Geologic Map of the Slate Creek Quadrangle, Idaho County, Idaho

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2009

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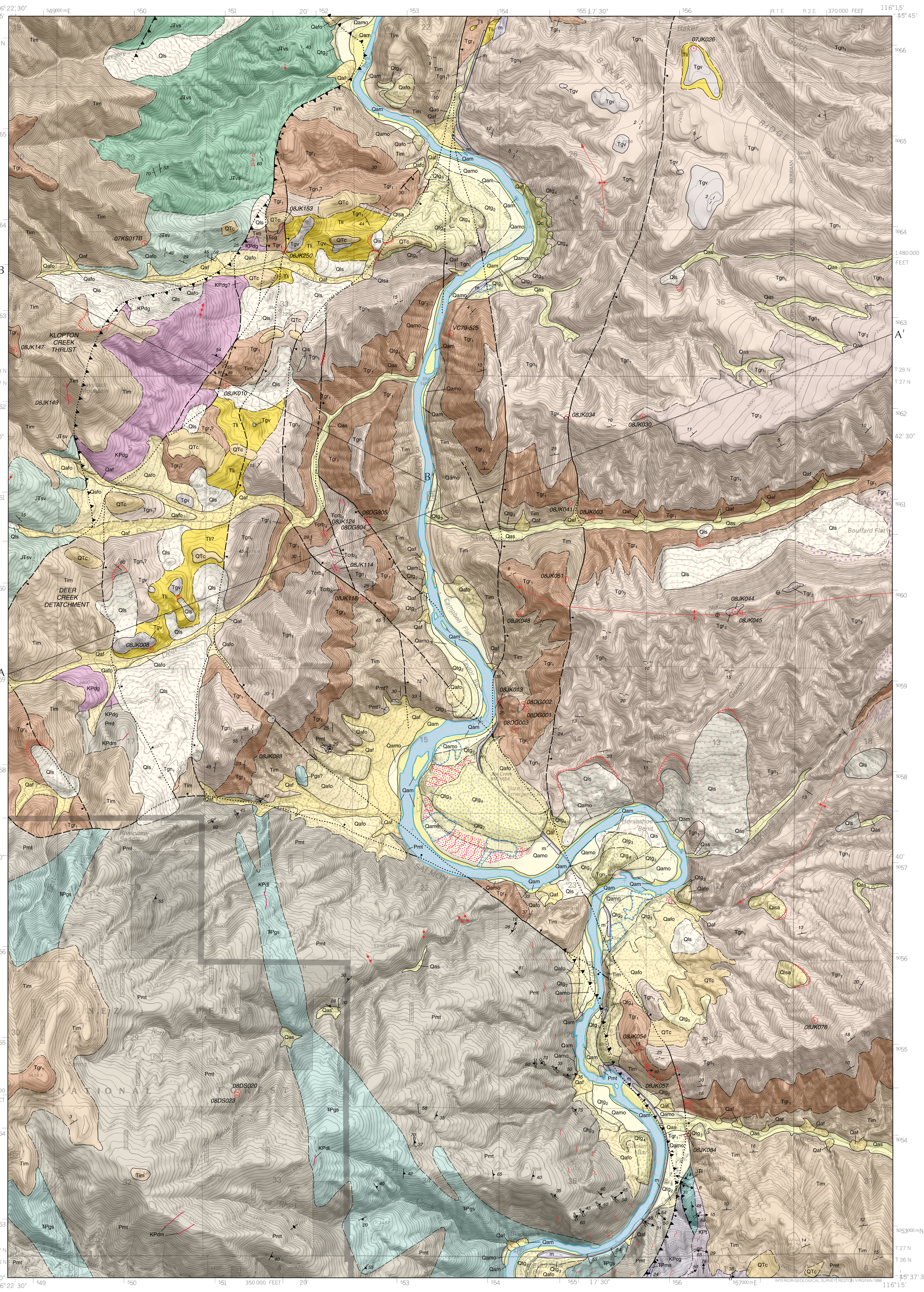
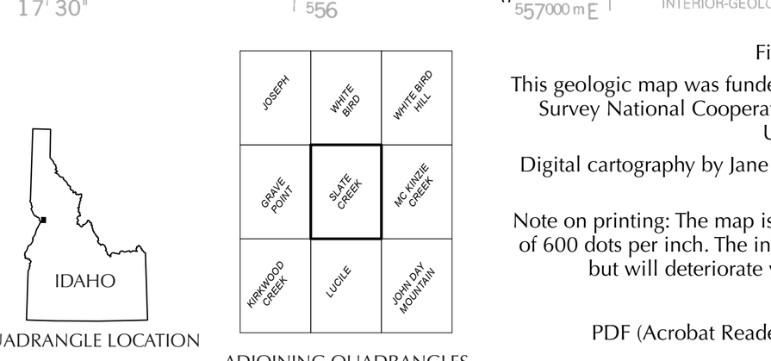


Base map scanned from USGS film positive, 1995.
Shaded elevation from 10 m DEM, vertically exaggerated 1.5x.
Topography by photogrammetric methods from aerial photographs taken 1961. Planimetry derived from imagery taken 1992. Partial field check by U.S. Forest Service 1995.
Transverse Mercator projection. 1927 North American Datum.
10,000-foot grid ticks based on Idaho coordinate system, west zone.
1000-meter Universal Transverse Mercator grid ticks, zone 11.

UTM Grid and 1997 Magnetic North Declination at Center of Map

SCALE 1:24,000

Contour interval 40 feet



Field work conducted 2007-2008.

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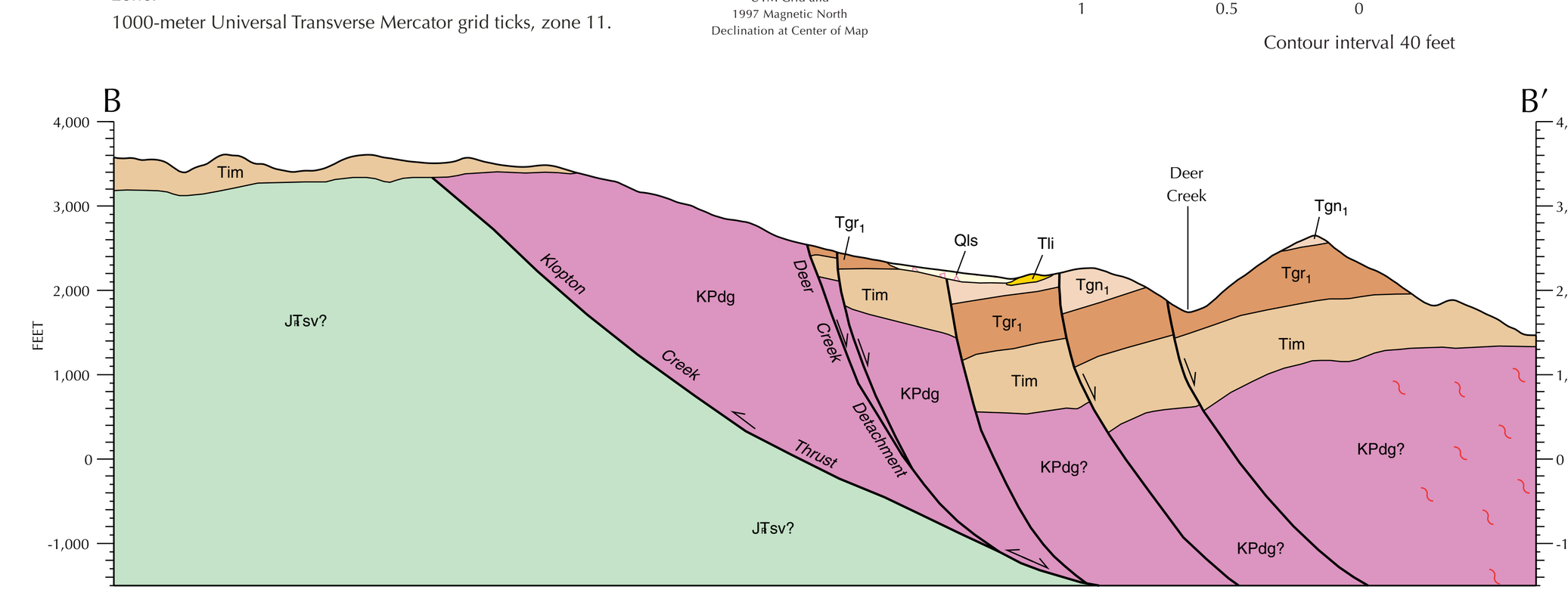
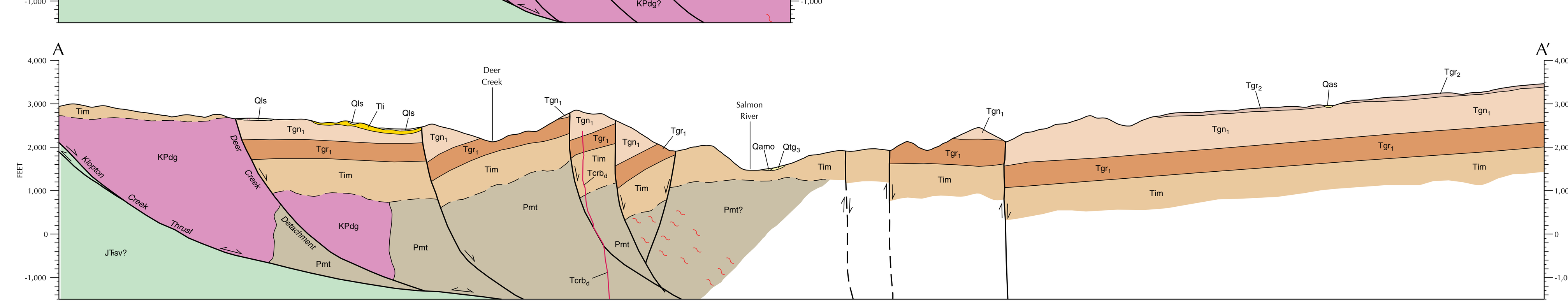
Digital cartography by Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.

Note on printing: The map is reproduced at a high resolution of 600 dots per inch. The inks are resistant to run and fading but will deteriorate with long-term exposure to light.

Map version 11-24-2009.

PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org.

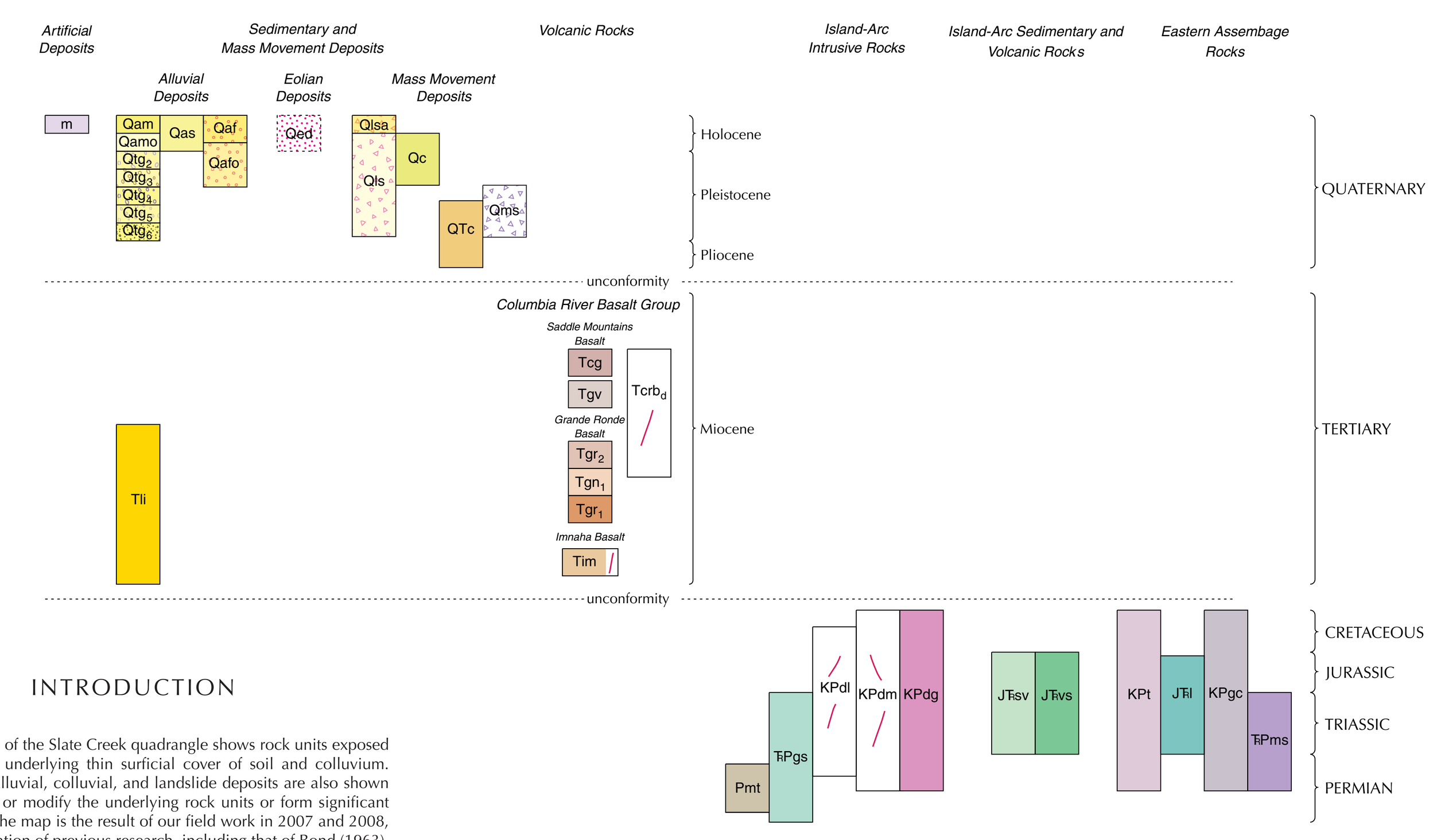




ACKNOWLEDGMENTS

We appreciate the cooperation of the private landowners who allowed access to their property. Dr. Peter Wampler, Grand Valley State University, Michigan, studied the geomorphology in the Slate Creek quadrangle during the 2007 and 2008 field seasons. He collected and submitted samples for the OSL dates, and provided interpretations of the terrace sequence and landslide events in the Salmon River canyon. The Bureau of Land Management in Cottonwood provided trailer space at the Hammer Creek campground. V.E. Camp provided copies of his field notes and map of the area.

CORRELATION OF MAP UNITS



INTRODUCTION

The geologic map of the Slate Creek quadrangle shows rock units exposed at the surface or underlying thin surficial cover of soil and colluvium. Thicker surficial alluvial, colluvial, and landslide deposits are also shown where they mask or modify the underlying rock units or form significant mappable units. The map is the result of our field work in 2007 and 2008, as well as compilation of previous research, including that of Bond (1963), Coffin (1967), Lund and others (1993), and reconnaissance mapping from 1978 to 1980 by V.E. Camp (Camp, 1981; Swanson and others, 1981).

The oldest rocks in the quadrangle are metamorphosed Permian to Jurassic volcanic, volcaniclastic, sedimentary, and associated intrusive rocks of the accreted Wallowa terrane. These folded and faulted basement rocks are capped by Columbia River Basalt Group lava flows, which are also faulted and tilted in a zone several miles wide paralleling the Salmon River. Structural offset in the basalt is more than 2000 feet between the Salmon River and the west edge of the map. Latah Formation sediments associated with the basalt probably were deposited in a developing trough west of and approximately parallel to the river. The basalt of Grangeville covered some of the sediments and the basalt of Craigmont filled a small, narrow valley. The sediments and Grangeville basalt are commonly slumped. The relatively flat soil surfaces in the Salmon River valley include loess and eolian sand parent material (Barker, 1982), but because loess deposits are thin, they are not included on this map. Eolian sand is shown as a pattern where it is thickest. In addition to present channel deposits, Salmon River alluvial deposits form terrace remnants of at least six older regimes of the river. Pleistocene and recent alluvial deposits, both stream sediments and fan deposits, are mostly related to the Salmon River and its tributaries. The map also shows landslide deposits and areas of thick colluvial cover.

DESCRIPTION OF MAP UNITS

In the following unit descriptions and later discussion of structure, we use the metric system for sizes of mineral or clast constituents of rock units, and also for small-scale features of outcrops, such as thin layering. We use the English system for most thickness and distance measurements to conform to those on the base map. 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).

Pre-Miocene volcanic rocks are classified by total alkalies versus silica chemical composition according to IUGS recommendations (LeMaitre, 1984). The Miocene Columbia River Basalt Group contains basalt, basaltic andesite, and andesite by that classification, but the term "basalt" is applied here, as it has been historically.

ARTIFICIAL DEPOSITS

m **Made ground (Holocene)**—Artificial fills composed of excavated, transported, and emplaced construction materials of highly varying composition, but typically derived from local sources. Mostly fill along U.S. Highway 95.

SEDIMENTARY AND MASS MOVEMENT DEPOSITS

Alluvial Deposits

Qam **Alluvium of the Salmon River (late Holocene)**—Channel and flood-plain deposits that are part of the present river system. Two grain-size suites are typically present: coarse sand in thin shoreline deposits, and well-sorted and rounded pebble to boulder gravel in river bars and islands. Gravel clasts include basaltic, granitic, and metamorphic rocks. Peak-flow gaging-station records indicate flood stage was exceeded less than ten times since 1894. A wood charcoal radiocarbon date of 1,770 ± 110 years BP in sand and silt shoreline deposits suggests a late Holocene to present range in age (Davis, 2001).

Qamo **Older alluvium of the Salmon River (Holocene)**—Primarily stratified sand and well-rounded pebble to boulder gravel. Forms a terrace that is significantly higher than the average historic peak flow of the Salmon River. The terrace was probably inundated during the two greatest flood stages on record, but it hosts groves of Ponderosa Pine indicating soils are predominantly dry. Presence of Mazama tephra indicates a maximum age of at least middle Holocene (Davis, 2001). Gravel clast lithology similar to *Qam*. May be capped by thin loess and eolian sand. Height above present river level averages 20 feet. Represents the first of a sequence of terraces, but distinguished from *Qtg* units (see below) by young age and potential for flooding hazard. Interfingers with or is capped by colluvium and alluvial-fan deposits at toe of canyon slope. Thickness 5-20 feet.

Qas **Channel and flood-plain deposits of Salmon River tributaries (Holocene)**—Primarily stratified and rounded pebble to boulder gravel in channels and flood plains of Deer Creek, McKinzie Creek, Skookumchuck Creek, Slate Creek, and other tributary streams. Includes finer-grained deposits of small streams in the northeast part of the map. Gravel clasts predominantly basalt. Thickness 5-30 feet.

Qaf **Alluvial-fan deposits (Holocene)**—Crudely bedded, poorly sorted brown muddy gravel derived from basalt and basement-rock colluvium on steep canyon slopes. Gravel is composed of subangular and angular pebbles, cobbles, and boulders in a matrix of granules, sand, silt, and clay. Cobbly and bouldery gravel deposited by debris flows. May include beds of silt and sand reworked from loess and Mazama ash. Also mapped in stream valleys where deposits are mostly debris flows. Thickness highly variable, ranging from 5 to 50 feet.

Qafo **Older alluvial-fan deposits (early Holocene to late Pleistocene)**—Poorly sorted gravel deposits of incised alluvial fan remnants. Cobbly and bouldery gravel deposited by debris flows. Texture and lithology similar to *Qaf*. Commonly mantled with thin loess. Thickness highly variable, ranging from 10 to 50 feet.

Gravel Terrace Deposits

Gravel deposits of high terraces in the Salmon River canyon consist of stratified sand and well-rounded pebble to boulder gravel that form remnants from 50 feet to 620 feet above the Salmon River. Gravel clast lithology is similar to *Qam*. Deposits may be capped by thin loess and eolian sand and are locally capped or interfingered with alluvial-fan deposits. Gravel of the lowest observed terrace is mapped as *Qamo* (see above), rather than Qtg_1.

Qtg_2 **Gravel of second terrace, averaging 50 feet above Salmon River (Pleistocene)**—Forms low relict point bars locally capped by thin loess and eolian sand, and small erosional remnants of a terrace. Thickness 20-40 feet. Gravel overlies bedrock strath in the southern part of the map. Gravel conformably overlain by thin-bedded silty slackwater sediments near Horseshoe Bend. Optically Stimulated Luminescence (OSL) date from sample of slackwater sediment (sample LS 06-03-07-2, collected by Peter Wampler) provides minimum age of 38.91 ± 4.93 ka for Qtg_2 gravels (Tammy Rittenour, written commun., 2008). Slackwater sediments may represent backwater from a landslide dam in the Horseshoe Bend reach of the river, which may have forced the river through a temporary channel where U.S. Highway 95 is now located (Peter Wampler, verbal commun., 2008).

Qtg_3 **Gravel of third terrace, averaging 120 feet above Salmon River (Pleistocene)**—Forms relict point bar and terrace remnants typically not well expressed except at Russell Bar where the gravel has been excavated for aggregate. Thickness 40-80 feet. Where exposed, thin loess capping the gravel has well-developed soil with a dark brown, clayey B horizon. Probable Holocene dune sand buries the terrace surface at Russell Bar. South of Horseshoe Bend, gravel is mostly covered by alluvial-fan deposits.

Qtg_4 **Gravel of fourth terrace, averaging 200 feet above Salmon River (Pleistocene)**—Forms prominent, well-exposed relict point bars at Horseshoe Bend and at Cooper, Russell, and Slicker bars. Thickness 80-120 feet. Overlies bedrock strath at Cooper Bar and Slicker Bar. Commonly capped by alluvial-fan deposits, which may bury well-developed, strongly calcic soil that cements the upper 3 feet of the gravel.

Qtg_5 **Gravel of fifth terrace, approximately 400 feet above Salmon River (Pleistocene)**—Forms relict point bar identified above Cooper Bar, and terrace remnant south of Horseshoe Bend (sec. 25, T. 27 N., R. 1 E.). Thickness 40-120 feet. Mostly covered by colluvium and alluvial-fan deposits.

Qtg_6 **Gravel of sixth terrace, approximately 620 feet above Salmon River (Pleistocene)**—Forms relict point bar identified above Cooper Bar along Deer Creek Road. Gravel interfingers with and is conformably overlain by bouldery colluvial to debris-flow deposit (*QTc*). Soil formed in debris-flow deposit has a well-developed caliche with duripan plates as much as 5 cm thick. OSL date from sand layer intercalated with terrace gravel (sample LS 06-03-07-1, collected by Peter Wampler) is 75.56 ± 8.98 ka (Tammy Rittenour, written commun., 2008). This date seems too young considering both the geomorphic position of and the soil development on the terrace.

Latah Formation Sediments

Sediments of the Latah Formation are associated with the Columbia River Basalt Group lava flows and are stratigraphically equivalent to the Ellensburg Formation in Washington (Swanson and others, 1979).

Tli **Sediments interbedded or associated with basalt flows (Miocene)**—Silt, sand, pebble, and ash deposits that occur beneath the basalt of Grangeville along Deer Creek Road and Banner Ridge Road. Along Deer Creek Road, the sediments are mostly slumped and commonly included in *Qls* map unit. A few leaf fossil fragments were noted at several locations. Locally, sand beds are indurated and cemented. Mapped as "Deer Creek sediments" by Coffin (1967). Equivalent to the fossiliferous sediments in the White Bird basin (Brown, 1935, 1936; Garwood and others, 2008). Although none are exposed or mapped in the quadrangle, thin discontinuous sediments may occur locally within the Grande Ronde Basalt sequence, as indicated by the presence of sand grains in soils at a few locations. The landslide deposit mapped on Bouffard Flat may be caused by a thin, discontinuous unmapped interbed.

Eolian Deposits

Qed **Dune sand (Holocene)**—Stratified fine- to medium-grained sand of stabilized wind dunes. Forms low-relief, hummocky land surface on Russell Bar and a small area at the mouth of Slippy Creek.

Mass Movement Deposits

Qlsa **Deposits of active landslides (Holocene)**—Slumps, slides, and debris flows of Miocene Latah Formation sediments (*Tli*) that show evidence of activity as recent as 25 years ago. Includes two landslides along Deer Creek Road north of Sotin Creek and two small landslides near Slippy Creek. The latter are probably associated with thin, unmapped sedimentary interbeds in the basalt.

Qls **Landslide deposits (Holocene and Pleistocene)**—Poorly sorted and poorly stratified angular to subrounded pebbles, cobbles, and boulders mixed with silt and clay. Deposited by slumps, slides, and debris flows. Map may also show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols). Location of landslide deposits often controlled by interface between basalt units and underlying basement rocks, by steep slopes, or by presence of sediments within or on the basalt flows. Landslides range in age from ancient movements that are relatively stable features to those that are more recent and potentially less stable.

Qms **Mass-movement deposits (Pleistocene to Pliocene(?))**—Angular to subangular poorly sorted silty and clayey gravel derived from basalt. Sand and clay may be present. Relative flat but undulating surface is stripped primarily by mass wasting to a common stratigraphic horizon in Tgn_1. Rubbly surface deposit is a complex of slump, slide, creep, and solifluction processes that were active during colder and wetter climatic conditions. Thickness is variable; water-well logs show thicknesses of 50-81 feet. Near edges, unit includes some talus, alluvial-fan gravel, and in-place basalt.

Qc **Colluvial deposits (Holocene to late Pleistocene)**—Poorly sorted and poorly stratified angular to rounded gravel. Mostly basalt cobbles and boulders mixed with eroded terrace gravel along U.S. Highway 95 east of Cooper Bar.

QTc **Colluvial deposits (Pleistocene to Pliocene)**—Poorly sorted and poorly stratified angular to subrounded older colluvial gravel remnants that cap ridges, mostly along Deer Creek Road. Colluvium interfingers with and caps Quaternary terrace gravels (Qtg_6) in gravel pit along east side of Deer Creek Road north of Sotin Creek, but parts of unit may be considerably older and of Pliocene age. Mostly basalt cobbles and boulders mixed with silt and clay. Basalt boulders as large as 1 m are common. Deposited by gravity movements of various sources, but primarily debris flows. As much as 60 feet thick, but thickness is typically difficult to determine.

VOLCANIC ROCKS

Columbia River Basalt Group

The stratigraphic nomenclature for the Columbia River Basalt Group (CRBG) follows that of Swanson and others (1979) and Camp (1981). CRBG units in the map are restricted to Imnaha Basalt, Grande Ronde Basalt, two Saddle Mountains Basalt flows, and several CRBG dikes of unknown affinity that are most likely Saddle Mountains Basalt or Wanapum Basalt in age. Imnaha Basalt is exposed in the lowlands along the Salmon River and its tributaries and on the slopes west of Deer Creek Road where the basalt has been structurally uplifted. One Imnaha dike is exposed on the southwest flank of Haystack Mountain. Grande Ronde Basalt forms much of the basalt sequence and includes flows of the informal R_1, N_1, and R_2 magnetostratigraphic units (Swanson and others, 1979). Saddle Mountains Basalt units include the basalt of Grangeville, which occurs as thin remnants along Deer Creek Road and along Banner Ridge Road generally overlying Latah Formation sediments, and the basalt of Craigmont, which occurs as a small valley fill west of Sotin point. The basalt dikes of unknown affinity, which cut Grande Ronde Basalt, are exposed on the ridges west of the Salmon River. Basalt units were identified using hand sample characteristics, paleomagnetic signatures, geochemical signatures, and compilation of previous data. Representative samples of most basalt units were collected for chemical analysis. Sample locations are identified on the map and analytical results are listed in Table 1. Samples were analyzed at Washington State University's GeoAnalytical Laboratory.

$Tcrb_d$ **Columbia River Basalt Group dikes of unknown affinity (Miocene)**—Several thin basalt dikes cut Grande Ronde Basalt on the ridge between the Salmon River and Deer Creek Road. The dikes consist of dark gray, fine-grained basalt with common plagioclase laths 1-2 mm long. Commonly finely vesicular; vesicles typically <1 mm in diameter; common amber vesicle-filling material of undetermined composition. Thin glassy selvage zones along margin of dikes. Thickness ranges from 1 to 6 feet. Chemical composition is somewhat similar to that of Weissenfels Ridge Member flows, Saddle Mountains Basalt, which occur north of the area west of and in the Lewiston Basin. Sampled dikes have similar compositions (see Table 1). Most strike about N. 35 W. and dip steeply northeast, although enclosing flows are tilted. It is unknown if the dikes were intruded prior to or after tilting of the flows; therefore, original dike attitude is uncertain. Small irregular apophyses into surrounding basalt are common.

Saddle Mountains Basalt

Tcg **Basalt of Craigmont (Miocene)**—Dense, dark gray to black, very fine-grained basalt with common white to clear plagioclase crystals <1 mm and uncommon plagioclase laths 2-4 mm long. Occurs in only one location north of Sotin Creek and west of Sotin point where the basalt is interpreted to be a narrow valley filling flow. No source for the flow was identified. Major oxide and trace element composition is indicative of Craigmont basalt.

Tgv **Basalt of Grangeville (Miocene)**—Medium to dark gray, fine- to medium-grained basalt with common plagioclase phenocrysts 1-4 mm long and scarce to common olivine phenocrysts generally <1 mm in diameter that tend to weather pinkish or orangish. Reverse magnetic polarity as determined in the laboratory for Grangeville basalt near Grangeville; a few samples had conflicting or normal polarity in the field. Consists of one flow ranging from 20 to 80 feet in thickness. Locally caps Latah Formation sediments along Deer Creek Road and also occurs as thin, isolated remnants along the lower segment of Banner Ridge Road. Commonly slumped along with the underlying sediments. Source undetermined, but probably extruded locally, possibly along the major faults. Equivalent to the Grangeville Member of Camp (1981) and the Amphitheater flow of Bard (1978). K-Ar age reported as 12.1 ± 0.4 by Evernden and James (1964) for Grangeville basalt capping Latah Formation sediments in the White Bird basin.

Grande Ronde Basalt

Tgr_2 **Grande Ronde Basalt, R_2 magnetostratigraphic unit (Miocene)**—Medium to dark gray, fine-grained basalt, commonly with a sugary texture. Uncommon to common plagioclase phenocrysts 1-2 mm long in some flows. Reverse magnetic polarity, although field magnetometer readings commonly give weak normal or conflicting results. Unit consists of one or two flows with a maximum thickness of about 75 feet. Caps the ridge north of Skookumchuck Creek and occurs as several thin remnants on the top of the ridge south of the creek.

Tgn_1 **Grande Ronde Basalt, N_1 magnetostratigraphic unit (Miocene)**—Dark gray, fine-grained, generally aphyric to plagioclase-microphyric basalt. Normal magnetic polarity. Consists of four to six flows with a total thickness of about 600 feet. Individual flows range from 50 to 200 feet in thickness. Flows near the top of the sequence are commonly 50-70 feet thick and typically sugary textured with scarce small plagioclase phenocrysts 1-3 mm long. Flows lower in the sequence are typically thicker, generally 100-200 feet, and commonly have thick entablatures and basal colonnades that form tiered cliffs of steep canyon slopes.

Tgr_1 **Grande Ronde Basalt, R_1 magnetostratigraphic unit (Miocene)**—Mostly dark gray, fine-grained aphyric to plagioclase-microphyric basalt. Rare to common plagioclase phenocrysts 2-4 mm long in one or more flows near the base of the section. Lowermost flow(s) is coarse grained and weathers to sooty brown, fine granular detritus, which is similar to weathering of the underlying Imnaha Basalt. Chemical composition of the coarse-grained flows is similar to that of the Buckhorn Springs unit of Reidel and others (1989). Reverse magnetic polarity, although flows near the R_1-N_1 boundary commonly have inconsistent and weak field magnetometer polarity readings. Outcrop characteristics of flows are similar to N_1 Grande Ronde Basalt units. Consists of about five to seven flows with a total thickness of 600-700 feet.

Imnaha Basalt

Tim **Imnaha Basalt (Miocene)**—Fine- to coarse-grained, sparsely to abundantly plagioclase-phyric basalt; olivine common; plagioclase phenocrysts generally 0.5-2 cm long, but some are as large as 3 cm. Normal magnetic polarity. Weathers to sooty brown granular detritus. Commonly has well-developed fanning or irregular columns 1-2 feet in diameter. Maximum exposed thickness is about 1,200 feet; the number of flows was not determined. A dike about 6 feet wide crosscuts Imnaha flows on the southwest slope of Haystack Mountain. The vertical dike, which trends north-south, is exposed for a length of about 200 feet and appears to terminate within the Imnaha Basalt sequence near the low saddle west of Haystack Mountain. The dike is medium to coarse grained and contains common plagioclase phenocrysts as large as 1 cm and has composition indicative of Imnaha Basalt (sample 08JK149, Table 1).

ISLAND-ARC SEDIMENTARY AND VOLCANIC ROCKS

JTvs **Volcanic and sedimentary rocks (Jurassic to Triassic?)**—Dominantly volcanic lithologies with some interlayered sedimentary units. Sequence is well bedded, and contains the following lithologies: (1) Mostly red to gray weathering, thick-bedded lithic tuffs and lava flows of rhyolitic to basaltic andesite composition. (2) Less commonly medium- to thick-bedded volcanic breccias and immature epiclastic conglomerates with subangular to subrounded clasts, and thin recrystallized limestone, graywacke, siltstone, and argillite layers. The tuffs and lava flows contain phenocrysts of plagioclase ± quartz. Epiclastic conglomerates are mostly matrix supported, uncommonly clast supported, and contain coarse sand-size plagioclase and quartz grains in a mud to fine sand matrix. Clasts as large as 20 cm are a mix of mostly porphyritic rock of volcanic or shallow intrusive origin. Contact relationships with other stratigraphic units are poorly exposed and uncertain. Lithologies are similar to parts of the Jurassic red tuff unit (White and Vallier, 1994) to the west in the Grave Point quadrangle, and to a package of volcanosedimentary rocks mapped to the north on the White Bird quadrangle (Garwood and others, 2008). The latter package also consists of dominantly volcanic lithologies, with sedimentary sequences increasing toward the south. Age is unknown, but we suspect the unit is Late Triassic or younger because of the relatively low degree of metamorphism compared to older units and because lithologies do not correlate well with older units described from other localities. Although folding and faulting preclude an accurate thickness measurement, the *JTvs* unit is estimated to be several thousand feet thick and thus considerably thicker than the red tuff unit, which is about 150 feet thick (White and Vallier, 1994).

JTsv **Sedimentary and volcanic rocks (Jurassic to Triassic?)**—Green, gray, and red sedimentary, volcaniclastic, and volcanic flow rocks. Similar to above *JTvs* unit, except most exposed rocks are sedimentary in origin and include calcareous sandstones, siltstones, and breccias as well as thin limestone beds. Clasts are epiclastic in origin. Breccias in upper Poe Creek are similar to the distinctive proximal channel breccia deposits in the Kurry unit in the Grave Point quadrangle to the west. The breccias vary from 0.3 to 1.5 m in thickness and are matrix to clast supported. Clasts typically range from 0.5 to 5 cm and consist mostly of plagioclase porphyritic basalt and basaltic andesite that are lithologically similar to rocks in the Big Canyon Creek unit in the Grave Point quadrangle to the west; less common clasts are immature sandstone and limestone. These breccia beds are commonly underlain by thin-bedded calcareous sedimentary rocks that are folded, scoured, ripped-up, and entrained in the overlying breccia. Another distinctive sedimentary lithology is thin-bedded gray chert that occurs in Sotin Creek. Interbedded with the sedimentary lithologies are volcanic lithologies, which include red to green weathered, thick-bedded tuffs(?), breccias, and lava flow rocks of probable rhyolitic to basaltic andesite composition. The tuffs(?) and lava flows contain phenocrysts of plagioclase and rare quartz. Strongly weathered volcaniclastic beds with a distinctive spotted appearance also occur that we interpret as peperite deposits. Contact relationships with other stratigraphic units are poorly exposed and uncertain. Lithologies are similar to parts of the Triassic Kurry and Jurassic red tuff units to the west in the Grave Point quadrangle, but also to a thick package of volcanosedimentary rocks that occur in the north part of the Slate Creek quadrangle (*JTvs* unit, discussed above) and in the White Bird quadrangle. The latter package consists of mostly volcanic sequences, with sedimentary lithologies increasing toward the south. As with the above *JTvs* unit, we suspect this unit is Late Triassic or younger because of the relatively low degree of metamorphism compared to the older units and because lithologies do not correlate well with older units described from other localities.

EASTERN ASSEMBLAGE ROCKS

The eastern assemblage rocks, exposed in the southeast corner of the quadrangle, consist of phyllite, schist, gneiss, tonalite, and minor marble of uncertain age and origin. The assemblage includes calcareous phyllite and schist (*JTl*); chlorite gneiss and schist (*KPcg*); and marble (*TPms*). These rocks contain a strongly developed mylonitic to schistose or gneissic fabric. Interlayered tonalite (*KPt*) locally shares the same mylonitic to gneissic fabric and either intrudes or had been tectonically interleaved with them. We are uncertain of the stratigraphic position of the calcareous and chloritic units, but consider that they may be equivalent to parts of the eastern and western Salmon River belts of Gray and Oldow (2005).

KPt **Tonalite (Cretaceous to Permian)**—Medium to light gray, foliated (mylonitic) to massive biotite tonalite.

JTl **Lucile Slate (Jurassic? to Triassic?)**—Medium to dark gray interlayered graphitic calcareous phyllite, and thinly layered marble. Layers 1 cm to 1 m in thickness. Displays mylonite foliation or lineation and foliation, which includes sc and extensional crenulation fabrics. Previously mapped by Lund and others (1993) as Triassic Martin Bridge Formation.

KPcg **Chlorite gneiss and schist (Cretaceous to Permian)**—Green to dark gray chlorite ± muscovite ± biotite quartzofeldspathic gneiss and layered schist. Layers 2 to 40 cm in thickness. Commonly contains plagioclase porphyroclasts of igneous origin as determined by relict igneous twinning. Protolith was probably mafic to intermediate igneous rock and possibly greywacke. Distinguished from gneiss and schist of *TPgs* unit mainly by the presence of muscovite and biotite, but could be the same unit at a higher metamorphic grade. Metamorphosed to greenschist grade. Commonly displays mylonite foliation or lineation and foliation, which includes sc and extensional crenulation fabrics. These fabrics are recrystallized and overprinted by gneissic textures in some outcrops. Mapped by Lund and others (1993) as chlorite schist of mafic volcanic protolith.

TPms **Marble of Sheep Gulch (Triassic? to Permian?)**—Small exposure of light gray marble that thickens to the south in the Lucile quadrangle. Calcite grains are as large as 3 mm. Textures range from massive to moderately developed foliation. Previously mapped by Lund and others (1993) as Triassic Martin Bridge Formation.

ISLAND-ARC INTRUSIVE ROCKS

Dike Rocks

KPdl **Leucocratic dike rocks, undivided (Cretaceous? to Permian?)**—Light colored dike rocks, probably tonalite, consisting largely of quartz and plagioclase. Textures range from coarse grained to aphanitic, with porphyritic samples containing phenocrysts of quartz (commonly resorbed) and plagioclase. Dike thickness varies from inches to several feet. Mostly metamorphosed to greenschist facies.

KPdm **Mafic dike rocks, undivided (Cretaceous? to Permian?)**—Generally green, fine-grained dikes that also occur as medium-grained and porphyritic bodies with plagioclase and hornblende phenocrysts. Most dikes have been metamorphosed to greenschist facies, with groundmass and phenocrysts largely recrystallized to chlorite and epidote. Dikes are as much as several feet thick.

Cougar Creek Complex

The Cougar Creek complex, which to the west occurs in the hanging wall of the Klopton Creek thrust south of Pittsburg Landing on the Snake River, is dominated by intrusive rocks that are interpreted as basement to the Seven Devils Group (Walker, 1986; Kurz, 2001). This package of rocks is heterogeneous in age, composition, texture, fabric, and metamorphism. The complex is long-lived, with U-Pb zircon plutonic rock ages ranging from Permian to Triassic; one discordant Pennsylvanian U-Pb zircon age has been obtained on a quartzofeldspathic layer of uncertain protolith (Walker, 1986). The complex is also compositionally diverse, ranging from mafic through silicic, and intrudes rocks of probable volcanic protolith that may predate the Seven Devils Group. Metamorphism varies from lower greenschist to amphibolite facies, but is predominantly greenschist facies. Much of the material that makes up the complex probably represents magma chambers and feeders that intruded the basement rocks en route to extrusion as the Seven Devils Group units overlying the complex itself.

KPdg **Diorite and Gabbro (Cretaceous? to Permian?)**—Composite intrusive body consisting primarily of diorite and quartz diorite, but also includes small bodies of gabbro, biotite-hornblende tonalite, and felsic aplite dikes. The diorite and quartz diorite are medium to dark gray with light-colored plagioclase and black pyroxene and hornblende, and typically contain a few percent quartz. The diorite weathers readily to a fine, dark brown soil. Textures are mostly medium grained to coarse grained, but locally are very fine grained. Metamorphism is generally not apparent in these rocks. This unit is equivalent to diorite and gabbro mapped in the White Bird quadrangle to the north (Garwood and others, 2008) and the Grave Point quadrangle to the west (Schmidt and others, 2009).

Pmt **Metatonalite (Permian)**—Light gray to medium gray rocks that occur as an intrusive package with variable composition and texture. Compositions range from hornblende-biotite tonalite with as much as 15 percent mafic minerals to leucocratic tonalite with less than 3 percent altered mafic minerals. At many outcrops, the metatonalite is intimately intermixed with greenstone (unit TPgs described below), and mutually cross-cutting relationships are apparent. Quartz composes 20 to 50 percent of the rock and occurs as either light gray to bluish phenocrysts that are locally resorbed and embayed or as a constituent of the groundmass. Altered plagioclase as much as 6 mm long composes from 40 to 80 percent of the rock and also occurs in the groundmass. Biotite and locally hornblende are present. Texture is generally medium grained and porphyritic, with locally occurring coarse-grained and fine-grained leucocratic varieties. The rocks are pervasively metamorphosed, with chlorite and epidote replacing most mafic minerals and plagioclase largely replaced by sericite. The metatonalite is locally foliated, and in places forms well-developed mylonites. Two zircon fractions from a sample of mylonitic tonalite, collected less than one mile south of the mouth of Slate Creek, yielded a concordant U-Pb age of 258 Ma (Walker, 1986). Two zircon fractions from a second sample described as trondhjemite from along the Salmon River just south of the map yielded a concordant 260 Ma age. These Permian dates indicate that the metatonalite forms part of the basement beneath the Seven Devils Group.

Although not shown on the map, a small intrusive body of coarse-grained muscovite tonalite less than 0.3 miles across and surrounded by metatonalite was identified on the ridge southeast of Joe Creek at an elevation of 2,500 feet (latitude 45.65558 N., longitude 116.30393 W.). Contact relationships between this intrusive and the surrounding metatonalite are obscured. The muscovite tonalite is strongly foliated and consists of approximately 35 percent quartz as large as 5 mm, 50 percent plagioclase as large as 1.5 mm, and 10 percent distinctive euhedral muscovite that forms books as large as 1 cm. Biotite is accessory. Although the age is poorly constrained, we interpret the muscovite tonalite as younger than the metatonalite and assume it is Permian to Cretaceous because it is less metamorphosed than the metatonalite.

TPgs **Fine-grained greenstone (Triassic to Permian)**—Mapped where greenstone dominates over intermixed metatonalite (unit Pmt) with mutually crosss-cutting relationships. Consists of light to dark gray-green, generally fine-grained rocks of mafic protolith, which locally display mediumm-grained and relict porphyritic textures. Pervasively metamorphosed to greenschist grade, with the groundmass and many crystals altered to chlorite, sericite, and epidote. Most of this unit appears to have been intrusive; however, some relict volcanosedimentary features, such as breccias and conglomerates, are locally present and represent wallrock screens and pendants to the Cougar Creek intrusive complex. In outcrops above Blackhawk Bar south of Slate Creek, lithologies include strongly recrystallized metavolcanic and metasedimentary rocks containing relict vesicles in mafic to intermediate lava flow rocks, relict embayed quartz phenocrysts in felsic to intermediate volcanic rocks, and relict rounded quartz clasts with quartz overgrowths preserved in clastic sedimentary rocks. Portions of this unit could be equivalent to the Permian Hunsaker Creek Formation of Vallier (1977), which is composed primarily of mafic volcanic sands and silts. It is also possible that at least some of the porphyritic metatonalite associated with the greenstone could be a deeper-level equivalent to the quartz keratophyre rocks Vallier (1977) describes from the lowest exposed portion of the Hunsaker Creek Formation, or with his quartz keratophyre-dominated Windy Ridge Formation, both of which consist of high-silica quartz-porphyritic volcanogenic rocks.

STRUCTURE

The structural history of this area is complex and long-lived, and several regional tectonic provinces intersect on the quadrangle. At least two contractional Mesozoic structural belts occur. One belt may be associated with the Salmon River suture and western Idaho shear zone to the east, and juxtaposes a poorly understood assemblage of metamorphosed sedimentary and possibly volcanic rocks to the east with basement rocks of the Seven Devils Group to the west. The other belt is part of the Klopton Creek-Hammer Creek oblique-dextral thrust system that transports Seven Devils Group basement westward over Jurassic-Triassic(?) volcanosedimentary cover sequences and offsets the Salmon River suture zone farther to the northeast where it crosses the South Fork of the Clearwater River. These basement assemblages and their associated structural belts were deformed, uplifted, and eroded before the eruption of the Miocene Columbia River Basalt Group. Miocene east-west directed extension that overlaps with and postdates basalt extrusion ensued in the Salmon River corridor, which forms a northern arm of Neogene Basin and Range extension. The geometry of normal faulting that accommodated extension was strongly influenced by the older contractional structural belts.

PRE-MIOCENE STRUCTURES

Much of the exposed pre-Tertiary basement rock is in the southwestern part of the quadrangle and consists of Wallowa terrane island-arc sequences represented here by rocks of the Cougar Creek complex and their host rocks. This basement assemblage is bounded to the southeast and northwest by mylonite shear zones, both of which appear to include complex contractional deformation with associated folding.

The southeast-bounding mylonite zone is poorly understood and involves an assemblage of phyllite, schist, gneiss, and marble of uncertain age and origin. Deformation in this zone includes anastomosing belts of mylonitic foliation, lineation, and small folds developed in rocks displaying compositional layering and weakly to moderately developed phyllitic foliation that parallel the mylonite foliation. Mylonite foliation generally strikes northwestward, but the strike varies considerably. Foliation dips shallowly to moderately, mostly to the northeast. Lineation plunges generally to the east-northeast, but plunge direction varies from north to southeast. Kinematics in mylonite rocks show consistent reverse-shear sense in directions parallel to lineation. The mylonite zone near the town of Slate Creek displays secondary brittle-ductile shears that cross-cut older contractional mylonitic fabrics. The secondary shears have a similar range of orientation of foliation and lineation as compared to the mylonite fabrics, but kinematics show consistent normal sense of shear. Thus, we interpret the southeast-bounding mylonite zone as a contractional belt that has been reactivated at shallow crustal levels to accommodate extension. At least some extension occurred following the extrusion of Miocene basalts. Lund and others (1993) mapped parts of this structural belt as the Rapid River thrust, a discrete fault that transported schistose assemblages of poorly understood origin (Triassic or Permian chlorite schist and muscovite schist) westward over Seven Devils Group and overlying rocks of the Wallowa Terrane (Triassic Martin Bridge Formation). However, Hamilton (1963) mapped only stratigraphic contacts in this area. McCollough (1984) mapped a minor thrust fault in the area, but placed the Rapid River thrust farther east. We believe that this shear zone is a major structure that may be the northern extension of the Rapid River thrust. In the vicinity of the town of Slate Creek deformation is distributed across a wide belt. Deformation appears to have been long-lived in this zone, and some of this distributed deformation may overprint older discrete structures such as the Rapid River thrust.

The Klopton Creek-Hammer Creek thrust belt northwest of the Cougar Creek complex has also been reactivated and modified by Miocene and younger normal faulting as explained in more detail below. Where parts of this oblique thrust fault still survive on Haystack Mountain and in Sotin Creek, exposures are poor and the trace of the fault is inferred from exposures of volcanosedimentary footwall and plutonic hanging wall assemblage rocks. Where the thrust system is well exposed on the Grave Point quadrangle to the west (White and Vallier, 1994; Schmidt and others, 2009) and White Bird quadrangle to the north (Garwood and others, 2008), older and originally deeper metaplutonic rocks of the Cougar Creek complex have been obliquely thrust westward over younger and originally shallower weakly metamorphosed volcanic and volcanosedimentary cover sequence rocks. Most displacement has occurred on the Klopton Creek-Hammer Creek fault, a 300- to 600-foot-wide moderately southeast-dipping mylonite zone overprinted by brittle shears. A one- to four-mile-wide fold and thrust belt is also well developed in the footwall sequences northwest of this fault. The thrust system continues 25 miles to the east-northeast where it crosses the South Fork of the Clearwater River and displaces the Salmon River suture and associated structures (Schmidt and others, 2007). The age of the Klopton Creek-Hammer Creek thrust system is broadly constrained to the period between Bajocian (Middle Jurassic) age for youngest rocks in the footwall and Miocene age of Columbia River basalts that unconformably overly these basement assemblages.

MIOCENE AND LATER STRUCTURES

Along the east and west margins of the quadrangle, synbasalt and postbasalt deformation is represented by gentle regional-scale tilting and minor folding and faulting. Between these relatively undeformed areas, however, deformation is represented by complex faulting and associated folding and tilting in a lobe-shaped zone several miles wide that extends from the north-central boundary of the quadrangle south to about Russell Bar in the central part of the quadrangle. Within the latter zone, normal displacement is accommodated by a complex array of fault slivers, cross faults, step faults, and folds above a moderately dipping detachment system, herein named the Deer Creek detachment, which may root into a more steeply dipping normal fault zone to the east. In general, there is substantial down-to-the-east displacement of several thousand feet across the width of the zone, with most of the displacement on the west-bounding detachment fault. Structural blocks of basalt within the zone show considerable discordance in attitude and amount of displacement. The detachment formed along a reactivated part of the Klopton Creek-Hammer Creek oblique thrust zone and has mostly obscured that structure. South of Russell Bar, displacement is accommodated by a single fault that has reactivated an older mylonite zone. Thus, the two major Mesozoic contractional structural zones, the Klopton Creek-Hammer Creek thrust and the older mylonite zone, have strongly controlled the geometry of Neogene extensional faulting. This conclusion is corroborated by studies to the south, along the Salmon River suture zone near McCall, where Giorgis and others (2006) observed that Neogene normal faulting has reactivated Cretaceous ductile structures.

We were able to discern only some of the considerable structural complexity above the Deer Creek detachment because the primary control for determining displacement in the basalt is the easily recognizable Imnaha-Grande Ronde basalt contact; this contact is only exposed in some of the faulted blocks. Although the R_1-N_1 Grande Ronde Basalt contact is exposed in many structural blocks in this small area, that contact is less useful in determining displacement because field magnetometer readings are commonly inconclusive near the contact. The presence of thick Latah Formation sediments and restriction of Grangeville basalt to the Deer Creek area indicate that a north-south-trending trough was developing above the Deer Creek detachment system at least by the time Grande Ronde Basalt extrusion had ceased. The faults bounding the zone may also have begun to form prior to deposition of the sediments, although the timing of movement is poorly constrained, in part because most of the sediments are now slumped and their original relation to the faults and the underlying Grande Ronde Basalt is difficult to reconstruct. At several locations, the sediments and overlying Grangeville basalt are tilted and may be faulted, indicating postbasalt movement. Faulting likely continued into the Pliocene and possibly the Pleistocene.

SYMBOLS

Contact: dashed where approximate.
Fault: bar and ball on downthrown side; dashed where inferred; dotted where concealed.
Thrust fault: teeth on upper plate; dashed where inferred; dotted where concealed.
Reactivated thrust fault: teeth on upper plate; bar and ball on downthrown side on reactivated fault segments; dashed where inferred; dotted where concealed.
Fold axis; arrow indicates direction of plunge.
Anticline.
Syncline.
14 Strike and dip of bedding or volcanic flows.
10 Estimated strike and dip of bedding or volcanic flows.
Strike of vertical bedding or volcanic flows.
81 Strike and dip of foliation.
Strike of vertical foliation.
Horizontal bedding or volcanic flows.
65 Strike and dip of mylonitic foliation.
70 Strike and dip of cleavage.
87 Strike and dip of fault plane.
29 Bearing and plunge of lineation, type unknown.
50 Bearing and plunge of mylonitic lineation.
Stabilized dune field.
Landslide headwall scarp.
Gravel pit or placer working.
Quartz vein.
Mylonite.
Intensely fractured or brecciated rock associated with faulting.
08JK057 Sample location and number.

REFERENCES

Bard, C.S., 1978, Mineralogy and chemistry of pyroxenes from the Imnaha and lower Yakima basalts of west-central Idaho: Washington State University M.S. thesis, 75 p.
Barker, R.J., 1982, Soil survey of Idaho County area, western part: U.S. Department of Agriculture, Soil Conservation Service, 266 p., 79 plates.
Bond, J.G., 1963, Geology of the Clearwater embayment: Idaho Bureau of Mines and Geology Pamphlet 128, 83 p.
Brown, R.W., 1935, Miocene leaves, fruits, and seeds from Idaho, Oregon, and Washington: Journal of Paleontology, v. 9, no. 7, p. 572-587.
Brown, R.W., 1936, Additions to some fossil floras of the western United States: U.S. Geological Survey Professional Paper 186-J, 206 p.
Camp, V.E., 1981, Geologic studies of the Columbia Plateau: Part II. Upper Miocene basalt distribution, reflecting source locations, tectonism, and drainage history in the Clearwater embayment, Idaho: Geological Society of America Bulletin, Part I, v. 92, p. 669-678.
Coffin, Peter, 1967, Geology of the Slate Creek quadrangle, Idaho County, Idaho: University of Idaho M.S. thesis, 57 p.
Davis, L.G., 2001, The coevolution of early hunter-gatherer culture and riparian ecosystems in the southern Columbia River Plateau: University of Alberta Ph.D. dissertation, Edmonton, Canada 486 p., 1 map.
Evernden, J.F., and G.T. James, 1964, Potassium-argon dates and the Tertiary floras of North America: American Journal of Science, v. 262, no. 8, p. 945-974.
Garwood, D.L., K.L. Schmidt, J.D. Kauffman, D.E. Stewart, R.S. Lewis, K.L. Othberg, and P.J. Wampler, 2008, Geology of the White Bird quadrangle, Idaho County, Idaho: Idaho Geological Survey Digital Web Map 101, scale 1:24,000.
Giorgis, S., B.Tikoff, P. Kelso, and M. Markley, 2006, The role of material anisotropy in the neotectonic extension of the western Idaho shear zone, McCall, Idaho: Geological Society of America Bulletin, v. 118, p. 259-273.
Gray, K.D., and J.S. Oldow, 2005, Contrasting structural histories of the Salmon River belt and Wallowa terrane: Implications for terrane accretion in northeastern Oregon and west-central Idaho: Geological Society of America Bulletin v. 117, no. 5/6, p. 687-706.
Hamilton, Warren, 1963, Metamorphism in the Riggins region, western Idaho: U.S. Geological Survey Professional Paper 436, 95 p.
Kurz, G.A., 2001, Structure and geochemistry of the Cougar Creek complex, northeastern Oregon and west-central Idaho: Boise State University M.S. thesis, 248 p.
LeMaitre, R.W., 1984, A proposal by the IUGS Subcommission on the Systematics of Igneous Rocks for a chemical classification of volcanic rocks based on the total alkali silica (TAS) diagram: Australian Journal of Earth Sciences, v. 31, p. 243-255.
Lund, K., W.F. McCollough, and E.H. Price, 1993, Geologic map of the Slate Creek-John Day area, Idaho County, Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-2299, scale 1:50,000.
McCollough, W.F., 1984, Stratigraphy, structure, and metamorphism of Permo-Triassic rocks along the western margin of the Idaho batholith, John Day Creek, Idaho: Pennsylvania State University M.S. thesis, 141 p.
Reidel, S.P., T.L. Tolan, P.R. Hooper, M.H. Beeson, K.R. Fecht, R.D. Bentley, and J.L. Anderson, 1989, The Grande Ronde Basalt, Columbia River Basalt Group; stratigraphic descriptions and correlations in Washington, Oregon, and Idaho, in S.P. Reidel and P.R. Hooper, eds., Volcanism and Tectonism in the Columbia River Flood-Basalt Province: Geological Society of America Special Paper 239, p. 21-53.
Schmidt, K.L., J.D. Kauffman, D.E. Stewart, D.L. Garwood, K.L. Othberg, and R.S. Lewis, 2009, Geologic map of the Grave Point quadrangle, Idaho County, Idaho, and Wallowa County, Oregon: Idaho Geological Survey Digital Web Map 111, scale 1:24,000.
Schmidt, K.L., J.D. Kauffman, D.E. Stewart, K.L. Othberg, and R.S. Lewis, 2007, Geologic map of the Grangeville East quadrangle, Idaho County, Idaho: Idaho Geological Survey Digital Web Map 86, scale 1:24,000.
Streckeisen, A.L., 1976, To each plutonic rock its proper name: Earth-Science Reviews, v. 12, p. 1-33.
Swanson, D.A., J.L. Anderson, V.E. Camp, P.R. Hooper, W.H. Taubeneck, and T.L. Wright, 1981, Reconnaissance geologic map of the Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, 32 p., sheet 3 of 5.
Swanson, D.A., T.L. Wright, P.R. Hooper, and R.D. Bentley, 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p.
Vallier, T.L., 1977, The Permian and Triassic Seven Devils Group, western Idaho and northeastern Oregon: U.S. Geological Survey Bulletin 1437, 58 p.
Walker, N.W., 1986, U-Pb geochronologic and petrologic studies in the Blue Mountains terrane, northeastern Oregon and westernmost-central Idaho—Implications for pre-Tertiary tectonic evolution: University of California, Santa Barbara, Ph. D. dissertation, 224 p.
White, D.L., and T.L. Vallier, 1994, Geologic evolution of the Pittsburg Landing area, Snake River canyon, Oregon and Idaho, in T.L Vallier and H.C. Brooks, eds., Geology of the Blue Mountains Region of Oregon, Idaho, and Washington: Stratigraphy, Physiography, and Mineral Resources of the Blue Mountains Region: U.S. Geological Survey Professional Paper 1439, p. 55-73.

Table 1. Major oxide and trace element chemistry of samples collected in the Slate Creek quadrangle.

Sample number	Latitude	Longitude	Unit name	Map unit	Major elements in weight percent										Trace elements in parts per million																	
					SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th	Nd
06JK250	45.72678	-116.33594	basalt of Grangeville	Tgv	52.62	1.306	15.61	8.68	0.167	7.12	11.25	2.35	0.73	0.163	63	218	32	229	282	14	246	115	23	10.6	18	67	80	3	15	31	3	18
07JK026	45.74682	-116.27807	basalt of Grangeville	Tgv	52.19	1.316	15.46	10.21	0.237	6.40	10.92	2.45	0.67	0.158	59	190	33	233	294	14	243	119	24	11.5	18	66	79	3	18	33	3	18
07KS017B	45.72749	-116.35574	Imnaha Basalt	Tim	51.02	2.192	13.87	13.34	0.232	5.51	9.77	2.89	0.86	0.304	39	65	43	404	332	18	289	159	38	9.3	20	189	117	3	12	34	4	23
08JK003	45.70025	-116.29253	R_1 Grande Ronde Basalt	Tgr_1	53.62	2.417	14.52	11.57	0.210	4.28	8.72	3.15	1.11	0.407	20	30	33	338	550	36	355	194	36	11.8	19	83	125	7	28	45	4	28
08JK008	45.68728	-116.35486	basalt of Grangeville	Tgv	53.24	1.340	15.68	8.78	0.178	6.09	11.33	2.42	0.77	0.165	46	193	34	237	262	17	243	122	23	11.3	18	69	81	3	16	34	2	18
08JK010	45.71336	-116.34423	R_1 Grande Ronde Basalt	Tgr_1	55.01	2.408	14.41	10.56	0.172	3.83	8.53	3.07	1.61	0.402	18	31	34	340	662	41	350	194	35	11.7	20	73	124	7	27	50	3	29
08JK013	45.68213	-116.30558	R_1 Grande Ronde Basalt	Tgr_1	52.95	2.505	14.38	11.58	0.234	4.96	9.15	3.06	0.82	0.360	16	56	35	346	455	31	344	185	33	12.7	20	45	123	6	24	48	4	26
08JK030	45.71032	-116.28529	R_2 Grande Ronde Basalt	Tgr_2	56.09	2.290	13.92	11.57	0.219	3.34	7.06	3.30	1.71	0.493	3	9	30	315	841	45	373	193	38	12.4	21	15	131	9	32	57	5	34
08JK034	45.71027	-116.2959	basalt of Grangeville	Tgv	52.27	1.283	15.65	8.62	0.160	7.40	11.47	2.34	0.65	0.159	63	254	33	230	257	12	244	111	22	9.7	17	72	80	3	16	32	1	17
08JK041	45.70177	-116.29559	Imnaha Basalt	Tim	50.16	2.193	15.96	11.35	0.176	6.61	9.71	2.98	0.62	0.261	103	123	31	311	244	13	370	144	29	9.6	19	56	102	3	16	32	1	22
08JK044	45.69101	-116.27223	R_2 Grande Ronde Basalt	Tgr_2	56.46	2.244	13.85	11.09	0.206	3.31	6.98	3.24	2.14	0.482	1	9	32	316	751	52	362	190	36	12.5	19	17	128	10	33	64	6	34
08JK045	45.69082	-116.27153	N_1 Grande Ronde Basalt	Tgn_1	55.81	2.168	13.75	12.15	0.261	3.08	6.90	3.50	1.96	0.426	5	9	32	390	736	57	307	188	38	11.3	19	16	133	6	26	53	4	28
08JK048	45.69077	-116.30297	R_1 Grande Ronde Basalt	Tgr_1	54.15	2.445	13.99	11.92	0.205	4.15	8.13	3.16	1.48	0.373	8	17	33	355	525	40	344	206	37	12.6	21	43	126	5	25	50	2	31
08JK051	45.69419	-116.29615	Imnaha Basalt	Tim	49.21	2.287	16.26	11.85	0.198	6.93	10.01	2.64	0.35	0.269	122	223	30	291	225	4	339	144	29	9.5	19	121	102	1	15	30	0	22
08JK054	45.64765	-116.28608	R_1 Grande Ronde Basalt	Tgr_1	54.54	2.319	14.39	10.51	0.163	4.42	8.81	3.09	1.43	0.329	19	62	33	324	493	37	330	187	33	12.2	19	45	116	5	24	50	3	29
08JK057	45.64465	-116.28309	R_1 Grande Ronde Basalt	Tgr_1	53.96	2.347	14.48	10.93	0.193	4.59	9.00	3.01	1.15	0.334	20	60	35	329	494	28	335	189	33	12.4	19	47	122	6	21	45	4	27
08JK076	45.65049	-116.26101	N_1 Grande Ronde Basalt	Tgn_1	55.58	2.158	13.79	12.02	0.211	3.58	7.31	3.10	1.84	0.427	6	9	32	348	693	39	304	184	39	11.3	19	21	127	7	27	53	3	29
08JK084	45.6391	-116.27904	R_1 Grande Ronde Basalt	Tgr_1	54.00	2.499	13.98	12.09	0.208	4.18	8.16	3.32	1.19	0.368	5	14	32	363	526	39	346	203	35	12.9	21	36	126	6	24	46	3	28
08JK088	45.67728	-116.33933	Imnaha Basalt	Tim	49.60	2.138	16.38	11.39	0.192	6.85	10.19	2.72	0.28	0.251	98	133	33	304	207	2	357	134	27	7.8	19	101	95	0	14	26	0	19
08JK114	45.69515	-116.32849	Columbia River basalt dike	$Tcrb_d$	49.89	2.767	13.98	13.23	0.220	5.42	10.71	2.35	0.80	0.623	36	86	41	344	457	21	242	216	45	20.7	19	57	131	5	38	72	3	39
08JK118	45.69222	-116.32484	Imnaha Basalt	Tim	50.46	2.422	16.71	10.43	0.145	5.28	10.56	3.01	0.69	0.305	125	225	32	308	266	14	386	166	33	10.7	22	130	113	3	16	32	2	21
08JK124	45.69894	-116.33024	Columbia River basalt dike	$Tcrb_d$	49.51	2.674	14.07	13.36	0.240	5.70	10.86	2.44	0.54	0.602	39	86	40	324	417	15	237	206	42	20.0	19	55	129	5	31	69	3	39
08JK147	45.71691	-116.37421	Imnaha Basalt	Tim	49.44	2.242	16.17	11.46	0.184	7.47	9.44	2.69	0.64	0.276	120	210	31	279	234	14	320	147	29	8.4	18	128	101	0	17	32	0	21
08JK149	45.71222	-116.36656	Imnaha Basalt dike	Tim	51.37	1.373	15.24	11.63	0.214	6.24	10.13	2.79	0.72	0.292	34	107	42	341	307	31	332	94	29	5.0	16	115	102	2	15	26	0	16
08JK153	45.72913	-116.33643	basalt of Craigmont	Tcg	53.51	3.029	13.60	13.17	0.208	3.42	7.62	2.94	1.93	0.582	15	9	29	318	802	49	289	270	46	25.1	21	26	137	9	49	91	6	46
08DG001	45.68135	-116.30168	R_1 Grande Ronde Basalt	Tgr_1	54.05	2.332	14.23	10.88	0.166	4.76	8.84	3.05	1.35	0.341	21	63	34	332	478	37	335	185	33	12.5	20	48	121	5	23	44	3	26
08DG002	45.68184	-116.30216	Imnaha Basalt	Tim	50.20	2.212	16.60	10.95	0.137	5.92	10.48	2.85	0.37	0.272	106	131	32	315	220	2	383	142	28	9.0	18	97	102	1	15	28	1	20
08DG003	45.67935	-116.30349	R_1 Grande Ronde Basalt	Tgr_1	54.26	2.359	14.18	11.66	0.200	4.01	8.36	3.13	1.44	0.394	20	30	32	328	523	48	342	191	35	11.9	19	78	121	6	24	49	3	29
08DG804	45.6998	-116.32409	Imnaha Basalt	Tim	49.04	2.670	15.77	12.97	0.192	6.09	8.73	3.22	0.95	0.365	109	95	30	290	331	23	364	205	36	13.2	22	97	130	3	19	44	2	27
08DG805	45.70011	-116.32423	Imnaha Basalt	Tim	49.47	2.337	15.64	12.02	0.196	6.75	9.65	2.92	0.70	0.312	126	207	31	297	265	16	358	170	33	10.4	21	144	115	2	19	36	2	25
08DS020	45.64336	-116.34257	leucocratic metatonalite	Pmt	72.79	0.444	13.05	3.80	0.109	1.48	4.62	3.11	0.50	0.092	1	6	15	87	135	9	269	72	18	2.3	11	0	33	1	5	11	0	9
08DS023	45.64312	-116.34264	basaltic andesite (in metatonalite)	Pmt	52.27	1.057	17.80	9.82	0.190	6.93	9.46	2.20	0.04	0.239	38	106	35	291	32	1	278	69	21	0.6	14	67	87	0	6	15	0	12
VC79-525	45.71859	-116.31242	R_1 Grande Ronde Basalt	Tgr_1	53.21	2.49	14.35	12.84	0.22	4.02	7.82	2.85	1.66	0.35																		

* 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.

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