Geologic Map of the Beacon Rock Quadrangle, Skamania County, Washington

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Pamphlet to accompany
Scientific Investigations Map 3367

Beacon Rock along north shore of Columbia River, Hamilton Mountain in background.

2017

U.S. Department of the Interior
U.S. Geological Survey

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Introduction

Geographic and Geologic Setting

The Beacon Rock 7.5′ quadrangle is located approximately 50 km east of Portland, Oregon (fig. 1), on the north side of the Columbia River Gorge, a scenic canyon carved through the axis of the Cascade Range by the Columbia River. Although approximately 75,000 people live within the gorge, much of the region remains little developed and is encompassed by the 292,500-acre Columbia River Gorge National Scenic Area, managed by a consortium of government agencies "to protect and provide for the enhancement of the scenic, cultural, recreational and natural resources of the Gorge and to protect and support the economy of the Columbia River Gorge area." As the only low-elevation corridor through the Cascade Range, the gorge is a critical regional transportation and utilities corridor (Wang and Chaker, 2004). Major state and national highways and rail lines run along both shores of the Columbia River, which also provides important water access to ports in the agricultural interior of the Pacific Northwest. Transmission lines carry power from hydroelectric facilities in the gorge and farther east to the growing urban areas of western Oregon and Washington, and natural-gas pipelines transect the corridor (Wang and Chaker, 2004). These lifelines are highly vulnerable to disruption by earthquakes, landslides, and floods. A major purpose of the work described here is to identify and map geologic hazards, such as faults and landslide-prone areas, to provide more accurate assessments of the risks associated with these features.

The steep canyon walls of the map area reveal extensive outcrops of Miocene flood-basalt flows of the Columbia River Basalt Group capped by fluvial deposits of the ancestral Columbia River, Pliocene lavas erupted from the axis of the Cascade arc to the east, and volcanic rocks erupted from numerous local vents. The Columbia River Basalt Group unconformably rests on a sequence of late Oligocene and early Miocene rocks of the ancestral Cascade volcanic arc, which underlies most of the map area. The resistant flood-basalt flows form some of the famous landforms in the map area, such as Hamilton Mountain. Extensive landslide complexes have developed where the basalt flows were emplaced on weak volcaniclastic rocks.

Previous Geologic Investigations in the Western Columbia River Gorge

The spectacular exposures in the Columbia River Gorge have attracted the attention of geologists for well over a century. Although observations and interpretations regarding specific aspects of gorge geology go back as far as the Lewis and Clark expedition of 1804–1807, the first comprehensive description of geologic relations in the Columbia River Gorge was by Ira S. Williams (1916). His popular account was published as a beautifully illustrated geologic road guide shortly after completion of the Columbia River Scenic Highway in Oregon. The report and accompanying map were the first to describe the major stratigraphic units visible in the walls of the gorge. He distinguished four major rock units: tuff and conglomerate that he named the Eagle Creek Formation, Miocene Columbia River basalt, cobbly gravels assigned to the Satsop Formation, and young andesitic and basaltic lavas and tuffs, which he called the Cascades Formation. All except the post-basalt gravels are present in the Beacon Rock area. Despite marked changes in geologic concepts and terminology in the past century, later workers have largely retained the basic stratigraphic framework outlined by Williams.

Hodge (1938) published a wide-ranging synthesis of more than a decade of work by him and his students in the Columbia River Gorge. Lacking adequate age constraints or chemical data to distinguish lavas of varying age, many of his concepts regarding the stratigraphy, structure, and geologic history have proved to be incorrect. Most subsequent studies (Chaney, 1959; Lowry and Baldwin, 1952; Trimble, 1963; Wise, 1970; Waters, 1973; Swanson and others, 1979a; Hammond, 1980; Tolan, 1982; Hammond and Korosec, 1983; Tolan and Beeson, 1984; Fleck and others, 2014) have been restricted to limited areas or have emphasized specific aspects of gorge geology. Wise (1970) mapped the area directly east of the Beacon Rock quadrangle and showed that the Eagle Creek Formation of Williams (1916) consists of two lithologically distinct volcanogenic units of the western Columbia River Gorge and discussed causes of the extensive landslides found north of the Columbia River. Swanson and others (1979b) established a formal stratigraphic nomenclature for the Columbia River Basalt Group and applied it to exposures in Washington. These revisions were incorporated into the reconnaissance geologic map of the southern Washington Cascade Range by Hammond (1980), who also broke out lithologic packages within the sub-basalt rocks of the ancestral Cascade volcanic arc, mapped the Plio-Pleistocene volcanic rocks, and inferred several major structures. Hammond and Korosec (1983) provided chemical analyses and a few K-Ar ages for some of the young volcanics.

The most recent geologic map that includes the Beacon Rock quadrangle is Phillips' (1987) compilation of the Vancouver 30′ x 60′ quadrangle at 1:100,000 scale, which was prepared as part of the state geologic mapping program of the Washington Division of Geology and Earth Resources (Walsh and others, 1987). The geology of the Columbia River Gorge area portrayed on this map is taken without modification from the small-scale regional reconnaissance maps of Swanson and others (1979a) and Hammond (1980).

Allen (1975) briefly discussed Quaternary volcanoes (Boring lavas) of the greater Portland region. Palmer (1977) summarized information on the huge landslides along the north bank of the Columbia River, and Pierson and others (2016) mapped landslides in the western Columbia River Gorge based largely on interpretation of digital elevation models derived from lidar data.

Our new work expands upon these previous efforts in several ways. It shows lithologic variations and structures within strata of the ancestral Cascade volcanic arc and provides extensive chemical analyses and $^{40}Ar/^{39}Ar$ incremental-heating

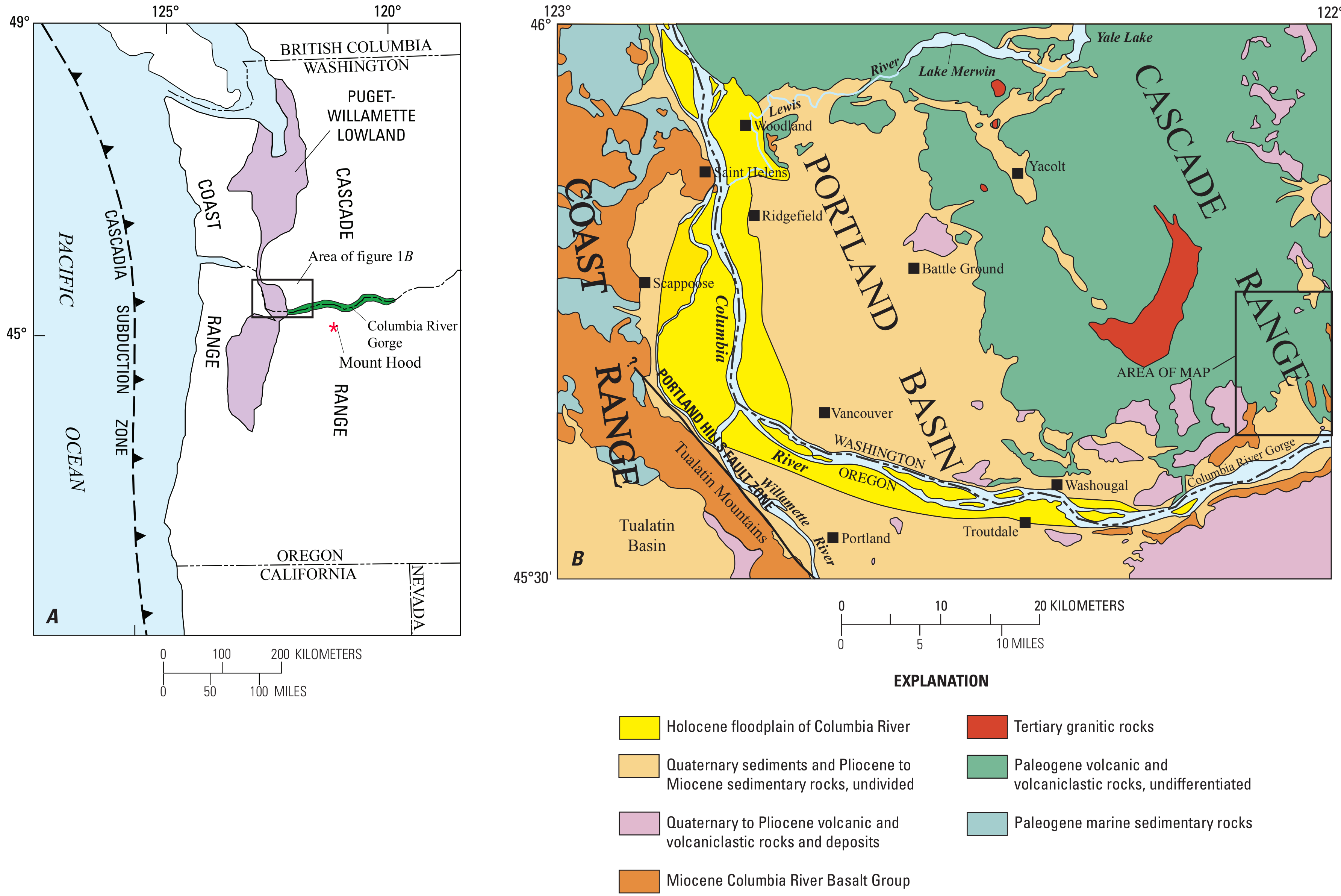

Figure 1. Regional setting of Beacon Rock 7.5′ quadrangle. *A*, Map showing major tectonic and physiographic features of the Pacific Northwest. *B*, Simplified geologic map of Vancouver 30′ × 60′ quadrangle, modified from Phillips (1987).

ages for these rocks. A more detailed stratigraphy for Grande Ronde Basalt, founded on abundant new chemical and paleomagnetic data, is presented. Similarly, the young volcanic rocks previously mapped as the Boring Lavas are differentiated based on their chemical and paleomagnetic properties, radiometric age determinations, and inferred source vents. The new chemical analyses are provided in tables 1–3, $^{40}Ar/^{39}Ar$ determinations in table 4, and paleomagnetic data in table 5.

Acknowledgments

Landowners and land-management agencies granted access that was essential for detailed mapping in the Beacon Rock quadrangle. We particularly thank Brian Poehlein of the Washington Department of Natural Resources; Erik Plunkett, supervisor of Beacon Rock State Park; and Denny Mohan of Longview Fibre Company. Philip A. Dinterman assisted with fieldwork in 2002. A lidar survey covering the map area, kindly provided by Stephanie Zurenko and Terry Curtis of the Washington Department of Natural Resources, was used by Karen Wheeler and Zenon Valin at the U.S. Geological Survey (USGS) to generate field sheets and the base map. Diane M. Johnson-Cornelius and Richard M. Conrey of Washington State University produced the high-quality chemical analyses required to differentiate Columbia River Basalt Group flows, and our USGS colleague Jonathan T. Hagstrum provided high-quality paleomagnetic data. Kenneth Bishop and Judith Fierstein of the USGS made available essential laboratory facilities. We obtained water-well drillers' logs from the Washington Department of Ecology website at https://fortress.wa.gov/ecy/waterresources/map/WCLSWebMap/default.aspx. Lee Walkling aided in obtaining information from the Washington Division of Geology and Earth Resources Library in Olympia, Washington. We have benefited immensely from discussions on various aspects of the regional stratigraphy, structure, and geologic history with Roger Ashley, Richard Conrey, Trevor Contreras, Paul Hammond, Jim O'Connor, William Phillips, Patrick Pringle, Stephen Reidel, Michael Sawlan, David Sherrod, James Smith, Terry Tolan, Richard Waitt, and Ray Wells. O'Connor provided descriptions of some Quaternary deposits along the Columbia River. We appreciate the careful reviews by Ralph Haugerud and Paul Stone that resulted in significant improvements in the content and presentation of this map.

Synopsis of Geology

For the past 40 m.y., the Cascade Range has been the locus of an episodically active volcanic arc associated with underthrusting of oceanic lithosphere beneath the North American continent along the Cascadia Subduction Zone. Late Oligocene to early Miocene rocks of the ancestral Cascade volcanic arc underlie most of the Beacon Rock quadrangle and comprise three unconformity-bounded stratigraphic packages (fig. 2). The lower part of the stratigraphic section in the map area consists of diverse, moderately altered, volcaniclastic rocks and lesser lava flows of late Oligocene to early Miocene age. An angular unconformity separates these rocks from an overlying and less-altered sequence of early Miocene porphyritic andesite and basaltic andesite flows, herein informally named the lava flows of Hamilton Creek. The top of this unit, locally marked by a thick paleosol, is an unconformable contact with weakly lithified volcaniclastic deposits of the early Miocene Eagle Creek Formation. Arc volcanism in southern Washington waned after the early Miocene.

In the middle Miocene, huge volumes of basaltic lava, the Columbia River Basalt Group, erupted from fissure vents in Idaho and eastern Washington and Oregon. Between 16 Ma and 12 Ma, several of these flood-basalt flows crossed the Cascade Range through a broad lowland and entered western Oregon and Washington. In the Beacon Rock quadrangle, these flows, mostly Grande Ronde Basalt, are banked against the eroded top of the Eagle Creek Formation and mark the north margin of the Miocene trans-arc valley.

Following cessation of flood-basalt eruptions, the ancestral Columbia River incised a canyon located south of the map area. During the late Pliocene, voluminous volcanic activity related to a northward-propagating intra-arc rift filled this paleocanyon, forcing the river northward to its present position. Young volcanism in southern Washington has been more dispersed and less vigorous than that to the south. Several small extinct volcanoes have been mapped in the Beacon Rock quadrangle; they are the northeasternmost centers of the Pliocene to Quaternary Boring Volcanic Field (Treasher, 1942; Trimble, 1963; Allen, 1975; Evarts and others, 2009).

In the latest Pleistocene, cataclysmic outburst floods poured through the Columbia River Gorge. Their effects in the gorge were primarily erosive and they left only sparse thin deposits in the map area, although they undercut canyon walls and may have triggered some of the large landslides along the Columbia River.

Deformation in the area is characterized by mild folding, with attitudes in the older beds generally striking northeast to north-northeast and dipping moderately (15–30°) southeast. Decreasing dips in progressively younger strata indicate that folding occurred gradually throughout the Miocene, but deformation of the 16-Ma Grande Ronde Basalt Group is limited to gentle tilting (2°) to the southwest. Only a few small faults have been mapped; none are known to have moved during the Quaternary.

Cascade Volcanic Arc

Stratigraphic Relations and Nomenclature

Williams (1916) applied the name Eagle Creek Conglomerate to volcaniclastic rocks that underlie Columbia River Basalt flows in the Columbia River Gorge. The unit was renamed the Eagle Creek Formation by Chaney (1918), who, in subsequent publications, described its fossil flora in detail and eventually assigned it an early Miocene age (Chaney, 1944, 1959). Wise (1961, 1970) and Waters (1973) recognized that the volcanic-arc strata in the area directly east of the Beacon Rock

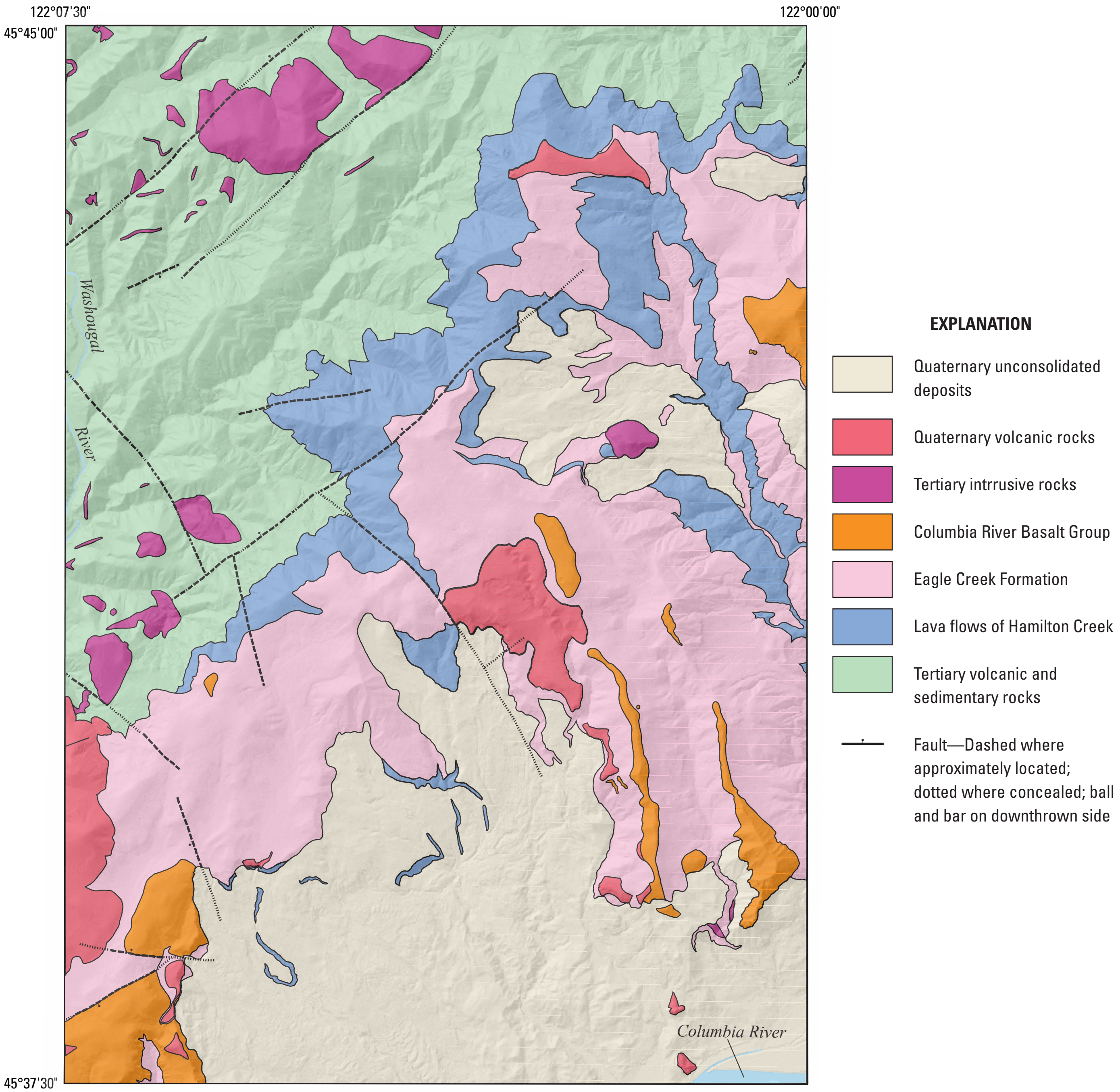

Figure 2. Simplified geology of Beacon Rock quadrangle showing distribution of rocks of ancestral Cascade volcanic arc, Columbia River Basalt Group, and Quaternary volcanic rocks.

quadrangle consisted of two dominantly volcaniclastic but lithologically distinct units separated by an erosional unconformity. Wise (1970) therefore redefined the Eagle Creek Formation as "the sequence of volcanic conglomerates, sandstones, and tuffs that are typically exposed south of the Columbia River along Eagle Creek." This definition restricted the name Eagle Creek to those rocks above the unconformity, which included all of the fossiliferous beds studied by Chaney (1944). Wise (1970) assigned the more altered and deformed strata below the unconformity to the Ohanapecosh Formation, which has its type area in Mount Rainier National Park, more than 100 km north of the map area.

Hammond (1980) traced the unconformity at the base of the Eagle Creek Formation westward into the Beacon Rock quadrangle, where the stratigraphic section contains numerous lava flows and is more heterogeneous than to the east. He divided the folded and altered strata beneath the unconformity into three units, from oldest to youngest: the Ohanapecosh Formation, the Stevens Ridge Formation, and the informal lava flows of Three Corner Rock. Although the stratigraphic relations shown by Hammond (1980) are broadly correct, the nomenclature he employed is not adopted here. Correlation of the Oligocene and earliest Miocene rocks in the Beacon Rock quadrangle with the Ohanapecosh (chiefly volcaniclastic sedimentary rocks) and Stevens Ridge (chiefly pyroclastic rocks) Formations in their type areas at Mount Rainier National Park is questionable. This correlation was based largely on gross lithologic similarity, but subsequent regional mapping (Evarts and Swanson, 1994) and age determinations (Vance and others, 1987) demonstrate that the strata in the two widely separated areas are neither coeval nor laterally contiguous. Furthermore, broadly equivalent strata elsewhere in southern Washington have been given other names (Wilkinson and others, 1946; Roberts, 1958; Hammond, 1980; Phillips, 1987), and no reliable criteria have been found for mapping contacts between these various units. For these reasons, we employ strictly lithologic names or, where appropriate, informal lithostratigraphic names in reference to the strata that Hammond (1980) mapped as Ohanapecosh and Stevens Ridge Formations.

The upper part of the pre-Eagle Creek section in the map area consists almost entirely of porphyritic lava flows, which Hammond (1980) informally named lava flows of Three Corner Rock. The detailed mapping presented here confirms the existence of these flows and shows that the basal contact of this flow-dominated unit is an unconformity. However, because Three Corner Rock is a Pleistocene volcanic plug (see Rocks of the Boring Volcanic Field section), we rename these Tertiary rocks the (informal) lava flows of Hamilton Creek.

Oligocene and Early Miocene Strata Older than the Lava Flows of Hamilton Creek

Lithologically diverse, northeast-striking and southeast-dipping strata that predate the lava flows of Hamilton Creek underlie much of the Washougal River drainage basin in the northwestern part of the map area. As much as 2,500 m of these rocks are exposed in the map area and comprise a lower volcaniclastic section, a middle section dominated by lava flows and ignimbrites, and an upper volcaniclastic section.

Volcaniclastic sedimentary rocks (Tvs) with rare small lava flows form the stratigraphically lowest part of this sequence in the map area. Thin- to medium-bedded, fine- to coarse-grained fluvial deposits predominate and are well exposed in the beds of the Washougal River and its tributaries, Prospector, Deer, and Timber Creeks. Thick, massive, pumiceous lapilli tuffs, probably deposited by pyroclastic flows, are subordinate but abundant locally, as along the Washougal River near the mouth of Stebbins Creek.

The lower volcaniclastic-dominated section is conformably overlain by a section composed of basaltic andesite (Tba), lesser andesite and dacite (Ta, Td), rare basalt (Tb, Tob), and lapilli tuff and tuff breccia (Tt, Tts). This flow-dominated section is best exposed in Stebbins Creek. Most of the flows are aphyric to sparsely phyric (<10–12 percent phenocrysts, although a coarsely porphyritic basaltic andesite at the base of this section holds up the ridgecrest between Timber Creek and Stebbins Creek; plagioclase from this flow gave an $^{40}Ar/^{39}Ar$ plateau age of 25.78±0.55 Ma, table 4). Thin (<2 m) sedimentary sections, commonly capped by orange-brown paleosols, separate many of the flows. Owing to differential erosion, the flows tend to form pronounced ribs separated by swales underlain by the sediments. As a result, the dipping flows form a flatiron topography that is particularly pronounced on the northwest bank of Stebbins Creek. Most of these lavas have medium-potassium, tholeiitic compositions (fig. 3) and are typical of late Eocene to early Miocene volcanics of the southern Washington Cascade Range (du Bray and others, 2006; R.C. Evarts, unpub. data).

The interbedded lapilli tuff and tuff breccias (Tt) are generally pumiceous, and two of them are densely welded ignimbrites that, like the lava flows, tend to form tabular ridges. One of these is a sparsely phyric, lithic-poor, totally devitrified, hypersthene-dacite tuff that rests on the coarsely porphyritic basaltic andesite flow noted above and was traced for more than 3 km in lower Stebbins Creek. The other, stratigraphically higher, ignimbrite is the tuff of Stebbins Creek (Tts), a stony to vitric, sparsely plagioclase- and pyroxene-phyric, rhyolitic tuff that was mapped from lower Stebbins Creek northward for 7 km. It exhibits extremely flattened fiamme, contains very few lithic fragments, and typically looks more like a flow; in a few places, rheomorphic flow folds were observed, indicating deposition on a sloping surface. Plagioclase from the tuff of Stebbins Creek yielded an $^{40}Ar/^{39}Ar$ plateau age of 24.30±0.11 Ma.

The middle lava-flow and ignimbrite section interfingers upward with the upper volcaniclastic section that, in contrast to the lower volcaniclastic section, consists largely of pyroclastic-flow deposits. Massive, green, nonwelded lapilli tuffs predominate, but densely welded beds, some vitric, are present locally. They are dacitic and more densely porphyritic than the tuffs lower in the stratigraphic section. Two widely separated welded tuffs, each within 150 m stratigraphically of the unconformable contact with the overlying lava flows of Hamilton Creek, yielded plagioclase $^{40}Ar/^{39}Ar$ plateau ages of 24.04±0.06 Ma and 22.79±0.13 Ma (table 4).

Lava Flows of Hamilton Creek

The lava flows of Hamilton Creek consist of two-pyroxene±olivine bearing andesite (Tha) and basaltic andesite (Thba) flows, flow breccia, and local lensoidal diamicts (Thtb) of probable laharic origin. The unit is thickest near Three Corner Rock, where it occupies a small paleovalley incised into the top of the subjacent volcaniclastic section. It thins to the south and northeast, in part due to erosion prior to deposition of the overlying Eagle Creek Formation. A coarsely porphyritic subvolcanic andesite body in Hard Scramble Creek (Tiah) may mark the vent for these flows; only a single, sparsely porphyritic dike has been found to cut the lava flows of Hamilton Creek. Chemically, the lava flows of Hamilton Creek possess transitional tholeiitic to calc-alkaline compositions (table 1; fig. 3) and differ from older lavas in the map area in their generally lower contents of FeO*, TiO_2, and P_2O_5, higher contents of Al_2O_3 and Sr, and higher Sr/Y and Ba/Nb. $^{40}Ar/^{39}Ar$ ages obtained for plagioclase separates from two Hamilton Creek flows indicate they were emplaced at 22.0 to 21.6 Ma (table 4).

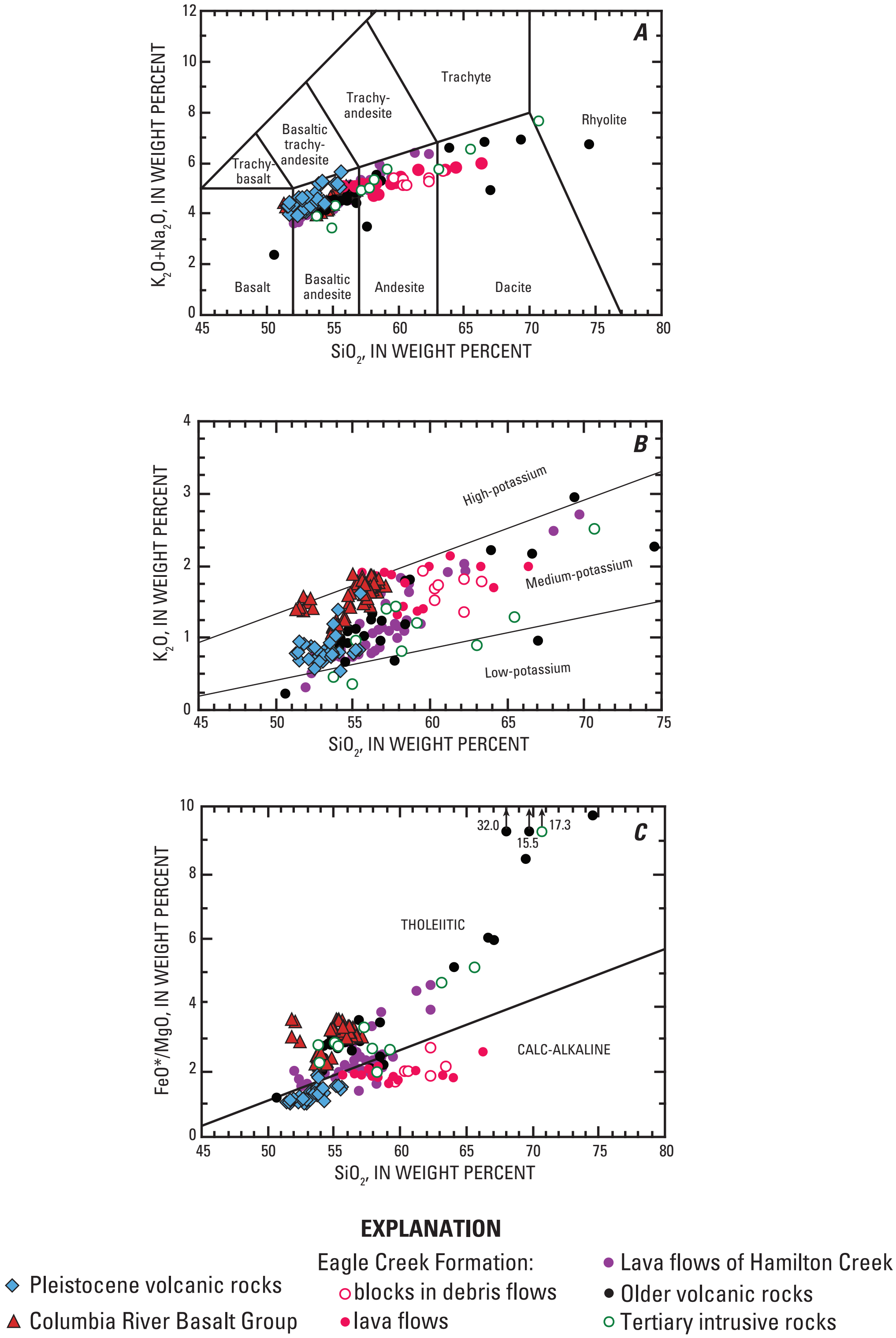

Figure 3. Chemical characteristics of volcanic rocks from Beacon Rock 7.5′ quadrangle (analyses recalculated volatile-free). *A*, K_2O+Na_2O versus SiO_2 contents, showing IUGS classification (Le Maitre, 2002). *B*, K_2O versus SiO_2 contents, showing low-, medium-, and high-potassium fields extrapolated from Gill (1981, p. 6). *C*, FeO*/MgO versus SiO_2 content, showing separation into tholeiitic and calc-alkaline rocks according to Miyashiro (1974). FeO*, total Fe as FeO.

Eagle Creek Formation

The Eagle Creek Formation underlies the crest of the divide between the Washougal and Columbia Rivers and is widely distributed in the valley of Hamilton Creek. In the map area, it rests unconformably on the lava flows of Hamilton Creek; whereas, to the east it overlies older volcaniclastic rocks. In many locations, a saprolitic paleosol as thick as 15 m developed on the subjacent rocks (Wise, 1961, 1970; Waters, 1973). Both upper and lower contacts of the Eagle Creek Formation are erosional surfaces of considerable relief, so its thickness varies substantially. The maximum known thickness of about 400 m is in Hamilton Creek (Wise, 1970).

The Eagle Creek Formation in the map area is lithologically similar to that described by Wise (1961, 1970) from the region to the east. It consists largely of fluvially deposited conglomerate, breccia, sandstone, and diamicts (paraconglomerates of Wise, 1970) deposited by debris flows. In comparison to older volcaniclastic rocks (Tvs, Tt), Eagle Creek beds are less consolidated and metamorphosed. East of Hamilton Mountain, the formation is divided into two informal members. The lower member (Tecl) consists largely of fluvially deposited conglomerate and sandstone with a few relatively fine grained debris-flow beds. Clasts include a variety of volcanic rocks but are dominated by porphyritic rocks similar to those of the underlying lava flows of Hamilton Creek, presumably the source. Conglomerate matrix and finer grained sediments are considerably altered to smectitic clay, giving the rocks dark-green to brown hues. Most of the area mapped as Eagle Creek Formation in the Beacon Rock quadrangle consists of the upper member (Tecu), which in Hamilton Creek valley rests sharply but conformably on the lower member. The upper member is dominated by poorly sorted breccias deposited by lahars (fig. 4) but also includes fluvial pebble- and cobble- conglomerate and tuffaceous sandstone, some densely packed monolithologic breccias probably emplaced as lithic pyroclastic (block-and-ash) flows, and a few lava flows. On the east valley wall of Hamilton Creek, a breccia that carries andesite megablocks many meters across may be a debris-avalanche deposit. Clasts consist chiefly of dense, porphyritic andesite and dacite; pumice clasts are

Figure 4. Cliff composed of upper Eagle Creek Formation on southeast flank of Hamilton Mountain. Consists of poorly sorted conglomerate of presumed laharic origin with minor, discontinuous sandstone beds. Large boulder near edge of cliff (arrow) is about 2.5 m across.

sparse and largely restricted to sandy beds and conglomerate matrix. Upper-member rocks are much less altered than those of the lower member. They are generally light colored and weather to light-gray to white soils that contrast with the darker soils derived from older rocks and reddish-brown soils developed on the Columbia River Basalt Group. Because the resistant volcanic clasts in the conglomerates readily separate from the weak matrix, areas underlain by the Eagle Creek Formation form boulder-strewn landscapes resembling those of moraines. Clasts in Eagle Creek conglomerates and diamicts are predominantly porphyritic, pyroxene- and hornblende-phyric, intermediate to silicic volcanic rocks (table 1).

Lava flows are rare in the Eagle Creek Formation to the east (Wise, 1970) but several (Tepa, Teha, Tehd) are present in the map area (table 1; fig. 2). They consist of pyroxene- and (or) hornblende-phyric basaltic andesite and andesite that are compositionally similar to clasts in the associated lahar and block-and-ash deposits. A distinctive, densely phyric, pyroxene dacite (Tipd) crops out in the lower Hardy Creek area, where contact relations indicate it intrudes Eagle Creek Formation lava flows and clastic rocks. Northwest-trending shears are common in this area and suggest emplacement of the dacite along a fault zone. Petrographic and chemical affinities with the host rocks suggest it is a shallow intrusion of probable Eagle Creek age. The Eagle Creek lavas and clasts in debris-flow deposits exhibit calc-alkaline compositions and are clearly distinguished from older andesitic and dacitic flows by their less altered nature, nearly ubiquitous hornblende phenocrysts, and generally higher Sr/Y (>20, fig. 5) and Ba/Nb. $^{40}Ar/^{39}Ar$ plateau ages on plagioclase separates from a lithic pyroclastic flow and two lava flows indicate deposition of the Eagle Creek Formation between 20.1 Ma and 19.4 Ma (table 4).

Although both members of the Eagle Creek Formation were deposited in fluvial settings, their lithologic differences record a change in source material. The lower member consists of debris eroded from a pre-existing volcanic highland, most likely the stratovolcano that produced the lava flows of Hamilton Creek. The upper member, in contrast, reflects contemporaneous volcanism. Wise (1970) and Waters (1973) interpreted the Eagle Creek Formation as a large debris fan originating at one or more active volcanoes. This interpretation is consistent with all major characteristics of the upper member, including relatively limited compositional range and distinctive chemistry of its clasts, abundance of lahar and lithic pyroclastic-flow deposits, ash-rich matrix of many beds, high-energy depositional environment, and presence of interbedded lava flows. Northwestward thickening of the Eagle Creek Formation suggested to Wise (1961, 1970) that the eruptive source area was located north of the map area. Eagle Creek beds are absent in this area, however, implying that erosion has completely destroyed the original volcanic edifice, its nature and location therefore unknown. Because Eagle Creek eruptions produced abundant lithic pyroclastic flows, which are typically generated by collapse of growing andesitic and silicic domes (Cas and Wright, 1987; Freundt and others, 2000), the source area was more likely a dome field rather than a single large stratovolcano. If so, the only remains of the Eagle Creek volcanic center would likely be small subvolcanic intrusions scattered throughout the area north of the Eagle Creek Formation outcrop belt. Three possible Eagle Creek vents are mapped in the Beacon Rock quadrangle. One is the hill in the center of the map area informally named "Croswell Butte" that consists of a blocky-surfaced deposit of hornblende dacite (Tehd); because highly viscous dacite cannot flow far from its source vent, this outcrop is likely a dome or shallow plug. A second possible vent is an intrusion of fresh andesite located about 4 km to the east, near Lily Lake. The Lily Lake body (Tial) is aphyric, unlike most Eagle Creek clasts, but possesses certain distinctive chemical characteristics, such as a high Sr content and high Sr/Y, that indicate an affinity to Eagle Creek magmas. Finally, a densely porphyritic dacite body cutting the Eagle Creek Formation in Hardy Creek (Tipd) also has relatively high Sr and Sr/Y and may be a late Eagle Creek-age subvolcanic intrusion.

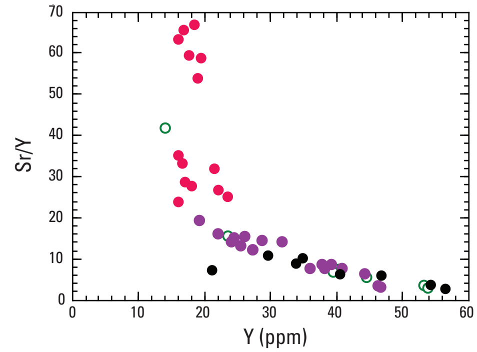

Figure 5. Plot of Sr/Y versus Y for igneous rocks in Beacon Rock 7.5′ quadrangle; ppm, parts per million.

Intrusive Rocks

A wide variety of intrusive rocks were emplaced into the older part of the Oligocene to early Miocene section of the Beacon Rock quadrangle. They range from phaneritic, variably altered, gabbro, pyroxene diorites, and quartz diorites (Tgb, Tdi, Tqd), presumably emplaced at considerable depth, to fine-grained, locally vitric, mafic to silicic rocks (Tiba, Tia, Tid) forming (possibly subvolcanic) dikes, sills, and plugs.

The largest intrusions in the map area, in the Deer Creek drainage, consist of moderately porphyritic dacite ($Tidc_d$) to rhyolite ($Tidc_r$) distinguished by chalky white plagioclase phenocrysts in a buff to light-gray, felsic groundmass. These rocks are highly jointed, extensively frost-heaved, and commonly disintegrate to barren talus. Plagioclase from a rhyolite sample on the ridge east of Deer Creek yielded an $^{40}Ar/^{39}Ar$ plateau age of 22.60±0.06 Ma.

The ages of other intrusions in the map area are poorly constrained. Those that cut the lowest stratigraphic horizons near the northwest corner of the quadrangle are generally altered as much as or more than their host rocks and may predate the pervasive low-grade metamorphism affecting those rocks (see next section). Elsewhere, many intrusive bodies are less altered than their host rocks and could be much younger. An $^{40}Ar/^{39}Ar$ experiment on one intrusion, exposed in Hard Scramble Creek (Tiah), did not yield a specific age but provides a maximum age of 23.14±0.18 Ma, permissive of a Hamilton Creek source vent (table 4). The only intrusions known to cut Hamilton Creek flows are the plug of platy aphyric andesite forming a conical hill south of Lily Lake (Tial) and an isolated sparsely phyric andesite dike about 4.2 km to the west. Neither of them petrographically resembles either the lava flows of Hamilton Creek or rocks of the Eagle Creek Formation, although, as noted above, the Lily Lake body is chemically similar to flows in the Eagle Creek Formation.

A distinctive, densely phyric, pyroxene dacite (Tipd) crops out in the lower Hardy Creek area, where contact relations indicate it intrudes Eagle Creek Formation lava flows and clastic rocks. Northwest-trending shears are common in this area and suggest emplacement of the dacite along a fault zone. Petrographic and chemical affinities with the host rocks suggest it is a shallow intrusion of probable Eagle Creek age.

Metamorphism and Hydrothermal Alteration

The ashy matrix of Eagle Creek Formation volcaniclastic rocks has typically been converted to iron-poor montmorillonite but otherwise the unit is unaltered (Wise, 1961). Underlying rocks, however, have been subjected to zeolite-facies regional metamorphism similar to that described from other areas in the southern Washington Cascade Range (Fiske and others, 1963; Wise, 1970; Evarts and others, 1987; Evarts and Swanson, 1994). This region-wide metamorphism reflects burial within the relatively high heat-flow environment of an active volcanic arc.

The degree of alteration in the sub-Eagle Creek rocks of the map area increases downsection. Alteration of the lava flows of Hamilton Creek is generally limited to partial replacement of olivine, orthopyroxene, and interstitial glass by iron-rich smectite. Alteration of associated tuff breccia is similarly limited. The weak alteration is consistent with shallow burial depths, less than 0.5 km, beneath the Eagle Creek Formation.

Metamorphic effects are more apparent in the volcaniclastic strata below the lava flows of Hamilton Creek, especially in originally vitric tuffs, most of which have been pervasively converted to iron-bearing smectites with or without celadonite, clinoptilolite, or analcime. In the lowest part of the sequence northwest of Stebbins Creek, minerals indicative of somewhat higher temperatures (albite, stilbite, laumontite, prehnite, pumpellyite, chlorite) are widely developed.

The highest temperature metamorphic assemblages in the map area, characterized by the presence of epidote, occur in an area of abundant dikes near the mouth of Stebbins Creek. Epidote-bearing propylitic alteration is closely associated with concentrations of intrusive rocks elsewhere in the Cascade Range and reflects hydrothermal activity rather than simple burial (Grant, 1969; Evarts and others, 1987; Evarts and Swanson, 1994). The exposed dikes, despite their abundance, seem insufficient to account for the intensity of propylitization in the Washougal River area, indicating that they may be offshoots from a substantial intrusive body in the shallow subsurface.

The timing of metamorphism is difficult to ascertain. Peak metamorphism presumably corresponds to the time of maximum burial and (or) maximum intrusive activity. Maximum burial in the map area occurred during deposition of the Eagle Creek Formation, about 20 Ma. This is consistent with regional relations that indicate a substantial decline in arc volcanism in southern Washington prior to eruption of the Columbia River Basalt Group (Evarts and Swanson, 1994). The few intrusive rocks in the area that have been dated yield early Miocene ages. Metamorphism in the northeastern part of the map area may be related to emplacement of the large granitic Silver Star stock, 5 km to the west, which has a K-Ar age of 19.6±0.7 Ma (Power and others, 1981). These observations suggest that metamorphism culminated in the early Miocene.

Columbia River Basalt Group

In the Miocene, between 16.5 and 6 Ma, huge volumes of tholeiitic flood basalt, erupted from fissures in southeastern Washington and adjacent Oregon and Idaho, formed the Columbia River Basalt Group. Some of the largest flows crossed the Cascade Range through a broad lowland and ultimately reached the Pacific Ocean (Beeson and others, 1989; Pfaff and Beeson, 1989; Beeson and others, 1989; Wells and others, 1989, 2009). The Columbia River Gorge is located near the northern margin of the Miocene lowland, where the flows are banked against the dissected erosional surface of the Eagle Creek Formation. Most of the flood-basalt flows erupted during a brief period between 16 and 15 Ma and constitute the voluminous Grande Ronde Basalt and Wanapum Basalt (Beeson and others, 1989; Tolan and others, 1989; Reidel and others, 1989a, 2013; Reidel and Tolan, 2013; Barry and others, 2010, 2013; Baksi, 2013). After emplacement of the Wanapum Basalt, flood-basalt eruptions became less frequent, and the ancestral Columbia River incised a deep canyon that confined the youngest flows (Waters, 1973; Tolan and Beeson, 1984; Beeson and others, 1989). The locations of the erosional remnants of Columbia River Basalt Group flows in the map area are shown on figure 2. Figure 6 portrays the stratigraphic nomenclature of the Columbia River Basalt Group employed in this report and shows the stratigraphic position of units found in the map area.

Columbia River Basalt Group flows possess the general character of pahoehoe lavas (Self and others, 1997; Thordarson and Self, 1998; Vye-Brown and others, 2013) and typically exhibit one of two distinctive cooling-jointing patterns referred to as blocky/columnar and entablature/colonnade (fig. 6; Waters, 1973; Long and Wood, 1986; Beeson and others, 1989; Tolan and others, 2009). Flows with entablature/colonnade

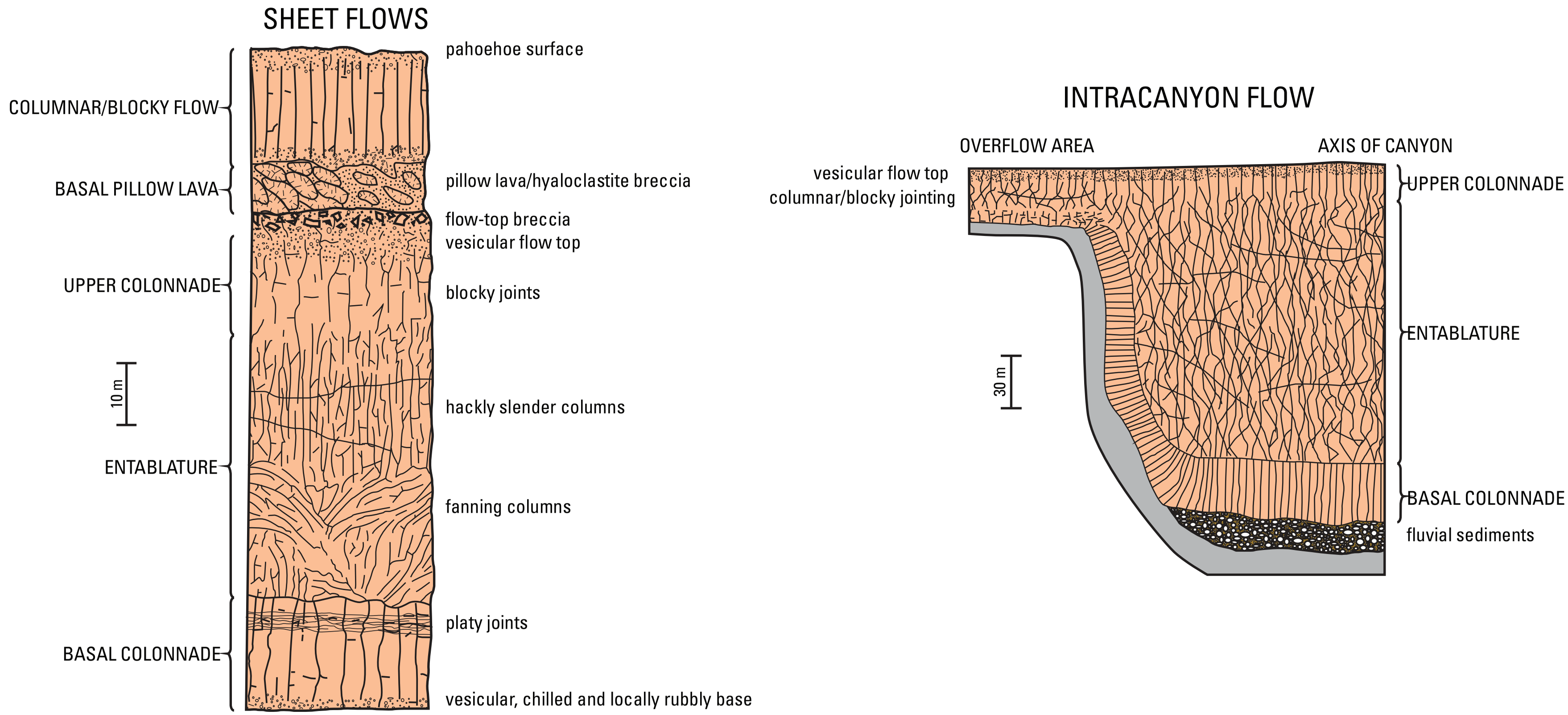

Figure 6. Typical jointing patterns exhibited by lava flows of the Columbia River Basalt Group (modified from Tolan and others, 2009).

jointing (the Type I flows of Long and Wood, 1986) have a basal zone of well-formed columns, 0.5 to 2 m across, overlain by a hackly-jointed entablature composed of thinner, poorly developed columns. The entablature commonly constitutes more than 50 percent of the flow thickness. Although much more densely jointed, entablatures, due to the interlocking nature of their curviplanar joints, are more resistant to erosion and tend to form the largest and most continuous cliffs. Blocky/columnar jointing (equivalent to the Type III flows of Long and Wood, 1986) is typically associated with thinner flows and consists of poorly developed vertical columns and horizontal cross joints. Internal jointing in some flows, however, may be complex, with multiple colonnades or entablatures (Type II flows of Long and Wood, 1986; McMillan and others, 1989; Tolan and others, 2009). Flow tops are vesicular and commonly weathered.

As noted by others (Reidel, 1998; Self and others, 1997; Thordarson and Self, 1998; Vye-Brown and others, 2013), defining precisely what constitutes a lava flow in flood-basalt provinces is not entirely straightforward. For mapping purposes, a flow, as used here, consists of a body of basalt with a jointing pattern that indicates it was emplaced and cooled during a single continuous event (sometimes referred to as cooling units (Reidel, 1998)). We have observed apparent contacts between cooling units that are chemically identical, suggesting that these contacts separate sheet-like flow lobes emplaced during a single eruptive episode. Contacts between lobes record breaks in deposition that range from a few hours to several years (Self and others, 1997; Thordarson and Self, 1998; Vye-Brown and others, 2013). The collection of flows and lobes produced by a single sustained eruption constitute a flow field composed of lavas with generally uniform compositions. Although flow tops are almost universally vesicular, internal vesicular zones are not uncommon (Long and Wood, 1986; Tolan and others, 2009). As noted above, individual flows may also show internally complex jointing. Furthermore, jointing patterns in individual flows may change laterally over distances of less than 100 m. These complications can render distinguishing flow contacts from internal boundaries difficult. The most reliable field indicators of interflow contacts, none that are common, include sedimentary interbeds, tree molds, oxidation, basal pillow lava-hyaloclastite zones, pipe vesicles, and flow breccia; cooling directions inferred from features on joint surfaces (DeGraff and others, 1989) are also useful. Despite the impression of sheetlike layers one gets from the seemingly continuous cliffs and stair-step topography in the Columbia River Gorge, detailed mapping and geochemistry suggest that Columbia River Basalt Group flows in the map area can vary substantially in thickness over relatively short distances.

Grande Ronde Basalt

Grande Ronde Basalt flows are generally aphyric to sparsely plagioclase-phyric, medium-potassium, tholeiitic basaltic andesites (fig. 3) that are readily distinguished from those in the other formations of the group by their generally aphyric character and comparatively high SiO_2 and low TiO_2 contents (Swanson and others, 1979b; Mangan and others, 1986; Beeson and others, 1989; Reidel and others, 1989a; Hooper, 1997; Reidel and Tolan, 2013). We estimate that about 12 individual eruptions are represented by flows exposed in the map area.

Grande Ronde Basalt flows in the map area range from aphyric to sparsely phyric with widely scattered plagioclase phenocrysts or glomerocrysts less than 10 mm across. Some flows are distinctly microphyric, with abundant plagioclase microphenocrysts ≤1 mm long. They consist largely of plagioclase, augite, pigeonite, Fe-Ti oxide, apatite, and dark glass; some flows contain minor olivine or orthopyroxene (Reidel and others, 1989a; Reidel and Tolan, 2013). Textures range from intergranular to intersertal; samples from colonnades are more coarsely crystalline than those from entablatures, which typically contain 35 to 65 percent glass (Long and Wood, 1986). In general, Grande Ronde flows are petrographically indistinguishable, although variations in the abundance of phenocrysts or microphenocrysts are locally useful.

The widespread and originally horizontal Grande Ronde Basalt flows potentially constitute excellent stratigraphic datums for analysis of post-middle-Miocene deformation (Beeson and others, 1989; Beeson and Tolan, 1990), but the remarkable physical and chemical similarity of these flows stymied early attempts to construct an internal stratigraphic framework for this thick formation. Swanson and others (1979b) showed that emplacement of the flood-basalt field spanned three paleomagnetic polarity reversals, allowing subdivision of the formation into four magnetostratigraphic units (fig. 7). Chemical analyses demonstrated that Grande Ronde flows could be divided into relatively high-MgO and low-MgO groups (fig. 8), with a gap at about 4.0 weight percent MgO (Reidel, 1983; Mangan and others, 1986). Employing a combination of petrographic characteristics, stratigraphic position, chemistry, and paleomagnetic properties, Reidel and others (1989a) developed an informal stratigraphic nomenclature for the Grande Ronde Basalt. We find this nomenclature useful and have adopted it, as revised and formalized by Reidel and Tolan (2013), for our mapping in the western Columbia River Gorge (fig. 7). Reidel and Tolan (2013) divided the Grande Ronde Basalt in the Columbia Basin into 25 formal and informal members based primarily on chemical composition; six of these members, mostly within the N_2 and R_2 magnetostratigraphic units of Swanson and others (1979b), are recognized in the map area. The members defined by Reidel and Tolan (2013) typically contain several chemically distinguishable flows or packages of flows, each probably equivalent to a flow field emplaced during a single, sustained eruption.

Analytical Issues

Assignment of Grande Ronde flows to Reidel and Tolan's (2013) members requires precise chemical analyses to detect the subtle compositional differences between units. Interlaboratory bias and weathering effects complicate assessments. To eliminate potential analytical bias, all analyses reported here (table 2) are from the Peter Hooper GeoAnalytical Laboratory at Washington State University using common instrumentation and standards. Although internally consistent, our data cannot

GROUP	SUB-GROUP	FORMATION	MEMBER	AGE (Ma)	MAGNETIC POLARITY
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	SADDLE MOUNTAINS BASALT	**Lower Monumental Member**	6	N
			erosional unconformity		
			Ice Harbor Member	8.5	
			basalt of Goose Island		N
			basalt of Martindal		R
			basalt of Basin City		N
			erosional unconformity		
			Buford Member		R
			Elephant Mountain Member	10.5	R,T
			erosional unconformity		
			Pomona Member	12	R
			erosional unconformity		
			Esquatzel Member		N
			erosional unconformity		
			Weissenfels Ridge Member		
			basalt of Slippery Creek		N
			basalt of Tenmile Creek		N
			basalt of Lewiston Orchards		N
			basalt of Cloverland		N
			Asotin Member	13	
			basalt of Huntzinger		
			Wilbur Creek Member		
			basalt of Lapwai		N
			basalt of Wahluke		N
			local erosional unconformity		
			Umatilla Member	13.5	
			basalt of Sillusi		N
			basalt of Umatilla		N
			local erosional unconformity		
		WANAPUM BASALT	**Priest Rapids Member**	14.5	N
			basalt of Lolo		R
			basalt of Rosalia		R
			local erosional unconformity		
			Roza Member		T,R
			Shumaker Creek member		N
			Frenchman Springs Member		
			basalt of Lyons Ferry		
			basalt of Sentinel Gap		N
			basalt of Sand Hollow	15.0	N
			basalt of Silver Falls		N,E
			basalt of Ginkgo		E
			basalt of Palouse Fallse Falls		E
			Eckler Mountain Member		
			basalt of Dodge		N
			basalt of Robinette Mountain		N
			local erosional unconformity		

GROUP	SUB-GROUP	FORMATION	MEMBER	AGE (Ma)	MAGNETIC POLARITY
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	GRANDE RONDE BASALT	***Sentinel Bluffs Member***	15.5	
			basalt of Museum		
			basalt of Spokane Falls		
			basalt of Stember Creek		
			basalt of Airway Heights		
			basalt of California Creek		
			basalt of McCoy Canyon		
			Winter Water Member		N_2
			Fields Spring Member		
			Indian Ridge Member		
			Buttermilk Canyon member		
			Armstrong Canyon member		
			Ortley member		
			Slack Canyon Member		
			Meyer Ridge Member		
			Grouse Creek member		R_2
			Wapshilla Ridge Member		
			Mount Horrible member		
			Cold Springs Ridge Member		
			Hoskins Gulch Member		
			China Creek Member		N_1
			Frye Point member		
			Downey Gulch member		
			Brady Gulch member		?
			Kendrick Grade member		
			Center Creek member		
			Skeleton Creek member		R_1
			Rogersburg member		
			Teepee Butte Member	16.0	
			basalt of Pruitt Draw		
			basalt of Joseph Creek		
			basalt of Limekiln Rapids		
			Birch Creek member		
			Buckhorn Springs Member		T,R
		IMNAHA BASALT		16.0	N_0

Figure 7. Stratigraphic nomenclature, ages, and magnetic polarities of the Columbia River Basalt Group, modified from Reidel and others (2013), Reidel and Tolan (2013), and Reidel (2005). For the Grande Ronde Basalt, formal members of Reidel and Tolan (2013) designated by M (Member), informal members designated by m (member). Magnetic polarity abbreviations are N, normal; R, reversed; T, transitional; E, excursional; subscripts refer to magnetostratigraphic units of Swanson and others (1979b). Units mapped in Beacon Rock 7.5′ quadrangle are shown in blue italics.

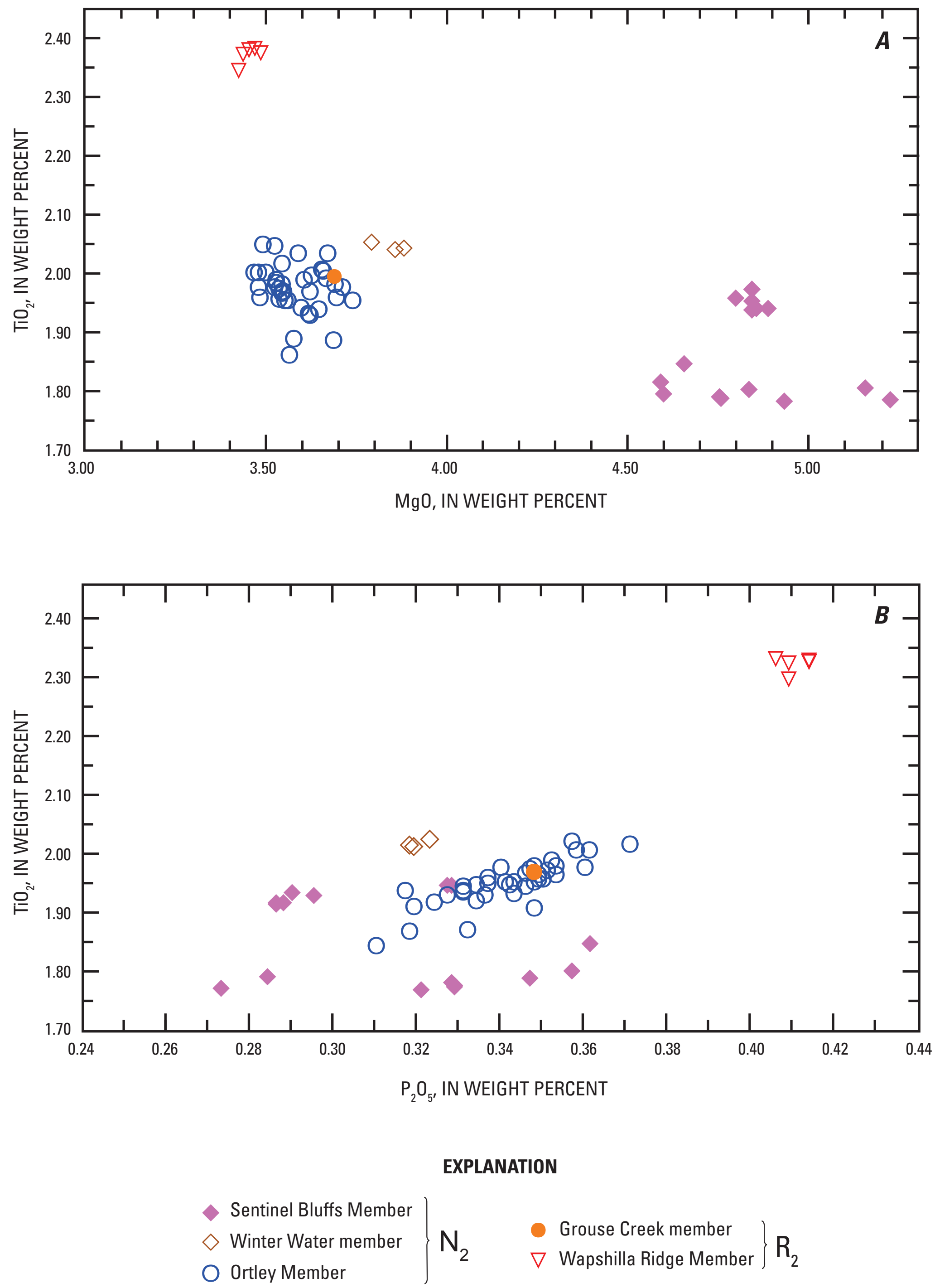

Figure 8. Chemical characteristics of Grande Ronde Basalt flows in the Beacon Rock 7.5′ quadrangle. N_2 and R_2 are magnetostratigraphic units of Swanson and others (1979b). *A*, TiO_2 versus MgO contents. *B*, TiO_2 versus P_2O_5 contents.

be compared directly to analyses performed in other labs or even with older data from the Washington State University laboratory (for example, Reidel and others, 1989a) that were produced using different equipment and data-reduction procedures.

A major difficulty in making correlations among Grande Ronde flows is accounting for the effects of chemical weathering, which can modify rock chemistry sufficiently to produce erroneous member assignments (Wells and others, 2009). Consequently, we rely mainly on analyses that meet two criteria related to extent of weathering. First is degree of hydration as recorded by loss-on-ignition or by anhydrous totals. We judge samples that have loss-on-ignition exceeding 3.0 weight percent, or anhydrous totals less than 97 weight percent, as possibly affected by weathering, although simple hydration will not affect normalized compositions. The second and more important criterion is total Fe calculated as FeO (FeO*) for normalized analyses (Wells and others, 2009). Most fresh Grande Ronde flows contain at least 11 weight percent FeO* (see Hooper, 2000; Reidel and Tolan, 2013), and we therefore consider samples with less than 11 weight percent FeO* as potentially altered. Importantly, this is true even for samples with anhydrous totals above 98 weight percent and for samples that appear fresh in hand sample and thin section. We interpret the reduction in FeO* to reflect long-duration chemical reaction with groundwater. This process can affect elements such as MgO, TiO_2, and P_2O_5 that are used to help distinguish Grande Ronde Basalt members. Therefore, we do not rely on data from rocks that have less than 11 weight percent FeO* for member assignments. Most analyses in table 2 are unaltered according to this criterion.

We also employ laboratory paleomagnetic analyses to distinguish Grande Ronde Basalt flows in the map area (table 5). This approach has two major advantages over field determinations with a portable fluxgate magnetometer. Firstly, chemical magnetic overprints resulting from post-emplacement weathering can be detected and eliminated, producing less ambiguous results. Secondly, the data provide paleomagnetic inclinations and declinations as well as polarities, potentially allowing chemically similar flows within a magnetostratigraphic unit to be differentiated (Wells and others, 1989, 2009).

Grande Ronde Basalt flows in the map area exhibit a pronounced onlap relation with the south-sloping paleovalley wall underlain by the Eagle Creek Formation. As a result, the number of flows and overall thickness of the formation decrease northward and the unit is absent north of the Columbia River valley. Our detailed chemical stratigraphy reveals major variations in the thickness of individual flows across the map area. These variations reflect, in part, the lobate character of Columbia River Basalt flows (Self and others, 1997; Thordarson and Self, 1998; Vye-Brown and others, 2013), which is probably best developed at locations near the province margins (Reidel, 1998). However, some of the more dramatic thickness changes, exemplified by the thick Ortley member flow at Hamilton Mountain, clearly record significant erosion during the relatively brief periods separating emplacement of Grande Ronde Basalt flows. The resulting intracanyon relations between Grande Ronde flows have not been described from elsewhere in the flood-basalt province. Such enhanced interflow erosion is likely restricted to areas at the margin of the province, where major tributaries of the ancestral Columbia River encountered the flow field and were shunted along its edge, carving canyons that were filled by succeeding lava flows (Wells and others, 2009). Another manifestation of interaction between basalt flows and tributary streams is the abundance of pillow lavas and hyaloclastite in the Grande Ronde section of the map area.

Wapshilla Ridge Member

The lowest Columbia River Basalt Group flows exposed in the map area belong to the Wapshilla Ridge Member (Tgwr) of Reidel and Tolan (2013). They are reversely magnetized, have relatively low MgO contents (3.3–3.6 weight percent) and possess higher TiO_2 (2.3–2.4 weight percent) and P_2O_5 contents (about 0.4 weight percent) than most other low-MgO Grande Ronde flows in western Oregon and Washington (table 2; fig. 8; Reidel and others, 1989a; Beeson and others, 1989). Wapshilla Ridge flows are nearly aphyric but contain abundant plagioclase microphenocrysts; this microphyric character is indicative but not diagnostic. Only the uppermost Wapshilla Ridge flow in the Columbia River Gorge crops out in the Beacon Rock quadrangle; it is found on the slopes of Hamilton Mountain, on the ridge west of Hardy Creek, and in a box canyon near the southwest corner of the map area. In the first two locations, it overlies and pinches out northward against the Eagle Creek Formation; in the third locality it probably overlies older Wapshilla Ridge Member flows that are buried by talus. This flow is distinguished from older Wapshilla Ridge flows by a slightly but consistently higher P_2O_5 content (≥0.40 weight percent; fig. 8) (Wells and others, 2009; R.C. Evarts, unpub. data).

Grouse Creek Member

The Grouse Creek member (Tggc) directly overlies the Wapshilla Ridge Member in the western Columbia River Gorge. Grouse Creek flows, like Wapshilla Ridge flows, are reversely magnetized and belong to the R_2 magnetostratigraphic unit of Swanson and others (1979b). Grouse Creek flows are generally aphyric and generally not microphyric (Reidel and Tolan, 2013). Only one Grouse Creek member flow crops out in the map area, at the head of the box canyon near the southwest corner of the map. It is characterized by moderately low MgO (about 3.6–3.7 weight percent) and relatively high P_2O_5 (about 0.36 weight percent) contents (table 2; fig. 8) and an unusual, low-inclination, magnetic direction (table 5; J.T. Hagstrum, written commun., 2010).

Ortley Member

Ortley member (Tgo) flows in the map area are lithologically and chemically similar to underlying Grouse Creek member flows (table 2) but exhibit normal magnetic polarities (Reidel and others, 1989a; Beeson and others, 1989; Reidel and Tolan, 2013). Most Ortley flows in the Beacon Rock quadrangle exhibit entablature/colonnade jointing patterns and are aphyric but not microphyric. The Ortley member is the thickest Grande Ronde Basalt member in the map area, and Ortley flows are some of the thickest individual Grande Ronde flows. Thick Ortley member sections underpin the ridges east and west of Hardy Creek. All paleomagnetically sampled flows in the Beacon Rock quadrangle belong to this member (fig. 9).

The landslide scarp that forms the high cliff of the south face of Hamilton Mountain provides a spectacular exposure of an intracanyon Grande Ronde Basalt flow (fig. 10; Waters, 1973; Wells and others, 2009). There, a 200-m-thick Ortley member flow occupies a paleovalley incised through the Wapshilla Ridge Member into the underlying Eagle Creek Formation, probably by a tributary of the ancestral Columbia River that entered the trans-arc lowland from the north. The basalt flow consists of a thick entablature over a thin, curving colonnade, banked against Eagle Creek Formation sedimentary

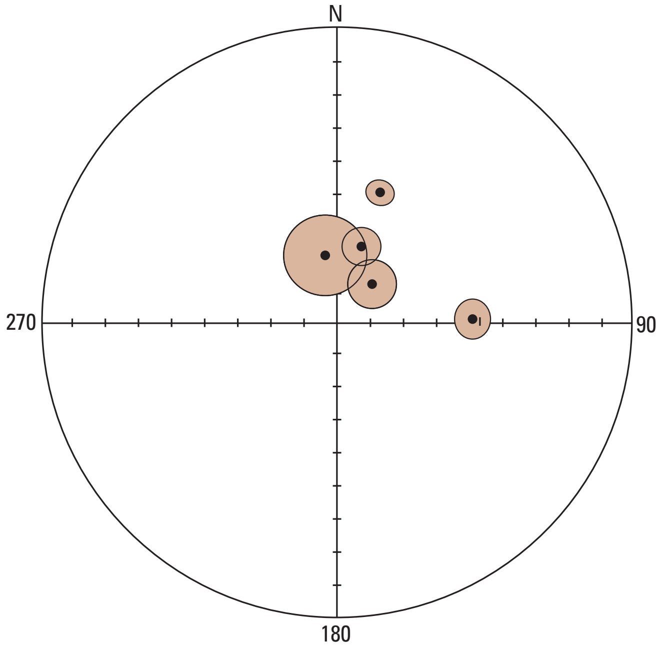

Figure 9. Paleomagnetic directions for Grande Ronde Basalt flows in the Beacon Rock 7.5′ quadrangle. Dots show lower-hemisphere (normal) directions. Thin lines outline areas of 95 percent confidence intervals. All sampled flows exhibit normal magnetic polarity and are assigned to the informal Ortley member of Reidel and Tolan (2013).

rocks on the east and overlying a thick deposit of pillow breccia and palagonitic hyaloclastite on the west. The hyaloclastic section, characterized by steeply north dipping foreset beds, is as thick as 100 m but pinches out abruptly to the north. Pillow fragments in the hyaloclastite are compositionally similar to the overlying flow, suggesting that they are products of the same eruption. The clastic wedge is interpreted as a delta that formed in a temporary lake created when the lava flow blocked the south-flowing tributary of the ancestral Columbia River. Later in the eruption, the lake water apparently drained away, allowing the basalt to flow down the delta front and fill the paleovalley.

Winter Water Member

The Winter Water member (Tgww) is the uppermost low-MgO N_2 member in the Grande Ronde Basalt (Reidel and others, 1989a; Beeson and others, 1989; Reidel and Tolan, 2013). Winter Water flows can be differentiated from most other Grande Ronde flows by the presence of scattered (<1 percent) plagioclase phenocrysts and radial, spokelike glomerocrysts (Tolan, 1982; Reidel and others, 1989a; Reidel and Tolan, 2013). In addition, some Winter Water flows exhibit an unusually shallow paleomagnetic inclination (Reidel and others, 1989a; Wells and others, 1989, 2009; J.T. Hagstrum, written commun., 2010). Two chemically and paleomagnetically distinguishable Winter Water flows crop out in the western Columbia River Gorge (Wells and others, 2009; R.C. Evarts, unpub. data) but only the upper one is present in the Beacon Rock quadrangle. Its chemical composition (table 2) is similar to that of some Grouse Creek and Ortley flows but it can be distinguished by a consistently lower Ba (<600 ppm) content, normal magnetic polarity, shallow paleomagnetic inclination (table 5; J.T. Hagstrum, written commun., 2010), and relatively abundant plagioclase phenocrysts. This flow exhibits a colonnade/entablature jointing pattern in which the entablature constitutes more than 90 percent of the flow thickness. It forms an imposing 60-m-high cliff on the west side of the box canyon near the southeast corner of the quadrangle but thins northward and is very thin or absent about 1.5 km to the north, where the Sentinel Bluffs Member rests directly on the Ortley member. The same Winter Water member flow crops out on the crest of the ridge west of Hardy Creek, where it is about 40 m thick, but is absent from the Grande Ronde Basalt section on (informally named) Birkenfeld Mountain, 5 km to the north. Its absence probably reflects erosion at the edge of the Miocene paleovalley prior to emplacement of the younger Sentinel Bluffs Member.

Sentinel Bluffs Member

The Sentinel Bluffs Member (Tgsb) is the uppermost member of the Grande Ronde Basalt (Reidel and others, 1989a; Reidel, 2005; Reidel and Tolan, 2013). Sentinel Bluffs flows are characterized by relatively high MgO contents (4.4 to 5.0 weight percent; table 2; fig. 8) and normal magnetic polarity. Some flows contain widely scattered plagioclase phenocrysts 5 to 15 mm long. Tolan (1982) referred to these as high-MgO N_2 flows. Sentinel Bluffs Member flows in the western Columbia River Gorge typically exhibit a blocky to columnar jointing style except near flow margins, where an entablature/colonnade jointing pattern may be found (Tolan, 1982; Beeson and others, 1989; Reidel, 2005). In the Beacon Rock quadrangle, the Sentinel Bluffs Member crops out in scattered localities on and southeast of the Washougal-Columbia divide. Its maximum thickness is about 75 m on Birkenfeld Mountain east of Hamilton Creek.

Reidel (2005) divided the Sentinel Bluffs Member into six compositional types, each associated with a stratigraphically confined lava flow or flow package; three of these compositional types, comprising four flows, are found in the map area (but were not mapped separately). The uppermost flow is assigned to the basalt of Museum of Riedel (2005), which is the youngest Sentinel Bluffs unit in the Columbia Basin. This flow is vaguely to distinctly microphyric and exhibits a colonnade/entablature jointing pattern. It is distinguished from the other Sentinel Bluffs flows by a combination of high MgO and low TiO_2 contents (table 2; fig. 8). The basalt of McCoy Canyon, the oldest and most voluminous Sentinel Bluffs compositional type (Riedel, 2005), is represented in the map area by two flows with distinct compositions, including one that has a lower Cr content than other Sentinel Bluffs flows in the quadrangle (table 2). Although McCoy Canyon flows crop out in several localities, the only place where both flows occur is on Hardy Ridge, where the lower-Cr flow overlies the higher-Cr flow, a relation observed at other locations in the western Columbia River Gorge (R.C. Evarts, unpub. data). A flow with a composition higher in MgO than the basalt of Museum, lower in TiO_2

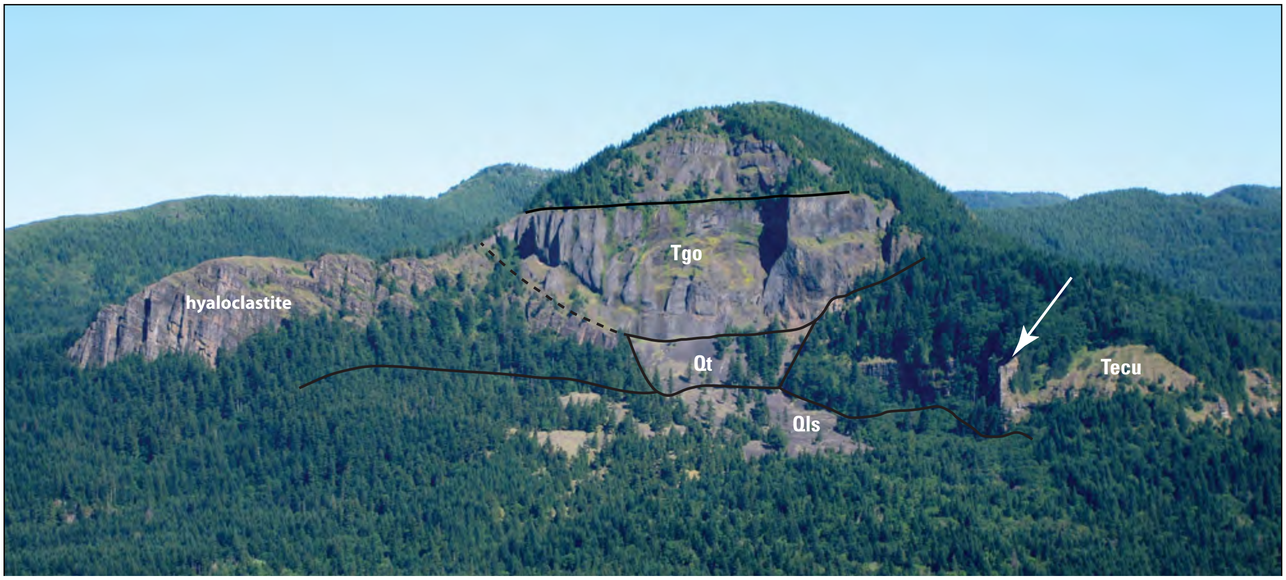

Figure 10. South face of Hamilton Mountain showing ~200-m-thick intracanyon Grande Ronde Basalt flow overlying basal foreset-bedded pillow breccia of same flow on the left and Eagle Creek Formation (Tecu) on the right. All visible flows belong to the informal Ortley member (Tgo) of Riedel and Tolan (2013). Arrow points to cliff of Eagle Creek Formation shown in figure 3. Qt, talus; Qls, landslide deposits.

than the basalt of McCoy Canyon, and lower in P_2O_5 and higher Cr than either (table 2) is found at scattered locations in the map area. It is relatively thin (<20 m thick) and generally exhibits blocky/columnar jointing. Where in contact with other Sentinel Bluffs Member flows, as on Birkenfeld Mountain, it always lies above the basalt of McCoy Canyon and below the basalt of Museum. Flows of this composition and stratigraphic position in the Columbia Basin belong to the basalt of Stember Creek of Riedel (2005).

Wanapum Basalt

Wanapum Basalt flows are generally more mafic, darker, and more coarsely crystalline than Grande Ronde Basalt flows and characteristically contain scattered plagioclase phenocrysts and glomerocrysts as large as 5 cm across (Mackin, 1961; Swanson and others, 1979b). Compositionally, Wanapum flows have much higher TiO_2 contents (Swanson and others, 1979b; Hooper, 1997). The Wanapum Basalt has been divided into formal members (Swanson and others, 1979b; Tolan and others, 1989; Reidel and others, 2013); the Frenchman Springs Member (Beeson and others, 1985; Martin and others, 2013) is present in the map area.

Frenchman Springs Member

Flows assigned to the Frenchman Springs Member crop out between McCloskey and Duncan Creeks in the southwestern part of the quadrangle and at the summit of Birkenfeld Mountain. In both locations, they directly overlie the Sentinel Bluffs Member of the Grande Ronde Basalt. In the Columbia Basin, these units are separated by a sedimentary interval, the Vantage Member of the Ellensburg Formation (Swanson and others (1979b). In the map area, as elsewhere throughout western Washington and Oregon, the Vantage Member is very thin (<1 m) or absent (Beeson and others, 1989), but the Grande Ronde-Wanapum contact is readily mapped based on the distinctly different physical and chemical properties of the two formations.

Martin and others (2013) divide the Frenchman Springs Member into five units on the basis of composition, paleomagnetic properties, stratigraphic position, and lithologic features. Most Frenchman Springs Member outcrops in the map area are assigned to the basalt of Sand Hollow ($Twfs_h$) of Beeson and others (1985) and Martin and others (2013). The basalt of Sand Hollow is the most voluminous unit of the Frenchman Springs Member and one Sand Hollow flow reached the Pacific Ocean (Beeson and others, 1985; Wells and others, 1989, 2009; Martin and others, 2013). Sand Hollow flows are distinguished by the persistent presence of amber plagioclase phenocrysts as much as 35 mm long and by relatively high Cr content (37–45 ppm).

Two small knobs on the flat ridgecrest south of McCloskey Creek consist of similar basalt but contain only scarce plagioclase phenocrysts and display distinctly lower MgO and Cr and higher P_2O_5 contents (table 2); these outcrops are assigned to the basalt of Sentinel Gap ($Twfs_s$) of Beeson and others (1985) and Martin and others (2013).

Rocks of the Boring Volcanic Field

Volcanic eruptions in and near the map area ended after the Eagle Creek Formation was deposited and did not resume until the Pleistocene, when several, small, short-lived volcanoes developed. These small centers consist of cinder cones that mark vents for associated lava flows of olivine-phyric basalt, basaltic andesite, and low-SiO_2 andesite (fig. 3). They are part of the Boring Volcanic Field (Evarts and others, 2009), a collection of several dozen monogenetic vents scattered throughout the region from Portland to Beacon Rock (Hodge, 1938; Treasher, 1942; Trimble, 1963; Allen, 1975; Tolan and Beeson, 1984). Products of eleven such centers have been identified in the Beacon Rock quadrangle based on field relations, petrography, geochemistry (table 3; fig. 11), paleomagnetic properties (table 5; fig. 12), and $^{40}Ar/^{39}Ar$ ages (table 4). They are distributed in two roughly north-south-oriented belts: one from Three Corner Rock to Beacon Rock and the other south of Hard Scramble Creek. Vents for eight units have been located (seven within the map area); vents for the other three have apparently been eroded, buried by younger volcanic rocks, or displaced by landslides.

Three Quaternary volcanic units in the map area erupted at about 1 Ma (table 4): the medium-potassium basaltic andesites of Three Corner Rock (Qtcr), Woodward Creek (Qmwc), and Little Creek (Qmlc). The chemically similar basaltic andesite of Duncan Creek (Qmdc) is about 200 k.y. younger. All four units are notable for low Ba/Nb (15–25), atypical of volcanic-arc magmas (Gill, 1981). Three Corner Rock (fig. 13) is a massive lava plug that fills the vent of a completely eroded scoria cone. The source for the Woodward Creek lavas, bisected by and well exposed in the high eastern headwall scarp of the Skamania Landslide Complex, consists of a plug partly encased in agglutinated scoria. Woodward Creek flows are notable for the presence of dark spheroidal pyroxene xenocrysts, some with reaction rinds of fine-grained olivine as large as 3 mm in diameter. The basaltic andesite of Little Creek is a flow remnant

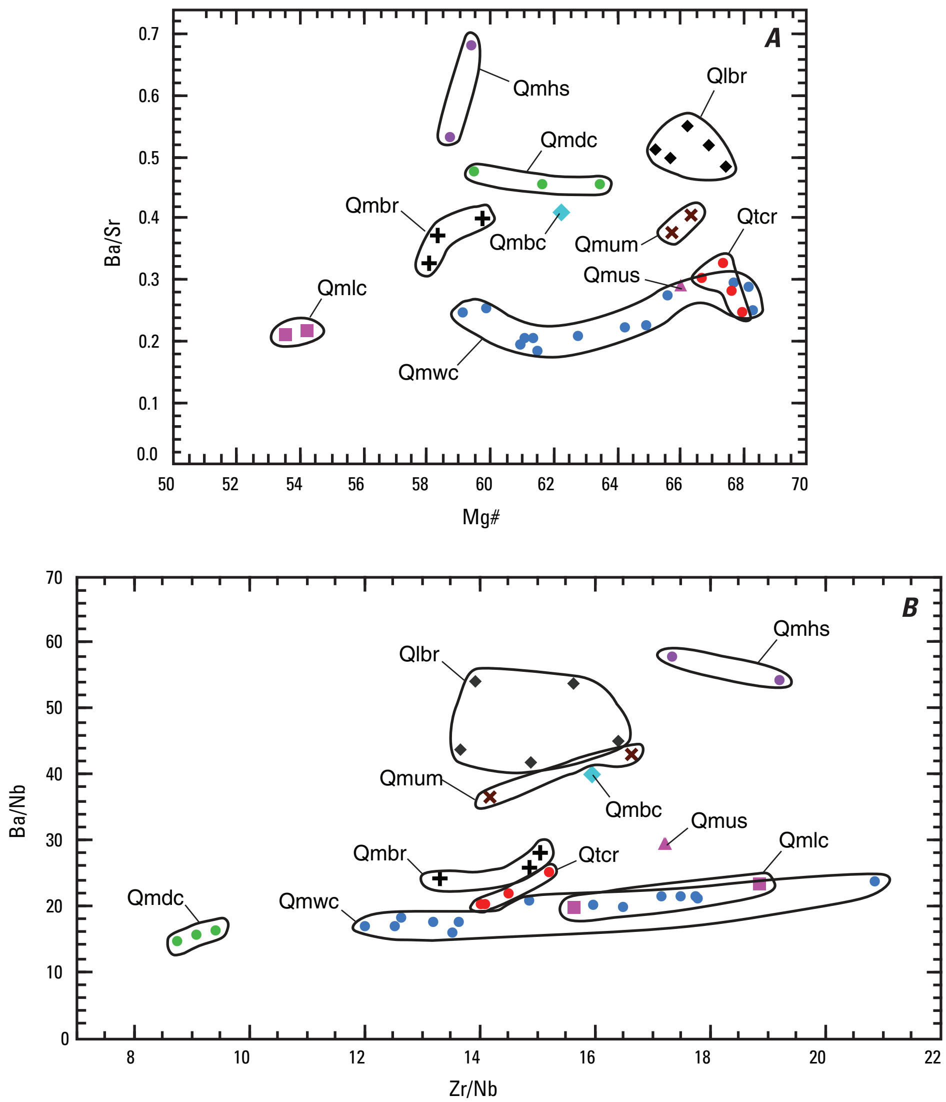

Figure 11. Selected chemical characteristics of Pleistocene volcanic and subvolcanic rocks in the Beacon Rock 7.5′ quadrangle. *A*, Ba/Sr versus Mg# (atomic ratio 100Mg/(Mg+Fe^{2+}) with Fe^{2+} set to 0.85 × Fe^{total}). *B*, Ba/Nb versus Zr/Nb. See Description of Map Units for unit identities.

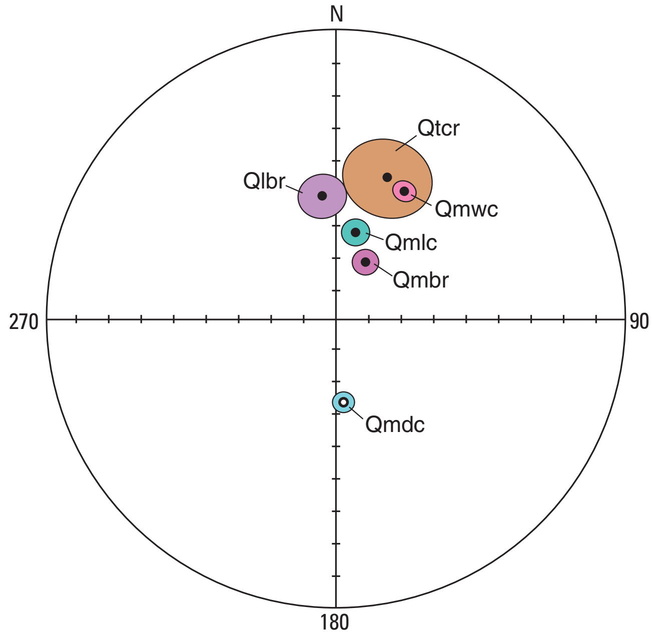

Figure 12. Paleomagnetic directions for Quaternary volcanic rocks in the Beacon Rock 7.5′ quadrangle. Dots show lower-hemisphere (normal) directions. Open circles show upper-hemisphere (reversed) directions. Thin lines outline areas of 95 percent confidence intervals. See Description of Map Units for unit identities.

banked against the east side of Hardy Ridge. It may have issued from the same vent as Woodward Creek. The Duncan Creek unit consists of several small flow remnants scattered along the top of the western scarp of the Skamania Landslide Complex. The location of its source is unknown but probably to the east in the area now underlain by landslide debris.

Most of the other Quaternary volcanic rocks in the map area are normally magnetized and were emplaced during the Bruhnes polarity chron. Little Beacon Rock, composed of coarse agglutinated scoria cut by irregular to tabular basalt intrusions, is the dissected core of a small volcano that generated a basalt flow (Qlbr) that overlies the Eagle Creek Formation to the northwest. It was active at 498±7 ka (table 4). The elevation of the vent complex at Little Beacon Rock is about 250 m lower than the flow remnant, suggesting that the vent complex is a large slump block.

The Quaternary volcanic rocks west of McCloskey Creek are on the east edge of a short north-south cluster of volcanoes in the adjacent Bobs Mountain quadrangle (Evarts and others, 2009; R.C. Evarts, unpub. mapping). Two scoria cones mark the vents for a series of basaltic andesite flows that moved westward into the ancestral Washougal River. These flows, the basaltic andesite of Boyles Creek (Qmbc) and the basaltic andesite of Hard Scramble Creek (Qmhs), are distinguished by their relatively high contents of large-ion lithophile elements such as potassium, barium, and strontium (table 3; figs. 2, 10). $^{40}Ar/^{39}Ar$ age determinations for this unit in the adjacent Bobs Mountain quadrangle show that most of these eruptions occurred between 260 ka and 290 ka (Fleck and others, 2014). During this time span, the andesite of McCloskey Creek (Qamc) issued from a dome at the south end of the McCloskey Creek cluster, about 1 km west of map area (R.C. Evarts, unpub. mapping). Two small mapped volcanic units, the basaltic andesite of upper McCloskey Creek (Qmum) and the basaltic andesite of upper Hard Scramble Creek (Qmus) have not been dated and their magnetic polarity is unknown. They underlie the other flow units in the McCloskey Creek cluster and differ chemically, with much lower K_2O contents; they presumably record an older eruptive episode.

The youngest volcano in the map area, as well as in the entire Boring Volcanic Field, is the basaltic andesite of Beacon Rock (Qmbr). This 250-m-high monolith (see cover photograph) has long been recognized as the exhumed neck of an ancient volcano, presumably a cinder cone (Williams, 1916; Hodge, 1938; Hammond, 1980; Hammond and Korosec, 1983; Waters, 1973). Its 58-ka $^{40}Ar/^{39}Ar$ age is surprisingly young considering the normal decay rates of cinder cones (Wood, 1980). The explanation must be that the enclosing scoria deposits were completely washed away by the late Pleistocene cataclysmic floods (16,000–12,000 ^{14}C yrs. B.P.; Waitt, 1985, 1994; Atwater, 1986; Benito and O'Connor, 2003; Clague and others, 2003); the largest flood would have totally engulfed Beacon Rock (Benito and O'Connor, 2003).

Alluvial and Mass-Wastage Deposits

Landslide and Talus Deposits

One of the most prominent geologic features in the Beacon Rock quadrangle is the huge Skamania Landslide Complex (Qls), one of the largest of a series of landslides that extends nearly continuously along the north side of the Columbia River Gorge from Cape Horn to Dog Mountain (Palmer, 1977). The complex underlies about 35 km^2 of the map area and consists of several geomorphic domains that apparently represent landslides of different ages. Like most of the large gorge slides, the Skamania complex is closely associated with exposures of the mechanically weak Eagle Creek Formation, particularly where overlain by thick sections of resistant Grande Ronde Basalt or Pleistocene lava flows (Hodge, 1938; Wise, 1970; Waters, 1973; Palmer, 1977; Hammond, 1980). At least some large slide events in the map area, however, evidently result from failure of water-saturated Eagle Creek strata without benefit of a superincumbent load. Waters (1973) emphasized the role of the thick saprolitic paleosol at the base of the Eagle Creek Formation in lubricating the Bonneville and other gorge slides, but, in the map area, failure planes appear to occur within as well as at the base of that unit. Periodic repairs to Washington State Route 14 and secondary roads, as well as the existence of incipient scarps behind the present landslide headwalls, testify to the active nature of parts of the slide complex.

Although the Skamania Landslide Complex is by far the largest, landslides are common in all areas underlain by the Eagle Creek Formation, such as those on the flanks of Hamilton Mountain, in upper Hamilton Creek, and in the headwaters of Deep Creek. Landslides are dispersed throughout

Figure 13. Three Corner Rock, a mass of basaltic andesite that occupied the throat of a now-eroded, approximately 1-Ma scoria cone. Barren rock outcrop is approximately 35 m tall.

areas underlain by older rocks as well, where they are generally associated with weathered or zeolitic volcaniclastic beds (Tt, Tvs), and the large landslide complex in Hamilton Creek valley formed where lavas flows of the Hamilton Creek rest on volcaniclastic rocks.

In addition to landslides formed by discrete failure events, talus deposits (Qt) created by slower incremental disintegration are common beneath cliffs composed chiefly of lava flows. In some places, the basal contacts of these units are buried for many kilometers by talus aprons; particularly extensive deposits are present at the base of the lava flows of Hamilton Creek in the northeast part of the quadrangle and beneath the Grande Ronde Basalt on the ridge west of Hardy Creek, the west slope of Hamilton Mountain, and Birkenfeld Mountain. Barren, post-landslide talus accumulations are also common at the base of steep landslide scarps.

Holocene and Pleistocene Alluvium of Tributary Streams

Most of the streams in the map area, including the Washougal River, occupy bedrock channels. The local accumulations of alluvium (Qa) along them consist predominantly of coarse sand and gravel. The alluvium in Hamilton Creek is exceptionally coarse, composed of boulders as large as 4 m in diameter that have weathered out of the Eagle Creek Formation.

The Washougal River in the map area is commonly flanked by strath terraces, with surfaces 2 to 5 m above the riverbed, that are mantled by as much as 6 m of cobble gravel ($Qtdw_u$). These are little weathered and probably late Pleistocene or Holocene.

Holocene Outburst-Flood Deposits

The bench directly east of Beacon Rock is underlain by gravel inferred to have been deposited by outburst flooding from breaching of the Bonneville landslide, which blocked the Columbia River about 7 km upstream between A.D. 1425 and 1450 (O’Connor and Burns, 2009). Breaching was likely soon after damming, seemingly before A.D. 1482, judging from correlative outburst flood deposits downstream that underlie Mount St. Helens Kalama-age (A.D. 1479 or 1482) tephra.

Structural Features

Oligocene and early Miocene strata of the ancestral Cascade volcanic arc generally strike northeast and dip southeast in the map area. Dips within the three major unconformity-bounded packages exhibit a clear decrease with time (see cross sections *A–A′* and *B–B′*). Abundant bedding measurements in the older, volcaniclastic-dominated strata give an average dip of about 25°. Although most deviations from this trend are attributable to localized deformation around intrusions, the flattening of dips in the northwestern part of the map reflects regional structure. Attitudes in the lava flows of Hamilton Creek are not as obvious because depositional contacts are rarely exposed and commonly irregular. Most measurements in this unit are from platy parting in lava flows, although variable attitudes of platy parting approximate original horizontal. These measurements are consistent with trends inferred from tracing individual flows within the unit; both trends indicate a regional dip of 5° to 15°. Volcaniclastic beds of the Eagle Creek Formation are insufficiently exposed in the map area to obtain reliable attitudes, but pronounced platy parting in some lava flows dips south to southeast at less than 10°. These dips probably are primary and represent deposition on the surface of a south-sloping fan. Tracing of individual flows shows that the Grande Ronde Basalt strikes northwest and dips southwest at about 2°.

The differential dips displayed by the unconformity-bounded rock packages indicate that the Oligocene strata were deformed prior to deposition of the lava flows of Hamilton Creek and that further mild southeasterly tilting took place prior to deposition of the Eagle Creek Formation. Late Oligocene strata in the Washougal area, approximately 6 km to the southwest, are oriented similarly to those in the Beacon Rock quadrangle (Evarts and others, 2013), but correlative beds in the poorly exposed intervening area instead strike west or southwest and exhibit shallower dips (R.C. Evarts, unpub. mapping), suggesting that these beds have been gently warped. Corresponding strata in the adjacent Bonneville Dam quadrangle strike west-northwest and dip south at low angles (Wise, 1961, 1970; R.C. Evarts, unpub. mapping), defining a shallow, southeast-plunging syncline that transects the northeastern part the map area. Broad open folds in pre-middle Miocene strata are typical of the Cascade Range of southwestern Washington (Wise, 1970; Hammond, 1980; Evarts and Swanson, 1994). These structures are large, and defining the trend of the fold axes requires mapping over areas much larger than a 7.5-minute quadrangle. While most folding apparently occurred prior to emplacement of the lava flows of Hamilton Creek, tilting of those flows indicates that deformation continued into the early Miocene. Whether deformation continued during deposition of the Eagle Creek Formation and the Grande Ronde Basalt is uncertain, because dips in the Eagle Creek Formation are likely depositional. The onlap relation between the Columbia River Basalt Group and the Eagle Creek Formation may simply record emplacement of the massive basalt flows against an eroded, south-sloping, volcano flank that locally defined the north margin of the middle Miocene trans-arc lowland (Tolan and Beeson, 1984). The slight regional southwest tilting that affects the approximately 16-Ma Grande Ronde flows may relate to late uplift of the Cascade Range and (or) to mild, long-term, north-south compression as manifested in the Yakima fold belt (Beeson and others, 1989; Beeson and Tolan, 1990).

Faults

Only a few faults, with east-west, northeast, or northwest strikes, were mapped in the Beacon Rock quadrangle; all are steep and exhibit only minor vertical offsets. Those cutting only Oligocene rocks are marked by outcrops of sheared, brecciated, or altered rock; the displacements and lateral extents of these structures are highly uncertain. North of Hamilton Mountain, an east-west fault offsets Grande Ronde Basalt flows by about 25 m. Faults in the upper McCloskey Creek area that juxtapose Columbia River Basalt Group flows against the Eagle Creek Formation appear to display larger displacements, but relief on the erosional unconformity between these two units makes it impossible to determine offsets with confidence. Some or all of these faults may be primarily strike-slip structures that accommodated the region-wide, clockwise, vertical-axis rotations determined from paleomagnetic studies (Beck and Burr, 1979; Wells and Heller, 1988; Hagstrum and others, 1999). No faults definitely cut Pleistocene volcanic rocks, thus none are known to have moved during the Quaternary.

Geologic Resources

Known geologic resources available in the Beacon Rock quadrangle are limited to nonmetallic industrial materials, chiefly aggregate for road construction and similar purposes. Small rock pits that provide material for logging roads in the northern part of the map area have been developed in various lava-flow and intrusive units. Road metal has also been obtained from large blocks of Grande Ronde Basalt in the Skamania Landslide complex.

Geologic Evolution

The ancestral Cascade volcanic arc initiated by 40 Ma and was continuously active for 20 m.y. (Priest, 1990; Smith, 1993; Evarts and Swanson, 1994; Sherrod and Smith, 2000). Volcanic activity diminished significantly by the middle Miocene, coincident with eruption of flood basalt flows of the Columbia River Basalt Group. The oldest rocks in the Beacon Rock quadrangle record deposition within a regional intra-arc fluvial system that received episodic influxes of debris flows, pyroclastic flows, and lava flows from contemporaneous volcanic centers. These late Oligocene to early Miocene rocks exhibit minor to pervasive zeolite-facies metamorphism owing to shallow burial. Localized propylitic alteration in the Washougal River area probably reflects the existence of a shallow, unexposed intrusion of substantial size. Shortly after deposition, these strata were folded and partly eroded. At about 22 Ma, porphyritic mafic to intermediate lava flows (lava flows of Hamilton Creek) buried the eroded surface of the mildly tilted older strata. The preserved flows were probably deposited on the lower flanks of a volcanic edifice that was centered to the west, perhaps in the area of Hard Scramble Creek. These eruptions were followed by another period of nondeposition, lasting less than 2 m.y., when tilting of the strata continued and the Hamilton Creek volcano was deeply eroded. This erosional episode produced a surface with more than 100 m of topographic relief. A thick saprolitic soil profile developed on uplands between drainages. Between 20 and 19.5 Ma, this surface was buried by a south-sloping fan of coarse volcaniclastic debris (Eagle Creek Formation) probably derived from a field of andesitic and dacitic domes (Wise, 1970; Waters, 1973), including some located in the map area. Cessation of Eagle Creek volcanism marked the beginning of a long hiatus in arc volcanism in southern Washington and northern Oregon, when a 60-km-wide valley, the Cascade trans-arc lowland of Beeson and others (1989) and Beeson and Tolan (1990), developed through the ancestral Cascade Range. This lowland, which apparently existed during deposition of the Eagle Creek Formation (Beeson and others, 1989), was presumably occupied by an ancestral Columbia River.

Between 16.5 and 12 m.y. ago, massive flood-basalt flows entered western Oregon and Washington from the east through the trans-arc lowland. The route of the modern Columbia River in the map area closely coincides with the northern margin of the lowland, which is delineated by the unconformable contact between the Grande Ronde Basalt and Eagle Creek Formation. During a roughly 1.2-m.y. period, voluminous Grande Ronde Basalt and early Wanapum Basalt flows inundated much of the back-arc region, forming vast horizontal sheets that filled the subsiding trans-arc lowland (Beeson and others, 1989; Beeson and Tolan, 1990). The flows issued so rapidly that the ancestral Columbia River was rarely able to re-establish integrated drainage between eruptions. The discontinuous distribution and variable thickness of many Grande Ronde Basalt flows in the map area, however, indicate that they possess a more lobate form in this area at the margin of the flood-basalt field than they do in the Columbia Basin. Although the lobate character may reflect emplacement dynamics (Self and others, 1997; Thordarson and Self, 1998), we believe that inter-eruption erosion by streams along the northern margin of the trans-arc lowland was also a factor. Streams flowing out of highlands to the north were able to locally incise the flows and underlying Eagle Creek beds between emplacement events, as shown by the paleocanyon fill relations of an Ortley member flow that is well exposed on Hamilton Mountain (fig. 10). The existence of such streams implies that a major trunk river was localized by the edge of the flow field during intervals between basalt eruptions. Such a stream would have captured and transported away any sediment carried in from the north by tributary streams, thus accounting for the virtual absence of sedimentary interbeds within the nearby Columbia River Basalt Group. Observed banking of Grande Ronde Basalt flows against the Eagle Creek Formation demonstrates that flood-basalt flows flowed around a highland composed of andesitic to dacitic volcanic centers and did not completely blanket a low-elevation, low-relief Cascade Range in southernmost Washington at this time (Mackin and Cary, 1965; Mitchell and Montgomery, 2006).

The youngest Columbia River Basalt Group flows in the Beacon Rock quadrangle belong to the 15-Ma Frenchman Springs Member of the Wanapum Basalt. At least two later flood-basalt flows passed through the trans-arc lowland, routed by ancestral Columbia River canyons located south of the map area (Waters, 1973; Tolan, 1982; Tolan and Beeson, 1984).

Arc volcanism was renewed in the late Pliocene, about 4 to 3 Ma, as voluminous low-potassium tholeiite flows erupted in the Cascade Range south of the map area (Tolan and Beeson, 1984; Conrey and others, 1996a, 2004). This influx of basaltic volcanic material from the northern Oregon Cascade Range eventually forced the ancestral Columbia River northward to its present location (Tolan and Beeson, 1984).

Beginning about 2.6 Ma, mafic volcanic activity began to spread westward from the Cascade Range into the Portland Basin to form the Boring Volcanic Field (Treasher, 1942; Trimble, 1963; Allen, 1975; Conrey and others, 1996b; Evarts and others, 2009). Somewhat later, volcanism extended northward across the Columbia River (Hammond and Korosec, 1983), and several small, monogenetic eruptive centers formed in and adjacent to the map area within the past million years.

The modern Columbia River Gorge was formed as the Cascade Range axis arched upward during the past 2 m.y (Tolan and Beeson, 1984; Mustoe and Leopold, 2014). Tilting of Grande Ronde flows in the map area probably reflects a combination of this broad uplift superimposed on mild north-south compression that produced the Yakima fold belt (Reidel and others, 1989b, 2003).

The quadrangle lies well beyond the limits of Pleistocene glaciers emanating from the Cascade Range. No evidence exists for glacial ice in the Washougal drainage and no sediments of likely outwash origin are found in the map area. Cataclysmic outburst floods from glacial Lake Missoula coursed through the Columbia River Gorge in the latest Pleistocene (Bretz, 1925; Trimble, 1963; Allison, 1978; O'Connor and Baker, 1992; Waitt, 1994, 1996; Benito and O'Connor, 2003) and probably during earlier Pleistocene glaciations. Erosion of bedrock by the huge floods was probably limited, but they doubtless excavated significant quantities of talus and other unconsolidated debris from the base of gorge cliffs (Waitt, 1994), as well as removed the scoria deposits housing the Beacon Rock plug. In this reach of the Columbia River, the largest floods were about 240 m deep (Benito and O'Connor, 2003). Most of the large slope failures along the gorge, such as the Skamania Landslide Complex, appear to postdate the cataclysmic floods, but the floods may have played a role in promoting slides by preferentially eroding the weakly consolidated Eagle Creek Formation and thus undercutting and oversteepening slopes capped by lava flows.

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Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[See figure 18 (sheet 2) for sample locations and table 4 for unit assignments. Preferred age shown in bold; for plateau ages, steps used to calculate age shown in bold. Analytical techniques described in Fleck and others (2014). --, not determined; Wtd, weighted]

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
				06BV-G633 Plagioclase IRR253-87 J = 0.00211592					
550	1.66216E-16	8.1438	7.8075	58.13962	393.14141	0.28946	0.00099	0.065460	23.273±2.613
625	6.0442E-16	29.6138	26.7119	18.95227	403.77861	0.15803	0.00095	0.026646	26.185±0.935
700	5.309E-16	26.0117	44.8319	10.73890	395.60875	0.12882	0.00098	0.020453	24.729±0.941
775	2.92748E-16	14.3433	38.7901	14.10144	386.48832	0.13545	0.00101	0.023488	27.844±1.295
850	1.17425E-16	5.7533	18.1085	30.74764	373.55515	0.18795	0.00106	0.085942	28.019±2.796
925	1.01343E-16	4.9654	19.2457	27.60780	153.86344	0.11773	0.00306	0.111912	22.441±2.727
1000	3.09423E-17	1.5160	3.1920	88.37206	299.83922	0.37206	0.00140	10.785405	13.386±10.173
1100	4.86903E-17	2.3856	13.1353	46.27887	342.75000	0.23029	0.00118	0.219630	29.770±5.399
1250	1.4832E-16	7.2670	29.7490	37.72643	321.79051	0.17817	0.00128	0.051954	53.634±2.217
				Wtd Mean Plateau age (Ma)			**MSWD = 1.3**		**25.780±0.548**
	Intercept = 293.0±6.1			Isochron age (Ma)			MSWD = 1.11		26.166±1.014
				Integrated age (Ma)					27.629±0.689
				06BV-G700B Plagioclase IRR253-82 J = 0.00221534					
550	1.55961E-16	0.6988	22.5447	16.71654	11.67381	0.04696	0.04460	0.00235	15.115±2.390
625	6.78876E-16	3.0419	38.7861	15.34791	12.93587	0.03532	0.04021	0.00024	23.839±0.678
700	1.53969E-15	6.8991	63.3062	9.77171	14.08902	0.01599	0.03689	0.00047	24.785±0.327
775	2.68925E-15	12.0502	85.2486	7.08893	14.59076	0.00752	0.03561	0.00017	24.225±0.177
850	3.88034E-15	17.3872	92.8930	6.54898	14.71305	0.00559	0.03531	0.00025	24.387±0.125
925	4.27408E-15	19.1516	93.7448	6.47058	14.57904	0.00535	0.03564	0.00007	24.315±0.128
1000	3.25692E-15	14.5938	86.4504	6.98395	14.46110	0.00715	0.03594	0.00015	24.201±0.151
1075	2.59891E-15	11.6454	92.5231	6.53369	14.27976	0.00555	0.03640	0.00009	24.228±0.177
1125	1.31179E-15	5.8779	81.7519	7.42387	14.03922	0.00842	0.03703	-0.00004	24.319±0.358
1200	8.69857E-16	3.8977	68.7224	8.50482	12.55449	0.01242	0.04145	0.00056	23.402±0.501
1400	1.06149E-15	4.7564	56.8427	10.78381	14.52248	0.01972	0.03578	0.00081	24.569±0.415
				Wtd Mean Plateau age (Ma)			**MSWD = 0.84**		**24.300±0.112**
	Intercept = 295.5±7.6			Isochron age (Ma)			MSWD = 1.05		24.290±0.091
				Total gas age (Ma)					24.220±0.068
				06BV-G685 Plagioclase IRR253-81 J = 0.00223501					
550	2.6877E-16	0.4102	6.0401	84.056142	8.84204	0.26970	0.05899	0.03162	20.476±3.427
625	8.59066E-16	1.3113	69.2354	8.685938	8.95685	0.01147	0.05823	0.01378	24.230±0.447
700	1.98469E-15	3.0294	86.1146	6.879232	9.19131	0.00573	0.05674	0.00402	23.874±0.204
775	3.69796E-15	5.6445	92.9978	6.417668	9.17245	0.00401	0.05686	0.00128	24.050±0.127
850	6.60559E-15	10.0826	95.4603	6.240220	9.28752	0.00348	0.05615	0.00187	24.007±0.085
925	9.70208E-15	14.8090	97.6099	6.123124	9.32759	0.00303	0.05591	0.00176	24.087±0.075
1000	8.88974E-15	13.5690	94.1271	6.304977	9.29239	0.00378	0.05612	0.04284	23.919±0.079
1075	1.05007E-14	16.0280	97.7726	6.109434	9.18887	0.00296	0.05675	0.00100	24.072±0.075
1150	8.80687E-15	13.4425	92.6957	6.450329	8.95849	0.00403	0.05822	0.00262	24.091±0.083
1250	1.23125E-14	18.7934	84.1123	7.101271	8.80606	0.00621	0.05924	0.00183	24.064±0.080
1400	1.88692E-15	2.8801	82.1836	7.292973	9.00098	0.00684	0.05795	0.00144	24.150±0.210
				Wtd Mean Plateau age (Ma)			**MSWD = 0.58**		**24.041±0.060**
	Intercept = 293.2±4.4			Isochron age (Ma)			MSWD = 0.89		24.046±0.061
				Total gas age (Ma)					24.030±0.028

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
				03BV-G122 Plagioclase IRR253-80 J = 0.00229562					
550	1.9251E-16	0.6072	42.6916	23.63018	17.92146	0.05076	0.02893	0.00220	41.214±2.145
625	6.84855E-16	2.1600	38.0070	16.54504	18.38332	0.03974	0.02819	0.00085	25.807±0.779
700	1.66028E-15	5.2365	66.1625	9.22046	18.86875	0.01571	0.02746	0.00036	25.049±0.333
775	2.82126E-15	8.8982	84.6697	6.96925	19.23067	0.00888	0.02694	0.00006	24.241±0.180
850	3.86859E-15	12.2015	89.4242	6.52316	19.34642	0.00763	0.02677	0.00021	23.967±0.133
925	4.32794E-15	13.6503	90.7341	6.35989	19.64489	0.00737	0.02636	0.00026	23.716±0.157
1000	3.71851E-15	11.7281	81.2835	6.92487	20.30514	0.00994	0.02549	0.00023	23.147±0.172
1075	2.43643E-15	7.6845	89.4591	6.54402	19.69367	0.00772	0.02630	0.00044	24.059±0.203
1150	1.79815E-15	5.6713	75.4627	8.64367	18.90978	0.01235	0.02740	0.00162	26.771±0.288
1250	6.48583E-15	20.4562	94.8805	6.97525	19.38640	0.00651	0.02672	0.00132	27.169±0.122
1400	3.71156E-15	11.7062	93.5362	6.80669	20.41203	0.00707	0.02536	0.00086	26.162±0.164
				Wtd Mean Plateau age (Ma)					**none**
	Intercept = 351±99			Isochron age (Ma)			MSWD = 14		23.124±1.623
				Integrated age (Ma)					25.142±0.133
				Age Minimum (Ma) (Max Age)					**23.144±0.183**
				02BV-G51A Plagioclase IRR201-1 J = 0.00478381					
Step (°C)	**mol ^{39}Ar**	**% $^{39}Ar_K$ Rel**	**% $^{40}Ar^*$**	**$^{40}Ar/39Ar$**	**$^{37}Ar/^{39}Ar$**	**$^{36}Ar/^{39}Ar$**	**K/Ca**	**Cl/K**	**Age (Ma)**
550	8.9932E-16	0.9139	0.0208	61.47521	15.85845	0.20791	0.03060	--	11.098±4.182
625	2.62332E-15	2.6659	0.4228	6.17870	18.50077	0.01700	0.02620	--	22.687±0.605
700	4.65142E-15	4.7270	0.6935	3.82415	19.25469	0.00906	0.02510	--	23.043±0.369
775	8.06215E-15	8.1931	0.8224	3.27421	19.47233	0.00712	0.02480	--	23.397±0.259
825	9.25085E-15	9.4011	0.8675	3.08623	19.47400	0.00653	0.02480	--	23.264±0.198
875	1.23668E-14	12.5677	0.8989	2.92920	19.42311	0.00614	0.02490	--	22.882±0.189
925	1.4873E-14	15.1146	0.8684	2.97248	19.23560	0.00641	0.02514	--	22.432±0.186
975	1.74318E-14	17.7150	0.8976	2.92074	19.09835	0.00606	0.02530	--	22.778±0.183
1025	7.17961E-15	7.2962	0.6217	4.17984	18.91016	0.01040	0.02560	--	22.576±0.219
1075	6.25732E-15	6.3590	0.8571	3.01930	18.49766	0.00635	0.02620	--	22.478±0.207
1150	4.49298E-15	4.5660	0.8377	3.20131	18.22926	0.00658	0.02650	--	23.283±0.232
1250	5.30634E-15	5.3925	0.7897	3.34670	18.13803	0.00718	0.02670	--	22.947±0.219
1350	5.00651E-15	5.0878	0.7925	3.35999	18.31225	0.00720	0.02640	--	23.121±0.225
				Wtd Mean Plateau age (Ma)			**MSWD = 2.1**		**22.789±0.132**
	Intercept = 295±16			Isochron age (Ma)			MSWD = 2.5		22.748±0.264
				Integrated age (Ma)					22.755±0.136
				06BV-G650 Plagioclase IRR253-86 J = 0.00213787					
550	5.83788E-16	1.3070	71.6447	8.58382	5.22688	0.00964	0.10004	0.01351	23.646±0.473
625	1.88675E-15	4.2241	87.4890	6.85629	5.18719	0.00430	0.10081	0.00641	23.067±0.153
700	3.71793E-15	8.3239	94.3855	6.23519	5.47046	0.00266	0.09557	0.00204	22.638±0.102
775	5.66797E-15	12.6897	96.7699	6.08305	5.82202	0.00224	0.08978	0.00100	22.649±0.082
850	7.24149E-15	16.2126	96.7406	6.07487	6.25688	0.00236	0.08351	0.00167	22.618±0.079
900	5.64182E-15	12.6311	97.1921	6.04661	6.53984	0.00234	0.07988	0.00180	22.623±0.084
960	5.3727E-15	12.0286	97.3495	6.04005	6.65635	0.00234	0.07848	0.00193	22.636±0.084
1025	4.31441E-15	9.6593	91.1534	6.35215	6.69505	0.00371	0.07802	0.06314	22.293±0.092
1100	5.84032E-15	13.0756	92.4171	6.38748	6.34817	0.00335	0.08231	0.00764	22.720±0.092
1200	4.39874E-15	9.8481	91.6589	6.40671	6.17099	0.00348	0.08468	0.00335	22.599±0.099
				Wtd Mean Plateau age (Ma)			**MSWD = 1.5**		**22.599±0.061**
	Intercept = 269±28			Isochron age (Ma)			MSWD = 1.9		22.698±0.081
				Integrated age (Ma)					22.639±0.113

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington—Continued.

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
				05BV-G437 Plagioclase IRR253-83 J = 0.00219861					
550	2.49645E-16	0.9304	0.3404	804.46108	21.28735	2.71891	0.02430	0.04428	10.982±27.580
575	3.45343E-16	1.2879	1.8304	285.48357	20.24176	0.95394	0.02557	0.02154	20.887±7.179
600	2.86951E-16	1.0698	68.3150	8.32630	20.68857	0.01457	0.02501	0.00965	22.731±1.048
650	7.17922E-16	2.6766	61.3218	9.23221	20.62020	0.01771	0.02510	0.00720	22.625±0.467
700	1.08275E-15	4.0369	74.9164	7.41524	20.60276	0.01193	0.02512	0.00440	22.202±0.298
775	2.5131E-15	9.3693	86.6183	6.33784	20.68135	0.00853	0.02502	0.00226	21.943±0.157
850	3.70591E-15	13.8166	75.2990	7.30469	20.65020	0.01175	0.02506	0.00364	21.985±0.143
925	5.13166E-15	19.1318	61.6434	8.93493	20.68155	0.01725	0.02502	0.00300	22.015±0.159
1000	3.52997E-15	13.1615	84.3676	6.46038	20.55590	0.00904	0.02518	0.10450	21.785±0.143
1075	1.84136E-15	6.8686	95.0882	5.76518	19.89296	0.00640	0.02603	0.00666	21.901±0.191
1150	1.41665E-15	5.2886	92.0766	5.84356	18.69794	0.00667	0.02771	0.01480	21.481±0.191
1250	5.99243E-15	22.3621	97.4560	5.66545	19.27165	0.00576	0.02688	0.00120	22.048±0.096
				Wtd Mean Plateau age (Ma)			**MSWD = 1.05**		**21.943±0.056**
	Intercept = 295.0±1.3			Isochron age (Ma)			MSWD = 1.5		21.907±0.142
				Integrated age (Ma)					21.860±0.161
				02BV-G52A Plagioclase IRR248-78 J = 0.00276831					
550	1.31094E-16	0.0157	-6.2312	17.63126	218.87917	0.12356	0.00205	0.25599	-6.337±4.510
625	5.67747E-16	0.0678	17.6943	13.31649	244.21438	0.10421	0.00180	0.26046	13.983±1.545
700	6.76344E-16	0.0808	29.5569	9.71182	227.34679	0.08565	0.00196	0.15955	16.797±1.137
775	5.82629E-16	0.0696	52.6237	6.87545	138.24987	0.04902	0.00345	0.04408	19.781±1.162
850	7.83399E-16	0.0936	57.0138	7.30261	88.69470	0.03500	0.00557	0.06671	21.956±0.844
925	1.44616E-15	0.1727	71.5191	5.86323	113.89289	0.03694	0.00426	0.03409	22.509±0.592
1000	2.46518E-15	0.2944	52.1640	7.49636	123.19778	0.04599	0.00391	0.46484	21.139±0.475
1100	5.28557E-16	0.0631	33.1587	12.76443	65.50597	0.04684	0.00766	0.05160	21.962±1.257
1250	1.19242E-15	0.1424	40.8427	14.77957	95.49602	0.05581	0.00515	0.03929	31.898±0.779
				Wtd Mean Plateau age (Ma)			**MSWD = 1.5**		**21.592 ± 0.314**
	Intercept = 291±54			Isochron age (Ma)			MSWD = 1.8		21.704±3.550
				Total gas age (Ma)		21.683±0.314			
				04BV-G281A Plagioclase IRR248-79 J = 0.00269623					
550	7.78611E-16	0.8048	63.8260	5.98304	6.06039	0.00897	0.08623	0.04601	18.294±0.614
625	3.70929E-15	3.8341	74.5527	5.46825	6.72614	0.00653	0.07766	0.01794	19.533±0.181
700	8.5138E-15	8.8003	92.3224	4.46980	7.21191	0.00311	0.07241	0.00445	19.776±0.100
775	1.27963E-14	13.2270	97.1349	4.19702	7.45831	0.00243	0.07000	0.00168	19.542±0.076
850	1.6631E-14	17.1907	95.9164	4.22814	7.52476	0.00262	0.06938	0.00278	19.441±0.072
925	1.80708E-14	18.6789	97.5558	4.16115	7.58184	0.00240	0.06886	0.00243	19.461±0.069
1000	1.15855E-14	11.9754	89.5435	4.53688	7.60745	0.00367	0.06862	0.10128	19.476±0.086
1100	9.29497E-15	9.6078	94.9919	4.25909	7.43642	0.00274	0.07021	0.00426	19.394±0.090
1250	1.53638E-14	15.8809	91.4304	4.44880	7.15277	0.00323	0.07301	0.00669	19.494±0.078
				Wtd Mean Plateau age (Ma)			**MSWD = 1.3**		**19.501±0.049**
	Intercept = 294±14			Isochron age (Ma)			MSWD = 1.9		19.493±0.061
				Integrated age (Ma)					19.490±0.101

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington—Continued.

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
02BV-G55B Plagioclase IRR253-78 J = 0.00230644									
550	1.44733E-16	0.2109	1.4179	129.60535	6.47250	0.43408	0.08072	0.02245	7.664±9.290
625	9.13854E-16	1.3314	11.3694	39.57453	6.22527	0.12037	0.08394	0.00976	18.702±1.142
700	1.86467E-15	2.7167	47.6567	9.80398	6.34741	0.01909	0.08232	0.00142	19.419±0.299
775	3.86647E-15	5.6331	77.1486	6.00851	6.58324	0.00643	0.07935	0.00036	19.270±0.150
850	6.45686E-15	9.4071	84.6598	5.50484	6.89872	0.00473	0.07571	0.00025	19.376±0.118
925	9.79488E-15	14.2703	86.8374	5.39471	7.11781	0.00433	0.07337	0.00028	19.480±0.120
1000	9.17238E-15	13.3633	82.2793	5.71575	7.15626	0.00537	0.07297	0.00029	19.556±0.104
1075	1.05866E-14	15.4237	96.2676	4.86809	7.20983	0.00257	0.07243	0.00012	19.488±0.088
1150	9.19118E-15	13.3907	92.2013	5.06578	7.23264	0.00329	0.07220	0.00064	19.423±0.091
1250	1.66468E-14	24.2528	97.2912	4.84362	7.19906	0.00239	0.07254	0.00148	19.595±0.087
1400	7.62247E-15	11.1053	96.6717	4.86975	7.32712	0.00253	0.07126	0.00125	19.577±0.124
				Wtd Mean Plateau age (Ma)			**19.483±0.041**		**19.483±0.041**
	Intercept = 293.5±3.5			Isochron age (Ma)			MSWD = 0.79		19.493±0.061
				Integrated age (Ma)					19.452±0.446
06BV-G599 Plagioclase IRR253-89 J = 0.00208011									
550	3.03776E-16	0.6141	27.2997	19.37521	7.53407	0.04971	0.06930	0.02821	19.840±1.148
625	9.23517E-16	1.8669	75.0825	7.02927	7.35544	0.00792	0.07099	0.01040	19.793±0.304
700	1.9772E-15	3.9969	91.1998	5.87082	7.55998	0.00379	0.06906	0.00281	20.081±0.152
775	3.78027E-15	7.6417	95.2604	5.60133	7.69396	0.00298	0.06785	0.00133	20.015±0.090
850	6.50888E-15	13.1576	93.8193	5.66446	8.75394	0.00356	0.05959	0.00224	19.948±0.079
925	9.44494E-15	19.0928	97.2517	5.49804	7.92528	0.00266	0.06586	0.00162	20.059±0.069
1000	8.49972E-15	17.1820	94.2973	5.67161	7.79143	0.00321	0.06700	0.04043	20.062±0.073
1100	1.1319E-14	22.8812	98.5153	5.45682	7.75265	0.00238	0.06733	0.00253	20.164±0.067
1200	6.71135E-15	13.5669	97.7764	5.50414	7.18733	0.00236	0.07266	0.00393	20.180±0.074
				Wtd Mean Plateau age (Ma)			**MSWD = 0.85**		**20.071±0.034**
	Intercept = 260±39			Isochron age (Ma)			MSWD = 0.70		20.172±0.081
				Integrated age (Ma)					20.077±0.114
05BV-G345 Basaltic Andesite Groundmass IRR243-16 J = 0.00030841									
550	4.48138E-16	1.6661	12.9794	11.12044	3.86688	0.03381	0.13532	0.00069	0.805±0.116
625	1.95863E-15	7.2834	23.2068	8.00642	3.58676	0.02182	0.14592	0.00035	1.037±0.046
700	4.20471E-15	15.6396	34.0298	5.60834	3.24189	0.01343	0.16148	0.00025	1.064±0.021
775	6.7049E-15	24.9447	42.1895	4.57464	2.93253	0.00977	0.17855	0.00025	1.076±0.014
850	6.63988E-15	24.7070	43.7517	4.34119	2.68928	0.00902	0.19474	0.00023	1.059±0.013
925	4.05652E-15	15.0924	37.7347	5.12993	2.86958	0.01161	0.18248	0.00027	1.079±0.018
1000	1.74908E-15	6.5028	22.3457	8.78490	3.89405	0.02418	0.13437	0.00048	1.095±0.045
1075	6.57287E-16	2.4392	8.1417	21.11479	6.48643	0.06744	0.08052	0.00653	0.961±0.115
1250	4.84571E-16	1.7249	2.7612	62.31435	63.68291	0.22297	0.00787	0.00417	1.002±0.274
				Wtd Mean Plateau age (Ma)			**MSWD = 0.43**		**1.068±0.008**
	Intercept = 294.5±3.3			Isochron age (Ma)			MSWD = 0.49		1.074±0.012
				Integrated age (Ma)					1.060±0.011
				Recoil Age (Ma) (50.00%)			MSWD = 0.570		1.067±0.008
				Recoil Age (Ma) (70.00%)			MSWD = 0.397		1.069±0.008

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
05BV-G345-2 Basaltic Andesite Groundmass IRR330-3 J = 0.00022190									
575	2.26682E-15	2.3274	26.6324	10.42079	3.74090	0.02689	0.13989	0.00026	1.114±0.065
650	8.06363E-15	8.2791	38.2426	7.27041	3.50392	0.01618	0.14937	0.00009	1.116±0.022
725	1.4044E-14	14.4192	50.8074	5.45717	3.13871	0.00997	0.16680	0.00019	1.112±0.013
800	2.27804E-14	23.3891	54.4607	4.80772	2.82015	0.00820	0.18568	0.00025	1.050±0.009
875	2.2373E-14	22.9708	55.0158	4.72762	2.65474	0.00794	0.19727	0.00027	1.043±0.010
950	1.48165E-14	15.2124	49.2232	5.38104	2.74542	0.01002	0.19075	-0.00007	1.062±0.012
1025	7.15785E-15	7.3491	29.8109	7.93146	3.90167	0.01994	0.13411	0.00069	0.949±0.038
1100	3.20081E-15	3.2863	16.5930	12.65444	4.78743	0.03705	0.10923	0.00244	0.843±0.081
1175	2.08366E-15	2.1393	6.5344	27.07588	7.53116	0.08775	0.06930	0.00735	0.712±0.136
1250	6.10894E-16	0.6272	2.1682	93.30018	100.19734	0.33708	0.00486	0.00859	0.871±0.609
				Wtd Mean Plateau age (Ma)			**MSWD = 0.75**		**1.050±0.006**
	Intercept = 291±14			Isochron age (Ma)			MSWD = 5.8		1.073±0.027
				Integrated age (Ma)					1.044±0.009
				Recoil Age (Ma) (50.00%)			MSWD = 6.781		1.048±0.013
				Recoil Age (Ma) (70.00%)			MSWD = 6.781		1.059±0.013
02BV-G10A Basaltic Andesite Groundmass IRR212-60 J = 0.00038322									
625	-4.71679E-17	-0.1806	-40.1675	6.92678	4.86952	0.03427	0.10029	-0.00070	-1.904±0.542
700	6.44608E-15	24.6911	28.3694	4.34717	3.98931	0.01166	0.12248	-0.00001	0.855±0.012
775	3.64944E-15	13.9821	39.5963	3.80269	3.66309	0.00880	0.13342	0.00007	1.044±0.012
850	2.69357E-15	10.3180	32.6875	4.70431	3.91222	0.01182	0.12490	0.00021	1.066±0.015
925	3.22424E-15	12.3561	38.9731	4.00045	3.30721	0.00919	0.14782	0.00029	1.080±0.014
1000	4.18905E-15	16.0639	42.9300	3.54153	2.38948	0.00751	0.20472	0.00039	1.053±0.011
1075	3.18284E-15	12.1894	35.7372	4.35437	4.23341	0.01066	0.11540	0.00098	1.079±0.012
1150	9.51301E-16	3.6242	25.8962	6.05268	11.60104	0.01844	0.04189	0.00052	1.092±0.037
1400	1.82104E-15	6.9558	33.5185	4.63376	7.93638	0.01266	0.06140	0.00053	1.079±0.019
				Wtd Mean Plateau age (Ma)			**MSWD = 1.2**		**1.065±0.006**
	Intercept = 304±11			Isochron age (Ma)			MSWD = 0.69		1.013±0.032
				Integrated age (Ma)					1.014±0.008
				Recoil Age (Ma) (50.00%)			MSWD = 1.521		1.060±0.008
				Recoil Age (Ma) (70.00%)			MSWD = 46.270		1.034±0.035
02BV-G10A-2 Basaltic Andesite Groundmass IRR330-99 J = 0.00022233									
675	1.159E-14	10.2956	19.3702	10.06327	3.13557	0.02834	0.16697	0.00293	0.783±0.049
750	2.24851E-14	19.9739	27.2042	7.57298	3.22673	0.01956	0.16224	0.00173	0.828±0.020
800	1.47875E-14	13.1360	36.6971	7.01274	2.85813	0.01582	0.18321	0.00020	1.034±0.017
850	1.2223E-14	10.8579	33.2327	7.79255	2.69454	0.01836	0.19436	-0.00038	1.041±0.028
900	7.87062E-15	6.9916	25.7266	10.19476	3.49162	0.02660	0.14990	-0.00005	1.054±0.029
950	5.38755E-15	4.7859	21.0792	12.72579	4.50823	0.03524	0.11602	-0.00025	1.079±0.083
1000	6.35182E-15	5.6424	24.4515	10.82402	3.96861	0.02879	0.13184	-0.00066	1.064±0.043
1075	9.41954E-15	8.3676	33.3380	7.89208	3.11838	0.01867	0.16789	-0.00043	1.057±0.024
1150	1.50414E-14	13.3616	31.9409	8.42637	2.83409	0.02020	0.18477	0.00031	1.081±0.016
1250	7.41563E-15	6.5874	32.9939	9.52940	11.84427	0.02494	0.04393	-0.00064	1.271±0.041
				Wtd Mean Plateau age (Ma)			**MSWD = 0.39**		**1.066±0.011**
	Intercept = 296±15			Isochron age (Ma)			MSWD = 0.49		1.055±0.061
				Integrated age (Ma)					0.997±0.011
				Recoil Age (Ma) (50.00%)			MSWD = 14.538		1.025±0.038
				Recoil Age (Ma) (70.00%)			MSWD = 15.210		1.004±0.032

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
05BV-G420 Basalt Groundmass IRR243-22 J = 0.00034704									
575	9.23178E-16	3.2106	17.6822	7.08576	3.77328	0.02081	0.13869	0.00100	0.786±0.099
650	3.32604E-15	11.5672	34.3812	5.18220	3.75586	0.01256	0.13933	0.00036	1.118±0.025
725	5.4489E-15	18.9501	43.3623	4.10426	3.36168	0.00881	0.15571	0.00038	1.117±0.017
800	5.43163E-15	18.8900	41.1017	4.08773	2.91363	0.00897	0.17971	0.00031	1.054±0.016
875	3.89499E-15	13.5459	32.0856	5.11961	3.62127	0.01278	0.14452	0.00053	1.031±0.022
950	2.72504E-15	9.4771	27.3738	5.87961	4.21574	0.01563	0.12409	0.00071	1.010±0.029
1025	2.59253E-15	9.0163	31.2295	5.40288	3.53098	0.01356	0.14823	0.00122	1.059±0.031
1125	2.92145E-15	10.1601	20.3717	7.87580	7.96924	0.02346	0.06547	0.00369	1.010±0.038
1250	1.49025E-15	5.1828	9.6719	15.70003	11.46978	0.05121	0.04537	0.00159	0.958±0.074
				Wtd Mean Plateau age (Ma)					no plateau
	Intercept = 291.1±4.9			Isochron age (Ma)			MSWD = 0.35		1.071±0.021
				Integrated age (Ma)					1.049±0.011
				Recoil Age (Ma) (50.00%)			MSWD = 5.022		1.051±0.022
				Recoil Age (Ma) (70.00%)			**MSWD = 3.416**		**1.061±0.017**
02BV-G90B Basaltic Andesite Groundmass IRR243-19 J = 0.00028544									
550	3.71263E-16	1.3868	-0.3563	9.282269	2.911145	0.032335	0.179870	0.004775	-0.017±0.155
625	1.95358E-15	7.2970	24.5779	6.536152	2.937820	0.017503	0.178229	0.000747	0.829±0.043
700	4.48549E-15	16.7539	35.1429	4.750594	2.954836	0.011259	0.177201	0.000263	0.861±0.018
775	6.39922E-15	23.9075	39.8847	4.185268	2.628741	0.009253	0.199229	0.000238	0.861±0.013
850	4.4186E-15	16.5110	30.8794	5.078650	2.360454	0.012543	0.221915	0.000373	0.808±0.017
925	3.34289E-15	12.4891	19.8148	7.209434	2.626073	0.020303	0.199432	0.000491	0.736±0.025
1000	3.14484E-15	11.7497	12.6881	11.045135	2.548776	0.033354	0.205490	0.000860	0.723±0.035
1100	1.52855E-15	5.6870	5.1832	23.176564	8.449868	0.076735	0.061723	0.003190	0.622±0.072
1250	1.14631E-15	4.2181	6.7803	24.314842	23.811172	0.083394	0.021663	0.001152	0.863±0.087
	Intercept = 289.2±6.7			Isochron age (Ma)			MSWD = 4.3		0.862±0.031
				Integrated age (Ma)					0.793±0.010
				Recoil Age (Ma) (50.00%)			**MSWD = 7.657**		**0.821±0.024**
				Recoil Age (Ma) (70.00%)			MSWD = 8.106		0.813±0.023
02BV-G116A Basaltic Andesite Groundmass IRR275-09 J = 0.00039181									
550	3.01502E-15	4.2240	53.5690	2.37824	2.24056	0.00436	0.23381	-0.00004	0.902±0.018
600	5.65517E-15	7.9234	57.4566	2.23757	2.11826	0.00382	0.24733	0.00008	0.910±0.012
650	8.65756E-15	12.1312	59.2339	2.13471	1.98156	0.00350	0.26442	0.00011	0.895±0.009
700	1.13944E-14	15.9678	59.5421	2.12662	1.83121	0.00343	0.28616	0.00017	0.896±0.008
750	1.06674E-14	14.9499	59.9815	2.07427	1.75270	0.00330	0.29899	0.00012	0.880±0.008
800	9.67167E-15	13.5532	57.2348	2.14280	1.88112	0.00363	0.27856	0.00019	0.868±0.025
850	7.39086E-15	10.3543	51.6211	2.35777	2.25395	0.00449	0.23242	0.00021	0.861±0.011
900	4.79195E-15	6.7101	43.1920	2.81135	2.91890	0.00623	0.17939	0.00034	0.860±0.016
950	3.00585E-15	4.2080	35.2803	3.37160	3.28049	0.00831	0.15957	0.00052	0.843±0.022
1025	2.99423E-15	4.1942	27.0181	4.23068	2.45607	0.01114	0.21326	0.00087	0.809±0.024
1100	2.01366E-15	2.8129	10.9294	9.73930	6.31944	0.03113	0.08266	0.00281	0.756±0.050
1200	1.16476E-15	1.5969	6.2374	22.19434	32.33075	0.07950	0.01586	0.00168	1.001±0.109
1325	9.9543E-16	1.3743	7.1952	16.86481	22.68993	0.05933	0.02275	0.00164	0.871±0.100
				Wtd Mean Plateau age (Ma)					none
	Intercept = 292.5±5.3			Isochron age (Ma)			MSWD = 3.2		0.887±0.010
				Integrated age (Ma)					0.876±0.006
				Recoil Age (Ma) (50.00%)			**MSWD = 2.739**		**0.879±0.007**
				Recoil Age (Ma) (70.00%)			MSWD = 2.454		0.879±0.006

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued.

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
QV01-36 Basaltic Andesite Groundmass IRR189-A-6 J = 0.00035207									
550	-1.40209E-18	-0.0014	-0.0274	25.98126	4.20709	0.09151	0.11612	--	-0.447±0.112
625	1.03219E-14	10.6346	0.0684	11.02339	3.51251	0.03574	0.13916	--	0.480±0.028
700	1.46348E-14	15.0782	0.1199	6.74436	3.01406	0.02093	0.16223	--	0.514±0.018
775	1.92054E-14	19.7873	0.1393	5.69057	2.65258	0.01732	0.18438	--	0.504±0.015
850	1.75851E-14	18.1178	0.1434	5.69740	2.51035	0.01722	0.19485	--	0.519±0.015
925	1.44932E-14	14.9323	0.1161	6.56929	3.44035	0.02062	0.14208	--	0.486±0.018
1000	8.92187E-15	9.1922	0.0802	8.83951	3.18738	0.02841	0.15339	--	0.451±0.024
1050	5.89761E-15	6.0763	0.0711	10.33048	2.46145	0.03317	0.19872	--	0.468±0.031
1100	3.05759E-15	3.1502	0.0441	16.91182	6.60017	0.05656	0.07389	--	0.476±0.056
1200	1.88502E-15	1.9421	0.0121	25.59089	32.60441	0.09472	0.01468	--	0.201±0.104
1400	1.05831E-15	1.090371075	0.02484819	35.17061	25.36495	0.12319	0.01897	--	0.565±0.146
				Wtd Mean Plateau age (Ma)			**MSWD = 1.2**		**0.498±0.007**
	Intercept =292.3±2.7			Isochron age (Ma)			MSWD = 1.07		0.541±0.020
				Integrated age (Ma)					0.490±0.006
				Recoil Age (Ma) (50.00%)			MSWD = 0.793		0.506±0.008
				Recoil Age (Ma) (70.00%)			MSWD = 1.758		0.501±0.010
QV98-17 Basaltic Andesite Whole Rock IRRCLX-B-21 J = 0.00040588									
600	2.29479E-16	0.4048	-0.1234	25.14080	3.58134	0.09659	0.13647	--	-2.248±0.541
675	3.88096E-15	6.8462	0.0146	7.99321	2.94377	0.02748	0.16611	--	0.085±0.039
750	5.22847E-15	9.2233	0.0236	2.48434	2.70277	0.00897	0.18095	--	0.043±0.025
825	1.00268E-14	17.6878	0.0495	1.73347	2.64366	0.00632	0.18500	--	0.063±0.014
900	1.43362E-14	25.2899	0.0606	1.53575	2.51051	0.00559	0.19483	--	0.068±0.011
975	1.02077E-14	18.0070	0.0208	1.57335	2.53788	0.00593	0.19273	--	0.023±0.014
1060	6.27121E-15	11.0628	0.0443	2.52663	3.10422	0.00904	0.15750	--	0.082±0.021
1160	4.03186E-15	7.1124	0.0216	3.89190	3.64973	0.01391	0.13391	--	0.062±0.033
1350	2.47487E-15	4.3658	-0.0120	7.63098	22.57346	0.03248	0.02136	--	-0.067±0.069
				Wtd Mean Plateau age (Ma)			**MSWD = 1.8**		**0.056±0.006**
	Intercept =295.7±7.2			Isochron age (Ma)			MSWD = 2.1		0.055±0.021
				Integrated age (Ma)					0.056±0.007
				Recoil Age (Ma) (50.00%)			MSWD = 3.452		0.054±0.013
				Recoil Age (Ma) (70.00%)			MSWD = 2.160		0.056±0.010
QV98-17-2 Basaltic Andesite Groundmass IRR189-4 J = 0.00037187									
550	3.38133E-16	0.27319	-0.04424	50.89200	3.71537	0.18089	0.13154	--	-1.494±0.390
600	2.27127E-15	1.83507	0.01214	15.93179	3.41456	0.05422	0.14316	--	0.130±0.068
675	1.43754E-14	11.61457	0.04967	3.61449	2.83720	0.01242	0.17236	--	0.121±0.013
750	1.15155E-14	9.30391	0.09368	1.92075	2.68445	0.00665	0.18219	--	0.121±0.013
825	3.25922E-14	26.33280	0.08651	1.56232	2.57505	0.00555	0.18994	--	0.090±0.007
900	2.40757E-14	19.45196	0.09182	1.29600	2.50179	0.00469	0.19551	--	0.080±0.008
975	1.65967E-14	13.40924	0.09130	1.43477	2.79139	0.00520	0.17519	--	0.088±0.010
1050	9.60201E-15	7.75793	0.05777	2.03125	3.85942	0.00756	0.12662	--	0.079±0.016
1100	5.4576E-15	4.40946	0.01845	3.62588	3.57889	0.01305	0.13657	--	0.045±0.025
1200	4.99987E-15	4.03964	0.03473	4.63396	10.09875	0.01797	0.04817	--	0.109±0.033
1400	1.94596E-15	1.57224	0.06300	8.10564	27.27211	0.03337	0.01762	--	0.349±0.084
				Wtd Mean Plateau age (Ma)			**MSWD = 0.82**		**0.084±0.005**
	Intercept =	298±19		Isochron age (Ma)			MSWD = 0.66		0.079±0.030
				Integrated age (Ma)					0.092±0.004
				Recoil Age (Ma) (50.00%)			MSWD = 0.484		0.086±0.005
				Recoil Age (Ma) (70.00%)			MSWD = 1.896		0.090±0.006

Appendix 1. $^{40}Ar/^{39}Ar$ incremental-heating data for samples from the Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued.

Step (°C)	mol ^{39}Ar	% $^{39}Ar_K$ Rel	% $^{40}Ar^*$	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	K/Ca	Cl/K	Age (Ma)
QV01-35B Basaltic Andesite Groundmass IRR203-8 J = 0.00042913									
550	1.2883E-15	1.8117	-0.0365	12.39052	3.27998	0.04438	0.14905	--	-0.346±0.232
625	8.78007E-15	12.3471	0.0194	3.78270	3.14988	0.01344	0.15522	--	0.057±0.037
700	1.35659E-14	19.0772	0.0250	2.15958	2.63919	0.00787	0.18532	--	0.042±0.013
775	1.97302E-14	27.7458	0.0456	1.80305	2.39012	0.00650	0.20467	--	0.064±0.010
840	1.24489E-14	17.5065	0.0391	2.04524	2.79654	0.00744	0.17487	--	0.062±0.014
900	6.30539E-15	8.8670	0.0243	3.01532	4.03227	0.01109	0.12117	--	0.057±0.024
960	3.56462E-15	5.0128	0.0352	4.69351	5.14368	0.01677	0.09492	--	0.129±0.041
1025	3.14426E-15	4.4217	0.0069	7.97078	4.18617	0.02796	0.11671	--	0.043±0.049
1100	2.07033E-15	2.9114	-0.0029	27.31662	21.07084	0.09863	0.02291	--	-0.062±0.108
1200	2.12532E-16	0.2989	-0.0115	93.13997	34.82139	0.32861	0.01373	--	-0.84±0.696
				Wtd Mean Plateau age (Ma)			**MSWD = 0.84**		**0.058±0.006**
	Intercept = 296.0±4.8			Isochron age (Ma)			MSWD = 1.04		0.055±0.015
				Integrated age (Ma)					0.047±0.009
				Recoil Age (Ma) (50.00%)			MSWD = 0.964		0.060±0.007
				Recoil Age (Ma) (70.00%)			MSWD = 0.643		0.057±0.007

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[X-ray fluorescence analyses. Map No., see figure 16 (sheet 2). Rock-type names assigned in accordance with IUGS system (Le Maitre, 2002) applied to recalculated analyses. FeO*, total Fe calculated as FeO; Mg#, atomic ratio 100 Mg/(Mg+Fe^{2+}) with Fe^{2+} set to 0.85 x Fe^{total}. Modal analyses, secondary minerals counted as primary mineral replaced. --, not present. Analyses by D.M. Johnson Cornelius and R.M. Conrey at Peter Hooper GeoAnalytical Laboratory of Washington State University, Pullman, Washington, using methods described in Johnson and others (1999)]

Map No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Field sample No.	02BV-G76	06BV-G634A	06BV-G743	06BV-G712	06BV-G657B	06BV-G630	06BV-G766B	06BV-G692	09BV-G1280
Latitude (N)	45°43.929'	45°43.707'	45°42.502'	45°43.599'	45°44.507'	45°42.922'	45°41.954'	45°44.227'	45°44.742'
Longitude (W)	122°05.986'	122°05.218'	122°05.768'	122°04.247'	122°04.230'	122°06.179'	122°05.641'	122°03.790'	122°03.467'
Map unit	Tob	Tba	Tba	Tba	Tba	Tba	Tba	Tba	Tba
Rock type	Basalt	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	50.54	52.84	53.51	53.99	53.74	53.95	54.58	54.42	54.32
TiO_2	0.90	1.22	1.70	1.53	1.90	1.62	1.73	1.74	1.49
Al_2O_3	17.22	17.03	15.52	16.01	15.82	18.59	15.17	15.17	16.56
FeO*	8.90	9.23	10.93	10.23	10.54	8.36	11.11	11.13	9.28
MnO	0.16	0.16	0.20	0.18	0.20	0.15	0.21	0.20	0.18
MgO	8.17	4.79	4.08	4.42	3.84	2.75	4.09	3.82	3.55
CaO	11.82	8.36	8.21	8.75	8.08	8.65	8.30	8.02	8.14
Na_2O	2.10	2.93	3.45	3.26	3.46	3.25	3.35	3.40	3.43
K_2O	0.24	0.98	0.86	1.00	0.67	1.08	0.93	1.12	1.11
P_2O_5	0.10	0.16	0.27	0.21	0.27	0.25	0.26	0.26	0.25
Total	100.14	97.69	98.73	99.58	98.52	98.65	99.74	99.28	98.30
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	50.47	54.09	54.20	54.22	54.55	54.69	54.72	54.81	55.25
TiO_2	0.90	1.24	1.72	1.54	1.93	1.64	1.73	1.75	1.51
Al_2O_3	17.20	17.43	15.72	16.08	16.06	18.84	15.21	15.28	16.85
FeO*	8.89	9.45	11.07	10.27	10.70	8.47	11.14	11.21	9.44
MnO	0.16	0.16	0.20	0.18	0.20	0.15	0.21	0.21	0.18
MgO	8.16	4.91	4.13	4.44	3.90	2.79	4.11	3.85	3.61
CaO	11.80	8.56	8.32	8.79	8.20	8.77	8.32	8.08	8.28
Na_2O	2.10	2.99	3.49	3.27	3.52	3.30	3.36	3.42	3.49
K_2O	0.24	1.00	0.88	1.00	0.68	1.09	0.94	1.13	1.13
P_2O_5	0.09	0.16	0.27	0.21	0.27	0.25	0.26	0.26	0.26
Mg#	65.8	52.7	44.2	47.6	43.7	41.2	43.7	42.0	44.9
Modes (volume percent)									
Plagioclase	6.6	20.5	1.0	0.3	0.1	27.2	1.7	0.4	10.5
Clinopyroxene	0.1	1.3	trace	0.1	trace	0.8	trace	--	0.9
Orthopyroxene	--	--	--	--	--	--	--	--	1.3
Olivine	--	5.1	trace	trace	--	1.2	--	--	--
Fe-Ti Oxide	--	0.1	--	--	--	--	--	--	trace
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Quartz	--	--	--	--	--	--	--	--	--
Groundmass	93.3	73.0	99.0	99.6	99.9	70.8	98.3	99.6	87.3
No. points counted	825	850	850	850	850	850	800	850	850
Texture (rock/ groundmass)	porphyritic/ trachytic	seriate/ intergranular	~aphyric/ trachytic	aphyric/ trachytic	aphyric/ trachytic	seriate/ intergranular	sparsely phyric/ trachytic	aphyric/ trachytic	porphyritic/ trachytic
Trace element analyses (parts per million)									
Ba	101	223	218	222	223	267	263	266	232
Rb	4	25	18	31	14	29	15	30	33
Sr	303	248	268	264	298	307	256	253	288
Y	15	32	34	34	35	36	36	38	35
Zr	47	144	146	157	156	188	168	168	167
Nb	3.6	7.3	8.2	8.3	10.2	11.0	8.7	9.4	10.9
Ni	107	29	10	16	4	5	18	17	20
Cu	108	122	169	166	70	99	169	244	166
Zn	71	88	106	96	107	87	110	110	100
Cr	635	61	13	20	3	10	33	32	40
Sc	38	31	38	37	36	27	36	38	30
V	235	228	279	287	277	216	301	301	238

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Field sample No.	06BV-G719C	06BV-G686	06BV-G679B	06BV-G583	06BV-G689B	06BV-G745	06BV-G764	06BV-G706	06BV-G704
Latitude (N)	45°43.489'	45°40.851'	45°40.798'	45°44.856'	45°43.964'	45°42.850'	45°42.248'	45°42.782'	45°43.735'
Longitude (W)	122°04.018'	122°06.016'	122°07.147'	122°00.224'	122°03.651'	122°05.253'	122°05.730'	122°04.624'	122°03.723'
Map unit	Tba	Tba	Tba	Tba	Tba	Tba	Tba	Td	Td
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Andesite	Dacite	Dacite
Analyses as reported (weight percent)									
SiO_2	55.24	55.60	55.29	55.43	56.13	56.53	58.35	63.45	65.98
TiO_2	1.77	1.83	1.66	1.48	1.89	1.43	1.70	1.02	0.97
Al_2O_3	15.41	15.72	16.03	16.51	14.97	15.99	15.74	15.33	14.25
FeO*	10.32	9.72	9.37	8.69	10.39	9.39	9.13	6.54	6.29
MnO	0.18	0.18	0.16	0.18	0.19	0.18	0.18	0.15	0.13
MgO	3.68	3.17	3.29	3.42	3.01	3.33	2.69	1.29	1.05
CaO	7.64	7.63	7.76	7.42	6.99	7.85	6.37	4.48	3.23
Na_2O	3.49	3.33	3.24	3.69	3.85	3.22	4.19	4.40	4.68
K_2O	1.03	1.38	1.23	1.32	0.95	1.24	1.19	2.20	2.14
P_2O_5	0.34	0.32	0.28	0.27	0.41	0.21	0.34	0.28	0.28
Total	99.10	98.88	98.32	98.40	98.77	99.37	99.88	99.13	99.00
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	55.75	56.23	56.24	56.32	56.82	56.89	58.42	64.00	66.64
TiO_2	1.78	1.85	1.69	1.50	1.91	1.43	1.71	1.03	0.98
Al_2O_3	15.55	15.89	16.30	16.78	15.15	16.09	15.76	15.46	14.39
FeO*	10.41	9.83	9.53	8.83	10.52	9.45	9.14	6.60	6.35
MnO	0.18	0.19	0.16	0.19	0.20	0.18	0.18	0.15	0.13
MgO	3.71	3.20	3.35	3.48	3.04	3.35	2.70	1.30	1.06
CaO	7.71	7.72	7.89	7.54	7.08	7.90	6.38	4.52	3.27
Na_2O	3.52	3.36	3.29	3.75	3.90	3.24	4.19	4.44	4.73
K_2O	1.04	1.39	1.25	1.34	0.96	1.25	1.19	2.22	2.16
P_2O_5	0.34	0.33	0.29	0.27	0.41	0.21	0.34	0.28	0.29
Mg#	43.0	40.9	42.9	45.6	38.0	42.8	38.2	29.4	26.1
Modes (volume percent)									
Plagioclase	8.9	0.2	--	19.4	0.2	0.3	1.4	9.0	3.3
Clinopyroxene	1.1	--	--	2.5	--	--	0.3	1.4	0.5
Orthopyroxene	0.7	trace	--	0.5	--	--	0.2	1.4	0.4
Olivine	1.6	--	--	1.4	--	--	trace	--	--
Fe-Ti Oxide	trace	trace	--	0.1	trace	--	0.2	0.3	0.2
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	87.7	99.8	100.0	76.1	99.8	99.7	97.9	87.9	95.6
No. points counted	850	850	--	850	850	850	850	790	850
Texture (rock/ groundmass)	seriate/ intersertal	aphyric/ microseriate	microphyric/ intersertal	porphyritic/ intergranular	aphyric/ pilotaxitic	aphyric/ microseriate	sparsely phyric phyric/ pilotaxitic	seriate/ pilotaxitic	sparsely phyric/ micropoikil-itic
Trace element analyses (parts per million)									
Ba	269	307	289	298	286	258	299	408	464
Rb	28	47	47	38	39	19	32	67	65
Sr	262	264	271	354	262	247	277	223	182
Y	40	40	37	31	42	34	41	55	57
Zr	195	232	198	180	202	172	207	292	323
Nb	11.9	12.5	9.9	9.6	12.3	8.5	11.8	15.4	17.0
Ni	19	9	13	17	5	10	2	4	0
Cu	176	202	229	98	132	152	93	60	44
Zn	107	107	99	102	109	94	107	90	111
Cr	56	15	18	21	4	17	3	10	1
Sc	33	32	32	28	34	30	28	21	20
V	201	281	245	209	179	245	170	71	19

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5′ quadrangle, Skamania County, Washington.—Continued

Map No.	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Field sample No.	06BV-G780	06BV-G792A	06BV-G719A	08BV-G1197	06BV-G600	02BV-G88	06BV-G626	06BV-G589	06BV-G601[1]
Latitude (N)	45°41.135'	45°40.579'	45°43.513'	45°38.354'	45°43.330'	45°41.033'	45°41.317'	45°44.569'	45°44.624'
Longitude (W)	122°06.663'	122°06.259'	122°04.054'	122°05.270'	122°03.494'	122°03.736'	122°04.789'	122°02.599'	122°02.469'
Map unit	Td	Ttw	Tts	Thba	Thba	Thba	Thba	Thba	Thba
Rock type	Dacite	Dacite Welded Tuff	Rhyolite Welded Tuff	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	63.30	67.23	73.38	49.66	51.82	51.67	52.72	53.07	53.88
TiO_2	0.77	0.54	0.48	1.35	1.08	1.04	1.07	1.17	1.08
Al_2O_3	14.16	15.29	12.39	18.78	19.59	18.73	18.88	18.95	19.73
FeO*	5.53	3.85	3.04	8.34	7.96	8.00	8.06	7.75	7.27
MnO	0.13	0.05	0.11	0.19	0.16	0.14	0.14	0.13	0.13
MgO	0.93	0.46	0.31	4.31	4.74	5.40	5.23	4.34	3.63
CaO	4.65	2.60	1.94	9.32	9.99	9.57	9.44	9.11	9.48
Na_2O	3.79	3.89	4.46	3.08	3.07	2.98	3.09	3.36	3.36
K_2O	0.91	2.86	2.23	0.30	0.50	0.73	0.77	0.73	0.72
P_2O_5	0.21	0.08	0.10	0.22	0.14	0.15	0.15	0.17	0.16
Total	94.39	96.84	98.43	95.57	99.05	98.39	99.54	98.78	99.45
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	67.07	69.42	74.55	51.96	52.32	52.51	52.96	53.73	54.17
TiO_2	0.81	0.56	0.49	1.42	1.09	1.05	1.08	1.19	1.09
Al_2O_3	15.00	15.79	12.58	19.65	19.78	19.03	18.96	19.19	19.84
FeO*	5.86	3.97	3.09	8.73	8.03	8.13	8.09	7.84	7.31
MnO	0.14	0.05	0.11	0.20	0.16	0.14	0.14	0.13	0.13
MgO	0.99	0.47	0.31	4.51	4.79	5.49	5.25	4.40	3.65
CaO	4.92	2.68	1.97	9.75	10.09	9.73	9.49	9.22	9.53
Na_2O	4.02	4.02	4.53	3.23	3.09	3.03	3.10	3.40	3.38
K_2O	0.97	2.95	2.26	0.32	0.50	0.74	0.78	0.74	0.73
P_2O_5	0.23	0.08	0.10	0.23	0.15	0.15	0.15	0.17	0.16
Mg#	27.3	20.5	17.6	53.1	55.8	59.0	57.8	54.3	51.3
Modes (volume percent)									
Plagioclase	1.9	18.0	2.0	31.3	23.3	31.5	27.4	24.3	25.7
Clinopyroxene	0.6	0.3	0.3	--	0.8	0.9	1.4	0.3	0.6
Orthopyroxene	0.6	1.8	0.2	0.4	--	--	--	--	--
Olivine	--	--	--	2.4	4.3	3.8	5.5	1.9	2.9
Fe-Ti Oxide	0.1	0.1	0.1	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	96.8	79.8	97.4	65.9	71.6	63.8	65.7	73.5	70.8
No. points counted	850	850	850	830	850	850	850	850	850
Texture (rock/groundmass)	sparsely phyric/pilotaxitic	porphyritic/eutaxitic	sparsely phyric/eutaxitic	seriate/intersertal	seriate/intergranular	seriate/intergranular	seriate/intergranular	porphyritic/intergranular	porphyritic/intergranular
Trace element analyses (parts per million)									
Ba	507	482	493	205	169	182	187	200	192
Rb	86	99	65	8	12	19	20	20	23
Sr	295	161	112	406	416	466	467	386	420
Y	47	21	48	24	18	17	19	19	19
Zr	290	278	329	146	89	88	95	105	94
Nb	14.8	10.1	17.2	7.6	4.6	4.4	4.5	6.3	5.4
Ni	0	5	0	13	33	30	29	18	20
Cu	50	50	21	144	109	69	125	152	105
Zn	88	46	85	93	79	79	79	80	74
Cr	3	8	2	39	45	49	43	43	42
Sc	17	10	12	29	26	25	26	26	23
V	18	57	4	218	210	210	212	202	192

[1] Block in talus deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Field sample No.	06BV-G614	06BV-G618	02BV-G11B	02BV-G85[2]	06BV-G594	06BV-G703	06BV-G615	02BV-G52A	02BV-G64B
Latitude (N)	45°42.617'	45°42.595'	45°43.298'	45°42.920'	45°43.816'	45°43.048'	45°42.386'	45°43.316'	45°40.588'
Longitude (W)	122°03.891'	122°04.958'	122°03.421'	122°04.283'	122°03.345'	122°03.824'	122°04.279'	122°03.665'	122°03.944'
Map unit	Thba	Thba	Thba	Thba	Thba	Thba	Thba	Thba	Thba
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	53.46	54.55	55.07	54.63	55.31	55.83	56.10	56.18	55.83
TiO_2	1.10	1.12	1.47	1.03	1.03	1.05	1.71	1.13	1.25
Al_2O_3	18.84	17.71	17.89	18.27	18.76	18.25	16.72	18.43	17.91
FeO*	7.78	8.00	8.71	7.73	7.18	7.54	8.84	7.49	7.67
MnO	0.14	0.17	0.14	0.15	0.13	0.14	0.16	0.15	0.13
MgO	4.15	4.19	3.19	4.51	3.40	3.77	3.26	3.30	3.05
CaO	8.86	8.39	8.08	8.73	8.69	8.10	7.50	8.25	7.70
Na_2O	3.28	3.51	3.45	3.34	3.53	3.63	4.00	3.61	3.69
K_2O	0.81	0.75	1.18	0.72	0.89	0.78	1.05	0.81	1.10
P_2O_5	0.16	0.15	0.27	0.16	0.17	0.18	0.29	0.18	0.21
Total	98.58	98.54	99.45	99.26	99.09	99.27	99.61	99.53	98.55
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	54.23	55.35	55.38	55.04	55.82	56.24	56.31	56.44	56.65
TiO_2	1.12	1.13	1.48	1.03	1.04	1.05	1.71	1.14	1.27
Al_2O_3	19.11	17.98	17.99	18.40	18.93	18.38	16.78	18.51	18.18
FeO*	7.90	8.12	8.76	7.79	7.25	7.60	8.88	7.53	7.78
MnO	0.14	0.17	0.14	0.15	0.14	0.14	0.16	0.15	0.13
MgO	4.20	4.25	3.21	4.54	3.43	3.80	3.27	3.31	3.10
CaO	8.99	8.51	8.12	8.80	8.77	8.16	7.52	8.29	7.82
Na_2O	3.33	3.56	3.47	3.37	3.56	3.66	4.01	3.63	3.75
K_2O	0.83	0.77	1.19	0.73	0.90	0.78	1.05	0.82	1.12
P_2O_5	0.17	0.15	0.27	0.16	0.17	0.18	0.29	0.18	0.22
Mg#	53.1	52.7	43.6	55.2	50.0	51.4	43.7	48.1	45.9
Modes (volume percent)									
Plagioclase	1.9	18.0	2.0	31.3	23.3	31.5	27.4	24.3	25.7
Clinopyroxene	0.6	0.3	0.3	--	0.8	0.9	1.4	0.3	0.6
Orthopyroxene	0.6	1.8	0.2	0.4	--	--	--	--	--
Olivine	--	--	--	2.4	4.3	3.8	5.5	1.9	2.9
Fe-Ti Oxide	0.1	0.1	0.1	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	96.8	79.8	97.4	65.9	71.6	63.8	65.7	73.5	70.8
No. points counted	850	850	850	850	850	850	850	850	850
Texture (rock/ groundmass)	sparsely phyric/ pilotaxitic	porphyritic/ eutaxitic	sparsely phyric/ eutaxitic	seriate/ intersertal	seriate/ intergranular	seriate/ intergranular	seriate/ intergranular	porphyritic/ intergranular	porphyritic/ intergranular
Trace element analyses (parts per million)									
Ba	208	208	284	186	218	226	281	228	270
Rb	25	21	38	23	25	24	30	34	33
Sr	373	364	341	370	400	387	364	364	357
Y	20	24	30	18	18	18	27	19	27
Zr	113	93	174	97	109	114	153	111	156
Nb	6.5	4.4	11.7	5.1	5.0	6.0	9.0	5.5	8.3
Ni	21	12	11	26	9	20	13	8	10
Cu	59	50	152	99	97	84	167	98	59
Zn	82	82	96	84	79	82	100	78	94
Cr	33	27	23	56	23	33	27	23	22
Sc	26	28	27	25	24	23	27	24	25
V	203	234	213	198	188	181	249	198	187

[2]Block in landslide deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Field sample No.	02BV-G83A	02BV-G70	06BV-G585	06BV-G720	06BV-G622	02BV-G69	02BV-G53	06BV-G616	06BV-G791
Latitude (N)	45°42.150'	45°41.993'	45°44.599'	45°42.672'	45°41.721'	45°41.721'	45°42.908'	45°42.285'	45°40.530'
Longitude (W)	122°05.249'	122°01.972'	122°00.717'	122°01.024'	122°04.598'	122°04.598'	122°03.356'	122°04.567'	122°06.198'
Map unit	Thba	Thba	Thba	Tha	Tha	Tha	Tha	Tha	Tha
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite
Analyses as reported (weight percent)									
SiO_2	55.78	55.98	56.44	56.42	56.69	57.36	56.59	57.19	57.24
TiO_2	1.05	0.95	1.15	1.28	1.25	1.15	1.45	1.16	0.93
Al_2O_3	17.73	16.45	19.11	17.53	17.46	17.73	16.61	17.06	18.49
FeO*	7.55	7.07	6.41	6.99	7.39	7.32	8.27	7.44	6.67
MnO	0.14	0.14	0.13	0.10	0.13	0.14	0.14	0.14	0.12
MgO	3.74	5.33	2.72	3.65	3.27	4.02	2.50	3.48	2.94
CaO	7.46	7.76	7.87	7.42	7.48	7.26	6.85	7.17	7.57
Na_2O	3.75	3.04	3.91	3.71	3.81	3.51	3.78	3.86	3.76
K_2O	0.85	1.58	1.13	1.46	1.07	1.18	1.38	1.14	0.98
P_2O_5	0.18	0.14	0.26	0.24	0.26	0.25	0.28	0.20	0.17
Total	98.24	98.44	99.13	98.80	98.82	99.92	97.86	98.84	98.88
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	56.78	56.86	56.94	57.11	57.37	57.41	57.83	57.86	57.89
TiO_2	1.07	0.97	1.16	1.30	1.27	1.15	1.48	1.17	0.94
Al_2O_3	18.05	16.71	19.28	17.74	17.67	17.74	16.98	17.26	18.70
FeO*	7.68	7.19	6.46	7.08	7.47	7.33	8.45	7.53	6.75
MnO	0.15	0.14	0.13	0.10	0.13	0.14	0.14	0.14	0.13
MgO	3.81	5.41	2.75	3.69	3.31	4.02	2.55	3.52	2.97
CaO	7.59	7.88	7.94	7.51	7.57	7.27	7.00	7.26	7.66
Na_2O	3.82	3.09	3.94	3.76	3.86	3.51	3.86	3.91	3.80
K_2O	0.87	1.61	1.14	1.48	1.09	1.18	1.41	1.16	0.99
P_2O_5	0.19	0.15	0.26	0.24	0.26	0.25	0.29	0.20	0.17
Mg#	51.4	61.6	47.3	52.5	48.5	53.5	39.3	49.8	48.3
Modes (volume percent)									
Plagioclase	25.4	16.4	31.2	25.5	25.2	21.8	16.1	25.2	31.2
Clinopyroxene	2.4	5.1	1.5	1.8	5.5	0.6	1.9	3.0	3.6
Orthopyroxene	1.5	3.3	0.4	2.6	2.4	4.7	0.3	2.4	4.6
Olivine	0.5	2.5	1.3	0.9	0.8	0.1	0.9	1.5	0.4
Fe-Ti Oxide	0.2	0.2	0.1	0.1	1.3	0.1	0.1	0.5	0.8
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	70.0	72.5	65.5	69.1	64.8	72.7	80.7	67.4	59.4
No. points counted	850	850	850	850	850	850	850	850	850
Texture (rock/ groundmass)	porphyritic/ intergran- ular	porphyritic/ intergranular	porphyritic/ intersertal	porphyritic/ pilotaxitic	porphyritic/ intergranular	porphyritic/ microgran- ular	porphyritic/ intergranular	porphyritic/ intergranular	porphyritic/ pilotaxitic
Trace element analyses (parts per million)									
Ba	223	285	284	313	300	298	322	309	245
Rb	23	48	33	44	40	28	44	35	33
Sr	357	407	424	416	342	417	325	346	379
Y	19	21	25	26	28	29	41	26	19
Zr	115	181	161	217	155	176	205	157	121
Nb	5.3	7.1	8.4	10.1	7.6	12.8	10.5	7.7	6.1
Ni	14	48	14	32	10	44	4	34	12
Cu	115	89	65	125	57	89	89	72	87
Zn	88	67	77	83	87	90	95	85	77
Cr	32	149	17	54	23	70	13	62	22
Sc	20	25	20	20	22	23	26	23	20
V	182	179	132	175	176	161	196	176	160

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5′ quadrangle, Skamania County, Washington.—Continued

Map No.	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**
Field sample No.	02BV-G52B	06BV-G579	09BV-G1276	02BV-G15	06BV-G625	05BV-G441	05BV-G435	09BV-G1338	02BV-G81[2]
Latitude (N)	45°43.330'	45°43.450'	45°42.875'	45°44.067'	45°41.099'	45°42.268'	45°41.550'	45°42.055'	45°41.517'
Longitude (W)	122°03.660'	122°01.285'	122°02.492'	122°01.431'	122°05.351'	122°00.898'	122°01.020'	122°03.318'	122°04.940'
Map unit	Tha	Tha	Tha	Tha	Tha	Tha	Tha	Tha	Tha
Rock type	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite	Andesite
Analyses as reported (weight percent)									
SiO_2	58.03	56.88	57.11	58.29	57.62	56.85	57.24	57.78	58.60
TiO_2	1.01	0.97	1.44	1.18	1.18	1.73	1.45	1.20	1.02
Al_2O_3	18.57	16.22	16.06	17.13	17.15	15.71	15.95	16.64	17.42
FeO*	6.64	6.95	7.64	7.06	7.08	8.20	7.65	7.25	6.62
MnO	0.12	0.11	0.13	0.14	0.11	0.14	0.14	0.15	0.11
MgO	3.00	4.51	3.24	3.72	3.06	2.20	3.13	3.42	2.80
CaO	7.36	7.01	6.39	6.86	6.89	6.16	6.38	6.48	6.58
Na_2O	3.95	3.20	3.70	3.47	3.97	3.99	3.70	3.46	4.11
K_2O	1.09	1.79	1.75	1.61	1.22	1.72	1.71	1.78	1.18
P_2O_5	0.18	0.15	0.29	0.22	0.20	0.42	0.29	0.21	0.20
Total	99.96	97.80	97.75	99.68	98.49	97.12	97.63	98.37	98.64
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	58.05	58.16	58.43	58.48	58.50	58.53	58.63	58.74	59.41
TiO_2	1.01	0.99	1.47	1.18	1.20	1.78	1.49	1.22	1.03
Al_2O_3	18.58	16.58	16.43	17.19	17.42	16.18	16.33	16.92	17.66
FeO*	6.64	7.10	7.81	7.08	7.19	8.45	7.83	7.37	6.71
MnO	0.12	0.12	0.13	0.14	0.12	0.14	0.15	0.16	0.11
MgO	3.00	4.61	3.31	3.73	3.11	2.27	3.20	3.47	2.84
CaO	7.36	7.17	6.53	6.88	6.99	6.35	6.54	6.58	6.67
Na_2O	3.95	3.28	3.79	3.48	4.03	4.11	3.79	3.52	4.17
K_2O	1.09	1.83	1.79	1.62	1.24	1.77	1.75	1.81	1.19
P_2O_5	0.18	0.16	0.30	0.22	0.21	0.43	0.30	0.22	0.21
Mg#	48.7	58.2	47.7	52.6	47.9	36.7	46.8	50.1	47.3
Modes (volume percent)									
Plagioclase	24.9	15.8	20.5	29.0	23.4	6.8	19.6	26.9	22.5
Clinopyroxene	1.4	3.6	2.5	4.0	4.1	0.2	2.1	3.5	3.1
Orthopyroxene	0.3	4.2	3.6	6.8	1.8	0.1	4.1	6.2	3.7
Olivine	0.7	1.1	--	0.1	0.4	trace	--	--	1.5
Fe-Ti Oxide	0.1	0.7	--	0.5	0.5	--	0.4	0.3	0.6
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	72.6	74.6	73.4	59.6	69.8	92.9	73.8	63.1	68.6
No. points counted	850	850	850	850	850	850	850	850	850
Texture (rock/ groundmass)	porphyritic/ intergranular	porphyritic/ intergranular	porphyritic/ pilotaxitic	porphyritic/ intersertal	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ microphyric	porphyritic/ cryptocrystalline	porphyritic/ intergranular
Trace element analyses (parts per million)									
Ba	270	307	391	347	300	396	373	375	287
Rb	30	57	61	43	40	58	60	62	41
Sr	357	379	320	450	342	352	349	334	353
Y	23	25	34	31	28	40	38	30	24
Zr	141	208	268	181	155	252	258	264	152
Nb	8.7	7.6	14.4	9.3	7.6	13.7	12.5	13.5	7.4
Ni	7	41	47	38	10	11	30	30	12
Cu	91	102	115	114	57	181	98	75	40
Zn	80	73	87	83	87	100	95	87	79
Cr	19	118	87	64	23	6	33	49	26
Sc	19	23	22	22	22	22	23	21	19
V	162	165	195	164	176	167	175	177	138

[2] Block in landslide deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5′ quadrangle, Skamania County, Washington.—Continued

Map No.	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**
Field sample No.	08BV-G1065	06BV-G577	05BV-G448	02BV-G11C	02BV-G63B	05BV-G427	06BV-G797	05BV-G432	05BV-G433[2]
Latitude (N)	45°39.620'	45°43.737'	45°42.605'	45°43.339'	45°40.523'	45°39.824'	45°39.440'	45°40.777'	45°40.614'
Longitude (W)	122°03.728'	122°01.571'	122°01.243'	122°03.353'	122°03.642'	122°01.243'	122°01.929'	122°01.068'	122°00.228'
Map unit	Tha	Tha	Tha	Thd	Thd	Teha	Teha	Teha	Teha
Rock type	Andesite	Andesite	Andesite	Dacite	Dacite basaltic	Hornblende basaltic	Hornblende andesite	Hornblende andesite	Hornblende
Analyses as reported (weight percent)									
SiO_2	59.33	60.54	61.03	65.99	67.38	54.72	56.05	56.17	56.39
TiO_2	1.48	1.20	1.19	0.50	0.64	1.04	1.01	1.02	1.00
Al_2O_3	15.47	15.76	15.34	14.78	15.04	17.79	17.86	17.50	17.39
FeO*	7.38	6.54	7.18	5.99	3.88	7.00	6.85	6.69	6.82
MnO	0.18	0.09	0.17	0.08	0.05	0.13	0.14	0.13	0.17
MgO	1.69	1.73	1.57	0.19	0.25	3.74	3.59	3.53	3.30
CaO	4.96	5.00	4.55	1.94	1.89	8.43	8.14	7.80	7.38
Na_2O	4.27	4.13	4.59	5.06	4.76	3.09	3.16	3.19	3.19
K_2O	1.84	1.97	1.89	2.41	2.62	1.89	1.85	1.89	1.85
P_2O_5	0.39	0.32	0.46	0.12	0.13	0.30	0.28	0.26	0.26
Total	96.99	97.28	97.97	97.06	96.64	98.14	98.93	98.17	97.74
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	61.17	62.23	62.30	67.99	69.72	55.76	56.66	57.21	57.69
TiO_2	1.53	1.23	1.21	0.52	0.66	1.06	1.02	1.04	1.02
Al_2O_3	15.95	16.20	15.66	15.23	15.57	18.12	18.06	17.82	17.79
FeO*	7.60	6.72	7.33	6.17	4.02	7.14	6.92	6.81	6.98
MnO	0.19	0.09	0.17	0.09	0.05	0.13	0.14	0.13	0.17
MgO	1.74	1.77	1.60	0.19	0.26	3.81	3.63	3.60	3.38
CaO	5.12	5.14	4.64	2.00	1.95	8.59	8.23	7.95	7.55
Na_2O	4.40	4.25	4.69	5.21	4.92	3.15	3.20	3.25	3.26
K_2O	1.90	2.02	1.92	2.48	2.71	1.93	1.87	1.92	1.89
P_2O_5	0.40	0.33	0.47	0.12	0.14	0.31	0.28	0.26	0.26
Mg#	33.1	36.3	31.9	6.3	12.3	53.3	52.6	53.0	50.9
Modes (volume percent)									
Plagioclase	0.3	16.6	0.6	10.2	8.4	12.0	11.6	10.2	14.1
Clinopyroxene	0.1	1.5	trace	--	--	0.3	1.0	0.8	1.2
Orthopyroxene	--	1.2	trace	1.0	1.3	1.5	1.4	1.5	2.9
Olivine	--	trace	0.1	--	--	--	--	--	--
Fe-Ti Oxide	--	0.5	trace	--	0.3	0.1	0.3	0.5	0.6
Hornblende	--	--	--	--	--	1.0	0.6	1.0	0.5
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	0.2	0.8	0.6	1.0
Groundmass	99.6	80.2	99.3	88.8	90.0	84.9	84.3	85.4	79.7
No. points counted	850	850	850	850	800	850	850	850	850
Texture (rock/ groundmass)	porphyritic/ intergran-ular	porphyritic/ pilotaxitic	~aphyric pilotaxitic	porphyritic/ micropoikil-itic	porphyritic/ micropoikil-itic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic
Trace element analyses (parts per million)									
Ba	403	420	434	572	611	685	618	571	611
Rb	81	68	60	77	81	28	29	30	33
Sr	303	286	300	183	167	1252	1157	1123	1060
Y	39	36	45	47	47	19	20	17	18
Zr	274	292	301	346	371	150	150	145	150
Nb	15.6	14.3	16.3	16.2	19.6	4.6	4.5	5.3	5.0
Ni	0	4	6	0	0	28	25	28	28
Cu	36	92	28	29	26	74	69	62	82
Zn	100	91	101	104	96	75	65	74	77
Cr	0	10	1	2	1	28	25	30	28
Sc	23	19	20	12	11	18	18	17	17
V	109	102	44	8	18	177	170	174	166

[2] Block in landslide deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**
Field sample No.	04BV-G281A	11BV-G1555	08BV-G1179[3]	05BV-G405A	05BV-G409	06BV-G599	05BV-G440A[3]	02BV-G61	02BV-G07[4]
Latitude (N)	45°38.535'	45°38.518'	45°41.691'	45°40.796'	45°40.305'	45°43.463'	45°41.882'	45°40.893'	45°41.011'
Longitude (W)	122°00.919'	122°00.830'	122°00.232'	122°04.514'	122°02.928'	122°02.522'	122°00.278'	122°03.789'	122°05.062'
Map unit	Teha	Teha	Tepa	Tepa	Tepa	Tepa	Tepa	Tehd	Tecu
Rock type	Hornblende andesite	Hornblende andesite	Hbl-Pyx andesite	Pyroxene andesite	Pyroxene andesite	Pyroxene andesite	Pyroxene andesite	Hornblende dacite	Hbl-Pyx andesite
				Analyses as reported (weight percent)					
SiO_2	57.59	57.51	55.08	58.55	58.20	59.49	59.69	63.85	59.34
TiO_2	0.98	0.99	0.98	1.00	0.99	0.91	0.88	0.70	0.97
Al_2O_3	17.61	17.35	18.12	16.85	16.98	16.91	16.53	17.06	17.16
FeO*	6.55	6.76	6.20	6.31	6.23	6.02	5.43	4.60	6.05
MnO	0.12	0.14	0.12	0.10	0.11	0.11	0.12	0.09	0.10
MgO	3.54	3.09	3.42	3.82	3.31	3.39	2.65	2.68	3.92
CaO	7.95	7.55	5.66	6.70	6.35	6.57	6.13	4.96	6.71
Na_2O	3.34	3.27	3.10	3.74	3.71	3.40	3.44	4.00	3.35
K_2O	1.33	1.74	1.37	1.37	1.39	1.98	2.10	1.69	1.91
P_2O_5	0.22	0.21	0.19	0.17	0.17	0.17	0.17	0.16	0.17
Total	99.24	98.61	94.25	98.60	97.43	98.96	97.13	99.78	99.68
				Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)					
SiO_2	58.03	58.32	58.44	59.38	59.74	60.12	61.45	63.99	59.53
TiO_2	0.99	1.01	1.04	1.01	1.01	0.92	0.91	0.70	0.97
Al_2O_3	17.75	17.60	19.22	17.09	17.43	17.09	17.02	17.10	17.22
FeO*	6.60	6.85	6.58	6.40	6.39	6.09	5.59	4.61	6.07
MnO	0.12	0.14	0.13	0.10	0.11	0.11	0.12	0.09	0.10
MgO	3.57	3.13	3.63	3.88	3.40	3.42	2.72	2.69	3.93
CaO	8.01	7.66	6.00	6.79	6.52	6.64	6.31	4.97	6.73
Na_2O	3.37	3.32	3.29	3.79	3.81	3.44	3.55	4.01	3.36
K_2O	1.34	1.77	1.46	1.39	1.42	2.00	2.16	1.69	1.92
P_2O_5	0.22	0.22	0.20	0.17	0.17	0.18	0.18	0.16	0.17
Mg#	53.3	49.3	55.1	56.3	53.4	54.4	51.3	55.1	57.7
				Modes (volume percent)					
Plagioclase	16.8	17.3	15.8	17.3	18.3	13.5	18.6	12.8	14.9
Clinopyroxene	0.5	0.5	3.3	1.8	1.3	2.1	1.4	--	3.2
Orthopyroxene	1.4	1.4	2.9	2.4	2.3	2.2	2.1	--	3.5
Olivine	--	--	--	0.8	1.0	--	--	--	1.4
Fe-Ti Oxide	0.3	0.3	0.5	0.2	0.3	0.6	0.4	0.4	0.4
Hornblende	1.3	0.5	0.4	--	--	0.5	0.2	8.0	--
Biotite	--	--	--	--	--	--	--	0.3	--
Other	0.6	0.8	--	--	--	--	0.1	--	--
Groundmass	79.1	79.2	77.1	77.5	76.8	81.1	77.2	78.5	76.6
No. points counted	850	820	830	850	850	830	850	850	770
Texture (rock/ groundmass)	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	porphyritic/ pilotaxitic	seriate/ intersertal	seriate/ intersertal	porphyritic/ felsitic	seriate/ intersertal
				Trace element analyses (parts per million)					
Ba	455	446	408	303	307	358	377	351	305
Rb	31	31	28	31	31	44	51	24	35
Sr	1035	1015	602	510	496	694	598	556	479
Y	16	19	24	18	17	22	22	17	19
Zr	131	138	217	153	152	188	202	121	155
Nb	3.4	6.4	7.6	7.1	6.5	6.5	7.7	8.2	8.2
Ni	23	25	25	58	52	23	21	28	53
Cu	72	67	59	64	143	57	74	40	80
Zn	74	75	77	76	76	61	65	52	70
Cr	25	27	34	76	74	34	32	19	78
Sc	18	16	17	17	17	17	16	14	15
V	160	162	150	149	146	141	136	89	144

[3] Block in debris-avalanche deposit?

[4] Block in lahar deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**	**81**
Field sample No.	02BV-G04B[4]	02BV-G864	02BV-G55B[5]	03BV-G170[4]	02BV-G024	02BV-G67A[5]	02BV-G875	06BV-G655B	06BV-G786A
Latitude (N)	45°40.316'	45°41.285'	45°41.376'	45°40.968'	45°39.061'	45°41.192'	45°41.377'	45°44.049'	45°41.680'
Longitude (W)	122°06.203'	122°03.320'	122°02.999'	122°04.528'	122°07.058'	122°01.815'	122°03.646'	122°04.428'	122°06.897'
Map unit	Tecu	Tecu	Tecu	Tecu	Tecu	Tecu	Tecu	Tiba	Tiba
Rock type	Pyroxene andesite	Pyroxene andesite	Pyroxene andesite	Pyroxene andesite	Hornblende andesite	Pyroxene dacite	Hornblende dacite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	59.77	59.88	58.89	61.90	60.66	62.14	69.24	52.98	52.49
TiO_2	0.88	0.90	0.91	0.81	0.85	0.76	0.46	1.56	1.35
Al_2O_3	17.46	17.30	16.79	16.70	17.59	17.03	16.83	17.53	17.57
FeO*	5.74	6.01	6.02	5.30	5.54	4.70	3.08	9.55	9.06
MnO	0.09	0.10	0.10	0.09	0.08	0.08	0.06	0.17	0.22
MgO	3.29	3.09	3.05	2.94	2.07	2.25	0.61	3.49	4.11
CaO	6.89	6.75	6.37	6.02	5.27	5.37	1.97	9.09	8.82
Na_2O	3.72	3.40	3.27	3.76	3.92	3.81	3.29	3.29	3.28
K_2O	1.51	1.67	1.68	1.80	1.32	1.74	2.23	0.79	0.44
P_2O_5	0.15	0.15	0.15	0.14	0.19	0.18	0.09	0.21	0.21
Total	99.50	99.26	97.23	99.45	97.48	98.04	97.87	98.66	97.54
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	60.07	60.33	60.56	62.24	62.23	63.38	70.75	53.70	53.81
TiO_2	0.88	0.91	0.93	0.82	0.87	0.77	0.47	1.58	1.38
Al_2O_3	17.55	17.43	17.27	16.79	18.04	17.37	17.20	17.77	18.01
FeO*	5.77	6.06	6.19	5.33	5.68	4.79	3.15	9.68	9.28
MnO	0.09	0.10	0.11	0.09	0.08	0.08	0.06	0.17	0.22
MgO	3.31	3.11	3.14	2.95	2.12	2.29	0.62	3.54	4.22
CaO	6.92	6.80	6.55	6.05	5.41	5.48	2.01	9.21	9.04
Na_2O	3.74	3.42	3.36	3.78	4.02	3.89	3.36	3.33	3.36
K_2O	1.52	1.68	1.73	1.81	1.35	1.77	2.28	0.80	0.45
P_2O_5	0.15	0.15	0.15	0.14	0.20	0.18	0.10	0.22	0.22
Mg#	54.7	52.1	52.3	53.9	44.5	50.6	29.8	43.8	49.4
Modes (volume percent)									
Plagioclase	17.9	20.4	21.9	28.0	22.4	19.3	6.4	14.1	18.5
Clinopyroxene	1.6	1.2	1.1	1.4	--	0.5	--	0.9	1.3
Orthopyroxene	3.4	4.1	2.9	3.6	2.0	2.8	--	--	2.0
Olivine	1.2	--	--	--	--	--	--	0.2	0.6
Fe-Ti Oxide	0.3	0.6	0.6	0.3	0.5	0.4	0.1	--	0.1
Hornblende	--	0.4	0.5	1.1	9.0	0.1	3.8	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	1.0	2.5	--	--	--	0.4	--	--
Groundmass	75.6	72.3	70.5	65.6	66.1	76.9	89.3	84.8	77.5
No. points counted	850	850	850	850	830	750	850	850	850
Texture (rock/ groundmass)	seriate/ felsitic	seriate/ pilotaxitic	seriate/ microphyric	seriate/ microphyric	seriate/ microphyric	seriate/ microphyric	seriate/ microphyric	seriate/ intergranular	seriate/ intersertal
Trace element analyses (parts per million)									
Ba	305	336	339	349	412	381	604	208	155
Rb	32	30	31	40	17	25	44	20	8
Sr	510	789	738	510	713	494	280	299	313
Y	22	19	19	21	20	13	11	29	32
Zr	151	131	134	179	123	150	107	136	156
Nb	8.0	5.6	5.6	7.4	7.0	9.3	10.3	6.9	7.9
Ni	37	23	20	34	33	22	16	12	16
Cu	50	89	25	42	47	27	20	167	125
Zn	61	65	63	61	62	72	39	101	94
Cr	74	30	30	43	32	29	13	17	27
Sc	17	15	16	14	12	10	9	33	32
V	131	144	147	124	102	91	46	296	229

[4] Block in lahar deposit.

[5] Block in lithic pyroclastic-flow deposit.

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
Field sample No.	02BV-G77	06BV-G676	06BV-G681	06BV-G779	03BV-G71A	07BV-G820	06BV-G770A	06BV-G799	06BV-G650
Latitude (N)	45°44.339'	45°40.827'	45°40.211'	45°41.346'	45°42.000'	45°44.916'	45°43.644'	45°41.643'	45°44.829'
Longitude (W)	122°06.364'	122°06.472'	122°07.297'	122°06.519'	122°01.673'	122°03.753'	122°06.269'	122°06.082'	122°04.654'
Map unit	Tiba	Tiba	Tiah	Tia	Tial	Tqd	Tid	Tid	Tidcr
Rock type	Basaltic andesite	Basaltic andesite	Andesite	Andesite	Andesite quartz diorite Diorite	Pyroxene	Dacite	Dacite	Rhyolite
Analyses as reported (weight percent)									
SiO_2	53.45	54.43	56.46	56.45	57.44	58.00	61.51	63.94	69.03
TiO_2	1.82	1.50	1.60	1.47	1.15	1.02	1.30	0.94	0.38
Al_2O_3	15.46	16.78	16.20	15.85	17.89	17.55	14.50	14.59	14.39
FeO*	10.38	9.28	8.99	8.29	6.55	6.61	7.61	6.26	4.42
MnO	0.18	0.19	0.16	0.14	0.10	0.13	0.15	0.14	0.09
MgO	3.69	3.46	2.75	3.16	3.48	2.55	1.65	1.23	0.26
CaO	8.66	8.47	7.50	7.17	6.60	6.38	4.89	3.92	1.59
Na_2O	2.93	3.22	3.40	3.43	4.37	4.39	4.65	5.06	4.93
K_2O	0.35	0.95	1.38	1.41	0.81	1.19	0.87	1.26	2.46
P_2O_5	0.23	0.21	0.31	0.30	0.29	0.19	0.37	0.25	0.07
Total	97.16	98.48	98.74	97.66	98.69	98.01	97.50	97.59	97.62
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	55.02	55.27	57.18	57.81	58.21	59.18	63.09	65.52	70.71
TiO_2	1.87	1.52	1.62	1.50	1.16	1.05	1.33	0.96	0.39
Al_2O_3	15.91	17.04	16.40	16.23	18.13	17.91	14.87	14.94	14.75
FeO*	10.68	9.42	9.11	8.49	6.63	6.74	7.81	6.42	4.53
MnO	0.19	0.19	0.16	0.14	0.10	0.13	0.15	0.15	0.09
MgO	3.80	3.51	2.78	3.23	3.53	2.60	1.69	1.26	0.26
CaO	8.91	8.61	7.59	7.34	6.69	6.51	5.01	4.01	1.63
Na_2O	3.01	3.27	3.44	3.51	4.43	4.47	4.77	5.19	5.05
K_2O	0.36	0.96	1.40	1.44	0.82	1.21	0.89	1.30	2.52
P_2O_5	0.24	0.21	0.31	0.31	0.29	0.19	0.38	0.26	0.07
Mg#	43.4	44.3	39.4	45.0	53.0	45.2	31.8	29.7	11.1
Modes (volume percent)									
Plagioclase	trace	15.5	31.8	11.5	--	24.5	0.9	6.7	14.7
Clinopyroxene	trace	0.2	0.7	1.6	--	1.6	0.1	1.8	0.3
Orthopyroxene	--	--	0.3	1.5	--	1.5	0.1	1.3	0.7
Olivine	trace	0.2	--	--	--	0.7	--	trace	--
Fe-Ti Oxide	--	--	--	--	--	0.4	0.1	0.2	0.1
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	1.7
Groundmass	100.0	84.1	67.2	85.4	100.0	71.3	98.8	90.0	82.5
No. points counted	--	850	850	850	--	850	850	850	780
Texture (rock/ groundmass)	aphyric/ intergran- ular	seriate/ intergranular	porphyritic/ intersertal	porphyritic/ intersertal	aphyric/ pilotaxitic	seriate/ hypidiomor- phic	~aphyric/ pilotaxitic	sparsely phyric/ pilotaxitic	porphyritic/ felsitic
Trace element analyses (parts per million)									
Ba	156	251	345	343	243	295	382	436	625
Rb	22	30	36	57	13	37	66	84	80
Sr	443	294	300	273	603	373	241	193	156
Y	27	31	41	40	14	24	45	54	54
Zr	120	149	231	259	132	155	281	318	357
Nb	6.3	8.1	11.2	13.1	9.4	7.4	13.6	16.8	18.6
Ni	7	8	10	21	47	2	1	1	0
Cu	201	182	163	16	62	66	106	50	20
Zn	100	95	102	92	98	82	95	93	117
Cr	12	18	19	29	57	7	3	3	2
Sc	35	34	28	25	12	20	22	19	16
V	302	274	188	189	128	147	70	44	0

Table 1. Chemical and modal analyses of igneous rocks of the ancestral Cascade volcanic arc, Beacon Rock 7.5′ quadrangle, Skamania County, Washington.—Continued

Map No.	**91**	**92**
Field sample No.	05BV-G513	11BV-G1554A
Latitude (N)	45°38.758′	45°38.591′
Longitude (W)	122°00.743′	122°00.885′
Map unit	Tipd	Tipd
Rock type	Pyroxene dacite	Pyroxene dacite
Analyses as reported (weight percent)		
SiO_2	62.14	64.68
TiO_2	0.76	0.67
Al_2O_3	16.11	15.67
FeO*	4.91	4.32
MnO	0.08	0.05
MgO	2.57	1.66
CaO	5.54	4.46
Na_2O	3.65	3.70
K_2O	1.97	2.15
P_2O_5	0.15	0.12
Total	97.87	97.47
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)		
SiO_2	63.49	66.36
TiO_2	0.78	0.68
Al_2O_3	16.46	16.08
FeO*	5.02	4.43
MnO	0.08	0.05
MgO	2.62	1.70
CaO	5.66	4.58
Na_2O	3.73	3.79
K_2O	2.01	2.21
P_2O_5	0.15	0.12
Mg#	52.8	45.2
Modes (volume percent)		
Plagioclase	39.4	37.9
Clinopyroxene	2.3	1.1
Orthopyroxene	5.2	3.1
Olivine	--	--
Fe-Ti Oxide	0.5	0.3
Hornblende	0.2	trace
Biotite	--	--
Other	4.8	--
Groundmass	47.6	53.3
No. points counted	850	720
Texture (rock/ groundmass)	porphyritic/ cryptocrys- talline	porphyritic/ cryptocrys- talline
Trace element analyses (parts per million)		
Ba	441	444
Rb	44	52
Sr	558	388
Y	17	16
Zr	167	195
Nb	6.3	9.2
Ni	29	22
Cu	38	31
Zn	60	61
Cr	38	33
Sc	13	10
V	119	87

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[X-ray fluorescence analyses. Map No., see figure 16 (sheet 2). Rock-type names assigned in accordance with IUGS system (Le Maitre, 2002) applied to recalculated analyses. FeO*, total Fe calculated as FeO; Mg#, atomic ratio 100 Mg/(Mg+Fe^{2+}) with Fe^{2+} set to 0.85 x Fe^{total}. Analyses by D.M. Johnson Cornelius and R.M. Conrey at Peter Hooper GeoAnalytical Laboratory of Washington State University, Pullman, Washington, using methods described in Johnson and others (1999)].

Map No.	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**100**	**101**
Field sample No.	04BV-G323	05BV-G510	05BV-G403	09BV-G1377	09BV-G1385	05BV-G402	04BV-G282A[1]	04BV-G283	12BV-G1566
Latitude (N)	45°38.728′	45°38.939′	45°37.606′	45°39.040′	45°39.302′	45°37.780′	45°38.661′	45°38.906′	45°38.905′
Longitude (W)	122°01.450′	122°00.567′	122°06.517′	122°01.072′	122°00.353′	122°06.593′	122°00.614′	122°00.465′	122°00.459′
Map unit	Tgwr	Tgwr	Tgwr	Tgwr	Tgwr	Tggc	Tgo	Tgo	Tgo
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	54.83	54.51	54.08	54.38	54.55	55.33	55.30	54.76	55.17
TiO_2	2.35	2.35	2.31	2.33	2.34	1.97	1.93	1.95	1.96
Al_2O_3	13.34	13.43	13.23	13.41	13.37	13.80	13.66	13.64	13.71
FeO*	12.46	12.35	12.11	12.19	12.15	11.53	11.83	11.75	10.97
MnO	0.20	0.20	0.19	0.20	0.19	0.19	0.19	0.19	0.19
MgO	3.45	3.43	3.36	3.43	3.41	3.66	3.64	3.61	3.65
CaO	7.05	7.01	6.91	7.02	7.01	7.12	7.22	7.17	7.17
Na_2O	3.10	3.15	3.15	3.14	3.19	3.23	3.37	3.17	3.19
K_2O	1.87	1.74	1.77	1.68	1.76	1.75	1.46	1.69	1.69
P_2O_5	0.41	0.40	0.40	0.41	0.41	0.34	0.32	0.34	0.34
Total	99.07	98.56	97.52	98.20	98.38	98.93	98.91	98.27	98.04
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	55.35	55.30	55.45	55.38	55.45	55.93	55.91	55.72	56.27
TiO_2	2.37	2.38	2.37	2.38	2.38	1.99	1.95	1.99	2.00
Al_2O_3	13.47	13.63	13.57	13.65	13.59	13.95	13.81	13.88	13.98
FeO*	12.58	12.53	12.42	12.42	12.35	11.65	11.96	11.95	11.19
MnO	0.20	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.19
MgO	3.48	3.48	3.45	3.49	3.46	3.70	3.68	3.67	3.72
CaO	7.12	7.11	7.09	7.15	7.12	7.20	7.30	7.30	7.31
Na_2O	3.13	3.20	3.23	3.20	3.25	3.26	3.41	3.23	3.25
K_2O	1.88	1.77	1.82	1.71	1.78	1.77	1.47	1.72	1.72
P_2O_5	0.41	0.41	0.41	0.41	0.41	0.35	0.32	0.35	0.35
Mg#	36.9	36.8	36.8	37.5	37.0	40.0	39.5	39.6	41.1
Trace element analyses (parts per million)									
Ba	698	710	697	693	710	687	655	664	683
Rb	53	51	51	51	51	49	48	50	50
Sr	331	329	321	335	332	325	324	330	328
Y	37	39	37	37	39	36	34	35	35
Zr	192	186	183	192	191	172	175	177	172
Nb	14.8	13.6	13.0	14.3	14.0	12.2	12.7	12.7	11.2
Ni	11	13	13	10	12	13	11	11	10
Cu	23	20	23	24	23	21	19	24	20
Zn	132	127	126	132	131	122	122	121	122
Cr	3	9	9	6	7	14	11	11	12
Sc	33	31	31	32	31	31	32	31	31
V	378	376	372	381	380	333	327	327	328

[1] Clast in pillow breccia.

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**
Field sample No.	12BV-G1567	12BV-G1568	08BV-G1211A	08BV-G1211B[1]	12BV-G1569[1]	12BV-G1570[1]	05BV-G429A	05BV-G429B	04BV-G322
Latitude (N)	45°38.879′	45°38.864′	45°38.892′	45°38.902′	45°38.790′	45°38.633′	45°39.517′	45°39.561′	45°38.822′
Longitude (W)	122°00.460′	122°00.460′	122°00.285′	122°00.281′	122°00.492′	122°00.598′	122°00.733′	122°00.721′	122°01.459′
Map unit	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	55.45	54.98	54.08	54.39	54.49	55.37	54.81	54.39	55.36
TiO_2	1.97	2.03	1.99	1.91	1.91	1.93	1.94	1.95	1.93
Al_2O_3	13.81	13.66	13.64	13.68	13.54	13.67	13.70	13.59	13.65
FeO*	11.46	11.69	11.48	11.35	11.29	11.52	11.44	11.38	11.53
MnO	0.19	0.19	0.20	0.19	0.19	0.19	0.19	0.19	0.19
MgO	3.64	3.60	3.40	3.60	3.62	3.65	3.65	3.57	3.65
CaO	7.17	7.10	7.07	7.14	7.16	7.20	7.12	7.09	7.19
Na_2O	3.21	3.15	3.27	3.23	3.17	3.38	3.20	3.15	3.12
K_2O	1.70	1.80	1.45	1.49	1.55	1.41	1.68	1.73	1.78
P_2O_5	0.34	0.36	0.35	0.31	0.35	0.33	0.34	0.34	0.32
Total	98.94	98.56	96.92	97.29	97.27	98.65	98.07	97.38	98.73
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	56.04	55.78	55.80	55.90	56.02	56.13	55.89	55.85	56.07
TiO_2	1.99	2.06	2.05	1.96	1.96	1.96	1.98	2.01	1.96
Al_2O_3	13.96	13.86	14.07	14.06	13.92	13.86	13.97	13.96	13.83
FeO*	11.58	11.86	11.85	11.66	11.61	11.68	11.67	11.68	11.68
MnO	0.19	0.19	0.21	0.20	0.20	0.19	0.19	0.19	0.19
MgO	3.68	3.65	3.50	3.70	3.72	3.70	3.72	3.66	3.70
CaO	7.25	7.20	7.29	7.34	7.36	7.30	7.26	7.28	7.28
Na_2O	3.24	3.20	3.37	3.32	3.26	3.43	3.26	3.24	3.16
K_2O	1.72	1.83	1.50	1.54	1.59	1.43	1.71	1.78	1.80
P_2O_5	0.34	0.37	0.36	0.32	0.36	0.33	0.34	0.35	0.33
Mg#	40.0	39.2	38.3	40.0	40.2	39.9	40.1	39.7	40.2
Trace element analyses (parts per million)									
Ba	677	683	696	643	675	674	671	690	713
Rb	49	50	46	45	48	49	51	53	47
Sr	328	324	323	319	321	325	325	316	329
Y	34	35	34	33	33	34	35	35	34
Zr	175	180	175	171	169	175	177	191	170
Nb	11.4	12.7	11.1	11.4	12.1	12.5	13.3	13.7	12.1
Ni	12	12	9	11	14	11	11	9	14
Cu	23	23	24	18	20	24	19	18	21
Zn	121	125	126	120	119	123	121	128	120
Cr	12	10	12.7	11	14	12	9	10	14
Sc	32	32	31.5	32	32	31	32	31	32
V	332	346	334.4	327	329	332	329	328	326

[1] Clast in pillow breccia.

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**
Field sample No.	04BV-G321A	05BV-G419	05BV-G398A	02BV-G115B-2	04BV-G201A	02BV-G116B	05BV-G401	04BV-G201B	05BV-G346A
Latitude (N)	45°38.898′	45°39.634′	45°37.813′	45°37.977′	45°38.739′	45°37.954′	45°37.534′	45°38.577′	45°38.463′
Longitude (W)	122°01.488′	122°02.016′	122°06.599′	122°06.603′	122°06.165′	122°06.388′	122°06.192′	122°06.100′	122°06.170′
Map unit	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	55.53	54.63	55.01	55.75	55.56	55.75	55.58	55.36	54.98
TiO_2	1.99	1.94	1.90	1.83	1.88	1.95	1.91	1.98	1.99
Al_2O_3	13.58	13.69	13.53	13.80	13.68	13.74	13.74	13.62	13.49
FeO*	11.87	11.09	10.96	10.88	11.62	11.17	11.05	11.26	11.34
MnO	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
MgO	3.49	3.58	3.48	3.51	3.72	3.50	3.55	3.49	3.51
CaO	7.06	7.09	6.97	7.10	7.26	7.04	7.07	7.01	6.87
Na_2O	3.12	3.20	3.13	3.10	3.06	3.15	3.15	3.19	3.33
K_2O	1.84	1.70	1.80	1.76	1.84	1.85	1.81	1.85	1.65
P_2O_5	0.35	0.34	0.33	0.30	0.32	0.33	0.33	0.35	0.35
Total	99.02	97.46	97.29	98.21	99.13	98.65	98.38	98.30	97.69
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	56.08	56.05	56.54	56.77	56.05	56.51	56.50	56.32	56.27
TiO_2	2.01	1.99	1.95	1.86	1.90	1.97	1.94	2.02	2.03
Al_2O_3	13.71	14.05	13.91	14.05	13.80	13.93	13.97	13.85	13.81
FeO*	11.98	11.38	11.26	11.08	11.72	11.32	11.23	11.45	11.61
MnO	0.20	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
MgO	3.52	3.67	3.57	3.57	3.75	3.55	3.61	3.55	3.60
CaO	7.13	7.28	7.16	7.23	7.32	7.14	7.19	7.14	7.03
Na_2O	3.16	3.29	3.22	3.15	3.09	3.19	3.21	3.24	3.41
K_2O	1.86	1.75	1.85	1.79	1.86	1.87	1.84	1.88	1.69
P_2O_5	0.35	0.35	0.34	0.31	0.32	0.34	0.33	0.35	0.36
Mg#	38.4	40.4	39.9	40.8	40.4	40.0	40.3	39.8	39.4
Trace element analyses (parts per million)									
Ba	686	717	670	697	687	694	671	727	670
Rb	50	49	50	50	50	50	45	48	44
Sr	306	311	312	312	308	307	299	333	304
Y	36	40	35	33	35	36	35	35	37
Zr	177	184	183	179	176	181	179	176	179
Nb	12.6	11.3	13.2	11.5	12.2	12.5	12.4	11.0	12.9
Ni	11	0	10	16	12	12	13	12	10
Cu	15	12	13	15	16	18	17	22	14
Zn	117	122	122	125	119	125	121	124	125
Cr	13	7	11	16	15	15	14	14	8
Sc	31	32	31	31	31	30	31	32	31
V	319	305	318	327	322	331	338	340	328

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**120**	**121**	**122**	**123**	**124**	**125**	**126**	**127**	**128**
Field sample No.	05BV-G346B	05BV-G349A	04BV-G153[2]	05BV-G508A	05BV-G508B	09BV-G1380	09BV-G1381	04BV-G320A	04BV-G320B
Latitude (N)	45°38.504′	45°38.540′	45°38.368′	45°38.973′	45°39.054′	45°39.160′	45°39.004′	45°39.140′	45°39.034′
Longitude (W)	122°06.080′	122°06.141′	122°06.694′	122°00.339′	122°00.315′	122°00.419′	122°00.304′	122°01.523′	122°01.521′
Map unit	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	55.04	55.50	55.15	55.68	56.49	55.58	55.94	55.71	55.44
TiO_2	2.00	1.95	1.95	1.85	1.97	1.90	1.97	1.92	1.99
Al_2O_3	13.84	13.43	13.47	13.64	13.85	13.64	13.63	13.69	13.48
FeO*	11.33	11.22	11.33	10.98	10.58	11.51	11.93	11.52	11.83
MnO	0.19	0.18	0.20	0.19	0.16	0.17	0.19	0.19	0.19
MgO	3.56	3.46	3.54	3.52	3.44	3.57	3.52	3.48	3.51
CaO	7.20	6.87	7.10	7.06	6.72	6.78	7.16	7.13	6.82
Na_2O	3.20	3.32	3.08	3.19	3.36	3.30	3.27	3.07	3.35
K_2O	1.66	1.63	1.85	1.71	1.73	1.68	1.65	1.61	1.66
P_2O_5	0.40	0.35	0.34	0.33	0.34	0.34	0.35	0.33	0.36
Total	98.42	97.90	98.02	98.15	98.63	98.48	99.61	98.65	98.63
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	55.92	56.69	56.27	56.72	57.27	56.43	56.15	56.48	56.21
TiO_2	2.03	1.99	1.99	1.89	2.00	1.93	1.98	1.95	2.02
Al_2O_3	14.06	13.72	13.74	13.90	14.04	13.85	13.69	13.87	13.67
FeO*	11.51	11.46	11.56	11.19	10.73	11.69	11.98	11.68	12.00
MnO	0.20	0.18	0.20	0.19	0.16	0.18	0.19	0.19	0.19
MgO	3.62	3.54	3.61	3.59	3.49	3.63	3.54	3.53	3.56
CaO	7.32	7.02	7.24	7.19	6.82	6.89	7.19	7.22	6.91
Na_2O	3.26	3.39	3.14	3.25	3.41	3.35	3.28	3.11	3.40
K_2O	1.69	1.66	1.89	1.75	1.75	1.70	1.66	1.63	1.68
P_2O_5	0.40	0.35	0.35	0.33	0.34	0.35	0.35	0.34	0.36
Mg#	40.1	39.3	40.1	40.2	40.6	39.4	38.2	39.1	38.7
Trace element analyses (parts per million)									
Ba	667	686	691	670	682	718	673	688	719
Rb	48	50	49	46	49	45	47	49	50
Sr	309	311	324	307	318	303	317	309	298
Y	34	36	36	36	37	37	38	35	35
Zr	180	181	194	187	189	171	191	176	170
Nb	12.1	12.8	12.4	13.3	14.2	12.4	14.8	12.1	11.2
Ni	13	9	8	6	9	5	9	12	6
Cu	13	12	12	14	16	12	18	17	12
Zn	123	120	123	124	127	121	129	122	121
Cr	7	8	6	6	5	8	5	14	12
Sc	31	33	30	31	32	32	32	31	30
V	330	310	312	321	329	323	334	320	321

[2] Float.

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**
Field sample No.	05BV-G434	04BV-G321B	09BV-G1383	05BV-G507	05BV-G509	09BV-G1378	05BV-G418	05BV-G430	05BV-G439
Latitude (N)	45°39.843′	45°38.952′	45°39.000′	45°39.374′	45°38.950′	45°39.228′	45°39.665′	45°40.181′	45°42.684′
Longitude (W)	122°00.855′	122°01.511′	122°00.199′	122°00.586′	122°00.371′	122°00.574′	122°01.903′	122°00.933′	122°00.524′
Map unit	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	54.94	55.96	55.69	55.75	55.73	55.57	55.31	54.50	54.91
TiO_2	1.92	1.94	1.94	1.93	1.95	1.93	1.93	1.99	1.96
Al_2O_3	13.57	13.65	13.68	13.73	13.80	13.66	13.69	13.51	13.73
FeO*	11.19	11.47	11.64	11.23	10.77	11.61	11.35	11.72	10.87
MnO	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.20	0.19
MgO	3.46	3.39	3.51	3.52	3.47	3.45	3.49	3.60	3.58
CaO	6.94	6.96	7.03	7.02	7.00	7.00	7.02	7.08	7.11
Na_2O	3.19	3.06	3.20	3.25	3.16	3.19	3.14	3.11	3.22
K_2O	1.72	1.76	1.71	1.76	1.80	1.74	1.69	1.79	1.70
P_2O_5	0.33	0.34	0.33	0.32	0.33	0.33	0.32	0.35	0.34
Total	97.45	98.70	98.92	98.70	98.20	98.66	98.13	97.86	97.59
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	56.38	56.70	56.30	56.48	56.76	56.33	56.36	55.70	56.27
TiO_2	1.97	1.96	1.96	1.95	1.99	1.96	1.97	2.03	2.00
Al_2O_3	13.93	13.83	13.83	13.91	14.05	13.84	13.95	13.80	14.07
FeO*	11.48	11.62	11.77	11.38	10.96	11.76	11.57	11.98	11.14
MnO	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21	0.19
MgO	3.55	3.43	3.55	3.56	3.54	3.50	3.55	3.68	3.66
CaO	7.12	7.06	7.11	7.11	7.13	7.10	7.16	7.24	7.28
Na_2O	3.28	3.10	3.24	3.29	3.21	3.23	3.20	3.18	3.29
K_2O	1.77	1.78	1.73	1.79	1.84	1.76	1.73	1.83	1.74
P_2O_5	0.33	0.34	0.33	0.33	0.34	0.33	0.33	0.36	0.35
Mg#	39.4	38.5	38.7	39.6	40.4	38.4	39.2	39.2	40.8
Trace element analyses (parts per million)									
Ba	685	693	723	686	727	674	713	715	669
Rb	51	50	52	52	50	47	49	54	49
Sr	312	307	322	312	312	307	328	319	329
Y	35	35	36	35	36	36	34	36	35
Zr	185	179	181	185	180	180	171	188	175
Nb	13.1	12.7	12.4	13.0	12.2	12.7	12.4	13.9	12.4
Ni	8	12	11	8	10	12	14	10	11
Cu	17	15	15	15	14	17	22	16	23
Zn	123	121	123	122	122	125	121	125	122
Cr	11	14	15	10	14	16	16	11	11
Sc	31	31	31	31	32	32	32	32	32
V	328	322	323	322	324	334	331	328	332

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**138**	**139**	**140**	**141**	**142**	**143**	**144**	**145**	**146**
Field sample No.	09BV-G1388	09BV-G1379A	09BV-G1379B	09BV-G1384	09BV-G1382	09BV-G1376	06BV-G572	05BV-G417	02BV-G115A
Latitude (N)	45°39.185′	45°39.234′	45°39.235′	45°39.197′	45°39.007′	45°39.085′	45°42.748′	45°39.639′	45°37.962′
Longitude (W)	122°01.630′	122°00.638′	122°00.667′	122°00.255′	122°00.226′	122°01.184′	122°00.473′	122°01.731′	122°06.712′
Map unit	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgo	Tgww	Tgww
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	55.93	55.25	55.15	55.73	55.69	54.43	55.11	53.71	54.35
TiO_2	1.94	1.96	1.97	1.94	2.03	2.06	1.92	2.00	2.03
Al_2O_3	13.76	13.75	13.76	13.82	13.54	13.52	13.49	13.43	13.58
FeO*	11.41	11.67	11.72	11.65	11.81	12.24	11.29	12.38	12.44
MnO	0.19	0.19	0.19	0.19	0.18	0.20	0.19	0.20	0.21
MgO	3.44	3.66	3.59	3.73	3.50	3.69	3.48	3.78	3.75
CaO	7.00	7.17	7.11	7.19	6.91	7.27	7.04	7.51	7.52
Na_2O	3.14	3.26	3.19	3.26	3.34	3.03	3.15	3.07	3.02
K_2O	1.79	1.67	1.76	1.65	1.65	1.89	1.71	1.49	1.63
P_2O_5	0.34	0.35	0.35	0.34	0.37	0.37	0.34	0.31	0.32
Total	98.80	99.50	99.01	98.70	97.71	97.89	98.84	97.97	98.28
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	56.53	55.85	55.82	56.02	56.24	55.15	56.40	54.87	54.99
TiO_2	1.96	1.98	2.00	1.95	2.05	2.09	1.97	2.04	2.05
Al_2O_3	13.90	13.90	13.93	13.89	13.68	13.70	13.81	13.72	13.74
FeO*	11.53	11.80	11.87	11.70	11.93	12.40	11.55	12.65	12.59
MnO	0.19	0.19	0.19	0.19	0.18	0.20	0.20	0.21	0.21
MgO	3.48	3.70	3.63	3.75	3.54	3.74	3.56	3.86	3.79
CaO	7.08	7.25	7.20	7.22	6.98	7.36	7.20	7.68	7.61
Na_2O	3.18	3.30	3.23	3.27	3.38	3.07	3.22	3.14	3.05
K_2O	1.81	1.68	1.78	1.66	1.66	1.91	1.75	1.52	1.65
P_2O_5	0.34	0.35	0.35	0.34	0.37	0.37	0.35	0.32	0.32
Mg#	39.0	39.7	39.1	40.2	38.3	39.1	39.8	39.0	39.0
Trace element analyses (parts per million)									
Ba	692	671	677	654	667	696	656	542	587
Rb	50	49	46	49	48	46	45	40	40
Sr	329	329	308	318	313	323	317	309	314
Y	35	34	37	37	36	34	33	36	35
Zr	177	175	189	186	181	175	171	170	174
Nb	13.3	13.0	13.6	13.5	12.2	11.1	10.5	12.3	12.6
Ni	10	13	9	11	9	9	9	9	14
Cu	22	23	19	21	15	24	19	9	10
Zn	123	121	129	128	124	126	121	124	127
Cr	12	15	12	14	6	13	11	11	12
Sc	32	33	32	32	33	32	32	35	35
V	331	330	340	363	328	334	329	367	368

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**147**	**148**	**149**	**150**	**151**	**152**	**153**	**154**	**155**
Field sample No.	14BV-G1702B	05BV-G415	05BV-G416	02BV-G01[2]	05BV-G413	05BV-G424B	06BV-G573	06BV-G576	14BV-G1702A
Latitude (N)	45°38.623′	45°39.961′	45°39.715′	45°39.000′	45°40.371′	45°40.655′	45°43.171′	45°42.666′	45°38.614′
Longitude (W)	122°06.593′	122°01.710′	122°01.690′	122°06.642′	122°01.895′	122°01.321′	122°00.172′	122°00.038′	122°06.636′
Map unit	Tgww	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	54.58	52.75	52.89	53.92	53.35	52.97	52.92	53.01	53.54
TiO_2	2.07	1.93	1.94	1.95	1.92	1.90	1.91	1.90	1.97
Al_2O_3	13.57	13.74	13.73	14.03	13.82	13.70	13.67	13.73	14.00
FeO*	12.35	11.69	11.84	11.76	11.83	11.95	11.64	11.75	11.82
MnO	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22
MgO	3.73	4.73	4.75	4.77	4.79	4.75	4.73	4.78	4.66
CaO	7.51	8.45	8.45	8.58	8.51	8.45	8.40	8.44	8.52
Na_2O	2.98	3.00	2.99	2.96	2.95	2.92	2.87	2.91	2.88
K_2O	1.70	1.16	1.15	1.25	1.18	1.15	1.24	1.12	1.25
P_2O_5	0.33	0.32	0.32	0.29	0.28	0.28	0.29	0.28	0.29
Total	99.03	97.97	98.28	99.72	98.83	98.29	97.87	98.14	99.15
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	55.11	53.84	53.82	54.08	53.99	53.89	54.07	54.01	54.00
TiO_2	2.09	1.97	1.97	1.96	1.94	1.94	1.95	1.94	1.99
Al_2O_3	13.70	14.02	13.97	14.07	13.98	13.94	13.96	13.99	14.12
FeO*	12.47	11.93	12.05	11.79	11.97	12.15	11.90	11.97	11.93
MnO	0.22	0.21	0.21	0.21	0.21	0.21	0.22	0.21	0.22
MgO	3.76	4.83	4.83	4.79	4.84	4.83	4.83	4.87	4.70
CaO	7.58	8.62	8.60	8.60	8.61	8.60	8.58	8.60	8.59
Na_2O	3.01	3.06	3.04	2.97	2.98	2.97	2.93	2.97	2.90
K_2O	1.72	1.19	1.17	1.25	1.19	1.17	1.27	1.14	1.26
P_2O_5	0.33	0.33	0.33	0.29	0.29	0.29	0.30	0.29	0.29
Mg#	39.0	45.9	45.7	46.1	46.2	45.5	46.5	46.5	45.5
Trace element analyses (parts per million)									
Ba	578	524	480	496	453	456	468	456	491
Rb	41	27	27	28	30	30	30	29	29
Sr	317	305	306	318	314	311	315	317	321
Y	39	36	36	35	33	34	33	33	54.5
Zr	184	160	159	157	154	155	155	156	164
Nb	13.8	12.0	12.3	11.3	10.8	10.9	9.5	10.1	12.1
Ni	5	16	15	20	13	14	13	13	12
Cu	14	28	27	30	26	27	26	26	29
Zn	128	118	118	119	114	115	115	115	120
Cr	8	36	35	25	25	21	22	22	20
Sc	33	38	38	38	37	37	37	37	37
V	367	317	316	342	332	332	332	336	336

[2] Float.

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Cotinued

Map No.	**156**	**157**	**158**	**159**	**160**	**161**	**162**	**163**	**164**
Field sample No.	05BV-G414	05BV-G424A	02BV-G05-2	02BV-G56A	12BV-G1562	12BV-G1563	04BV-G202	08BV-G1067	10BV-G1403
Latitude (N)	45°40.166′	45°40.776′	45°40.338′	45°41.077′	45°41.173′	45°41.463′	45°38.967′	45°37.600′	45°37.844′
Longitude (W)	122°01.809′	122°01.401′	122°06.090′	122°02.475′	122°02.387′	122°02.592′	122°06.212′	122°07.310′	122°06.786′
Map unit	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb	Tgsb
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	53.54	52.97	54.18	54.09	54.00	54.30	54.49	52.92	53.59
TiO_2	1.79	1.76	1.83	1.76	1.77	1.82	1.80	1.86	1.76
Al_2O_3	14.13	14.05	14.18	14.12	14.24	14.02	14.11	14.54	13.97
FeO*	11.30	11.43	11.31	11.14	11.30	11.27	10.94	11.10	10.97
MnO	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
MgO	5.10	5.13	4.48	4.82	4.80	4.65	4.54	4.32	4.66
CaO	8.77	8.86	8.36	8.39	8.46	8.31	8.32	8.52	8.50
Na_2O	2.90	2.85	2.93	3.02	2.93	2.98	2.94	2.82	2.92
K_2O	1.23	1.08	1.41	1.31	1.27	1.38	1.43	1.18	1.35
P_2O_5	0.28	0.27	0.36	0.32	0.33	0.35	0.35	0.35	0.32
Total	99.24	98.61	99.23	99.16	99.31	99.27	99.13	97.80	98.25
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	53.95	53.72	54.60	54.55	54.38	54.70	54.97	54.11	54.55
TiO_2	1.80	1.78	1.85	1.78	1.79	1.83	1.81	1.90	1.79
Al_2O_3	14.24	14.25	14.29	14.24	14.34	14.12	14.24	14.87	14.22
FeO*	11.39	11.59	11.39	11.23	11.38	11.35	11.04	11.35	11.17
MnO	0.20	0.21	0.20	0.20	0.20	0.20	0.20	0.21	0.20
MgO	5.13	5.20	4.52	4.86	4.84	4.68	4.58	4.41	4.75
CaO	8.84	8.99	8.42	8.46	8.52	8.37	8.40	8.71	8.65
Na_2O	2.92	2.89	2.95	3.04	2.95	3.00	2.97	2.88	2.98
K_2O	1.24	1.10	1.42	1.33	1.28	1.39	1.45	1.21	1.37
P_2O_5	0.28	0.27	0.36	0.32	0.33	0.36	0.36	0.36	0.33
Mg#	48.6	48.5	45.6	47.8	47.3	46.6	46.7	45.5	47.6
Trace element analyses (parts per million)									
Ba	500	441	575	540	534	561	561	634	577
Rb	29	29	36	33	32	35	34	29	34
Sr	308	308	321.7	310	315	316	300	327	325
Y	35	32	36	32	39	35	34	43	34
Zr	153	149	173	161	165	169	156	173	165
Nb	10.7	10.3	11.8	11.7	11.1	11.5	11.1	10.9	11.1
Ni	19	19	15	19	15	14	10	11	16
Cu	35	36	26	25	26	27	23	26	27
Zn	112	109	124	117	119	120	116	126	118
Cr	46	46	33.8	41	39	34	38	34	35
Sc	36	37	36	35	35	35	34	37	35
V	327	320	299	306	308	299	299	312	310

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**165**	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**
Field sample No.	06BV-G575	06BV-G574A	05BV-G397	06BV-G574B	10BV-G1402	04BV-G198[2]	09BV-G1308	10BV-G1404	14BV-G1690A
Latitude (N)	45°42.782′	45°43.078′	45°37.570′	45°42.963′	45°37.849′	45°38.046′	45°37.822′	45°37.990′	45°38.030′
Longitude (W)	122°00.076′	122°00.034′	122°06.917′	122°00.128′	122°06.824′	122°07.150′	122°06.857′	122°06.836′	122°06.994′
Map unit	Tgsb	Tgsb	Twfsh	Twfsh	Twfsh	Twfss	Twfss	Twfss	Twfss
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basalt	Basalt	Basaltic andesite	Basaltic andesite	Basalt	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	53.10	53.64	51.74	50.86	50.73	51.36	51.02	50.28	51.76
TiO_2	1.73	1.80	3.03	2.95	2.93	2.96	2.96	3.04	3.02
Al_2O_3	13.97	13.94	13.63	13.33	13.11	13.23	12.85	13.24	13.00
FeO*	10.75	10.97	12.39	13.31	14.15	13.91	14.30	14.31	14.47
MnO	0.19	0.20	0.22	0.23	0.23	0.23	0.31	0.24	0.24
MgO	4.78	4.54	4.22	4.34	4.39	3.95	3.97	4.02	4.03
CaO	8.37	8.26	8.47	8.22	8.25	7.91	7.84	8.01	7.95
Na_2O	2.82	2.88	2.85	2.74	2.77	2.76	2.82	2.87	2.85
K_2O	1.24	1.47	1.41	1.37	1.38	1.49	1.58	1.35	1.60
P_2O_5	0.31	0.35	0.58	0.57	0.60	0.68	0.66	0.71	0.70
Total	97.28	98.06	98.53	97.91	98.54	98.48	98.31	98.07	99.61
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	54.58	54.70	52.51	51.94	51.48	52.15	51.90	51.27	51.96
TiO_2	1.78	1.84	3.07	3.01	2.98	3.00	3.01	3.10	3.03
Al_2O_3	14.36	14.22	13.83	13.62	13.31	13.44	13.07	13.51	13.05
FeO*	11.05	11.19	12.57	13.59	14.36	14.13	14.55	14.59	14.52
MnO	0.20	0.20	0.23	0.23	0.24	0.24	0.32	0.24	0.24
MgO	4.92	4.63	4.28	4.43	4.45	4.01	4.03	4.10	4.05
CaO	8.61	8.43	8.59	8.39	8.37	8.03	7.98	8.17	7.98
Na_2O	2.90	2.93	2.89	2.80	2.81	2.81	2.87	2.93	2.86
K_2O	1.28	1.50	1.44	1.40	1.40	1.51	1.60	1.37	1.61
P_2O_5	0.32	0.36	0.59	0.58	0.61	0.69	0.67	0.72	0.70
Mg#	49.0	46.9	42.0	41.1	39.8	37.7	37.2	37.5	37.0
Trace element analyses (parts per million)									
Ba	509	556	632	578	551	680	626	724	649
Rb	33	36	34	34	37	33	41	33	40
Sr	312	319	322	318	318	300	310	321	315
Y	32	35	46	43	43	47	46	51	47
Zr	157	166	195	191	194	197	213	223	220
Nb	9.8	11.5	15.4	14.3	14.7	15.1	16.8	16.0	17.4
Ni	15	14	29	22	20	12	18	18	14
Cu	25	23	28	27	29	18	26	22	25
Zn	112	117	144	140	143	146	152	161	155
Cr	39	36	44	40	37.3	19	14	14	14
Sc	35	36	38	37	37	36	37	38	35
V	303	296	429	420	416	400	395	400	392

[2] Float.

Table 2. Chemical analyses of the Columbia River Basalt Group, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**174**
Field sample No.	14BV-G1690B
Latitude (N)	45°38.077′
Longitude (W)	122°06.979′
Map unit	Twfss
Rock type	Basaltic andesite
Analyses as reported (weight percent)	
SiO_2	51.63
TiO_2	2.99
Al_2O_3	13.06
FeO*	13.90
MnO	0.23
MgO	3.97
CaO	7.92
Na_2O	2.84
K_2O	1.65
P_2O_5	0.69
Total	98.88
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)	
SiO_2	52.21
TiO_2	3.02
Al_2O_3	13.21
FeO*	14.06
MnO	0.23
MgO	4.01
CaO	8.01
Na_2O	2.87
K_2O	1.66
P_2O_5	0.70
Mg#	37.7
Trace element analyses (parts per million)	
Ba	652
Rb	40
Sr	316
Y	48
Zr	222
Nb	17.7
Ni	13
Cu	23
Zn	157
Cr	15
Sc	36
V	385

Table 3. Chemical and modal analyses of Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[X-ray fluorescence analyses. Map No., see figure 16 (sheet 2). Rock-type names assigned in accordance with IUGS system (Le Maitre, 2002) applied to recalculated analyses. FeO*, total Fe calculated as FeO; Mg#, atomic ratio 100 Mg/(Mg+Fe^{2+}) with Fe^{2+} set to 0.85 x Fe^{total}. Modal analyses, secondary minerals counted as primary mineral replaced. -, not present. Analyses by D.M. Johnson Cornelius and R.M. Conrey at Peter Hooper GeoAnalytical Laboratory of Washington State University, Pullman, Washington, using methods described in Johnson and others (1999)]

Map No.	**175**	**176**	**177**	**178**	**179**	**180**	**181**	**182**	**183**
Field sample No.	02BV-G10A	02BV-G10B	02BV-G14	06BV-G580[1]	02BV-G59[1]	05BV-G407	05BV-G408	05BV-G410	05BV-G412A
Latitude (N)	45°43.942′	45°43.922′	45°43.979′	45°43.866′	45°40.563′	45°40.722′	45°40.326′	45°39.967′	45°40.649′
Longitude (W)	122°02.970′	122°02.942′	122°02.269′	122°01.547′	122°03.229′	122°02.460′	122°02.308′	122°02.187′	122°02.243′
Map unit	Qtcr	Qtcr	Qtcr	Qtcr	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc
Rock type	Basaltic andesite	Basalt	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	52.23	51.62	52.91	53.22	54.22	53.32	53.84	53.46	53.36
TiO_2	1.18	1.23	1.15	1.18	1.23	1.22	1.22	1.28	1.28
Al_2O_3	17.79	17.68	17.65	17.55	18.15	18.06	18.26	18.65	19.08
FeO*	7.84	8.08	7.85	7.68	7.34	7.57	7.47	7.64	7.57
MnO	0.13	0.14	0.13	0.13	0.12	0.13	0.13	0.13	0.13
MgO	7.17	7.74	7.28	7.60	5.38	6.46	6.00	5.68	5.64
CaO	8.45	9.18	8.82	8.95	8.34	8.45	8.51	8.08	8.44
Na_2O	3.32	3.30	3.35	3.35	3.72	3.47	3.66	3.61	3.78
K_2O	0.73	0.72	0.76	0.77	0.83	0.83	0.83	0.84	0.71
P_2O_5	0.22	0.21	0.21	0.22	0.24	0.23	0.23	0.24	0.24
Total	99.06	99.90	100.12	100.65	99.58	99.73	100.16	99.61	100.22
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	52.73	51.67	52.85	52.88	54.45	53.46	53.75	53.67	53.24
TiO_2	1.19	1.23	1.15	1.17	1.24	1.22	1.22	1.28	1.28
Al_2O_3	17.96	17.69	17.63	17.44	18.23	18.11	18.23	18.72	19.04
FeO*	7.91	8.09	7.84	7.63	7.37	7.59	7.46	7.67	7.55
MnO	0.13	0.14	0.13	0.13	0.12	0.13	0.13	0.13	0.13
MgO	7.24	7.75	7.27	7.55	5.41	6.48	5.99	5.71	5.62
CaO	8.53	9.19	8.81	8.89	8.38	8.47	8.50	8.11	8.42
Na_2O	3.35	3.31	3.35	3.33	3.74	3.48	3.65	3.63	3.77
K_2O	0.74	0.72	0.76	0.77	0.83	0.84	0.83	0.85	0.71
P_2O_5	0.22	0.21	0.21	0.22	0.24	0.23	0.23	0.24	0.24
Mg#	66.0	66.8	66.0	67.3	60.7	64.2	62.7	61.0	60.9
Modes (volume percent)									
Plagioclase	--	--	--	--	--	0.1	--	--	--
Clinopyroxene	--	--	--	--	0.7	1.0	0.2	trace	trace
Orthopyroxene	--	--	--	--	0.6	0.3	0.4	0.3	0.1
Olivine	--	--	--	--	--	--	--	--	--
Fe-Ti Oxide	--	--	--	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Quartz	--	--	--	--	--	--	--	--	--
Groundmass	100.0	100.0	100.0	100.0	98.7	98.6	99.4	99.7	99.9
No. points counted	--	--	--	--	850	850	850	850	850
Texture (rock/ groundmass)	aphyric/ intergranular	seriate/ trachytic	aphyric/ intergranular	aphyric/ intergranular	microphyric/ intergranular	microphyric/ trachytic	microphyric/ trachytic	microphyric/ trachytic	aphyric/ trachytic
Trace element analyses (parts per million)									
Ba	182	179	176	196	144	146	143	150	141
Rb	5	5	6	6	4	4	4	4	3
Sr	620	684	631	605	733	671	696	740	732
Y	18	18	18	17	15	16	16	16	17
Zr	123	113	121	119	120	115	117	120	119
Nb	9.2	8.6	8.3	7.8	7.4	7.2	6.7	7.0	6.7
Ni	138	140	144	144	83	106	89	83	75
Cu	122	66	47	71	66	82	61	69	58
Zn	76	73	72	70	79	72	75	77	76
Cr	202	242	250	254	141	197	174	125	115
Sc	25	25	25	26	19	23	22	20	21
V	190	199	187	195	170	181	174	171	174

[1]Block in landslide deposit.

Table 3. Chemical and modal analyses of Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**184**	**185**	**186**	**187**	**188**	**189**	**190**	**191**	**192**
Field sample No.	05BV-G422	05BV-G342	05BV-G345	05BV-G423	05BV-G343	02BV-G65	09BV-G1387	04BV-G318[2]	09BV-G1389
Latitude (N)	45°41.057′	45°40.800′	45°40.746′	45°41.184′	45°40.995′	45°41.281′	45°39.172′	45°38.773′	45°38.859′
Longitude (W)	122°02.854′	122°02.726′	122°03.199′	122°02.825′	122°03.255′	122°03.092′	122°01.712′	122°01.717′	122°01.663′
Map unit	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc	Qmwc
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	53.44	52.81	53.33	53.28	52.57	52.11	53.51	53.87	53.98
TiO_2	1.27	1.25	1.25	1.19	1.20	1.20	1.15	1.16	1.19
Al_2O_3	19.04	18.27	17.73	17.23	17.21	17.59	17.84	18.90	18.85
FeO*	7.60	7.39	7.69	7.52	7.60	7.82	7.62	7.54	7.75
MnO	0.13	0.12	0.13	0.13	0.13	0.14	0.13	0.13	0.13
MgO	5.64	5.50	6.79	7.75	7.70	7.69	6.94	5.36	5.35
CaO	8.13	8.00	8.65	9.01	8.70	8.67	8.68	8.38	8.32
Na_2O	3.69	3.58	3.48	3.39	3.32	3.24	3.55	3.69	3.75
K_2O	0.80	0.79	0.85	0.84	0.87	0.74	0.79	0.83	0.85
P_2O_5	0.23	0.23	0.24	0.23	0.25	0.24	0.23	0.24	0.25
Total	99.98	97.94	100.14	100.56	99.54	99.45	100.45	100.08	100.42
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	53.45	53.92	53.26	52.98	52.81	52.40	53.27	53.82	53.76
TiO_2	1.27	1.27	1.25	1.18	1.20	1.21	1.15	1.16	1.18
Al_2O_3	19.05	18.66	17.71	17.13	17.29	17.69	17.76	18.88	18.77
FeO*	7.60	7.54	7.68	7.48	7.64	7.87	7.59	7.53	7.72
MnO	0.13	0.12	0.13	0.13	0.13	0.14	0.13	0.13	0.13
MgO	5.64	5.62	6.78	7.71	7.73	7.73	6.91	5.36	5.33
CaO	8.13	8.17	8.64	8.96	8.74	8.71	8.64	8.37	8.29
Na_2O	3.70	3.66	3.48	3.37	3.33	3.25	3.53	3.69	3.73
K_2O	0.80	0.81	0.84	0.83	0.87	0.75	0.79	0.83	0.85
P_2O_5	0.23	0.23	0.24	0.23	0.25	0.24	0.23	0.24	0.25
Mg#	60.9	61.5	64.9	68.3	68.1	67.5	65.5	59.8	59.1
Modes (volume percent)									
Plagioclase	--	--	--	--	--	--	--	--	--
Clinopyroxene	trace	0.5	0.1	0.5	0.3	trace	0.1	--	--
Orthopyroxene	trace	0.2	0.1	1.2	0.3	trace	trace	--	--
Olivine	--	--	--	--	--	--	--	--	--
Fe-Ti Oxide	--	--	--	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	100.0	99.3	99.8	98.3	99.4	100.0	99.9	100.0	100.0
No. points counted	850	850	850	850	850	--	850	--	--
Texture (rock/ groundmass)	aphyric/ trachytic	microphyric/ trachytic	aphyric/ trachytic	microphyric/ trachytic	microphyric/ intergranular	microphyric/ trachytic	microphyric/ trachytic	aphyric/ trachytic	aphyric/ trachytic
Trace element analyses (parts per million)									
Ba	140	130	145	153	167	171	163	160	167
Rb	3	5	5	6	5	4	7	6	8
Sr	735	716	650	623	582	616	602	641	683
Y	17	15	17	16	17	18	17	17	18
Zr	117	115	123	114	119	124	123	114	130
Nb	7.1	5.5	9.1	9.1	9.9	10.2	9.3	7.7	9.5
Ni	77	84	112	146	152	156	126	75	73
Cu	65	40	175	50	56	62	64	31	34
Zn	73	76	72	71	69	76	74	73	76
Cr	115	139	211	332	336	334	241	112	106
Sc	20	18	25	26	27	24	24	20	21
V	172	171	191	184	191	186	182	158	169

[2]Block in talus deposit.

Table 3. Chemical and modal analyses of Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**193**	**194**	**195**	**196**	**197**	**198**	**199**	**200**	**201**
Field sample No.	02BV-G90B	02BV-G116A	05BV-G350	QV01-36[1]	QV03-212A[1]	QV03-212D[1]	QV01-37[2]	04BV-G319	05BV-G411[2]
Latitude (N)	45°39.088′	45°37.987′	45°38.252′	45°38.000′	45°37.998′	45°38.014′	45°38.565′	45°38.803′	45°40.029′
Longitude (W)	122°05.588′	122°06.405′	122°06.374′	122°01.345′	122°01.288′	122°01.290′	122°01.943′	122°01.872′	122°01.988′
Map unit	Qmdc	Qmdc	Qmdc	Qlbr	Qlbr	Qlbr	Qlbr	Qlbr	Qmlc
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basalt	Basalt	Basalt	Basalt	Basalt	Basaltic andesite
				Analyses as reported (weight percent)					
SiO_2	52.14	53.57	54.31	52.17	51.32	51.24	50.61	51.42	53.00
TiO_2	1.46	1.36	1.45	1.26	1.26	1.31	1.22	1.27	1.13
Al_2O_3	17.68	17.82	17.97	17.22	17.26	17.30	17.06	17.19	19.81
FeO*	8.10	7.77	7.73	7.93	8.25	8.29	8.27	7.89	7.95
MnO	0.14	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14
MgO	6.67	5.82	5.44	6.96	7.76	7.29	7.71	7.32	4.31
CaO	7.97	8.07	7.84	8.79	9.01	8.36	8.92	9.46	7.62
Na_2O	3.79	3.94	4.16	3.58	3.46	3.38	3.47	3.45	3.67
K_2O	0.91	0.96	1.07	0.88	0.80	0.93	0.81	0.98	0.75
P_2O_5	0.36	0.35	0.38	0.33	0.33	0.31	0.31	0.33	0.24
Total	99.22	99.80	100.46	99.25	99.60	98.54	98.51	99.45	98.62
				Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)					
SiO_2	52.55	53.68	54.06	52.56	51.52	51.99	51.37	51.70	53.74
TiO_2	1.47	1.36	1.44	1.27	1.27	1.33	1.23	1.28	1.14
Al_2O_3	17.81	17.86	17.89	17.35	17.33	17.56	17.32	17.28	20.09
FeO*	8.17	7.79	7.69	7.99	8.29	8.41	8.40	7.94	8.06
MnO	0.15	0.13	0.13	0.14	0.14	0.15	0.14	0.14	0.14
MgO	6.73	5.83	5.41	7.01	7.79	7.40	7.83	7.37	4.37
CaO	8.03	8.09	7.80	8.86	9.05	8.49	9.05	9.51	7.72
Na_2O	3.82	3.94	4.14	3.61	3.48	3.43	3.52	3.47	3.72
K_2O	0.92	0.96	1.06	0.89	0.81	0.94	0.82	0.98	0.76
P_2O_5	0.36	0.35	0.38	0.33	0.33	0.32	0.31	0.33	0.24
Mg#	63.5	61.2	59.5	65.0	66.4	65.2	66.5	66.2	53.6
				Modes (volume percent)					
Plagioclase	--	0.4	0.1	trace	--	--	trace	0.1	--
Clinopyroxene	0.1	--	--	--	--	--	--	--	--
Orthopyroxene	--	--	--	--	--	--	--	--	--
Olivine	3.7	4.5	4.0	4.7	5.7	6.4	5.6	8.5	--
Fe-Ti Oxide	--	--	--	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	96.2	95.1	95.9	95.3	94.3	93.6	94.4	91.4	100.0
No. points counted	850	850	850	810	850	850	850	850	--
Texture (rock/ groundmass)	porphyritic/ trachytic	porphyritic/ trachytic	porphyritic/ trachytic	microphyric/ trachytic	microphyric/ trachytic	seriate/ trachytic	seriate/ trachytic	seriate/ trachytic	microseriate/ trachytic
				Trace element analyses (parts per million)					
Ba	282	273	299	420	451	361	376	484	146
Rb	8	9	11	8	6	9	5	8	5
Sr	610	624	630	875	918	714	811	886	709
Y	23	22	23	21	21	21	21	20	17
Zr	165	165	172	135	139	133	138	125	119
Nb	18.3	16.4	19.0	10.8	10.4	8.1	10.8	9.0	6.3
Ni	132	96	87	131	165	167	168	129	32
Cu	50	53	23	54	51	57	34	28	140
Zn	85	246	86	83	87	81	81	72	74
Cr	186	133	110	229	271	268	287	262	41
Sc	22	20	21	22	24	26	24	27	16
V	172	166	158	187	190	197	187	202	144

[1]Block in landslide deposit.

[2]Block in talus deposit.

Table 3. Chemical and modal analyses of Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**
Field sample No.	05BV-G420	QV02-64A	QV02-64B	03BV-G120	QV97-13A	QV97-14	QV98-17	QV01-35B	QV03-211B[2]
Latitude (N)	45°39.793′	45°38.558′	45°38.446′	45°40.073′	45°39.419′	45°39.894′	45°37.699′	45°37.612′	45°37.654′
Longitude (W)	122°02.014′	122°07.065′	122°07.252′	122°07.225′	122°07.453′	122°07.384′	122°01.313′	122°01.195′	122°01.146′
Map unit	Qmlc	Qmum	Qmum	Qmus	Qmbc	Qmhs	Qmbr	Qmbr	Qmbr
Rock type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite	Basaltic andesite
Analyses as reported (weight percent)									
SiO_2	53.77	51.81	51.99	54.47	53.20	52.68	55.36	55.09	53.93
TiO_2	1.16	1.18	1.19	0.93	1.21	1.21	1.12	1.13	1.14
Al_2O_3	19.91	18.06	18.25	17.24	17.73	18.29	17.93	17.93	17.68
FeO*	7.96	7.68	7.37	7.45	7.36	7.36	7.16	7.27	7.03
MnO	0.14	0.12	0.13	0.13	0.12	0.12	0.12	0.12	0.12
MgO	4.49	6.51	6.63	6.77	5.56	4.98	5.05	4.97	4.57
CaO	7.61	7.89	8.28	8.31	8.03	7.20	7.61	7.52	7.59
Na_2O	3.76	3.94	3.97	3.77	3.85	3.72	4.16	4.22	4.22
K_2O	0.79	0.68	0.60	0.57	1.21	1.38	0.86	0.85	0.84
P_2O_5	0.25	0.28	0.29	0.22	0.33	0.32	0.27	0.27	0.29
Total	99.84	98.16	98.70	99.85	98.60	97.25	99.65	99.36	97.40
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)									
SiO_2	53.86	52.78	52.68	54.55	53.96	54.17	55.56	55.44	55.37
TiO_2	1.16	1.20	1.20	0.93	1.22	1.24	1.12	1.14	1.17
Al_2O_3	19.94	18.40	18.49	17.26	17.98	18.80	17.99	18.04	18.16
FeO*	7.97	7.82	7.47	7.46	7.46	7.57	7.19	7.32	7.21
MnO	0.14	0.13	0.13	0.13	0.12	0.13	0.12	0.12	0.12
MgO	4.50	6.64	6.72	6.78	5.64	5.12	5.07	5.00	4.69
CaO	7.62	8.04	8.39	8.33	8.15	7.40	7.64	7.57	7.80
Na_2O	3.77	4.02	4.02	3.77	3.90	3.82	4.17	4.24	4.33
K_2O	0.79	0.70	0.61	0.57	1.23	1.42	0.86	0.85	0.86
P_2O_5	0.25	0.28	0.29	0.22	0.34	0.33	0.27	0.28	0.29
Mg#	54.2	64.5	65.7	65.6	61.7	59.3	59.1	57.4	58.4
Modes (volume percent)									
Plagioclase	--	trace	0.1	--	--	--	--	--	0.3
Clinopyroxene	--	--	--	--	3.7	--	trace	0.1	0.3
Orthopyroxene	--	--	--	--	--	--	--	--	--
Olivine	--	4.4	3.5	4.8	3.9	--	0.5	1.8	1.4
Fe-Ti Oxide	--	--	--	--	--	--	--	--	--
Hornblende	--	--	--	--	--	--	--	--	--
Biotite	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--
Groundmass	100.0	95.6	96.4	95.2	92.4	100.0	99.5	98.1	98.0
No. points counted	--	830	775	850	820.0	--	810	850	850
Texture (rock/groundmass)	microseriate/trachytic	microphyric/trachytic	microphyric/trachytic	microphyric/trachytic	porphyritic/intersertal	microphyric/trachytic	~aphyric/intergranular	sparsely phyric/intergranular	sparsely phyric/trachytic
Trace element analyses (parts per million)									
Ba	153	333	337	175	420	571	253	253	255
Rb	5	3	1	5	9	10	10	9	9
Sr	718	874	910	617	1029	860	684	749	691
Y	18	19	17	15	19	22	17	17	17
Zr	122	134	130	102	166	185	147	145	142
Nb	7.8	9.4	7.8	6.7	10.6	10.2	10.6	10.4	10.7
Ni	32	130	131	102	100	71	83	65	63
Cu	25	52	42	60	60	55	27	35	41
Zn	76	79	80	85	85	96	77	87	82
Cr	44	189	195	344	147	110	92	86	80
Sc	18	20	20	21	19	19	17	16	19
V	153	333	337	175	420	571	253	253	255

[2]Block in talus deposit.

Table 3. Chemical and modal analyses of Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.—Continued

Map No.	**211**
Field sample No.	QV01-40[3]
Latitude (N)	45°40.172′
Longitude (W)	122°07.513′
Map unit	Qmhs
Rock type	Basaltic andesite
Analyses as reported (weight percent)	
SiO_2	54.99
TiO_2	1.19
Al_2O_3	17.74
FeO*	7.09
MnO	0.12
MgO	4.53
CaO	7.48
Na_2O	3.96
K_2O	1.63
P_2O_5	0.33
Total	99.06
Analyses recalculated volatile-free and normalized to 100% with all Fe as FeO (weight percent)	
SiO_2	55.51
TiO_2	1.20
Al_2O_3	17.91
FeO*	7.15
MnO	0.12
MgO	4.57
CaO	7.55
Na_2O	4.00
K_2O	1.65
P_2O_5	0.33
Mg#	57.5
Modes (volume percent)	
Plagioclase	--
Clinopyroxene	--
Orthopyroxene	--
Olivine	--
Fe-Ti Oxide	--
Hornblende	--
Biotite	--
Other	--
Groundmass	100.0
No. points counted	--
Texture (rock/ groundmass)	microphyric/ trachytic
Trace element analyses (parts per million)	
Ba	509
Rb	20
Sr	973
Y	20
Zr	183
Nb	10.1
Ni	60
Cu	38
Zn	87
Cr	89
Sc	17
V	162

[3]Locality in adjacent Bobs Mountain quadrangle.

Table 4. Summary of $^{40}Ar/^{39}Ar$ incremental-heating age determinations, Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[See figure 17 (sheet 2) for sample locations. Analytical data provided in appendix 1. Ages calculated to a monitor age equivalent to an age of 28.02 Ma for the Fish Canyon Tuff sanidine (FCs) standard (Renne and others, 1998), as described in Fleck and others (2014)]

Field sample no.	Location (NAD 83)		Map unit	Rock type	Material dated	Age (±1σ error)	Comments
	Latitude (N)	Longitude (W)					
06BV-G633	45°42.627′	122°06.590′	Tba	Andesite	Plagioclase	25.78±0.55 Ma	This report
06BV-G700B	45°43.051′	122°04.564′	Tts	Welded tuff	Plagioclase	24.30±0.11 Ma	This report
06BV-G685	45°40.913′	122°05.914′	Ttw	Welded tuff	Plagioclase	24.04±0.06 Ma	This report
03BV-G122	45°40.271′	122°07.166′	Tiah	Andesite	Plagioclase	<23.14±0.18 Ma	Maximum age; this report
02BV-G51A	45°44.699′	122°01.869′	Tt	Welded tuff	Plagioclase	22.79±0.13 Ma	This report
06BV-G650	45°44.829′	122°04.654′	Tidcr	Rhyolite	Plagihoclase	22.60±0.06 Ma	Tis report
05BV-G437	45°41.372′	122°00.772′	Tha	Andesite	Plagioclase	21.94±0.06 Ma	This report
02BV-G52A	45°43.317′	122°03.664′	Thba	Basaltic andesite	Plagioclase	21.59±0.31 Ma	This report
04BV-G281A	45°38.535′	122°00.919′	Teha	Andesite	Plagioclase	19.50±0.05 Ma	This report
02BV-G55B	45°41.376′	122°02.999′	Tecu	Dacite block	Plagioclase	19.48±0.04 Ma	This report
06BV-G599	45°43.463′	122°02.522′	Tepa	Andesite	Plagioclase	20.07±0.03 Ma	This report
05BV-G345	45°40.746′	122°03.199′	Qmwc	Basaltic andesite	Groundmass	1,068±8 ka	Fleck and others, 2014
						1,050±6 ka	This report
						1,056±9 ka	Weighted mean age
02BV-G10A	45°43.942′	122°02.970′	Qtcr	Basaltic andesite	Groundmass	1,065±6 ka	Fleck and others, 2014
						1,066±11 ka	This report
						1,065±5 ka	Weighted mean age
05BV-G420	45°39.793′	122°02.014′	Qmlc	Basaltic andesite	Groundmass	1,061±17 ka	Corrected from Fleck and others, 2014
02BV-G90B	45°39.088′	122°05.588′	Qmdc	Basaltic andesite	Groundmass	821±24 ka	Fleck and others, 2014
02BV-G116A	45°37.987′	122°06.405′	Qmdc	Basaltic andesite	Groundmass	879±7 ka	Preferred age of unit; Fleck and others, 2014
QV01-36	45°38.000′	122°01.345′	Qlbr	Basaltic andesite	Groundmass	498±7 ka	Fleck and others, 2014
QV98-17	45°37.700′	122°01.313′	Qmbr	Basaltic andesite	Whole rock	55.8±6.1 ka	Fleck and others, 2014
QV98-17	45°37.700′	122°01.313′	Qmbr	Basaltic andesite	Whole rock	84.2±5.1 ka	Considered spurious; Fleck and others, 2014
QV01-35B	45°37.612′	122°01.195′	Qmbr	Basaltic andesite	Groundmass	58.4±6.4 ka	Preferred age of unit; Fleck and others, 2014

Table 5. Paleomagnetic data for Columbia River Basalt flows and Quaternary volcanic rocks, Beacon Rock 7.5' quadrangle, Skamania County, Washington.

[See figure 18 (sheet 2) for sample locations. λ_{SITE} and ϕ_{SITE} are latitude and west longitude of site (degrees). Strike/Dip, strike and dip of host rock (strike 90° counterclockwise of dip direction). I_c, D_c, paleomagnetic directions corrected for structural tilt. N/N_0 is number of samples analyzed/number of samples collected. *R* is vector sum of *N* unit vectors. *k* is the concentration parameter (Fisher, 1953) for means calculated using Bingham statistics, *R* is not calculated. α_{95}, the radius of 95% confidence (degrees). λ_P and ϕ_P, latitude and east longitude of virtual geomagnetic pole (degrees) corrected for structural tilt. --, not applicable. Analyses by J.T. Hagstrum, U.S. Geological Survey, Menlo Park, California, using techniques described in Fleck and others (2014). Latitudes and longitudes in North American Datum of 1983 coordinates]

Fieldsample No	Laboratory Sample No.	Map Unit	λ_{SITE}	ϕ_{SITE}	Strike/ Dip	I_c	D_c	N/N_0	*R*	*k*	α_{95}	λ_P	ϕ_P
02BV-G115B	CB9199	Tgo	45.63295	-122.11005	135/2	52.0	18.5	8/8	7.9692	227	3.7	70.7	3.9
02BV-G116B	T5065	Tgo	45.63257	-122.10646	135/2	68.2	18.0	7/8	5.9685	159	5.3	76.8	295.7
05BV-G429B	T6239	Tgo	45.65935	-122.01201	135/2	71.5	349.7	6/8	5.8874	44	11.3	77.7	210.5
05BV-G507	T6247	Tgo	45.65624	-122.00977	135/2	75.9	43.2	8/8	7.8990	69	6.7	60.2	276.2
05BV-G398A	T6311	Tgo	45.63022	-122.10998	135/2	52.0	89.1	7/8	6.9555	135	5.2	23.2	304.3
04BV-G321A[1]	--	Tgo	45.64830	-122.02480	135/2	61.8	85.5	--	--	--	--	--	--
04BV-G322[1]	--	Tgo	45.64704	-122.02432	135/2	70.8	17.7	--	--	--	--	--	--
QV03-211A	T3374	Qmbr	45.62638	-122.01972	0/0	72.0	27.3	9/9	8.9597	198	3.7	69.7	284.2
QV03-212A[2]	T3383	Qlbr	45.63361	-122.02183	0/0	54.7	353.6	8/8	7.9061	75	6.5	78.5	85.4
02BV-G10A	4T048	Qtcr	45.73237	-122.04950	0/0	46.8	19.9	7/8	6.7788	27	11.8	66.3	9.6
02BV-G90A	4T040	Qmdc	45.65117	-122.09190	0/0	-66.4	174.9	8/8	7.9801	352	3.0	85.3	192.7
04BV-G319	T6319	Qmlc	45.64672	-122.03120	0/0	64.9	12.6	8/8	7.9653	202	3.9	81.2	315.5
05BV-G345	T6217	Qmwc	45.68325	-122.05425	0/0	48.5	28.1	8/8	7.9785	326	3.1	62.7	354.6
03BV-G1201	--	Qmus	45.66788	-122.12042	0/0	2.7	4.8	--	--	--	--	--	--

[1] Oriented hand specimen; considered reliable for polarity only.

[2] Locality is in large slump block; considered reliable for polarity only.