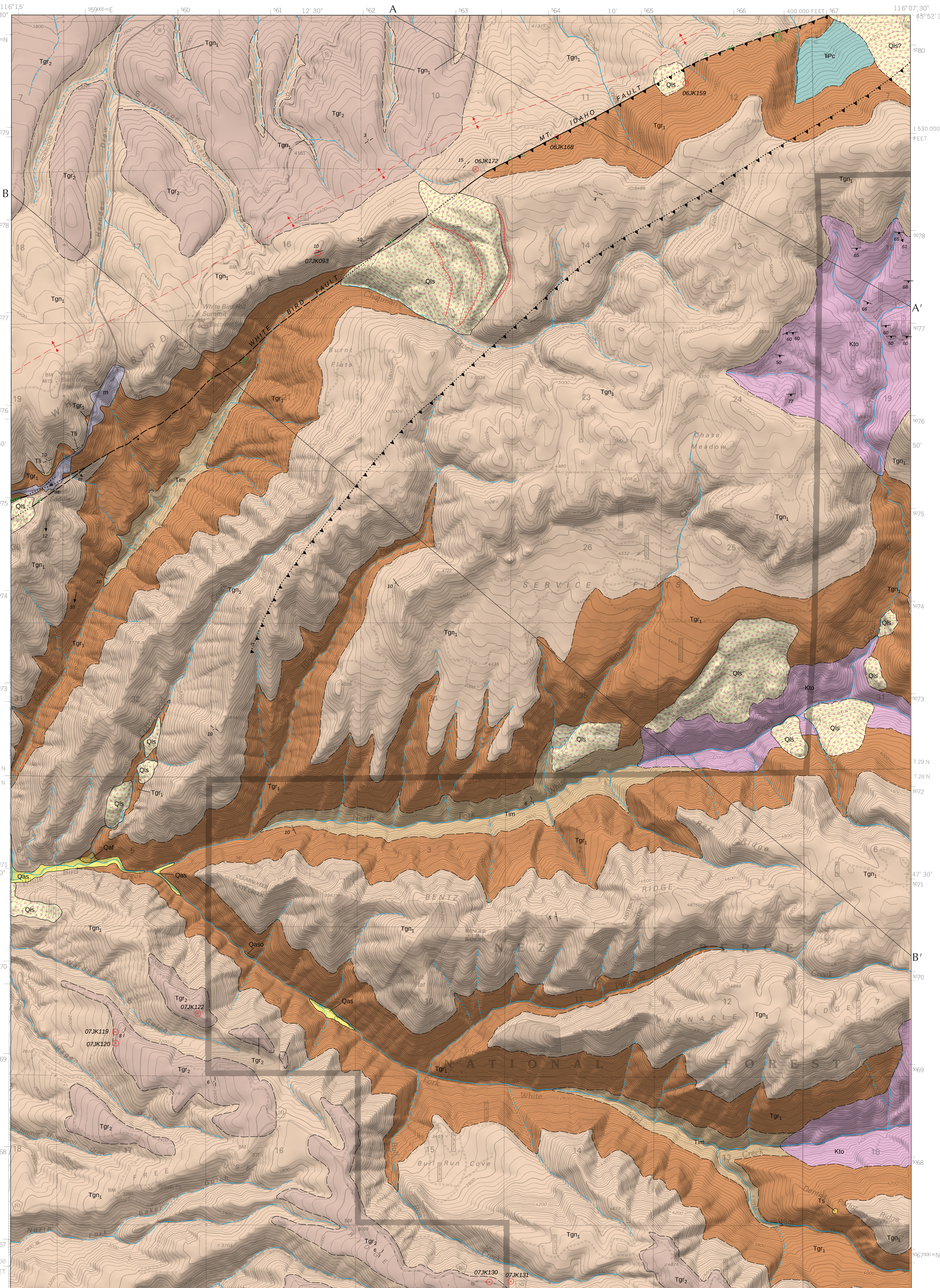
Geologic Map of the White Bird Hill Quadrangle, Idaho County, Idaho

John D. Kauffman, Reed S. Lewis, Keegan L. Schmidt, and David E. Stewart

2008

Disclaimer: This Digital Web Map is an informal report and may be revised and formally published at a later time. Its content and format may not conform to agency standards.



Base map scanned from USGS film positive, 1981.

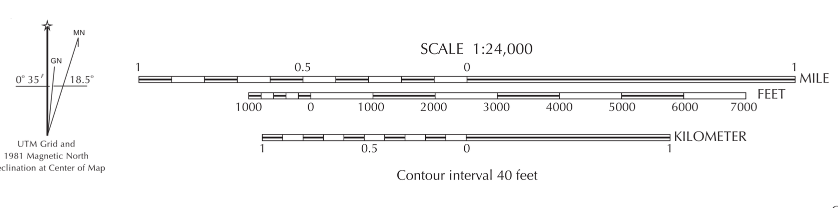
Shaded elevation from 10 m DEM, vertically exagerated 2x.

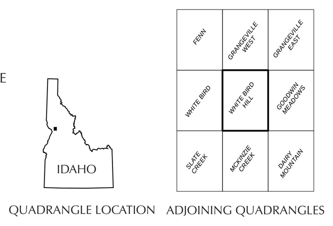
Topography by photogrammetric methods from aerial photographs taken 1961. Field checked 1963. Photorevised 1981.

Polyconic projection. 1927 North American Datum.

10,000-food grid ticks based on Idaho coordinate system, west zone.

1000-meter Universal Transverse Mercator grid ticks, zone 11.





Field work conducted 2006 and 2007.

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program, USGS Award No. 07HQAG0070.

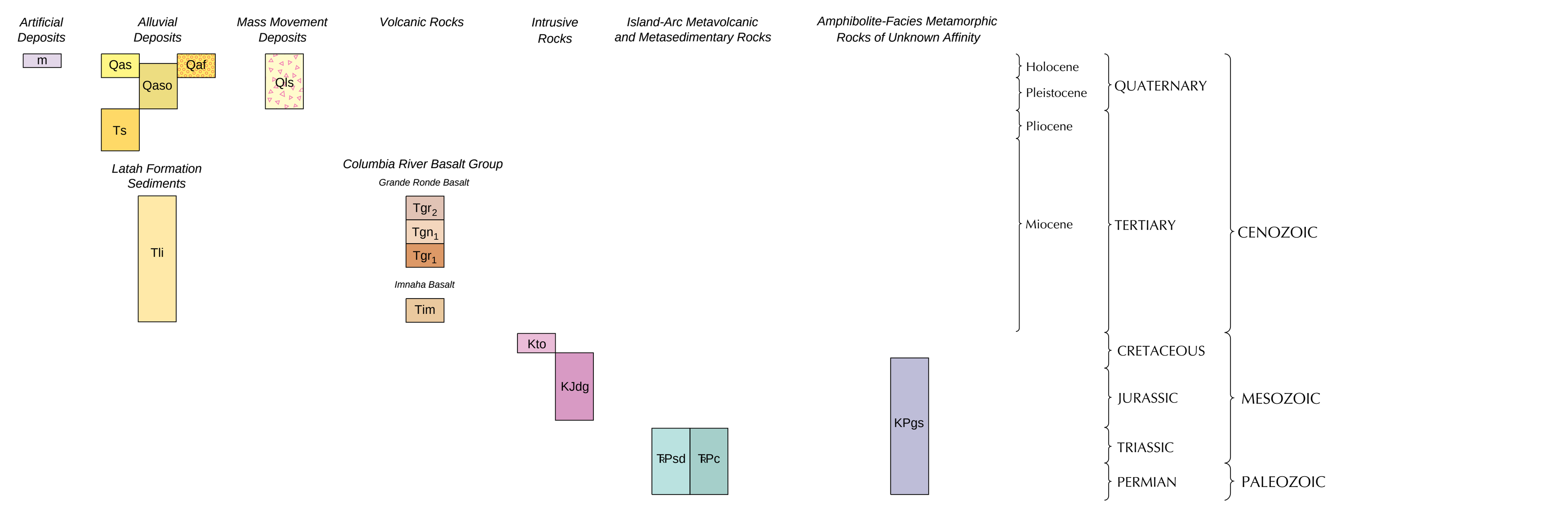
Digital cartography by Theresa A. Taylor, Loudon R. Stanford, and Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.

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 8-28-2008.

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

CORRELATION OF MAP UNITS



INTRODUCTION

The geologic map of the White Bird Hill quadrangle depicts rock units exposed at the surface or underlying thin surficial cover of soil and colluvium. Thicker surficial deposits of alluvium and landslides are also depicted where they mask or modify the underlying rock or form significant mappable units. The map is the result of field work conducted in 2006 and 2007 by the authors. Previous work includes that of Bond (1963) and reconnaissance mapping and sampling in the area from 1978 to 1980 (Camp, 1981; Swanson and others, 1981).

Most of the quadrangle is underlain by Miocene basalt flows of the Columbia River Basalt Group. Cretaceous intrusive biotite tonalite is exposed in several drainages along the eastern edge of the quadrangle. Permian to Triassic chlorite schist occurs in a window through the basalt in the northeast corner of the map. The basalt flows invaded ancestral drainages and flooded the paleotopography. Structural warping of the basalt occurred both during and after emplacement, in part controlling the distribution of younger basalt flows and stream development. Landslides are associated with the contact between basalt and basement rocks or with steep canyon slopes. Alluvial deposits are found within the canyons of the White Bird Creek drainage system. A high gravel deposit at an elevation of about 4,300 feet in the southeast corner of the map is of unknown origin, but may be a small alluvial remnant of an early stage of the South Fork White Bird Creek and Little White Bird Creek.

DESCRIPTION OF MAP UNITS

Throughout the following descriptions and later discussion of structure, we use the metric system for sizes of mineral or clast constituents of rock units. However, we use English system for thickness and distance measurements because that system is used on the base map.

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. Fill related to construction of White Bird grade of Highway 95.

SEDIMENTARY AND MASS MOVEMENT DEPOSITS

Alluvial Deposits

Qas **Alluvial deposits in drainages and tributaries to White Bird Creek (Holocene)**—Stratified silt, sand, and clay with minor intercalated subrounded to subangular pebbles and cobbles. Gravel clasts predominantly basalt. Thickness 5-20 feet.

Qaso **Older alluvial deposits (Pleistocene or Holocene)**—One small gravel deposit along South Fork White Bird Creek, located about 50 feet above present creek level. Consists of subrounded to well-rounded mostly basalt cobbles and gravels.

Qaf **Alluvial-fan deposits (Holocene)**—One small alluvial fan mapped at the mouth of Cottonwood Creek, a tributary to White Bird Creek. Consists of subangular to subrounded poorly sorted basalt clasts in fine-grained matrix.

Ts **Sediment, undivided (late Miocene or Pliocene?)**—One small gravel deposit remnant at about 4,300 feet elevation mapped on the north slope of Little White Bird Creek in the southeast corner of the map. Mostly basalt pebbles and cobbles, but contains a few small quartz pebbles. Probably represents an ancestral White Bird Creek drainage deposit.

Latah Formation Sediments

Sediments of the Latah Formation within the basalt sequence are stratigraphically equivalent to the Ellensburg Formation (Swanson and others, 1979) in Washington.

Tl **Latah Formation, sedimentary interbed (Miocene)**—Mostly clay, silt, and sand deposits interbedded between basalt flows just above the Grande Ronde R_1-N_1 contact near the top of the White Bird grade. Probably more extensive than mapped, but typically poorly exposed because of colluvial cover.

Mass Movement Deposits

Qls **Landslide deposits (Pleistocene and Holocene)**—Poorly sorted and poorly stratified angular rock debris mixed with silt and clay. Some consist of large, nearly intact basalt blocks that moved downslope. Deposited by slumps, slides, and debris flows. In addition to the landslide deposit, the unit may include the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols). Location is commonly controlled by the presence of sedimentary deposits at the interface between basalt units and underlying basement rocks. Landslides range in age from ancient, relatively stable features, to those formed more recently, which may be less stable.

VOLCANIC ROCKS

Columbia River Basalt Group

The stratigraphic nomenclature for the Columbia River Basalt Group follows that of Swanson and others (1979). In Idaho, the group is divided into four formations. From oldest to youngest, these are Imnaha Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Imnaha Basalt is exposed in the drainages of Cottonwood Creek, North Fork White Bird Creek, and South Fork White Bird Creek. Grande Ronde Basalt, from oldest to youngest, has been subdivided into the informal R_1, N_1, R_2, and N_2 magnetostratigraphic units (Swanson and others, 1979). Of these units, flows of the R_1, N_1, and R_2 are exposed and cover most of the quadrangle. Wanapum Basalt and Saddle Mountains Basalt units are absent. Representative samples of 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.

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 1-2 mm plagioclase phenocrysts. Reverse magnetic polarity, although field magnetometer commonly gives weak normal or conflicting results, particularly near the top of the R_2 section. Consists of one or two flows that pinch out on the north flank of White Bird Hill and one or two thin flows at the south edge of the quadrangle along Free Use Road. Maximum thickness less than 100 feet.

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 5 or 6 flows. 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 in length. Flows lower in the sequence are typically thicker, generally 100-200 feet, and have thick entablatures. Colonnades of thin flows and entablatures of thick flows tend to form tiered cliffs on steep canyon slopes. Thickness of the unit ranges from 400 to 600 feet. Probably thinned over developing Mount Idaho structure.

Tgr_1 **Grande Ronde Basalt, R_1 magnetostratigraphic unit (Miocene)**—Mostly dark gray, fine-grained aphyric to microphyric basalt. Uncommon plagioclase phenocrysts 2-4 mm in length in one or more flows. Reverse magnetic polarity, although flows near the R_1-N_1 boundary commonly have inconsistent and weak field magnetometer polarity readings; therefore the mapped contact is poorly constrained. Outcrop characteristics of flows are similar to those in the Grande Ronde N_1 unit. Flow just below the R_1-N_1 contact and flow just above the R_1-Imnaha contact are thick, have well-developed entablatures, and are probably equivalent to the Center Creek and Grave Creek units, respectively, of Bond (1963). Unit thickness is about 700-800 feet.

Tim **Imnaha Basalt (Miocene)**—Medium- to coarse-grained, sparsely to abundantly plagioclase-phyric basalt; olivine common; plagioclase phenocrysts generally 0.5-2 cm, but some are as large as 3 cm. Flows examined in the field have normal polarity. Typically weathered to sooty brown granular detritus and poorly exposed. Exposed thickness is about 400 feet; base is not exposed except where it forms erosional contact with Kto unit.

INTRUSIVE ROCKS

Kto **Tonalite (Cretaceous)**—Light gray biotite- and hornblende-biotite tonalite. Locally characterized by a distinctive mottling due to the presence of large biotite plates; weathers to micaceous light tan grus. Generally medium grained, with plagioclase comprising approximately 65-70 percent and quartz 18-25 percent of the rock. Biotite plates, locally are as large as 2 cm, comprise from 5-10 percent and impart a foliation in the northernmost exposures. Garnet is common. Epidote is locally conspicuous in hand specimens and interpreted to be primary on the basis of textural relations with other minerals. In the South Fork Clearwater River area to the northeast, similar rock (and a possible extension of the same intrusive body) is referred to as trondhjemite of the Blacktail pluton by Myers (1982). However, normative values plot in the tonalite field on an Ab-An-Or diagram (after Barker, 1979). Unit belongs to a suite of trondhjemite and tonalite plutons that occur along and west of (outboard) the Salmon River suture and which contain primary epidote indicative of high pressure (≥8 kb) crystallization (Zen and Hammerstrom, 1984). U-Pb zircon dating of a tonalite sample collected northeast of the map along the South Fork Clearwater River yielded a 111.0 ± 1.6 Ma age (McClelland and Oldow, 2007). U-Pb zircon dating has yielded 116-119 Ma ages in tonalite and trondhjemite of the Sixmile Creek pluton to the north near Orofino (Lee, 2004) and an age of about 118 Ma in tonalite in the Hazard Creek complex to the south near McCall (Manduca and others, 1993).

KJdg **Diorite complex (Jurassic to Cretaceous)**—Shown only in cross-sections. Described from exposures in adjacent White Bird quadrangle (Garwood and others, 2008). Composite intrusive body primarily of textural variations of diorite, but also includes small bodies of gabbro, quartz diorite, and felsic dikes. The diorite is dark gray with light-colored plagioclase 1-3 mm in length and black hornblende 2-5 mm in length, giving the rock a mottled appearance. Specimens typically contain a few percent quartz. Texture ranges from mostly medium grained to, in places, very fine grained. Weathers readily to a fine, dark brown soil.

ISLAND-ARC METAVOLCANIC AND METASEDIMENTARY ROCKS

These metamorphosed volcanic, volcaniclastic, and sedimentary rocks are interpreted to belong to the Wallowa accreted terrane assemblage (Silberling and others, 1984; Vallier, 1995). In this quadrangle, the *TRPc* unit occurs as fragments in soil in the northeast corner of the map and the other units are interpreted to occur at depth as shown in the cross sections.

Seven Devils Group

TRPsd **Seven Devils Group, undivided (Permian to Triassic)**—Mostly metavolcanic rocks that are equivalent to the Seven Devils Group of Vallier (1977). Shown only in cross-section B-B′. Presence at depth interpreted from exposures in adjacent quadrangles to the northeast and west.

Seven Devils Group(?)

TRPc **Chlorite-epidote-actinolite schist and gneiss (Permian to Triassic)**—Medium to dark green chlorite-epidote-actinolite schist and gneiss with subordinate intrusive rocks. Light to medium green on weathered surfaces; weathers easily to fine, dark gray to brownish gray soil. Found only as float fragments on the north flank of Mount Idaho in a window through the basalt. Interpreted to be primarily igneous in origin and equivalent to the Seven Devils Group of Vallier (1977).

AMPHIBOLITE-FACIES METAMORPHIC ROCKS OF UNKNOWN AFFINITY

Amphibolite-facies metasedimentary (and metavolcanic?) rocks that are east of and structurally above the Wallowa accreted terrane assemblage, but are west of continental North American rocks (Myers, 1982; Hoover, 1986). May be equivalent to the Orofino series exposed 36 miles to the northwest (Anderson, 1930; Hietanen, 1962) or to the Riggins Group of Hamilton (1963) exposed 40 miles to the south. Shown only in cross-sections; presence in the subsurface interpreted from exposures in adjacent quadrangles. The following description is from exposures east of the quadrangle.

KPgs **Gneiss and schist (Permian to Cretaceous)**—Fine- to medium-grained hornblende gneiss that grades into hornblende ± biotite ± chlorite schist and muscovite-plagioclase-quartz ± biotite ± epidote schist, and epidote-plagioclase quartzite. Light gray or green to black, weathering to a fine gray brown soil. Texture is fine to medium grained. Hornblende gneiss contains subordinate epidote, zoisite, chlorite, quartz, and plagioclase. Garnet is common. Locally tightly folded to centimeter-scale isoclinal and chevron folds with no consistent fold axes.

STRUCTURE

MOUNT IDAHO-WHITE BIRD FAULT

The southwest-northeast-trending Mount Idaho-White Bird fault extends across the northern part of the map. The structure is part of a wide zone of deformation that has a poorly understood, complex, and probably lengthy history of development (Schmidt and Lewis, 2007). Columbia River Basalt units are faulted and tilted and nearly vertical outcrops of brecciated basalt occur along the structure, indicating a fault with a relatively steep dip. The Mount Idaho fault, which extends from the north-central part of the map to northeast of Grangeville, has relative movement of down-to-the-northwest (cross-section A-A′). Southwest from the north-central part of the map, the relative displacement along the fault changes to down-to-the-southeast (cross-section B-B′), and we identify that segment of the structure as the White Bird fault. At Poe Saddle near the west edge of the quadrangle, the fault bifurcates into two nearly parallel splays. One splay, the subsidiary White Bird Hill fault, closely follows Highway 95 into the adjacent White Bird quadrangle, where maximum displacement is about 300 feet. The main splay, the White Bird fault, is inferred to continue beneath landslide deposits in the White Bird quadrangle, where maximum displacement is as much as 1000 feet. These two splays appear to merge again at the town of White Bird (Garwood and others, 2008). At two locations near Poe Saddle, exposed small faults along this structure strike about N. 45-50° E. and dip 65-68 degrees southeast.

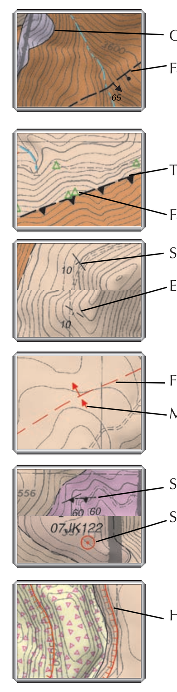
From recent mapping on nearby quadrangles (Schmidt and others, 2007; Garwood and others, 2008), we infer that the Neogene Mount Idaho and White Bird faults merge at depth with the Cretaceous or Paleogene Hammer Creek thrust (cross-section B-B′), which has older strike-slip and thrust components. North-south contraction during the Miocene may have caused initial folding and later faulting of the Columbia River basalt units on the Mount Idaho segment of the fault, possibly as a result of renewed activity on the Hammer Creek thrust. Later east-west extension, probably related to the northern limits of Basin and Range extension, may be responsible for the normal displacement on the White Bird and associated White Bird Hill faults.

Alternatively, the entire fault system may have experienced complex deformation that included normal faulting along north-northeast-striking White Bird fault system simultaneously with reverse faulting along the east-northeast-striking Mount Idaho fault system. This implies that the Mount Idaho segment forms an accommodation zone along the northern limit of Basin and Range extension in the Salmon River corridor.

FOLDING IN THE COLUMBIA RIVER BASALT

Most of the folding in the basalt is probably related to Miocene reactivation of movement on the Hammer Creek thrust and displacement along the Mount Idaho-White Bird fault, and to the associated development of the White Bird basin west of the quadrangle. North of the Mount Idaho-White Bird fault, Grande Ronde Basalt units are tilted to the north, decreasing in dip from 10-15 degrees near the structure to ~3 degrees at the northwest edge of the map. Tilted Grande Ronde R_2 pinches out on the north flank of the structure, indicating uplift had begun to develop prior to extrusion of that unit. South of the Mount Idaho structure and north of the North Fork White Bird Creek, the basalt flows dip to the southwest, increasing from about 5 degrees at the east edge of the quadrangle to 10 degrees or more at the west edge. Farther south, dips are westward and increase from 4 or 5 degrees in the east to 6 or 7 degrees in the west. At the south edge of the quadrangle, dips are to the northwest at about 6 degrees. This arcuate change in strike represents a broad open synclinal warp that plunges to the west to the White Bird basin.

SYMBOLS



Contact: dashed where approximately located.

Fault: bar and ball on downthrown side; dashed where approximately located; dotted where concealed. A/T on cross-section indicates strike-slip direction on fault: A = away from observer; T = toward observer. Strike and dip of shear or fault plane.

Thrust fault: dashed were approximately located; dotted where concealed; teeth on upper plate.

Fault breccia.

Strike and dip of basalt flows.

Estimated strike and dip of basalt flows.

Fold axis.

Monocline: synclinal flexure; shorter arrow on steeper limb.

Strike and dip of foliation.

Sample location and number.

Headwall scarp of landslide.

REFERENCES

Anderson, A.L., 1930, The geology and mineral resources of the region about Orofino, Idaho: Idaho Geological Survey Pamphlet 34, 63 p.

Barker, F., 1979, Trondhjemite: definition, environment, and hypotheses of origin, *in* F. Barker, ed., Trondhjemites, Dacites, and Related Rocks: Elsevier, New York, p. 1-12.

Bond, J.G., 1963, Geology of the Clearwater embayment: Idaho Bureau of Mines and Geology Pamphlet 128, 83 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.

Garwood, D.L., K.L. Schmidt, J.D. Kauffman, D.E. Steward, R.S. Lewis, K.L. Othberg, and P.J. Wampler, 2008, Geologic map of the White Bird quadrangle, Idaho County, Idaho: Idaho Geological Survey Digital Web Map 101, scale 1:24,000.

Hamilton, Warren, 1963, Metamorphism in the Riggins region, western Idaho: U.S. Geological Survey Professional Paper 436, 95 p.

Hietanen, Anna, 1962, Metasomatic metamorphism in western Clearwater County, Idaho: U.S. Geological Survey Professional Paper 344-A, 116 p.

Hoover, A.L., 1986, Transect across the Salmon River suture, South Fork of the Clearwater River, western Idaho: Rare earth element geochemical, structural, and metamorphic study: Oregon State University M.S. thesis, 138 p.

Lee, R.G., 2004, The geochemistry, stable isotope composition, and U-PB geochronology of tonalite trondhjemites within the accreted terrane, near Greer, north-central Idaho: Washington State University M.S. thesis, 132 p.

Manduca, C.A., M.A. Kuntz, and L.T. Silver, 1993, Emplacement and deformation history of the western margin of the Idaho batholith near McCall, Idaho: Influence of a major terrane boundary: Geological Society of America Bulletin, v. 105, p. 749-765.

McClelland, W.C., and J.S. Oldow, 2007, Late Cretaceous truncation of the western Idaho shear zone in the central north American Cordillera: Geology, v. 35, no. 8, p. 723-726.

Myers, P.E., 1982, Geology of the Harpster area, Idaho County, Idaho: Idaho Bureau of Mines and Geology Bulletin 25, 46 p.

Schmidt, K.L., and R.S. Lewis, 2007, Role of NE-striking oblique dextral thrust faults in the development of the Wallowa terrane in the northern Cordillera: Implications for terrane accretion and clockwise rotation: Geological Society of America Abstracts with Programs, v. 39, no. 6, ISSN 0016-7592, Paper 106-4.

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.

Siberling, N.J., D.L. Jones, M.C. Blake, Jr., and D.G. Howell, 1984, Lithotectonic terrane map of the western conterminous United States, Pt. C, *in* N.J. Siberling and D.L. Jones, eds., Litiotectonic Terrane Maps of the North American Cordillera: U.S. Geological Survey Open-File Report 84-523, 43 p.

Swanson, D.A., J.L. Anderson, R.D. Bentley, G.R. Byerly, V.E. Camp, J.N. Gardner, 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.

Vallier, T.L., 1995, Pertology of pre-Tertiary igneous rocks in the Blue Mountains region of Oregon, Idaho, and Washington: Implications fo the geologic evolution of a complex island arc, *in* T.L. Vallier and H.C. Brooks, eds., Geology of the Blue Mountains Region of Oregon, Washington, and Idaho: Petrology and Tectonic Evolution of Pre-Tertiary Rocks of the Blue Mountains Region: U.S. Geological Survey Professional Paper 1438, p. 125-209.

Zen, E-an, and J.M. Hammerstrom, 1984, Magmatic epidote and its petrologic significance: Geology, v. 12, p. 515-518.

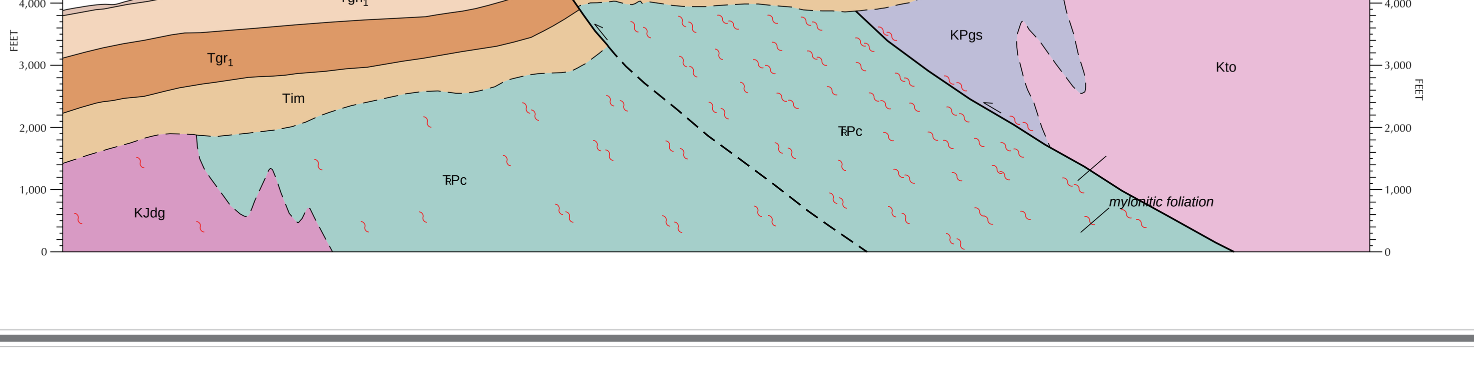
Table 1. Major oxide and trace element chemistry of samples collected in the White Bird Hill quadrangle.

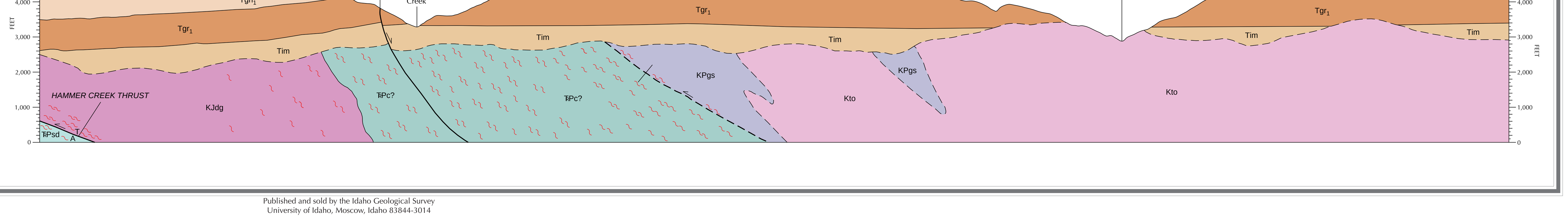
Sample number	Latitude	Longitude	Unit name	Map unit	Major elements in weight percent										Trace elements in parts per million																	
					SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th	Nd
06JK159	45.86836	-116.15624	Grande Ronde R_1	Tgr_1	55.08	2.641	14.26	11.33	0.192	3.31	8.08	3.01	1.69	0.402	14	13	33	377	734	51	363	212	36	13.8	24	31	136	9	22	51	3	33
06JK168	45.86333	-116.17427	Grande Ronde R_1	Tgr_1	55.00	2.643	14.68	10.69	0.177	3.27	8.20	3.14	1.79	0.413	13	20	35	383	587	42	361	218	39	14.0	23	41	136	10	23	59	3	34
06JK172	45.86003	-116.18547	Grande Ronde N_1	Tgn_1	55.37	2.145	14.10	11.62	0.204	3.81	7.65	3.14	1.58	0.385	15	12	35	382	652	35	321	184	39	11.1	21	40	131	8	20	47	4	29
07JK093	45.85189	-116.20742	Grande Ronde N_1	Tgn_1	54.62	2.289	13.73	12.34	0.214	3.91	7.71	3.37	1.41	0.410	12	10	36	381	677	30	330	173	39	11.4	20	19	131	6	22	49	6	29
07JK119	45.77619	-116.23546	Grande Ronde R_2	Tgr_2	55.55	2.260	13.97	12.23	0.196	3.46	7.05	3.18	1.67	0.427	8	11	31	326	729	44	354	189	37	11.7	20	13	127	7	29	54	7	31
07JK120	45.77509	-116.23541	Grande Ronde R_2	Tgr_2	55.96	2.407	13.78	12.32	0.192	3.03	6.59	3.44	1.83	0.449	10	5	31	366	752	49	324	196	39	13.0	19	25	132	9	26	61	8	31
07JK122	45.77799	-116.22403	Grande Ronde R_2	Tgr_2	55.79	2.365	13.57	12.05	0.215	3.38	7.04	3.29	1.85	0.439	11	4	31	363	763	44	326	194	39	12.5	21	23	130	7	30	63	6	34
07JK130	45.75191	-116.18356	Grande Ronde R_2	Tgr_2	56.47	2.274	14.08	10.89	0.244	3.45	7.12	3.15	1.88	0.444	8	11	32	326	888	47	372	190	43	11.6	20	11	131	7	27	60	8	33
07JK131	45.75196	-116.18057	Grande Ronde N_1	Tgn_1	55.68	2.162	13.69	12.45	0.212	3.37	6.92	3.47	1.61	0.426	12	9	33	358	711	42	308	188	41	11.4	22	18	136	7	25	51	6	31

* 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.

ACKNOWLEDGMENTS

We thank the landowners in the area, and especially the Heckman family, for access to their property. V.E. Camp provided copies of his field notes and maps of the area.





Published and sold by the Idaho Geological Survey
University of Idaho, Moscow, Idaho 83844-3014