
GEOLOGIC MAP OF THE REPUBLIC 1:100,000 QUADRANGLE, WASHINGTON

Compiled by
KEITH L. STOFFEL

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
OPEN FILE REPORT 90-10

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This revised version supersedes the previous release, which is no longer available.

This report has not been edited or reviewed for conformity with
Division of Geology and Earth Resources standards and nomenclature



WASHINGTON STATE DEPARTMENT OF
Natural Resources

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CONTENTS

	Page
Introduction	1
DGER northeast quadrant open-file reports	1
Acknowledgments	6
Geologic setting	7
Description of map units	7
Sedimentary and volcanic deposits and rocks	7
Quaternary sedimentary deposits	7
Nonglacial deposits	7
Glacial deposits	9
Tertiary sedimentary and volcanic rocks	9
Metasedimentary and metavolcanic rocks	17
Mesozoic metasedimentary and metavolcanic rocks	17
Paleozoic metasedimentary and metavolcanic rocks	20
Proterozoic metasedimentary and metavolcanic rocks	27
Intrusive igneous rocks	27
Tertiary intrusive igneous rocks	27
Tertiary hypabyssal intrusive rocks	27
Tertiary plutonic rocks	31
Mesozoic intrusive igneous rocks	38
Metamorphic rocks	41
Metamorphic Rocks of Tenas Mary Creek	41
Meta-igneous rocks	44
Layered metamorphic rocks	46
Mixed metamorphic and igneous rocks	49
Metamorphic rocks in the southwest part of the map area	49
References cited	51

ILLUSTRATIONS

		Page
Figure 1.	Map showing 1:100,000-scale quadrangles in the northeast quadrant of Washington State	2
Figure 2a.	Index map showing sources of geologic map data, Republic 1:100,000-scale quadrangle, map scales 1:9,600 to 1:24,000	3
Figure 2b.	Index map showing sources of geologic map data, Republic 1:100,000-scale quadrangle, map scales 1:27,500 to 1:290,000	5
Figure 3.	Flow chart for age assignment of geologic units	6
Figure 4.	Generalized geologic map, Republic 1:100,000-scale quadrangle	8
Figure 5.	Total alkali-silica (TAS) diagram for Eocene volcanic rocks, Republic 1:100,000-scale quadrangle	12
Figure 6.	Total alkali-silica (TAS) diagram for Eocene hypabyssal intrusive rocks, Republic 1:100,000-scale quadrangle	30
Figure 7.	Map showing metamorphic core complexes in the Okanogan highlands of northeastern Washington	43
Plate 1.	Geologic map of the Republic 1:100,000-scale quadrangle [accompanies text]	

TABLES

Table 1:	Radiometric age data, Republic 1:100,000-scale quadrangle	58
Table 2:	Major oxide geochemistry data, Republic 1:100,000-scale quadrangle	61
Table 3:	Trace element geochemistry data, Republic 1:100,000-scale quadrangle ...	62

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INTRODUCTION

The Republic quadrangle is one of sixteen 1:100,000-scale quadrangles in the northeast quadrant of Washington State (Fig. 1). Geologic maps of these quadrangles have been compiled by Washington Division of Geology and Earth Resources (DGER) geologists and will be the principal data sources for a new 1:250,000-scale geologic map of northeastern Washington. Fourteen of these quadrangles will be released as DGER open-file reports (listed below). The Chelan and Wenatchee quadrangles will not be open-filed because they have been published recently by the U.S. Geological Survey (Tabor and others, 1982, 1987).

Literature review and preliminary compilation of the Republic quadrangle geologic map began in 1985. Between 1986 and 1988, reconnaissance and detailed geologic mapping was performed by DGER geologists in areas where previous geologic mapping was either inadequate or lacking. New geologic mapping was also acquired during that time through a DGER graduate student mapping program. Figures 2a and 2b are index maps showing sources of geologic map data used for compilation of the Republic quadrangle map.

Age assignments of geologic units in the Republic 1:100,000-scale quadrangle were made following the flow chart in Figure 3. The geologic time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador, 1985) was used, with slight modifications of the Eocene-Oligocene and Pliocene-Pleistocene boundaries (Armentrout and others, 1983; Prothero and Armentrout, 1985; Montanari and others, 1985; Aguirre and Pasini, 1985). All known radiometric ages from the Republic quadrangle are listed in Table 1, which follows the list of cited references.

Modal analyses and the International Union of Geological Sciences rock classification (Streckeisen, 1973) were used to assign plutonic rock names. Whole-rock geochemical data and the total alkali-silica (TAS) diagram (Zanettin, 1984) were the basis for assigning names to volcanic rocks. New whole-rock geochemical data, from samples collected by DGER geologists, are given in Tables 2 and 3, at the end of the report.

A U.S. Geological Survey topographic map of the Republic 1:100,000-scale quadrangle (48118-E1-TM-100) is available from Washington Division of Natural Resources, Division of Engineering, Photo and Map Sales, 1065 S. Capitol Way, Olympia, WA 98504 (206-753-5338) for \$4.50 plus 7.8% tax for state residents. This map is also available over the counter from the U.S. Geological Survey Public Inquiry Office, Room 678, U.S. Courthouse, 1200 W. Riverside, Spokane, WA 99201 (509-353-2524).

DGER Northeast Quadrant Open-File Reports

Bunning, B. B., compiler, 1990, Geologic map of the east half of the Twisp 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-9, 51 p., 1 pl.

Gulick, C. W., compiler, 1990, Geologic map of the Moses Lake 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-1, 9 p., 1 pl.

Gulick, C. W., compiler, 1990, Geologic map of the Ritzville 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-2, 7 p., 1 pl.

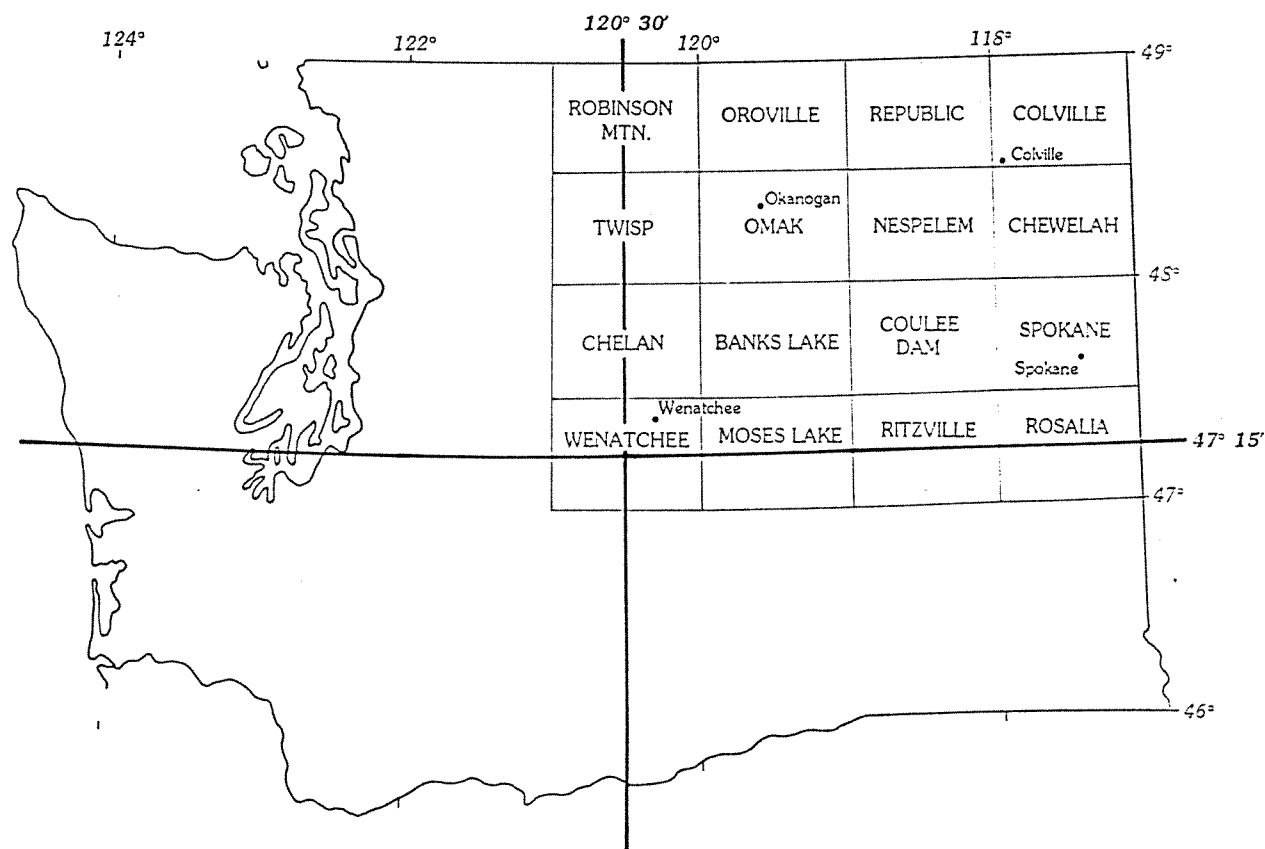
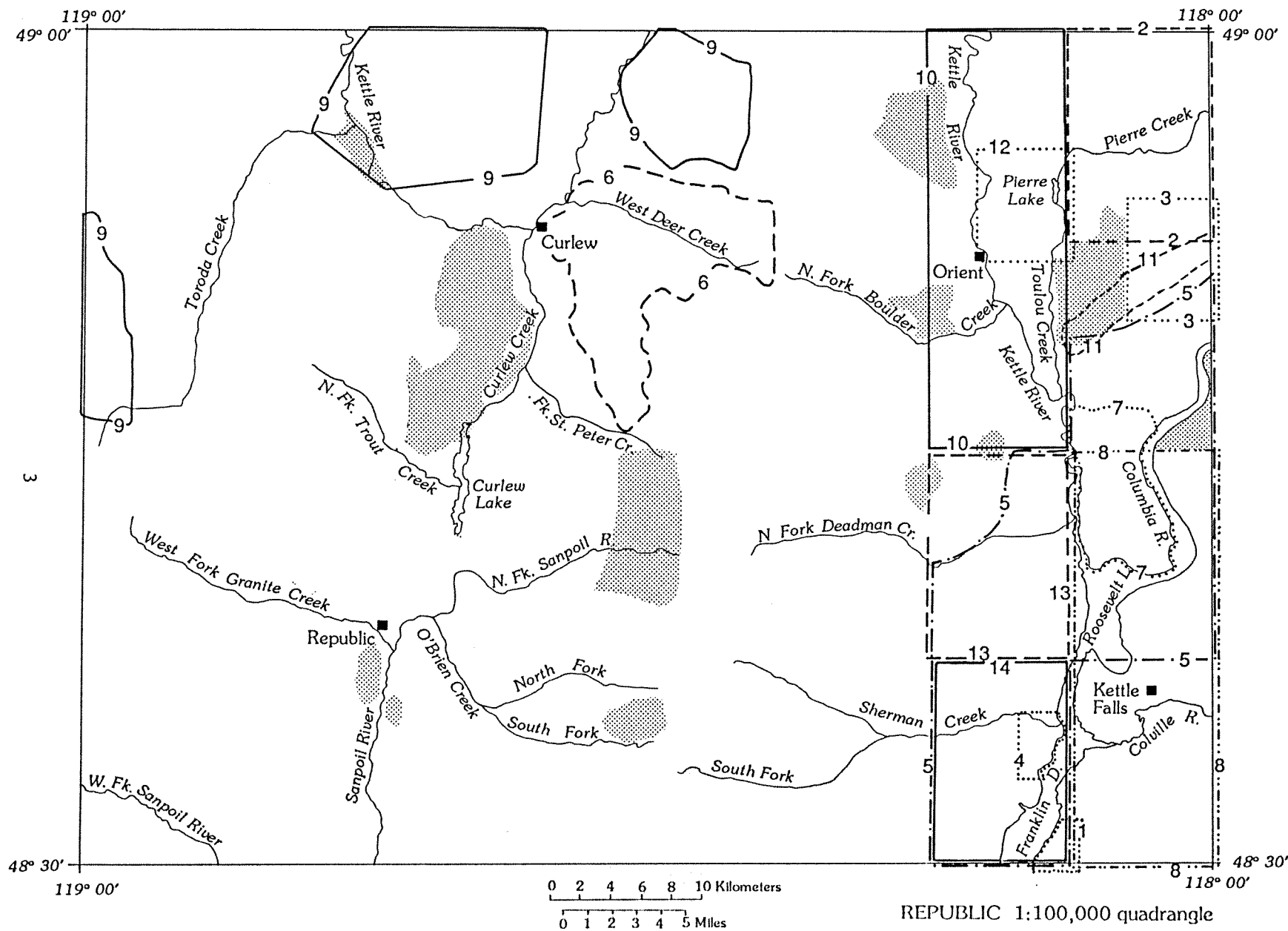


Figure 1. 1:100,000-scale quadrangles in the northeast quadrant of Washington.

Sources of Map Data

(Explanation for Figure 2a, facing page)

1. Cole, 1960, scale 1:21,480
 2. Fox, 1981, scale 1:24,000
 3. Hyde, 1985, scale 1:12,000
 4. Jones and others, 1961, scale 1:9,600
 5. Kiver, E. P.; Stradling, D. F., Eastern Washington Univ., written commun., 1986, scale 1:24,000
 6. Knaack, C. M., Washington Div. of Geology and Earth Resources unpublished mapping, 1987, scale 1:24,000
 7. Kuenzi, 1961, scale 1:16,800
 8. Mills, 1985a, scale 1:24,000
 9. Orr, 1985, scale 1:24,000
 10. Rhodes, 1980, scale 1:24,000
 11. Roback, R. C., Washington Div. of Geology and Earth Resources unpublished mapping, 1989, scale 1:24,000
 12. West, J. R., 1976, scale 1:12,000
 13. Wilson, 1980, scale 1:24,000
 14. Wilson, 1981a, scale 1:24,000
- Stippled areas, DGER staff unpublished mapping, this report



REPUBLIC 1:100,000 QUADRANGLE

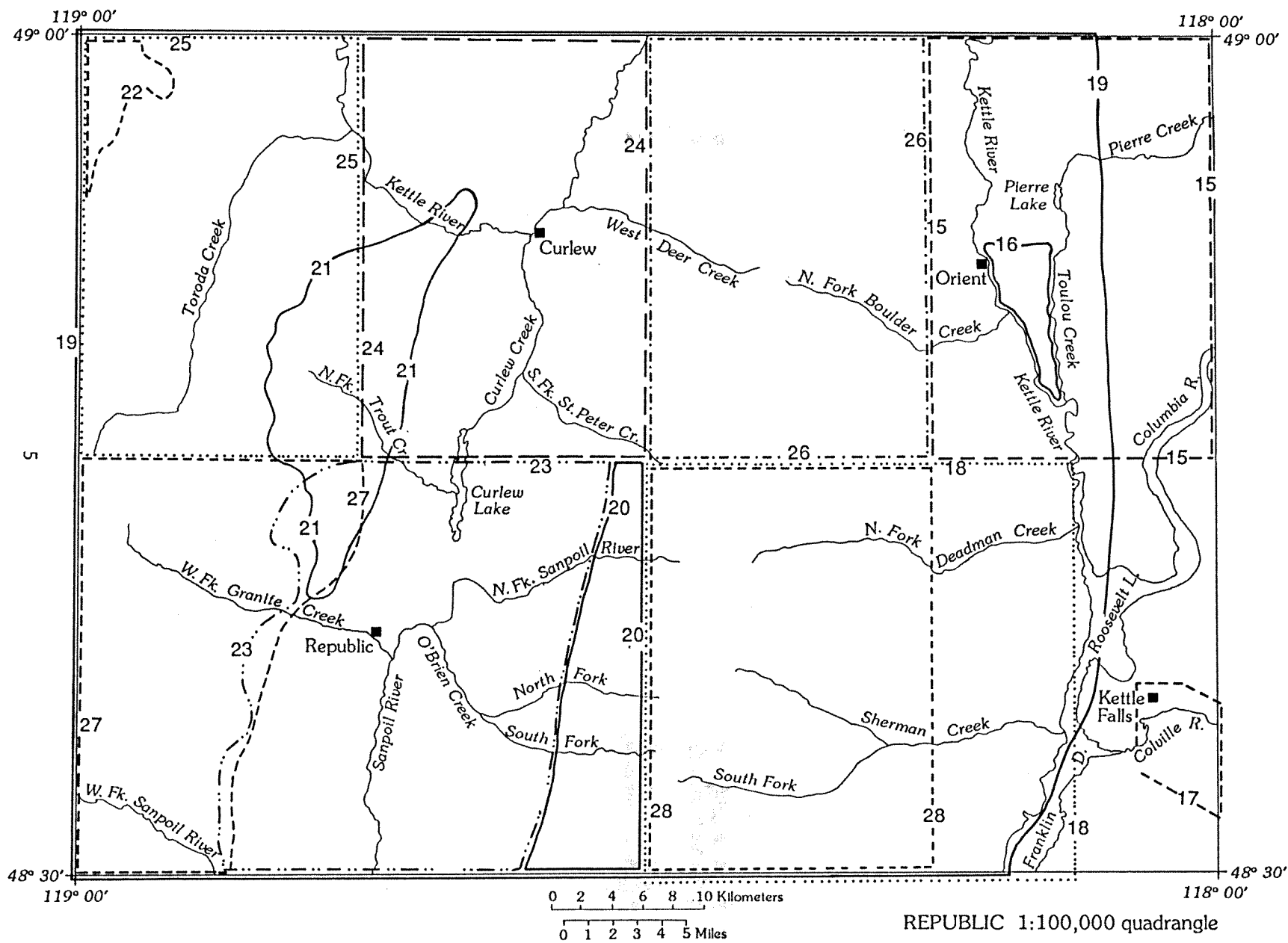
OPEN FILE REPORT 90-10

- Gulick, C. W.; Korosec, M. A., compilers, 1990, Geologic map of the Banks Lake 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-6, 20 p., 1 pl.
- Gulick, C. W.; Korosec, M. A., compilers, in press, Geologic map of the Omak 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources open-file report.
- Joseph, N. L., compiler, in press, Geologic map of the Colville 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources open-file report.
- Joseph, N. L., compiler, in press, Geologic map of the Nespelem 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources open-file report.
- Joseph, N. L., compiler, in press, Geologic map of the Spokane 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources open-file report.
- Stoffel, K. L., compiler, in press, Geologic map of the Oroville 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources open-file report.
- Stoffel, K. L., compiler, 1990, Geologic map of the Republic 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-10, p., 1 pl.
- Stoffel, K. L.; McGroder, M. F., compilers, 1990, Geologic map of the Robinson Mtn. 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-5, 39 p., 1 pl.
- Waggoner, S. Z., compiler, in press, Geologic map of the Chewelah 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources open-file report.
- Waggoner, S. Z., compiler, in press, Geologic map of the Coulee Dam 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources open-file report.
- Waggoner, S. Z., compiler, 1990, Geologic map of the Rosalia 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources open-file report 90-7, 20 p., 1 pl.

Sources of Map Data

(Explanation for Figure 2b, facing page)

15. Bowman, 1950, scale 1:63,360
16. Braun, E. R., consultant; Fields, E. D., Boise Cascade Corp., written commun., 1989, scale 1:100,000
17. Bradshaw, 1964, scale 1:27,500
18. Campbell and Thorsen, 1975, scale 1:62,500
19. Cheney and others, 1982, scale 1:290,000
20. Holder, 1985, scale 1:185,000
21. Holder, 1990, scale 1:50,688
22. McMillen, 1979, scale 1:31,680
23. Muessig, 1967, scale 62,500
24. Parker and Calkins, 1964, scale 1:62,500
25. Pearson, 1967, scale 1:62,500
26. Pearson 1977, scale 1:62,500
27. Rinehart and Greene, 1988, scale 1:48,000
28. Wilson, J. R., formerly USGS, written commun., 1987, scale 1:62,500



REPUBLIC 1:100,000 QUADRANGLE

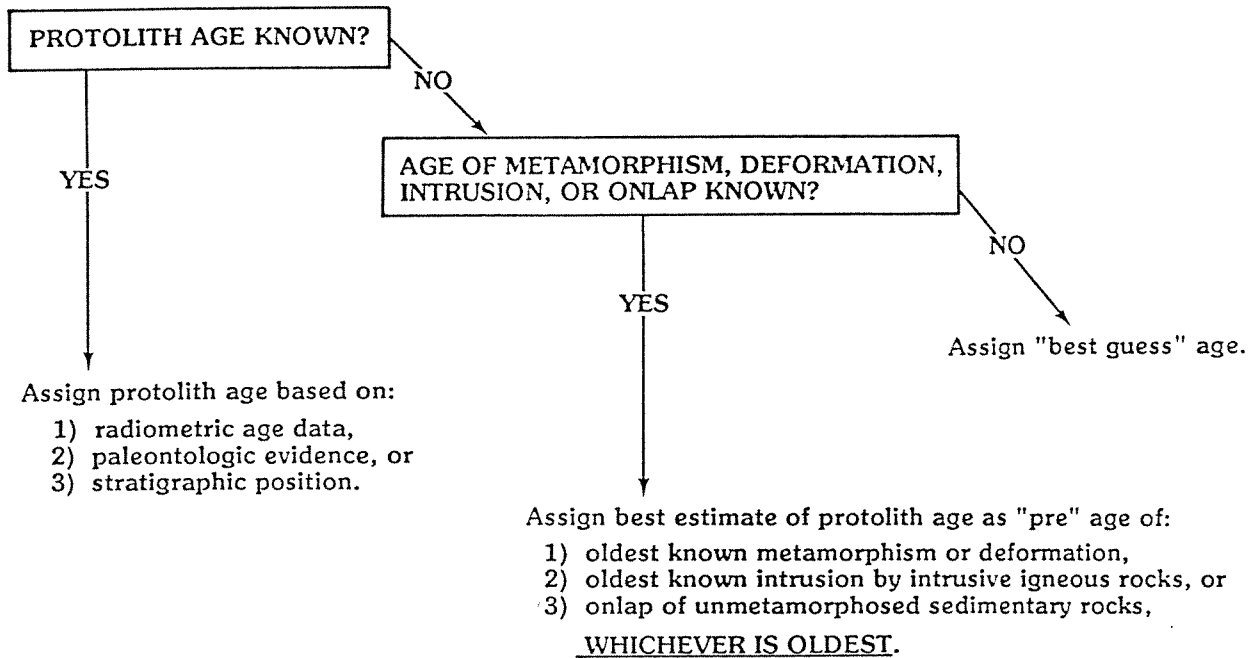


Figure 3. Flow chart for age assignment of geologic units. Protolith age or estimated protolith age can be assigned by correlation with other units. The unit description will include information on how the age of the unit was determined.

Acknowledgments

This geologic map is the culmination of the efforts of dozens of geologists over the better part of a century. All have made vital contributions to the accuracy of the map, but obviously only a few can be cited here. Special thanks to:

- * E. S. Cheney, M. A. Korosec, Richard Tschauder, E. R. Braun, R. C. Roback, and Trygve Höy for thorough and constructive reviews of an earlier draft of the manuscript
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GEOLOGIC SETTING

The Republic 1:100,000-scale quadrangle contains six generalized rock packages (Fig. 4): (1) Carboniferous(?)–Proterozoic Z miogeoclinal rocks; (2) Jurassic–Ordovician eugeoclinal rocks; (3) Mesozoic igneous intrusions; (4) amphibolite-facies metamorphic rocks of unknown age; (5) Tertiary igneous intrusions; and (6) Tertiary sedimentary and volcanic rocks. The miogeoclinal rocks, which are restricted to the eastern border of the map area, were deposited on shelves and in shallow basins along the western margin of the North American continent during the late Proterozoic and early Paleozoic. The eugeoclinal rocks were deposited in rapidly subsiding basins peripheral to or in a series of volcanic archipelagos during the Paleozoic and early Mesozoic. The eugeoclinal rocks, now known as the terrane "Quesnellia", were probably accreted to the North American continent during the Triassic and Early Jurassic. Emplacement of the Mesozoic plutons apparently post-dates the accretionary event(s). Regional extension during the latest Cretaceous(?) and early Tertiary resulted in the formation of amphibolite-facies metamorphic core complexes, the emplacement of Tertiary batholiths, and the deposition of early Tertiary volcanic and sedimentary rocks. The last are preserved in several tectonic depressions that formed during the extensional event.

DESCRIPTION OF MAP UNITS

Sedimentary and Volcanic Deposits and Rocks

Quaternary Sedimentary Deposits

Nonglacial Deposits

Qa

Alluvium (Holocene)--Stratified silt, sand, and gravel on modern alluvial plains and fans

Qoa

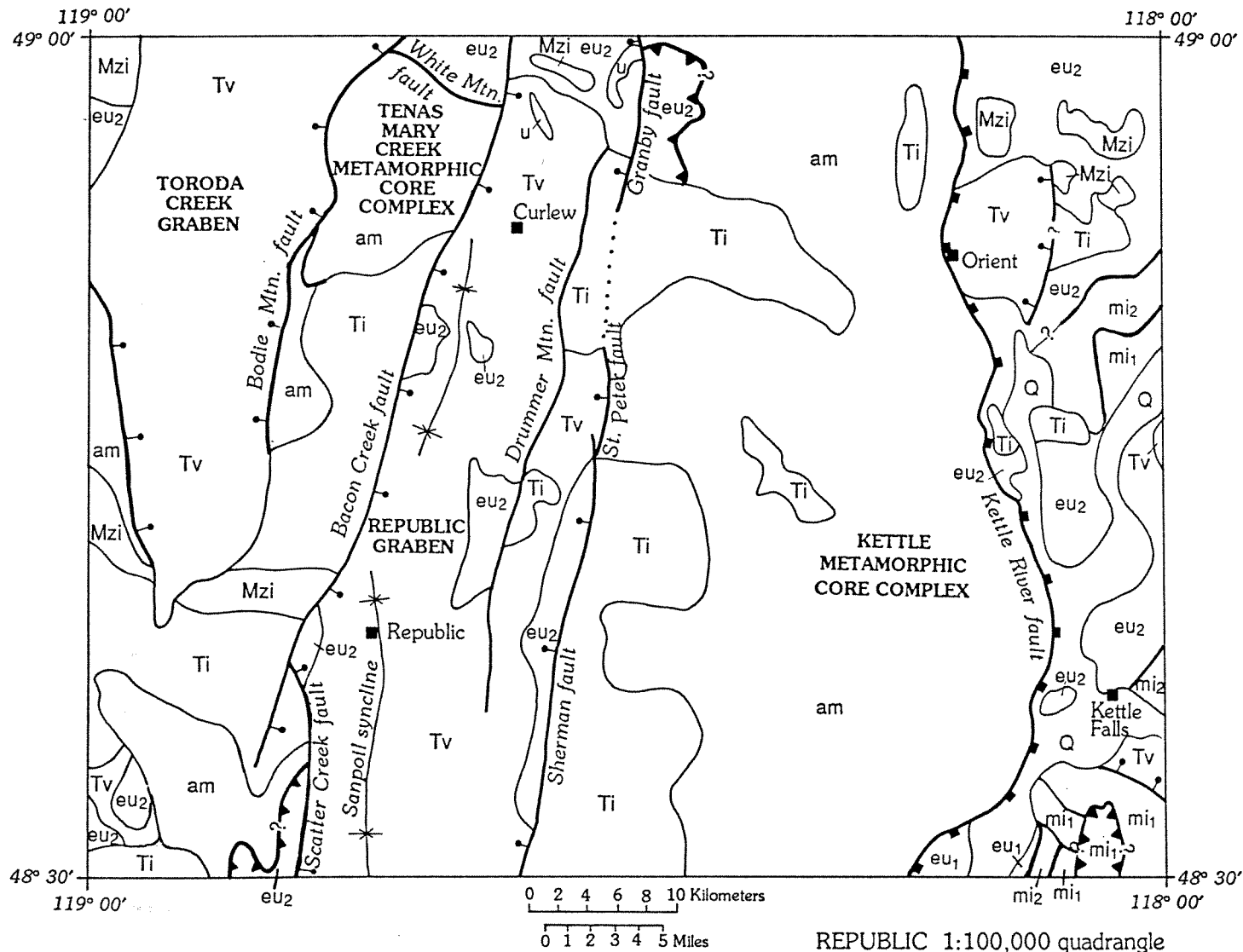
Older alluvium (Pleistocene)--Stratified silt, sand, and gravel in terraces 10 to 30 m above the modern floodplain of the West Fork Sanpoil River

Qls

Mass-wasting deposits (Holocene)--Landslide deposits, talus, and colluvium

Qd

Dunes (Holocene)--Well-sorted, fine sand in eolian dunes along the Columbia River near Marcus (T. 37 N., R. 38 E.)



- Q Quaternary sediments (includes Franklin D. Roosevelt Lake)
- Tv Tertiary volcanic and sedimentary rocks
- eu₂ Jurassic to Permian eugeoclinal rocks
- eu₁ Ordovician eugeoclinal rocks
- mi₂ Carboniferous(?)–Devonian miogeoclinal rocks
- mi₁ Ordovician-Proterozoic Z miogeoclinal rocks
- Ti Tertiary intrusive rocks
- Mzi Mesozoic intrusive igneous rocks
- u ultrabasic rocks
- am amphibolite-facies metamorphic rocks

See Plate 1 for explanation of map symbols.

Figure 4. Generalized geologic map, Republic 1:100,000-scale quadrangle

Glacial Deposits

Qgt

Till (Pleistocene)--Unstratified to poorly stratified glacial deposits of subrounded to subangular pebbles, cobbles, and boulders in an unsorted matrix of sand, silt, and clay

Qgo

Glacial outwash (Pleistocene)--Stratified sand, gravel, pebbles, and cobbles forming prominent terraces throughout much of the map area. In the valley of Deadman Creek (T. 37 N., R. 36 E.), the unit contains thin interbeds of layered sand, silt, and clay (Wilson, 1980).

Qgl

Glaciolacustrine deposits (Pleistocene)--Well-stratified, thinly bedded fine sand, silt, and clay in terraces along the Columbia River

Qgd

Glacial drift (Pleistocene)--Till, glacial outwash, and glaciolacustrine deposits, undivided; fills valleys and mantles uplands throughout the map area; locally includes colluvium on slopes and alluvium along floodplains

Tertiary Sedimentary and Volcanic Rocks

Eocene volcanic and sedimentary rocks in the map area are preserved in two major northeast-trending tectonic depressions, the Republic and Toroda Creek grabens¹ (Parker and Calkins, 1964; Muessig, 1967; Pearson, 1967), and in smaller structural lows near Kettle Falls, First Thought Mountain, and Aeneas (Pearson and Obradovich, 1977) (Fig. 4). The Eocene strata have been subdivided into three formations, which are, in ascending order: the O'Brien Creek Formation, Sanpoil Volcanics, and Klondike Mountain Formation (Muessig, 1962, 1967; Pearson and Obradovich, 1977). The O'Brien Creek Formation is composed of conglomerate, sandstone, and siltstone intercalated with tuffaceous sandstone and tuff. The Sanpoil Volcanics is a thick series of porphyritic hornblende-biotite dacite, andesite, and trachyte flows intercalated with minor tuff, tuff breccia, and volcanoclastic rocks. The Klondike Mountain Formation is a heterogeneous package of shale, volcanic sandstone and conglomerate, tuff, tuff breccia, and minor porphyritic hornblende-biotite dacite and andesite flows that is overlain by a thick pile of vitrophyric and microcrystalline pyroxene dacite and andesite flows.

¹Cheney (1980); Cheney and others (1982); and Orr and Cheney (1987) believe that these two tectonic depressions are "synclines" that are bounded by both high- and low-angle normal faults. They think that the term "graben" is inappropriate for these structural lows and should be abandoned.

Evdv_k, Evr_k, Evc_k, Ec_k, Ebx_k, Evd_k, Evt_k

Klondike Mountain Formation (Eocene)--The Klondike Mountain Formation, the youngest Tertiary stratified rock unit in the map area, forms broad northeast-trending belts in the Republic and Toroda Creek grabens and comprises the upper part of the Eocene volcanic strata at First Thought Mountain and near Kettle Falls. The Klondike Mountain Formation consists of a wide variety of volcanic and sedimentary rocks. Near Republic, the formation has been subdivided into three members (in ascending order): the Tom Thumb Tuff, middle, and basalt members (Muessig, 1962, 1967). Similar stratigraphic sequences have been described in the northern part of the Republic graben (Parker and Calkins, 1964), the Toroda Creek graben (Pearson, 1967; Rinehart and Greene, 1988), at First Thought Mountain (Bowman, 1950; J. R. West, 1976; Rhodes, 1980), and near Kettle Falls (Bradshaw, 1964), but correlation of these strata with the Klondike Mountain Formation members near Republic cannot be made at this time. Therefore, in this report, the Klondike Mountain Formation is simply subdivided into seven lithologic units.

Early workers (Parker and Calkins, 1964; Muessig, 1967; Pearson and Obradovich, 1977) thought that the Klondike Mountain Formation unconformably overlies the Sanpoil Volcanics, but recent studies indicate that the contact between the two formations in the Republic graben is generally conformable and gradational (Richard Tschauder, Hecla Mining Co., written commun., 1989; D. R. Gaylord, Washington State University, oral commun., 1989; DGER unpublished data). In the Toroda Creek graben, Klondike Mountain Formation rhyolite(?) flows unconformably overlie the Sanpoil Volcanics (Pearson, 1967).

Evdv_k

Vitrophyric and microcrystalline dacite and andesite flows--Black vitrophyric flows composed of plagioclase and clinopyroxene phenocrysts in a groundmass of glass and plagioclase microlites. They locally contain minor orthopyroxene and olivine phenocrysts. Dark-gray microcrystalline flows consist of similar constituents, but phenocrysts are larger and more numerous and the groundmass is micro- to holocrystalline and contains little or no glass. Flow banding is locally well preserved in the rocks. Whole-rock, major- and trace-element geochemical data from 31 samples of the vitrophyric and microcrystalline flows indicate they are chiefly dacite and andesite (Fig. 5; Tables 2 and 3). The flows and flow breccias form the upper part of the Klondike Mountain Formation in the Republic and Toroda Creek grabens (Muessig, 1962, 1967; Parker and Calkins, 1964; Pearson, 1967; Rinehart and Greene, 1988) and at First Thought Mountain (Bowman, 1950; J. R. West, 1976; Rhodes, 1980). Thin beds of tuff breccia and conglomerate are intercalated with the flows in places.

The thickness of the vitrophyric and microcrystalline flows varies from 60 m on Klondike and First Thought Mountains to 365 m on Mount Elizabeth (sec. 17, T. 38 N., R. 33 E.). Stacks of thin flows (less than 5 m thick) with well-developed basal colonnades and vesicular flow tops are recognizable in places, particularly along the south and east slopes of Franson Peak (sec. 27, T. 39 N., R. 33 E.).

In the northern part of the Republic graben and near First Thought Mountain, the vitrophyric and microcrystalline flows unconformably overlie Klondike Mountain Formation sedimentary and pyroclastic rocks. At Klondike Mountain (sec. 24, T. 37 N., R. 32 E.), the nature of the contact between the vitrophyric flows and the underlying volcanic conglomerate is not well defined. In the Toroda Creek graben, the contact between the vitrophyric and microcrystalline flows and Klondike Mountain Formation rhyolite(?) flows is apparently conformable.

K-Ar hornblende ages reported from the vitrophyric and microcrystalline flows range from 41.3 ± 2.0 Ma to 48.0 ± 1.9 Ma (Table 1). A K-Ar whole-rock age of 33.7 ± 1.6 Ma (DGER data) is inconsistent with the hornblende ages.

Evr_k

Rhyolite(?) flows--Gray, green, purple, and brown rhyolite(?) flows, hundreds of meters thick, that form a 10-km-wide belt along the east side of the Toroda Creek graben (Pearson, 1967; Rinehart and Greene, 1988). These flows are composed of sparse phenocrysts of plagioclase and mafic minerals in an aphanitic groundmass that contains abundant plagioclase microlites. The plagioclase phenocrysts are commonly strongly sericitized, and the mafic minerals are generally replaced by some combination of chlorite, calcite, epidote, and sphene. Euhedral shapes of the altered mafic minerals suggest that most were originally pyroxene. Whole-rock geochemical data from the flows plot in the rhyolite field on the total alkali-silica (TAS) diagram (Fig. 5; Tables 2 and 3). However, the presence of silica stringers and veinlets in some of these rocks indicate that silica has been introduced during alteration. Therefore, the original geochemical composition of the flows is not known with certainty.

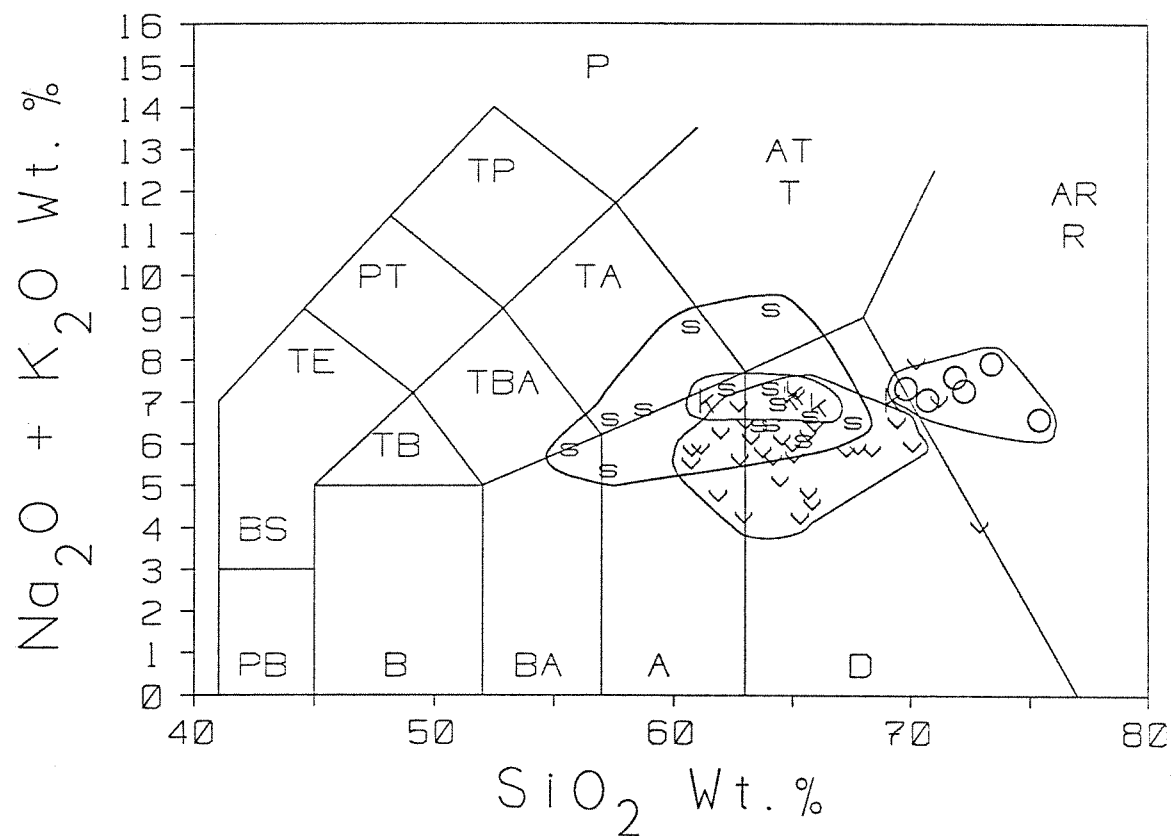
The rhyolite(?) flows unconformably overlie Klondike Mountain Formation sedimentary rocks, Sanpoil Volcanics, and older metamorphic and granitic rocks. They are conformably(?) overlain by Klondike Mountain Formation vitrophyric and microcrystalline dacite and andesite flows. The rhyolite(?) flows have yielded four K-Ar ages ranging from 47.4 ± 1.6 Ma to 49.1 ± 1.7 Ma (Table 1).

Evc_k

Volcanic conglomerate--Rounded to subrounded clasts, as much as 40 cm in diameter, in a sandy matrix of quartz, feldspar, and biotite crystals and lithic fragments (Oliver, 1986). Clasts are dominantly gray, green, or purple porphyritic dacite and andesite, but microcrystalline volcanic rocks, black shale, and quartzite are also present. Bedding in the conglomerate is rare, but a poorly developed subhorizontal parting is common. Cut-and-fill structures are locally preserved.

The volcanic conglomerate crops out on the west side of Klondike Mountain, on the east flank of Mount Elizabeth, at the north end of Curlew Lake, and south of Kettle Falls. The 250-m-thick volcanic conglomerate at Klondike Mountain contains thin beds of pebbly volcanic sandstone, fine- to coarse-grained tuff, and tuffaceous sandstone (Muessig, 1967; Oliver, 1986).

Volcanic conglomerate at Mount Elizabeth and Curlew Lake is only a few tens of meters thick (Parker and Calkins, 1964; DGER unpublished mapping). It is composed of rounded to angular pebbles, cobbles, and boulders in a poorly sorted, volcanic sandstone matrix. The clasts are dominantly gray, green, or purple porphyritic dacite and andesite, but nonvolcanic rocks also are present and are locally abundant. Minor interbeds of sandstone, compositionally similar to the conglomerate matrix, locally impart stratification to the massive conglomerate.



MAP SYMBOL

v Evdv_k
o Evr_k
k Evd_k and Evt_k
s Evd_s

TAS DIAGRAM FIELDS

PB	microbasalt	TA	trachyandesite
B	basalt	TBA	trachybasaltic andesite
BA	basaltic andesite	TB	trachybasalt
A	andesite	BS	basinite
D	dacite	TE	tephrite
R	rhyolite	PT	phonotephrite
AR	alkali rhyolite	TP	tephriphonolite
T	trachyte	P	phonolite
		AT	alkali trachyte

Figure 5. Total alkali-silica (TAS) diagram for Eocene volcanic rocks, Republic 1:100,000-scale quadrangle.

Volcanic conglomerate with thin interbeds of tuffaceous sandstone and siltstone also crops out southeast of Kettle Falls (secs. 3 and 4, T. 35 N., R. 38 E.). The conglomerate is composed of rounded clasts of andesite and dacite, 5 to 30 cm in diameter, and smaller subangular fragments of quartzite, argillite, chert-pebble conglomerate, wacke, limestone, and granite (Bradshaw, 1964). Previous workers (Pearson and Obradovich, 1977; Mills, 1985a) assigned this volcanic conglomerate to the Sanpoil Volcanics, but because the rocks are compositionally similar to volcanic conglomerate in the Klondike Mountain Formation near Republic and because they lie at approximately the same stratigraphic position, it is more likely that the volcanic conglomerate near Kettle Falls is correlative with the lower part of the Klondike Mountain Formation in the Republic graben (H. E. Bradshaw, consulting geologist, written commun., 1989).

Ec_k

Sedimentary rocks--A basal unit of volcanic conglomerate that is overlain by an upward-coarsening sequence of carbonaceous shale, laminated tuffaceous siltstone, and medium- to coarse-grained volcanic sandstone (Gaylord and others, 1988; Gaylord, 1989). Thin beds of very fine grained, well-sorted crystal tuff, composed of plagioclase, biotite, augite, and rare hornblende crystals, are locally intercalated with the sedimentary rocks. The massive, unsorted volcanic conglomerate is composed of angular to subrounded clasts, 1.5 mm to 2 mm in diameter, in a matrix of tuffaceous sand or crystal lithic tuff. The clasts are chiefly porphyritic rocks derived from the Sanpoil Volcanics and their hypabyssal intrusive equivalents (Oliver, 1986), but fragments of tuff and tuffaceous sandstone are also common. Clasts of banded silica veins are found in the conglomerate and breccia in places. Their presence indicates that these rocks post-date at least some of the mineralization in the Republic mining district.

Sandstone, siltstone, shale, and conglomerate also occur in the lower part of the Klondike Mountain Formation on the southwest flank of Clackamas Mountain (sec. 20, T. 37 N., R. 31 E.), in the northern parts of the Toroda Creek and Republic grabens and at First Thought Mountain. The sandstone is generally poorly sorted, fine to medium grained, and composed of plagioclase, biotite, chlorite, quartz, and volcanic rock fragments. The siltstone and shale are laminated to thinly bedded rocks that commonly contain organic detritus. The poorly sorted conglomerate is composed of subangular to rounded rock clasts in a sandy matrix. Clasts are chiefly volcanic rocks, but conglomerate at First Thought Mountain also contains rounded to subrounded fragments of granite and quartzite (J. R. West, 1976); conglomerate near Curlew Lake (sec. 20, T. 38 N., R. 33 E.) lacks volcanic rock clasts but contains rounded quartzite, phyllite, gneiss, and granitoid rock fragments; and conglomerate near Wauconda Summit is composed chiefly of granitoid rock clasts (Rinehart and Greene, 1988), but contains some amphibolite.

Sandstone, siltstone, shale, and conglomerate form much of the lower part of the Klondike Mountain Formation in the Republic and Toroda Creek grabens (Muessig, 1962, 1967; Parker and Calkins, 1964; Pearson, 1967; Rinehart and Greene, 1988) and at First Thought Mountain (Bowman, 1950; J. R. West, 1976; Rhodes, 1980). Muessig (1962, 1967) assigned the sedimentary rocks at the base of the Klondike Mountain Formation in the Republic mining district to the Tom Thumb Tuff Member. Elsewhere, the Klondike Mountain Formation sedimentary rocks have not been named.

The sedimentary rocks near Republic form a narrow, concave belt along the west side of Klondike Mountain from Barrett Creek (sec. 13, T. 37 N., R. 32 E.) to the Sanpoil River (sec. 19, T. 36 N., R. 33 E.), and an isolated fault-bounded block on the east flank of Bald Peak (sec. 12, T. 37 N., R. 32 E.). Muessig (1967) estimated that these rocks are approximately 580 m thick near the Knob Hill mine (sec. 27, T. 37 N. R. 32 E.).

Fossiliferous shale beds in the sedimentary rocks near Republic (the Tom Thumb Tuff Member of Muessig, 1967) and in the northern part of the Toroda Creek graben have yielded the remarkably diverse "Republic flora", assigned an early middle Eocene age by Wolfe and Wehr (1987). Eocene fossil fish, including *Amyzon*, *Trychophanes*, *Erismatopterus*, and an unidentified salmon have also been recovered from the sedimentary rocks in the Toroda Creek graben (Pearson, 1967). A single K-Ar biotite age of 55.0 ± 1.7 Ma is reported from a tuff(?) bed in the sedimentary rocks near Republic (Axelrod, 1966), but this age is probably not the depositional age of the sediments because it is older than all K-Ar ages reported from the underlying Sanpoil Volcanics.

Ebx_k

Breccia--Broken clasts of quartz monzonite and greenschist-facies metamorphic rocks (Pearson, 1967) in the northern part of the Toroda Creek graben. North of Toroda Creek, the breccia is monolithologic (quartz monzonite) and forms sheets tens of meters thick that grade westward into conglomerate and fine-grained sedimentary rocks. Clasts in the breccia are angular and range from a few centimeters to several meters in diameter. In O'Connor Canyon and along the Kettle River opposite the mouth of Tenas Mary Creek (sec. 21, T. 40 N., R. 32 E.) the breccia is composed of huge bodies of shattered, but otherwise unbrecciated quartz monzonite. The O'Connor Canyon body covers approximately $2/3$ km², and the Kettle River body is more than $1\frac{1}{4}$ km long and 150 m thick.

Evd_k

Porphyritic dacite and andesite flows--Abundant 1- to 5-mm-long phenocrysts of plagioclase, hornblende, biotite, and minor quartz and pyroxene in a microcrystalline groundmass of feldspar and quartz. Modal and geochemical data indicate that the composition of the porphyritic dacite and andesite flows is more similar to that of the porphyritic flows in the underlying Sanpoil Volcanics (Evd_k) than to that of the overlying vitrophyric and microcrystalline flows in the Klondike Mountain Formation (Evdv_k) (Fig. 5; Tables 2 and 3).

Thin flows of porphyritic dacite and andesite are intercalated with tuff, tuff breccia, volcanic conglomerate, sandstone, siltstone, and shale along the southeastern flank of Mount Elizabeth and on the south side of Franson Peak (Parker and Calkins, 1964; DGER unpublished mapping). Thin porphyritic flows are also interbedded with epiclastic and pyroclastic rocks near Republic (Muessig, 1967), but they are too limited to show at the 1:100,000 map scale.

The presence of these Sanpoil-like flows in the lower part of the Klondike Mountain Formation and the conformable and gradational nature of the contact between the lower Klondike Mountain Formation and the upper Sanpoil Volcanics have led several recent workers to suggest that the lower part of the Klondike Mountain Formation (below the vitrophyric and microcrystalline flows) should either be reassigned to the Sanpoil Volcanics or be given a new formation name (Richard Tschauder, Hecla Mining Co., oral commun., 1989; E. R. Braun, University of Montana, oral commun., 1989; D. R. Gaylord, Washington State University, oral commun., 1989). However, because revision of the stratigraphic nomenclature of Eocene volcanic and sedimentary rocks in northeastern Washington is beyond the scope of this report, the existing nomenclature is herein retained, and the porphyritic flows are assigned to the Klondike Mountain Formation.

Evt_k

Tuff and tuff breccia--Pale green, buff, and lavender tuff composed of euhedral to subhedral crystals of hornblende, plagioclase, biotite, and quartz; tuff breccia consisting of angular to subrounded clasts of porphyritic biotite-hornblende-plagioclase dacite and andesite in a crystal tuff matrix. Compositions of the tuff and tuff breccia are similar to those of flows in the underlying Sanpoil Volcanics (Fig. 5; Tables 2 and 3). Massive beds of tuff and tuff breccia are abundant in the lower part of the Klondike Mountain Formation in the northern part of the Republic graben (Parker and Calkins, 1964; DGER unpublished mapping).

Evd_s, Evt_s

Sanpoil Volcanics (Eocene)--Flows and flow breccias, ranging in composition from latite to rhyodacite, that dominate the Sanpoil Volcanics. Pyroclastic and sedimentary rocks are locally intercalated with the flows, particularly in the upper part of the formation.

The Sanpoil Volcanics form broad northeast-trending belts in the Republic and Toroda Creek grabens and cover several square kilometers near Orient and Kettle Falls. Small bodies also crop out near Aeneas in the southwestern corner of the map area.

The Sanpoil Volcanics were named for exposures along the Sanpoil River south of Republic (Muessig, 1962), and were subsequently mapped throughout the northern part of the Republic graben (Muessig, 1967; Parker and Calkins, 1964) and the Toroda Creek graben (Pearson, 1967; Rinehart and Greene, 1988). The volcanic rocks in the Orient area were originally assigned to the First Thought Formation (Bowman, 1950), and those in the Kettle Falls area were named the Palmer Volcanics (Weaver, 1920; Bradshaw, 1964). They were re-assigned to the Sanpoil Volcanics by Pearson and Obradovich (1977). The Sanpoil Volcanics are correlative with part of the Marron Formation in southern British Columbia (Monger, 1968).

The thickness of the Sanpoil Volcanics is difficult to estimate because the stratigraphy and internal structure of the formation are poorly known. The most reliable measured section is on the east flank of Klondike Mountain, where approximately 1,200 m is exposed (Muessig, 1967).

The Sanpoil Volcanics conformably and gradationally overlie the O'Brien Creek Formation in places, and unconformably overlie pre-Tertiary rocks in other places. The Sanpoil Volcanics are cut by and locally grade into porphyritic dacite intrusions (Eida), particularly along Curlew Creek between St. Peter and Rincon Creeks (T. 39 N., R. 33 E.) (Parker and Calkins, 1964). The Sanpoil Volcanics are conformably overlain by Klondike Mountain Formation sedimentary rocks (Ec_k) and tuff (Evt_k) and are unconformably overlain by Klondike Mountain Formation vitrophyric and microcrystalline dacite and andesite flows (Evd_{v_k}).

Most K-Ar ages reported from the Sanpoil Volcanics in the map area range from 44.8 ± 2.2 Ma to 52.4 ± 1.8 Ma (Table 1). The majority fall between 48 and 52 Ma. Propylitically altered Sanpoil Volcanics in the Knob Hill mine near Republic have yielded fission-track zircon ages of 39.4 ± 0.9 and 39.4 ± 1.1 Ma (Oliver, 1986), but these ages are younger than those reported from the overlying Klondike Mountain Formation. They may represent the age of post-mineralization alteration in the mine area.

Evd_s

Porphyritic dacite, andesite, and trachyte flows--Gray, brown, green, and purple porphyritic rocks composed of 20 to 60 percent phenocrysts, 1 to 5 mm long, in a microcrystalline groundmass. Plagioclase (andesine to labradorite), hornblende, biotite, and augite phenocrysts are most abundant; hypersthene occurs locally. The groundmass is composed of microlites of plagioclase and mafic minerals embedded in a microgranular matrix of quartz and K-feldspar. The rocks are commonly propylitically altered, with mafic minerals partially to wholly replaced by some combination of chlorite, calcite, epidote, and sphene. Modal and geochemical data indicate that the composition of the flows ranges from trachyte to dacite, but dacite and andesite are most abundant (Fig. 5; Tables 2 and 3). These massive to fragmental flows and flow breccias dominate the Sanpoil Volcanics.

Evt_s

Tuff and tuff breccia--Euhedral to subhedral crystals of hornblende, plagioclase, biotite, and quartz. The tuff breccia consists of angular to subrounded clasts of porphyritic dacite and andesite in a matrix similar in composition to the tuff.

Tuff and tuff breccia are intercalated with porphyritic dacite and andesite flows at Bear Mountain and Eagle Rock (T. 35 N., R. 33 E.) (Muessig, 1967) and at First Thought Mountain (T. 39 N., R. 37 E.) (Allen Martin, Boise Cascade Corp., oral commun., 1989). Tuff and tuff breccia are also abundant in the upper part of the Sanpoil Volcanics near Republic (Braun, 1989; Richard Tschauder, Hecla Mining Co., written commun., 1989; D. R. Gaylord, WSU, oral commun., 1989), but because they have not been mapped separately from the porphyritic flow rocks, they are not shown on Plate 1.

Ec_o

O'Brien Creek Formation (Eocene)--Interbedded tuff, tuffaceous sandstone, siltstone, shale, and conglomerate. The cream to pale green tuffaceous rocks are composed of broken crystals of plagioclase, quartz, and orthoclase in a tuffaceous matrix. They contain abundant angular chips of black argillite. Siltstone and dark-gray carbonaceous shale are locally interbedded with the tuffaceous rocks. Volcanic sandstone and siltstone, composed of volcanic rock fragments and plagioclase, quartz, hornblende, and augite crystals, occur in the upper part of the formation near Kettle Falls (Bradshaw, 1964) and Bossburg (DGER unpublished mapping). Conglomerate, several tens of meters thick, is present near both the base and top of the O'Brien Creek Formation in the Republic and Toroda Creek grabens. Near Kettle Falls and Orient, the conglomerate is restricted to the base of the formation. Clasts are chiefly angular to subrounded in the lower conglomerate and well-rounded in the upper conglomerate. They include quartzite, argillite, phyllite, schist, greenstone, chert, chert-pebble conglomerate, wacke, and granitoid rocks. Volcanic rock clasts are present in the upper conglomerate, but are absent in the lower conglomerate. The matrix of the conglomerate is composed of sand-size grains of quartz and feldspar.

Graded beds, trough cross-beds, small channels, ripple marks, and oriented argillite chips are common in the O'Brien Creek Formation. They indicate that at least part of the formation was deposited in fluvial and/or lacustrine environments. Crystal-rich tuff(?) beds in the formation may have been deposited by primary pyroclastic processes.

The O'Brien Creek Formation crops out in narrow belts along the margins and near the center of the Republic graben (Muessig, 1967; Parker and Calkins, 1964), in a wide belt along the west side of the Toroda Creek graben (Pearson, 1967), southeast of Kettle Falls (Bradshaw, 1964; Mills, 1985a), northeast of Bossburg (DGER unpublished mapping), and near First Thought Mountain (Bowman, 1950; J. R. West, 1976). The thickness of the formation is approximately 1,300 m near Cooke Mountain (sec. 18, T. 37 N., R. 34 E.) (Muessig, 1967), 610 m in the Toroda Creek graben (Pearson, 1967), 350 m near Kettle Falls (Bradshaw, 1964), and less than 100 m near Orient (Bowman, 1950).

This is the oldest Tertiary stratified rock unit in the map area. The O'Brien Creek Formation unconformably overlies greenschist-facies metasedimentary and metavolcanic rocks in places, but the basal contact is generally marked by faults or intrusive contacts. The O'Brien Creek Formation grades upward into and is interbedded with the Sanpoil Volcanics. The zone of mixed lithologies is locally more than 100 m thick (Richard Tschauder, Hecla Mining Co, written commun., 1989).

Because no reliable radiometric ages have been reported from the O'Brien Creek Formation in the Republic and Toroda Creek grabens, the age of the formation is unknown. Bedded tuff in the Pend Oreille valley near the Idaho border, which has been correlated with the O'Brien Creek Formation in the grabens (Pearson and Obradovich, 1977), has yielded a K-Ar biotite age of 53.1 ± 1.5 Ma.

Metasedimentary and Metavolcanic Rocks

Mesozoic Metasedimentary and Metavolcanic Rocks

Jmv_r, Jmm_r, Jcg_r

Rossland Group (Jurassic)--Rossland Group metasedimentary and metavolcanic rocks form a broad belt east of the Kettle River in the northeastern corner of the map area. They extend east into the Colville 1:100,000-scale quadrangle and north into southern British Columbia. In British Columbia, the Rossland Group has been subdivided into three units, in ascending order, the Archibald, Elise, and Hall Formations (Höy and Andrew, 1988, 1989). The Archibald Formation consists of strongly deformed metasedimentary rocks. The Elise Formation is a thick package of metavolcanic rocks. The Hall Formation is composed of weakly deformed metasedimentary rocks. The Rossland Group in the Republic map area has not been formally subdivided, but it is probably correlative with the Archibald and Elise Formations.

In the map area, the Rossland Group unconformably overlies Permian metasedimentary rocks (R. C. Roback, University of Texas, written commun., 1988), is in fault contact with Triassic metacarbonate and the Kelly Hill phyllite (Hyde, 1985), and is intruded by Jurassic(?) basic intrusive rocks and by the Eocene Fifteenmile Creek pluton (Fox, 1981; Hyde, 1985).

Marine macrofossils in the Archibald and Hall Formations indicate that the age of the Rossland Group in British Columbia ranges from Sinemurian to Toarcian (Höy and Andrew, 1988). No-age diagnostic fossils have been found in the Rossland Group in the Republic map area, but two radiometric ages are reported from it. At Sackit Canyon (secs. 3 and 4, T. 38 N., R. 37 E.), granitic boulders in metaconglomerate at the base of the Rossland Group have yielded a U-Pb zircon age of 196 ± 1 Ma (Roback and Walker, 1989), providing a maximum age for the unit. A U-Pb zircon age of $165 \pm 3 - 11$ Ma is reported from a metafelsite body in the upper part of the Rossland Group at Sackit Canyon (R. C. Roback, University of Texas, written commun., 1989). However, because the composition of the metafelsite is more silicic than most of the Rossland Group flows, and because the stratigraphic relation

between the metafelsite and the surrounding Rossland Group greenstone is unknown, it is not clear whether the metafelsite is part of the Rossland Group or is a post-Rossland Group flow or hypabyssal intrusion. Therefore, the upper age limit of the Rossland Group in the map area is unknown.

Jmv,

Metavolcanic rocks--Massive, dark-green greenstone and augite porphyry composed of augite, plagioclase, and rare hornblende phenocrysts in fine- to medium-grained groundmasses of similar composition. The rocks contain abundant amygdules, pillows, and flow bands. The massive, aphanitic greenschist probably represents metamorphosed pyroclastic rocks. Geochemical data are not available from the Rossland Group in the map area, but major- and trace-element analyses of similar rocks in British Columbia indicate that the greenstone and augite porphyry are shoshonitic in composition and the greenschist is more silicic (Höy and Andrew, 1989). Agglomerate in the Rossland Group consists of rounded to subangular pebbles, cobbles, and boulders of volcanic rocks in a poorly sorted, sandy matrix.

Greenstone, augite porphyry, and greenschist dominate the Rossland Group in the map area (Fox, 1981; R. C. Roback, University of Texas, written commun., 1989). Agglomerate is locally intercalated with the volcanic rocks. The metavolcanic rocks are probably correlative with the Elise Formation in southern British Columbia (Höy and Andrew, 1988).

Jmm, Jcg,

Metasedimentary rocks--Dark-gray and green, massive to thinly laminated, poorly sorted argillite, metasiltstone, metawacke, and minor metaconglomerate (Jmm) composed of subangular to subrounded grains of quartz, chert, and plagioclase, and broken fragments of volcanic and plutonic rocks. Metaconglomerate (Jcg), locally interlayered with argillite, metasiltstone, metawacke, and metavolcanic rocks, crops out near Hope and Bower Mountains along the Canadian border (T. 40 N., R. 37 E.) (Rhodes, 1980; Fox, 1981). Pebbles and cobbles in the metaconglomerate are chiefly mafic to felsic volcanic rocks, but chert, argillite, and siltstone clasts also occur. Granitic cobbles are rare.

The unit crops out along Fifteenmile Creek (sec. 24, T. 39 N., R. 37 E.), northeast of Fisher Creek (sec. 2, T. 39 N., R. 37 E.), and along Pierre Creek (sec. 28, T. 40 N., R. 37 E.). Argillite, metasiltstone, metawacke, and metaconglomerate locally underlie and interfinger with Rossland Group metavolcanic rocks in the map area (Fox, 1981). The metasedimentary rocks may be correlative with the Archibald Formation in southern British Columbia (Höy and Andrew, 1988; Andrew and others, 1990).

Rcb

Triassic metacarbonate--Gray, thin-bedded metalimestone interbedded with argillite, metasiltstone, and metawacke. The unit is exposed at Kelly Hill (secs. 33 and 35, T. 38 N., R. 37 E.), near Hope Creek (sec. 17, T. 39 N., R. 38 E.), and northeast of Curlew (T. 40 N., R. 34 E.). At Kelly Hill, the metalimestone contains four genera of pelecypods, three genera of cephalopods (ammonoids), and three genera of gastropods of Scythian (Early Triassic) age (Kuenzi, 1961, 1965). The metalimestone near Hope Creek has yielded Late Triassic conodonts (*Neogondolella polygnathiformis*) (A. G. Harris, USGS, written commun., 1989). The metalimestone near Curlew contains Late Triassic pelecypods, ammonites, brachiopods, and crinoid columnals (Parker and Calkins, 1964).

Small bodies of gray recrystallized limestone also crop out along Cedar Creek (T. 40 N., R. 31 E.) (Pearson, 1967) and near the junction of Limestone and Pierre Creeks (sec. 28, T. 40 N., R. 37 E.) (Fox, 1981). Because fossils have not been found in these metalimestones, their age is uncertain. They are tentatively assigned to the Triassic, but a Permian age cannot be ruled out.

T_{Pmm} , T_{Pmv} , T_{Pmt}

Triassic-Permian metasedimentary and metavolcanic rocks--Intricately folded and faulted Triassic and Permian argillite, metasiltstone, metawacke, chert-pebble metaconglomerate, greenstone, and metachert form (1) a 5.5-km-wide arcuate belt along the Columbia River between Kettle Falls and Bossburg; (2) northeast-trending linear belts within the Republic graben; (3) a 4-km-long belt along the southwestern margin of the Toroda Creek graben near Old Wauconda; (4) a narrow belt along the northeastern margin of the Toroda Creek graben near the Canadian border; and (5) scattered outcrops on and northeast of Buckhorn Mountain (T. 40 N., R. 30 E.). Small pods and irregular bodies of both Triassic and Permian metalimestone (T_{cb} and P_{cb}) are scattered throughout the metasedimentary and metavolcanic rocks, but because no fossils have been recovered from the clastic and volcanic rocks themselves, they cannot be subdivided into Triassic and Permian rock units at this time. Some of the rocks in this unit are probably correlative with the Permian metasedimentary rocks (P_{mm}) described below.

Contacts between the Triassic-Permian metasedimentary and metavolcanic rocks and older rock units are generally marked by faults. Faults also separate the Triassic-Permian rocks from Eocene volcanic and sedimentary rocks in places, but the Eocene rocks unconformably overlie the Triassic-Permian rocks in other places. Jurassic(?) and Cretaceous plutonic rocks and Eocene hypabyssal intrusive rocks locally cut the Triassic-Permian metasedimentary and metavolcanic rocks.

T_{Pmm}

Metasedimentary rocks--Metasedimentary rocks that crop out along the Columbia River between Kettle Falls and Bossburg (Kuenzi, 1961; Mills, 1985a) and along Cedar Creek northeast of Buckhorn Mountain (T. 40 N., R. 31 E.) (Pearson, 1967). Along the Columbia River, the unit includes argillite, metasiltstone, metawacke, and minor chert-pebble metaconglomerate. The metawacke is composed of subangular to angular grains of quartz, chert, calcite, and phyllite. The metaconglomerate is composed of rounded pebbles of chert, argillite, volcanic rocks, and greenstone in a poorly sorted sandy matrix similar in composition to the metawacke. The small body of metasedimentary rocks along Cedar Creek is chiefly metaconglomerate composed of rounded pebbles, cobbles, and boulders of chert or limestone in poorly sorted sandy matrix.

T_{Pmv}

Metavolcanic rocks--Chiefly massive to schistose greenstone, with minor interbeds of sandy argillite and very thin bedded gray metachert. The greenstone is generally strongly altered, but relict igneous textures are locally preserved. Altered plagioclase is commonly the only remaining primary mineral. Secondary minerals include calcite, chlorite, sericite, leucoxene, epidote, sphene, and quartz. The metachert is green, gray, or white and crypto- to microcrystalline.

Triassic-Permian(?) metavolcanic rocks crop out along the Columbia River at Hawks Nest, south of Marcus, on the southern end of Kelly Hill, and on the west side of the Kettle River valley. The relation between these metavolcanic rocks and the Triassic-Permian metasedimentary

rocks (T₃Mm) along the Columbia River is uncertain because the metavolcanic rocks only occur in isolated outcrops or fault-bounded blocks and no fossils have been recovered from them.

Triassic-Permian metavolcanic and meta-intrusive(?) rocks also crop out in the vicinity of Granite Mountain and along Lone Ranch Creek in the Republic graben (Parker and Calkins, 1964; Pearson, 1977). Massive, vesicular, and amygdaloidal greenstone, composed of altered plagioclase and augite phenocrysts in a fine-grained groundmass of chlorite, epidote, plagioclase, and sphene, is the most abundant rock type. It locally contains thin interbeds of green phyllite, argillite, metawacke, and metaconglomerate, and massive pods and lenses of metalimestone. Subordinate dark-green, fine- to medium-grained rocks with subophitic to hypidiomorphic-granular textures may represent metamorphosed intrusions (Muessig, 1967).

Pillowed greenstone, fragmental meta-andesite, and massive hornblende metabasalt porphyry are also exposed on Buckhorn Mountain and along Cedar Creek, in the northwestern corner of the map area (McMillen, 1979). The metabasalt porphyry is composed of altered pyroxene phenocrysts in a light-green recrystallized groundmass of plagioclase, epidote, amphibole, and biotite (Pearson, 1967).

T₃Mmt

Metasedimentary and metavolcanic rocks, undivided--Roughly equal proportions of clastic rocks (argillite, metawacke, and metaconglomerate) and greenstone. Compositions of these rocks are very similar to those of the metasedimentary and metavolcanic rocks described above (T₃Mm and T₃Mmv), but the metasedimentary and metavolcanic rocks in the Republic graben are so intimately interbedded that they cannot be subdivided at the 1:100,000 map scale. This unit comprises most of the exposures of Triassic and Permian rocks in the Republic graben.

Paleozoic Metasedimentary and Metavolcanic Rocks

Pzmm_h

Metasedimentary rocks at Heidegger Hill (Paleozoic)(?)--Black and green siliceous argillite, intercalated with fine-grained quartzite (metachert)(?) and metalimestone, that crops out at Heidegger Hill (T. 34 N., R. 37 E.) (Cole, 1960; Mills, 1985a). These rocks were assigned to the Ledbetter Formation by Mills (1985a), but they are now thought to be part of a previously unrecognized unit that forms a discontinuous north-trending belt along the east side of the Columbia River from Heidegger Hill to Hunters Creek (in the Nespelem 1:100,000-scale quadrangle) (M. T. Smith, University of Arizona, written commun., 1989).

Faults separate the metasedimentary rocks at Heidegger Hill from the Covada Group on the west and the Ledbetter Slate on the east (Cole, 1960; Wilson, 1981a, 1981b). Because it is fault-bounded and because it has yielded no fossils, the age of this unit is essentially unknown. A Paleozoic(?) age is tentatively assigned.

Pzmm₃, Pzcb₃

Metasedimentary rocks near Swan Lake (Paleozoic(?))--Thinly bedded, dark greenish-gray phyllite and schist (Pzmm₃) composed of quartz, sericite, biotite, and chlorite. They contain a few thin beds of quartzite, metawacke, and metalimestone. This unit of phyllite, schist, and metalimestone forms the hills near Swan Lake in the southwestern part of the map area (T. 35 N., R. 32 E.) (Staatz, 1964; Muessig, 1967; Cheney and others, 1982; Orr and Cheney, 1987). The thinly laminated, dark-gray, fine- to medium-grained, siliceous metalimestone (Pzcb₃), which forms most of Sheep Mountain and the hill 1 km to the south, is composed chiefly of recrystallized calcite and quartz. Tremolite, diopside, andesine, sphene, clinozoisite, hematite, and graphite(?) are minor constituents.

The metasedimentary rocks near Swan Lake are tightly folded into a series of south-plunging structures. Foliation in the phyllite and schist is generally parallel to bedding. Most of the metalimestone is strongly contorted.

A thrust fault(?) apparently separates the greenschist-facies metasedimentary rocks near Swan Lake from amphibolite-facies metamorphic rocks to the north and west (Cheney and others, 1982; Orr and Cheney, 1987). A high-angle normal fault probably separates the metasedimentary rocks from Eocene volcanic rocks to the east (Staatz, 1964; Muessig, 1967). The metasedimentary rocks are cut by a plug of Eocene porphyritic dacite along Scatter Creek. Because they are bounded by faults, and because no fossils have been recovered from them, the age of the metasedimentary rocks near Swan Lake is essentially unknown. A Paleozoic age is tentatively assigned.

P₁mm, P₁cb

Permian metasedimentary rocks--Argillite, phyllite, quartzite, metawacke, chert-pebble metaconglomerate, and metalimestone. The unit crops out (1) at Buckhorn Mountain in the northwestern corner of the quadrangle (Pearson, 1967; McMillen, 1979); (2) between Pierre Creek and the Canadian border in the northeastern corner of the map area (Fox, 1981); (3) in a broad arcuate belt east of the Columbia River, between Kettle Falls and Bossburg (Mills, 1985a; DGER unpublished mapping); (4) along the southern Kettle River valley near Toulou Creek (Bowman, 1950; Rhodes, 1980; Wilson, 1980; R. C. Roback, University of Texas, written commun., 1989); (5) on Vulcan Mountain, 15 km northwest of Curlew (Parker and Calkins, 1964; Orr, 1985); (6) near Boundary Mountain, 15 km northeast of Curlew (Pearson, 1977; Orr, 1985); and (7) near the West Fork Sanpoil River in the southwestern corner of the map area (Rinehart and Greene, 1988). Small bodies of Permian metalimestone also crop out at Kelly Hill (Kuenzi, 1961, 1965; Mills, 1985a) and near Curlew (Parker and Calkins, 1964). The rocks in the northwestern corner of the map area are laterally continuous with the Anarchist Group in the Oroville 1:100,000-scale quadrangle and in southern British Columbia (Rinehart and Fox, 1972; Fox, 1978; McMillen, 1979). Those in the northeastern corner of the map area are laterally continuous with the Mount Roberts Formation in the Colville 1:100,000-scale quadrangle and in southern British Columbia (Yates, 1971; Fox, 1981). The remaining rocks have not been formally named.

P₂mm

Metasedimentary rocks--Dominantly dark-gray phyllite and argillite, composed of quartz, sericite, biotite, and/or chlorite. These lithologies are interbedded with fine-grained quartzite (metachert?), metawacke, chert-pebble metaconglomerate, metalimestone, and minor greenstone. The poorly sorted, fine- to coarse-grained metawacke is composed of angular to subangular grains of quartz, plagioclase, chert, argillite, and volcanic and plutonic rocks in a dark-colored matrix of sericite, chlorite, and microcrystalline quartz. The metaconglomerate consists of chert and volcanic rock

fragments in a poorly sorted sandy matrix similar in composition to the metawacke. The metasedimentary rocks at Buckhorn Mountain were upgraded to hornfels by contact metamorphism during intrusion of the Buckhorn Mountain pluton (Pearson, 1967; McMillen, 1979).

Mcb

Metacarbonate--Abundant pods, lenses, and irregular bodies of massive white metalimestone. These metasedimentary rocks crop out at Buckhorn Mountain, along the Columbia River between Kettle Falls and Bossburg, at Kelly Hill, and near Curlew. Massive to weakly layered, dolomitic metalimestone also forms several large bodies along the southern Kettle River valley between Little Marble Mountain and the Columbia River. Two types of metalimestone are present: (1) dark-gray, fine-grained, laminated limestone; and (2) gray, poorly sorted, bioclastic limestone composed of fine- to coarse-grained fossil debris, fine sand-size quartz grains, minor carbonate rock fragments, clay, and silt.

Stratigraphic relations between the Permian metasedimentary rocks and surrounding rock units are poorly known because faults generally mark the contacts. Some workers believe that the Permian(?) metasedimentary rocks near the West Fork Sanpoil River grade into amphibolite-facies quartz-mica schist, quartzite, marble, and amphibolite (Rinehart and Greene, 1988; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988), but others believe that the contacts between the greenschist- and amphibolite-facies rocks are abrupt and are marked by faults (Cheney, 1980; Cheney and others, 1982; Orr and Cheney, 1987). Near Pierre and Toulou Creeks in the northeastern part of the map area, the Permian metasedimentary rocks are unconformably overlain by the Jurassic Rossland Group (R. C. Roback, University of Texas, written commun., 1989). Eocene rocks unconformably overlie the Permian(?) metasedimentary rocks near the West Fork Sanpoil River. Jurassic(?), Cretaceous, and Eocene intrusions cut the Permian metasedimentary rocks at several localities.

The phyllite on Buckhorn Mountain contains sheared and fragmented fossils, identified by W. J. Sando of the U.S. Geological Survey as

"...solitary corals, identified as *Caninia* s.l. ... and colonial corals identified as *Heintzella*(?) sp. ... the material is clearly upper Paleozoic. Mississippian is an unlikely possibility. Middle or Upper Pennsylvanian or Lower Permian is more probable. The lack of diagnostic Permian forms give slightly more credence to a Pennsylvanian age." (McMillen, 1979, p. 6).

Both the argillite and metalimestone between Kettle Falls and Bossburg are highly fossiliferous (Mills and Davis, 1962; B. J. West, 1976; Mills, 1985a). Brachiopods, pelecypods, gastropods, scaphopods, crinoid stems, and plant fragments are abundant in the argillite. Fusilinids, tetracorals, bryozoans, ostracods, crinoids, and foraminifers occur in the metalimestone, which is thought to have been deposited in relatively shallow water (less than 70 m deep) (B. J. West, 1976). The majority of the fossils identified range from late Leonardian to early Guadalupian (Middle Permian), but several species of Late Pennsylvanian(?) *Pseudoendothyra* (fusilinids) also occur.

Metalimestone on the north side of Sackit Canyon (near Toulou Creek) contains abundant late Early Permian macrofossils (R. C. Roback, University of Texas, written commun., 1988) and conodonts (A. G. Harris, USGS, written commun., 1988). Permian (probably Middle Permian) fusilinids, fragmental crinoids, bryozoans, productid and spirifer brachiopods, and poorly preserved corals have been recovered from some of the limestone bodies at Kelly Hill (Kuenzi, 1961, 1965; Skinner and Wilde, 1966). Wolfcampian to Leonardian (Early Permian) fusilinids, bryozoans, brachiopods, and corals are found in the metalimestone near Curlew (Muessig, 1967).

Fossils have not been found in the Permian metasedimentary rocks elsewhere in the map area. The rocks in the northeastern corner of the map area were assigned a Permian age because they are laterally continuous with the Mount Roberts Formation in southern British Columbia, which has yielded Permian and Pennsylvanian(?) fossils. The metalimestone in the southern Kettle River valley was assigned a Permian age because of its proximity to and similarity with the fossiliferous metalimestone in Sackit Canyon (R. C. Roback, University of Texas, written commun., 1988). The metasedimentary rocks on Vulcan and Boundary Mountains were assigned a Permian age because they are apparently continuous with a rock package in southern British Columbia that has yielded Permian and Carboniferous(?) fossils (Church, 1986). The metasedimentary rocks along the West Fork Sanpoil River are thought to be correlative with the Permian Anarchist Group in the Oroville 1:100,000-scale quadrangle because they contain blue quartzite and chert-pebble metaconglomerate, which are distinctive lithologies in the Anarchist Group.

CDmm_k

Kelly Hill phyllite--Principally black argillite and phyllite (Bowman, 1950; Beka, 1980; Hyde, 1985; R. C. Roback, University of Texas, written commun., 1989). The argillite and phyllite are chiefly siliceous rocks, but calcareous and graphitic varieties also are present. They are thinly layered, with beds ranging from 1 mm to 5 cm thick. The argillite and phyllite are thinly foliated, finely crinkled, and intensely deformed. Two distinct foliations are commonly identifiable. The S₁ foliation is commonly so pronounced that the original bedding in the rocks is obscured.

Green phyllite is locally intercalated with the black argillite and phyllite. It is composed chiefly of quartz and chlorite, but plagioclase porphyroclasts are locally abundant. The green phyllite is spatially associated with thin beds of metaconglomerate that consists of pebbles and cobbles of porphyritic volcanic rocks in a sandy matrix composed chiefly of broken plagioclase crystals. The green phyllite and metaconglomerate are probably metavolcanic rocks.

Quartzite, metalimestone, and chert-pebble metaconglomerate also form thin interbeds and lens-like masses, as much as 10 m thick, in the argillite and phyllite. The light gray to cream, fine- to medium-grained quartzite is composed of quartz and feldspar. The gray, fine-grained, platy metalimestone contains thin phyllitic partings. The chert-pebble metaconglomerate is restricted to the upper(?) part of the unit, within 20 m of the contact with the Permian metasedimentary rocks.

These fine-grained metasedimentary rocks form a 6.5-km-wide, northeast-trending belt parallel to the Columbia River from Kelly Hill (T. 38 N., R. 37 E.) in the Republic 1:100,000-scale quadrangle to the Canadian border in the Colville 1:100,000-scale quadrangle. The rocks in the map area were informally named the Kelly Hill phyllite (Bowman, 1950). Those in the Colville 1:100,000-scale quadrangle were named the Flagstaff Mountain sequence (Yates, 1971, 1976).

The Kelly Hill phyllite is separated from the Jurassic Rossland Group and Triassic and Permian metasedimentary rocks on the north by a series of northeast-trending faults (Hyde, 1985; R. C. Roback, University of Texas, written commun., 1989). The contact between the Kelly Hill phyllite and the Cambrian metacarbonate to the southeast is also apparently marked by a fault (Yates, 1971, 1976; Hyde, 1985).

Beka (1980) subdivided the Kelly Hill phyllite/Flagstaff Mountain sequence into six conformable stratigraphic units, which he designated units Ds₁ through Ds₆. Only his uppermost two units, Ds₅ and Ds₆, crop out in the map area. Fossils have not been found in these two units, but late Famennian (Late Devonian) conodonts (*Palmatolepis marginifera duplicata*) have been recovered from argillaceous metalimestone in unit Ds₄ in the Colville 1:100,000-scale quadrangle. Beka (1980) thought that because units Ds₅ and Ds₆

conformably overlies unit Ds₄, they must be either Late Devonian or Early Carboniferous in age. Therefore, the Kelly Hill phyllite is tentatively assigned a Carboniferous(?)–Devonian age.

CDmm_{m'}, CDmv_m

Metasedimentary and metavolcanic rocks near Mission Lake (Carboniferous?)–Devonian--Argillite, metawacke, greenstone, and minor metalimestone. Principal constituents of the argillite and metawacke (CDmm_{m'}) are quartz and muscovite. The greenstone (CDmv_m) is massive to schistose and commonly strongly calcareous. Metalimestone forms thin interbeds in the argillite and metawacke and discontinuous pods and lenses in the greenstone. These rocks form the hills surrounding Mission Lake, northeast of Kettle Falls (Mills, 1985a, 1985b). They cover less than 7.5 km² in the map area, but extend northeast into the Colville 1:100,000-scale quadrangle (Laskowski, 1982; Mills, 1985b).

The metasedimentary and metavolcanic rocks near Mission Lake are in fault contact with Permian metasedimentary rocks to the west, and with the Ordovician Ledbetter Slate to the east. No fossils have been found in this unit in the map area, but early Late Devonian conodonts have been recovered from a 5-m-thick metalimestone bed in the Colville 1:100,000-scale quadrangle (Laskowski, 1982). Because the fossiliferous beds in the Colville 1:100,000-scale quadrangle are thought to be stratigraphically lower than the rocks in the map area, the metasedimentary and metavolcanic rocks near Mission Lake are probably Late Devonian or younger (Laskowski, 1982; Mills, 1985a). A Carboniferous(?)–Devonian age is tentatively assigned.

Omm_c, Ocb_c, Omv_c

Covada Group (Ordovician)--The Covada Group, a heterogeneous assemblage of phyllite, argillite, quartzite, metawacke, metalimestone, and minor greenstone and metabasalt, crops out along both sides of the Columbia River (Roosevelt Lake) in the southeast corner of the map area (Wilson, 1981a, 1981b). It extends south into the Nespelem 1:100,000-scale quadrangle, where it forms a broad south-trending belt (J. R. Snook, Eastern Washington University, written commun., 1987; M. T. Smith, University of Arizona, written commun., 1989).

The contact between the Covada Group and amphibolite-facies metamorphic rocks in the Kettle metamorphic core complex to the west is probably a low-angle normal fault (Cheney, 1980; Wilson, 1981a, 1981b; Cheney and others, 1982; Orr and Cheney, 1987; Rhodes and Hyndman, 1988). A fault also separates the Covada Group from the Paleozoic(?) metasedimentary rocks at Heidegger Hill (unit Pzmm_n) (Wilson, 1981a, 1981b).

No fossils have been found in the Covada Group in the map area, but Early to early Late Ordovician macrofossils and conodonts have been recovered from the rocks in the Nespelem 1:100,000-scale quadrangle to the south (Snook and others, 1981).

Omm_c

Metasedimentary rocks--Dominantly dark-gray to black, thinly foliated phyllite and argillite. The rocks contain thin interbeds of quartzite, metawacke, metaconglomerate, metalimestone, calc-silicate rocks, and greenstone. Layering in the argillite and phyllite is commonly distorted by minor isoclinal and disharmonic folds. Near the contact between the Covada Group and the amphibolite-facies rocks in the Kettle metamorphic core complex, the Covada Group consists of massive, fine- to medium-grained, poorly sorted quartzite that is composed chiefly of subrounded quartz grains.

Ocb_c

Metacarbonate--Massive to well-layered, gray, fine-grained metacarbonate forming irregularly shaped bodies in the Covada Group. The metacarbonate is chiefly recrystallized calcite, but dolomite is locally abundant. It contains thin interlayers of calc-silicate rocks.

Omv_c

Metavolcanic rocks--Black, fine-grained porphyry composed of 2- to 10-mm-long crystals of altered plagioclase and pyroxene. This greenstone and metabasalt porphyry unit forms a narrow, 2-km-long belt along the east side of the Columbia River southwest of Kettle Falls (Cole, 1960; Wilson, 1981a, 1981b).

Omm_l

Ledbetter Slate--Interbedded black argillite and phyllite, with subordinate fine-grained quartzite and impure metalimestone layers. The Ledbetter Slate crops out along the east side of the Columbia River (Roosevelt Lake) in the southeastern corner of the map area, where it forms the core of a tectonically disrupted, refolded syncline (Cole, 1960; Mills, 1985a).

The Ledbetter Slate conformably overlies the Metaline Formation (Mills, 1985a). It is apparently separated from the Addy Quartzite and Monk Formation to the east by a thrust fault (Mills, 1985a). Faults also separate the Ledbetter Slate from the Covada Group (Wilson, 1981a, 1981b) and from the Paleozoic(?) metasedimentary rocks at Heidegger Hill (unit Pzmm_h) (Cole, 1960).

Age-diagnostic fossils have not been found in the Ledbetter Slate in the map area, but Llanvirnian to Caradocian (late Early to Late Ordovician) graptolites have been recovered from the formation at several localities outside of the map area (Park and Cannon, 1943; Mills, 1977; Snook and others, 1981).

OCcb_m

Metaline Formation (Ordovician-Cambrian)--The Metaline Formation crops out in the hills southwest of Kettle Falls (T. 35 N., R. 37 E.) (Mills, 1985a) and between Glasgo Lakes and Fifteenmile Creek (T. 38 N., R. 37 and 38 E.) (Bowman, 1950; Kuenzi, 1961; Hyde, 1985). Southwest of Kettle Falls, the formation is chiefly gray to black, thin-bedded metalimestone with thin interbeds of gray dolomite and discontinuous pods of zebra dolomite. Near Glasgo Lakes, the Metaline Formation consists of light-gray to white, massive to banded, recrystallized limestone and dolomite, with thin interbeds of quartz-tremolite marble, fine-grained platy quartzite, and andalusite schist.

Trilobites, brachiopods, conodonts, and a fossil fish recovered from the Metaline Formation at several localities in northeastern Washington indicate the age of the formation ranges from Middle Cambrian to Middle Ordovician (Park and Cannon, 1943; Miller and Clark, 1975; Repetski, 1978, 1989; Schuster and others, 1989). Because fossils have not been found in the metacarbonate at either locality in the map area, correlation of these rocks with the Metaline Formation is tentative. Mills (1985a) assigned the rocks southwest of Kettle Falls to the Metaline Formation because they conformably overlie the Maitlen Phyllite and are conformably overlain by the

Ledbetter Slate. Bowman (1950) named the rocks near Glasgo Lake the "Glasgo Marble", but recognized that "The belt of marble appears to be continuous from Glasgo Lakes to Northport... If the marble is continuous, the Glasgo marble is equivalent to the Metaline limestone and is actually part of it. In such an event, the name Metaline should be applied to the marble near Glasgo Lakes" (Bowman, 1950, p. 29).

Cph_m, Ccb_m

Maitlen Phyllite (Cambrian)--Dominantly gray and green phyllite (Cph_m) with thin interbeds of gray metalimestone, yellow-white metadolomite, and gray quartzite. Metacarbonate bodies (Ccb_m) large enough to show at the 1:100,000 map scale are present in only a few places (Mills, 1985a). The Maitlen Phyllite covers approximately 12 km² in the southeastern corner of the map area.

In the map area, the Maitlen Phyllite conformably overlies the Addy Quartzite in places, but the contacts between the two formations are commonly marked by faults (Mills, 1985a). The Metaline Formation conformably overlies the Maitlen Phyllite. A small intrusion of Cretaceous granite cuts the Maitlen Phyllite in sec. 28, T. 35 N., R. 37 E. It has metamorphosed the phyllite to quartz-mica schist and andalusite schist.

No fossils have been recovered from the Maitlen Phyllite in the map area, but Early Cambrian Archaeocyatha (paleosponges) have been collected from the formation elsewhere in northeastern Washington (Dings and Whitebread, 1965; Hampton, 1978).

CZq_a

Addy Quartzite (Cambrian-Proterozoic Z)(?)--Mills (1985a, p. 2) subdivided the formation into three informal members,

"a lower quartzite-rich member of gray to purplish color, an upper quartzite member of white to pink to light-brown color, and an intervening middle member consisting mostly of phyllite of light-brown to olive color, and up to 20 percent interbedded quartzite".

The Addy Quartzite crops out at Mingo Mountain (T. 35 N., R. 38 E.) in the southeastern corner of the map area, where it

"is folded into symmetrical, upright folds plunging approximately 42 degrees southerly. The folds are thought to be first-stage folds because the foliation, in the few places it can be seen, parallels the axial surface of the major folds...south of the major fault zone bounding the Colville Valley, the formation forms tightly appressed south-southwest plunging anticlines and synclines slightly overturned to the east-southeast" (Mills, 1985a, p. 2).

The Addy Quartzite disconformably overlies the Proterozoic Z Monk Formation and is conformably overlain by the Maitlen Phyllite. In the map area, contacts between the Addy Quartzite and other rock units are commonly marked by faults.

Early Cambrian brachiopods, molluscs, and trilobites are reported from the Addy Quartzite in the Chewelah 1:100,000-scale quadrangle to the southeast (Okulitch, 1951; Lindsey, 1987, 1988). Fossils are restricted to metasiltite and argillite beds in the upper part of the formation. Similar rocks in the lower part of the formation are barren of fossils. Lindsey (1987, p. 70) believes that the sudden appearance of fossils in the upper part of the Addy Quartzite represents "a true 'evolutionary' first appearance, and not a facies controlled first appearance", and that the Precambrian-Cambrian boundary is in the lower part of the formation. Therefore, the Addy Quartzite is herein assigned a Cambrian-Proterozoic Z age.

Proterozoic Metasedimentary and Metavolcanic Rocks

Zmt_m, Zcb_m

Windermere Group, Monk Formation (Proterozoic Z)--Dolomite, quartzite, greenstone, metalimestone, and argillite. These rocks are subdivided into two informal map units (Mills, 1985a). The lower member (Zcb_m) is composed of light-gray to light-brown metadolomite with minor interlayers of quartzite, greenstone, metalimestone, and argillite. The rocks are cut by stringers and blebs of white quartz. The upper member (Zmt_m) consists of varied amounts of fine-grained quartzite, greenstone, metalimestone, and phyllitic argillite.

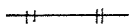
The unit disconformably underlies the Addy Quartzite on Mingo Mountain in the southeast corner of the map area. The Monk Formation and Addy Quartzite on Mingo Mountain are folded into a series of doubly plunging anticlines and synclines that are structurally discordant with surrounding rock units to the west, north, and east. Mills (1985a) interprets this structural discontinuity as a thrust fault. Assignment of these rocks to the Monk Formation

"is tentative, for it is not certain how these rocks are to be correlated with others in northern Washington, Idaho, and British Columbia. The presence of greenstone this low in the regional stratigraphic section is reminiscent of the Precambrian Huckleberry Greenstone or Leola Volcanics. However, unlike the Huckleberry/Leola, the greenstone in the Kettle Falls quadrangle is not underlain by conglomerate but by rocks very much like those described by Daly (1912), Walker (1934), Park and Cannon (1943), and Miller and Clark (1975), and mapped as the Monk Formation. Although greenstone is not typically part of the Monk Formation in Washington and Idaho, the various rock units beneath the Cambrian quartzite in the Kettle Falls map area are considered to be Precambrian and to belong to the Monk Formation" (Mills, 1985a, p. 2).

Intrusive Igneous Rocks

Tertiary Intrusive Igneous Rocks

Tertiary Hypabyssal Intrusive Rocks




Pyroxene dacite and andesite dikes and sills (Eocene)--Brownish gray, aphanitic to sparsely phyrlic, and locally amygdaloidal; composed of plagioclase (andesine) and minor altered pyroxene phenocrysts in an aphanitic groundmass of plagioclase (andesine), chlorite, calcite, and disseminated magnetite. Geochemical data from the dike near Aeneas indicate it is dacitic in composition (Tables 2 and 3). These north-northeast-trending dikes and sills crop out near Aeneas (T. 35 N., R. 31 E.) (DGER unpublished mapping) and on the southern flank of Granite Mountain (Parker and Calkins, 1964). The dikes near Aeneas intrude Permian metasedimentary rocks and Klondike Mountain Formation vitrophyric flow breccia. The dikes on Granite Mountain intrude Triassic-Permian greenstone and

"clearly cut some of the flows at the base of the upper part of the Klondike Mountain Formation and may represent feeders to some calcic andesite flows in the upper part of the formation or to flows that have been removed by erosion" (Parker and Calkins, 1964).

Olive-brown, microcrystalline andesite(?) dikes also crop out northwest of Republic, between Mud Lake and the Bacon Creek fault zone (Muessig, 1967). These rocks are composed of plagioclase (andesine) microlites and interstitial augite, biotite, and magnetite (Muessig, 1967). They contain abundant stretched vesicles and

amygdules filled with quartz, chalcedony, and calcite. The andesite(?) dikes cut some epithermal veins in the Republic mining district and have a close spatial association with other epithermal veins. The dikes also cut Klondike Mountain Formation sedimentary rocks (E_{c_k}) and volcanic conglomerate (E_{vc_k}). The relation between the dikes and the Klondike Mountain Formation vitrophyric and microcrystalline flows (E_{vd_k}) is unclear.

E_{vd} , 

Vitrophyric dacite and andesite plugs and dikes (Eocene)--Plugs and dikes of black vitrophyric and microcrystalline dacite and andesite that cut Klondike Mountain Formation sedimentary rocks (E_{c_k}) between Bodie and Toroda in the northern part of the Toroda Creek graben. These rocks are compositionally and texturally very similar to the vitrophyric flows and flow breccias in the Klondike Mountain Formation (E_{vd_k}) and are probably their hypabyssal intrusive equivalents (Fig. 6; Tables 2 and 3).

E_{ian} ,

Andesite and basalt sills(?) near Republic (Eocene)--Dark-brown to greenish-black andesite, basaltic andesite, and basalt that forms sills(?) in Klondike Mountain Formation sedimentary rocks in the town of Republic, in the hills northeast of town, and near the Knob Hill mine northwest of town (secs. 26 and 27, T. 37 N., R. 32 E.) (Muessig, 1967; Oliver, 1986). The rocks in downtown Republic are porphyritic, with plagioclase (labradorite) and augite phenocrysts in a microcrystalline groundmass. Rocks north and east of Republic are sparsely phyrific, with plagioclase and augite phenocrysts in a devitrified glassy groundmass (Oliver, 1986). Muessig (1967) believed that these intrusive rocks are hypabyssal intrusive equivalents of the Klondike Mountain Formation vitrophyric and microcrystalline dacite and andesite flows, but whole rock geochemical data indicate that the sills(?) contain less SiO_2 than the andesite and dacite flows (Fig. 6; Tables 2 and 3). Sills(?) in the Klondike Mountain Formation sedimentary rocks near the Knob Hill mine (not shown on Plate 1) are basaltic in composition (Fig. 6; Tables 2 and 3) and may not be correlative with the andesite sills(?) in Republic.



Rhyolite dikes (Eocene)--Rhyolite dikes on the southwest flank of Granite Mountain (sec. 6, T. 38 N., R. 33 E.), in the Toroda Creek graben near the Canadian border (sec. 2, T. 40 N., R. 32 E.), near the Bacon Creek fault west of Republic (secs. 4, 8, and 9, T. 36 N., R. 32 E.), on the south flank of First Thought Mountain (DGER unpublished mapping), and along the Sherman fault (sec. 19, T. 37 N., R. 34 E.) (Parker and Calkins, 1964; Muessig, 1967; Oliver, 1986). For cartographic reasons, the dikes along the Sherman fault are not shown on the geologic map.

On Granite Mountain, the porphyritic rhyolite dikes are composed of quartz, oligoclase, orthoclase, and biotite phenocrysts in a gray microcrystalline groundmass of orthoclase, sodic plagioclase, and quartz(?) (Parker and Calkins, 1964). The rhyolite dikes near the Canadian border are similar in composition, but they are spherulitic and contain fewer quartz phenocrysts (Parker and Calkins, 1964). The dikes near the Bacon Creek fault and along the Sherman fault are light gray, fine grained, and weakly porphyritic. They are composed of small phenocrysts of plagioclase (andesine), biotite, and quartz in a fine-grained equigranular groundmass of plagioclase, biotite, hornblende, and intergrown quartz and orthoclase (Muessig, 1967; Oliver, 1986).

The rhyolite dikes on Granite Mountain cut Triassic-Permian greenstone. Those near the Canadian border intrude Sanpoil Volcanics. The dikes west of Republic cut porphyritic dacite dikes and Keller Butte suite granodiorite. Those along the Sherman fault intrude sheared porphyritic dacite, Sanpoil Volcanics, and Herron Creek suite intrusions. The rhyolite along the Sherman fault is sheared, indicating fault movement continued after emplacement of the dike (Muessig, 1967).

Eitr, Eida, Eian

Porphyritic trachyte, dacite, and andesite plugs and dikes (Eocene)--Abundant plugs and dikes of porphyritic trachyte, dacite, and andesite in the Republic graben (Parker and Calkins, 1964; Muessig, 1967; Pearson, 1977; C. M. Knaack, Washington State University, written commun., 1987) and in part of the northern segment of the Toroda Creek graben (Pearson, 1967). Smaller intrusions and dikes are found near Kettle Falls (Bradshaw, 1964; Mills, 1985a), on Kelly Hill (Kuenzi, 1961; Mills, 1985a), and in the northeastern corner of the quadrangle (Fox, 1981; Hyde, 1985; DGER unpublished mapping). Whole-rock, major-element geochemical data indicate that these intrusions are dacitic, andesitic, trachyandesitic, and trachytic in composition. The intrusions are compositionally similar to flows in the Sanpoil Volcanics, suggesting that they are hypabyssal intrusive equivalents of the flows.

Eitr,

Porphyritic trachyte--Pink orthoclase and chalky white plagioclase (oligoclase-andesine) phenocrysts as much as 10 mm long and biotite phenocrysts less than 2 mm long, in an aphanitic holocrystalline groundmass of orthoclase and quartz. Mafic clots of hornblende and augite occur locally. Feldspars are commonly sericitized, and mafic minerals are generally altered to chlorite, calcite, and sphene.

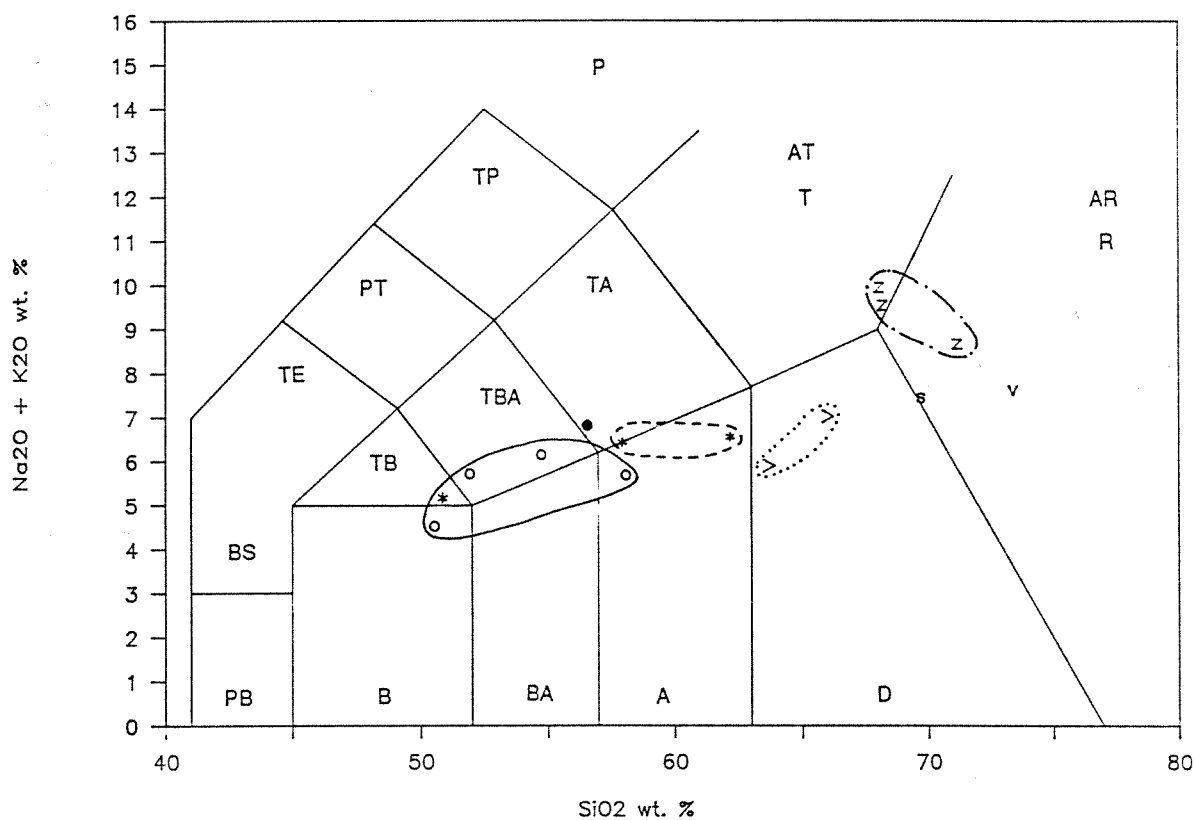
These intrusions crop out in the Toroda Creek graben (Pearson, 1967), in the northern part of the Republic graben (Parker and Calkins, 1964; Muessig, 1967; Pearson, 1977; C. M. Knaack, Washington State University, written commun., 1987), and at First Thought Mountain near Orient (J. R. West, 1976).

The porphyritic trachyte plugs and dikes cut the Sanpoil Volcanics, Herron Creek suite intrusions, and Eocene porphyritic dacite plugs.

Eida,

Porphyritic dacite--Gray, greenish gray, or pinkish gray and weakly to strongly porphyritic. Euhedral 1- to 5-mm-long phenocrysts are chiefly plagioclase, biotite, and hornblende; augite and quartz are less common. Irregular mafic clots as much as 10 mm in diameter occur locally. The aphanitic to fine-grained crystalline groundmass is composed of K-feldspar, quartz, plagioclase, and minor mafic minerals. Mafic phenocrysts and mafic minerals in the groundmass are commonly altered to chlorite, calcite, sphene, and epidote.

Porphyritic dacite plugs and dikes cover many tens of square kilometers in the map area. The porphyritic rhyodacite intrusions in the Republic 15-minute quadrangle were named "Scatter Creek Rhyodacite" by Muessig (1962, 1967). That name was also assigned to porphyritic dacite plugs in the Curlew 15-minute quadrangle to the north (Parker and Calkins, 1964). Dacitic intrusions elsewhere in the map area have not been assigned a formal name.



MAP SYMBOL

> Eivd
 * Eian,
 o Eib_k
 o Eibt
 s Eida
 v rhyolite
 z trachyte dikes

TAS DIAGRAM FIELDS

PB	picrobasalt	TA	trachyandesite
B	basalt	TBA	trachybasaltic andesite
BA	basaltic andesite	TB	trachybasalt
A	andesite	BS	basinite
D	dacite	TE	tephrite
R	rhyolite	PT	phonotephrite
AR	alkali rhyolite	TP	tephriphonolite
T	trachyte	P	phonolite
AT	alkali trachyte		

Figure 6. Total alkali-silica (TAS) diagram for Eocene hypabyssal intrusive rocks, Republic 1:100,000-scale quadrangle.

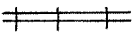
The porphyritic dacite intrusions cut pre-Tertiary rocks, the O'Brien Creek Formation, and the Sanpoil Volcanics. The contacts between the intrusions and the Sanpoil Volcanics are gradational in many places. In the northern part of the Republic graben, the dacite porphyry intrusions are unconformably overlain by the Klondike Mountain Formation and are intruded by Herron Creek suite intrusions and porphyritic trachyte plugs and dikes (Parker and Calkins, 1964; C. M. Knaack, Washington State University, written commun., 1987).

Porphyritic dacite intrusions southwest of Republic have yielded K-Ar hornblende and biotite ages of 53.9 ± 2.9 Ma and 50.6 ± 2.0 Ma, respectively, a fission-track apatite age of 56.9 ± 10.9 Ma, and a fission-track zircon age of 39.7 ± 1.0 Ma (Oliver, 1986). Concordant K-Ar biotite and hornblende ages of 53.4 ± 2.0 Ma and 52.6 ± 2.1 Ma, respectively, are reported from porphyritic dacite plugs southwest of Danville (T. 40 N., R. 34 E.) (Pearson and Obradovich, 1977). Concordant K-Ar hornblende and biotite ages of 47.7 ± 2.7 Ma and 44.6 ± 2.0 Ma, respectively, are reported from a porphyritic dacite plug on the east side of Klondike Mountain (Oliver, 1986). The radiometric ages show these intrusions are roughly coeval with those reported from the Sanpoil Volcanics.

Eian

Porphyritic andesite--Pinkish to greenish-gray and fine-grained. Principal constituents are similar to those in the porphyritic dacite, but this andesite contains less quartz and more plagioclase than the dacite.

Porphyritic andesite plugs crop out in the northern Toroda Creek graben (Pearson, 1967) and along Granite Creek west of Republic (Full and Grantham, 1968; Muessig, 1967; Oliver, 1986). The porphyritic andesite intrusions in the northern part of the Toroda Creek graben cut the O'Brien Creek Formation. The intrusions west of Republic cut the O'Brien Creek Formation and apparently intrude and grade into flows of the Sanpoil Volcanics (Oliver, 1986), suggesting they are hypabyssal intrusive equivalents of the volcanic rocks.

Ei, 

Plagioclase porphyry near Lone Ranch Creek (Eocene(?))--Prismatic to augen-shaped plagioclase phenocrysts, 5 to 10 mm long, in a gray, very fine grained, recrystallized groundmass of quartz, feldspar, biotite, hornblende, and clinopyroxene. These rocks near Vulcan Mountain are strongly deformed and altered. Secondary minerals include epidote, calcite, sphene, and sericite.

These plugs, dikes, and sills crop out southwest of Lone Ranch Creek (sec. 26, T. 40 N., R. 34 E.) and 3 km west of Vulcan Mountain (sec. 6, T. 40 N., R. 33 E.) (Pearson, 1977; Orr, 1985), where they cut Permian metasedimentary rocks. Composition and texture of the porphyry are similar to some of the Eocene hypabyssal intrusions in the map area, but the deformed and recrystallized nature of some of the porphyry suggests it could be older.

Tertiary Plutonic Rocks

Tertiary plutonic rocks are widespread and voluminous in northeastern Washington. The Tertiary plutonic rocks in the western half of the map area and in the Oroville, Omak, and Nespelem 1:100,000-scale quadrangles have been subdivided into three intrusive suites, from oldest to youngest, the Keller Butte, Devils

Elbow, and Herron Creek suites (Holder and Holder, 1988; Holder and others, 1989). The Tertiary plutonic rocks in the eastern half of the map area are compositionally similar to, and are probably correlative with the rocks in the western half, but because they have not been studied in detail, these plutonic rocks have not been assigned to the intrusive suites of Holder and Holder (1988).

Structural and cross-cutting relations among the Tertiary plutonic rocks, the Eocene volcanic and sedimentary rocks in the Republic and Toroda Creek grabens, and the amphibolite-facies metamorphic rocks in the Kettle, Tenas Mary Creek, and Okanogan metamorphic core complexes indicate that the Keller Butte and Devils Elbow suites were emplaced during formation of the grabens and metamorphic core complexes (Holder and Holder, 1988; Holder and others, 1989). Herron Creek suite intrusions are post-tectonic with respect to ductile deformation in the metamorphic core complexes, but the intrusions are brecciated and complexly sheared along graben-bounding faults.

K-Ar biotite and hornblende ages ranging from 53 to 45 Ma are reported from the Devils Elbow and Herron Creek suites, suggesting that they were "comagmatic with the Sanpoil Volcanics and rhyolite domes that intrude the Sanpoil" (Holder and Holder, 1988). K-Ar biotite ages between 61 and 49 Ma are reported from the Keller Butte suite plutons. It is unclear whether these Keller Butte suite ages are crystallization ages of the plutons or "reset" ages that represent a middle Eocene regional thermal event.

Eig_h , $Eiqm_h$, Eim_h , $Eigd_h$

Herron Creek suite (Eocene)--Medium- to coarse-grained, inequigranular to subporphyritic, hornblende-biotite quartz monzonite and monzonite ($Eiqm_h$, Eim_h), fine-grained, equigranular biotite granite (Eig_h), and minor fine-grained porphyritic granodiorite ($Eigd_h$) (Holder and Holder, 1988). Herron Creek suite intrusions in the map area include: (1) the Fire Mountain pluton, a 1- to 5-km-wide, north-northeast-trending intrusion along the east side of the Republic graben; (2) the Herron Creek intrusion, a 12-km² pluton east of Curlew Lake; (3) the Long Alec Creek pluton, a large intrusion between Curlew and North Fork Boulder Creek (T. 39 N., R. 35 E.); (4) the Empire Lakes pluton, a composite intrusion near Empire Lake (sec. 13, T. 38 N., R. 32 E.); and (5) monzonite east of Storm King Mountain, an 8-km² body along the west side of the Republic graben (T. 37 N., R. 32 E.) (Parker and Calkins, 1964; Muessig, 1967; Pearson, 1967, 1977; Cheney and others, 1982; Holder, 1985, 1990; Orr and Cheney, 1987).

Eig_h →→→→

Granite--Generally fine-grained (0.5 - 1.0 mm) and equigranular, but locally porphyritic, with rare equant plagioclase phenocrysts as much as 10 mm across. Principal constituents are orthoclase, plagioclase (oligoclase), quartz, biotite, and hornblende. Apatite and sphene are common accessory minerals. Mafic minerals are generally altered to chlorite, calcite, and iron oxides. Plagioclase is locally altered to sericite and calcite.

Herron Creek suite granite cuts Herron Creek suite quartz monzonite and monzonite. Contacts are generally gradational over several tens of meters. Granite in the Long Alec Creek pluton has yielded a K-Ar biotite age of 52.5 ± 2.0 Ma (Table 1). Herron Creek suite granite may be the intrusive equivalent of a series of small rhyolite domes in the Republic graben in the Nespelem 1:100,000-scale quadrangle to the south (Moye, 1984).

Eiqm_h

Quartz monzonite--Medium to coarse grained and inequigranular to subporphyritic. It consists of subhedral to anhedral phenocrysts of pink orthoclase (as much as 25 mm long) and white plagioclase (as much as 5 mm long) in a medium- to coarse-grained groundmass of orthoclase, plagioclase, quartz, biotite, and hornblende. Sphene, apatite, zircon, magnetite, and allanite are common accessory minerals. Mafic minerals are commonly concentrated in clots. Some hornblende grains enclose clinopyroxene cores (Holder, 1985). Most orthoclase phenocrysts are poikilitic (with small crystals of plagioclase and biotite); some are cored by plagioclase (Parker and Calkins, 1964). Hornblende is generally altered to chlorite, calcite, and magnetite. Biotite is commonly altered to chlorite and iron oxides.

Quartz monzonite in the Long Alec Creek pluton has yielded K-Ar biotite ages of 52.8 ± 2.0 Ma and 51.7 ± 1.6 Ma (Table 1). A K-Ar biotite age of 51.1 ± 1.6 Ma is reported from the Fire Mountain pluton.

Eim_h

Monzonite--Pinkish-gray, medium- to coarse-grained (1 to 5 mm), subporphyritic hornblende-biotite monzonite forming much of the Empire Lakes pluton and the intrusion southeast of Storm King Mountain (Holder, 1990). It is composed of gray subhedral orthoclase phenocrysts in a groundmass of plagioclase, orthoclase, biotite, hornblende, and minor sphene. The color index is approximately 20 to 25. Hornblende grains and mafic clots are commonly cored with green clinopyroxene. The monzonite body southeast of Storm King Mountain is highly varied in texture and composition. It is chiefly monzonite, but quartz monzonite, quartz monzodiorite, granodiorite, and granite are also present (Rinehart and Greene, 1988).

The northern and western parts of the monzonite body in the Empire Lakes pluton contains a discontinuous border phase of medium- to coarse-grained monzodiorite that grades into the Henry Creek monzodiorite of the Devils Elbow suite. Along the west side of Lake Butte (secs. 2 and 11, T. 38 N., R. 32 E.) the Empire Lakes pluton contains a narrow, north-trending belt composed of intimately mixed blocks of monzonite and monzodiorite.

A K-Ar biotite age of 49.9 ± 1.9 Ma is reported from monzonite in the Empire Lakes pluton (Table 1).

Eigd_h

Granodiorite--Porphyritic granodiorite composed of plagioclase, hornblende, and biotite phenocrysts in a fine-grained groundmass of granular feldspar, quartz(?), and minor hornblende and biotite (Holder, 1990). Herron Creek suite granodiorite is limited to a small body in the Empire Lakes pluton, on and southeast of Hardscrabble Mountain (T. 38 N., R. 32 E.).

This granodiorite cuts the Mount Bonaparte pluton (Keller Butte suite) and amphibolite-facies metamorphic rocks. Concordant K-Ar biotite and hornblende ages of 50.9 ± 2.0 Ma and 50.8 ± 2.8 Ma, respectively, are reported from the granodiorite (Table 1).

Eimd_k, Eimd_h

Devils Elbow suite (Eocene)--Medium-grained, equigranular, biotite- and hornblende-bearing plutons that are chiefly quartz monzodiorite in composition, but range from granodiorite to monzogabbro (Holder and Holder, 1988; Holder and others, 1989). Devils Elbow suite intrusions in the map area include the Kettle Crest pluton (Eimd_k), a north-trending pluton east of the Republic graben (Cheney and others, 1982; Holder, 1985; Orr and Cheney, 1987; J. R. Wilson, formerly USGS, written commun., 1987), and the Henry Creek monzodiorite (Eimd_h), a 10-km² pluton northwest of Curlew Lake (Holder, 1990). The rocks are composed of plagioclase (andesine), biotite, hornblende, altered clinopyroxene, interstitial quartz, and minor orthoclase(?). Sphene is a common accessory mineral. Clinopyroxene generally occurs as cores in hornblende grains or as mafic clots. Mafic minerals typically compose 15 to 25 percent of the rocks, but the plutons locally contain thin, discontinuous mafic borders consisting of as much as 50 percent mafic minerals.

Near Washington State Route 20, the contact between the Kettle Crest pluton and the Fire Mountain pluton (Herron Creek suite) is abrupt and chloritic, and it is probably marked by a fault (E. S. Cheney, University of Washington, written commun., 1990). Elsewhere, the contacts between the two units are gradational (Holder, 1985). The Henry Creek monzodiorite is intruded by and grades into the Empire Lakes pluton (Herron Creek suite) (Holder, 1990). Both Devils Elbow suite plutons cut Keller Butte suite intrusions and pre-Tertiary rocks. Contacts are generally sharply discordant, and the Devils Elbow suite intrusions commonly contain abundant blocks and xenoliths of the older rocks (Holder, 1985).

The Kettle Crest pluton is generally discordant with the mylonitically deformed rocks of the Kettle metamorphic core complex. However, along its southern and southeastern margin, the pluton is deformed along with its gneissic envelope (Holder and Holder, 1988; Holder and others, 1989). Foliation, lineation, and mylonitic fabrics in the pluton are parallel to those in the gneisses, which indicates that the Kettle Crest pluton was emplaced during the waning stages of ductile deformation in the Kettle metamorphic core complex. The Kettle Crest pluton is elongate parallel to the Republic graben. It may have been intruded along an ancestral fault along the eastern margin of the Republic graben (Holder and Holder, 1988; Holder and others, 1989). The pluton is sheared along the present graben-bounding faults, indicating that fault movement continued after emplacement of the pluton.

Devils Elbow suite plutons grade texturally into porphyritic dacite hypabyssal intrusions, which in turn grade into the Sanpoil Volcanics (Holder and Holder, 1988; Holder and others, 1989). Devils Elbow Suite plutons have yielded concordant K-Ar hornblende and biotite ages of 53.7 ± 2.7 Ma and 52.2 ± 1.7 Ma, respectively, and a K-Ar biotite age of 50.7 ± 1.9 Ma, which are similar to ages reported from the Sanpoil Volcanics.

EP_Aia_m, EP_Aia_b

Keller Butte suite (Eocene-Paleocene)(?)--Leucocratic (color index < 5), medium- to coarse-grained, equigranular to porphyritic biotite granodiorite and granite. Principal constituents are plagioclase (andesine), quartz, orthoclase, biotite, and opaque minerals. Accessory minerals include apatite, zircon, allanite, and muscovite (both primary and secondary). The porphyritic rocks are composed of subhedral orthoclase phenocrysts and subequant quartz aggregates, 1 to 3 cm long, in a medium- to coarse-grained groundmass (Rinehart and Greene, 1988). Dikes, veins, and discontinuous pods of garnetiferous pegmatite, aplite, and alaskite are abundant in Keller Butte suite plutons.

Keller Butte suite plutons in the map area include the Mount Bonaparte and Moses plutons (Cheney and others, 1982; Orr and Cheney, 1987; Holder and Holder, 1988; Holder and others, 1989). The Mount Bonaparte pluton (EP_Aia_b) is a V-shaped intrusion near Republic that extends west into the Oroville

1:100,000-scale quadrangle (Muessig, 1967; Fox, 1970, 1978; Cheney and others, 1982; Orr and Cheney, 1987; Rinehart and Greene, 1988; Holder, 1990). The Moses pluton (EP ia_m) is a circular intrusion that straddles the West Fork Sanpoil River in the southwestern corner of the map area and extends south and west into the Oroville, Omak, and Nespelem 1:100,000-scale quadrangles (Cheney, 1980; Cheney and others, 1982; Atwater and Rinehart, 1984; Singer, 1984; Gulick, 1987; Orr and Cheney, 1987; Holder and Holder, 1988; Holder and others, 1989; Rinehart and Greene, 1988; Holder and others, 1989; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988).

Xenomorphic-granular textures and rounding of orthoclase megacrysts indicate that the Keller Butte suite plutons in the map area have been cataclastically deformed (Cheney and others, 1982; Orr and Cheney, 1987; Rinehart and Greene, 1988). The cataclastic foliation and lineation in the plutons, which are weakly to moderately developed, are parallel to the structural fabric in the amphibolite-facies metamorphic rocks of the Okanogan metamorphic core complex to the southwest, indicating that the Keller Butte suite intrusions were "emplaced during regional mylonitic deformation associated with the gneiss domes" (Holder and Holder, 1988).

In the Omak and Oroville 1:100,000-scale quadrangles, contact relations between the Moses pluton and the Swimptkin Creek pluton (Devils Elbow suite) are ambiguous (Singer, 1984; Gulick, 1987). In places, the Moses pluton appears to cut the Swimptkin Creek pluton, but in other places the reverse is true. Locally, the contact between the two plutons is marked by a swirled zone. These relations suggest that intrusion of the two plutons was roughly contemporaneous. A K-Ar biotite age of 49.4 ± 1.2 Ma is reported from the Moses pluton in the Omak 1:100,000-scale quadrangle (Atwater and Rinehart, 1984). This age is similar to ages reported from the Swimptkin Creek pluton. K-Ar biotite ages reported from Keller Butte suite intrusions elsewhere in northeastern Washington range from 49 to 61 Ma (Holder and Holder, 1988; Holder and others, 1989). Because it is possible that the biotite ages were reset during the emplacement of the Devils Elbow and Herron Creek suites, they represent minimum ages for the Keller Butte suite. However, because

"field relations establish that a close temporal relationship exists between KBS [Keller Butte suite] intrusions and proximal gneiss dome and graben structures which are known to have been active well into Eocene time, we agree with Carlson and Moye (1987) that a pre-Paleocene age for the KBS is unlikely" (Holder and Holder, 1988).

Eig_u

Granite near U S Creek (Eocene)(?)--Directionless, fine-grained biotite granite that forms several small intrusions near U S Creek (T. 37 N., R. 35 E.) (Pearson, 1977; J. R. Wilson, formerly USGS, written commun., 1987). The age of the granite is probably Eocene because it cuts cataclastically deformed metamorphic rocks in the Kettle metamorphic core complex but is itself not deformed. The granite near U S Creek may be correlative with granite in the Herron Creek suite plutons to the west.

Eiqm_k

Quartz monzonite near Kerry Creek (Eocene)(?)--Light-gray, directionless to weakly foliated, fine-grained quartz monzonite principally composed of orthoclase, plagioclase, quartz, and biotite. The quartz monzonite near Kerry Creek is an elongate, 5-km² intrusion along the west side of the Kettle River near the Canadian border (T. 40 N., R. 36 E.) (Pearson, 1977; Rhodes, 1980). The age of the quartz monzonite is probably Eocene because it cuts cataclastically deformed metamorphic rocks in the Kettle metamorphic core complex but is itself not deformed.

Eig_o

Granite near Orient (Eocene)--Massive, fine- to medium-grained, and equigranular granite composed of quartz, feldspar, and biotite. The color index ranges from 10 to 20. The granite near Orient consists of several small intrusions on the flanks of First Thought and Toulou Mountains near Orient (Bowman, 1950; J. R. West, 1976; Rhodes, 1980). The intrusions along the Kettle River fault southeast of Orient (Fig. 4) are crushed and strongly altered. Secondary minerals in these mottled pink and green rocks include chlorite, sericite, and calcite.

The age of the granite near Orient is probably Eocene because it intrudes the O'Brien Creek Formation and Sanpoil Volcanics.

Eiqm_d

Quartz monzonite near Deep Creek (Eocene)(?)--Three small intrusions of directionless, leucocratic, fine-grained, biotite quartz monzonite exposed near Deep Creek in the northeastern corner of the map area (Fox, 1981). The quartz monzonite intrudes Permian metasedimentary rocks and the Jurassic Rossland Group.

Eim_h

Hodgson Creek monzonite (Eocene)(?)--Chiefly monzonite and diorite with subordinate granodiorite. Principal constituents of the massive, fine-grained, porphyritic rocks are plagioclase (oligoclase-andesine), orthoclase, quartz, biotite, and hornblende. Feldspar phenocrysts form as much as 50 percent of the rocks, and mafic minerals compose 10 to 15 percent of the rocks. The Hodgson Creek monzonite is a 4-km² pluton along both sides of Hodgson Creek, southwest of Barstow (Bowman, 1950; Rhodes, 1980; Wilson, 1980). Along the Kettle River fault near Barstow (sec. 20, T. 38 N., R. 37 E.), the pluton is propylitically altered.

The Hodgson Creek monzonite intrudes Permian(?) metalimestone and Triassic-Permian(?) metavolcanic rocks. Dikes emanating from the pluton cut the Barstow granodiorite to the east.

Eia_f

Fifteenmile Creek pluton (Eocene)(?)--Highly varied in composition and texture (Bowman, 1950; Fox, 1981; Hyde, 1985; DGER unpublished mapping). The pluton consists of equigranular and porphyritic granite, quartz monzonite, and granodiorite, and pods and dikes of aplite, feldspar porphyry, and rhyolite porphyry. The fine- to medium-grained, equigranular rocks are composed of quartz, feldspar, biotite, and hornblende. The porphyritic rocks consist of plagioclase and K-feldspar phenocrysts, as much as 1 cm long, in a fine-grained groundmass similar in composition to the equigranular rocks. The feldspar porphyry is composed of feldspar phenocrysts, as much as 2 cm long, in a medium-grained, equigranular groundmass of feldspar and biotite.

The Fifteenmile Creek pluton, a 10-km² intrusion in the northeastern corner of the map area, intrudes the Jurassic Rossland Group and is cut by elongate intrusions of Eocene porphyritic dacite.

Eigd_b

Barstow granodiorite (Eocene)(?)--Massive, light-gray to pale-pink, fine- to medium-grained, and equigranular biotite granite. The Barstow granodiorite is a small pluton on the north end of Kelly Hill, between the Kettle and Columbia Rivers (Bowman, 1950; Kuenzi, 1961). It intrudes Triassic-Permian(?) metasedimentary rocks and is cut by numerous monzonite and diorite dikes that apparently emanate from the Hodgson Creek monzonite to the west.

Eii

Eocene(?) intermediate intrusive rocks--Several small intrusions of weakly foliated and lineated monzonite, granodiorite, diorite, and hornblendite that cut the metamorphic rocks of Tenas Mary Creek in the northern part of the Kettle metamorphic core complex (Pearson, 1977; C. M. Knaack, Washington State University, written commun., 1987). They are locally intruded by dikes of Eocene granite. These intrusions are compositionally similar to, and may be correlative with, the Eocene Kettle Crest pluton (Devils Elbow suite) in the southern part of the Kettle core complex.

Eik

Eocene alkalic intrusive rocks--Mafic alkalic rocks that form several small intrusions along the west side of the Toroda Creek graben (Pearson, 1967; Fox, 1973; Rinehart and Greene, 1988) and a small intrusion 2 km northeast of Bossburg (T. 38 N., R. 38 E.) (DGER unpublished mapping). The alkalic rocks near Cumberland Mountain (T. 38 N., R. 30 E.) include foyaite, malignite, pyroxenite, and shonkinite (Fox, 1973). The rocks along Cedar Creek (T. 40 N., R. 31 E.) are dominantly fine-grained, augite-biotite shonkinite (Pearson, 1967). Along the West Fork Beaver Creek (T. 39 N., R. 30 E.), the alkalic rocks are brecciated. The alkalic rocks near Bossburg are chiefly shonkinite(?), composed of K-feldspar phenocrysts and pyroxene glomerocrysts in a gray, fine-grained groundmass.

The foyaite, malignite, and pyroxenite near Cumberland Mountain cut Permian(?) schist and greenstone and are apparently overlain by the O'Brien Creek Formation. The shonkinite there cuts at least part of the O'Brien Creek Formation. The alkalic breccias along Beaver Creek intrude the O'Brien Creek Formation in places, but are overlain by the formation in other places. The shonkinite(?) near Bossburg intrudes the O'Brien Creek Formation.

"Clearly, the alkalic rocks were intruded not as a single synchronous event, but by stages through an appreciable length of geologic time, which began prior to and terminated during or after deposition of the O'Brien Creek Formation" (Fox, 1973).

Eib_t

Basic intrusive rocks near Toroda (Eocene)--Very fine grained and weakly porphyritic rocks composed of sparse phenocrysts of plagioclase and pyroxene in a fine-grained groundmass of plagioclase, pyroxene, biotite, and opaque minerals. Whole-rock geochemical data indicate a trachyandesitic composition (Fig. 6; Tables 2 and 3).

This small plug of "diabase" crops out along the north side of Toroda Creek, 4 km west of Toroda (Pearson, 1967). It cuts the Sanpoil Volcanics and Klondike Mountain Formation sedimentary rocks and is therefore probably Eocene in age.

Eib_k

Basic intrusive rocks near Kettle Falls (Eocene)(?)--Dark greenish-gray, fine- to medium-grained, equigranular diorite and gabbro composed of euhedral to subhedral plagioclase and pyroxene crystals, 1 to 2 mm long, and minor black opaque minerals. Pyroxene is generally altered to chlorite and calcite, and plagioclase is commonly altered to sericite. Whole-rock geochemical data indicate compositions ranging from basalt to andesite (Fig. 6; Tables 2 and 3).

These intrusive rocks are exposed in the hills north and west of Kettle Falls (Mills, 1985a; Kuenzi, 1961). The largest body, a narrow northeast-trending intrusion along the southeastern flank of Gold Hill, was apparently emplaced along a fault separating Triassic-Permian(?) metasedimentary rocks and Permian metasedimentary rocks. The smaller intrusions cut rocks as young as Triassic. These relations, and the fact that the basic intrusive rocks have not been metamorphosed, suggest that they were emplaced in the late Mesozoic or early Tertiary. An Eocene(?) age is tentatively assigned.

Mesozoic Intrusive Igneous Rocks

Kiat

Two-mica granite at Mingo Mountain (Cretaceous)(?)--Brown, medium- to coarse-grained, equigranular, muscovite-biotite granite that crops out on the east flank of Mingo Mountain in the southeastern corner of the map area (Mills, 1985a). A small body (<1/4 km²), the granite intrudes the Cambrian Maitlen Phyllite. K-Ar ages of approximately 100 Ma are reported from similar two-mica intrusions in the Colville and Chewelah 1:100,000-scale quadrangles to the east and southeast.

Kiqm

Quartz monzonite near Kettle Falls (Cretaceous)(?)--Several small quartz monzonite intrusions near Kettle Falls (Mills, 1985a). The rocks 3 km east of Marcus and 6 km southwest of Kettle Falls are gray, fine grained, and equigranular. The intrusion on the west side of Gold Hill (T. 36 N., R. 38 E.) consists of a central phase of massive, inequigranular quartz monzonite, granodiorite, and granite and a border phase of quartz monzodiorite. These intrusions are locally altered. Secondary minerals include sericite, chlorite, epidote, carbonate, and montmorillonite.

The quartz monzonite intrusions near Kettle Falls cut Triassic, Permian, and Cambrian metasedimentary rocks.

"The age of these intrusives is not known for certain; however they strongly resemble the calc-alkaline intrusive rocks of the Spirit pluton and the Kaniksu batholith [in the Colville 1:100,000-scale quadrangle] in their mineral make-up, hence they are thought to be Late Cretaceous in age" (Mills, 1985a).

KJigd_b, KJid_b,

Buckhorn Mountain pluton--(Cretaceous or Jurassic?)--A central phase of gray, fine- to medium-grained, biotite-hornblende granodiorite (KJigd_b), and a border phase of dark-gray, fine-grained hornblende diorite (KJid_b). Scattered dikes of alaskite and fine-grained hornblende diorite cut the granodioritic phase.

Much of the Buckhorn Mountain pluton is hydrothermally altered. Secondary minerals include saussurite, epidote, biotite, sericite, and chlorite. The pluton is also locally cut by sericitic mylonite zones, a few meters to tens of meters wide.

The Buckhorn Mountain pluton is a 20-km² intrusion in the northwestern corner of the quadrangle that extends west into the Oroville 1:100,000-scale quadrangle and north into British Columbia (Daly, 1912; Pearson, 1967; Fox, 1978; McMillen, 1979; Tempelman-Kluit, 1989). It cuts Permian and Triassic(?) metasedimentary rocks and metavolcanic rocks. Contact metamorphism by the pluton has locally transformed the metasedimentary rocks into hornfels, marble, and garnet-epidote-magnetite skarn.

The age of the Buckhorn Mountain pluton is uncertain. Both Jurassic and Cretaceous radiometric ages are reported from compositionally similar plutons in southern British Columbia (Little, 1957; Tempelman-Kluit, 1989).

KJigd_w

Wauconda pluton (Cretaceous or Jurassic(?))--Gray, medium- to coarse-grained, porphyritic granodiorite and quartz monzodiorite composed of blocky K-feldspar megacrysts, as much as 7 cm across, in a medium- to coarse-grained groundmass of plagioclase (oligoclase-andesine), quartz, and K-feldspar. Hornblende and biotite typically form 5 to 10 percent of the rocks. Accessory minerals include sphene, apatite, allanite, epidote, zircon, monazite(?), and opaque minerals.

The Wauconda pluton is massive to weakly foliated. The foliation is best developed near the contact with the Mount Bonaparte pluton (Keller Butte suite). Thin-sections reveal that the gneissic rocks have suffered cataclasis and recrystallization. Evidence includes

"1) xenomorphic-granular texture, 2) rounded K-feldspar phenocrysts with milled-off corners; 3) intergranular mortar (recrystallized); 4) locally entrained apatite; 5) bent, broken, and rehealed plagioclase showing distorted or offset twin lamellae; 6) undulose, flamboyantly recrystallized quartz, commonly showing implication texture" (Rinehart and Greene, 1988, p. 6).

The pluton forms a broad, northwest-trending intrusion west of Republic that extends into the Oroville 1:100,000-scale quadrangle (Fox, 1978; Rinehart and Greene, 1988; C. D. Rinehart, USGS, written commun., 1988). The Wauconda pluton intrudes Permian metasedimentary rocks and is cut by the Mount Bonaparte pluton (Keller Butte suite). A Cretaceous or Jurassic age is suspected.

KJik_s

Alkalic rocks of Shasket Creek (Cretaceous or Jurassic(?))--Chiefly hornblende syenite, pyroxene syenite, shonkinite, and monzonite. These plutons are cut by small plugs and dikes of porphyritic syenite. The dikes are vertical and trend west-northwest, parallel to the belt of alkalic rocks.

Principal constituents of the equigranular hornblende syenite are perthite, hornblende, albite, and granular epidote. The porphyritic shonkinite is composed of hornblende phenocrysts, as much as 8 mm long, in a groundmass of augite, hornblende, perthite, and minor magnetite, sphene, calcite, chlorite, epidote, and apatite. The pyroxene syenite consists of oriented subhedral prismatic orthoclase phenocrysts in a medium-grained groundmass of sodic plagioclase, pyroxene, amphibole, garnet, and sericite. The monzonite is composed of suboriented plagioclase laths, 1 to 2 mm long, in a groundmass of plagioclase (oligoclase-andesine), perthitic orthoclase, microcline, hornblende, and minor sphene and magnetite. The porphyritic syenite plugs and dikes

consist of tabular euhedral crystals of perthitic orthoclase, 1 to 50 mm long, in a groundmass of anhedral perthitic orthoclase, biotite, hornblende, garnet, and minor plagioclase. The orthoclase phenocrysts are commonly aligned parallel to the walls of the plugs and dikes.

The alkalic rocks of Shasket Creek form west-northwest-trending belt across the northern part of the Republic graben, 2 km southwest of Danville (Parker and Calkins, 1964; Pearson, 1977). They intrude Triassic and Permian metasedimentary and metavolcanic rocks and are cut by Eocene hypabyssal intrusions (Parker and Calkins, 1964). The age of the alkalic rocks is probably Cretaceous or Jurassic.

Jib

Basic intrusive rocks (Jurassic)(?)--Massive, dark greenish-gray, fine- to coarse-grained and locally pegmatitic, basic intrusive rocks. These intrusions range from diorite to pyroxenite, with an average composition of gabbro. Primary constituents were chiefly plagioclase and pyroxene, but many of the rocks have been thermally metamorphosed and are now composed of secondary hornblende, serpentine, zoisite, and calcite.

This unit forms a roughly circular mass on the south side of McKinley Mountain (sec. 19, T. 40 N., R. 37 E.), a small intrusion along the Kettle River (sec. 1, T. 39 N., R. 36 E.), numerous irregular masses north and east of Billy Goat Mountain (sec. 11, T. 39 N., R. 37 E.), and a group of sills along the north side of Sackit Canyon (sec. 3, T. 38 N., R. 37 E.) (Bowman, 1950; Rhodes, 1980; Fox, 1981; R. C. Roback, University of Texas, written commun., 1989). These basic intrusive rocks cut Permian metasedimentary rocks and the Jurassic Rossland Group. They grade into Rossland Group metavolcanic rocks in places, and are commonly difficult to distinguish from them.

"The similarities in composition between the Rossland Group and the related mafic intrusive rocks along with the gradational nature of at least some of the contacts between the two suggests that the gabbros may be the coarse-grained equivalent of the basalts" (Rhodes, 1980).

Jiq

Quartz diorite (Jurassic)(?)--Greenish-gray porphyritic quartz diorite, composed of blocky plagioclase phenocrysts as much as 1 cm long in an aphanitic to fine-grained groundmass.

The unit is exposed in the northeastern corner of the quadrangle near Limestone Creek (sec. 22, T. 40 N., R. 37 E.) and Mineral Mountain (sec. 8, T. 39 N., R. 38 E.) (Fox, 1981).

The porphyritic quartz diorite intrudes Permian metasedimentary rocks and the Jurassic Rossland Group, and it is cut by Eocene(?) lamprophyre dikes. The quartz diorite is commonly metamorphosed and sheared. The porphyritic quartz diorite near Limestone Creek grades into Jurassic(?) basic intrusive rocks. Compositions similar to those of the metavolcanic rocks in the Jurassic Rossland Group suggest that these rocks are the intrusive equivalent of the Rossland Group.

TRMid

Metadiorite near Buckhorn Mountain (Triassic or Permian)(?)--A few small bodies of massive, fine- to coarse-grained metadiorite crop out near Buckhorn Mountain in the northwestern corner of the map area (McMillen, 1979). Compositionally similar intrusions are widespread in the Oroville 1:100,000-scale quadrangle to the west (Fox, 1970, 1978; Rinehart and Fox, 1972). The metadiorite cuts Permian metasedimentary rocks, but apparently pre-dates the deposition of Late Triassic(?) metasedimentary rocks (McMillen, 1979).

Mzid

Metadiorite near Swan Lake (Mesozoic)(?)--Medium- to coarse-grained metadiorite consisting of hornblende porphyroblasts as much as 5 mm long in a light-gray, fine-grained crystalloblastic groundmass of plagioclase and minor hornblende, chlorite, epidote, and clinozoisite. Sphene, ilmenite, quartz, and apatite are common accessory minerals. Most of the metadiorite is directionless, but the western part of the body is lineated and foliated. The metadiorite forms a small mass along the southern border of the map area near Swan Lake (T. 35 N., R. 32 E.) (Muessig, 1967) that extends south into the Nespelem 1:100,000-scale quadrangle (Staatz, 1964). The metadiorite truncates bedding in the Paleozoic(?) phyllite and schist and is therefore probably intrusive into them. A Mesozoic age is tentatively assigned, but a Paleozoic age cannot be ruled out.

Mzu

Ultrabasic rocks (Mesozoic)(?)--Massive, dark-green to black, fine- to coarse-grained ultrabasic rocks that include dunite, pyroxenite, serpentinite, and altered serpentinite (silica-carbonate rocks). They are strongly sheared in places, particularly along the Sherman and Granby faults on the east side of the Republic graben. Relict pyroxene grains and accessory magnetite and chromite in the weakly serpentinized rocks indicate they were originally intrusions of ultrabasic composition (Parker and Calkins, 1964).

Small masses of ultrabasic rocks also crop out in the northeastern corner of the map area (Bowman, 1950; Rhodes, 1980; Fox, 1981) and in the northern part of the Republic graben (Parker and Calkins, 1964; Pearson, 1977; Orr, 1985). Ultrabasic rocks are also exposed along the Sherman fault east of Republic (Muessig, 1967), but these bodies are too small to show at the 1:100,000 map scale. The intrusive age(s) of the rocks is unknown.

Metamorphic Rocks

Metamorphic Rocks of Tenas Mary Creek

The metamorphic rocks of Tenas Mary Creek are a heterogeneous assemblage of upper amphibolite-facies quartzite, schist, marble, amphibolite, and gneiss that forms the Kettle and Tenas Mary Creek metamorphic core complexes (Parker and Calkins, 1964; Cheney, 1980; Cheney and others, 1982; Orr and Cheney, 1987; Parrish and others, 1988; Fox and Wilson, 1989). The Kettle metamorphic core complex is a 25-km-wide, north-trending complex that forms most of the eastern half of the Republic 1:100,000-scale quadrangle and extends north into British Columbia and south into the Nespelem 1:100,000-scale quadrangle (Figs. 4 and 7). The Tenas Mary Creek metamorphic core complex² is a 6-km-wide, 18-km-long complex that is restricted to the northwestern part of the map area (Fox and Rinehart, 1988).

The metamorphic rocks of Tenas Mary Creek are penetratively foliated and lineated. The foliation is generally parallel to compositional layering in the rocks. Lineations strike east in the Kettle core complex and northwest in the Tenas Mary Creek core complex. They are defined by slickenside-like striations, oriented

²Cheney (1980); Cheney and others (1982); and Orr and Cheney (1987) believe that the amphibolite-facies metamorphic rocks in the Tenas Mary Creek core complex are part of a continuous belt of metamorphic and plutonic rocks that form a northeast-trending arm of the Okanogan metamorphic core complex.

mineral grains, and mineral streaks. Boudins and recumbent isoclinal folds are common in the layered rocks, indicating that a thorough transposition of original compositional layering has occurred. Locally, the isoclinal folds have been refolded into open, symmetrical structures.

South of 48° 50' latitude in the Kettle core complex, foliations in the metamorphic rocks of Tenas Mary Creek define a broad asymmetrical antiform that plunges gently to the south (Cheney, 1980; Orr and Cheney, 1987). The foliations dip less than 40 degrees along the eastern and western margins of the complex and are nearly horizontal in the center of the complex. North of 48° 50' latitude, foliations in the Kettle core complex define several large overturned folds with axes transverse to the general north-northeast trend of the complex (Preto, 1970; Cheney and others, 1982; Orr and Cheney, 1987). Foliations in the rocks of the Tenas Mary Creek core complex form a gently warped, northward-dipping homocline (Parker and Calkins, 1964; Orr, 1985).

Ultramylonitic, mylonitic, and protomylonitic rocks³ form a gently east-dipping, 1- to 2-km-wide zone along the eastern margin of the Kettle metamorphic core complex. The mylonitic rocks are separated from Mesozoic and Paleozoic greenschist-facies metasedimentary and metavolcanic rocks and unmetamorphosed Tertiary volcanic, sedimentary, and plutonic rocks by a narrow zone of chloritic breccia. The western border of the Kettle core complex is bounded by several north-northeast-trending, high-angle(?) normal faults (Granby, St. Peter, and Sherman faults). The Tenas Mary Creek core complex is bounded on the west by the Bodie Mountain fault, on the east by the Bacon Creek fault, and on the north by the White Mountain fault (Fig. 4).

The protolith age of the metasedimentary and metavolcanic(?) rocks in the metamorphic rocks of Tenas Mary Creek is unknown.

"Specific correlation of the paragneissic rocks with sequences elsewhere in the Cordillera is difficult because the rocks in the domes are highly metamorphosed and deformed and cannot be traced out of the core into lower grade equivalents" (Orr and Cheney, 1987, p. 61).

K-Ar hornblende and biotite ages of 67.2 ± 2.0 Ma and 50.4 ± 1.4 Ma are reported from the amphibolite in the metamorphic rocks of Tenas Mary Creek (Table 1), but these are probably not magmatic ages. Rb-Sr and U-Pb zircon data from some of the orthogneiss "yield probable Late Mesozoic magmatic ages with a component of older (Precambrian) inherited zircon (R. L. Armstrong, personal communication, 1985)" (Orr and Cheney, 1987). Modal and geochemical data suggest that some of the penetratively - deformed orthogneiss within the metamorphic rocks of Tenas Mary Creek could be early Tertiary Keller Butte suite intrusions (Holder and Holder, 1988).

The metamorphic rocks of Tenas Mary Creek have been subdivided into three meta-igneous and four layered metamorphic rock units. They form a coherent structural sequence that is recognizable in both the Kettle and Tenas Mary Creek metamorphic core complexes (Parker and Calkins, 1964; Cheney, 1980; Cheney and others, 1982; Orr and Cheney, 1987). The absence of sedimentary structures and the thorough transposition of compositional layering prohibit recognition of the original stratigraphic order of the layered metamorphic rock units. For the convenience of this discussion, the layered units are herein designated units 1 through 4 (unit 4 is the structurally highest unit). The meta-igneous rocks are subdivided into porphyritic orthogneiss (pTog_p), equigranular orthogneiss (pTog_e), and amphibolite (pTam).

³Cataclastic rock definitions after Higgins (1971):

Ultramylonite--A rock composed of sparse porphyroclasts, typically less than 2 mm in diameter, scattered throughout an aphanitic matrix of finely crushed minerals

Mylonite--A rock composed of 10 to 50 percent porphyroclasts, typically greater than 2 mm in diameter, in an aphanitic matrix of finely crushed minerals

Protomylonite--A rock composed of lenticular lithic masses separated by thin films of finely crushed minerals

Blastomylonite--A rock with a megascopic fabric similar to any of the above, but with a granoblastic matrix of recrystallized minerals instead of finely crushed minerals

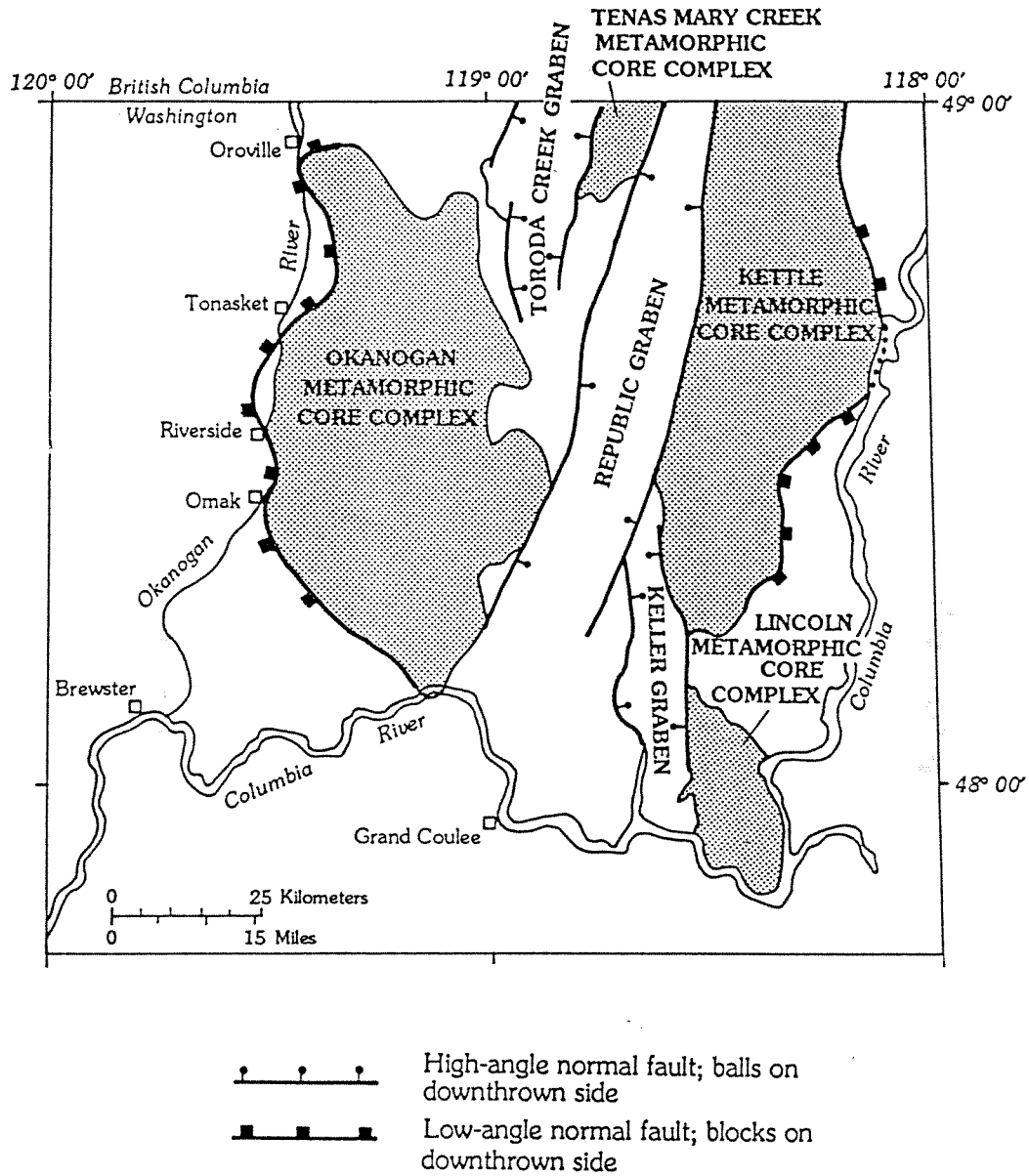


Figure 7. Metamorphic core complexes in the Okanogan highlands of northeastern Washington (modified from Fox and Rinehart, 1988).

Meta-igneous Rocks

pTog_p

Porphyritic orthogneiss (pre-Tertiary)(?)--Gray, medium- to coarse-grained, leucocratic gneiss, with abundant euhedral to subhedral K-feldspar phenocrysts as much as 10 cm long. Average composition of the gneiss is approximately 50 percent plagioclase, 20 percent orthoclase, 20 percent quartz, and 10 percent biotite. Common accessory minerals include garnet, zircon, rutile, apatite, and magnetite. The porphyritic orthogneiss contains abundant streaks, lenses, and irregular cross-cutting bodies of pegmatite, which is composed of orthoclase, quartz, and minor garnet, biotite, and muscovite. The pegmatite is locally foliated, with foliations parallel to those in the enclosing orthogneiss.

The porphyritic orthogneiss is a stratiform 850-m-thick intrusion that is regionally conformable with the layered metasedimentary rocks of the metamorphic rocks of Tenas Mary Creek (Cheney, 1980; Cheney and others, 1982; Orr and Cheney, 1987), but locally cross-cuts these rocks (Cheney, 1980; Rhodes, 1980). The porphyritic orthogneiss is massive and lacks compositional layering. It is only weakly foliated and is generally not lineated. Along the eastern margin of the Kettle core complex, the porphyritic orthogneiss is recrystallized and weakly mylonitic. The mylonitic rocks consist of 50 to 70 percent feldspar porphyroclasts with broken and ragged margins in a fine-grained, recrystallized matrix of quartz and biotite (Wilson, 1980, 1981a, 1981b). Foliation in these rocks is defined by oriented biotite grains that wrap around the feldspar crystals. Porphyroclastic textures also characterize most of the porphyritic orthogneiss north of the Kettle River in the Tenas Mary Creek core complex. These rocks are composed of deformed oligoclase, orthoclase, and garnet crystals as much as 0.5 cm across that are enclosed in a fine-grained, recrystallized mortar of quartz, oligoclase, and orthoclase (Parker and Calkins, 1964). Bent plagioclase twin lamellae and undulatory quartz grains are common.

This unit forms a large part of the Kettle and the Tenas Mary Creek core complexes (Bowman, 1950; Parker and Calkins, 1964; Pearson, 1977; Cheney, 1980; Rhodes, 1980; Holder, 1985; Orr, 1985). The porphyritic orthogneiss is cut by Devils Elbow and Herron Creek suite plutons, which locally contain abundant pendants and blocks of the orthogneiss (Holder, 1985). Modal analyses, geochemistry, and field observations suggest that at least some of the porphyritic orthogneiss could be metamorphosed Keller Butte suite plutons (Holder and Holder, 1988).

pTog_e

Equigranular orthogneiss (pre-Tertiary)(?)--Gray, medium- to coarse-grained, equigranular granodioritic gneiss. Principal constituents of the gneiss are plagioclase, quartz, orthoclase, biotite, muscovite, and hornblende. Accessory minerals include apatite, sphene, zircon, and magnetite. Quartz content is typically 25 to 30 percent. Mafic minerals (chiefly biotite) form less than 15 percent of the rocks. This unit forms much of the Kettle and Tenas Mary Creek metamorphic core complexes (Bowman, 1950; Parker and Calkins, 1964; Pearson, 1977; Cheney, 1980; Rhodes, 1980; Wilson, 1980, 1981a, 1981b; Mills, 1985a; Orr, 1985; Orr and Cheney, 1987).

The equigranular orthogneiss is massive to weakly layered, but moderately to strongly foliated and lineated. Along the east side of the Kettle core complex, the equigranular orthogneiss is mylonitic and contains thin interlayers of ultramylonite (Wilson, 1980, 1981a, 1981b; Rhodes, 1980). Foliations and lineations in the gneiss are defined by flattened or elongate quartz grains or ribbon quartz, flattened and elongate feldspar augen, and aligned quartz, feldspar, and biotite grains.

The equigranular orthogneiss forms large, tabular, stratiform intrusions in the metamorphic rocks of Tenas Mary Creek, but the gneiss locally cross-cuts the layered metasedimentary rocks. Inclusions of metasedimentary rocks, as much as 100 m across, are common in the orthogneiss. The inclusions are typically lenticular and concordant with the foliation in the gneiss. These relations clearly demonstrate that the equigranular gneiss is an orthogneiss that has a deformational history similar to that of the layered metasedimentary rocks (Orr and Cheney, 1987).

Dikes and lenses of garnetiferous aplite and pegmatite cut the equigranular orthogneiss in the Tenas Mary Creek core complex. Lenticular concordant masses and cross-cutting veins and dikes of alaskite gneiss and leucocratic pegmatite intrude the equigranular orthogneiss in the Kettle core complex. The largest body of alaskite gneiss, nearly 40 m thick, is a concordant mass along the contact between the equigranular orthogneiss and amphibolite (sec. 6, T. 35 N., R. 37 E.) (Wilson, 1980, 1981a, 1981b). The medium- to coarse-grained alaskite gneiss is composed of 20 to 30 percent quartz, less than 5 percent muscovite and biotite, and approximately equal proportions of orthoclase and plagioclase. The alaskite gneiss and pegmatite bodies along the eastern margin of the Kettle core complex are mylonitic.

pTam

Amphibolite (pre-Tertiary)--Black to dark-green amphibolite, hornblende schist, and minor hornblende gneiss. These rock form concordant and discordant sheets in the metamorphic rocks of Tenas Mary Creek (Pearson, 1977; Cheney, 1980; Wilson, 1980, 1981a, 1981b; Rhodes, 1980; Mills, 1985a). Along the southeastern side of the Kettle core complex, amphibolite lies between unit 4 quartzite and equigranular orthogneiss (pTog_e). Elsewhere, amphibolite is interlayered with quartzite, marble, and paragneiss of unit 2. Contacts with surrounding rocks are commonly sharp and discordant.

The amphibolite and hornblende schist in the Kettle core complex are fine to medium grained, and composed almost entirely of intergrown hornblende and plagioclase. They locally contain thin interlayers of quartzite and calc-silicate rocks, as well as thin concordant layers, pods, or boudins of marble. Concordant and discordant veins and stringers of pegmatite and alaskite gneiss cut the amphibolite and schist. The amphibolite and hornblende schist are massive to weakly layered and weakly to strongly foliated and lineated. Along the east side of the Kettle core complex, the amphibolite and schist are mylonitic and contain thin layers of ultramylonite. Hornblende gneiss in the Kettle core complex is restricted to a small body near Orient (sec. 23, T. 39 N., R. 36 E.). The gneiss is fine grained and contains biotite porphyroblasts (1 cm across) and concordant stringers of quartzofeldspathic material.

Schistose amphibolite and hornblende schist in the Tenas Mary Creek core complex form a narrow, northwest-trending belt between the equigranular orthogneiss (pTog_e) and unit 2 quartzite (pTqz₂) (Parker and Calkins, 1964; Pearson, 1967; Orr, 1985). Maximum thickness of the amphibolite is approximately 210 m; it pinches out to the southeast (Parker and Calkins, 1964). The rocks near Toroda are dominantly dark-green to black, massive to weakly layered, strongly foliated, fine-grained hornblende schist. Principal constituents are hornblende, andesine, and quartz; accessory minerals include sphene, zircon, apatite, magnetite, and calcite. The hornblende schist is weakly layered, with bands from 1 to 5 cm thick. Pure quartzite and anthophyllite-andesine schist layers as much as 0.5 m thick are locally intercalated with the hornblende schist. Massive, fine- to medium-grained augen gneiss forms the upper 27 m of the amphibolite unit near Toroda. It also forms layers as much as 5 m thick near the base of the unit (Parker and Calkins, 1964). The augen gneiss is composed of labradorite and hornblende, with accessory sphene, ilmenite, and apatite. The augen are labradorite crystals as much as 9 mm long that have been partially recrystallized along grain boundaries and fractures.

Strongly foliated amphibolite also forms dikes, sills, and small intrusions that cut unit 3 schist (pTsc₃) and unit 2 paragneiss (pTgn₂) in the Tenas Mary Creek core complex. The dikes and sills consist of coarse-grained amphibolite that is composed of anhedral to equant, poikiloblastic hornblende crystals as much as 5 mm long in a granoblastic matrix of andesine. Chlorite, magnetite, and apatite are common accessory minerals. The amphibolite in the small intrusions is fine grained and schistose. It is composed of finely crystalline actinolite in a granoblastic matrix of andesine and chlorite-epidote-plagioclase aggregates that are probably altered mafic mineral phenocrysts.

Cross-cutting relations and relict igneous textures indicate the amphibolite bodies along Catherine Creek in the Tenas Mary Creek complex are metamorphosed intrusions. The amphibolite and hornblende schist near Toroda could be either metamorphosed basic tuff or dolomitic shale (Parker and Calkins, 1964). The protolith of the augen gneiss near Toroda was probably basic volcanic rocks.

Layered Metamorphic Rocks

pTqz₄

Unit 4 (pre-Tertiary)--Thin-bedded, light-brown, fine- to medium-grained, micaceous quartzite and subordinate quartz-muscovite schist, feldspar schist, and quartz-biotite schist. The quartzite contains abundant veins of massive white quartz.

This unit is restricted to the southeastern margin of the Kettle metamorphic core complex, where it forms a 5-km-wide belt extending from Lake Ellen (sec. 26, T. 35 N., R. 36 E.) to Davis Lake (sec. 3, T. 37 N., R. 36 E.) (Cheney, 1980; Rhodes, 1980; Wilson, 1980, 1981a, 1981b). Along the northeast side of Tie Camp Creek (sec. 7, T. 37 N., R. 37 E.), numerous veins and pods of white biotite-muscovite pegmatite cut the quartzite (Rhodes, 1980).

Most of the quartzite in unit 4 is strongly foliated and lineated, but the pegmatite-bearing quartzite near Tie Camp Creek is massive and weakly foliated. The strong lineation is defined by mica streaks and quartz ribbons. Most of the quartzite is blastomylonitic, but mylonitic and ultramylonitic rocks are present locally (Wilson, 1981b).

Unit 4 is less than 300 m thick. It generally overlies amphibolite (pTam), but near Tie Camp Creek it is interlayered with amphibolite and locally overlies equigranular orthogneiss (pTog_e). The lack of sillimanite and the absence of thick interbeds of marble and gneiss in the quartzite of unit 4 serve to distinguish it from the thick, feldspathic quartzite in unit 2 (Cheney, 1980).

pTsc₃

Unit 3 (pre-Tertiary)--Hornblende schist, muscovite-biotite schist and quartzite, garnet-staurolite-muscovite-biotite schist, calc-silicate schist and gneiss, and minor amphibolite, metaconglomerate, and medium- to coarse-grained marble.

This unit forms a northwest-trending belt along the southwest side of Vulcan Mountain (Parker and Calkins, 1964; Orr, 1985), a narrow north-trending belt between the South Fork Day Creek and the Canadian border (T. 40 N., R. 35 E.), and a few isolated outcrops along the North Fork Boulder Creek (sec. 25, T. 39 N., R. 35 E.) (Cheney, 1980; Pearson, 1977; Orr, 1985). The unit is approximately 1,000 m thick. On Vulcan Mountain,

unit 3 structurally overlies unit 2 paragneiss and is in fault contact with Permian metasedimentary rocks to the northeast. Near Boundary Mountain, unit 3 is apparently separated from Permian metasedimentary rocks by a thrust fault (Orr, 1985; Orr and Cheney, 1987).

Strongly foliated and lineated, fine-grained biotite-muscovite schist is the principal lithology in the upper 200 m of unit 3 on Vulcan Mountain. Strongly foliated, medium-grained, muscovite-biotite-quartz schist (\pm garnet), chlorite schist, and cummingtonite schist dominate the lower 600 m of the unit there. The schist contains discontinuous metaconglomerate lenses, as much as 150 m thick (Orr, 1985). The metaconglomerate is composed of pebbles and cobbles of quartzite or silicic volcanic rocks in a biotite-quartz schist matrix. The clasts, commonly tectonically stretched, range from 10 cm to 1 m long. A few irregular bodies of amphibolite cut unit 3 on Vulcan Mountain.

pTpg₂, pTqz₂, pTmb₂

Unit 2 (pre-Tertiary)--A heterogeneous package of quartzite, marble, paragneiss, and schist that forms the core of the Kettle core complex and is the dominant unit in the Tenas Mary Creek core complex (Cheney, 1980; Cheney and others, 1982; Orr and Cheney, 1987). Feldspathic quartzite dominates the middle of the unit, it contains thin interlayers of marble and sillimanitic gneiss and schist. Interlayered marble, sillimanitic gneiss and schist, and minor quartzite form the upper and lower parts of unit 2. Pods and lenses of pegmatite and aplite cut the layered metasedimentary rocks, which are subdivided into the following lithologic units:

pTpg₂

Paragneiss--Sillimanite-muscovite-biotite gneiss, biotite-quartz gneiss, and minor calc-silicate gneiss in the Kettle core complex. Feldspathic quartzite and marble layers a few tens of meters thick are commonly intercalated with the gneiss (Pearson, 1977; Rhodes, 1980; Orr, 1985). Between Mount Leona (sec. 26, T. 38 N., R. 34 E.) and Long Alec Creek (sec. 34, T. 39 N., R. 34 E.), unit pTpg₂ contains thick layers of quartzite and marble (Pearson, 1977).

In the Tenas Mary Creek core complex, unit pTpg₂ consists of strongly foliated, fine- to medium-grained, leucocratic hornblende-biotite-quartz-plagioclase gneiss. Mafic minerals generally form less than 5 percent of the rocks. The gneiss contains interlayers of pure quartzite, garnet-cummingtonite-andesine-quartz schist, garnet-epidote-andesine-quartz gneiss, and biotite-hornblende-quartz-andesine schist. Unit 2 paragneiss grades into schist of unit 3 (pTsc₃).

Rocks in unit pTpg₂ are strongly foliated and lineated. Along the east side of the Kettle core complex, the rocks are mylonitic (Rhodes, 1980). Along the Kettle River fault near Barstow (secs. 6 and 7, T. 38 N., R. 37 E.), the rocks are chloritically altered.

pTqz₂

Quartzite--Vitreous feldspathic quartzite intercalated with schist, gneiss, and minor marble and calc-silicate rocks. White, tan, and pink, massive to medium-bedded, fine- to medium-grained quartzite is the principal lithology in the unit. It is composed of 85 to 95 percent quartz, minor orthoclase and andesine, and accessory biotite, muscovite, sillimanite, and magnetite. Most of the schist consists of quartz and mica, with minor sillimanite, hornblende, and garnet, but a few schist layers are composed chiefly of sillimanite, biotite, and orthoclase with very little quartz. Principal constituents of the gneiss are feldspar, biotite, and hornblende.

Unit pTqz₂ forms much of the core of the Kettle metamorphic core complex (Pearson, 1977; Rhodes, 1980; Cheney, 1980; Orr and Cheney, 1987) and extensive belts on both sides of the Kettle River in the Tenas Mary Creek core complex (Parker and Calkins, 1964; Pearson, 1967; Orr, 1985). It is more than 1,250 m thick in the Tenas Mary Creek core complex (Orr, 1985) and more than 650 m thick in the Kettle core complex (Cheney, 1980).

Much of the quartzite in unit pTqz₂ is massive and exhibits a granoblastic texture. Foliated quartzite contains elongate quartz grains and subparallel biotite, muscovite, and feldspar. Foliation is generally parallel to bedding, which is defined by thin partings of mica and sillimanite. Lineation is produced by mineral streaking or oriented sillimanite needles. The quartzite is strongly deformed along the east side of the Kettle core complex (Rhodes, 1980; Wilson, 1981b). The deformed rocks contain feldspar porphyroclasts surrounded by flattened quartz grains.

pTmb₂

Marble--White to gray, medium- to coarse-grained marble composed chiefly of equidimensional calcite. Dolomite, forsterite, diopside, spinel, epidote, and/or phlogopite are minor components. This massive to weakly foliated marble forms thick layers in unit 2 in the Kettle core complex (Pearson, 1977; Rhodes, 1980; Wilson, 1980, 1981a, 1981b).

Intercalated marble, calc-silicate rocks, gneiss, schist, and quartzite form the lowermost unit in the metamorphic rocks of Tenas Mary Creek in the Tenas Mary Creek core complex. This unit crops out in narrow belts southwest of Little Vulcan Mountain and along Bamber Creek (Parker and Calkins, 1964; Pearson, 1967). Maximum thickness of the marble is 250 m; it thins and disappears to the east (Parker and Calkins, 1964). The white, medium- to coarse-grained marble forms beds from 1 cm to more than 6 m thick. Hornblende, diopside, phlogopite, and biotite are common accessory minerals in the marble, which commonly grades into calc-silicate rocks. Biotite-quartz-feldspar gneiss, biotite schist, sillimanite-quartz schist, and schistose quartzite are interlayered with the marble and calc-silicate rocks. Discontinuous layers and lenses of foliated pegmatite and sill-like bodies of gneissic quartz monzonite, as much as 12 m thick, cut the marble, gneiss, and schist in places.

pTsc₁, pTmb₁

Unit 1 (pre-Tertiary)--Chiefly gray, finely laminated, fine-grained calc-silicate schist (pTsc₁). Principal constituents are diopside, calcic plagioclase, quartz, orthoclase, biotite, graphite, magnetite, and calcite. The calc-silicate schist is locally interbedded with biotite-quartz schist, fine-grained micaceous quartzite, and white, fine- to coarse-grained, dolomitic marble (pTmb₁). Some of the biotite-quartz schist contains sillimanite clusters and cordierite porphyroblasts, which are commonly altered to sericite. The alignment of mica and elongation of quartz and diopside grains produce a strong foliation in the mica-rich layers. Mica-poor layers are characterized by weak foliations and granoblastic textures.

This unit of schist, quartzite, and marble crops out along the west side of the Kettle core complex from the North Fork St. Peter Creek to Sherman Pass on Washington State Route 20 (Parker and Calkins, 1964; Muessig, 1967; Cheney, 1980; Holder, 1985). Blocks, sheets, and inclusions of these rocks also are found in Eocene plutonic rocks on Edds Mountain (sec. 3, T. 35 N., R. 34 E.) and Mount Washington (sec. 21, T. 36 N., R. 34 E.) (Holder, 1985). Unit 1 is absent in the Tenas Mary Creek core complex.

In the Kettle core complex, unit 1 is in fault contact with unit 2 (Parker and Calkins, 1964; Cheney, 1980). It is intruded by the Fire Mountain pluton (Herron Creek suite) (Holder, 1985).

Mixed Metamorphic and Igneous Rocks

pTmg

Migmatite (pre-Tertiary)--Migmatization of the layered metasedimentary rocks and amphibolite in the metamorphic rocks of Tenas Mary Creek is common in the Kettle core complex. The degree of migmatization ranges from thin streaks of granitic material in the metasedimentary rocks to pervasive granitization of the metasedimentary rocks. In general, migmatization increases as the orthogneisses of the metamorphic rocks of Tenas Mary Creek are approached (Cruson and Pansze, 1980).

Although migmatite is widespread in the Kettle core complex, it has only been mapped in the vicinity of Sherman Creek and South Fork Sherman Creek (Campbell and Thorsen, 1975). These migmatite bodies are spatially associated with intrusions of both the equigranular orthogneiss (pTog_e) and the porphyritic orthogneiss (pTog_p).

Metamorphic Rocks in the Southwest Part of the Map Area

Amphibolite-facies schist, quartzite, marble, calc-silicate rocks, amphibolite, and gneiss are exposed along Toroda Creek (T. 38 N., R. 30 E.), along the West Fork Sanpoil River, near Golden Harvest Creek, and on the east side of the Toroda Creek graben between Bamber Creek and the West Fork Trout Creek (Muessig, 1967; Pearson, 1967; Fox, 1973; Cheney and others, 1982; Orr, 1985; Orr and Cheney, 1987; Rinehart and Greene, 1988). These metamorphic rocks extend west and south into the Oroville and Nespelem 1:100,000-scale quadrangles (Staatz, 1964; Fox, 1978; Cheney and others, 1982; Orr and Cheney, 1987; C. D. Rinehart and K. F. Fox, Jr., USGS, written commun., 1988).

The amphibolite-facies metamorphic rocks along Toroda Creek are in fault contact with Triassic-Permian(?) greenschist-facies metasedimentary and metavolcanic rocks, Sanpoil Volcanics, and the O'Brien Creek Formation (Pearson, 1967; Cheney and others, 1982; Orr, 1985; Orr and Cheney, 1987; Rinehart and Greene, 1988). They are intruded by the Wauconda pluton. The metamorphic rocks along the West Fork Sanpoil River are apparently in thrust fault contact with greenschist-facies metasedimentary rocks to the southeast. They are cut by Keller Butte suite plutons. The amphibolite-facies metamorphic rocks along the east side of the Toroda Creek graben are in fault contact with the Klondike Mountain Formation and may be separated from the metamorphic rocks of Tenas Mary Creek by a fault (Pearson, 1967). They are intruded by Keller Butte and Herron Creek suite plutons.

Some workers believe that the amphibolite-facies metamorphic rocks along the West Fork Sanpoil River grade into the Permian(?) greenschist-facies metasedimentary rocks (P₁mm), and that they are simply thermally upgraded equivalents of the metasedimentary rocks (Pearson, 1967; Fox, 1973; Rinehart and Greene, 1988; K. F. Fox, Jr., USGS, written commun., 1989). Other workers believe that the contacts between the amphibolite-facies and greenschist-facies rocks are abrupt and are probably marked by faults (McMillen, 1979; Cheney and others, 1982; Orr, 1985; Orr and Cheney, 1987). The latter workers think that all of the amphibolite-facies metamorphic rocks in the southwest part of the map area are contiguous with the metamorphic rocks of Tenas Mary Creek to the north and that they are part of the Okanogan metamorphic core complex. Foliations in the amphibolite-facies metamorphic rocks generally strike northwest (Rinehart and Greene, 1988; E. S. Cheney, University of Washington, written commun., 1990), parallel to foliations in the Okanogan metamorphic core complex to the southwest.

pTsc

Schist (pre-Tertiary)--Quartz-mica schist with thin beds and discontinuous lenses of quartzite, amphibolite, calc-silicate rocks, and marble; Chiefly quartz, biotite, muscovite, and plagioclase, but garnet, staurolite, and sillimanite occur locally. The greenish-gray, massive to laminated calc-silicate rocks are composed chiefly of calcic plagioclase, quartz, diopside, and/or tremolite. The amphibolite consists of plagioclase, hornblende, and minor quartz, K-feldspar, and biotite. Fine- to medium-grained schist is the dominant lithology in the unit. The unit crops out along Toroda Creek, along the West Fork Sanpoil River, near Golden Harvest Creek, and on the east side of the Toroda Creek graben between Tonata Creek and the West Fork Trout Creek.

Near the West Fork Sanpoil River the schist unit is intruded by abundant pegmatite dikes. Along Lost Creek (sec. 19, T. 35 N., R. 31 E.), the rocks are shattered and have been partly assimilated into granodiorite of the Moses pluton (Keller Butte suite) (Rinehart and Greene, 1988).

pTmb

Marble (pre-Tertiary)--Massive white calcite marble; average grain size is 1 mm, but grains as much as 5 mm across are not uncommon. The marble contains thin, discontinuous lenses of calc-silicate rocks and thinly foliated schist. The unit is exposed along Toroda Creek (T. 38 N., R. 30 E.), north of Swan Lake (T. 35 N., R. 32 E.), on Horseshoe Mountain (sec. 19, T. 38 N., R. 32 E.), and near Tonata Creek (secs. 17 and 20, T. 39 N., R. 32 E.).

pTam

Amphibolite (pre-Tertiary)--Greenish-black, massive to laminated, and composed of plagioclase (andesine to labradorite) and hornblende, with minor quartz, epidote, and biotite. Accessory minerals include K-feldspar, chlorite, sphene, apatite, magnetite, pyrite, and zircon. Pillow structures are locally preserved in the amphibolite, indicating that it was derived from volcanic rocks. The amphibolite is interlayered with minor quartz-mica schist, calc-silicate rocks, and marble. This amphibolite forms a narrow northwest-trending belt along the West Fork Sanpoil River on the border of the Republic and Nespelem 1:100,000-scale quadrangles (Staat, 1964; Rinehart and Greene, 1988).

pTog

Orthogneiss (pre-Tertiary)--Chiefly quartz, plagioclase (andesine), and K-feldspar; biotite, chlorite, and opaque minerals form less than 5 percent of the rocks. This coarse-grained, leucocratic granodiorite gneiss forms a northwest-trending body along the north side of the West Fork Sanpoil River between Swan Lake and Cobey Creek (T. 35 N., R. 31 and 32 E.), and a small mass on the west side of Frosty Creek (T. 36 N., R. 31 E.) (Muessig, 1967; Cheney and others, 1982; Orr and Cheney, 1987; Rinehart and Greene, 1988).

Microscopically, the foliated and exceptionally well lineated gneiss exhibits

"1) xenomorphic-granular texture; 2) milled phenocrysts in porphyritic rocks; 3) much intergranular mortar; 4) recrystallized (probably redistributed) quartz showing marked fluxion structure and undulose character; 5) shredded, commonly aligned biotite; 6) bent and broken twin lamellae in plagioclase; and 7) apatite locally entrained" (Rinehart and Greene, 1988, p. 5).

In most places, the cataclastic textures have been modified by recrystallization.

The granodiorite gneiss is cut by and locally forms inclusions in the Moses and Mount Bonaparte plutons (Keller Butte suite) (Cheney and others, 1982; Rinehart and Greene, 1988). Therefore, it is probably pre-Tertiary in age.

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Table 1. Radiometric age data, Republic 1:100,000 quadrangle.

Loc. no.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
1	88Bol54	Granitic boulder in basal Rossland Group metaconglomerate	Jmv _r	SE/4NE/4 sec. 34, T. 39 N., R. 37 E.	U-Pb	zircon	196 +/- 1	Roback and Walker (1989), R. C. Roback, University of Texas, written commun., 1989 ¹
2	88Bol09	Rosslund Group flow(?) or post-Rosslund intrusion(?)	Jmv _r	NW/4NW/4 sec. 3 T. 38 N., R. 37 E.	U-Pb	zircon	165 +/- 11	R. C. Roback, University of Texas, written commun., 1989 ¹
3	G17C177	Henry Creek monzodiorite (Devil's Elbow suite)	Eimd _h	48°52.5'N, 118°41'W	Pb-alpha	zircon	130 +/- 15	Engels and others (1976) ²
4	032M362	Porphyritic dacite hypabyssal intrusion	Eida	48°39'N, 118°40'W	Pb-alpha	zircon	80 +/- 15	Engels and others (1976) ²
5	58M-360	Mt. Bonaparte pluton (Keller Butte suite), granodiorite	EPa ia _b	48°37.5'N, 118°50.3'W	Pb-alpha	zircon monazite	75 +/- 10 60 +/- 10	Engels and others (1976) ²
-	I33M202	Sanpoil Volcanics?	Evd _s	Unknown, probably in Curlew quadrangle	Pb-alpha	zircon	70 +/- 10	Engels and others (1976) ²
6	F-2222-55	Texas Mary Creek sequence, amphibolite	pTam	48°38'N, 118°22'W	K-Ar	hornblende	67.2 +/- 2.0	Engels and others (1976) ²
7	H4P119	Long Alec Creek pluton (Herron Creek suite), quartz monzonite	Eigm _h	48°54'N, 118°30.5'W	Pb-alpha	zircon	65 +/- 10	Engels and others (1976) ²
8	09M363	O'Brien Creek Formation, tuff	Ec _o	48°43.5'N, 118°39.2'W	Pb-alpha	zircon	60 +/- 15	Engels and others (1976) ²
9	01M364	Herron Creek intrusion (Herron Creek suite), quartz monzonite	Eigm _h	48°44.3'N, 118°35.3'W	Pb-alpha	zircon	60 +/- 10	Engels and others (1976) ²
10	ESC-4003	Porphyritic dacite hypabyssal intrusion	Eida	NE/4 sec. 10, T. 35 N., R. 32 E.	Fission track K-Ar K-Ar Fission track	apatite hornblende biotite zircon	56.9 +/- 10.9 53.9 +/- 2.9 50.6 +/- 2.0 39.7 +/- 1.0	Oliver (1986) ³
11	B0445	Klondike Mountain Formation, tuff	Ec _k	48°38'N, 118°44'W	K-Ar	biotite	55.0 +/- 1.7	Axelrod (1966) ⁴
12	Q16M259	Fire Mountain pluton, (Herron Creek suite), quartz monzonite	Eigm _h	48°37.5'N, 118°33'W	Pb-alpha	zircon	55 +/- 15	Engels and others (1976) ²

Table 1. Radiometric age data, Republic 1:100,000 quadrangle, (continued).

Loc. no.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
13	OBP-65-07	Henry Creek monzodiorite (Devils Elbow suite)	Eimd _h	SW/4NW/4 sec. 17, T. 39 N., R. 33 E.	K-Ar	hornblende biotite	53.7 +/- 2.7 52.2 +/- 1.7	Pearson and Obradovich (1977) ⁶
14	OBP-65-06	Porphyritic dacite hypabyssal intrusive	Eida	SW/4NW/4 sec. 19, T. 40 N., R. 34 E.	K-Ar	biotite hornblende	53.4 +/- 2.0 52.6 +/- 2.1	Engels and others (1976) ² Pearson and Obradovich (1977) ⁶
15	CMK-11-20	Long Alec Creek pluton (Herron Creek suite), quartz monzonite	Eigm _h	SW/4NW/4NE/4 sec. 5, T. 38 N., R. 34 E.	K-Ar	biotite	52.8 +/- 2.0	This report, DGER data (1988) ⁵
16	CMK-11-21	Long Alec Creek pluton (Herron Creek suite), granite	Eig _h	SW/4NW/4NE/4 sec. 19, T. 39 N., R. 35 E.	K-Ar	biotite	52.5 +/- 2.0	This report, DGER data (1988) ⁵
17	OBP-65-03	Sanpoil Volcanics	Evd _s	SE corner NE/4 sec. 35, T. 36 N., R. 33 E.	K-Ar	biotite biotite plagioclase biotite plagioclase	52.4 +/- 1.8 51.2 +/- 1.7 50.4 +/- 2.5 50.1 +/- 1.7 48.4 +/- 3.0	Pearson and Obradovich (1977) ⁶
18	OBP-65-02	Sanpoil Volcanics	Evd _s	SE/4SE/4 sec. 24, T. 35 N., R. 32 E.	K-Ar	biotite plagioclase plagioclase	52.1 +/- 1.7 45.2 +/- 1.6 44.8 +/- 2.2	Pearson and Obradovich (1977) ⁶
19	OBP-65-08	Long Alec Creek pluton (Herron Creek suite), quartz monzonite	Eigm _h	NW/4 sec. 27, T. 39 N., R. 34 E.	K-Ar	biotite	51.7 +/- 1.6	Pearson and Obradovich (1977) ⁶
20	OBP-65-04	Fire Mountain pluton (Herron Creek suite), quartz monzonite	Eigm _h	SW/4SE/4 sec. 16, T. 36 N., R. 31 E.	K-Ar	biotite	51.1 +/- 1.6	Pearson and Obradovich (1977) ⁶
21	OBP-65-01	Sanpoil Volcanics	Evd _s	SW/4SW/4 sec. 21, T. 39 N., R. 34 E.	K-Ar	plagioclase	51.1 +/- 3.0	Pearson and Obradovich (1977) ⁶
22	SK 86 81	Empire Lakes pluton (Herron Creek suite), granodiorite	Eigd _h	SE/4SE/4 sec. 8, T. 38 N., R. 32 E.	K-Ar	biotite hornblende	50.9 +/- 2.0 50.8 +/- 2.8	This report, DGER data (1988) ⁵
23	SK 86 28	Henry Creek monzodiorite (Devils Elbow suite)	Eimd _h	NW/4NW/4 sec. 19, T. 39 N., R. 33 E.	K-Ar	biotite	50.7 +/- 1.9	This report, DGER data (1988) ⁵
24	F-2411-68	Tenas Mary Creek sequence, amphibolite	pTam	48°38'N, 118°22'W	K-Ar	biotite	50.4 +/- 1.4	Engels and others (1976) ²
25	P-6-2	Sanpoil Volcanics	Evd _s	SE/4NW/4 sec. 34, T. 36 N., R. 38 E.	K-Ar	biotite	50.2 +/- 1.3	Engels and others (1976) ² Pearson and Obradovich (1977) ⁶

Table 1. Radiometric age data, Republic 1:100,000 quadrangle, (continued).

Loc. no.	Sample no.	Unit	Map symbol	Location	Method	Material	Age (Ma)	Reference
26	SK 86 31	Empire Lakes pluton (Herron Creek suite), monzodiorite	Eim _h	SW/4SE/4 sec. 1, T. 38 N., R. 32 E.	K-Ar	biotite	49.9 +/- 1.9	This report, ⁵ DGER data (1988)
27	A32-4-81	Klondike Mountain Formation, rhyolite(?) flow	Evr _k	SW/4SE/4 sec. 32, T. 40 N., R. 32 E.	K-Ar	biotite biotite biotite	49.1 +/- 1.7 48.1 +/- 1.4 47.4 +/- 1.6	Pearson and Obradovich (1977) ⁶
28	H50730877	Klondike Mountain Formation, rhyolite(?) flow	Evr _k	NE/4SE/4NW/4 sec. 17, T. 38 N., R. 31 E.	K-Ar	whole rock	48.1 +/- 2.0	This report, ⁵ DGER data (1988)
29	LO-232	Porphyritic dacite hypabyssal intrusive	Eida	SW/4 sec. 20, T. 37 N., R. 33 E.	K-Ar	hornblende biotite	47.7 +/- 2.7 44.6 +/- 2.0	Oliver (1986) ³
30	8a-BM-7	Klondike Mountain Formation, vitrophyric flow	Evdv _k	SW/4SW/4 sec. 32, T. 40 N., R. 32 E.	K-Ar	hornblende hornblende hornblende	48.0 +/- 1.9 46.6 +/- 1.9 46.3 +/- 1.7	Pearson and Obradovich (1977) ⁶
31	LO-632	Plutonic rock clast from breccia along Bacon Creek fault	---	NE/4 sec. 10, T. 37 N., R. 32 E.	Fission track	zircon apatite	44.9 +/- 1.4 38.5 +/- 6.8	Oliver (1986) ³
32	OBP-65-05	Klondike Mountain Formation, vitrophyric flow	Evdv _k	SE/4SW/4 sec. 32, T. 40 N., R. 32 E.	K-Ar	hornblende hornblende	41.4 +/- 1.5 41.3 +/- 2.0	Pearson and Obradovich (1977) ⁶
33	Alpine	Propylitically altered Sanpoil Volcanics	Evd _s	Knob Hill #2 mine, #5 level, 2676	Fission track	zircon	39.4 +/- 0.9	Oliver (1986) ³
34	Knob Hill #2	Propylitically altered Sanpoil Volcanics	Evd _s	Knob Hill #2 mine, #7 level	Fission track	zircon	39.3 +/- 1.1	Oliver (1986) ³
35	H50731879	Klondike Mountain Formation, vitrophyric flow	Evdv _k	NW/4SW/4NW/4 sec. 7, T. 39 N., R. 32 E.	K-Ar	whole rock	33.7 +/- 1.6	This report, ⁵ DGER data (1988)

1. R. C. Roback, University of Texas, written commun., 1989:

Decay constants: $^{238}\text{U} = 1.55125 \times 10^{-10}/\text{yr}$; $^{235}\text{U} = 9.8485 \times 10^{-10}/\text{yr}$; atomic ratio of $^{238}\text{U}/^{235}\text{U} = 137.88$

2. Engels and others (1976): constants not reported.

3. Oliver (1986): $\lambda\beta = 4.962 \times 10^{-10}/\text{yr}$; $\lambda\epsilon = 0.581 \times 10^{-10}/\text{yr}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.167 \times 10^{-4}$

4. Axelrod (1966): constants not reported.

5. DGER data (1988): $\lambda\beta = 4.962 \times 10^{-10}/\text{year}$; $\lambda_e + \lambda_{e'} = 0.581 \times 10^{-10}/\text{year}$; $^{40}\text{K}/\text{K}^{\text{total}} = 1.193 \times 10^{-4}$

6. Pearson and Obradovich (1977): constants not reported.

Table 2. Major oxide geochemistry data, Republic 1:100,000 quadrangle; analyses by XRF, Washington State University; analyses normalized to 100% on a volatile-free basis; FeO* is total iron expressed as FeO.

Sample Number	Map Symbol	Subsection	Sec	Twp	Rge	SiO ₂	Al ₂ O ₃	TiO ₂	FeO*	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅
N3933226H	Evdv(k)	NE/4 NW/4	22	39	33E	73.00	12.13	0.83	3.77	0.04	4.24	1.27	1.53	2.67	0.51
N3933225G	Evdv(k)	NE/4 NW/4	22	39	33E	62.07	15.79	1.08	5.79	0.10	5.11	3.08	2.65	3.77	0.56
N3933167E	Evdv(k)	SW/4 NW/4	16	39	33E	64.66	15.46	0.93	5.03	0.09	4.53	2.56	3.56	2.70	0.47
N3933166E	Evdv(k)	SE/4 NW/4	16	39	33E	61.26	16.09	1.01	6.02	0.10	5.73	3.20	2.47	3.57	0.54
N3933158D	Evdv(k)	NW/4 SW/4	15	39	33E	69.56	14.51	0.48	3.69	0.05	3.09	1.77	3.79	2.89	0.16
N3933156B	Evdv(k)	SE/4 SW/4	15	39	33E	63.06	15.80	0.92	5.42	0.10	6.52	3.28	0.88	3.53	0.49
3937076C1	Evdv(k)	NE/4 SW/4	7	39	37E	65.45	15.67	0.77	4.68	0.08	6.21	2.40	1.05	3.34	0.36
3937067A	Evdv(k)	SW/4 SW/4	6	39	37E	65.95	15.54	0.74	4.54	0.08	5.85	2.24	1.57	3.16	0.33
3936011B2	Evdv(k)	SE/4 SE/4	1	39	36E	65.79	15.64	0.73	4.43	0.08	5.73	2.26	1.66	3.33	0.34
3933277H	Evdv(k)	NW/4 NW/4	27	39	33E	63.85	15.96	0.65	4.40	0.08	4.78	4.09	2.45	3.52	0.22
3933276H	Evdv(k)	NE/4 NW/4	27	39	33E	65.78	15.85	0.67	4.08	0.05	4.40	2.59	2.59	3.78	0.22
3933275G	Evdv(k)	NE/4 NW/4	27	39	33E	64.58	15.71	0.74	4.75	0.08	5.15	3.49	0.88	4.40	0.22
3933226A	Evdv(k)	SE/4 SW/4	22	39	33E	65.13	15.93	0.66	4.16	0.08	4.75	2.99	1.95	4.15	0.22
3932063D	Evdv(k)	NW/4 SE/4	6	39	32E	64.11	15.29	0.83	5.58	0.10	4.87	2.86	2.37	3.39	0.35
3931226H	Evdv(k)	NE/4 NW/4	22	39	31E	68.33	16.14	0.51	3.47	0.06	3.84	1.29	2.75	3.23	0.16
3931157C	Evdv(k)	NW/4 SW/4	15	39	31E	68.06	16.29	0.50	3.40	0.54	3.91	1.36	2.93	3.14	0.15
3833316G	Evdv(k)	NE/4 NW/4	31	38	33E	61.87	15.53	0.99	6.01	0.10	5.53	4.56	1.06	3.86	0.33
3833168D	Evdv(k)	NW/4 SW/4	16	38	33E	60.53	15.82	0.97	6.19	0.12	6.50	4.39	0.92	4.14	0.42
3833094C	Evdv(k)	NW/4 SE/4	9	38	33E	60.87	15.66	0.94	5.81	0.11	5.97	4.24	2.12	3.88	0.40
3833093C	Evdv(k)	NW/4 SE/4	9	38	33E	60.86	15.78	0.94	5.99	0.11	5.93	4.29	1.20	4.50	0.39
3732244B	Evdv(k)	SW/4 SE/4	24	37	32E	63.39	15.96	0.88	5.11	0.09	4.89	3.02	1.55	4.73	0.39
3732245B	Evdv(k)	SE/4 SW/4	24	37	32E	63.12	15.91	0.88	5.34	0.08	4.91	2.74	2.72	3.92	0.38
HS1004884	Evdv(k)	SW/4 SE/4	21	37	31E	66.06	15.85	0.61	3.98	0.08	4.26	2.38	2.12	4.47	0.20
HS1005883	Evdv(k)	SE/4 SE/4	15	36	31E	65.27	16.60	0.72	4.26	0.07	3.81	1.61	3.32	4.03	0.31
HS1005886	Evdv(k)	SECR NW/4	7	35	31E	62.87	16.87	0.95	5.15	0.07	4.13	2.41	3.12	3.94	0.48
HS1006886	Evdv(k)	NE/4 NW/4	26	37	31E	71.32	15.62	0.34	2.13	0.05	2.16	1.08	3.47	3.72	0.11
MK870831	Evdv(k)	SW/4 SE/4	20	38	33E	62.89	15.76	1.12	5.74	0.09	5.00	3.19	0.86	4.93	0.43
MK870832	Evdv(k)	NW/4 NE/4	29	38	33E	70.19	13.75	0.93	2.10	0.12	5.67	0.77	3.64	2.46	0.38
MK870857	Evdv(k)	NE/4 SW/4	7	39	37E	65.17	15.85	0.75	4.66	0.08	4.85	2.46	1.64	4.21	0.34
HS07318704	Evdv(k)	NW/4 SW/4	2	38	31E	70.36	15.20	0.39	2.54	0.05	2.60	0.66	3.67	4.41	0.12
HS07318709	Evdv(k)	SW/4 NW/4	7	39	32E	67.40	15.68	0.50	3.65	0.07	4.15	2.41	1.62	4.36	0.17
HS1006884	Evr(k)	SE/4 NW/4	35	38	31E	71.99	15.28	0.34	2.30	0.04	1.49	0.94	3.82	3.69	0.11
HS07308705	Evr(k)	NE/4 SE/4	21	38	31E	72.36	15.05	0.38	2.21	0.03	1.60	1.01	3.76	3.48	0.12
HS07308706	Evr(k)	NW/4 NW/4	21	38	31E	75.54	14.41	0.33	2.08	0.02	0.41	0.53	4.27	2.32	0.11
HS07308707	Evr(k)	NW/4 NE/4	17	38	31E	69.99	15.69	0.37	2.59	0.05	3.01	0.87	3.26	4.05	0.12
HS07318703	Evr(k)	NE/4 SW/4	1	38	31E	73.50	15.25	0.36	1.53	0.01	1.19	0.17	4.01	3.88	0.11
HS07318705	Evr(k)	NE/4 NE/4	4	38	31E	70.90	15.55	0.35	2.31	0.04	2.84	0.86	3.37	3.67	0.11
MK870822	Evd(k)	SW/4 NW/4	20	38	33E	66.24	15.86	0.62	4.50	0.05	3.40	2.13	2.74	4.22	0.23
MK870755	Evd(k)	SW/4 SW/4	15	38	33E	69.48	16.37	0.40	2.33	0.05	2.93	1.22	3.05	4.03	0.15
MK870758	Evd(k)	SE/4 SW/4	16	38	33E	61.53	14.27	0.78	5.84	0.14	7.96	1.94	3.51	3.56	0.47
MK870826	Evd(k)	SE/4 NW/4	20	38	33E	65.05	16.28	0.63	4.81	0.07	3.68	2.14	2.72	4.39	0.24
HS1004881C	Evt(k)	NE/4 NW/4	31	38	33E	65.23	16.31	0.83	3.83	0.06	5.07	1.08	3.14	4.10	0.36
MK870806	Evd(s)	NW/4 SE/4	22	39	33E	64.20	16.42	0.68	3.51	0.06	3.22	2.26	6.63	2.71	0.31
3937185F2	Evd(s)	SE/4 NW/4	18	39	37E	57.47	15.83	1.06	6.75	0.16	9.17	2.26	3.89	2.85	0.56
3936128E	Evd(s)	SW/4 NW/4	12	39	36E	57.40	15.55	1.23	7.49	0.14	7.37	4.80	2.49	3.02	0.51
3936127E	Evd(s)	SW/4 NW/4	12	39	36E	64.18	15.46	0.78	4.68	0.07	4.07	2.93	4.67	2.81	0.35
3936111D	Evd(s)	NE/4 SE/4	11	39	36E	64.20	15.70	0.73	4.85	0.08	4.57	2.95	2.52	4.10	0.28
HS1005885	Evd(s)	NE/4 SE/4	16	35	31E	65.58	16.62	0.65	3.92	0.05	4.30	2.40	2.59	3.65	0.25
HS1005884	Evd(s)	SE/4 SE/4	9	35	31E	67.68	14.90	0.67	4.46	0.05	3.06	2.22	2.62	4.05	0.28
HS1005888	Evd(s)	NE/4 SW/4	7	35	31E	63.71	16.26	0.99	5.55	0.08	4.05	2.37	2.89	3.72	0.39
MK870752	Evd(s)	SE/4 NW/4	15	38	33E	58.87	16.69	1.01	5.86	0.08	6.92	3.06	4.08	2.90	0.52
MK870760	Evd(s)	NE/4 NW/4	30	38	33E	60.85	16.40	1.07	5.24	0.11	4.42	2.46	5.50	3.44	0.51
MK870765	Evd(s)	SW/4 SW/4	24	36	32E	55.86	16.02	0.60	4.10	0.08	4.36	1.94	2.76	4.05	0.23
MK870864	Evd(s)	SW/4 SE/4	13	39	36E	55.78	16.42	1.32	7.37	0.12	8.29	4.03	3.17	2.85	0.63
MK870868	Evd(s)	SE/4 NW/4	13	39	36E	62.32	15.77	0.92	5.20	0.08	4.44	3.40	4.47	2.99	0.42
HS07318706	Eivd	SW/4 SE/4	2	39	31E	66.01	15.47	0.72	4.50	0.08	3.88	1.99	3.08	3.98	0.30
HS07318710	Eivd	NW/4 SW/4	36	40	31E	63.69	16.06	0.77	4.91	0.09	5.17	3.15	1.75	4.18	0.24
HS07308701	Eian(r)	SE/4 NE/4	1	36	32E	62.16	15.90	0.84	5.31	0.08	5.89	2.95	2.94	3.56	0.36
HS07308702	Eian(r)	NW/4 SW/4	6	36	32E	57.95	15.90	1.14	6.91	0.12	6.31	4.72	2.38	3.99	0.58
HS1005889	Center	Center	7	35	31E	64.50	16.21	0.85	4.69	0.08	4.20	2.03	3.44	3.67	0.32
MK870865	SE/4 SE/4	SE/4 SE/4	13	39	36E	73.38	15.81	0.32	1.50	0.01	0.37	0.83	4.46	3.22	0.10
3937075G	NE/4 NW/4	NE/4 NW/4	7	39	37E	68.02	16.56	0.62	2.47	0.02	1.11	0.89	5.47	4.54	0.30
3937074E	SW/4 NE/4	SW/4 NE/4	7	39	37E	68.15	15.28	0.54	2.83	0.06	1.84	1.43	5.32	4.28	0.28
3937073E	SW/4 NE/4	SW/4 NE/4	7	39	37E	71.12	15.30	0.41	2.11	0.03	1.48	0.68	4.71	4.02	0.14
HS08018703	Eida	NW/4 NE/4	16	35	32E	69.67	15.73	0.41	2.34	0.05	2.89	1.27	3.30	4.21	0.15
3738343F	Eib(k)	SW/4 NE/4	34	37	38E	58.07	14.51	1.91	10.43	0.17	4.41	4.41	0.27	5.47	0.36
3638033B	Eib(k)	SW/4 SE/4	3	36	38E	54.73	16.42	1.23	11.14	0.19	4.82	5.10	0.54	5.67	0.16
3637181A	Eib(k)	SE/4 SE/4	18	36	37E	50.53	14.60	1.86	12.23	0.20	8.39	7.52	0.57	4.01	0.10
3638103H	Eib(k)	NW/4 NE/4	10	36	38E	51.91	19.22	0.81	9.80	0.18	7.45	4.74	0.90	4.88	0.11
HS07318712	Eib(t)	SW/4 NE/4	25	40	31E	56.55	16.57	1.42	7.30	0.13	6.79	3.70	2.57	4.31	0.66
MK870501	Eian _r	SW/4 SW/4	26	37	32E	50.77	16.69	2.31	11.27	0.27	7.42	5.73	1.28	3.91	0.34

Table 3. Trace element geochemistry data, Republic 1:100,000 quadrangle; analyses by XRF, Washington State University; locations given in Table 2.

Sample	Map Symbol	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn
N3933226H	Evdv(k)	23	42	11	79	863	35	842	231	22	21.0	12	25	67
N3933225G	Evdv(k)	28	73	14	106	1019	83	736	288	27	27.0	19	36	94
N3933167E	Evdv(k)	23	39	14	104	1233	105	733	305	36	25.0	17	29	85
N3933166E	Evdv(k)	14	37	21	136	1359	120	858	250	29	34.0	17	20	78
N3933158D	Evdv(k)	19	36	9	67	1175	84	455	207	27	12.0	14	25	66
N3933156B	Evdv(k)	16	57	17	118	1450	66	973	251	25	31.0	19	20	81
3937076C1	Evdv(k)	17	48	17	101	1158	89	878	249	21	22.0	20	37	77
3937067A	Evdv(k)	16	41	16	81	1600	107	801	244	23	21.0	17	26	76
3936011B2	Evdv(k)	16	41	15	93	1094	71	823	245	21	22.0	19	29	80
3933277H	Evdv(k)	59	88	12	74	922	55	577	195	19	11.0	19	30	65
3933276H	Evdv(k)	58	85	11	82	826	67	500	194	18	12.0	19	35	69
3933275G	Evdv(k)	66	103	17	100	970	101	442	212	21	10.0	19	48	76
3933226A	Evdv(k)	60	88	13	89	908	74	609	197	20	11.0	19	39	67
3932063D	Evdv(k)	39	62	8	101	1172	95	623	261	27	16.0	22	29	85
3931226H	Evdv(k)	14	12	8	78	1174	104	497	171	18	9.0	22	8	52
3931157C	Evdv(k)	16	11	10	67	1131	86	497	167	18	9.0	19	7	52
3833316G	Evdv(k)	89	143	16	127	1043	107	566	253	24	15.0	20	32	86
3833168D	Evdv(k)	79	145	19	128	1030	46	684	231	24	23.0	20	45	84
3833094C	Evdv(k)	79	143	19	124	923	59	610	226	24	20.0	17	45	81
3833093C	Evdv(k)	78	141	17	127	952	71	598	229	25	20.0	21	50	93
3732244B	Evdv(k)	42	70	15	112	1106	137	634	255	22	18.0	19	42	85
3732245B	Evdv(k)	40	66	14	109	1077	76	625	252	21	18.0	18	39	81
HS1004884	Evdv(k)	24	49	11	90	961	107	413	196	22	13.0	20	16	64
HS1005883	Evdv(k)	10	1	12	87	1227	91	598	239	25	17.1	18	18	74
HS1005886	Evdv(k)	6	1	12	108	1279	82	672	240	25	24.8	21	14	81
HS1006886	Evdv(k)	12	4	8	41	1188	108	289	144	16	8.8	21	15	45
MK870831	Evdv(k)	49	72	15	115	1268	75	706	275	23	23.8	16	66	89
MK870832	Evdv(k)	39	62	17	101	594	65	417	226	18	20.4	17	60	151
MK870857	Evdv(k)	24	42	14	101	1168	127	611	240	23	22.1	17	29	71
HS07318704	Evdv(k)	21	9	7	47	1297	104	453	177	15	8.3	17	25	55
HS07318709	Evdv(k)	35	56	13	73	1046	79	494	160	17	9.7	15	41	64
HS1006884	Evr(k)	14	2	6	35	1415	111	362	166	15	8.2	14	26	54
HS07308705	Evr(k)	15	10	6	34	1384	98	375	186	17	7.7	15	26	70
HS07308706	Evr(k)	15	3	5	59	1566	137	219	162	16	8.2	18	20	45
HS07308707	Evr(k)	17	6	7	42	1115	108	413	137	16	5.5	16	28	57
HS07318703	Evr(k)	11	7	6	44	1478	118	358	166	16	7.6	15	26	39
HS07318705	Evr(k)	16	9	7	49	1213	105	477	158	14	8.4	17	30	52
MK870822	Evd(k)	23	38	13	89	1258	70	896	173	15	10.3	18	21	66
MK870755	Evd(k)	19	12	6	58	860	89	743	161	14	10.5	19	6	49
MK870758	Evd(k)	91	127	18	108	1462	97	673	193	28	14.5	21	36	73
MK870826	Evd(k)	18	33	14	95	1194	67	794	167	17	10.9	19	38	69
HS1004881C	Evt(k)	33	98	13	109	1362	82	910	232	18	18.7	20	15	79
MK870806	Evd(s)	35	65	12	62	1687	276	2032	326	24	39.6	19	21	59
3937185F2	Evd(s)	76	231	23	122	1762	123	1043	332	27	44.0	21	39	85
3936128E	Evd(s)	50	201	23	172	1256	56	906	253	27	21.0	19	24	99
3936127E	Evd(s)	32	73	14	82	1361	152	752	308	24	32.0	20	22	68
3936111D	Evd(s)	27	53	13	96	1268	55	1001	191	18	12.6	21	22	68
HS1005885	Evd(s)	19	38	11	84	1413	55	863	169	14	11.1	21	19	68
HS1005884	Evd(s)	29	62	12	81	1297	59	750	175	15	11.5	14	15	68
HS1005888	Evd(s)	26	38	12	111	1552	75	487	218	24	20.8	17	33	80
MK870752	Evd(s)	46	145	19	121	1287	137	705	328	27	39.4	21	30	81
MK870760	Evd(s)	36	128	16	123	2000	202	870	341	31	46.5	19	23	92
MK870765	Evd(s)	19	30	12	49	1258	68	774	167	16	10.4	18	37	63
MK870864	Evd(s)	14	93	26	206	1371	78	991	220	27	25.8	19	31	88
MK870868	Evd(s)	41	114	15	92	1422	153	812	346	26	41.8	21	28	77
HS07318706	Eivd	18	18	13	91	1077	69	501	240	26	17.1	17	45	73
HS07318710	Eivd	34	65	17	110	930	74	519	181	21	12.4	16	30	68
HS07308701	Eian(r)	28	89	16	129	1311	75	961	221	22	16.2	20	29	88
HS07308702	Eian(r)	77	148	18	134	1148	58	836	241	27	29.5	15	44	89
HS1005889	--- ---	12	8	10	106	1243	115	470	242	25	21.1	18	10	75
MK870865	--- ---	19	11	3	26	1089	166	258	119	10	6.7	20	16	43
3937075G	--- ---	31	75	8	65	1617	170	818	299	19	47.7	16	27	54
3937074E	--- ---	30	79	5	42	1490	194	791	257	20	37.0	15	25	59
3937073E	--- ---	18	10	5	30	1393	164	818	190	15	26.3	20	26	55
HS08018703	Eida	21	20	7	47	1371	81	942	165	15	10.2	20	21	46
3738343F	Eib(k)	3	13	27	283	185	6	313	170	37	7.0	22	270	73
3638033B	Eib(k)	15	46	35	376	486	16	425	91	20	4.0	19	216	70
3637181A	Eib(k)	21	47	46	626	317	12	370	75	19	3.0	12	3	55
3638103H	Eib(k)	20	50	31	271	581	34	636	78	17	3.0	14	145	72
HS07318712	Eib(t)	22	47	23	164	1142	65	826	287	33	40.6	17	29	90
MK870501	Eianr	40	105	26	248	432	35	393	187	31	14.2	19	87	101