UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE SNOQUALMIE PASS 1:100,000 QUADRANGLE, WASHINGTON

By

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Open-File Map OF-84-693

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INTRODUCTION

Geological work began in the Snoqualmie Pass 1:100,000 quadrangle before the turn of the century with investigations of coal found along the Green River (Willis, 1886, p. 759-760). The basic geologic framework east of the Cascade Crest was established by Smith and Calkins (1906) in the Snoqualmie Pass 30-minute quadrangle, and many workers (see fig. 1) have drawn on their ideas. Fuller (1925) was one of the first to address the complexities of what we call the western melange belt and to develop the idea that some of the bodies of magma that ultimately formed the Tertiary batholiths vented to form the Tertiary volcanic cover, a theme since expanded upon (Cater, 1960, 1969; Fiske and others, 1963; Tabor and Crowder, 1969). Hammond (1963) was the first to attack the difficult problems of regional correlation presented by post-Eocene volcanic rocks and has continued his regional studies in subsequent years (1977, 1980). Detailed mapping in the western foothills was begun on modern base maps by Vine (1962) and Gower and Wanek (1963). Our work, which we began in 1975, is part of a larger project that includes mapping the Wenatchee 2° quadrangle at 1:100,000 scale (Tabor and others, 1980, 1982a, b, 1984).

Frizzell, Tabor, Booth, and Ort mapped and compiled most of the bedrock geology. Booth mapped the unconsolidated deposits in the northwestern third of the map area and Waitt mapped unconsolidated deposits elsewhere.

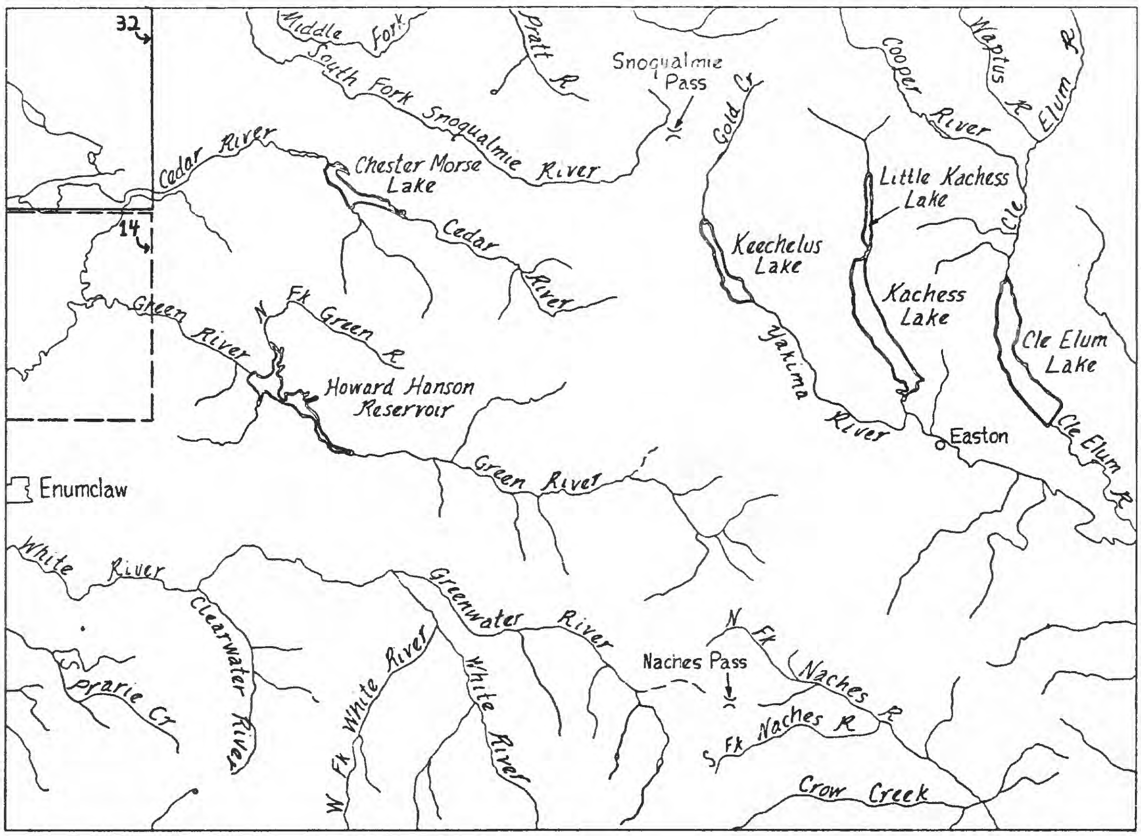
Our field work was considerably aided by the efforts of Sharon Allshouse and Eduardo Rodriquez in 1975, Jay Coburn and Ron Tal in 1976, Bill Gaum, Margaret Goddard, and Kim Marcus in 1977, Elizabeth L. Matthinson and Nora Shew in 1978, Steve Connelly, Stephen A. Sandburg, Fred Beall, Frederika C. Moser, and Susan Cook in 1981, and by Carol Eddy and Tad Schirmer in 1982. M. Jean Hetherington, Steve Connelly, Bill Gaum, and Mark Gordon also helped with lab and office work; Catherine R. McMasters provided drafting support. Dennis H. Sorg continues to help make radiometric dating experiments feasible by supplying clean mineral separates. The late Jack Johnson helicoptered us to the rocks in 1979 and 1981.

We benefited from conversations with many colleagues including Larry Chitwood, Eric Erickson, Sheri Goetsch, Howard Gower, Paul Hammond, Bob Miller, Bill Phillips, Don Turner, Joe Vance, Tim Walsh, Ray Wells, John Whetten, and Jim Yount. Don Swanson provided unpublished data on the Columbia River Basalt Group. Jim Mattinson, Joe Vance, and Bob Zartman graciously discussed and shared isotopic data with us.

GENERAL GEOLOGY

The Snoqualmie Pass quadrangle encompasses several major geologic and tectonic elements of the Pacific Northwest (fig. 2). Just north of the quadrangle (Tabor and others, 1982b), the broadly exposed rocks of the pre-Tertiary metamorphic and plutonic core of the North Cascades and flanking Paleozoic and Mesozoic melange sequences pass beneath the edge of the Tertiary volcanic and sedimentary cover that forms most of the southern Cascade Range of Washington. On the east side of the quadrangle, the north-south trending Straight Creek fault forms a boundary between fundamentally different geologic terranes, a difference expressed in both the crystalline rocks to the north and the Tertiary rocks to the south. The Straight Creek fault, and its probable extensions in Canada and Alaska, is a major strike-slip fault with

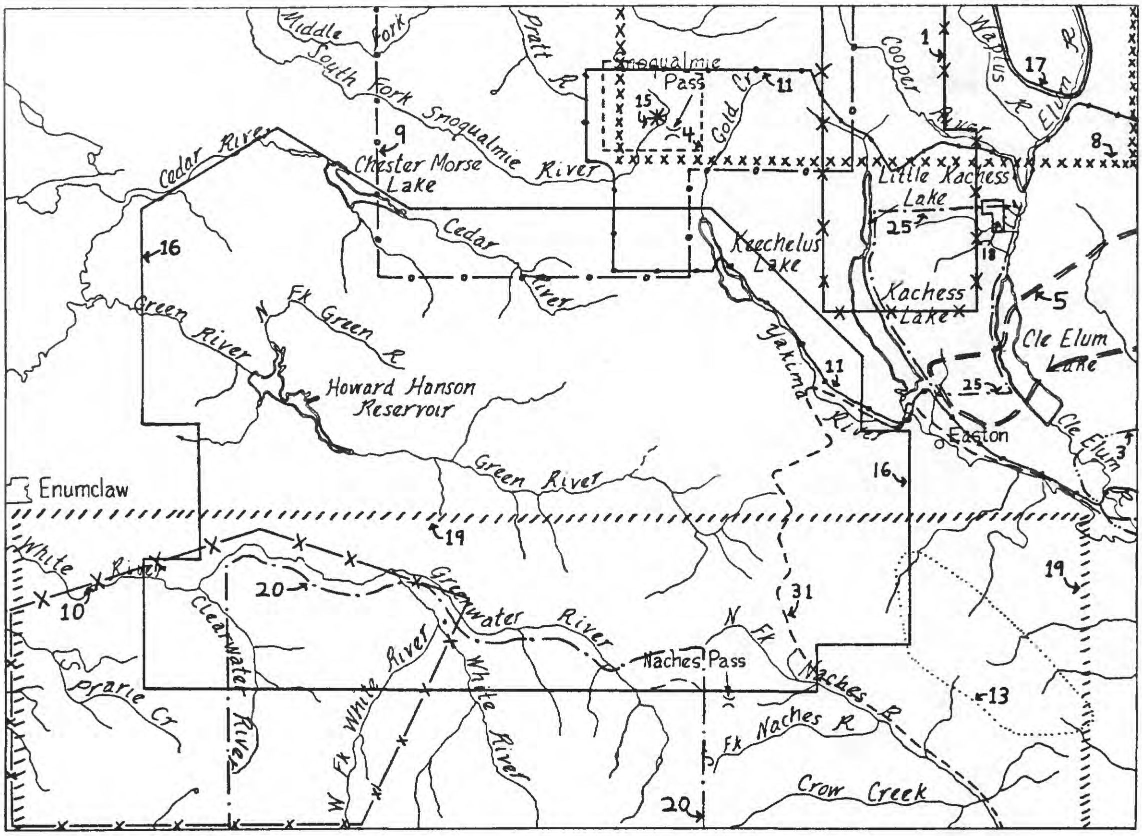
A



Location	Map	Location	Map
1) Ashleman, 1979	B	17) Hammond, 1965	B
2) Bethel, 1951	C	18) Hammond, 1977	B
3) Biekman and others, 1961	B	19) Hammond, 1980	B
4) Chitwood, 1976	B	20) Hartman, 1973	B
5) Clayton, 1973	B	21) Hirsch, 1975	C
6) Crandell, 1973	C	22) Kinnison and Sceva, 1963	C
7) Danner, 1966	C	23) Kremer, 1959	C
8) Ellis, 1959	B	24) Livingston, 1971	C
9) Erickson, 1969	B	25) Lofgren, 1974	B
10) Fischer, 1970	B	26) Newcomb, 1970	C
11) Foster, 1960, 1967	B	27) Porter, 1976	C
12) Fuller, 1925	C	28) Richardson and others, 1968	C
13) Goetsch, 1978	B	29) Rosengreen, 1965	C
14) Gower and Wanek, 1963	A	30) Smith and Calkins, 1906	C
15) Gualtieri and others, 1975	B	31) Stout, 1964	B
16) Hammond, 1963	B	32) Vine, 1969	A
		33) Warren and others, 1945	C

Figure 1. Sources of map compilation data for Snoqualmine Pass 1:100,00 sheet. Map A, much data used; little to modest modifications; Map B, some data used; Map C, consulted, but not used in complication.

B


Middle Fork
South Fork Snoqualmie River
Pratt R
Snoqualmie Pass
Gold Cr
Cooper River
Waptus R
Cle Elum R
Cedar River
Chester Morse Lake
Cedar River
Keechelus Lake
Little Kachess Lake
Kachess Lake
Cle Elum Lake
Green River
N Fk Green R
Howard Hanson Reservoir
Yakima River
Easton
Cle Elum R
Green River
Enumclaw
White River
Greenwater River
Clearwater River
S Prarie Cr
W Fk White River
White River
Naches Pass
N Fk Naches R
S Fk Naches R
Crow Creek
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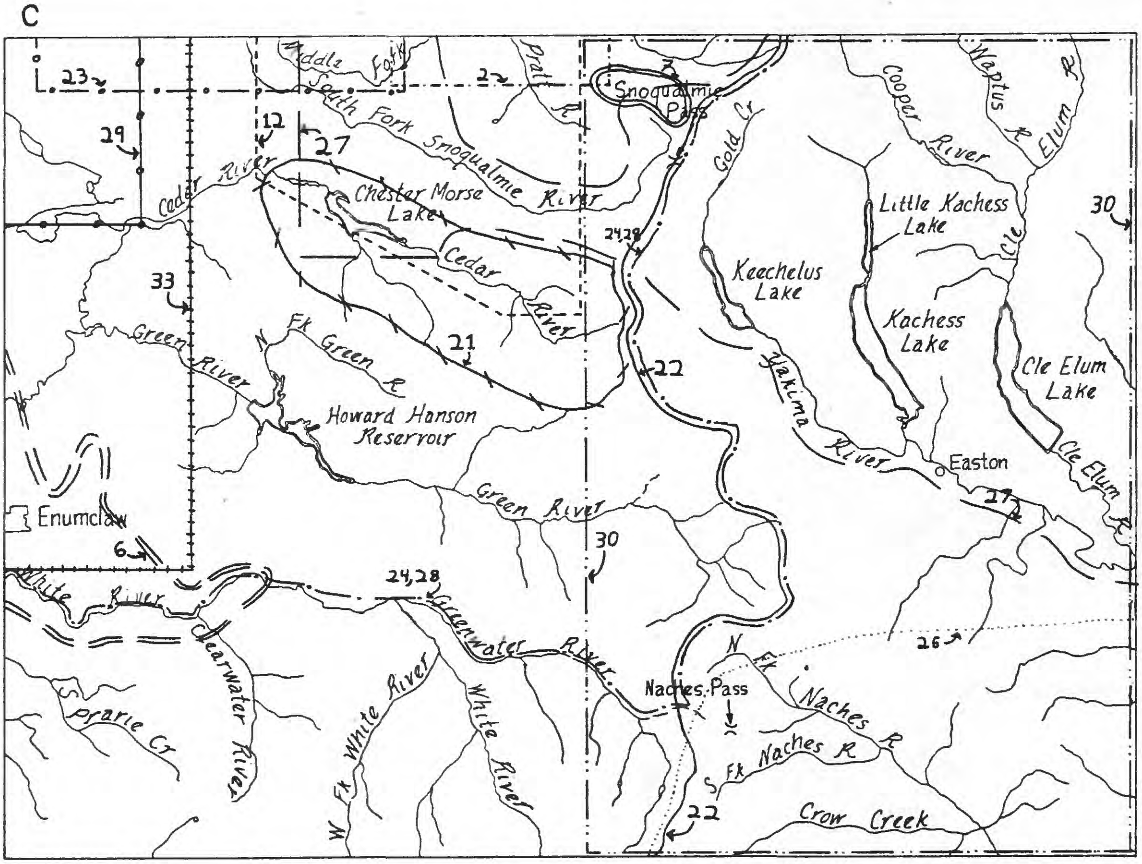
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Easton
Cle Elum R
Green River
Enumclaw
White River
Greenwater River
Clearwater River
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W Fk White River
White River
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probable post-middle Cretaceous, pre-Oligocene right-lateral displacement variously estimated between 180 and 90 km (Misch, 1977; Frizzell, 1979; Vance and Miller, 1981). Oligocene movement along the Straight Creek mostly down-dropped rocks on the western side. Near the southeast corner of the quadrangle, near where it disappears under Miocene lava of the Columbia River Basalt Group, the Straight Creek Fault intersects the Olympic-Wallowa lineament of Raisz (1945; See also Kienle and others, 1977; Tabor and Frizzell, 1979) in a complex of curving faults and folds. The lineament, originally defined by its physiographic expression, stretches from the Wallowa Mountains in Oregon to the Strait of Juan de Fuca between the Olympic Peninsula and Vancouver Island. The lineament traverses the Snoqualmie Pass quadrangle almost diagonally from the southeast to northwest and is expressed by a broad zone of faults and folds in rocks ranging in age from Jurassic to Miocene. The lineament is most strongly expressed in the faulted and folded rocks of the Manastash River block (Tabor and others, 1984) where it meets the Straight Creek fault; faults in the Straight Creek zone appear to swing southeastward into the lineament trend (Tabor and Frizzell, 1979). The lineament loses definition where it crosses the Cascade Crest just west of the the Straight Creek fault, but it appears to be expressed in broad northwest-trending folds and faults in Miocene volcanic rocks between the South Fork of the Snoqualmie and White Rivers.

In the uplifted block east of the Straight Creek fault, the oldest rocks exposed comprise three separate tracts:

1) A tectonic melange of serpentinite, serpentinized peridotite, gabbro, diabase, and greenstone that crops out in the northeast corner of the quadrangle is continuous with the Ingalls Tectonic Complex, exposed to the east and northeast (Tabor and others, 1982; Tabor and others, in press). The Ingalls Tectonic Complex is a dismembered ophiolite with mostly Late Jurassic components. It was thrust over the protolith of the Chiwaukum Schist (Miller, 1980a) now part of the Cascade crystalline core, prior to the Late Cretaceous metamorphic event documented by Mattinson (1972).

2) Adjacent to the Straight Creek fault, the Easton Schist and unnamed metavolcanic rock on North Peak are exposed in anticlinal cores in Eocene rocks. The Easton, composed of phyllite, greenschist, and blue amphibole schist, correlates with the Shuksan Metamorphic Suite of Misch (1966) which is thought to have a protolith age of Late Jurassic and a metamorphic age of Early Cretaceous (Brown and others, 1982). Just south of Easton, the type area, the schist is in tectonic contact with a hornblende tonalite orthogneiss that yields 150 m.y. old (Late Jurassic) zircons.

3) The Lookout Mountain Schist of Stout (1964) is separated from the Easton Schist by infolded and faulted Tertiary rocks and a wide shear zone or tectonic melange containing slivers of Easton Schist. The Lookout Mountain schist is mostly an aluminum-rich garnet-mica schist with scattered lenses of gneissic amphibolite and is locally recrystallized near a 157 m.y. old tonalite intrusion.

West of the Straight Creek fault, the oldest rocks are found in limited exposures of melange that contain diverse rock types with probable Paleozoic and certain Mesozoic ages. North of Snoqualmie Pass, thermally metamorphosed chert, basalt, and marble are the southernmost outcrops of an eastern melange belt more widely exposed to the north (Frizzell and others, 1982, in press; Tabor and others, 1982b). In the northwest part of the quadrangle isolated exposures of graywacke, argillite, chert, and metagabbro represent a western melange belt that is also extensively exposed to the north (Frizzell and others, 1982, in press; Tabor and others, 1982b). To the north, the melange belts contain Permian marbles as well as Late Jurassic to Early Cretaceous chert, argillite, and gabbro components and were probably accreted to North America after the Early Cretaceous and before the Eocene.

The most complete record of geologic history in the Snoqualmie quadrangle embraces the Tertiary period. In the uplifted block east of the Straight Creek fault, the oldest Tertiary rocks crop out in two subsidiary structural blocks: the Teanaway River block and the Manastash River block (fig. 2; Tabor and others, 1984). In the Teanaway River block, the tightly folded and faulted Swauk Formation consists of fluviatile feldspathic subquartzose sandstone, siltstone, and conglomerate and the interbedded early to middle Eocene dacite and andesite flows, breccia, and tuff of the Silver Pass Volcanic Member. The relatively undeformed middle Eocene Teanaway Formation of andesite and basalt flows, tuff, and breccia with minor rhyolite unconformably overlies the Swauk. The late Eocene Roslyn Formation conformably overlies the Teanaway and is composed of subquartzose feldspathic sandstone, is conglomerate-rich in the lowermost part, and contains extensively mined coal beds in the uppermost of three subunits.

The threefold sequence--Swauk, Silver Pass, Teanaway--in the Teanaway River block is repeated in the Manastash River block where all the rocks are tightly folded and faulted along structures that help define the intersection of the Straight Creek fault with the Olympic-Wallowa lineament (Tabor and Frizzell, 1979; Tabor and others, 1984). The feldspathic subquartzose to quartzose sandstone and lesser amounts of siltstone, conglomerate, and bituminous coal of the Manastash Formation correlate with the Swauk Formation. Andesite, dacite, and rhyolite in flows, tuff, and breccia of the Taneum Formation conformably overly the Manastash Formation, and, above the Taneum, the conformable Basalt of Frost Mountain correlates with the Teanaway Formation.

No rocks representing these threefold sequences are exposed west of the Straight Creek fault in the Snoqualmie Pass quadrangle, but limited exposures in the western foothills of the range, in a block informally refered to as the Green River block, reveal late early to early middle Eocene shallow-marine volcanic-lithic subquartzose sandstone, the Raging River Formation, which is the temporal equivalent of the Swauk and Manastash Formations. The base of the Raging River Formation is not exposed, but it is overlain conformably by nonmarine feldspathic subquartzose sandstone of the Tiger Mountain Formation of the Puget Group.

The late early to late Eocene Puget Group is the more western of two units of complexly deformed Paleogene sedimentary and interbedded volcanic rocks that crop out west of the Straight Creek fault. The more eastern of the units occurs in the Cabin Creek block of Tabor and others (1984) and consists of interbedded volcanic rocks and fluviatile feldspathic subquartzose sandstone comprising the middle Eocene to early Oligocene Naches Formation. The area between the Puget Group and the Naches is covered by mildly deformed Oligocene and Miocene volcanic rocks that predominate the Cascade Range to the

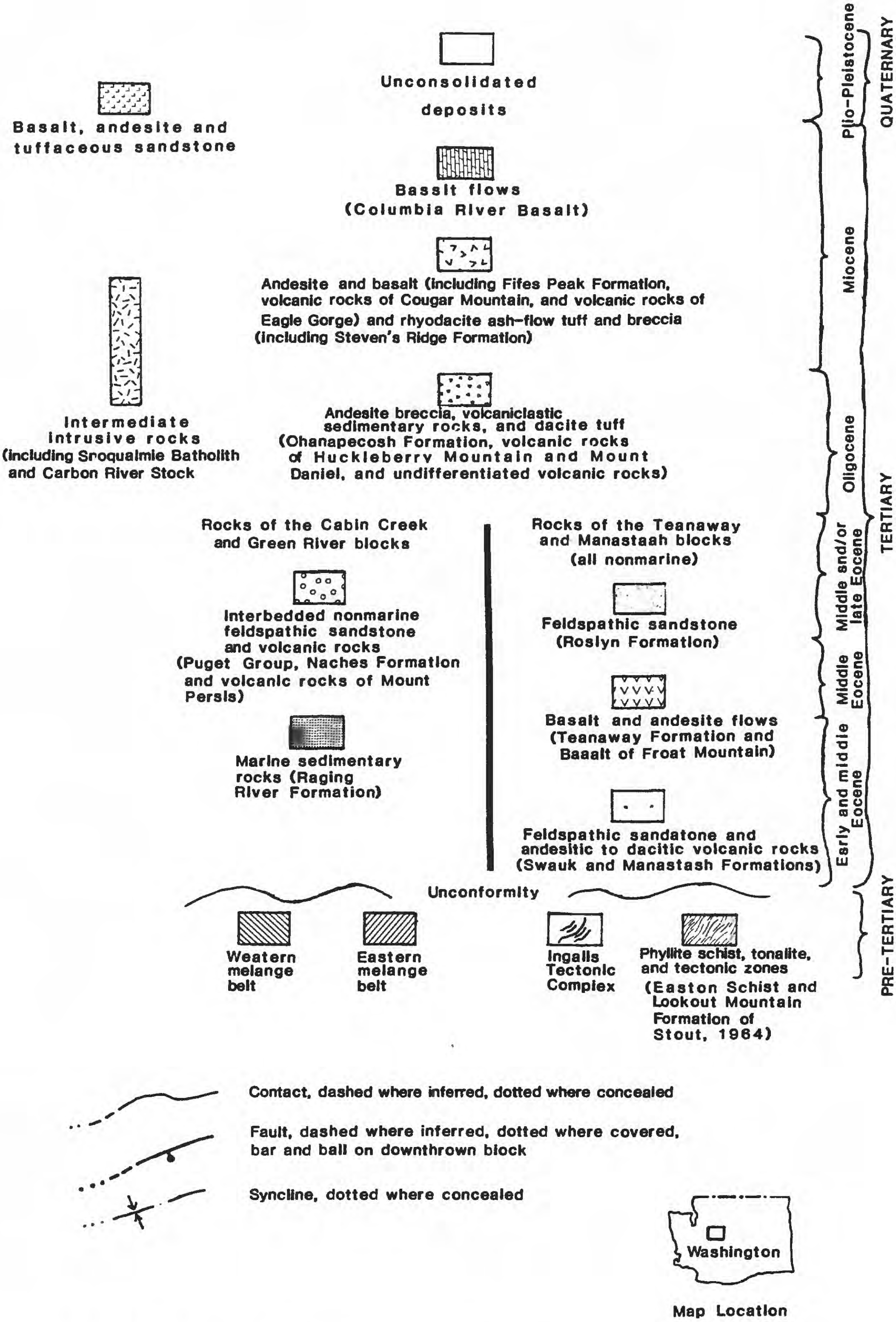
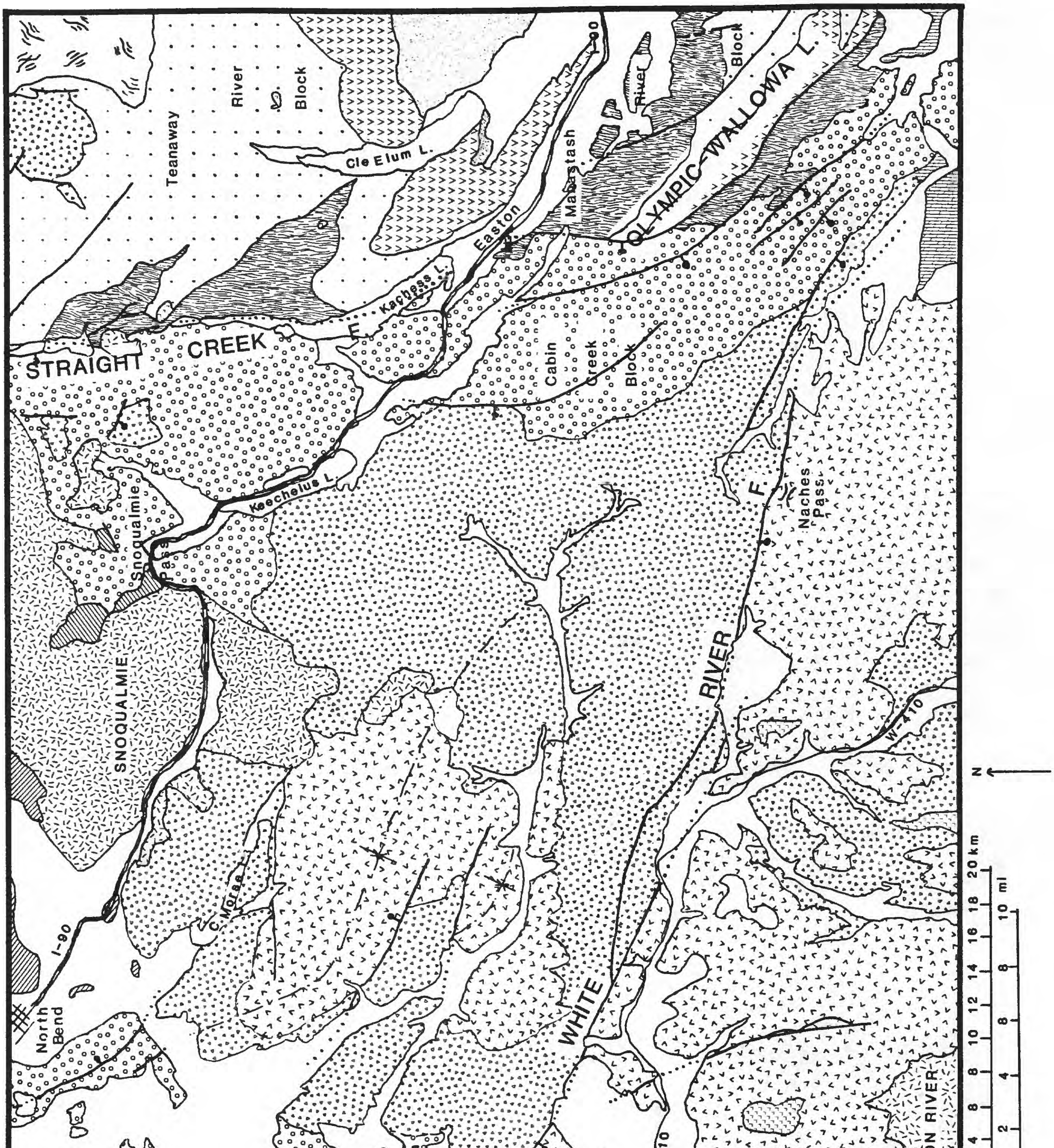


Figure 2 -- Simplified geologic map of the Snoqualmie Pass 1:100,000 quadrangle


STRAIGHT CREEK F.
Teanaway River Block
Cle Elum L.
Kachess L.
Easton
Manastash River Block
OLYMPIC-WALLOWA L.
I-90
Cabin Creek Block
Keechelus L.
Snoqualmie Pass
SNOQUALMIE
WHITE RIVER F.
Naches Pass
W-410
C. Morse
North Bend
Green River Block
Enumclaw
CARBON RIVER
N
0 2 4 6 8 10 12 14 16 18 20 km
0 2 4 6 8 10 mi

south. Although containing similar isotopic ages of about 40-45 m.y., similar fossil megaflora, and similar deformational style, the Naches Formation and the Puget Group are nowhere seen in contact and the Puget Group contains a much higher proportion of muscovite than does the Naches. Nevertheless, rocks of these units may have been deposited by a single Eocene fluvial-deltaic system along the Eocene continental margin (c.f. Johnson, in press).

Volcanic rocks of Mount Persis, mostly exposed north of the quadrangle, may have erupted during the same middle to late Eocene interval as the volcanic rocks in the Puget Group and Naches Formation. The Persis volcanic rocks are in fault contact with the Puget Group on Rattlesnake Mountain. The mild deformation of the volcanic rocks of Mt. Persis contrast with the pronounced deformation of the Puget rocks (Tabor and others, 1982b).

A thick sequence of Oligocene and Miocene volcanic rocks underlies the southwest half of the quadrangle (fig. 2) and forms the bulk of the southern Cascade Range in Washington and Oregon. In the Snoqualmie Pass quadrangle these rocks crop out in two structural blocks separated by the west-northwest trending White River fault.

A tripartite sequence of volcanic rocks crops out south of the White River fault and is in part equivalent to and continuous with rocks mapped south of the quadrangle near and around Mount Rainier (Fiske and others, 1963). These rocks underlie the Quaternary volcanoes that give the southern Cascade Range its striking profile. The oldest unit of this trio, the Ohanapecosh Formation, consists mostly of colorful, highly altered, well-bedded andesite to dacite breccia, volcaniclastic sedimentary rocks, and locally abundant altered basalt and andesite flows. The Miocene Stevens Ridge Formation was deposited in pronounced canyons cut into the Ohanapecosh Formation. It consists mostly of rhyodacitic ash-flow tuff and interbedded silicic tuff and breccia. Miocene basalt and andesite flows, breccias, and subordinate volcanic sedimentary rocks and rare rhyodacite tuff generally overlie the Stevens Ridge rocks, but are in part contemporaneous with them. These relatively unaltered lavas and pyroclastic rocks form the Fifes Peak Formation and flank a high in the upper White River area.

A prominent interbed in the upper part of the Fifes Peak Formation called the rhyolite tuff of White River appears to be the extrusive equivalent of the rhyolite intrusive complex of Clear West Peak (Fiske and others, 1963; Fischer, 1970; Mattinson, 1977).

North of the White River fault, well-bedded tuff, breccia, and minor flows of highly altered andesite, basalt, and dacite --the volcanic rocks of Huckleberry Mountain-- appear to be temporal and lithologic correlatives of the Ohanapecosh Formation south of the fault. Overlying the bedded tuff and breccia are flows of porphyritic andesite and subordinate breccia--here called the volcanic rocks of Eagle Gorge. The flows of Cougar Mountain lie conformably on top of the Eagle Gorge unit; they consist of generally fresh porphyritic andesite, some basalt, and conspicuous interbeds of andesitic mudflow breccia. The Cougar Mountain rocks appear correlative with the Fifes Peak Formation, but the underlying flows and breccias of the Eagle Gorge unit may include both flows of the overlying Cougar Mountain unit and flows of the underlying Huckleberry Mountain unit. Conspicuously missing in the section are the thick rhyodacite ash-flow tuffs representing Stevens Ridge equivalents. A discontinuous rhyodacite ash-flow tuff at the base of the Eagle Gorge unit may be Stevens Ridge, but another candidate is an extensive ash-flow tuff about 350 m up in the Eagle Gorge section.

Among the few outliers of the Oligocene-Miocene volcanic cover that crop out north of the main volcanic terrane is a prominent accumulation east of the Straight Creek Fault. Andesite and dacite breccia and tuff in the Goat Mountain area are continous with the volcanic rocks of Mount Daniel (Tabor and others, 1982b, 1984). A partial ring dike on Goat Mountain and nearby catastrophic breccias suggest that the volcanic rocks were deposited in a tectono-volcanic depression (Hammond, 1965; Tabor and others, 1984).

Overlying the Fifes Peak Formation along the lower Little Naches River is the Miocene Grande Ronde Basalt of the Columbia River Basalt Group. Along the southwest side of the Manastash River block, this flood basalt has been offset more than 1000 meters along north-northwest-trending high-angle faults that parallel the Straight Creek fault and the Olympic-Wallowa lineament.

An outlier of Late Miocene volcanic rocks and associated dikes, the Howson Andesite, crops out on ridge tops on both sides of Cle Elum Lake. Possibly younger thin flows and pyroclastic deposits of olivine basalt overlie Fifes Peak flows on ridge tops near Canyon Creek and on Dalles Ridge. Their age is uncertain, but they may be Pliocene or Pleistocene.

Based upon the isotopic ages on the Oligocene to Miocene volcanic rocks, mapped lithologic units have considerable temporal overlap, hampering precise correlation and reconstruction of eruptive events. The eruption of the tripartite sequence of volcanic rocks in the quadrangle appears to have begun about 35 m.y. ago (early Oligocene) and ended about 20 m.y ago (early Miocene) (Vance, 1982; Frizzell and Vance, 1983; Turner and others, 1983). The Stevens Ridge and Fifes Peak Formations have a considerable overlap in age in the range 25 to 22 m.y., which suggests rapid erosion and a quick sucession of constrasting volcanic eruptions.

The Miocene Snoqualmie batholith and related stocks intrude pre-Tertiary rocks, the Naches Formation, and Tertiary volcanic rocks north of the White River fault. Rocks of the Ohanapecosh, Stevens Ridge, and Fifes Peak Formations are intruded by the Miocene Carbon River stock (a probable satellite of the Tatoosh pluton which is exposed south of the quadrangle) and related plugs near the southwest corner of the quadrangle. Intrusive events at 25 and 17-20 m.y. ago formed the Snoqualmie and Tatoosh bodies; a 14 m.y event is recorded in the Tatoosh (Mattinson, 1977). Numerous smaller intrusive bodies have invaded the volcanic pile between these major intrusions and may be the high-level apophyses of a continuous Miocene batholith in the subsurface.

A thick flow of early Pleistocene andesite, an early lava of the Mount Rainier volcano, caps a ridge near Huckleberry Creek. In the last 10,000 years, numerous mudflows swept down the White River valley from Mount Rainier (Crandell, 1969), and several eruptions have blanketed the southern part of the area with varying thicknesses of tephra (Mullineaux, 1974).

Moraines and outwash record as many as three alpine glaciations in the high Cascades. Late-glacial and Holocene alpine deposits occupy many of the higher mountain valleys and cirques. In the western quarter of the quadrangle, multiple advances of the Puget lobe of the Cordilleran ice sheet left a record dominated by the most recent invasion of ice about 14,000 years B. P. (Crandell, 1963; Waitt and Thorson, 1983) during the Vashon stade of the Fraser Glaciation (Armstrong and others, 1965). Marginal and submarginal drainage has blanketed much of this area with waterlain ice-contact deposits and recessional outwash. Together with a sequence of channels, spillways, and terraces they express the progressive northwest retreat of the Vashon ice margin during deglaciation (Booth, 1984).

CORRELATION OF MAP UNITS
Snoqualmie Pass 1:100,000 quadrangle

Note: For melange and metamorphic units, positions of boxes with solid boundaries indicate age of assemblage or metamorphism, respectively, boxes with dashed boundaries indicate age of the protolith

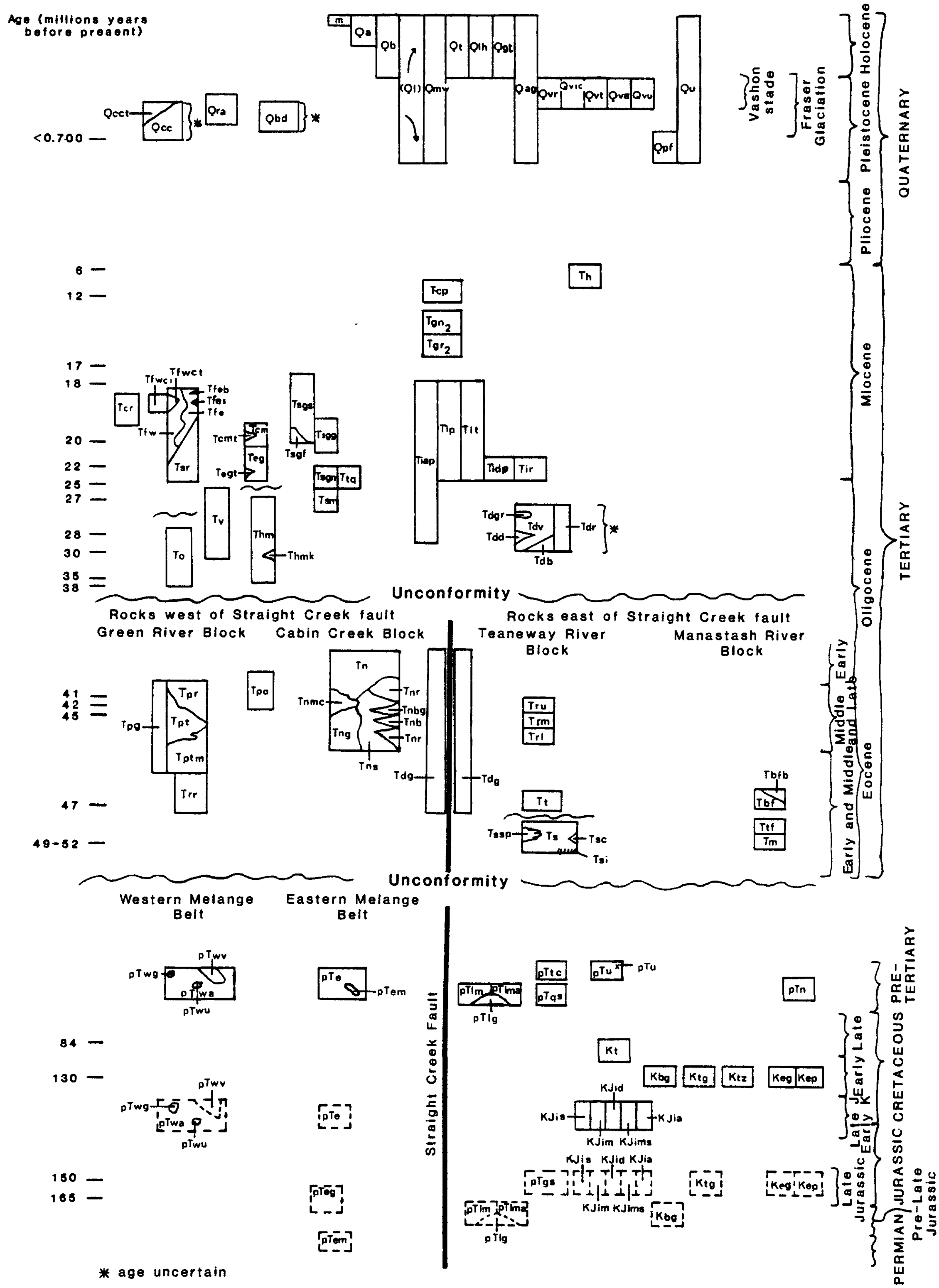


Table 1

Radiometric analyses of rocks in the Snoqualmie Pass Quadrangle

[All new ages calculated on the basis of 1976 IUGS decay and abundance constants. K-Ar ages from reports earlier than 1976 corrected after Dalrymple (1979). Errors on single K-Ar ages referenced to this report based on empirical function relating coefficient of variation in the age to percent radiogenic argon (R. W. Tabor, R. V. Mark and F. H. Wilson, written communication, 1984). Uranium-thorium-lead isotope ages reported in the following order: $^{206}Pb/^{238}U$; $^{207}Pb/^{235}U$; $^{207}Pb/^{206}Pb$; $^{208}Pb/^{232}Th$.]

No.	Sample Number	Method	Materials	Location Latitude	Location Longtitude	Units or Formation	Age (m.y.)	Comment	Reference
1	VF-76-479	K-Ar	Hornblende	47°21.4'	121°04.0'	Howson Andesite	6.2±1.8	Average of two extractions	This report
2	VF-78-370	K-Ar	Hornblende	47°25.2'	121°13.6'	Volcanic rocks of Cooper Pass	12.4±1.7	Average of three extractions	do.
		F-T	Zircon				28.5±0.8;14.4±0.6	Two populations; see text	
	VF-75-148	do.	do.			do.	9.4±0.4		do.
3	VF-82W-565	K-Ar	Hornblende	47°00.7'	121°51.7'	Carbon River stock	19.4±3.0		do.
			Biotite				17.1±0.4	Average of two extractions	
4	RWT-608-79	K-Ar	Biotite	47°29.2'	121°30.7'	Snoqualmie batholith	19.7±0.7	Tsgg	This report
5	PEH 3-68	do.	do.	47°21.0'	121°34.5'		16.9±2	Tsgg	Laursen and Hammond, 1974, p. 19
6	PEH 2-68	do.	do.	47°23.7'	121°27.5'	do.	20.5±2	do.	do.
7	-----	do.	do.	47°24.3'	121°26.8'	do.	17.	do.; location uncertain	Lipson and others, 1961, p. 460
8	Ar-91	do.	do.	47°24.1'	121°26.9'	do.	18.5±0.9	do.	Baadsgard and others, 1961, p. 691
9	RWT-262-81	F-T	Zircon	47°17'	121°29.5'	Volcanic rocks of Huckleberry Mountain	17.6±0.6	Rhyolite reset by Tsgs	This report
10	RWT-525-77	K-Ar	Hornblende	47°17.7'	121°26.3'	Dacite porphyry	24.2±1.4	Intrusive into Huckleberry Mountain	do.
11	RWT-361-79	K-Ar	do.	47°26.4'	121°14.7'	Three Queens Stock	27.0±3.0	Average of two extractions	This report
12	----	K-Ar	Plagioclase	46°59'	121°51'	Fifes Peak Formation; western facies	17.1±4.3	Andesite, Mowich Lake area; south of map	Hartman, 1973, p. 25
13	----	do.	do.	do.	do.		20.8±2.6		do.
14	----	do.	Wholerock	47°00.3'	121°42.2'	do.	19.1±0.4	Tfwci	Hartman, 1973, p. 30
15	71-21b	U-Pb	Zircon	47°00.1'	121°42.3'	do.	21.8	do.	Mattinson, 1977, p. 1512, table 1
	71-21a	do.	do.			do.	22.6	do.	do.
16	----	K-Ar	Wholerock	47°00.6'	121°28.1'	do.	22.3±1.9	Tfe; andesite; location uncertain	Hartman, 1973, p. 24
17	----	do.	do.	do.	do.	do.	24.0±1.4	do.	do.
18	R-165	K-Ar	Hornblende	47°02.3'	121°35.5'	Stevens Ridge Formation	22.0±0.5		This report; J. A. Vance, written comm., 1981
19	CRS-413	do.	do.	47°08.8'	121°42.2'	do.	34.9±1.2	Probably too old	Fischer, 1976, p. 51
			Biotite				23.9±0.9		do.
20	----	do.	Plagioclase	47°03.2	121°34.1'	do.	21.0±1.5		Hartman, 1973, p. 21
21	----	do.	do.	do.	do.	do.	20.0±1.8		do.
22	RWT-76-82	do.	Hornblende	47°07.1'	121°39.8'	do.	21.3±0.7		This report
		do.	Biotite			do.	22.0±0.8		do.
23	RWT-289-81	F-T	Zircon	47°02.0'	121°57.2'	do.	23.1±0.7		do.
24	DB-81-421	F-T	Zircon	47°15.2'	121°43.2'	Volcanic rocks of Eagle Gorge	20.8±0.7	Teg	do.
25	VF-82W-699	K-Ar	Biotite	47°06.0'	121°21.4'	Volcanic rocks of Huckleberry Mountain	26.5±.08		This report
									do.
26	RWT-252-81	F-T	Zircon	47°23.1'	121°47.6'	do.	24.7±1.7		do.
27	DT-78-28A	K-Ar	Wholerock	47°16.0'	121°52.9'	do.	>27.9±1.6	Intrusion into Thm	Turner and others, 1983, table 1
28	R-14	F-T	Zircon	47°16.8'	121°21.0'	do.	30.2±1.1		Tabor and others, 1964, table 2
29	VF-78-323	do.	do.	47°16.8'	121°21.0'	do.	32.4±0.6		do.
30	R-6	do.	do.	47°20.6	121°21.5'	do.	30.4±1.2	Thmk	do.
31	DT-78-20	K-Ar	Wholerock	47°17.8'	121°57.3'	do.	>29.1±1.8	Basalt intruding Tpg	Turner and others, 1983, table 1
32	-27B	do.	do.	47°16.1'	121°52.8'	do.	>32.5±2.0	Intrusion into Thm	do.
33	-30A	do.	do.	47°15.9'	121°52.8'	do.	>35.2±2.2	Flow breccia	do.

Table 1 -- continued

Map No.	Sample Number	Method	Materials	Location Latitude	Location Longitude	Units or Formation	Age (m.y.)	Comment	Reference
34	RWT-365-79	F-T	Apatite	47°28.6'	121°04.0'	Volcanic rocks of Mount Daniel	33.5±3.8	Tdd	Tabor and others, 1984, table 2
35	DT-78-32A	K-Ar	Plagioclase	47°16.9'	121°58.7'	Puget Group	>43.4±1.9	Ash parting in coal	Turner and others, 1983, table 1
36	-26	do.	do.	47°18.7'	121°57.3'	do.	41.2±1.8	do.	do.
37	-27A	do.	do.	47°18.7'	121°57.3'	do.	≥55.4±2.6	do.; age unreliable	do.
		F-T	Apatite			do.	42.2±7.8	Ash parting in coal	do.
38	-36F	K-Ar	Plagioclase	47°19.3'	121°56.8'	do.	>44.2±2.1	do.	do.
39	-31B	do.	do.	47°18.0'	121°57.0'	do.	45.0±2.1	do.	do.
40	-37A	do.	do.	47°19.2'	121°56.0'	do.	41.7±3.1	do.	do.
		F-T	Apatite			do.	46.8±6.0	do.	do.
41	-37B	K-Ar	Plagioclase	47°19.2'	121°56.0'	do.	44.4±2.0	do.	do.
42	R-11	F-T	Zircon	47°19.6'	121°19.7'	Naches Formation	39.9±1.6	Tnr	Tabor and others, 1984, table 2
43	RWT-363-79	do.	do.	47°05.4'	121°07.2'	do.	40.0±1.4	do.	do.
44	R-130	do.	do.	47°05.1'	121°06.8'	do.	43.8±2.5	do.	do.
45	R-38	do.	do.	47°02.3'	121°03.5'	do.	44.0±1.8	do.	do.
46	R-129	do.	do.	47°05.8'	121°08.6'	do.	44.6±3.2	do.	do.
47	R-12	do.	do.	47°19.9'	121°20.2'	do.	30.4±2.8	do; probably reset	do.
48	R-13	do.	do.	47°23.6'	121°23.3'	do.	35.5±1.4	Tnmc	do.
49	R-15	do.	do.	47°22.8'	121°23.5'	do.	35.9±1.5	do.	do.
50	RWT-336-77C	K-Ar	Wholerock	47°10.7'	121°10.8'	do.	40.5±0.3	Basalt; probable minimum age, but interpreted to be close to real age	Tabor and others, 1984, table 1
51	BG-209-77A	do.	do.	47°06.2'	121°09.0'	do.	43.2±3.9	Tnb; do.	do.
52	M84A-77A	do.	do.	47°03.6'	121°05.2'	do.	43.0±8.3	Tnb; age unreliable	Tabor and others, 1984, p. 40
53	RWT 140-75B	K-Ar	Wholerock	47°16.3'	121°10.2'	Teanaway Formation	46.9±0.7	prepared fraction	Tabor and others, 1984, table 1
54	RWT-435-76	K-Ar	Wholerock	47°03.7'	120°59.7'	Basalt of Frost Mountain	32.2±1.3	East of map; unreliable minimum age of prepared fraction	Tabor and others, 1984, p. 40
55	RWT-250-77A	do.	do.	47°05.0'	121°02.2'	do.	47.4±4.6		Tabor and others, 1984, table 1
56	R-20	F-T	Zircon	47°19.6'	121°11.5	Silver Pass Volcanic Member; Swauk Formation	52.2±1.9		Tabor and others, 1984, table 2
57	R-19	do.	do.	47°19.8'	121°11.9'	do.	54.1±2.1		do.
58	PEH-5-68	K-Ar	Plagioclase	47°28.5'	121°02.5'	Fortune Creek Stock	50±4	Too young for crystallization age	Laursen and Hammond, 1974, p. 18
59	RWT-151-75	do	Hornblende	47°28.5'	121°02.7	do.	83.6±2.2	Average of two extractions	This report
60	MR4-1	U-Pb	Zircon	47°08.6'	121°04.7'	Tonalite gneiss of Hicks Butte	(coarse) 153±2;153±2;151±15;--- (fine) 153±2;153±2;153±10;---		J. M. Mattinson and C. A. Hopson, written comm., 1980
61	MRI-1	do	do	47°04.4'	121°04.6'	Quartz Mountain stock	157±2;157±2;164±10;---		J. M. Mattinson and C. A. Hopson, written comm., 1980
62	JTW-79-216	U-Th-Pb	Zircon	47°27.1'	121°24.5'	Eastern melange	(coarse) 164.7;165.9; 183.4;173.4 (fine) 158.2;159.3;175.9;152.3	Metagabbro	Frizzell and others, in press

DESCRIPTION OF THE UNITS

SURFICIAL DEPOSITS

m — MAN-MODIFIED LAND--Gravel or diamicton as fill, or extensively graded natural deposits

Qa — ALLUVIUM--Moderately sorted cobble gravel along rivers to poorly sorted gravelly sand on small-tributary fans; some fan material is similar to that included in unit Qt. Includes post-glacial terrace gravels that are perched above modern floodplain surfaces

Qb — BOG DEPOSITS--Peat and alluvium. Poorly drained and at least intermittently wet. Grades into unit Qa

Ql — LANDSLIDE DEPOSITS--Diamicton of angular clasts of bedrock and surficial deposits derived from upslope. Shown without letter symbol, but with arrows denoting downslope direction of movement

Qmw — MASS-WASTAGE DEPOSITS--Colluvium, soil, or landslide debris with indistinct morphology, where sufficiently continuous and thick to obscure underlying material. Deposit is gradational with units Ql and Qa

Qt — TALUS DEPOSITS--Nonsorted angular boulder gravel to boulder diamicton. At lower altitudes gradational with unit Qa. At higher altitudes includes small rock-avalanche deposits as well as some Holocene moraine, rock glacier, and protalus rampart deposits that lack characteristic morphology. Generally unvegetated

Qlh — LAHARIC DEPOSITS--Nonsorted to muddy boulder diamicton to moderately sorted sand in the White River valley and adjacent lowlands. Includes deposits of numerous Holocene catastrophic mudflows from Mt. Rainier volcano south of the quadrangle, the most extensively exposed being the Osceola mudflow of Crandell and Waldron (1956)

GLACIAL DRIFT AND RELATED DEPOSITS

Qgt — GLACIAL AND TALUS DEPOSITS--Similar material to unit Qt but showing distinct morainal form indicating deposition at terminus of small glacier or permanent snowfield, or by active rock glaciers. Generally unvegetated

Qag — ALPINE GLACIAL DEPOSITS--Ranges from boulder till in uplands and upvalley to gravel or sand outwash on broad valley floors. On valley sides and uplands includes areas veneered with drift but also includes bedrock, alluvial fans, colluvium, or talus deposits. On valley floors also includes small fans, bogs, and modern stream alluvium. Areas of thin, sparse drift not distinguished from bedrock. In headward reaches of high alpine streams, grades into unit Qgt

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION (CORDILLERAN ICE SHEET)--Divided into:

Qvr Recessional outwash deposits--Stratified sand and gravel, moderately to well sorted, and well-bedded silty sand to silty clay deposited in proglacial and ice-marginal environments. Numeral subscripts indicate chronologic sequence of major fluvial deposits, with 1 being the oldest. Arrows indicate water-flow direction, and numbers adjacent to arrows specify the present-day altitude of lake-draining spillways

Qvic Ice-contact deposits--Stratified waterlain sand and gravel, silt, clay, and minor till with abrupt grain-size changes and collapse features indicating deposition adjacent to active or stagnant ice. Numeral subscripts follow the same chronology as Qvr, and indicate probable ice-marginal zones during deposition of the corresponding recessional outwash deposit

Qvt Till--Mainly compact diamicton with subangular to rounded clasts, glacially transported and deposited. Includes minor stratified fluvial deposits. In ice-marginal areas and where covered by a thin layer of recessional outwash, contact with unit Qvr or Qvic is gradational

Qva Advance outwash deposits--Well-bedded gravelly sand to fine sand, generally unoxidized, deposited in proglacial streams. Includes minor pre-Fraser stratified sediment

Qvu Vashon Drift, undifferentiated

Qpf PRE-FRASER GLACIAL AND NONGLACIAL DEPOSITS--Firm gray clay and deeply weathered stratified sand and gravel. Evidence of strong in place weathering throughout exposures includes oxidation, weathering rinds, and clay-mineral replacement

Qu SURFICIAL DEPOSITS, UNDIFFERENTIATED

BEDROCK UNITS

Qcc BASALT OF CANYON CREEK--Light-gray olivine basalt. Olivine with iddingsite rims occurs as phenocrysts in an intergranular matrix of plagiclase microlites and very-fine grained clinopyroxene, opaque minerals, and olivine. In part vesicular. Forms flows with crude columns. Described by Fischer (1970, p. 86-92) who differentiated four flows based upon phenocryst content. Age unknown, but may be younger than 700,000 years (Hammond, 1980, p. 18) Also includes:

Qcct Unconsolidated to semiconsolidated and crudely bedded basaltic tuff and breccia.

Qra ANDESITE OF MT. RAINIER--Gray, porphyritic two-pyroxene andesite rich in phenocrysts of zoned plagioclase, augite, hypersthene and opacitised hornblende. Pilotaxitic groundmass with plagioclase, pyroxene, and opaque minerals. Detailed descriptions of Mount Rainier lavas are in Fiske and others (1963, p. 65-80). Columnar-jointed andesite in Huckleberry Creek forms the northern terminus of the thick, early, valley filling Grand Park flow of Fiske and others (1963, p. 68). Another early flow, immediately to the south (the Burroughs Mountain-Yakima Park flow) that has similar characteristics; has yielded 600,000 and 320,000-year K-Ar ages on plagioclase and whole rock samples, respectively (Crandell and Miller, 1974, p. 17)

Qbd BASALT FLOWS OF DALLES RIDGE--Light gray, pilotaxitic basalt with phenocrysts of olivine, partially to completely altered to iddingsite, in a groundmass composed of plagioclase, clinopyroxene, olivine, and opaque. Hartman (1973, p. 36-37) recognized five flows ranging individually from 3 to 24 m in thickness and totalling about 91 m. Individual flows exhibit well developed columns and have scoriaceous tops and bottoms. Age unknown, but may be younger than 700,000 years (Hammond, 1980, p. 18)

Th HOWSON ANDESITE--Gray hornblende porphyry that is actually dacitic rather than andesitic in composition. Containing plagioclase and either oxyhornblende or common hornblende phenocrysts, in part with hypersthene microphenocrysts, in a groundmass of plagioclase, potassium feldspar, quartz, and opaque. In part with volcanic rock fragments. The body east of Cle Elum Lake exhibits crude columns with variable orientations and contains irregularly shaped vesicles. Although the western body exhibits some flow-like textures, its limited outcrop area and shape indicate that it may be a shallow intrusion. Hornblende yields a potassium-argon (hereafter K-Ar) age of about 6 m.y., late Miocene (table 1, no. 1). The unit was named by Smith and Calkins (1906, p. 10)

Tcp VOLCANICLASTIC ROCKS OF COOPER PASS--Tuffaceous sandstone and volcanic conglomerate. Light green to dark gray dacitic tuffaceous sandstone that grades into gray volcanic-rich conglomerate and breccia. Well-bedded tuffaceous sandstone contains altered plagioclase, quartz (in part rounded and embayed), and opaque mineral grains and volcanic, sedimentary, metamorphic, and granitic lithic clasts in an matrix altered to clay minerals. Sandy volcanic conglomerate-breccia contains volcanic, sandstone, siltstone, phyllite, schist, chert, and granitic clasts. One sample of lithic rhyodacite tuff from the unit yielded a zircon fission-track (hereafter F-T) age of 9 m.y. (table 1, no. 2). A sample intermediate tuff yielded a 12 m.y. K-Ar age on hornblende as well as F-T ages on sparse zircons that attest to 14 m.y. and 28 m.y. igneous events. The three younger ages indicate that these volcaniclastic rocks are middle to late Miocene in age; the zircons yielding the 28 m.y. age are probably reworked from an older volcanic unit described below

YAKIMA BASALT SUBGROUP OF THE COLUMBIA RIVER BASALT GROUP--Consists of:

Grande Ronde Basalt--D. A. Swanson (written communication, 1983) reports flows of fine-grained, aphyric and slightly plagioclase-phyric basalt. Commonly columnar- or hackly-jointed. Interbeds of tuffaceous fine-grained sandstone, siltstone, and mudstone abundant. Flows generally have dense interiors and vesicular upper zones. Invasive flows--lava flows that invade sedimentary deposits, generally as sill-like bodies--are common and have dense upper zones. Pillows present locally, such as 500 m southeast of Jungle Creek Campground on the Naches River. Flows continuous with those on the Columbia Plateau south and east of map area where radiometric ages range from about 16.5 to 15.0 m.y. Subdivided on the Columbia Plateau into four magnetostratigraphic units on the basis of magnetic polarity. The two youngest magnetostratigraphic units occur within the quadrangle--

Tgn_2 Flows of normal magnetic polarity--

Tgr_2 Flows of reversed magnetic polarity--

Tcr CARBON RIVER STOCK--Hypidiomorphic-granular biotite pyroxene granodiorite in the main body and in subordinate sills, locally with micro-quartz diorite (tonalite) border phase. Main phase approximately 40 to 50 percent euhedral to subhedral phenocrystic plagioclase with twinning and oscillatory zoning, 20 percent slightly elongate interstitial orthoclase, 20 to 25 percent equant interstitial quartz, 5 percent biotite which occurs generally as small grains in the groundmass, and 5 to 10 percent euhedral pyroxene or uralite (Fischer, 1970, p. 137 to 150). Pyroxene crystals are mostly uralitized; scarce primary hornblende occurs interstitially. The pervasive replacement of pyroxene by pale green amphibole, magnetite, and biotite is discussed in detail by Fischer (1970, p. 164-173). The Carbon River stock is satellitic to the much larger Tatoosh pluton 16 km to the southeast. Uranium-lead and K-Ar ages from the Tatoosh pluton indicate that its early phases are about 24 and 20 m.y. old, and the main, core phases about 17 and 14 m.y. old (Mattinson, 1973, p. 1512; Fiske and others, 1963, p. 63). Hornblende from the Carbon River stock yields a 19 m.y. K-Ar age, and biotite yields a 17 m.y. age (table 1, no. 3), well within the age range of the Tatoosh

ROCKS OF THE SNOQUALMIE BATHOLITH--Divided into:

Tsgs Granodiorite and tonalite, southern phase--Hornblende-biotite granodiorite and tonalite, medium-grained, mostly equigranular with hypidiomorphic texture, locally with clinopyroxene. CI = 9-24. Based on normative minerals from chemical analyses available in Erikson (1969, appendix 2), overall, the southern phase of the pluton is slightly more K-feldspar rich than the northern phase described below. The sothern phase is mostly light colored and coarsely jointed. Hammond (1963, p. 198-199) described a tonalite (his quartz diorite) border zone. A collection of K-Ar ages on biotite suggest the southern pluton of the batholith is about 17-20 m.y. old (table 1, nos. 5-8). A probably reset F-T age on zircon from a rhyolite tuff near the intrusion on the Cedar River is 19 m.y. (table 1, no. 9)

Tsgf Fine grained monzonite--Highly altered, light-colored fine-grained monzonite with cloudy plagioclase and chloritized hornblende in a discontinuous mesostasis of quartz

Tsgg Granodiorite and granite--Medium-grained hypidiomorphic granular to porphyritic granophyric granodiorite and granite (Erikson, 1969, p. 2221). Mostly with biotite and CI of 1-5, rarely to 10. Normative composition is mostly granodiorite (Erikson, 1969, appendix 2), but with considerably more quartz than the northern and southern phases. Includes most of Erikson's Preacher Mountain quartz monzonite which he considered to be younger than the main phases of the batholith although he described (1969, p.

2221) gradational contacts. We saw evidence of mutual intrusion of the granodiorite-granite with tonalite of the southern phase. A K-Ar age on biotite from the granodiorite and granite unit is about 20 m.y. (table 1, no. 4)

Tsgn Granodiorite and tonalite, northern phase--Biotite-hornblende granodiorite and tonalite, medium-grained, mostly equigranular, with hypidiomorphic texture; locally with clinopyroxene. CI = 9-24. Mostly light-colored, coarsely jointed rock. Description adapted from Erikson (1969, p. 2218-2219). The northern phase is about 25 m.y. old based on interpretation of numerous discordant K-Ar ages of both hornblende and biotite (Tabor and others, 1982b)

Tsm Mafic diorite and gabbro--Biotite-hornblende diorite and gabbro, including mafic pyroxene-bearing tonalite and quartz diorite. CI = 20-40 (Erikson, 1969, p. 2217). We include in the metagabbro of the western melange belt some bodies of rock included by Erikson (1969) in his early phase of the batholith (our Tsm), because of cataclasis and recrystallization (see Tabor and others 1982b)

Ttq THREE QUEENS STOCK--Medium-grained biotite-hornblende tonalite and granodiorite. A uniform hypidiomorphic granular rock characterized by graphic intergrowth of K-feldspar and quartz. Considerable sulfide associated with the tonalite in Mineral Creek. Two hornblende K-Ar ages, averaging 27±3 m.y. (table 1, no. 11), although poorly reproducible, are close in age to the 25 m.y.-old northern phase of the batholithic rocks (our Tsgn) dated by Tabor and others (1982b)

INTRUSIVE ROCKS, MISCELLANEOUS divided into:

Tiap Altered porphyry, commonly with hornblende--Highly altered brown to green hornblende and pyroxene plagioclase phyric andesite with holocrystalline to intersertal groundmass, locally trachytoid. Includes some dacites with groundmass quartz. Commonly altered to smectite and zeolite. Hammond (1963, p. 187-191) describes these rocks in detail. Mapped bodies may be closely spaced dike swarms. Dikes of altered porphyry are common throughout the volcanic rocks of Huckleberry Mountain and the Ohanapecosh Formation

Tip Pyroxene andesite porphyry--Gray to green hypersthene and (or) clinopyroxene andesite with hyalocrystalline to intergranular matrix. Generally partially altered with glass replaced by smectites. Fresh rocks, mostly in the area of the Fifes Peak Formation, are black with unaltered brown glass. Slightly altered, mostly clinopyroxene-bearing porphyritic rocks intrusive into the Puget Group are described by Vine (1968, p. 32-34). Isolated plug-like bodies of porphyritic andesite grading to diabase and gabbro near Enumclaw are included here. Some could be remnant cores of thick Fifes Peak flows. The intrusive complex on South Prairie Creek consists of a mixture of faulted rocks with various lithologies and textures, including some tonalite

Tit Tonalite--Uralitic pyroxene tonalite, mostly with hypersthene and clinopyroxene grading to rare granodiorite or quartz diorite.

Most bodies are plagioclase-pyroxene phyric and have fine-grained hypidiomorphic granular Texture; quartz is interstitial and commonly mesostasic. Some bodies are texturally transitional to pyroxene andesite porphyry. Intrusion north of Blowout Mountain ranges to quartz gabbro (Stout, 1964, p. 331). Small intrusions on Dalles Ridge, Amabilis Ridge, and west of Tacoma Pass are quartz-bearing olivine-pyroxene gabbro. Many small tonalite masses may be satellitic to the Snoqualmie or Tatoosh batholith (exposed south of the quadrangle). Small masses in the Cedar River area are rich in sulfides, mostly pyrite (Hammond, 1963, p. 200). The tonalite bodies may also grade into Tdp. Some areas mapped tonalite may be made up of closely spaced dikes

Tidp Dacite porphyry--Gray hornblende and (or) pyroxene dacite and rhyodacite porphyry with fine-grained to microgranular holocrystalline or devitrified groundmass. Contains clinopyroxene and hypersthene where fresh. Generally, the mafic minerals and groundmass are partially altered to smectites and calcite. Includes some highly altered quartz-bearing volcanic rocks and some microporphyritic rhyolite on North Fork of Little Naches River. On Meadow Mountain porphyritic rocks grade into medium-grained tonalite similar to Tit (Smith and Calkins, 1906, p. 9), although Hammond (1963, p. 192) thought that the coarser-grained rocks intruded the porphyry. A K-Ar analysis of hornblende (table 1, no. 10) indicates the porphyry on Meadow Mountain is about 24 m.y. old and is probably the chilled margin of a high-level cupola of the Snoqualmie batholith

Tir Rhyolite porphyry breccia--On Cle Elum River rhyolite porphyry is filled with inclusions of country rock and broken phenocrysts of quartz, plagioclase, and K-feldspar. Thermally metamorphosed

VOLCANIC ROCKS OF THE FIFES PEAK FORMATION--Andesite and basalt flows and breccias and volcaniclastic sedimentary rocks. Divided into:

Tfw Western facies--Massive, fine- to medium-grained, two pyroxene basaltic andesite and basalt flows, and interbedded andesite breccia and tuff, volcaniclastic sedimentary rock, and crystal-lithic tuff. Green to porphyritic gray or black andesite, described in detail by Fischer (1970, p. 51-71), contains 20 to 30 percent, generally well-zoned, plagioclase (An_{50} to An_{30}) and 5 to 15 percent hypersthene and clinopyroxene. Flow banding is indicated by color bands and layers with different amounts of crystals. Greenish breccias contain angular to well-rounded andesite clasts similar to the porphyritic flow rocks. The breccia matrix is commonly rich in feldspar crystals. Breccias are mostly monolithologic, but colorful polymictic breccias are also present. Although Fischer (1970, p. 71-80) calls some of these breccias (in his Enumclaw Formation) autobreccias that formed at or near their present position due to differential shear within the flowing lavas, most breccias appear to have a laharic origin. Feldspar crystal-rich tuffaceous rocks also contain pyroxene and pumice. Well-bedded greenish volcanic conglomerates and fine-grained silty layers sporadically contain organic-rich layers with leaf fossils. Quartz-bearing, crystal-rich, lithic tuff interbeds present between The Three Sisters and Pinnacle Peak are reminiscent of tuffs in the Stevens Ridge

Formation. Flows and breccia in the headwaters area of South Prarie Creek bear abundant green hornblende, commonly opacitized or altered to smectite. According to Hartman (1973, p. 39-42), andesite flow rocks and breccias of the Fifes Peak Formation in the quadrangle were only slightly affected by low-grade metamorphism (primarily heulandite-clay-(chlorite)-quartz). Two splits of plagioclase from a porphyritic andesite exposed near Mowich Lake (south of the study area) yield K-Ar ages of 17 and 21 m.y. (Hartman, 1973, p. 25; our table 1, nos. 12, 13)

Clear West Peak Complex of Fischer (1971): includes--

Tfwci Intrusive rhyolite--Mostly gray to purple, sparsely plagioclase phyric devitrified rhyolite. Most rocks highly altered but Fischer (1970, p. 102-113) describes black vitrophyre with plagioclase, augite and hypersthene phenocrysts and abundant crystallites of hornblende. Many of the altered rocks have pseudomorphs of smectites after hornblende (?). Some weakly preserved vitroclastic texture and some breccia contains andesite clasts. Rocks are conspicuously banded perpendicular to columnar joints, features suggesting steep and variable flow layering or multiple dikes. Rhyolite may be mostly intrusive, but includes eruptive material. The body is locally intruded by andesite dikes. See Fischer (1970, p. 93-114) for detailed descriptions, modes, and chemical analyses. Hartman (1973, p. 30; table 1, no. 14) reports a K-Ar whole rock age of 19 m.y; Mattinson (1977, p. 1512; table 1, no. 15) reports U-Pb ages of 23 and 22 m.y. from two zircon fractions. A probable extrusive equivalent (Tfwct) of the intrusive body is interbedded near the top of a considerable pile of Fifes Peak lavas which elsewhere are between 20 and 24 m.y. old in age. The Fifes Peak flows in the area of Clear West Peak in turn rest on eroded Stevens Ridge Formation (see below) that yields concordant hornblende and biotite K-Ar ages of about 22 m.y. The zircon ages of the Clear West rhyolite are appropriate for the overall range of ages in the Fifes Peak, but the underlying Steven Ridge age implies an extremely high rate of eruption from Stevens Ridge time to Clear West time

Tfwct Rhyolite tuff--Grey to white devitrified, mostly banded rhyolite with rare black welded vitrophyre and local basal unwelded pumice-perlite tuff (reported by Fischer 1970, p. 98). Texture, mineralogy, and chemistry (Fischer, 1970, p. 93-113), are similar to the intrusive rhyolite, but flattened shards, local folded flow bands, and rare beds of rhyolitic sandstone, siltstone and coal indicate origin as eruptive rock. Fischer (1970, p. 100-104) proposed that the tuff was emplaced as an ignimbrite, locally fused and subsequently flowed (a rheo-ignimbrite). The rhyolite tuff is overlain by pyroxene andesite flows north of the White River and by andesite breccia north of Mineral Creek, hence we consider it a part of the Fifes Peak Formation

Tfe Eastern facies--Similar in overall appearance to Tfw. Green to dark gray and black andesite flows consists of plagioclase, clinopyroxene, and hypersthene phenocrysts or glomerocrysts, in intergranular to intersertal groundmass of plagioclase microlites, pyroxene, opaque, and reddish-brown glass. Black basalt with plagioclase, and less abundant pyroxene microphenocrysts, in a pilotaxitic groundmass. Andesite and basalt flows exhibit platy jointing to hackly fracture and basalt flows locally have well-developed columns. Massive to well bedded, green, red, and brown colored breccias contain andesite clasts similar to flows. Breccias predominate, but are not as easily seen as flows in the field due to slumping. Buff to green volcaniclastic sandstone, siltstones, and lapilli-tuff are generally well bedded. Pumice and quartz-bearing rhyolite tuff crops out in association with the sedimentary rocks.

Two samples of porphyritic andesite from the Castle Mountain area yield 22 and 24 m.y.-old K-Ar whole-rock dates (Hartman, 1973, p. 24 and table 11; our table 1, nos. 16, 17). Also includes:

Tfes Volcaniclastic sedimentary rocks--Well-bedded andesitic breccia, tuff, and volcanic sandstone. Porphyritic andesite breccia clasts commonly multicolored. In part with pebbly volcanic sandstone. Cut-and-fill structures and graded bedding present in some exposures. Thin pumice-bearing white ash layers and leaf fossils present but uncommon. Interbedded in Tfe

Tfeb Andesite and basalt megabreccia--Megabreccia containing blocks up to 4 m across. Clasts of andesite similar to Tfe, and including very fine-grained, sugary, to coarse-grained andesite porphyry. Interbedded and gradational with Tfe

Tsr STEVENS RIDGE FORMATION--Rhyodacite ash-flow tuff and well-bedded volcaniclastic sedimentary rocks. Typically light-gray or tan, locally reddish tan or light green. Vitric to crystal-lithic tuff and interbedded volcanic sandstone, conglomerate, siltstone, and tuff. Rhyodacite ash-flow tuff generally contains abundant euhedral to subrounded plagioclase, clinopyroxene, hornblende, hypersthene, and biotite, rounded and embayed quartz, pumice and felsic to mafic volcanic rock fragments in a generally highly altered matrix of glass shards and dust and very fine-grained minerals. Alteration minerals include smectites, chlorite, and calcite. Alteration is locally so pervasive that original grain types and textures are not discernable, but rocks are generally less altered than dacite tuff in Ohanapecosh Formation. Locally welded and with crude columns. Gray to tan, in part greenish, well-bedded polymictic volcanic sandstone, conglomerate, siltstone, and tuff contain polymictic volcanic clasts and locally exhibit sedimentary structures such as cross-bedding and ripple marks. Includes rare mudflow breccia.

Rocks in the quadrangle are in part described by Hartman (1973, p. 15-21, tables 6, 7) and Fischer (1970, p. 34-53) and, south of the quadrangle, in the type area, by Fiske and others (1963, p. 20-27).

Based on paleontological data Fiske and others (1963, p. 27) concluded the unit is middle Oligocene to early Miocene in age. Fission-track and K-Ar ages range from about 20 to 24 m.y. (Miocene; table 1, nos. 18-23), but ages as old as 27 m.y. have been obtained from the correlative rocks south of the quadrangle (Vance, 1982; Frizzell and Vance, 1983) and an inexplicable K-Ar hornblende age of about 35 m.y., has been reported by Fischer

(1970, p. 51-52). The 20 to 24 m.y. dates probably represent the age of the unit. Because the Stevens Ridge and Fifes Peak Formations are essentially the same age, and because the type Fifes Peak is older than the type Stevens Ridge, J. A. Vance (written commun., 1984) proposes that the Stevens Ridge be reduced to member status within the Fifes Peak Formation

Tcm VOLCANIC ROCKS OF COUGAR MOUNTAIN--Two-pyroxene andesite and basalt flows and flow breccia, mudflow breccia, and minor volcanic sedimentary rocks. Generally dark reddish to black porphyritic andesite and basalt flows and flow breccia. Flows exhibit platy jointing and crude columns. Porphyritic to microporphyritic andesite contains phenocrysts, and less commonly glomerocrysts, of plagioclase, clinopyoxene, and hypersthene in trachytic groundmass containing the same minerals plus opaques and clays. Basalt flows are similar, but contain olivine which has generally been altered to smectites (iddingsite) in a fine-grained holocrystalline or hyalocrystalline matrix. Breccia matrix contains similar mineral species plus a variety of volcanic rock fragments. Characteristic mudflow breccia generally contains clasts of basalt and andesite porphyries. Rounded clasts generally have knobby relief on cut slopes. Include local well bedded, thin, sandy to silty beds. Cougar Mountain unit differs from upper part of Eagle Gorge unit (Teg below) by presence of mudflow breccia.

Includes most of the Cougar Mountain Formation of Hammond (1963) and minor parts of his Snow Creek and Huckleberry Mountain Formations. Also includes:

Tcmt Crystal-lithic andesitic tuff--White to gray tuff with crystals of plagioclase, pyroxene, and quartz and clasts of pumice and volcanic rock in a brownish matix of devitrified glass. At Boulder Creek grades upward into a diamictite consisting of a matrix similar to the tuff studded with andesite and basalt blocks

Teg VOLCANIC ROCKS OF EAGLE GORGE--Andesite and basalt flows, breccia, and minor well-bedded tuff and volcanic sedimentary rocks. Predominantly dark green to black andesitic flows and flow breccia. Flows variously exhibit platy jointing, columnar jointing with uniform to splayed orientations, vesicular tops, scoriaceous or amygdaloidal zones, and minor drusy quartz zones. Breccias are generally monolithologic and contain angular clasts, but locally contain rounded clasts. Plagioclase, clinopyroxene, and lesser hypersthene and hornblende phyric andesite with intersertal and intergranular texture; with secondary smectites, hematite, calcite, and quartz. Minor well-bedded multicolored tuff and breccia; volcanic sandstone, conglomerate, and siltstone, and dacite; rare mud-flow breccia.

Includes most of the Eagle Gorge Andesite of Hammond (1963, p. 114-123) and small parts of his Snow Creek, Huckleberry Mountain, and Cougar Mountain Formations. Also includes:

Tegt Rhyodacite tuff--Predominately tan, locally light green, in part flow banded, crystal-lithic ash-flow tuff with vitroclastic texture. Rounded, resorbed quartz, euhedral to rounded feldspar, clinopyroxene, and volcanic lithic clasts (to 1.5 cm) in a matrix of mostly undeformed arcuate glass shards and glass dust. Yields a zircon F-T age of 21 m.y. (table 1, no. 24)

Tv VOLCANIC ROCKS--Mostly andesite with minor dacite and rhyolite in coarse breccia, tuff, ash flow tuff, and rare flows. Mostly highly recrystallized by thermal metamorphism; many rocks are hornblende-biotite hornfels. Probably correlative with the volcanic rocks of Hucklebery Mountain but may locally include some Naches Formation

Thm VOLCANIC ROCKS OF HUCKLEBERRY MOUNTAIN--Generally well-bedded andesite and basalt breccia, tuff and flows, minor dacite and rhyolite tuff and breccia, volcanic sandstone, siltstone, and conglomerate, and subquartzose sandstone. Although andesite and basalt breccia and tuff predominate, flows are abundant in basal parts of the unit near its eastern and western margins. Dark green, brown or black, weathering to light green or brown, one- and two-pyroxene andesite contains phenocrysts or glomerocrysts of plagioclase or plagioclase and pyroxene. Commonly trachytic with a groundmass composed of plagioclase microlites, clinopyroxene, opaque minerals, and alteration products. Locally shows platy jointing. Dark basalt with small plagioclase, clinopyroxene, and olivine phenocrysts set in a groundmass of plagioclase, opaque, clinopyroxene, and alteration minerals. In part exhibits platy jointing, columns, or vesicular tops. Andesite and basalt flows commonly highly altered. Plagioclase locally replaced by calcite, and pyroxene by smectite. Other alteration minerals include quartz, zeolite, calcite, chalcedony, smectite, clays, and chlorite which replace minerals, lithic grains, or fill vugs. Massive to well-bedded, mono- to polymictic breccias contain red, yellow, brown, green or blue-green clasts to 2 m in maximum dimension in a feldspar crystal-rich matrix. Flows and breccias interbedded with pistachio-green, in part maroon, well-bedded tuff and tuff breccia in which plagioclase or volcanic lithic fragments predominate and that locally contain flattened pumice. Well-bedded volcanic sandstone and conglomerate are also rich in plagioclase crystals and contain a variety of volcanic rock fragments as well as rare chert and granitoid clasts. Volcanic argillite in part organic rich and with leaf impressions. Subordinate crystal-rich dacite and rhyolite tuff generally contains plagioclase and partially resorbed quartz crystals as well as volcanic rock fragments, pumice, or altered glass shards in a generally altered matrix which may contain potassium feldspar. In part with clinopyroxene microphenocrysts which are generally at least partially altered to smectite. On the south side of Huckleberry Mountain, between strands of the White River fault, unit includes a variety of atypical rocks, including dacite ash-flow tuffs similar to Tsr and poorly consolidated tuffaceous shales that may be still younger then Tsr.

Unit includes most of Enumclaw, Huckleberry Mountain, and Snow Creek Formations of Hammond (1963). Probably correlative with the Ohanapecosh Formation. Zircon F-T ages on a tuff at Stampede Pass are about 30 to 32 m.y. (Tabor and others, 1984; our table 1, no. 28, 29). A zircon F-T age on a tuff west of Chester Morse Reservoir (table 1, no. 26) indicates an age of about 25 m.y. A K-Ar age from a flow east of Cumberland indicates a minimum age of 35 m.y. (Turner and others, 1983, our table 1, no. 33). Biotite from a quartz-bearing green tuff yields a 26.5 m.y. K-Ar age (table 1, no. 25). Also includes:

Thmk Tuff of Lake Keechelus--Dacite crystal-vitric tuff and breccia consisting of plagioclase (20 to 25 percent), quartz (7 to 11 percent), and pyroxene (trace to 4 percent, altered to smectite) phenocrysts in a groundmass of quartz, plagioclase, potassium feldspar, and devitrified glass. Light greenish, weathering to light pink or salmon. Bedding locally defined by flattened pumice. Breccia blocks to 1 m. Includes the eastern exposures of the Stampede tuff of Hammond (1963), who describes the unit in detail (1963. p. 123-144). Fission-track ages on zircon indicate a 30 m. y. age (Tabor and others, 1984; our table 1, no. 30)

VOLCANIC ROCKS OF MT. DANIEL--Divided into:

Tdv Andesite, dacite, and rhyolite volcanic rocks--Predominantly clinopyroxene and clinopyroxene and hypersthene andesite and dacite tuff, breccia, and subordinate flows. Breccia beds to 25 m thick. Commonly highly altered to calcite and smectites. Some thinly bedded (water laid?) tuff and volcanic sandstone. Detailed descriptions in Ellis (1959, p. 65-70) and north of the quadrangle in Simonson (1981). Hammond (1965) proposed that the volcanic rocks were deposited in a small collapsed caldera. For rocks in the Mount Daniel area, north of the quadrangle, Simonson (1981, p. 66-67) presents arguments to support the validity of F-T ages of about 25 m.y. for ash-flow tuffs that were coeval with and intruded by the Snoqualmie batholith. A F-T age of about 34 m.y. age on apatite from ash-flow tuff (Tdd) from Goat Mountain (table 1, no. 34), however, suggests that the unit may be older then the Snoqualimie

Tdgr Granophyre and rhyolite porphyry--East of the Waptus River grades from medium-grained hornblende granite to fine-grained porphyritic granophyre. Highly altered to chlorite, epidote, sericite and prehnite. West of the river plagioclase and quartz phyric rhyolite with devitrified groundmass

Tdr Rhyolite--Quartz and plagioclase phyric devitrified rhyolite. Mostly tuff and breccia rich in devitrified shards, locally eutaxitic. May include some intrusive rhyolite on Cone Mountain

Tdd Rhyodacite tuff--Vitric crystal lithic dacite tuff, commonly with plagioclase, resorbed quartz and silicic to intermediate volcanic fragments in a devitrified glassy matrix. Similar to the Lake Keechelus tuff (Thmk), but with more quartz phenocrysts

Tdb Breccia--Monolithologic breccia composed of angular sandstone clasts of the Swauk Formation up to 3 m across. Rare volcanic clasts. Further descriptions in Simonson (1981, p. 40-41) and Ellis (1959, p. 66-67). Breccia may have been debris flows

To OHANAPECOSH FORMATION--Well-bedded, multicolored, volcanic- and crystal-lithic andesitic tuff and breccia and volcaniclastic sedimentary rocks alternating with massive tuff-breccia and subordinate rhyolite, basalt, and andesite flows. Mostly light green, but also light bluish green, purplish, black, brown, or white, generally thin bedded, mixed volcanic lithic, in part feldspar crystal-rich, tuff-breccia, fine- to coarse-grained lithic- to feldspar-rich volcanic sandstone, thin-bedded volcanic argillite, and volcanic conglomerate. Locally with plant remains. Massive, mostly light greenish, tuff-breccia contains altered clasts of andesite porphyry and basalt; locally with flattened pumice. Clasts generally less than 6 cm in diameter, mostly about 2 cm. Rarely fresh to mostly highly altered porphyritic andesite and black basalt occur also as flows which are generally massive but also exhibit platy jointing. Rare, light colored devitrified rhyolite.

Rocks in the quadrangle described in part by Fischer (1971, p. 25-34) and Hartman (1973, table 4, p. 11-15) and, south of the quadrangle, in the type area by Fiske and others (1963, p. 4-20).

Although on the basis of paleontological data, Fiske and others (1963, p. 20), stated that rocks of the Ohanapecosh ranged in age from middle Eocene to early Oligocene and were mostly late Eocene, numerous F-T ages on zircon south of the quadrangle indicate the rocks were erupted 28 to 36 m.y. ago (Oligocene; see Vance, 1982; Frizzell and Vance, 1983)

Tdg DIABASE, GABBRO, AND BASALT--Fine to medium-grained black diabase and gabbro dikes and plugs weathering to brown and reddish brown. Contains labradorite, clinopyroxene, rare olivine, and opaque ores. Subophitic to ophitic texture; variously altered to smectites, calcite, and chlorite (Stout, 1961, p. 350).

Tdg that intruded rocks east of the Straight Creek fault may be the intrusive equivalent of the Teanaway Formation and restricted to pre-Roslyn Formation time, because the Roslyn is not intruded by similar diabase dikes. Mapped bodies and numerous unmapped dikes of the Teanwaway dike swarm (see below) are lithologically similar to Tdg. Diabase and gabbro bodies intruding the Naches Formation and Puget Group, west of the Straight Creek fault, may be related to Naches and Tukwila volcanism, respectively. Although Stout (1961) suggested that fresher diabase intrusions on both sides of the Straight Creek fault fed flows of the Columbia River Basalt Group, the preponderance of evidence suggests that the Miocene Columbia River flow came from the southeast (Tabor and others, 1982a, p. 13). As in many Tertiary volcanic rocks, degree of alteration is not a reliable guide to age

Tpa VOLCANIC ROCKS OF OF MOUNT PERSIS--Mostly gray to black, locally reddish, porphyritic two-pyroxene andesite and andesite breccia. Phenocrysts and glomerocrysts of plagioclase, clinopyroxene, hypersthene, and opaque in devitrified matrix. Mostly highly altered. Massive to blocky joints. Flow layering obscure

Tpg ROCKS OF THE PUGET GROUP--Predominantly fluviatile, but, in part, nearshore marine, micaceous feldspathic subquartzose sandstone, siltstone, claystone, and coal. Rocks in the Green River area, described in detail by Vine (1969, p. 6-13), total about 1900 m in thickness. There, white, very fine-grained to gritty sandstone contains subangular to rounded grains consisting of about 40 to 60 percent quartz, 30 to 50 percent feldspar, and about 5 percent lithics (Frizzell, 1979, Appendix III). Tabular beds of sandstone are massive to cross bedded and occasionally exhibit channel cut-and-fill structures. The sandstone body in the southwestern corner of the map is adjacent to rocks referred to the Carbonado and Spiketon Formations by Gard (1968, p. B6-B8) which total more than 2600 m in thickness. These light grayish to brownish sands contain similar grain ratios as do the sandstones in the Green River area. Light to dark siltstones form poor outcrops, are commonly thinly laminated, and contain organic matter. Coal beds range up to 5 m thickness and are described in detail by Beikman and others (1961). In northwest corner of map area, near Tiger Mountain, unit symbol Tpg designates interbedded mixtures of nonmarine sandstone and volcanic breccia from the Tiger Mountain and Tukwila Formations shown in more detail by Vine (1969). Immediately west of Lookout Mountain north of the Cedar River and along the western edge of the map north of Enumclaw, outcrop labeled Tpg? may represent nonmarine sands of the Puget Group in contact with Thm (see Walsh, 1984, and Phillips, 1984, for more detailed maps in the Tiger Mountain and Green River areas).

K-Ar and F-T ages from volcanic ash partings in coal beds in the Green River area indicate a time span of about 41 to 45 m.y. (middle and late Eocene; Turner and others, 1983; and our table 1, nos. 35-41), contradicting an early Eocene through early Oligocene age based on fossil leaves (Wolfe, 1968; 1981). A basaltic intrusion into the Puget Group yields a minimum K-Ar age of 29 m.y. (Turner and others, 1983, table 1; our table 1, no. 31). Locally divided into:

Tpr Renton Formation--Fine- to coarse-grained feldspathic to lithofeldspathic subquartzose sandstone with interbedded siltstone, claystone, and coal. The fluvatile to nearshore marine rocks, described in detail by Vine (1969, p. 23-26), attain at least 670 m thickness near Taylor Mountain. Contains 30 to 45 percent quartz, 40 to 50 percent feldspar, and 10 to 20 percent lithic grains (Frizzell, 1979, appendix III) The Renton is probably middle and late Eocene in age (Turner and others, 1983, p. 528)

Tpt Tukwila Formation--Volcanic breccia, conglomerate, sandstone, and flows with intercalated feldspathic sandstone and impure coal beds. Tuff and breccia with clasts of porphyritic andesite and dacite and polymictic volcanic conglomerate probably predominate, but flow rocks (in part sills or dikes?) form resistant layers. Unit described in detail in Vine (1969, p. 19-23). Breccia of the Tukwila northwest of the map area yielded a zircon F-T age of 41 m.y. and an average K-Ar age of about 42 m.y. (middle Eocene; Frizzell and others, 1979; Turner and others, 1983). The unit probably ranges into the late Eocene in age.

The strong folding of the Tukwila and the interfingering feldspathic subquartzose sandstones of the Renton and Tiger Mountain Formations differentiates the Tukwila from the gently deformed volcanic rocks of Mount Persis which crop out on Rattlesnake ridge and to the north (Tabor and others, 1982b) as well as from the younger Oligocene to Miocene, totally volcanicly derived sequence to the southeast

Tptm Tiger Mountain Formation--Light-colored, medium-grained, micaceous feldspathic subquartzose sandstone interbedded with siltstone, minor pebble conglomerate, and coal beds. These fluviatile to shallow marine rocks have been described in detail by Vine (1969, p. 16-19), and are late early to middle Eocene in age (Turner and other, 1983, p. 528)

Trr RAGING RIVER FORMATION--Marine sandstone, siltstone, shale and minor conglomerate. Described in detail in Vine (1969, p. 13-16). Foraminifers from this unit are now considered to be late early to middle Eocene in age (Rau, in Vine, 1969, p. 16; Rau, 1981, fig. 11)

Cabin Creek Block

Tn NACHES FORMATION--Rhyolite, andesite, and basalt flows, tuff, and breccia with interbeds of feldspathic subquartzose sandstone and siltstone and rare coal. Well-bedded andesite and basalt flows and breccia are somewhat nondescript, porphyritic to aphyric, dark green to black rocks, weathering to brown. In part amygdaloidal, with columns, or with brecciated and vesicular tops. Rhyolite forms mostly flow-banded flows or domes and minor ash-flow tuffs. Interbedded sedimentary rocks are white to light tan or gray, coarse-grained micaceous feldspathic sandstones, exhibiting cross-beds and graded bedding, and black argillite and laminated siltstone. Both volcanic and sedimentary rocks are thermally metamorphosed adjacent to Miocene stocks and plutons. Nomenclature and stratigraphy discussed in Tabor and others (1984). Chemistry of the volcanic rocks is in Ort and others (1983). Locally divided into:

Tnbg Glomeroporphyritic basalt--Mostly basalt and glomeroporphyritic basalt with interbeds of andesite and rare feldspathic sandstone and siltstone. Occurs as thick flows, in part with vesicular tops, some of which contain tabular plagioclase phenocrysts as large as 2 cm across, that in some flows are strongly flow-aligned. Described in some detail by Foster (1960, p. 39, 40)

Tns Feldspathic sandstone and volcanic rocks--Well-bedded, medium- to coarse-grained, tan to gray, predominantly micaceous feldspathic to feldspatholithic subquartzose sandstone and interbedded siltstone and shale, with conspicuous rhyolite and andesite and basalt flows, tuff, and breccia. Interbeds of coaly shale and rare volcanic-rich pebble conglomerate and small quartz pebble grit. Leaf fossils locally common. Only about 2-8 percent of framework grains in sandstone are volcanic clasts (Frizzell, 1979, p. 47)

Tnr Rhyolite--Mostly white to gray, flow banded, platy jointed flows or domes with ash-flow tuff containing flattened pumice fragments.

In beds meters to hundreds of meters thick. Includes some probably intrusive rhyolite, especially near Rampart Ridge north of Keechelus Lake. Mainly aphyric or with minor plagioclase or quartz phenocrysts; mostly completely devitrified to white spherulitic masses. Contains minor interbeds of basaltic tuffs and flows and feldspathic sandstone. Rhyolites, mostly low in the section, yield 40 to 44 m.y. F-T ages on zircon (Tabor and others, 1984, table 2, nos. 16-20; our table 1, nos. 42-47)

Tnmc Mount Catherine Rhyolite Member--Commonly flow-banded, platy jointed, black, welded, crystal-lithic ash-flow tuff containing highly flattened pumice lapilli, some breccia, and minor thin feldspathic sandstone and shale interbeds. Unusual hardness and apparent freshness probably due to recrystallization during the intrusion of the Snoqualmie batholith. Discussed by Foster (1960, p. 114), Hammond (1963, p. 50-54), and Tabor and others (1984). Two F-T ages on zircon of about 36 m.y. have been interpreted as reset ages (Tabor and others, 1984, table 2; our table 1, nos. 48-49)

Tnb Basalt--Mostly basalt flows and breccia with interbedded feldspathic sandstone and siltstone. Basalt forms somewhat nondescript porphyritic to aphyric dark green to black rocks that weather brown. The holocrystalline to intersertal microporphyritic rocks contain plagioclase, clinopyroxene, opaques, glass and alteration minerals and many are so highly altered to smectite or calcite that identification of original textures and minerals is difficult. Whole rock K-Ar ages from the basalts indicate a 40 to 43 m.y. age for the Naches (Tabor and others, 1984; our table 1, nos. 50-52)

Tng Guye Sedimentary Member--Light to dark gray feldspathic sandstone, black slaty shale, and hard chert-pebble conglomerates; rare volcanic interbeds. Argillite is leaf-bearing. Locally hornfelsed. Discussed by Foster (1960, p. 111-113), Hammond (1963, p. 45-48), and, more recently, by Tabor and others (1984)

Teanaway River Block

ROSLYN FORMATION--Divided into:

Tru Upper member--Medium- to fine-grained, non-marine white, weathering to yellow, micaceous, lithofeldspathic sandstone, some with calcite cement. Dark olive-gray to greenish-yellow siltstone, predominantly quartz and feldspar; thin-bedded to laminated. Subordinate 0.6- to 6-m thick seams of well-jointed, banded bituminous coal. See "Coal Measures" of Bressler (1951, p. 31). The palynomorph assemblage present in Tru indicates a late Eocene age (Newman, 1981, p. 56)

Trm Middle member--Similar to upper member (Tru) but contains only very minor stringers of coal

Trl Lower member--Mostly white, weathering to yellowish and pale orange, medium- to coarse-grained, micaceous, in part zeolitic, lithic, feldspathic, and lithofeldspathic sandstone in beds to 15 cm thick with crossbedding, pebble stringers, and cut-and-fill structures. Abundant conglomerate and pebbly sandstone in beds to 15 cm thick with crossbeding, pebble stringers, and cut-and-fill structures. Abundant conglomerate and pebbly sandstone with rounded pebbles of granitic and aphanitic extrusive or hypabyssal rock. Includes Bressler's (1951, p. 35) basal beds of red to red-brown fine-grained sandstone with minor angular clasts of quartz, metamorphic rock fragments, some feldspar, and other rocks. Some sandstone with abundant calcite

TEANAWAY DIKE SWARM--In the area of the Teanaway dike swarm, density of dots represents proportion of terrain underlain by dikes. Although diabase dikes are also common in the Manastash block, we do not show their frequency there. Dikes are mostly dark green and brown to black basalt and diabase weathering reddish brown. Includes pale, dull holocrystalline dikes with plagioclase laths and granular clinopyroxene in intergranular texture. Interstices are filled with quartz, plagioclase, zeolite, and clays (Southwick, 1966, p. 9). Waxy, partly glassy dikes with andesine, clinopyroxene, and minor olivine: altered to chlorophaeite and devitrified glass (Southwick 1966, p. 10-11). See Tabor and others (1982a, p. 11) for a summary of past investigations of the dikes and discussion of their origin as feeders for the basalt of the Teanaway Formation

Tt TEANAWAY FORMATION--Basalt, basaltic tuff, and breccia with minor andesite, dacite, and rhyolite. Black, generally dense to glassy nonporphyritic pyroxene and rare olivine basalt, weathering red brown to yellow. Commonly fine-grained intersertal with plagioclase laths and clinopyroxene; interstices of brown glass or alteration products (Clayton, 1973, p. 18-19). Blocky to columnar-jointed flows characterized by large chalcedony and calcite amygdules. Tuff and breccia commonly altered to clays. Silicic varieties including welded tuff are white, purple, and highly altered but contain relict phenocrysts of quartz, plagioclase, and rare K-feldspar. Contains minor feldspathic sedimentary rock (Clayton, 1973, p. 35-36). Basalt is about 47 m.y. old based upon whole-rock K-Ar ages (Tabor and others, 1984, p. 40, table 1; our table 1, no. 53). Described in detail by Smith (1904, p. 5-6), Clayton (1973, p. 16-30), and Lofgren (1974, p. 41-46)

SWAUK FORMATION--Divided into:

Ts Sandstone--Predominantly fluviatile, gray weathering to tan, zeolitic, locally carbonate-bearing, medium-grained, micaceous feldspathic to lithofeldspathic subquartzose sandstone averaging 40, 48, and 12 percent quartz, feldspar, and lithic clasts, respectively, overall, and containing 40 to 80 percent quartz, 20 to 50 percent feldspar, and 5 to 15 percent lithics in the map area (Frizzell, 1979). In part with secondary epidote, laumontite, prehnite, and pumpellyite. Basal beds resting on Easton Schist consist of pebbly sandstone with quartz and phyllite clasts which rapidly grade up section into the more feldspathic sandstone. Thin to very thick bedded, poorly sorted, locally crossbedded, and with lesser interbeds of carbonaceous siltstone and shale, pebbly sandstone, and conglomerate

Tssp Silver Pass Volcanic Member--Mostly dacite and andesite flows and pyroclastic rocks but compositions range from rnyolite to basalt (Ort and others, 1983). Light tan to dark-green-gray andesite and feldspar porphyry with phenocrysts, microphenocrysts, or glomerocrysts of plagioclase-hypersthene and plagoclase-clinopyroxene in a groundmass containing plagioclase microlites, pyroxene, opaques, and alteration minerals. Commonly highly altered with plagioclase altered to calcite and chlorite and pyroxene altered to smectite. Locally contains zeolite-filled amygdules. Altered rhyolite or dacite ash-flow tuff and tuff-breccia contain plagioclase and quartz crystals, volcanic clasts, and flattened shards and pumice. Described in greater detail by Lofgren (1974, p. 25 - 34). Interbedded with sandstone of the Swauk Formation and occurs as discontinuous outcrops of dark-yellowish-green mafic tuff-breccia. Includes small plug of highly altered andesite porphyry just north of Silver Pass. F-T ages on zircon from the type area and in tuffs interbedded in the Swauk near Swauk Creek (east of the map area) mostly indicate a 50 to 52 m.y. ages for the unit (Vance and Naeser, 1977; Tabor and others, 1984; our table 1, nos. 56, 57)

Tsc Conglomerate facies--20 to 50 percent conglomerate and conglomeratic sandstone in feldspathic and lithofeldspathic sandstone, siltstone, and shale. Boulders to pebbles of quartzite, chert, argillite, granitic, phyllite, and serpentinite in matrix of micaceous feldspathic and lithofeldspathic sandstone. Cross-bedded and with cut-and-fill structures

Tsi Ironstone--Iron-rich sandstone, shale, and conglomerate, locally well bedded. Iron minerals are limonite, hematite, and magnetite. Conglomerate composed of peridotite and serpentinized peridotite in iron-rich matrix. Most deposits are rich in nickel (Lamey, 1950). Shown only by dots where it occurs as thin discontinuous beds overlying serpentinite (KJis)

Manastash River Block

Tbf BASALT OF FROST MOUNTAIN--Dense black microporphyritic olivine basalt; microphenocrysts of plagioclase, clinopyroxene, and olivine in intersertal matrix of plagioclase, clinopyroxene, opaque ore, and brown glass. Weathers red and is locally columnar jointed. Locally altered to siliceous white rock. Potassium-argon ages of 47 and 32 m.y. (table 1, nos. 54, 55) are contradictory, but as described by (Tabor and others, 1982a, 1984) unit is probably correlative with the Teanaway Formation . As mapped includes:

Tbfb Basalt breccia and tuff--Brown to red oxidized basaltic breccia and tuff with thin basalt flows. Crudely bedded

Ttf TANEUM FORMATION--Mostly gray to green and brown, generally highly altered porphyritic to nonporphyritic andesite, dacite, and rhyolite flows, tuff, and breccia; greenish-blue, purple, and white altered ash-flow tuffs, commonly welded with relict quartz and plagioclase phenocrysts and flattened pumice lappilli. Two F-T ages (Tabor and others, 1984, table 2) on zircons from separate ash-flow tuffs in the Taneum are about 52 m.y., an age similar to that of the Silver Pass Volcanic Member of the Swauk Formation, and about 46 m.y., more appropriate for the Naches Formation. Our preference for a correlation with the Silver Pass is discussed by Tabor and others (1984)

Tm MANASTASH FORMATION--Non-marine sandstone, siltstone, and conglomerate. Light-greenish-gray or tan, massive to well bedded, medium- to coarse-grained feldspathic quartzose to subquartzose sandstone and thin siltstone and interbeds of conglomerate. Averages 55 to 60 percent quartz and 5 to 10 percent lithic clasts (Frizzell, 1979). Fine to coarse crossbeds locally present. Minor seams of bituminous coal; leaf fossils locally present. Probably correlative with the Swauk Formation (Tabor and others, 1982a, 1984)

Pre-Tertiary rocks

Rocks west of the Straight Creek Fault

ROCKS OF THE WESTERN MELANGE BELT--Consists of:

pTwa Argillite and graywacke--Well-bedded marine sandstone and argillite and subordinate pervasively sheared argillite. Purplish, reddish, gray and black, fine- to coarse-grained and pebbly lithofeldspathic and volcanolithic subquartzose sandstone interbedded with black argillite. Sandstone is mixed clast type commonly with mostly plagioclase, chert, volcanic rocks, and quartz, as well as grains of sandstone, siltstone, phyllite, biotite, muscovite, and epidote. Alteration minerals are calcite, chlorite, sericite, limonite, epidote, and prehnite. Near Tertiary plutons the rocks have been hornfelsed, commonly with conspicuous new biotite. Sedimentary features such as graded bedding and load casts are locally well preserved. Highly folded sheared and recrystallized banded cherts. Unit includes metagabbro, polymictic and quartz pebble conglomerate and shale-chip breccia. East of North Bend sandstone and argillite are highly sheared, forming outcrops of lenticular sandstone clasts in crudely foliated argillite. This deformational style is more typical of the western melange belt exposed north of the quadrangle (Tabor and others, 1982b, in press; Frizzell and others, in press)

pTwv Metavolcanic rocks--Greenstone, greenstone breccia, and metadiabase with boudinaged meta-quartz porphyry dikes

pTwg Metagabbro--Massive to foliated, fine- to medium-grained metagabbro. Many outcrops sheared on all scales. In massive rocks, euhedral, mottled, locally crushed plagioclase; intergranular to euhedral uralitized clinopyroxene, and opaque minerals common. Metamorphic minerals are uralite, chlorite, sphene and calcite. Unit includes rare hornblende metatonalite and well recrystallized amphibolite. Zircons from metagabbro at Mount Si just north of the quadrangle yield slightly discordant U-Th-Pb ages of about 165 m.y. (Whetten and others, 1980; Frizzell and others, in press)

pTwu Ultramafite--Serpentinized pyroxenite. Predominantly coarse-grained anhedral and fine-grained subhedral to euhedral clinopyroxene in a sea of sepentine minerals with mesh structure

ROCKS OF THE EASTERN MELANGE BELT--Consists of:

pTe Chert and metamafic volcanic rock, amphibolite, and marble--Highly deformed chert and medium- to fine-grained banded purplish biotite quartzite (metachert) intimately mixed with tectonized greenstone, greenstone breccia, and marble. In part with hornblende schist and muscovite, biotite quartz schist and dikes of metadiorite and metagabbro. Original sedimentary and volcanic textures largely obscured by penetrative deformation and static thermal metamorphism. Adjacent to Snoqualmie batholith, rock is greenish pyroxene hornfels. These rocks are in part described by Chitwood (1976, p. 10-14). Zircons in metagabbro on Cave Ridge yielded U-Th-Pb ages of 165 m.y. (Frizzell and others, in press; our table 1, no. 62) which we interpret to be the age of magmatic crystallization

pTem Marble--Lenticular beds and pods of banded white to grayish medium- to fine-grained crystalline marble that is locally intercalated with metachert and greenstone. In part with fine-grained pale green silica carbonate replacement masses (Danner, 1966; Mogk, 1978)

Rocks east of the Straight Creek Fault

pTtc TECTONIC COMPLEX OF STOUT (1964)--Cataclastic to blastomylonitic blocks and slivers of predominantly fine-grained schistose amphibolite, as well as phyllite, greenstone and pillowed greenstone, blueschist, tonalite gneiss, leucogreenschist (metatuff), metasandstone, and ultramafite. Stout (1964, p. 323) reports tectonic breccia, biotite gneiss, slate, and argillite as well. Goetsch (1978, p. 41-49) described the zone in detail, and much of the mapped gradational contact with pTlma to the south is from her mapping

pTu ULTRAMAFITE--Mostly serpentinite and serpentinized peridotite. Strongly foliated. Depicted by "x" where too small to show mapped body

pTn METAVOLCANIC ROCKS OF NORTH PEAK--Greenstone, green to red metamafic to silicic tuff, breccia, metacalcareous tuff, and impure marble. Ashleman (1979, p. 21) reports meta-andesite and rhyodacite. Rocks are slightly schistose with considerable amounts of metamorphic minerals including chlorite, quartz, albite (?), carbonate, pumpellyite, and lawsonite in spite of preserved volcanic and clastic textures. The rocks of North Peak were identified by Smith and Calkins (1906), described by Foster (1960, p. 102) and Lofgren (1974) and most thoroughly studied and described by Ashleman (1979, p. 20-27) who also found rare crossite and actinolite

LOOKOUT MOUNTAIN FORMATION OF STOUT (1964)--As mapped includes:

pTlm Mica schist--Black, very fine-grained graphitic garnet biotite schist, locally with staurolite, andalusite, and rare cordierite. Relict bedding, graded bedding, and clastic grains are common. Includes unmapped bodies of mafic hornblende metatonalite and gabbro. Goetsch (1978, p. 19-37) describes the Lookout Mountain Formation in detail pTlma Amphibolite and hornblende tonalite gneiss--mostly very fine-grained schistose epidote amphibolite with green to blue-green hornblende, locally with biotite. Includes some mica schist similar to pTlms (see also Stout, 1964, p. 319). Includes small masses of metadiorite and metagabbro. Grades in heterogeneity and increased shearing into pTtc. Goetsch (1978, p. 16-17) describes small bodies of cataclastic hornblende tonalite gneiss

pTlg Gabbro and metagabbro--Cataclastically foliated to medium grained massive gabbro and metagabbro, (meta)tonalite, and (meta)quartz-diorite. A small mass on the south side of Lookout Mountain is mostly hornblendite with relict pyroxene (Goetsch, 1978, p. 28-29)

pTqs QUARTZ MOUNTAIN STOCK--Medium-grained hornblende metatonalite and metagranodiorite, locally with biotite and garnet. Hypidiomorphic granular, but with local bent plagioclase and statically recrystallized plagioclase, crystalloblastic growth of sodic plagioclase rims on both feldspars, replacement of feldspar cores by clinozoisite, and recrystallization of biotite. The stock intruded the Lookout Mountain formation with sharp contacts and many apotheses. J. M. Mattinson and C. A. Hopsen (written comm., 1980; table 1, no. 61) obtained relatively concordant U-Pb ages from zircons from the stock of about 157 m.y. which represent its crystallization age in the Late Jurassic

Kt TONALITE--Medium-grained hornblende-biotite tonalite with hypidiomorphic texture exposed near Fortune Creek. A K-Ar hornblende age of about 84 m.y. (table 1, no. 59) suggests the small stock is satellitic to the Mount Stuart batholith exposed northeast of the quadrangle (Tabor and others, 1980 and not a younger Tertiary pluton as earlier reported by Laursen and Hammond (1974, p. 18; our table 1, no. 58)

Kbg BANDED GNEISS--Very fine-grained pyroxene granofelsic gneiss. Locally with replacement veins of poikiloblastic clinozoisite and plagioclase replaced by zoisite

Ktg TONALITE GNEISS OF HICKS BUTTE--Lineated, medium-grained hornblende tonalite and tonalite gneiss, locally porphyroclastic and mylonitic. In least-deformed rock, green hornblende and labradorite are subhedral with integranular quartz, opaque ores, and minor biotite. Patchy alteration of plagioclase and hornblende to epidote and late zoisite. Zircons from the tonalite gneiss yield roughly concordant U-Pb ages of 153 m.y. (J. M. Mattinson and C. A. Hopson, written comm., 1980; our table 1, no. 60)

Ktz TECTONIC ZONE--Mostly fine-grained epidote hornblende schist and hornblende pumpellyite schist. Zoisite clearly replaces plagioclase. Rocks are blastomylonitic and porphyromylonitic with lenses of coarser mylonitic hornblende gneiss derived from Ktg. Some epidote quartz schist and actinolitic greenschist. Grades into greenschist of Keg. Described by Smith and Calkins (1906, p. 4) and Stout (1964, p. 322)

EASTON SCHIST--as mapped includes:

Keg Greenschist and blueschist--Very fine-grained albite-epidote-chlorite schist with varying amounts of quartz, actinolite, crossite and (or) late glaucophane, pumpellyite, and muscovite. Also contains sphene, opaques, and calcite. Ashleman (1979, p. 12) reports lawsonite in actinolite schists and describes intercalations of ironstone and ferruginous quartzites in the greenschist. Locally with layers of phyllite. Most rocks are highly foliated and well-recrystallized with fair mineral segregation, but many rocks south of Little Kachess Lake are texturally undifferentiated and have relict textures suggesting derivation from porphyritic volcanic rocks, tuffs, and rare mafic intrusive rocks. North of Hicks Butte, greenschist retains pillow structures, and in the Kachess Lake area, Ashleman (1979, p. 13) also reports possible pillow structures. Rocks of the Easton Schist have been described by Smith and Calkins (1906, p. 2), who named the unit, Ellis (1959, p. 10-12), Stout (1964, p. 322-323), and most recently and thoroughly by Ashleman (1979, p. 5-19). Easton Schist has been traced discontinuously northward into the Shuksan Metamorphic Suite of Misch (1966) which has been most recently shown by Brown and others (1982, p. 1095) to have a probable Late Jurassic protolith age and an Early Cretaceous metamorphic age

Kep Phyllite--Mostly very fine-grained, black to grey graphitic chlorite-sericite-quartz phyllite with minor albite (?), and opaque ores. Ashleman (1979, p. 7) reports minor spessartine and stilpnomelane. Phyllite is commonly highly crinkled and contains many quartz segregation lenses and veins that are often ptygmatically folded. Through the phyllite is locally interbedded with greenschist and blueschist, as mapped it represents the predominant lithology

INGALLS TECTONIC COMPLEX--Consists of:

KJis Foliated and massive serpentinite and serpentinized metaperidotite--On south (with pattern) mostly grey and grey-green to dark green, commonly foliated and slickensided, rubbly serpentinite; part of Cowen and Miller's (1980; see also Miller, 1980b, p. 235-273, 269-299) Navaho Divide fault zone, a probable oceanic fracture zone. On north (shown without pattern) serpentinized lherzolite, originally described by Frost (1973, p. 8-12) north of the quadrangle and named the South Peak unit by Miller (1980b, p. 52-69). The ophiolite origin of the Ingalls Tectonic Complex has been described by Hopson and Mattinson (1973), Southwick (1974), Miller (1977), Miller and Frost (1977). Miller (1980b) has made the most comprehensive study

KJim Metabasalt (greenstone), tuff, and breccia--Metavolcanic rocks as mapped are green with red to purple oxidized zones (Miller, 1980b, P. 148-149); mostly coarse monolithologic pillow breccia. Clasts are porphyritic and amygdaloidal; originally plagioclase and augite phyric, integranular to diabasic. Altered to chlorite, sphene, epidote, opaque and fine-grained unidentified material. Includes minor siliceous argillite and chert

KJid Diabase and gabbro--Mostly heterogeneous uralitized pyroxene diabase and gabbro in a complex of dikes and irregular bodies (Miller, 1980b, p. 99-107)

KJims Metasedimentary rocks--Pelitic slates, silty argillitec, and graywacke. Also includes ribbon chert and limestone pods. See Miller (1980b) for detailed descriptions

Kjia Amphibolite--Medium-grained, locally diopside-bearing, layered, polymetamorphic amphibolite, locally with impure metachert and hornblende-biotite schist (Miller, 1980b, p. 221-222)

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EXPLANATION OF SYMBOLS

60-80 1-10 Area underlain by dikes of the Teanaway dike swarm--Estimates in percent

Contact--Dashed where inferred; dotted where concealed; zig-zaged where gradational

High-angle fault--Dashed were inferred; dotted where concealed. Bar and ball on downthrown side

Major folds--Dotted where concealed. Arrows along axis show direction of plunge

Anticline

Syncline

Overturned syncline

Strike and dip of bedding--Ball on bar indicates top direction known

35 Inclined

75 Overturned

Vertical

60 Variable

Horizontal

Strike and dip of foliation in igneous and metamorphic rocks

45 Inclined

50 Variable

Vertical

Bearing and plunge of lineation--May be combined with other symbols

65 Inclined

Horizontal

Zone of sheared rock

Crest of moraine

Landslide--Arrow shows direction of movement

58 Dated sample locality--See table 1 in pamphlet