), hornblende, epidote, zoisite, clinozoisite, garnet, and scapolite (Hietanen, 1962). The garnet is locally abundant (as much as half the rock), light brownish red, and mainly grossularite (Heitanen, 1962).

Mzmo—Marble of the Orofino series (Mesozoic)—Tan-weathering, white to light bluish gray marble in discontinuous lenses. Most beds are pure calcite (grains 0.5-5 mm in diameter) with minor amounts of pyrite, tremolite, diopside, quartz, and sphene (Hietanen, 1962). Kopp (1959) reported graphite, plagioclase, and mica.

Mzqo—Quartzite of the Orofino series (Msozoic)—Quartzite, biotite quartzite, and feldspathic quartzite. Grain size 0.1-2 mm. Typically mylonitic. Contains 0-17 percent potassium feldspar and 1-59 percent plagioclase.

Mzao—Amphibolite of the Orofino series (Mesozoic)—Foliated or lineated plagioclase-hornblende rocks with less than 10 percent quartz. Locally contain garnet and biotite.

PALEOZOIC(?) METASEDIMENTARY ROCKS

Ꞓqk—Quartzite of Kamiak Butte (Cambrian?)—Coarse-grained quartzite. Unlike quartzite units in the Belt Supergroup it lacks appreciable feldspar. Quartz grains are entirely recrystallized. Locally contains larger grains that may be relict granules and small pebbles. Exposures west of the map area on Kamiak Butte in Washington contain conglomeratic intervals (Savage, 1973) and have been tentatively assigned a Cambrian age (Webster and Nuñez, 1982). Detrital zircons from Kamiak Butte are dominated by 1,700-1,900 Ma ages (Ellis and others, 2004). This is similar to results from quartzite of the Cambrian Hamill Group in British Columbia (Gehrels and Ross, 1998). Thus, the lack of young ages may reflect an old source for these quartzites and does not require an old age of deposition. Contact with adjoining Libby Formation may be a fault or an unconformity.

SYRINGA METAMORPHIC SEQUENCE

Amphibolite-facies muscovite-biotite schist, feldspar-poor quartzite, and calc-silicate rocks that we believe are distinct from rocks in the Belt Supergroup are exposed in the southern part of the quadrangle and extend discontinuously west of map to Smoot Hill. Termed the Syringa metamorphic sequence (Lewis and others, 1992; Lewis and others, 1998), they are only exposed north and east of the initial $^{87}Sr/^{86}Sr$ 0.704-0.706 line (Criss and Fleck, 1987) and were deposited on the North American craton. Athough Hietanen (1962, 1963) mapped most of the sequence as metamorphosed Belt rocks (primarily Revett quartzite), enough lithologic differences exist between the Syringa metamorphic sequence and the Belt Supergroup to justify a separate designation. In particular, the intimate association of feldspar-poor quartzite and calc-silicate rocks is a characteristic not found in the Belt Supergroup. Preliminary U-Pb dating of detrital zircons from quartzite at locality MM, north of Mason Butte, suggests this quartzite may be as young as 680 Ma and thus postdate the Belt Supergroup (Peter Oswald and Jeff Vervoort, written commun., 2005). These results are similar to those obtained from quartzite west of Lowell, east-southeast of the map area, to which Lund and others (2005) assigned a Neoproterozoic age.

Zss—Schist and gneiss of the Syringa metamorphic sequence (Neoproterozoic)—Muscovite-biotite schist and subordinate biotite gneiss. Cordierite present east of Teakean Butte. Rare garnet more common in schist than gneiss; as much as 1 cm in diameter. Includes 1- to 10-m-thick layers of either calc-silicate rocks similar to *Zcs* or quartzite similar to *Zqs*.

Zcs—Calc-silicate rocks of the Syringa metamorphic sequence (Neoproterozoic)—Calc-silicate gneiss and granofels intervals interlayered with *Zss*. Layering absent or indistinct. Includes quartzite with as much as 50 percent garnet, massive garnet rock with 25 cm diameter poikiloblastic garnets, and minor amphibolite near *Zss*. Contains thin interlayers of quartzite, biotite quartzite, and hornblende-actinolite-diopside gneiss.

Zqs—Quartzite of the Syringa metamorphic sequence (Neoproterozoic)—Quartzite and lesser schist. Quartzite characteristically very pure (<2 percent feldspar) and coarse grained, although some thinner and finer grained layers contain as much as 15 percent feldspar. Resembles vein quartz. Grain size commonly 3-5 mm with accessory biotite 1-2 mm and muscovite of intermediate size. Locally sillimanite bearing. Small grains of hematite may be oxidation products of another mineral. Locally, sillimanite accompanies or replaces muscovite, especially on parting (shear?) surfaces. Interlayered schist is muscovitic but rarely seen because it is commonly covered by a lag of orange-weathered quartzite boulders and cobbles. Northwest of Aldermand Ridge, thicknesses of quartzite layers decrease from about 1 m to 5-10 cm toward the concentration of calc-silicate rocks (*Ycs*).

BELT SUPERGROUP

Weakly metamorphosed (greenschist facies) metasedimentary rocks of the Belt Supergroup are exposed in the northwest part of the area. Only the upper Wallace Formation and stratigraphically higher units are present there. Unusual extent of the Libby Formation indicates that it is thicker here than to the north. One explanation for the unusual thickness is that the unconformity at the base of the Cambrian was higher here and that rocks are preserved which were eroded farther north and northeast.

Yl—Libby Formation (Mesoproterozoic)—Green siltite, light gray, fine-grained quartzite, thin-bedded dolomitic siltite and quartzite, and gray argillite and siltite. Local mudcracks and small mudchips. Predominantly siltite and fine-grained quartzite. Quartzite is typically flat laminated with intervals of ripple cross lamination. The dolomitic siltite and quartzite are similar to the middle part of Wallace Formation but are interbedded with mudcracked (formerly red?) siltite and argillite, and planar-laminated quartzite unknown in the Wallace Formation. Breccia present near a carbonate interval on Gold Creek is unlike breccia in the Wallace Formation along the Montana-Idaho border. It differs in that the matrix is carbonate-poor and the clasts angular; this breccia may be tectonic, possibly along a north-northwest-trending fault. Calc-silicate minerals have formed in carbonate-bearing beds just west of Harvard and at the northern contact of the Gold Hill stock. Thinly laminated gray argillite and siltite are exposed in a small quarry northeast of Potlatch in the SW¼ sec. 20, T. 42 N., R. 4 W. Similar rocks are present on the north side of Moscow Mountain along Gnat Creek and 2.9 km (1.8 miles) north of Ball Butte, but are otherwise rare.

Ysp—Striped Peak Formation (Mesoproterozoic)—Gray to white to pale red feldspathic quartzite with lesser amounts of red and green siltite and argillite. Quartzite typically contains 20-25 percent feldspar. Lower part contains flat-laminated, medium- to thin-bedded, fine-grained quartzite and lesser amounts of siltite and argillite. Plagioclase typically much more abundant than potassium feldspar in the quartzite. Lower part equivalent to Mount Shields Formation in western Montana (Harrison and others, 1986). Upper part contains trough cross-bedded, medium- to coarse-grained quartzite with potassium feldspar content equal to or greater than plagioclase. Upper part equivalent to Bonner Formation in western Montana (Nelson and Dobell, 1961).

Ywu$_3$—Wallace Formation, upper member 3 (Mesoproterozoic)—Phyllitic argillite and siltite. Similar to Yswu$_3$, but is slightly lower metamorphic grade (lacks garnet).

METAMORPHOSED BELT SUPERGROUP

Belt formations can be traced with some certainty as far south as Moscow Mountain and Bovill and east to Hemlock Butte despite increased metamorphic grade. Argillaceous rocks formed phyllite and schist, whereas carbonate-bearing quartzitic rocks formed calc-silicate quartzite and gneiss. Exposures at Jackson Mountain, southeast of Bovill, and south of there are tentatively assigned to the Belt Supergroup, as are exposures along and northeast of Wietas Creek near the eastern map boundary.

Ysw—Schist and phyllite of the Wallace Formation (Mesoproterozoic)—Fine- to medium-grained schists with either muscovite or biotite dominant and minor calc-silicate gneiss. Locally, less deformed, centimeter-thick layers of finer, more equigranular and feldspathic material are relict siltite of original siltite-argillite couplets. Characteristically contains pale lavender garnet as much as 1 cm in diameter, but typically much smaller. Garnets appear to be late, relative to deformation at most places, but are flattened on the east side of Jackson Mountain. Contains sillimanite near or where injected with igneous material. McNeill (1971) reported porphryroblasts of andalusite and less commonly staurolite, along with “balls” of muscovite interpreted as andalusite altered to muscovite. Kyanite is reported in the Emerald Creek area west of Bechtel Butte (Chris Dail, written commun., 2003). Mapped as middle part of Wallace Formation by McNeill (1971). Correlated here with the upper member of the Wallace Formation or its stratigraphic equivalent, the Snowslip and Shepard formations, in Montana (Lemoine and Winston, 1986) on the basis of stratigraphic position.

Yswu$_3$—Schist and phyllite, upper member 3 of the Wallace Formation (Mesoproterozoic)—Fine-grained biotite-muscovite schist and biotite-muscovite phyllite. Garnets rare. Tends to be more muscovitic and quartzose (sandier) than *Yswu$_1$*. Equivalent to the upper argillitic part of the Shepard Formation in western Montana (Lemoine and Winston, 1986).

Ycwu$_2$—Calc-silicate rocks, upper member 2 of the Wallace Formation (Mesoproterozoic)—Gneiss and schist that contain scapolite, diopside, and actinolite in addition to major constituents of biotite, quartz, and feldspar. Centimeter- to decimeter-scale layering. Equivalent to the lower, main part of the Shepard Formation present in western Montana (Lemoine and Winston, 1986).

Yswu$_1$—Schist and phyllite, upper member 1 of the Wallace Formation (Mesoproterozoic)—Biotite-muscovite schist, muscovite-biotite schist, and phyllite. Lowest part scapolitic, suggesting former presence of saline minerals. Some layers have abundant garnets 2-5 mm in diameter; others are garnet free. Some garnets flattened in foliation plane. Locally iron-stained and nearly muscovite free, but elsewhere contains abundant muscovite. Sillimanite-bearing near pegmatites and granitic bodies. Bedding at high angle to schistosity near Mica Mountain. Numerous pegmatites that cut the schist south of Mica Mountain contain quartz, feldspar, muscovite, apatite, beryl, and tourmaline (Forrester, 1942) and were once mined.

Yqcw—Quartzite and calc-silicate rocks of the Wallace Formation (Mesoproterozoic)—Fine-grained feldspathic quartzite, biotite granofels, calc-silicate quartzite, and minor schist. Parting typically on decimeter or meter scale. Grains typically 1 mm or less across. Muscovite porphyroblasts to 5 mm common in places. Layering 1-10 cm thick defined by phlogopite or biotite granofels or concentrations of stubby prisms of actinolite. Layering appears relict and locally preserves grading and truncation of laminae. Molar-tooth structures are near the Palouse River divide (McNeill, 1971). Diopside more common around Anthony Peak; actinolite more common in southeasternmost exposures. Hornblende present but rare in map area. Typically feldspathic (17-67 percent feldspar), but minor quartz-rich intervals. Plagioclase generally more abundant than potassium feldspar. McNeill (1971) reported oligoclase (An_{23}) in the Beals Butte area. Correlated with the pinch and swell (middle) member of the Wallace Formation on the basis of abundance, bedding style, and the feldspathic nature of quartz-rich rock, but is not as thick-bedded and lacks pronounced pinch and swell present along the St. Joe River to the north. On Jackson Mountain, includes unusually thin layers of diopside, actinolite calc-silicate gneiss, and granofels that may be correlative with the lower member of the Wallace Formation. Millimeter- and centimeter-scale layering there appears relict from original, perhaps cryptalgal, lamination. Similarly, exposures northwest of Dworshak Reservoir near the eastern edge of the map area are only tentatively assigned to this unit, and their stratigraphic position is uncertain.

Ysqw—Schist within quartzite and calc-silicate rocks of the Wallace Formation (Mesoproterozoic)—Garnet-muscovite-biotite schist. Subunit of *Yqcw* mapped near the head of Long Slim Creek, 11 km (7 miles) northeast of Bovill, on the northwest flank of Hemlock Butte, and north of Dworshak Reservoir near the east edge of the map area. Sillimanite and abundant garnet in unit near east edge of area. Exposures near the eastern map boundary are only tentatively assigned to this unit.

Yssr—Schist of the St. Regis(?) Formation (Mesoproterozoic)—Fine- to medium-grained garnet-muscovite-biotite schist. Mapped in several places as a lower schist unit in the Wallace Formation (Hietanen, 1963), but here tentatively assigned to the St. Regis Formation on the basis of stratigraphic position and lack of calc-silicate minerals. Contains slightly more quartz and less garnet than *Ysw*, but is otherwise similar.

Yqr—Quartzite of the Revett(?) Formation (Mesoproterozoic)—Feldspathic quartzite exposed only along the Middle Fork of the St. Maries River northwest of Hemlock Butte. Tentatively assigned to the Revett Formation, but may alternatively be *Yqcw*. Grain size 0.1-1 mm. Contains approximately 10-15 percent potassium feldspar, 13-14 percent plagioclase, 1 percent muscovite, and trace biotite.

Ysgp—Schist and gneiss of the Prichard(?) Formation (Mesoproterozoic)—Coarse-grained muscovite-biotite schist and minor muscovite-biotite gneiss. Locally garnetiferous. Typically associated with orthogneiss unit (*Kog*) and only exposed in northeast part of area.

METAMORPHOSED BELT SUPERGROUP(?)

Highly deformed amphibolite-facies metasedimentary rocks exposed in the central and eastern parts of the area. Most likely equivalent to lower grade rocks of the Belt Supergroup, but metamorphism and deformation preclude assignment to specific formations. If indeed Belt Supergroup equivalents, they are probably one or more of the following: (1) Libby Formation, (2) carbonate-bearing facies of the Prichard Formation, (3) upper members of the Wallace Formation, or (4) lower member of the Wallace Formation and the underlying St. Regis Formation. The lower Belt stratigraphic sequence is difficult to reconstruct because quartzite-rich rocks of the Ravalli Group, in particular the Revett Formation, have not been recognized. Moreover, sediments deposited in this part of the Belt basin may be facies not previously recognized. In particular, the Prichard Formation may contain more shallow-water facies here, including carbonate, than is typical to the northeast. If Prichard-equivalent, these carbonate-rich rocks (now calc-silicate gneisses), may indicate a nearby basin margin.

Ysg—Schist and gneiss (Mesoproterozoic)—Medium- to coarse-grained muscovite-biotite schist and biotite-quartz-feldspar gneiss. Schist typically weathers rusty orange-red and contains subordinate, discontinuous layers of *Ycs*. Biotite dominant in most places, with larger, apparently later growing muscovite porphyroblasts common. Variants include rocks with either mica exclusively. Sillimanite common, as much as 20 percent of the rock in places. Garnet as large as 1 cm in diameter abundant locally but not characteristic. Gneissic rocks most common in southeast part of area east of Dent Bridge and southeast of Alderman Ridge. Layering less than 1 cm commonly folded on outcrop scale. Near Dent Bridge, the gneiss of the *Ysg* unit contains augen gneiss (*Yag*) interpreted as small intrusions. The age of one of these constrains the schist and gneiss in that area to be as old as or older than the Belt Supergroup (see *Yag*).

Ycs—Calc-silicate gneiss (Mesoproterozoic)—Varied diopside-, actinolite-, hornblende-, garnet-, and scapolite-bearing gneiss, quartzite, granofels, and minor diopside marble. Includes meter-parting, centimeter-layered diopside gneiss, diopside quartzite, garnetiferous quartzite, and massive white scapolite(?) plagioclase assemblages mottled with diopside. Typically contains 30-50 percent plagioclase and 8 percent or less potassium feldspar. Interval of graphitic diopside marble along Three Bear Creek contains 30 percent potassium feldspar and is interlayered with wollastonite-garnet-diopside marble with garnet as much as 10 cm across. Rarely includes centimeter-scale quartzite similar to that of the Wallace Formation. In comparison to the Wallace Formation (*Yqcw*), unit contains more calc-silicate minerals, particularly hornblende, and is present in relatively thin intervals separated by sillimanite-rich schist (*Ysg*).

Yqs—Quartzite and schist (Mesoproterozoic)—Rare quartzite intervals and subordinate interlayered schist in *Ysg*. Quartzite typically feldspar poor. Tourmaline-bearing south-southwest of Deary in southeast corner of sec. 9, T. 39 N., R. 2 W.

UNNAMED METAMORPHIC ROCKS

The age and correlation are unknown for amphibolite-facies metasedimentary rocks in the northeastern part of the quadrangle. Likely correlative units include the Syringa metamorphic sequence, the Belt Supergroup, or the quartzite-dominated metasedimentary sequence at Bertha Hill east of the map area (Headquarters 30' x 60' quadrangle). The quartzite in the Syringa sequence and that at Bertha Hill are feldspar poor, as is the unnamed quartzite described below. A detrital zircon sample from Bertha Hill lacks the young grains typical of nearby Belt metasediments, and the Bertha Hill quartzite may be stratigraphically low in or below the Belt Supergroup (Lewis and others, 2004). The Bertha Hill quartzite yielded an age spectrum similar to that for Belt formations with east-derived sediment, including the Neihart Formation quartzite at the base of the Belt section in the eastern part of the Belt basin (Keefer, 1972; Ross and Villeneuve, 2003) and the Aldridge Formation, a lower Belt equivalent in Canada (Ross and Villeneuve, 2003). Lacking are the young (1,490-1,610 Ma), non-Laurentian grains typical of the western facies of the Belt Supergoup. However, other permissive ages exist for the Bertha Hill quartzite, including Neoproterozoic and Cambrian.

ZXs—Schist (Proterozoic)—Biotite-muscovite schist and muscovite-biotite schist. Includes zones with thin, fine-grained, feldspar-quartz granofelsic layering. Locally contains garnets as much as 2 cm in diameter. Contains rare kyanite (kyanite and cordierite present at locality 404 north of Stony Creek). Sillimanite increasingly abundant to the south. Includes thin (1- to 10-m) layers of either calc-silicate rocks similar to *ZXcs* or rarer quartzite similar to but perhaps more feldspathic than *ZXq*.

ZXcs—Calc-silicate rocks (Proterozoic)—Calc-silicate gneiss and granofels. Includes centimeter-scale layered intervals and less distinctly layered zones of diopside quartzite and diopside-actinolite gneiss.

ZXq—Quartzite (Proterozoic)—Quartzite and lesser muscovite-biotite schist. Quartzite typically muscovitic with low feldspar content. Relict(?) compositional layering on a centimeter-scale well preserved in some places. Schist contains garnet as large as 1 cm in diameter locally. Includes centimeter-scale layered biotite-feldspar quartzite and biotite gneiss. Locally mylonitic. Where deformed, quartz grains are platy to elongate and separated by parallel flakes of mica.

Table 1. Rb/Sr isotopic data for plutonic rocks in the Potlatch 30' x 60' quadrangle. Mosdified from Fleck and Criss (2004) with the addition of lithology designation and slightly different age assignments.

Map no.	Sample #	Lithology	Unit	Latitude	Longitude	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Ri	Age (Ma)
423	00WMC084	bt tonalite	KJqdg	46.5270°N	116.2879°W	30	492	0.176345	0.703500	0.703212	115
424	00WMC086	hb -bt quartz diorite	Kqdg	46.5562°N	116.2839°W	54	666	0.234582	0.707439	0.707139	90
387	00RL503	hb -bt granodiorite	Kqd	46.5443°N	116.5608°W	86	308	0.808395	0.714516	0.713482	90
388	00RL508	hb -bt quartz diorite	Kqd	46.5539°N	116.5500°W	41	742	0.159872	0.707874	0.707670	90
407	00RL589	bt tonalite	KJbtg	46.5330°N	116.3073°W	21	569	0.106735	0.703299	0.703125	115
420	DG-PC-2	bt hb quartz diorite	Kqd	46.5623°N	116.6574°W	31	874	0.102626	0.708215	0.708084	90

GEOCHEMISTRY

Over 440 samples of Eocene to Miocene volcanic rocks and more than 60 samples of Eocene and older basement rocks were analyzed by whole-rock X-ray fluorescence (XRF) methods for this study. The locations for most of these samples are shown on the map; a complete list of volcanic rock samples and chemical results is available in a digital format (Kauffman, 2004b) as are the data for the basement rocks (Lewis and Frost, 2005). The digital sample set includes eight unpublished XRF analyses of basement samples collected by Bill Bonnichsen during earlier regional reconnaissance of the Potlatch quadrangle (written commun., 2000). The digital data set of Kauffman (2004b) includes analyses of about a hundred volcanic rocks collected between 1978 and 1980 by Victor Camp in a regional study of the Columbia River Basalt Group (Swanson and others, 1979a). Locations for most of Camp's samples are also shown on the map. All basalt samples and most basement rocks were analyzed at Washington State University's GeoAnalytical Laboratory. Other samples were analyzed in the laboratory of Ronald B. Gilmore, University of Massachusetts at Amherst (Bill Bonnichsen's samples) or at U.S. Geological Survey laboratories in Denver, Colorado.

Six plutonic rock samples from the southeast part of the area were analyzed for Rb/Sr isotopic composition to more precisely locate the initial $^{87}Sr/^{86}Sr$ 0.704/0.706 line (Armstrong and others, 1977; Criss and Fleck, 1987). Results provided by Robert Fleck of the U.S. Geological Survey are reported in Table 1. These analyses are a subset of a much larger USGS collection available in Fleck and Criss (2004).

Volcanic Rock Chemistry

Some basalt units have distinctive physical characteristics that can be used to identify them in the field, whereas others are very similar in appearance and cannot be easily separated. Many previous workers have used chemical signatures to map individual flows or groups of flows, and this technique was used extensively to map basalt units on the Potlatch quadrangle. Table 2 presents averages of major oxides for the various Columbia River basalt (CRB) units. We have found that our chemical results closely match those of previous workers (Wright and others, 1980; Camp, 1981). Several basalt flows previously included in the Columbia River Basalt Group have been determined to be Oligocene in age rather than Miocene (Kauffman and others, 2003). Average major oxide chemistry for these units, composing the Onaway member of the Potlatch volcanics, indicates high total alkalis compared to Columbia River basalts (Table 2). Oligocene trachytic tuffs and lavas, composing the Hatter Creek member of the Potlatch volcanics, average 5.43 percent K_2O and 6.05 percent Na_2O (Table 2). The Hatter Creek member clearly differs from the Eocene(?) Potato Hill volcanics, which have lower total alkalies and lower Al_2O_3 contents (Table 2).

Plutonic Rock Chemistry

Table 3 presents averages of major oxides and selected trace elements for several of the plutonic rock units on the Potlatch quadrangle. The XRF analyses indicate that, in general, the Cretaceous plutonic rocks of the *Kgu*, *Kog*, and *Kqd* units are similar chemically to those of the Idaho batholith. With two exceptions, Na_2O contents exceed K_2O, a common feature in the batholith (Lewis and others, 1987). Sr concentrations in most samples are not as high as typical

Table 2. Average major oxide values of volcanic units collected in the Potlatch 30' x 60' quadrangle. Data from Kauffman (2004b).

		Major elements in weight percent									
Unit name	n	SiO_2	Al_2O_3	TiO_2	FeO*	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5
COLUMBIA RIVER BASALT GROUP											
SADDLE MOUNTAINS											
Swamp Creek	5	51.28	14.44	2.66	13.46	0.23	8.70	4.74	1.23	2.72	0.35
Weippe	31	51.34	14.97	1.76	11.12	0.19	10.77	6.58	0.48	2.45	0.23
Lewiston Orchards	8	49.42	15.49	2.29	10.84	0.19	11.32	7.10	0.38	2.43	0.52
Asotin	35	50.74	16.24	1.44	9.39	0.16	11.30	7.59	0.53	2.37	0.20
Wilbur Creek	6	54.56	14.92	1.94	10.34	0.16	8.48	4.41	1.88	2.75	0.51
Lapwai	1	52.28	15.32	1.70	10.95	0.18	9.19	5.94	1.43	2.47	0.36
WANAPUM											
Priest Rapids	168	50.27	13.85	3.28	13.49	0.24	9.21	5.04	1.16	2.64	0.77
GRANDE RONDE											
Grande Ronde R_2	28	55.38	13.96	2.30	11.50	0.20	7.55	3.82	1.70	3.17	0.39
Grande Ronde N_1	113	55.53	14.20	1.99	10.97	0.20	7.90	4.15	1.52	3.19	0.34
Grande Ronde R_1	58	55.32	13.95	2.24	11.59	0.20	7.61	3.89	1.63	3.19	0.35
IMNAHA											
Imnaha	8	51.78	15.65	2.40	12.05	0.17	8.69	5.14	0.96	2.77	0.34
POTLATCH VOLCANICS											
Onaway member	46	49.19	16.92	3.65	11.76	0.17	7.55	4.35	1.89	3.65	0.81
Hatter Creek member	6	65.22	17.93	0.46	3.44	0.05	1.11	0.13	5.43	6.05	0.14
POTATO HILL VOLCANICS	9	69.89	14.34	0.63	4.13	0.08	2.00	0.65	3.84	4.18	0.23

n = number of samples analyzed.
* Major elements are normalized on a volatile-free basis, with total Fe expressed as FeO.
Includes samples collected by V. E. Camp in 1978 and 1979. Analytical results used with permission (Camp, written commun., 2002).
All analyses performed at Washington State University GeoAnalytical Laboratory, Pullman, Washington.

batholith rocks but are well in excess of Rb (averages range from 449-702 ppm Sr and 51-95 ppm Rb). In contrast, the Tertiary granodiorite has low Sr concentrations (217 ppm). Most Rb/Sr ratios in the Cretaceous plutons are 0.39 or less, compared to values of 0.2 or less in the northern part of the Idaho batholith (Frost and Lewis, 2004). Anomalous samples with K_2O>Na_2O are sample C-40 (map no. 415) on the north side of Potato Hill (*Kgu* unit) and sample 00RL415 (map no. 369) along Cedar Creek northeast of Kendrick (*Kgdg* unit). Eocene plutonic rocks tend to have higher K_2O/Na_2O ratios, and sample C-40 may be from an Eocene intrusion incorrectly mapped as a Cretaceous one. Plutonic rocks with low initial $^{87}Sr/^{86}Sr$ values (units *KJbtg*, *KJdg*, and *KJqdg*) have lower concentrations of K_2O (average 0.21-1.21 percent) and Rb (22-24 ppm) than the *Kgu*, *Kog*, and *Kqd* units, which reflects the oceanic source area for these older plutonic units.

Proterozoic augen gneiss sills and plutons throughout the region, including the dated Proterozoic plutons near Elk City and Shoup, are characterized by high K_2O/Na_2O ratios (1.33-2.22) and high Rb/Sr ratios (0.48-2.8). These characteristics, along with low Al_2O_3 concentrations (average of 13.4 percent in the Potlatch quadrangle, Table 3), are typical of "anorogenic" Proterozoic granites and granitic gneisses elsewhere in the western United States (Anderson, 1983). These chemical characteristics, along with lithologic features, were used to assign the gneissic rocks near McGary Butte (map no. 389) and in Cedar Creek (map no. 370) to the Yag unit rather than the Cretaceous orthogneiss unit (*Kog*).

Sample 00RL415 (map no. 369 in *Kgdg* along Cedar Creek northeast of Kendrick) is an orthogneiss that shares some, but not all, chemical characteristics of Proterozoic augen gneiss (unit *Yag*). In addition to the high K_2O content it has an unusually high Rb/Sr ratio (0.54) relative to the batholith. However, it lacks the elevated Y concentration that typifies the Proterozoic augen gneiss (25 ppm versus typical values of 35 to 80 ppm for *Yag*). It may be that Proterozoic intrusive rocks are more extensive in Cedar Creek than presently mapped. Sample 00RL416 (map no. 370), collected upstream from sample 00RL415, has a composition more similar to the *Yag* unit and is mapped as such.

Initial $^{87}Sr/^{86}Sr$ values in plutonic rocks show a dramatic change from <0.704 in the southern part of the quadrangle to >0.706 in the central and northern parts of the quadrangle (Armstrong and others, 1977; Criss and Fleck, 1987; Fleck

Table 3. Average major oxide and selected trace element values for plutonic units on the Potlatch 30' x 60' quadrangle. Unpublished data from R. Lewis and T.Frost.

		Major elements in weight percent										Trace elements in parts per million				
Map unit	Unit name	SiO_2	Al_2O_3	TiO_2	FeO*	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	Ba	Rb	Sr	Zr	Y
Tggd	granite and granodiorite	n=2 67.4	n=2 15.5	n=2 0.68	n=2 3.70	n=2 0.08	n=2 2.69	n=2 1.14	n=2 3.52	n=2 4.20	n=2 0.19	n=1 847	n=1 99	n=1 217	n=1 177	n=1 16
Kgu	granitic rocks, undivided	n=5 70.5	n=5 16.3	n=5 0.23	n=5 1.77	n=5 0.04	n=5 2.26	n=5 0.66	n=5 3.04	n=5 4.43	n=5 0.12	n=4 867	n=4 86	n=4 604	n=4 111	n=4 17
Kog	orthogneiss	n=2 69.7	n=2 15.7	n=2 0.41	n=2 2.93	n=2 0.03	n=2 2.47	n=2 1.31	n=2 3.30	n=2 3.97	n=2 0.07	n=2 847	n=2 95	n=2 449	n=2 224	n=2 16
Kqd	quartz diorite	n=4 60.5	n=4 18.9	n=4 0.71	n=4 5.03	n=4 0.08	n=4 6.33	n=4 2.48	n=4 1.63	n=4 3.82	n=4 0.21	n=4 729	n=4 51	n=4 702	n=4 188	n=4 15
Ksy	syenite	n=1 64.9	n=1 19.0	n=1 0.050	n=1 0.26	n=1 0.010	n=1 0.07	n=1 0.00	n=1 10.81	n=1 3.83	n=1 0.000	--	--	--	--	--
KJbtg	biotite tonalite gneiss	n=3 70.9	n=3 16.3	n=3 0.28	n=3 2.06	n=3 0.04	n=3 3.47	n=3 0.77	n=3 1.11	n=3 4.92	n=3 0.09	n=3 502	n=3 22	n=3 650	n=3 98	n=3 4
KJdg	diorite and gabbro	n=2 52.7	n=2 20.2	n=2 0.78	n=2 7.00	n=2 0.15	n=2 9.12	n=2 4.60	n=2 0.21	n=2 4.02	n=2 0.26	--	--	--	--	--
KJqdg	quartz diorite gneiss	n=1 57.3	n=1 19.1	n=1 0.73	n=1 6.31	n=1 0.15	n=1 7.72	n=1 3.21	n=1 1.21	n=1 4.18	n=1 0.25	n=1 428	n=1 24	n=1 795	n=1 69	n=1 14
Yag	augen gneiss	n=3 72.5	n=3 13.4	n=3 0.54	n=3 3.73	n=3 0.05	n=3 1.67	n=3 0.78	n=3 4.42	n=3 2.41	n=3 0.13	n=3 942	n=3 162	n=3 123	n=3 363	n=3 74

n = number of samples analyzed.
* Major elements are normalized on a volatile-free basis, with total Fe expressed as FeO.
All analyses performed at Washington State University GeoAnalytical Laboratory, Pullman, Washington.

and Criss, 2004). The 0.704/0.706 "line" is more or less east-west near the southern map boundary (Figure 4). Our more detailed sampling, reported in Table 1, indicates that initial $^{87}Sr/^{86}Sr$ values do not increase in a simple fashion across the 0.704/0.706 line. From Ahsahka northeast for 2 km (1.2 miles) the initial $^{87}Sr/^{86}Sr$ values (Ri) are between 0.703 and 0.704 (Figure 5). They jump to >0.708 in granodiorite flaser gneiss at the Big Eddy Marina but decrease again to <0.704 before finally obtaining the highest values 6 km (3.7 miles) northeast of Ahsahka. A similar relationship is present to the west in Bedrock Creek where a sample of granodiorite gave a higher value (0.713, sample 00RL503, map no. 387) than a quartz diorite sample 1.3 km to the northeast (0.708, sample RL508, map no. 388). One explanation for these relatively high values within the granodiorite samples is that they represent younger intrusions whose more radiogenic (cratonic) sources were underthrust below the accreted Wallowa terrane after the older(?) low initial $^{87}Sr/^{86}Sr$ intrusions had formed. A similar scenario was postulated for the variation in initial $^{87}Sr/^{86}Sr$ values in Neogene volcanic rocks of eastern Oregon and western Idaho (Leeman and others, 1992). An alternative explanation is that the high initial $^{87}Sr/^{86}Sr$ values reflect fault slices of cratonic material within the accreted terrane (Fleck and Criss, 2004).

Metasedimentary Rock Chemistry

As expected, the metasedimentary rocks in the area have a wide range of chemical compositions that mirror the wide lithologic range from quartzite to calc-silicate gneiss to schist. One purpose in sampling the metasedimentary rocks was to better understand how bedrock composition is related to tree growth and tree mortality. Recent work by the Intermountain Forest Tree Nutrition Cooperative at the University of Idaho strongly correlated rock types with tree health (Garrison-Johnston and others, 2003b; Moore and others, 2004). Reasons for these correlations are uncertain, but different growth conditions may be in part related to the susceptibility of the local bedrock to weathering. Chemical analyses may be used as one aid in determining bedrock weathering potential in the forested areas of the Inland Northwest (Garrison-Johnston and others, 2003a).

STRUCTURE

Terrane Boundary

The most significant structure of the area is the tectonic boundary that separates the Orofino series from the Syringa metamorphic sequence in the southeast part of the map. This feature is the suture between the Wallowa accreted terrane

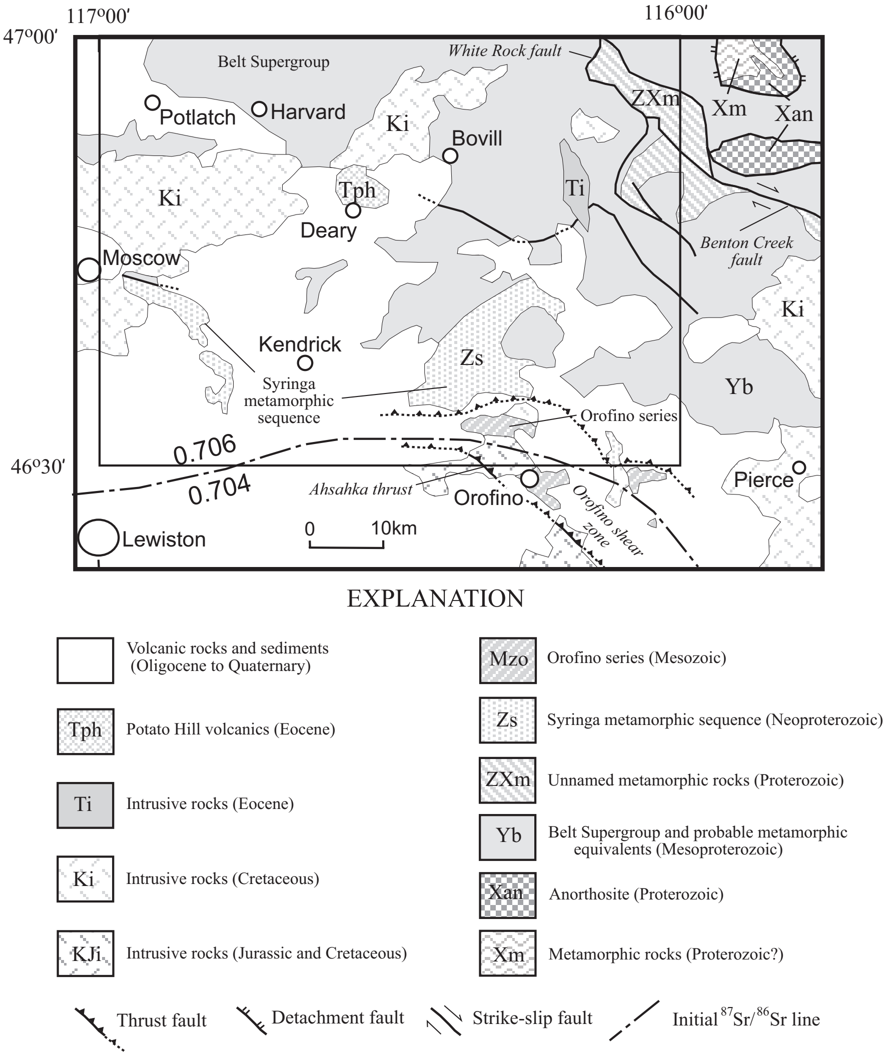


Figure 4. *Simplified geologic map of the Potlatch 30′ x 60′ quadrangle and nearby areas. Quadrangle boundary is outlined.*

to the southwest and the North American continent to the northeast (Figure 4). Although the fault contact itself is covered by Miocene Columbia River basalt and younger surficial deposits, planar fabrics near and southwest of the fault have a north to northeast dip, with kinematic indicators showing a consistent top-to-the-southwest motion (Strayer and others, 1989; Davidson, 1990). These fabrics suggest that the boundary is a reverse fault. As noted by Lund and others (1990), many of the plutons in and near this structure postdate the suture event that placed the Wallowa terrane against continental North America. The zone of deformation extends as far south as the Ahsahka thrust (Davidson, 1990) exposed near the southern map boundary. Rocks southwest of this structure lack the pervasive ductile deformation present to the northeast. Some of the deformation north of the Ahsahka thrust is younger than 88 Ma and may be related to movement along a post-suture fault zone that extends southeast from Ahsahka to the area near Lowell (Orofino shear zone of Payne and McClelland, 2002, and Payne, 2004).

Thrust Faults

Although they no doubt exist, thrust faults are difficult to identity because of a lack of distinctive lithologies in the Belt Supergroup, poor exposure, and the intensity of metamorphism and deformation across all but the northwest part of the area. One thrust fault was mapped northeast of

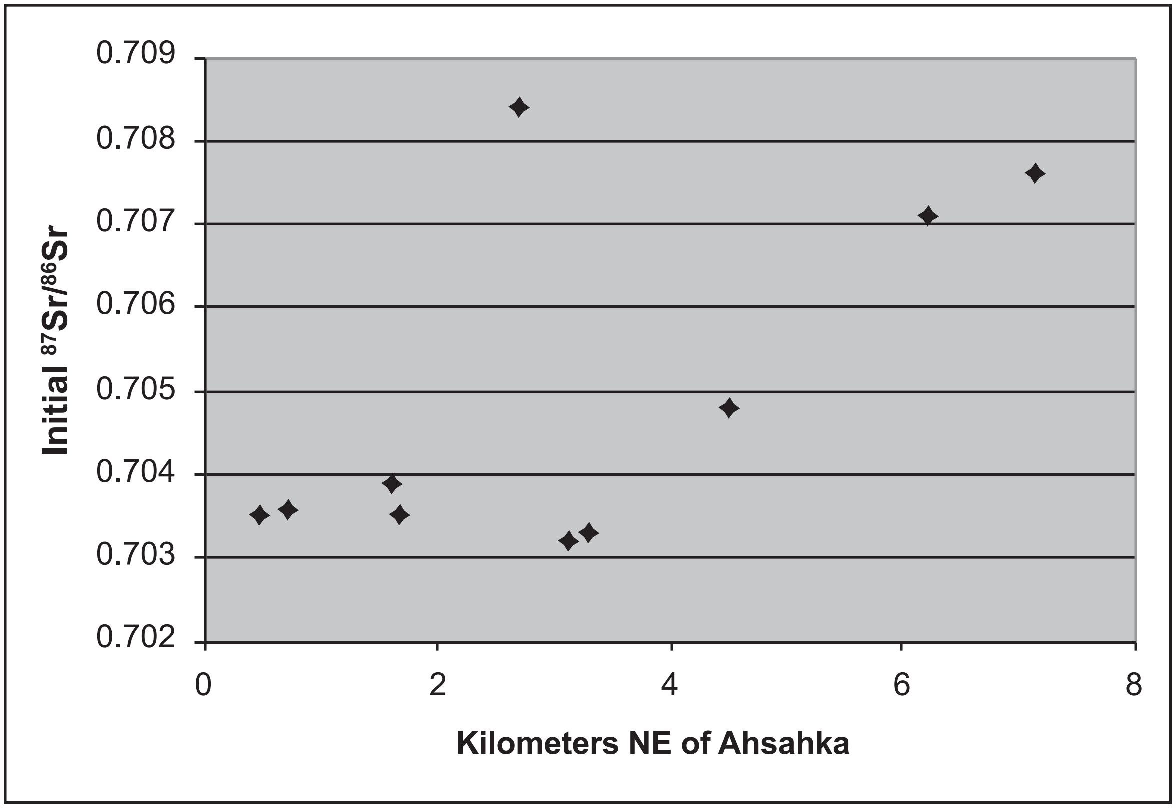


Figure 5. *Initial $^{87}Sr/^{86}Sr$ values versus distance northeast of Ahsahka. Data from Fleck and Criss (2004) and Armstrong and others (1977).*

Bovill, where *Yqcw* (quartzite and calc-silicate rocks of the Wallace Formation) is unreasonably thin between underlying *Yssr* (schist of the St. Regis Formation) and overlying *Ysw* (schist of the Wallace Formation). An alterative explanation is that this is a down-to-the-north normal fault.

Eocene Extensional Faults

The White Rock fault (Hietanen, 1984) extends into the northeast part of the map area from the St. Maries quadrangle (Lewis and others, 2000). There, it is a down-to-the-west normal fault. North of Hemlock Butte, the strike of the fault changes to east-southeast, and the fault is interpreted to have a significant component of strike-slip motion. Near the east edge of the map area, it joins the Benton Creek-Kelly Forks fault system. Collectively, the White Rock, Benton Creek, and Kelly Forks faults represent an Eocene extensional relay system between the Priest River metamorphic complex, northwest of the area, to the Bitterroot core complex to the southeast (Doughty and others, 1990; Burmester and others, 2004). To the north, the White Rock fault has brittle deformation superimposed on an older, top-to-the-west zone of ductile deformation. In the Potlatch quadrangle, mylonitic rocks are well developed along Stony Creek, but brittle fabrics are rare, perhaps indicating that uplift and erosion have been greater there. Brittle west-northwest extension appears to have been more common south of the White Rock fault in the Elk River area where north-south dikes and larger intrusions of Eocene age interrupt the older rocks. North-northwest-striking faults in this area probably date from this same extensional event.

East-west and northwest-striking faults are present in the central and northwest parts of the area, although poor exposure makes it difficult to delineate structural features. A northwest-striking fault mapped east of McGary Butte southeast of Bovill may be an important regional structure with greater lateral extent than shown on the map. Although the fault was not traced to the west, the map patterns show an apparent 15-20 km (9-12 miles) right-lateral offset of the granitic rocks (*Kgu* unit) from the Palouse Range in the west to the Moose Creek area in the east along an east-west line

5 km (3 miles) north of Deary. A short east-west fault mapped north of the Palouse Range may be the western strand of this fault. Additional detailed mapping would be needed to verify this hypothesis.

Miocene Folds and Faults

Structures in the southwest part of the area are dominated by folds and rare faults in the Columbia River basalt. Mapping shows that the basalts are rarely horizontal and that the folds have wide synclinal areas with flat to near flat troughs separated by narrow asymmetrical anticlinal ridges. Some of the folds are monoclines. The Cottonwood Creek fault (Bond, 1963) is mapped as a steep fault, probably southwest dipping and down-to-the northeast. If southwest dipping, then this is a reverse fault.

GEOLOGIC HISTORY

Major processes in the evolution of the Potlatch quadrangle's geology include the deposition of sedimentary sequences in the Proterozoic, the intrusion, metamorphism, and deformation in the Mesozoic, and the extensional faulting, intrusion, extrusion, and sedimentation in the Tertiary. Miocene and younger downcutting of canyons and Pleistocene accumulation of thick loess deposits account for much of the present topography. The simplified geologic map in Figure 4 shows the distribution of the major rock units in the Potlatch quadrangle and nearby area. Evidence for and details of the region's history are presented below.

The fine-grained siliciclastic and carbonate-bearing clastic rocks of the Belt Supergroup were deposited during the Mesoproterozoic between about 1,470 and 1,400 Ma (Anderson and Davis, 1995; Evans and others, 2000) with early deposition accompanied by intrusion of mafic magmas (Cressman, 1989). Continental reconstructions for the Proterozoic place North America against Australia-Antarctica (e.g., Moores, 1991; Dalziel, 1991; Doughty and others, 1998; Burrett and Berry, 2000) or Siberia (Sears and Price, 2000). These reconstructions suggest that the Belt and other Proterozoic basins were intracratonic. Thus, an intracratonic rifting event may have triggered initial and possibly also a later subsidence (Cressman, 1989; Sears and others, 1998). The Belt formations present in the quadrangle (Ravalli Group and higher) were deposited in relatively shallow water (near or above wave base). If calc-silicate rocks (*Ycs*), mapped tentatively as metamorphosed Belt Supergroup, are metamorphosed lower Belt (Prichard Formation), then the area may have once contained a shallow-water, carbonate-rich facies of the Belt Supergroup near its southwest margin. This carbonate facies would be analogous to the Newland Formation (Zieg, 1986) present on the east side of the basin.

Belt Supergroup deposition may have been terminated by a regional plutonic and tectonic event. Near or shortly after the end of Belt Supergroup deposition, A-type rapakivi granite plutons were intruded from southern British Columbia (Ryan and Blenkinsop, 1971) to Shoup (Evans and Zartman, 1990; Doughty and Chamberlain, 1996). Many of these bodies are now augen gneiss. Small sill-like bodies of augen gneiss (*Yag*) are preserved on a northwest trend near Dent in the Potlatch quadrangle. Larger orthogneiss bodies south of Bovill, south of Moscow, and along Cedar Creek may date from the same intrusive event. In British Columbia and near Shoup, structures in and metamorphism of the country rock appear to indicate that the rocks were deformed and metamorphosed before intrusion at about 1,370 Ma (Leech, 1962; Ryan, and Blenkinsop, 1971; McMechan and Price; 1982; Evans, 1986). Doughty and Chamberlain (1996) postulate deformation at 1,370-1,380 Ma during emplacement of the A-type granites. Although it has not been recognized, similar early deformation likely occurred in the Potlatch quadrangle. If so, contacts between Belt strata and overlying sedimentary sequences would be unconformities.

Rifting that formed the Paleozoic continental margin began in the Neoproterozoic. Sedimentary and volcanic rocks of the Windermere Supergroup in northeastern Washington (Miller, 1994) and southeast of the Potlatch area (Lund and others, 2003, 2005) are probably remnants of a more continuous rift sequence. Syringa metamorphic sequence quartzite (*Zqs*) in the Mason Butte area may be Windermere and part of this rift sequence (or late rift?), based on dating of detrital zircons as young as 680 Ma (Jeff Vervoort and Peter Oswald, written commun., 2005). Deformation before, during, and possibly after this rifting is documented by the angular unconformity of Cambrian sedimentary rocks on low metamorphic grade Belt rocks presently to the north and east of the Potlatch area (Campbell, 1959; Lewis and others, 2002). Feldspar-poor quartzite in the northwest part of the area, tentatively assigned a Cambrian age, may be a remnant of the basal Paleozoic section. The paucity of Neoproterozoic and particularly Paleozoic rocks may result from the considerable uplift and erosion necessary to expose the high-grade rocks now at the surface. Alternatively, contraction during the Cretaceous (see below) may have tectonically removed Neoproterozoic and Paleozoic rocks from the Potlatch area.

During the late Paleozoic and early Mesozoic, volcanic and volcaniclastic rocks of the Wallowa island-arc terrane were forming off the rifted continental margin somewhere west or south relative to their present-day position in North America. These rocks are present in the map area only in the extreme southern part (unit *JPg*) but are widely exposed farther south (Brooks and Vallier, 1978). In the Mesozoic, possibly in the early Cretaceous (about 144 Ma; Selverstone and others, 1992), the Wallowa terrane was accreted to continental North America along the Salmon River suture zone (Lund and Snee, 1988). The mechanics of this accretionary event are unclear, in part because of continued deformation along the suture zone following accretion. Evidence for simple convergence is east-west stretching lineation with sinstral sense of shear in quartzite near Green Knob in the southwestern part of the Potlatch quadrangle (Anderson, 1991) and the common eastward, down-dip lineations in the suture zone to the southeast. Oblique convergence is another possibility (Lund and Snee, 1988). Fabrics elsewhere in and east of the Potlatch quadrangle require a strong northward component, which could reflect dextral transpression during or after docking. Fabrics across the suture zone near Dworshak Dam indicate that movement was consistently northeast side up (Strayer and others, 1989), but these fabrics are likely to be relatively late. Deformation subsequent to suturing (as late as 72 Ma?) may play a strong role in the present configuration of the boundary and the "bend" in the 0.704/0.706 line southeast of the Potlatch quadrangle (McClelland and others, 2000; Payne and McClelland, 2002; Payne, 2004). Contraction across the suture zone probably continued through much of the Cretaceous, forming many of the folds and faults in the area. Argon ages of 88-85 Ma (Davidson, 1990) from shear zones in and immediately south of the Dworshak area may date the ductile to brittle transition in the arc rocks near the end of contraction. The Orofino series has an unclear role in the accretion history. It straddles the 0.704/0.706 line in the area near Dworshak Dam (Figure 4) and contains minor amounts of quartzite, suggesting some continental affinity, yet it has chemical and lithologic affinities with the arc complex. It must be older than its metamorphic age of about 80 Ma (Davidson, 1990).

Mesozoic magmatism began in the Jurassic in the island-arc terrane south of the map area. By the Cretaceous, magmatism was widespread throughout the quadrangle. Orthogneiss (*Kog*) present in the northeast part of the area records magmatism at deep crustal levels, probably in the Cretaceous. Plutons near Ahsahka also were deep seated; they contain primary epidote, a mineral indicative of pressures in excess of 9 kb (Zen and Hammarstrom, 1984). Later and probably shallower intrusions include extensive pegmatite and aplite bodies.

The Cretaceous also accommodated much of the metamorphism in the Potlatch quadrangle, although an earlier (Proterozoic?) metamorphic history cannot be discounted. Metamorphic rims on zircons in the augen gneiss (*Yag*) document an event at about 82-87 Ma. The garnet isograd illustrates the general metamorphic gradient across the quadrangle, although local irregularities may reflect uneven distribution of parent lithologies or later faulting. Low-grade (greenschist facies) metasedimetary rocks of the Belt Supergroup are exposed north and west of the isograd. Metamorphic grade increases gradually to the south and east. Andalusite is present north of Sand Mountain (McNeill, 1971) and sillimanite is present from Bechtel Butte southeast to Hemlock Butte and south to Ahsahka (Hietanen, 1962, 1963; Kemple, 1979). Sillimanite is particularly abundant in the central part of the quadrangle. Kyanite is present in the northeastern part of the quadrangle (e.g., on Anthony Peak and near Emerald Creek) and near Ahsahka (Davidson, 1990) but appears to be absent from Elk Butte southward to a few kilometers south of Dent (Hietanen, 1962, 1963). Staurolite is present in the northeast part of the quadrangle but is absent from Hemlock Butte south (Hietanen, 1963). Hietanen (1963) suggested the following progression: (1) initial growth of andalusite, (2) increase in pressure and growth of kyanite, and (3) increase of temperature and growth of sillimanite. However, to the east in the Boehls Butte area, andalusite is thought to have formed late during a period of unroofing (Grover and others, 1992), most likely in the Eocene. Possibly, thrust stacking is partly responsible for high-grade metamorphism, but the association of intrusive rocks with these metasediments makes it likely that some energy was supplied by magmatism at least during the growth of sillimanite. The end of amphibolite-grade conditions progressed northeast from late Cretaceous in the island-arc terrane to early Paleocene toward the northeast, as uplift and cooling of rocks presently at the surface progressed in that direction (Davidson, 1990).

The Eocene saw the return of plutonism and volcanism with the emplacement of granite and granodiorite stocks (*Tggd*, *Tgg*) and numerous dikes (*Tr*, *Tpd*, *Ta*). The Potato Hill volcanics (*Trdv*) are thought to be part of this igneous activity because they are compositionally similar to the intrusive rocks and the Challis Volcanics of central Idaho. However, they have yet to be dated. Uplift continued locally during the Eocene as west-northwest, east-southeast extension produced abrupt transition in metamorphic grade across some faults. For example, quartzite west of the White Rock fault is fine grained in contrast to quartzite east of the fault that is coarsely recrystallized and locally mylonitic. North along this fault, in the adjoining St. Maries quadrangle, low-grade rocks on the west are faulted against high-grade rocks on the east, and the garnet isograd is offset (Heitanen, 1963, 1967; Lewis and others, 2000). Although less distinct in the Potlatch quadrangle, metamorphic grade does appear to be higher east of the fault. Extension in the Elk River area was probably localized along north-northwest-striking faults, many now occupied by Eocene intrusions. Chilled margins and miarolitic cavities in some of the Eocene intrusions, and the presence of probable Eocene volcanic rocks, are consistent with these areas being at or near the surface before or during the Eocene. The age of well-developed linear and mylonitic fabrics in quartzite within the Syringa metamorphic sequence in the northeast part of the area is uncertain but suspected to be Eocene (Burmester and others, 2004). These fabrics, best developed in the northeast part of the quadrangle between Grice Ridge and Green Mountain, may result from uplift of the area east of the White Rock fault. Alternatively, they may be relict from Cretaceous or even Proterozoic deformation.

Tertiary igneous activity continued in the Oligocene with the extrusion of 25-26 Ma Potlatch volcanics. These include alkali basalt flows and less extensive trachytic volcanic rocks (Kauffman and others, 2003). During Miocene time (starting about 16 Ma), much of the area was invaded by Columbia River basalt. Some of the Wanapum and Saddle Mountains basalt units likely had their source in the eastern part of the quadrangle. The basalt flows repeatedly occupied and disrupted drainages in the area and established progressively higher base levels. Rivers that had previously transported sediment out of the area now deposited their loads upstream from and at the margins of the basalt flows (*Tls*). Additional sediment was deposited across the surface of the basalt flows. This sediment was commonly invaded or covered by subsequent flows, forming sedimentary interbeds (*Tli*) in the basalt sequence. Deposition continued after the last basalt extrusions. The sediments are typically composed of detritus derived from highland prebasalt terrains, similar to those elsewhere on and adjacent to the Columbia Plateau (Smith and others, 1989), and locally they contain clay deposits. Depositional environments include deltaic and quiet lake, flood plain, meandering and braided stream channel, and alluvial fan. Laterally the sediments grade into weathered rock, soil, and colluvium developed on basalt and prebasalt rocks. This type of lateral facies change from weathered basement rock to sediment can best be examined in the Stanford quadrangle (Priebe and Bush, 1999) near the Stanford pit. Regionally, the abundance and composition of the clay are controlled by a combination of depositional environment, paleohydrologic regime, and distance from and composition of prebasalt rocks. Deposition was typically controlled by lava damming the drainages and by local subsidence, which created deformational basins (Bond, 1963). The basalt surface has been warped in the area, but fault offset of basalt is rare. The Cottonwood fault is the only mapped postbasalt fault.

Plant fossils in Miocene sediments show that the climate was warm and wet similar to that of the southeast United States today (Smiley and Rember, 1979). Deep weathering, kaolinitic deposits, and paleosols that formed in Miocene sediments are relicts of the warm-climate chemical weathering, which may have continued into the Pliocene. The deep weathering produced saprolite that is common toward the east and northeast, a pattern that may correspond to the precipitation gradient. Since the late Miocene, the major streams have cut canyons deep into the plateau embayments. The canyons expose largely unweathered units of the Columbia River Basalt Group and basement rocks. Headward erosion is incomplete in many tributaries, resulting in a contrasting valley form above and below a nickpoint. The narrow, steep incised canyons change to broad, gently sloping valleys over a short distance. Many of the valleys upstream of a nickpoint contain Miocene sediments.

During Pleistocene glaciations, minor alpine glaciers deposited till in isolated moraines in the northeastern part of the area. The cooler and dryer climate of the Pleistocene brought on the cyclical deposition of wind-blown silt that forms the thick loess of the Palouse hills in the western part of the quadrangle. The loess thins eastward to a wind-blown soil mantle on the basalt plateau and mountain foothills.

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