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GEOLOGY OF THE EASTERN FLANK OF THE CENTRAL CASCADE RANGE

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NWGS FIELD TRIP GUIDEBOOK SERIES

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NORTHWEST GEOLOGICAL SOCIETY FIELD GUIDEBOOK SERIES
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I. ABSTRACT

[Read the abstract of Cheney and Hayman (2009) and then the abstract of Cheney and Hayman, (2007) below.]

Eocene volcanic and sedimentary rocks on the eastern flank of the Cascade Range consist of five regional, unconformity-bounded formations of the Challis synthem. These formations define a series of northwesterly-striking folds. Five anticlines are 9 to 28 km apart, have pre-Tertiary crystalline rocks in their cores, high-angle reverse faults on their steeper northeastern limbs, and pass down-plunge into more gentle folds in the Neogene Columbia River Basalt Group (CRBG). Such northwesterly trending folds extend from east of the Columbia River across the Cascade Range to the Puget Lowland.

The Chiwaukum graben and Swauk basin, which heretofore were thought to be local, extensional, depositional basins, are, instead, the major northwesterly trending synclines in this series of folds. The Eocene formations were preserved, not deposited, in these synclines. Dextral, N-S faults cut the reverse faults and the pre-CRBG portion of some of the folds. The post-CRBG folds control the regional distribution of the Eocene formations.

The Cascade Range is a southerly-plunging, post CRBG anticline. Clasts in the Thorp Gravel indicate that this anticline began to rise ca. 4 Ma. The anticline has an amplitude of ~3.5 km, and it causes the plunges of the northwesterly striking post CRBG-folds. The northerly and northwesterly post-CRBG folds form a regional interference pattern, or “egg-crate,” that dominates the present topography of Washington State.

II. INTRODUCTION

Purpose

A popular scenic drive on the eastern flank of the Cascade Range (Figure 1) is from Stevens Pass (US 2) to Blewett Pass (US 97) to Snoqualmie Pass (I 90). This field trip visits informative geological sites along and near this route. My interest in this area began with a NWGS field trip in 1996 (Bush and Cheney, 1996). Cheney (1999) and Cheney and Hayman (2007, 2009) show the areas I mapped through 2010.

The main purpose of the trip is to elucidate the Cenozoic stratigraphy and structure of this part of the range, but we will also examine some interesting pre-Cenozoic rocks. This trip emphasizes two major points. The first is that the kilometers-thick, Eocene formations were not deposited in local basins or grabens; instead, they are regional successions preserved in major northwesterly trending folds. The second is that the Miocene Columbia River Basalt Group (CRBG) did not

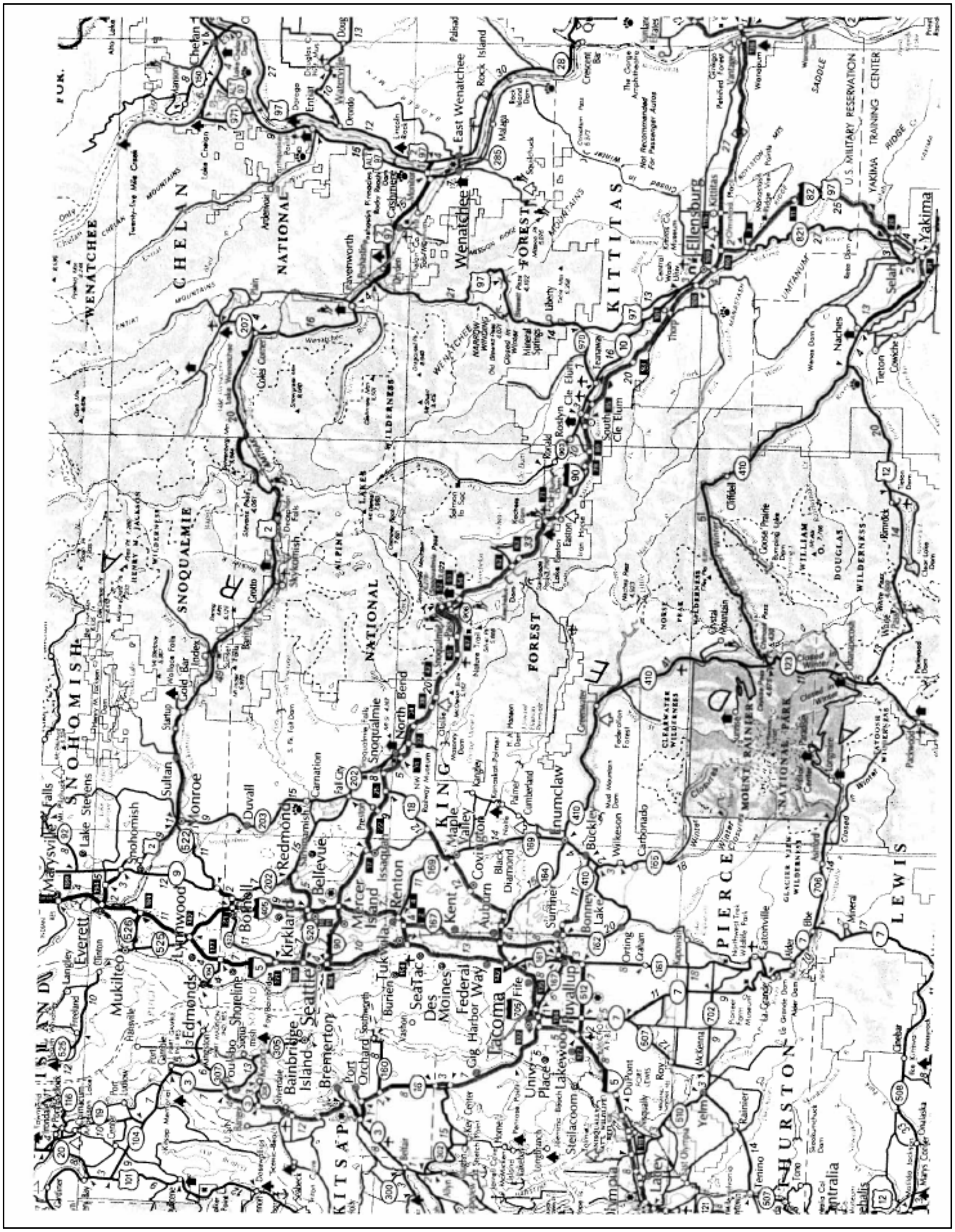

__Figure 1.__ Road map of the field trip area.

pond against the Cascade Range; instead, the present topography of the range is post-CRBG, < 4.5 Ma. This second point casts doubt on the popular notion that the course of an ancestral Columbia River was influenced by (and crossed topographic lows in) the Cascade Range.

Many authors from Willis (1953) to Evans (2010) believed that the kilometers-thick Eocene clastic rocks between Leavenworth and Wenatchee were deposited in the so-called Chiwaukum graben (bounded by the Entiat fault on the northeast and Leavenworth fault on the southwest). Specifically, they believed that deposition of these strata occurred while these faults were active. In contrast, Cheney and Hayman (2007, 2009, 2010) showed that the Leavenworth is a reverse fault; they stressed that the Eocene strata are regional successions in regional northwesterly trending folds and that some of these regional strata and folds are locally preserved between (not deposited between) the Leavenworth and Entiat faults. Hence, Cheney and Hayman (2007, 2009, 2010) called the area the Chiwaukum structural low (CSL), not the Chiwaukum graben.

Field Guide

On Day 1 we will investigate the CSL. Much of Day 2 examines evidence that the CRBG did not pond against the Cascade Range and that the present uplift of the range is < 4.5 Ma.

Tables 1 and 2 list the stops of this field trip and their equivalents in other field guides.

Parts of the field guides of Cheney and Hayman (2007, 2009) should be used with this field guide. Specifically, Cheney and Hayman (2009, p. 20-40) provides a better description of the regional and local geology; whereas, the stops not described in the present field guide are in Cheney and Hayman (2007, p. 197-206), and are listed in Tables 1 and 2. With the knowledge gained on this trip, participants can do the stops omitted from Cheney and Hayman (2007, 2009) on their own subsequent trips to the area.

The locations of most of the stops are by reference to mileposts on the appropriate highway. Figures 2 and 4 of Cheney and Hayman (2007) show the locations of the stops.

The trip begins at Stevens Pass on Day 1. We will overnight in Ellensburg. Day 2 begins in Ellensburg and ends at Easton. The weather will determine whether we do Stop 2-6 to 2-9.

This field guide has minimum of references. The abundant references in Cheney and Hayman (2007, 2009) offset this paucity. Cheney and Hayman (2010) replied to some classical objections by Evan (2010) to their account of the CSL.

III. REVIEW OF THE REGIONAL GEOLOGY

Read the Introduction and the Regional Setting and Tectonic History on p. 20 of Cheney and Hayman (2009). Also review the regional geologic map (their Figure 2), the regional stratigraphy (their Table 1), and the geological evolution of the area (their Figure 9). Because we will be transiting it, also pay attention to the Eagle Creek anticline (their Figure 5 and cross section C-D of their Figure 6).

IV. ROAD LOG

DAY ONE

Stops of This Field Trip	Equivalent Stops in Other Field Guides
STOP 1-1 Mount Stuart batholith W bound lanes, MP 69.2, US 2	New stop
STOP 1-2 Nason Ridge Gneiss/Chiwaukum schist MP 76.6, US 2	Magloughlin (1994, Stop 8)
REST STOP MP 81, US 2	
STOP 1-3 Zeolite tuff and Chumstick conglomerate MP 2.4, of Eagle Creek Road	Cheney and Hayman (2009, Stop 2-13)
STOP 1-4 Roslyn (Chumstick) sandstone MP 3.9, Eagle Creek Road	New stop
STOP 1-5 Swakane gneiss MP 4.7, Eagle Creek Road	New stop
STOP 1-6 Eagle Creek Winery MP 2.5, Eagle Creek Road	New stop
STOP 1-7 Icicle Creek Overview MP 4.8 of Mountain Home Road	Cheney and Hayman (2007, Stop 1-7)
STOP 1-8 Diamicitite of Devils Gulch MP 178.7 of US 97	Cheney and Hayman (2007, Stop1-12)
STOP 1-9 Camas Creek fault Old Blewett Highway	Cheney and Hayman (2007, Stop 1-13)
STOP 1-10 Felsic metavolcanic rock MP US 97	Bush and Cheney (1996, Stop 1-2)
STOP 1-11 Swauk/CRBG MP 0.4 of FS 9716	Cheney and Hayman (2007 Stop 1-16)
STOP 1-12 Teanway basalt and tuff MP 151.2 of US 97	Cheney and Hayman (2007, Stop 1-19)
STOP 1-13 Thorp/CRBG/Teanaway MP 147 of US 97	Cheney and Hayman (2007, Stop 1-20)
ELLENSBURG	

Table 1. *Stops of Day One of NWGS field trip, 2012.*

Stevens Pass is at MP 64.7 on US 2. At the pass, begin using Table 1 as a guide to the stops of Day 1. From the pass, drive eastward, but at MP 70.4 (Mill Creek Road to the Stevens Pass Nordic Ski Center) turn left down the ramp to the westbound lanes of US 2. Proceed 1.3 miles westbound (back toward Stevens Pass) to MP 69.2, which is marked by a sign, Bygone Byways.

STOP 1-1. MOUNT STUART TONALITE.

The large roadcut on the right (north) shoulder is in the northeastern arm of the of the 91 to 96 Ma Mount Stuart tonalitic batholith. For comparisons with Stops 1-2 and 1-8, note the size and texture of the hornblende. Also note the presence of more mafic ovoid enclaves (not xenoliths); these are fairly common in the Mount Stuart batholith and imply mixing of immiscible magmas.

Continue 0.5 miles westbound on US 2 to Smith Brook Road (USFS Road 6700). Turn left and enter the eastbound lane of US 2. Continue past the Mill Creek Road (the road to the Stevens Pass Nordic Ski Center). On the left (north) side at MP 76.1 is the road to the Lake Merritt Trailhead. Continue another 0.5 miles to the end of a large roadcut; where the high-voltage power lines cross the highway in a broad curve of the highway, very carefully avoid on-coming traffic to park in a large area beyond the left shoulder. Walk 0.1 to 0.2 miles back up the highway to examine the rocks in the roadcut. If you insist on inspecting rocks on the other side of the highway, be careful and fast.

STOP 1-2. NASON RIDGE GNEISS AND CHIWAUKUM SCHIST

Variably foliated, biotitic tonalitic dikes intrude pelitic hornfels and amphibolite of the Chiwaukum Schist of the Nason terrane. Pegmatites intrude the granitic rocks and the Chiwaukum Schist. For a sketch of this geologic zoo on the northern side of the roadcut, see Magloughlin (1994, fig. 2).

Presumably this is the contact zone of the Nason Ridge Gneiss. This composite body of variably foliated biotitic orthogneiss underlies Nason Ridge to the north and extends westward across the crest of the Cascade Range to the Beckler River valley north of Skykomish (Haugerud and Tabor, 2009). In contrast, east of here, most of valley of Nason Creek along US 2 is underlain by the Chiwaukum schist.

The Nason Ridge Gneiss on its eponymous ridge may indicate the position of the Leavenworth fault. Figure 2 of Cheney and Hayman (2009) shows that the northwesterly trending Leavenworth reverse fault is truncated by the north trending Coulter Creek fault. East of the Coulter Creek fault the Leavenworth fault is fairly easy to locate because it juxtaposes pre-Cenozoic crystalline rocks on the southwest against the Eocene arkosic rocks of the CSL. However, west of the Coulter Creek fault the location of the offset continuation of the Leavenworth fault in pre-Cenozoic crystalline rocks is unknown. Perhaps, the fault is between the gneiss on Nason Ridge and the Chiwaukum schist in the valley of Nason Creek. Look for faults and fault rocks in this roadcut.

Continue eastbound on US 2 toward Leavenworth. We will stop at the WDOT rest stop at about MP 81. This also is the approximate trace of the Coulter Creek fault, which here is the western boundary of the CSL.

After resting, continue eastbound on US 2. Just upstream from the bridge over the Wenatchee River at MP 90.5, US 2 exits the

CSL by crossing the northwesterly trending Leavenworth fault into crystalline rocks. For the next 8.6 miles of US 2, the Wenatchee River descends Tumwater Canyon through rocks of the Mount Stuart batholith and lesser amounts of serpentinite and Chiwaukum schist. Just beyond the mouth of the canyon on the western side of Leavenworth, US 2 crosses the northerly trending Icicle Creek fault and re-enters the CSL.

The town of Leavenworth, which centered on MP 100, is built on the youngest terminal moraine of several glaciers that originated at various times in Icicle Creek valley to the south (Porter and Swanson, 2008). Glaciation of this valley caused the Wenatchee River to hang above it, a condition remedied by the carving of Tumwater Canyon. Glacial erratics of the youngest moraine decorate downtown Leavenworth. The parking lot of the Bavarian Lodge across from the main square in the middle of town is a particularly good place to examine erratics of the Mount Stuart batholith.

However, we will continue eastbound on US 2 to the junction with SR 209 at the eastern end of Leavenworth. Turn north on SR 209, proceed 2.1 miles, and turn right (east) on Eagle Creek Road. Eagle Creek is the type area of the so-called Chumstick Formation, an outlier of the Roslyn and Wenatchee formations (Cheney and Hayman, 2009). We will be transiting the Eagle Creek anticline for 5.9 miles. As we do, note that for the first 4.3 miles sandstones of the Roslyn Formation dip westward in sparse roadcuts and in sparse outcrops in the forest above the road. Significantly, these sandstones contain pebbles, cobbles, and some conglomerate. At MP 2.4, park on the right (downhill) shoulder.

STOP 1-3. ZEOLITE TUFF OF THE "CHUMSTICK" FORMATION

This is the Zeolite Tuff (or "green tuff") described in Stop 2-13 of Cheney and Hayman (2009). It is one of the thickest of about 30 tuffs in the Chumstick Formation. Many of the tuffs in the CSL are < 1.5 m thick. Note the typically gray and blocky nature of the tuff, which distinguishes tuffs from the more rounded and tan outcrops of sandstone and conglomerate.

Three fission-track ages of this tuff ranged from 41.9 $\pm$ 6.8 Ma to 48.8 $\pm$ 7.2 Ma (Gresens et al., 1981). Attempts by MIT researchers to refine age with U-Pb dating of zircons have, so far, yielded pre-Cenozoic ages, indicating that the zircons are detrital.

Continue eastward on Eagle Creek Road past the Eagle Creek Winery at MP 2.5. At MP 3.9, park opposite house #9210.

STOP 1-4. WESTERN LIMB OF THE EAGLE CREEK ANTICLINE

The canyon behind house # 9210 dramatically displays the westerly dipping sandstones on the western limb of the Eagle Creek anticline.

Continue up Eagle Creek Road. The last roadcut of westerly dipping sandstone is at MP 4.3. Beyond MP 4.3, note that sandstones (or geomorphic evidence of them) are conspicuously absent from the slopes above the road. Stop opposite a large outcrop at MP 4.9.

STOPE 1-5. SWAKANE BIOTITE GNEISS

This is the Swakane Biotite Gneiss in the core of the anticline. The gneiss dips steeply eastward. Walk a few tens of meters up the road to glimpse easterly dipping sandstone on the middle skyline.

Obviously, and significantly, this anticline involves the crystalline basement. The CSL between the Leavenworth fault on the southwest and the Entiat fault on the northeast consists of this anticline and flanking synclines (Cheney and Hayman, 2009, Fig. 5, which, unfortunately, does not extend as far south as Eagle Creek Road). 40 km to the southeast, the Eagle Creek anticline passes into the Hog Ranch anticline (Cheney and Hayman, 2009, fig 2), which has less steeply dipping CRBG on its limbs. The lesser dips in CRBG show that at least two periods of folding occurred.

Continue up hill to the end of the pavement at MP 5.9. Scruffy out crops in this last mile uphill are not worth inspecting, but note that they appear to dip eastward and lack pebbles and conglomerate. Strata uphill on strike to the north demonstratively dip eastward. We are now on the eastern limb of the Eagle Creek anticline. The non-conglomeratic nature of the strata on the eastern limb shows that they are not the same succession as those on the western limb.

The explanation for the disparate limbs of the anticline is that the steeper eastern limb of the anticline is cut by the Eagle Creek reverse fault (Cheney and Hayman, 2009, figs. 5 and 6). The strata on the eastern limb are the somewhat younger Nahahum Canyon Member of the Chumstick Formation, which likely is the Wenatchee Formation (Cheney and Hayman, 2010). As noted by Cheney and Hayman, 2007, p 191), at Wenatchee a rhyodacite dike, with K-Ar dates varying from 41 to 45 Ma, intrudes the Eagle Creek fault.

The Eagle Creek anticline is important because it is but one example in the region of a basement-cored, major northwesterly trending anticline with a steeper northeastern limb that is cut by one or more reverse faults (Cheney and Hayman, 2007; Cheney and Hayman, 2009, Table 5). Other examples are the Blushastin anticline (Stop 1-9), the Ainsley Canyon anticline south of Cle Elum (Stop 2-9) , and the Newport Hills anticline, which is cut by the Seattle reverse fault system.

In summary, the CSL is not a local graben filled with flat lying strata (as commonly supposed). Instead of being an extension feature, it preserves part of a regional fold and thrust belt (a contractional system) that involves the crystalline basement.

At the end of the pavement, turn around and return downhill to the Eagle Creek Winery at MP 2.5.

STOP 1-6. EAGLE CREEK WINERY
Examine (and possibly sample) the Eagle Creek Winery.

From the Eagle Creek Winery (MP 2.5) resume the drive downhill to SR 209 and return to Leavenworth. At the junction of SR 209 and US 2 in Leavenworth, turn let (east) toward Wenatchee and in 0.2 miles, cross the bridge over the Wenatchee River. At the southeast abutment of the bridge (which is MP 100.5) turn right (south) on East Leavenworth Road, in 0.05 miles turn left on Mountain Home Road. At this point commence using the field guide of Cheney and Hayman (2007, p. 197, middle of right column) and proceed 4.8 miles to their Stop 1-7.
The remainder of this trip utilizes the field guide of Cheney and Hayman (2007). Use Table 1 to match the stops of this trip with the stops of Cheney and Hayman (2007) and as description of subsequent stops.

STOP 1-7. OVERVIEW OF ICICLE CREEK

This is Stop 1-7 of Cheney and Hayman, 2007).

When done with this stop, continue southward, by-pass Stop 1-8 of Cheney and Hayman (2007), and continue to US 97 (MP 181.1). Turn right (southbound) and proceed to MP 178.7 of US 97. Turn left (southwest) on Old Blewett Road and park.

STOP 1-8. DIAMICTITE OF DEVILS GULCH

This is stop 1-12 of Cheney and Hayman (2007, p. 199).

When done with stop proceed to Stop 1-13 of Cheney and Hayman (2007).

STOP 1-9. CAMAS CREEK REVERSE FAULT

This is Stop 1-13 of Cheney and Hayman (2007, p. 199).

When done with this stop, follow the direction of Cheney and Hayman (2007, p. 199) to continue southbound on US 97 to MP174.0. After we make a rolling stop here, continue to MP 173.6, turn left and follow the road 0.2 miles to its end.

STOP 1-10. METAVOLCANIC ROCKS OF THE INGALLS COMPLEX

This stop is of interest because a pre-Cenozoic metabasaltic rock is in contact with a felsic metavolcanic rock (of the sort that is associated with volcanogenic Zn-Cu-Pb-Au massive sulfide deposits). Such deposits occur in Archean to Miocene greenstone belts, but none are known in this Jurassic belt (the Ingalls tectonic complex, into which the Mount Stuart batholith is intruded). The typical characteristics of submarine felsic volcanic rocks displayed here are: limonitic weathering, including Liesegang banding (due to minor indigenous pyrite), white color, aphantic texture, and rare mm-scale phenocrysts of quartz (a.k.a. quartz eyes), muscovite, and, possibly, feldspar).

The remainder of this field trip for the rest of Day One and all of Day Two follows the field guide of Cheney and Hayman (2007), so use Tables 1 and 2 as guide. Specifically, from here we will continue southbound on US 97; our next stop (1-11) is stop 1-16 of Cheney and Hayman (2007). Stops 1-19 and 1-20 of Cheney and Hayman (2007) complete Day One of the present trip.

END OF DAY ONE

DAY TWO

Stops of This Field Trip	Equivalent Stops in Other Field Guides
STOP 2-1 Bristol volcaniclastics MP 90.2 of SR 10	Cheney and Hayman (2007, Stop 2-1)
STOP 2-2 Anatomy of a CRBG flow MP 96.0 of SR 10	Cheney and Hayman (2007, Stop 2-2)
STOP 2-3 Ellensburg Formation MP 98.3 of SR 10	Cheney and Hayman (2007, Stop 2-3)
STOP 2-4 Thorp Gravel MP 100.8 of SR 10	Cheney and Hayman (2007, Stop 2-4)
STOP 2-5 Views at Indian John Rest Stop MP 89.5 of I-90	Cheney and Hayman (2007, Stop 2-7)
STOP 2-6 CRBG/"Ellensburg" landslide FS 211 & 3550	Cheney and Hayman (2007, Stop 2-8)
STOP 2-7 Darrington Phyllite FS 115 & 3550	Cheney and Hayman (2007, Stop 2-9)
STOP 2-8 Manastash Formation FS 115	Cheney and Hayman (2007, Stop 2-10)
STOP 2-9 Peoh Point End of FS 114	Cheney and Hayman (2007, Stop 2-11)
STOP 2-10 Darrington Phyllite Via Golf Course Rd	Cheney and Hayman (2007, Stop 2-12)
STOP 2-11 Teanaway and Silver Pass Fms Entrance to Easton State Park	Cheney and Hayman (2007, Stop 2-13)
STOP 2-12 Shuksan Greenschist Easton State Park	Cheney and Hayman (2007, Stop 2-14)
STOP 1-12 Teanway basalt and tuff MP 151.2 of US 97	Cheney and Hayman (2007, Stop 1-19)

Table 2. *Stops of Day Two of NWGS field trip, 2012.*

Day 2 starts east of Cle Elum (via Exit 85 of I-90) at the junction of SR 970 (MP 2.6) and SR 10. So, begin using Table 2 and Cheney and Hayman (2007, p. 202, lower right column and Figure 3) as a guide to the stops of Day Two. Proceed eastbound on SR 10 to MP 90.2 (stop 2-1). Day 2 ends with Stop 2-12 (Stop-2-14 of Cheney and Hayman, 2007).

END OF DAY TWO.

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