GEOLOGIC MAP OF THE CLIFFDELL AND WESTERN TWO-THIRDS OF THE MANASTASH LAKE 7.5-MINUTE QUADRANGLES, YAKIMA AND KITTITAS COUNTIES, WASHINGTON

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Geologic Map of the Cliffdell and Western Two-thirds of the Manastash Lake 7.5-minute Quadrangles, Yakima and Kittitas Counties, Washington

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INTRODUCTION

The Cliffdell and Manastash Lake 7.5-minute quadrangles are located along the border between Yakima and Kittitas Counties on the central eastern slope of the Cascade Range, Washington, about 68 km (42 mi) northwest of Yakima and 39 km (24 mi) east of the crest of the Cascade Range at Chinook Pass (elevation 1656 m; 5432 ft) and Mount Rainier National Park. The quadrangles include part of the Mount Baker–Snoqualmie National Forest, administered by the Wenatchee National Forest. State Route (SR) 410, between Chinook Pass and Yakima, passes through the quadrangles. Paved and graveled Forest Service roads and foot and horse trails provide access to most parts of the quadrangles. The town of Cliffdell, located in the center of the Cliffdell quadrangle on SR 410, is the nearest community in the map area having a store, service station, restaurant, and overnight accommodations.

Mapping, aided by aerial photos and the topographic quadrangles, was conducted along roads and trails, ridge crests and slopes, and open stream courses. Field stations and geologic features were plotted by hand directly on the topographic quadrangles. Before 1996, field stations and samples sites were located by field inspection and recognition of landmarks, supplemented by altimeter readings, and recorded in Universal Transverse Mercator (UTM) coordinates. During the 1996 season and thereafter, sites were located by the global position system (GPS). However, GPS locations can be in error by as much as 75 m (250 ft) where samples were taken in forest, on steep slopes, or below cliffs. Therefore, the location in GPS can differ from that in UTM. Some sites are located in landslides (unit Qls) and talus (unit Qta). These locations are small, isolated outcrops that have the same lithology and attitude as bedrock marginal to the landslide or talus, but it is not evident if the outcrop is bedrock in place, in correct stratigraphic position, or a landslide block. At a few sites, samples may have been collected from several map units different than the labeled polygon shown on the map. For example, at a site near the contact between two stratigraphic units and two different intrusive units, four samples could be taken—one of each unit..

Of the 573 samples collected in the quadrangles, 363 were submitted for x-ray fluorescence analysis (XRF), 16 for inductively coupled plasma mass spectrometry analysis (ICP-MS), 4 for isotope analysis, and 11 for $^{40}Ar/^{39}Ar$ age-dating. These analyses are available in the data supplement to this report (Hammond, 2010). The names of the rocks follow the Total Alkali-Silica (TAS) classifications of Le Maitre and others (1989) for volcanic rocks, modified to include a field for rhyodacite (after Swanson, 1989), and Wilson (1989) for plutonic rocks. Some rocks in the Ellensburg Formation containing 60 to 63% SiO_2 are described as silicic andesite. Fragmental volcanic rocks are named after the classification of Schmid (1981). One to ten thin sections of most map units were point counted (1000 points) to give a range of mode in the descriptions of the units; in others, the mode was estimated in whole numbers. The Cenozoic epochs to which the map units were assigned follow the new 2009 Geologic Time Scale (Walker and Geissman, 2009).

Much of the area, especially around Edgar Rock volcano, was previously very well mapped and sampled by B. A. Carkin (1988). He submitted many samples for x-ray fluorescence (XRF), Instrumental Neutron Activation (INAA), and age-date analysis. His mapping is included in this map and his analyses are listed in the supplemental data (Hammond, 2010).

STRATIGRAPHY

As in the two quadrangles to the south (Hammond, 2009), the Cliffdell and Manastash Lake quadrangles are located in the transition zone between the geologic provinces of the Cascade Range to the west and the Columbia Plateau (Basin) to the east. The boundary between these two provinces lies along the Naches River (Campbell, 1988, 1989), which flows from northwest to southeast across both quadrangles. The west-lying Cliffdell quadrangle is underlain by a series of seven middle Eocene to upper Oligocene volcanic and sedimentary deposits. These deposits are overlapped by middle Miocene lava flows of Grande Ronde Basalt of the Columbia River Basalt Group and upper Miocene volcanic deposits of the Ellensburg Formation. The Manastash Lake quadrangle contains chiefly two deposits, the upper Oligocene deposits of Edgar Rock volcano, and the overlying lava flows of Grande Ronde Basalt.

Bedrock is composed of 20 mappable units. The oldest unit is very poorly exposed sandstone and tuff of the Naches Formation, structurally disrupted and obscured by landslides of the Milk Creek complex in the north-central part of the map (Cross Sections B–B′ and C–C′). These beds are overlain conformably by the basalt of north Milk Creek (unit Tnmb) and rhyolite of Lily Pond Lake (unit Tnlr). The sedimentary deposits of the

Naches Formation are believed to have been derived fluvially from north and east of this part of the Cascade Range and the Columbia Plateau (Winters, 1984, p. 137-141; Byrnes, 1985, p. 47-51). The interbedded basalt and rhyolite deposits are interpreted to have been erupted in the map area but could not be traced to their sources. The Naches Formation is in contact along the Devils Slide fault with the stratigraphically younger unit, the Ohanapecosh Formation (unit To).

The Ohanapecosh Formation is composed of tuff and volcanic sedimentary deposits chiefly of andesitic composition. These deposits were included in the Naches Formation by Carkin (1988) but contain no micaceous quartz-feldspathic sandstone typical of the Naches, and, therefore, are mapped separately in this study as Ohanapecosh Formation (unit To). This formation, named and described by Fiske and others (1963), was derived from eruptive sources to the west. The deposits are intruded by dikes and sills of basalt. The Ohanapecosh Formation is overlain unconformably by the andesite of Edgar Rock (unit Tfer) and lava flows of Grande Ronde Basalt, chiefly the Grouse Creek flow (unit Tgg); consequently, the formation is not in exposed contact with the next younger map unit, the rocks of Gold Creek (unit Tfgc), located in the center of the map and surrounded by andesite of Edgar Rock.

The next suite of stratigraphically younger rocks is the Fifes Peak Formation. These rock units, where their bases are exposed in the region, rest unconformably on the older Ohanapecosh and Naches Formations. This unconformity, representing a short interval between about 28 and 27 Ma, marks the first significant deformation—minor folding and faulting—affecting the older rock units.

The oldest rock unit of the Fifes Peak Formation in the map is the rocks of Gold Creek. They were recognized and named by Warren (1941), but little described. Carkin (1988) identified them as undifferentiated Tertiary volcanic rocks. The breccias mapped by Carkin (1988) underlying the andesite of Edgar Rock at the head of Milk Creek, east of Devils Slide fault in the northeast part of the map, are included on the map as the andesite of Edgar Rock (unit Tfer). Radiometric age dates indicate that the Gold Creek rocks are younger than the Ohanapecosh Formation. They consist of extensively altered and deeply weathered coarse volcanic breccia, abundant dikes, and possibly some lava flows identified by Carkin (1988); all are of chiefly andesite composition. These rocks are similar chemically and petrographically to the andesite of Edgar Rock. Therefore, they could be the core of Edgar Rock volcano or the remnants of an earlier volcano at the same site. A recent cut along SR 410, along the bend north of Gold Creek, exposes deeply weathered to nonweathered, well-compacted, massive, fine to very coarse breccia of many rock types, of probable debris avalanche origin, referred to in the unit descriptions as megabreccia. Basal breccia of the overlying andesite of Edgar Rock (unit Tfer) rests on deeply weathered megabreccia north of the bend, suggesting that a long time interval separated the two units.

The next stratigraphic unit up in the Fifes Peak Formation is the andesite of Edgar Rock (unit Tfer). It dominates the central part of the map. Campbell (1975) applied the name to the extensive outcrops along SR 410. Carkin (1988) presented a comprehensive description of the rocks and the volcano composing the map unit. It consists chiefly of basaltic andesite, with lesser amounts of basalt, andesite, and dacite, composing abundant deposits of laharic and lava breccia, intact lava flows, and sparse interbeds of variegated air-fall tuff. The unit contains the most abundant rubbly lava flows and breccias of all the mid-Tertiary-age volcanoes in the region. Note in the map the many radial dikes intruding the volcano; they probably erupted many of the lava flows. Edgar Rock volcano and Tieton volcano, in the Tieton Basin quadrangle (Swanson, 1966; Hammond, unpub. map), are the only two volcanoes in this area of the Cascade Range to show a well-developed radial dike swarm, possibly indicating increasing volume of injected magma and enlargement of the core during the life of the volcano.

The andesite of Edgar Rock is sharply overlain by lava flows of the andesite of Nile Creek (unit Tfnc) in the southwest part of the map. The name was applied by Carkin (1988) for the exposures along Nile Creek in the southwest corner of the map. Abundant lava flows, many platy jointed and flow layered and containing coarse crystals of orthopyroxene (hypersthene), and thick sections of laharic breccia and tuff typify this unit. The deposits originated from the volcano of North Rattlesnake Creek, west of the map, which was truncated during collapse of the Mount Aix caldera in the Timberwolf Mountain quadrangle (Hammond, 2005) and Bumping Lake quadrangle. Advance of Nile Creek lavas into the southwest quadrant of Edgar Rock volcano indicate that no flank or remnant volcano ring existed in this location during outpouring of the Nile Creek lavas. The southwest flank had probably collapsed, taking with it the extrusive core of the volcano, for no remnants of the core can be found at the margin of the Naches River valley southwest of Gold Creek (Carkin, 1988). Evidence of possible debris flow or avalanche deposits in the area southwest of the volcano are covered by lava flows of the andesite of Nile Creek (unit Tfnc) and deposits of the Ellensburg Formation (unit Tev).

About 215 m (700 ft) of younger lava flows and breccias of the apron of Fifes Peaks volcano (unit Tfpa), located about 10 km (6 mi) west of the map but not exposed at the surface of the map, are shown at depth in Cross Section C–C′. These deposits unconformably overlie andesite of Nile Creek (unit Tfnc).

Overlying the lavas of Fifes Peaks volcano is the tuff of Indian Flat (unit Tfit), the topmost unit of the Fifes Peak Formation in the map area. It is exposed in a very small area along the west margin of the map, south of the Bumping River and adjacent to the Indian Flat fault. It is part of a thick section of tuffs, ranging from rhyolite to andesite in composition, that separates lava flows of Fifes Peaks volcano from overlying lava flows of Grande Ronde Basalt. The eruptive source of the tuff is not well established but interpreted to be Fifes Peaks volcano.

Since deposition of the tuff of Sun Top (the uppermost unit of the Fifes Peak Formation exposed along the White River west of the map) at 22 Ma, no eruption of a large andesitic stratovolcano the size of Edgar Rock or Fifes Peaks volcano has occurred in this part of the Cascade Range. Only the dacite–silicic andesite domal volcanoes that supplied major debris to the Ellensburg Formation (since 11 Ma) and scattered cinder cones that fed small lava flows of basalt and andesite (since 3.3 Ma) have erupted.

The next stratigraphic suite up is the Grande Ronde Basalt (16.5 to 15.6 Ma), all flows of which unconformably overlie the older rock units. All older rock units show evidence of structural deformation, folding and faulting, and deep erosion, thus marking the second major interval of deformation in the region, this one being more intensive, from about 22 to 16 Ma. Locally, erosion removed the entire sedimentary and volcanic succession down to pre-Tertiary rocks.

In stratigraphic order, the Grande Ronde flows are the Wapshilla Ridge flow (unit Tgw), Grouse Creek flow (unit Tgg, locally called the Meeks Table flow; Swanson, 1967), Ortley flow (unit Tgo), McCoy Canyon flow (unit Tgm), Cohassett flow (unit Tgc), and the Rocky Coulee flow (unit Tgr) capping the sequence. The thick Grouse Creek and Cohassett flows have complex internal structure indicative of inflated or invasive lava flows. Thin tuff, sedimentary, and hyaloclastite beds commonly separate these lava flows. The thickest sequence, 85 m (280 ft)(Campbell, 1987), separates the McCoy Canyon and Grouse Creek flows along Rattlesnake Creek in the Meeks Table quadrangle (Hammond, 2009). The tuff beds are thin (generally <50 cm thick), white, very fine grained, and rhyolitic in composition. Of the six flows, only the Rocky Coulee flow completely surrounded Edgar Rock volcano, making the remnant volcano a steptoe. The other flows simply lapped out on the flanks of the volcano. The oldest, Wapshilla Ridge flow, advanced from the south only as far as the present location of Rock Creek. In a large area at the head of Milk Creek and extending south of Bald Mountain in the northeast part of the map, the thick Cohassett and McCoy Canyon flows encountered a major river, possibly either the ancestral Naches or Yakima River, and were converted to hyaloclastite and pillow lava deposits.

During latest Miocene–Pliocene time, post–Grande Ronde Basalt, a new, contrasting type of volcanism occurred in the region west of the Cliffdell and Manastash Lake quadrangles, especially in the Bumping Lake area, with emplacement of many domes of biotite-hornblende-plagioclase dacite and silicic andesite. These domal volcanoes erupted ashfall, pyroclastic flow, and especially voluminous debris flow deposits. When saturated with meteoric precipitation, these deposits became mobilized to form vast amounts of laharic breccias, conglomerates, and sandstones, which spread eastward unconformably across the Grande Ronde Basalt, andesite of Nile Creek, and older deposits, chiefly in the southwest part of the map. These deposits are the Ellensburg Formation volcanic facies (unit Tev)(Luker, 1985; Smith, 1988). Edgar Rock volcano, as a large remnant volcanic form, stood above these blanket deposits.

During the close of deposition of the Ellensburg Formation, between about 7 and 3 Ma, the region experienced the third and most intensive deformation, affecting all map units, folding and faulting Grande Ronde Basalt in the map area and elsewhere, and uplifting Manastash Ridge and the Cascade Range.

Surficial deposits of Quaternary age consist of alluvium (unit Qa), fan deposits (unit Qaf), talus (unit Qta), and landslide deposits (unit Qls). All are confined to and locally prominent in valleys, except landslides. Landslides are common; some are extensive and occur in complexes of coalescing and nested landslides. Most landslides are earthflows. They range in area from about 0.1 to nearly 10 km^2 (0.25–3.8 mi^2), although most are less than 0.5 km^2 (0.2 mi^2). Some landslides are spectacular landforms. Ten such landslides, including one block slide, are recognized in the quadrangles and shown by name on the map. They are named after a nearby geographic landmark and listed from northwest to southeast in Table 1.

STRUCTURE

In addition to forming the boundary between the Columbia Plateau (Basin) to the east and the Cascade Range to the west (Campbell, 1988, 1989), the Naches River valley is also the approximate boundary between two structural domains in the region—the northward narrowing Yakima fold belt to the west and the Olympic–Wallowa lineament (zone) to the east. In reality, the boundary lies a short distance west of the Naches River. It follows the river in the northwest corner of the map, then at about Spring Creek, north of Cliffdell, shifts west to the southeast-striking Indian Flat–Johnson Canyon fault and Nile Creek syncline. Some may argue that the boundary should include the Devil Creek fault in the southwest corner of the map.

The Olympic–Wallowa lineament, named by Raisz (1945) and further described by Kienle and others (1977) and Tabor and others (2000), consists predominantly of north-northwest-striking structures—fold axes and faults, with two transverse structures—the Benton Creek syncline and Rock Creek thrust (Cross Section B–B′). The Yakima fold belt consists chiefly of east-northeast-striking folds. Therefore, the two domains are oriented perpendicular to each other, forming a complex structural pattern. However, stereographic analysis of the structures shows that the dominant compressive stress is N35–50°W, approximately parallel to the Indian Flat–Johnson Canyon fault, and the Yakima folds in the map are perpendicular to this stress. The structures in the Olympic–Wallowa lineament were formed during the first deformational interval, between deposition of the Ohanapecosh Formation (unit To) and Fifes Peak Formation (unit Tfpa), about 28 to 26 Ma. They developed as second-order structures, as shear folds and faults, by the north-northwest–south-southeast-oriented compressive stress. The structures in the Olympic–Wallowa lineament were further intensified during the interval from the end of deposition of the Fifes Peak Formation (unit Tfp) and before deposition of Grande Ronde Basalt (unit Tgrb), between about 22 to 16 Ma. During the third and most intense deformational interval, between about 7 and 3 Ma, the Yakima folds, Benton Creek syncline, and Rock Creek thrust were developed.

Mapping reveals that the north- to northwest-striking faults and fractures initially formed, then the northeast-striking folds, including the folds and faults in the OWL, as the earlier formed structures intensified, and lastly the northeast-striking reverse and thrust faults—the Carmack Canyon (Meeks Table and Nile quadrangles, Hammond, 2009a), Rock Creek, and Cougar Canyon–Waterworks (Tieton Basin and Weddle Canyon quadrangles) faults.

All structures in the map are described in Tables 2 and 3; the domain of each is indicated in the rightmost column of the table. The main features in the structures are summarized below.

Folds

All folds are open, upright, and asymmetrical (Table 2). Limbs in the Yakima folds rarely dip more than 30°; fold limbs in the OWL dip as steeply as 80°. Small folds have limbs with variable dips, probably due to a combination of bedding plane slippage, axial plane shearing, and especially lack of parallel bedding in volcanic deposits. Axial planes are interpreted to dip no less steeply than 70°, and most folds plunge less than 5°. Several folds are the lateral extent of faults or closely parallel faults.

Table 1. Major landslides in the Cliffdell and western two-thirds Manastash Lake 7.5-minute quadrangles, Washington

Name of landslide[1]	Size	Length	Maximum width	Maximum thickness[2]	Percent grade[3]	Geologic units involved[4]	Type[5]	Active/ inactive[6,7]	Comments
Catchup Creek	0.76 km² (0.29 mi²)	1065 m (3500 ft)	610 m (2000 ft)	35 m (120 ft)	12–16	To tuff	earthflow	inactive	Extends north into Quartz Mountain quadrangle
Devils Slide complex	5.1 km² (2.0 mi²)			100 m (320 ft)			earthflow	active in upper part	Joined by five tributary slides
upper part		2135 m (7000 ft)	1065 m (3500 ft)		21				
lower part		1675 m (5500 ft)	5485 m (18,000 ft)		12				
Milk Creek complex	8.3 km² (3.2 mi²)					Tn sandstone, tuff; To tuff;	earthflow	active in upper part	Coalesces with Devils Slide
upper part		3350 m (11,000 ft)	4265 m (14,000 ft)	60 m (200 ft)	23–36	Tfer lava flows and basal tuff			
lower part		4875 m (16,000 ft)	60 m (200 ft) at Milk Pond	35 m (120 ft) above Milk Pond	5				
South Milk Creek complex						To tuff, Tfer lava flows, and basal tuff	earthflow	inactive	Landslides on slopes of glaciated valley
east part	1.48 km² (0.57 mi²)	1370 m (4500 ft)	1735 m (5700 ft)	50 m (160 ft)	21–27				East part feeds into Devils Slide
middle part	1.33 km² (0.51 mi²)	1430 m (4700 ft)	975 m (3200 ft)	50 m (160 ft)	31				Middle and west parts join Milk Creek landslide
west part	0.54 km² (0.20 mi²)	1160 m (3800 ft)	520 m (1700 ft)	50 m (160 ft)	23				
Swamp Creek									
north branch	9.69 km² (3.83 mi²)	5640 m (18,500 ft)	1830 m (6100 ft)	60 m (200 ft)	5–36	Tev conglomerate, laharic deposits, and tuff	earthflow	active	Originates as two narrow slides north of Little Bald Mountain; consists chiefly of Tev debris on dip slope of Tgrb; two branches join at lower Swamp Creek
south branch	6.56 km² (2.53 mi²)	6430 m (21,100 ft)	1980 m (6500 ft)	60 m (200 ft)	5–40		earthflow	inactive	
Spring Creek	1.71 km² (0.66 mi²)	2440 m (8000 ft)	1110 m (3500 ft)	85 m (280 ft)	16	Tfer lava flows and lava rubble (breccia)	earthflow	active in upper part	Terminal lobe of landslide exposed in cut along SR 410 north of Cliffdell
Bald Mountain									
west Bald Mountain; two sides of upper Lefthand Fork Rock Creek									
northwest side	1.86 km² (0.72 mi²)	915 m (3000 ft)	1525 m (5000 ft)	50 m (160 ft)	40–90	Tgrb lava flows,	earthflow	inactive	Landslides consist chiefly of hyaloclastite formed where Tgrb flows encountered a large stream, ancestral either Naches or Yakima Rivers
east side		762 m (2900 ft)	885 m (2900 ft)	35 m (120 ft)	36	hyaloclastite deposits			
north Bald Mountain	2.16 km² (0.83 mi²)	1500 m (4100 ft)	1770 m (9900 ft)	60 m (200 ft)	14–65	Tgrb lava flows, hyaloclastite deposits	earthflow	inactive	
south Bald Mountain	2.15 km² (0.83 mi²)	2680 m (8800 ft)	1430 m (4700 ft)	60 m (200 ft)	32–47	Tgrb lava flows, hyaloclastite deposits	earthflow	inactive	
Eagles Nest block slide	0.067 km² (0.016 mi²)	1250 m (4100 ft)	550 m (1800 ft)	300 m (985 ft)	– – –	Tfnc lava flows, laharic deposits	blockslide	inactive	Slide occurred a million or more years ago;Tfnc lava flows along highway are part of samelava flows atop ridge to west
Rock Creek									
upper slide, above FR 1720	0.57 km² (0.22 mi²)	610 m (2000 ft)	1435 m (4700 ft)	50 m (160 ft)	29–38	Tgrb lava, Tfer lava flows and breccia	earthflow	inactive	Slides in Tgrb are steeper, cliff-like, in upper parts
lower slide	1.10 km² (0.42 mi²)	2010 m (6600 ft)	1615 m (5300 ft)	35 m (120 ft)	19–42		earthflow	inactive	
North Cleman Mountain complex	1.91 km² (0.74 mi²)	1980 m (6500 ft)	1220 m (4000 ft)	35 m (120 ft)	16	Tgrb lava flows	earthflow	inactive	Part of a large complex on the steep southwest flank of Cleman Mountain

[1], Described from northwest to southeast across map.

[2], Based on relief of landslide surface.

[3], Measured between base of head scarp and toe of landslide along steepest slope.

[4], Tgrb = Grande Ronde Basalt lava flows.

[5], Some landslides, especially those in Tgrb basalt, have active talus at head.

[6], Active during 1989 to 2008 mapping—evidence of recent activity is shown by:
- scarplets exposing soil profile and roots,
- longitudinal ridges (levees) exposing roots and fresh rock, caused by differential movement,
- stands of “drunken” trees, and
- ponds submerging vegetation, especially shrubs and grasses.

[7], Landslide could become active in times of high precipitation because of loose rubble or weathered volcanic debris on a steep slope or a smooth, underlying, impermeable slope.

Table 2. Folds in the Cliffdell and western two-thirds of the Manastash Lake 7.5-minute quadrangles, described from northwest to southeast in map.

Name	Location	Length	Width	Height (amplitude)	Dip of limbs	Axial Plane[1]	Fold axis[1] (hinge line)	Comments
Little Naches River syncline	NW corner of map; Cliffdell 7.5′	4.5 km (2.8 mi)	1.1–1.7 km (0.7–1.1 mi)	~700 m (~2300 ft); Cross Section C–C′	NE 30–70° SW 11–70°	N57°W 78°NE	plunges 30° N57°W; upright, open asymmetric	Major fold; extends to NW and connects with White River fault (Tabor and others, 2000); connects to SE with Pine Creek fault; within SW side of OWL
Milk Creek syncline	NW corner of map; crosses lower Milk Creek; Cliffdell 7.5′	3.1 km (19 mi)	1.2 km (0.7 mi)	~760 m (~2500 ft); Cross Section C–C′	35–60°	~N5°W 90°	plunges ~9° N5°W; upright, open asymmetric; poorly defined	Fold poorly developed before deposition of overlying Tfer; lies within OWL
North Milk Creek anticline and South Milk Creek syncline	in upper Milk Creek; N central part of map	traceable 2.4 km (1.5 mi)	each 760 m (2500 ft)	each ~610 m (~2000 ft); Cross Section B–B′	25–80°	N88°E 72°S	plunges 5° N90°W; upright, open asymmetyric	Folds poorly developed before deposition of overlying? To and Tfer; lies within OWL
North Fork Wenas Creek syncline	NE corner of map; Manastash Lake 7.5′	>3.7 km (>2.3 mi);	~1.5 km (~0.9 mi)	~60 m (~200 ft); Cross Section A–A′	2–10°	ca N90°E 90°	plunges 1° N90°E; upright, broad, open asymmetric	Poorly defined in Grande Ronde Basalt hyaloclastite; extends east from Quartz Creek fault into adjacent quad; lies within OWL
Bumping River anticline, Boulder Cave Campground syncline, and Boulder Cave Campground anticline	NW part of map NW of Cliffdell; Cliffdell 7.5′	1.2–1.5 km (0.8–0.9 mi)	610–915 m (2000–3000 ft)	91–152 m (300–500 ft); Cross Section C–C′	7–25°	average N71°W 83°NE	average plunges 7° S72°E; upright, open asymmetric	Short, poorly defined folds in fault blocks of Grande Ronde Basalt; pop-up structures (see Faults) in hanging wall of Indian Flat fault; lies within Yakima folds
Swamp Creek syncline	NW part of map; NW of Cliffdell	1.3 km (0.8 mi)	610 m (2000 ft)	30 m (100 ft)	<5°	N70°E to N90°E ~90°	plunges <2°E; open, upright symmetric	Short, poorly defined fold in south part of pop-up structures; covered by Swamp Creek landslide; probable continuation of Devil Creek syncline
Bald Mountain anticline	NE part of map; Manastash Lake 7.5′	4.5 km (2.8 mi)	2.4 km (1.3 mi)	~150 m (500 ft); Cross Section A–A′	2–5°	N37°W 84°SW	plunges 2° S39°E	Major fold; marks SE strike of Manastash Ridge anticline; extends southeast of map; in hyaloclastite deposits; lies within OWL
Devil Creek syncline	W margin of map; Cliffdell 7.5′	~4.3 km (~2.7 mi)	2.0 km (1.2 mi)	30 m (100 ft)	<5°	N65°E to S75°E 90°	plunges 4–9° E to SE; open, upright, asymmetric	Shallow syncline in E-dipping homocline of Grande Ronde Basalt; undetermined offset of axis by faults; extends E through faults to Naches River; lies within Yakima folds
Naches River anticline (in Gold Creek rocks)	S of map center	4.6 km (2.9 mi)	1.8 km (1.1 mi)	610–915 m (2000–3000 ft); Cross Section A–A′	NE 10–50° SW 5–30°; near chevron fold	N43–69°W 84–88°NE	doubly plunging 43° N41°W 25° S71°E	Domal structure; formed after Fifes Peak Formation volcanism and before Grande Ronde Basalt lava flows; offdip of overlying Tfer lavas; lies within OWL
Gold Creek syncline	center of map	7.8 km (4.8 mi)	6.1 km (3.8 mi)	>305 m (1000 ft); Cross Section A–A′	NE 15–42° SW 4–35°	N33°W 80°NE	plunges 2° S33°E	Chevron fold; extends SE from Pine Creek fault; covered by Grande Ronde Basalt and landslide at southeast end; lies within OWL
Nile Creek syncline	S central part of map; Cliffdell 7.5′	3.1 km (1.9 mi)	3.0 km (1.9 mi); Meeks Table 7.5′	~350 m (1150 ft); Meeks Table 7.5′	4–55°; Meeks Table 7.5′	N71°W 87°NE	plunges 4° S71°E	Extends SE into Meeks Table 7.5′; poorly defined to NW; lies within Yakima folds yet parallel to OWL
Benton Creek syncline	SE corner of map; Manastash Lake 7.5′	4.3 km (2.7 mi)	2.4 km (1.5 mi)	~610 m (2000 ft); Cross Section B–B′	3–15°	curves S25°W–S85°E ~90°	plunges 5° SW	Crosses axis of Cleman Mountain anticline; formed during uplift of Edgar Rock volcano; lies within OWL yet transverse to strike of OWL
Cleman Mountain anticline	SE corner of map; Manastash Lake 7.5′	>0.9 km (0.6 mi)	>7.5 km (4.7 mi)	~260 m (850 ft)	NE 2–5° SW 5°	N20°W ~75°NE	plunges 1–2° NNW	Major fold; has greater length, width, and height to SE in Nile 7.5′ quad (Hammond, 2009a); lies within OWL

[1], Folds were plotted stereographically to determine strike and dip of their axial plane and bearing and plunge of their fold axis (Price and Cosgrove, 1990, p. 475-477).

Table 3. Major faults in the Cliffdell and western two-thirds of the Manastash Lake 7.5-minute quadrangles, described from northwest to southeast in map.

Fault name	Location	Length	Orientation	Displacement	Comments
Indian Flat fault	NW part of map, N of Cliffdell and E of Naches River, in Cliffdell 7.5′	~8.0 km/ ~5.0 mi	N35°W to N55°W, 90°; lessening dip to NE with increasing depth	SW side down in Cross Section C–C′; right lateral oblique-slip offsetting Bumping River anticline 0.85 km (0.5 mi)	Major fault, extends 11 km/7 mi NW of map; several faults splay off; better defines west margin of OWL than Naches River
Sawmill flat fault Boulder Cave Campground fault Boulder Cave fault	W of and along Naches River; in pop-up structures zone N of Cliffdell	5.0 km/3.1 mi 6.3 km/3.9 mi 4.0 km/2.5 mi	E–W to S25°E, ~90° E–W to S30°E, 75–90° S35°E, 90°	SW side down in Cross Section C–C′ SW side down in Cross Section C–C′ NE side down in Cross Section C–C′; displacement 65–185 m/200–400 ft	In pop-up zone; small displacement juxtaposes Grande Ronde Basalt flows; in structural transition zone between OWL and Yakima fold belt
Swamp Creek fault	W of Naches River; encloses SW side of pop-up structures zone	3.0 km/ 1.9 mi	curves from S50°E to N90°E	NW side down 90 m (300 ft) in Cross Section C–C′	SE splay off Indian Flat fault; terminates at Naches River at Boulder Cave Campground fault; lies within Yakima fold belt
Spring Creek fault	E of Naches River and N of Cliffdell	1.1 km/ 0.7 mi	curves from N80°E to S75°E	S side down 60 to 90 m (200–300 ft)	Terminates at west end with Boulder Cave Campground fault; connects to SE with Gold Creek syncline; cuts Pine Creek and Sawmill Flat faults; lies within OWL
Pine Creek fault	E of Naches River in NW part of Cliffdell 7.5′	1.4 km/ 0.9 mi	S25° E, 70–90°W	E side down, bringing Tfer into contact with Tgc, 60 to 90 m (200–300 ft)	Connects to NNW with Little Naches River syncline, at SSE terminates at Spring Creek fault; lies within OWL
Devils Slide fault	in N central part of map, extending NW to SE across map	13.1 km/ 8.1 mi	N70°W, ~90°,	SW side down 300–900 m (1000–3000 ft) at S side Bald Mtn; 150 m (500 ft) in Cross Sections A–A′, B–B′	Major fault in area; possible continuation of White River fault (Tabor and others, 2000); continues E with splay; lies within OWL
Quartz Creek fault	at head of Milk Creek valley, in NE corner of map; Manastash Lake 7.5′	3.4 km/ 2.1 mi	N65°E–W, dipping ~80° NE	NE side up >60 m (200 ft), increasing displacement to NW	Major fault, a probable thrust; becomes North Fork Wenas Creek syncline to SE; lies within OWL
Devil Creek fault	along Nile Creek in SE corner of map; Cliffdell 7.5′	3.4 km/ 2.1 mi	N35–40°W, 70–90°SW	NE side down 30 m (100 ft), displacement increasing northward; in Cross Section A–A′	Major fault, extends NW into Old Scab Mtn 7.5′ quad, becoming a thrust, and SE into Meeks Table 7.5′ quad (Hammond, 2009a); lies within Yakima fold belt
Johnson Canyon fault	S central part of map; Cliffdell 7.5′	6.4 km/ 4.0 mi	N50°W 90°, lessening in dip to SE	SW side down, 185–1000 m (600–3300 ft), displacement increasing to south; in Cross Section A–A′	Major fault that becomes Nile thrust to S in Nile 7.5′quad (Hammond, 2009a); possibly southward continuation of W branch of Indian Flat fault; trace through andesite of Edgar Rock is indefinite; lies in transition zone between Yakima fold belt and OWL
Gold Creek fault	E of Naches River in S central part of map; Cliffdell 7.5′	3.0 km/ 1.9 mi	N45°W, 90°	NE side down 120 m (400 ft); in Cross Section A–A′	With Johnson Canyon fault, bounds core of Naches River syncline and possible core of Edgar Rock volcano; lies in OWL
Rock Creek thrust	along S side of Rock Creek in SE corner of map; Manastash Lake 7.5′	6.1 km/ 3.8 mi	N30–35°E, 20°SE	moved Tgg over all other flows of Grande Ronde Basalt; in Cross Section B–B′	Major thrust fault with two slices; traverses strike of OWL
Benton Creek thrust	atop Rock Creek ridge in SE corner of map; Manastash Lake 7.5′	traced only 1.5 km/ 0.9 mi; concealed by landslide to SE	N45–50°E, ~20°SE	displacement undetermined	Slice or splay in hanging wall of Rock Creek thrust

Faults

Faults, with the exception of thrust faults, are steeply dipping, 70° or more (Table 3). Most are shown as normal or reverse faults on the map and cross sections, based on their stratigraphic displacement. A few, where traced in the field, change the direction of dip from normal to reverse or vice versa. Fault zones range from narrow contacts less than 1 m (3 ft) wide to breccia zones to about 20 m (70 ft) wide. Slickensides are rarely exposed; a few show dip or oblique slip. The only lateral displacement shown in the map is the 0.85 km (0.5 mi) right-lateral slip (offset) of the axis of the Bumping River anticline along the Indian Flat fault in the northwest corner of the map and in the west-adjacent Old Scab Mountain quadrangle.

Pop-up structures northwest of Cliffdell

Upright folds and vertical faults suggest that wedge-shaped blocks of varying widths and probable great depth were forced upward by lateral compressive stress. A small-scale example is the pop-up structures in the northwest corner of map, northwest of Cliffdell. Here five lens-shaped blocks (in map view) are bounded by curving, essentially vertical faults. The blocks are 550 to 1340 m (1800–4400 ft) wide. In each of three blocks, a shallow, upright fold occurs (Cross Section C–C′). Together the blocks form a larger lens-shaped block, oriented northwest-southeast, enclosed by curving fault splays of Indian Flat fault on the west, the Sawmill Flat fault on the northeast, and the Swamp Creek fault on the southwest. No evidence of lateral thrusting was noted. These structures were formed during the third interval of regional deformation (7–3 Ma). Note that the names applied to the pop-up structures are informal, there being no geographic names in this small area.

Radial dikes and deformation of Edgar Rock volcano

Projection of the many radial dikes in the core area of Edgar Rock volcano (unit Tfer) defines an elongated, 1525 m by 150 to 300 m wide (5000 by 500–1000 ft) focus, the possible main eruptive center of the volcano in a ridge of Gold Creek rocks (unit Tfgc) southwest of the Naches River (Carkin, 1988). The area is partly covered by 120 to 240 m (400–800 ft) thick andesite lava flows of Nile Creek (unit Tfnc). No clear evidence of an intrusive center or associated hydrothermal alteration was found in the underlying rocks in the focal area. As mentioned in the Description of Map Units, the lack of ridges of Edgar Rock deposits defining an ancient southwest rim to the volcano, the covering of the area by flows of Nile Creek, and a remnant of Nile Creek lava inside the perimeter of the volcano suggest that the southwest flank was destroyed by explosive eruptions or slid away as a debris avalanche. This breach of the volcano is about 4 km (2.5 mi) wide. No evidence of avalanche deposits of the volcano, overlain by Nile Creek lava flows, has been found. What happened to the southwest flank of Edgar Rock volcano remains an enigma.

The unconformity between Edgar Rock volcano and the younger lava flows of Nile Creek (unit Tfnc; Cross Section A–A′) is evidence of ongoing deformation during construction of the volcanoes of the Fifes Peak Formation. Edgar Rock volcano also shows the effects of compression (Carkin, 1988) during the second and third intervals of deformation. The remnant core of Eagle Rock volcano, that part between the Gold Creek syncline to the northeast and the Johnson Canyon fault on the southwest, is elongated N50–55°W, S50–55°E. It is about 9.8 km (6.1 mi) long and 7.3 km (4.5 mi) wide. Within this core area, dips are at or exceed the 33–37° angle of repose. (Here it should be pointed out that the dips to the northeast of the Gold Creek syncline are opposed to the expected northeastward dip in this flank of the volcano because this part has been uplifted with Bald Mountain to the northeast.) The dips in the four quadrants of the core area are: in the northwest quadrant, 13 dips average 50.0°; in the northeast quadrant, 16 dips average 31.3°; in the southeast quadrant, 7 dips average 32.7°; and in what remains of the southwest quadrant, 10 dips average 33.8°. Three flanks dip at the expected angle of repose; the northwest flank dips more steeply, indicating that the volcano has been subjected to some deformation, but it is not clear if a compressive stress was oriented NE–SW or NW–SE. A NE–SW stress could have caused a bulging of the upper northwest flank of the volcano as well as narrowing of the volcano. If the stress was NW–SE, the southeast flank, like the northwest flank, should show oversteepening.

The Gold Creek syncline is the name given in this report to the arcuate syncline mapped by Carkin (1988) in the north flank of Edgar Rock volcano. A southwest-dipping homocline, north of the syncline, also mapped by Carkin (1988) in the north flank of the volcano, was not noted as a significant structure in this survey. The dips gradually lessen north of the syncline.

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