Plutonism, Volcanism and Sedimentation Associated with Core Complex and Graben Development in the Central Okanogan Highlands, Washington
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INTRODUCTION

The central Okanogan Highlands in north-central Washington, bounded by the Columbia River on the east and south and the Okanogan River on the west, is characterized by: (1) Paleocene-Eocene intrusions of the Colville batholith, (2) three en echelon, NNE-trending, volcanic- and volcanioclastic-filled grabens, and (3) dominantly amphibolite-grade metamorphic rocks of the Kettle and Okanogan core complexes (gneiss domes) (Fig. 1). These rocks comprise the southwesternmost part of the Omineca crystalline belt. The locations of 12 fieldtrip stops in and adjacent to the Republican graben are shown in Figure 1 and discussed below.

Plutonic rocks

The numerous plutonic igneous intrusions in the central Okanogan Highlands are referred to collectively as the Colville batholith. Originally named by Pardee (1918) for exposures on the Colville Indian Reservation, most of the batholith has been subdivided on the basis of field evidence, mineral composition, and major element chemical composition into three intrusive suites, which are, from oldest to youngest, the Keller Butte suite, the Devils Elbow suite, and the Herron Creek suite (Holder and Holder, 1988). Distinctive characteristics of these suites are summarized in Table 1. Locations of intrusions in the suites are shown in Figure 2.

Rocks of the Keller Butte suite are texturally varied (fine to very coarse grained), light colored, hornblende-free biotite granite and granodiorite (Fig. 3) with abundant aplo-pegmatite veins, dikes, and pods. Distinctive features of the Keller Butte suite include its lack of hornblende, low color index, and widespread penetrative mineral fabrics where these intrusions are within or adjacent to the gneiss domes or metamorphic core complexes in the region.

The Devils Elbow suite includes several medium-grained, equigranular biotite-hornblende diorite-quartz monzodiorite-granodiorite plutons (Fig. 3) that are much darker than those of the Keller Butte suite; mafic minerals typically comprise 20 to 25 percent of Devils Elbow suite rock. Unambiguous cross-cutting relations documented at several localities indicate that the Devils Elbow suite is younger than the Keller Butte suite (Atwater and Rinehart, 1984; Carlson, 1984; C. D. Rinehart, oral commun., 1984; Moye, 1984; G. M. Holder, 1985; Holder, 1986). In contrast to the Keller Butte suite, the rocks of the Devils Elbow suite have been affected only very locally and mildly by deformation associated with core-complex development.

Each member of the Herron Creek intrusive suite is composed of: (1) an older medium- to coarse-grained, inequigranular or...
Figure 1. Generalized geologic map of the central Okanogan Highlands showing intrusive rocks of the Colville batholith (shaded), dominantly volcanic and volcaniclastic rocks in the grabens (stippled), and areas affected by penetrative mylonitic deformation associated with the gneiss domes (dashed). Graben-bounding faults, solid bold lines; limit of core complex deformation, dotted line; major highways, intermediate weight solid lines. Bold numerals are fieldtrip stops.
Figure 2. Index map showing the names and locations of intrusions in the Keller Butte suite, Devils Elbow suite, and Herron Creek suite. (From Holder and Holder, 1988; with permission, Geological Society of America Bulletin, v. 100, p. 1971-1980.)
hornblende-biotite quartz monzonite with abundant mafic clots, commonly containing cores of clinopyroxene, and (2) a younger, fine-grained, gray to brown, hornblende-biotite granite or “microgranite” (Fig. 3). In some Herron Creek suite intrusions, the microgranite is the dominant lithology, whereas in others inequigranular quartz monzonite is most abundant. In every place where relative age relations can be ascertained, the microgranite cuts or contains inclusions of the quartz monzonite. Herron Creek suite intrusions are normally associated with the Devils Elbow suite intrusions. Quartz monzonite of the Herron Creek suite contains foliated quartz monzodiorite inclusions of the Devils Elbow suite along the southern contact between the Kettle Crest pluton and Fire Mountain pluton (Fig. 2; G. M. Holder, 1985), and a dike of Herron Creek suite cuts the Henry Creek diorite (Fig. 2) (G. M. Holder, unpublished data). Contacts between Herron Creek suite quartz monzonite and the Devils Elbow suite range from gradational to razor sharp; relative age determinations are generally difficult to make. Herron Creek suite microgranite also cuts rocks of the Devils Elbow suite (see below).

Compilations of K-Ar ages for biotite in rocks in the central Okanogan Highlands (Fox and others, 1976, 1977; Pearson and Obradovich, 1977; Atwater and Rinehart, 1984) indicate a Paleocene to Eocene age (61-49 Ma) for the Keller Butte suite. However, thermal degradation of biotite in this suite in response to emplacement of the younger Devils Elbow and Herron Creek suites (Fox and others, 1976) requires that these ages be regarded as minimum. Biotite and hornblende ages from the Herron Creek and Devils Elbow suites indicate an Eocene age of between 45 and 53 Ma. The most believable and geologically significant ages are the concordant or nearly concordant biotite and hornblende ages from samples of the Swimptkin Creek pluton (49 Ma) and Kettle Crest pluton (45-47 Ma), both of the Devils Elbow suite.

Volcanic Rocks and Volcaniclastic Sedimentary Rocks

Eocene volcanic and volcaniclastic sedimentary rocks in the Republican graben have been subdivided into three formal stratigraphic units, in ascending order: O’Brien Creek Formation, Sanpoil Volcanics, and Klon–dike Mountain Formation (Muessig, 1967; Pearson and Obradovich, 1977) (Fig. 4). The O’Brien Creek Formation consists mainly of crystal-lithic tuffs and tuffaceous epiclastic (re-worked volcanic) sediments; the maximum exposed thickness of O’Brien Creek strata exceeds 1,200 m (Muessig, 1967). Correlative strata in north–eastern Washington yield a K-Ar biotite age of 54.5 Ma (Pearson and Obradovich, 1977, as corrected by Fox and Beck, 1985).
Figure 3. Modal analyses from the Henon Creek, Devils Elbow, and Keller Butte suites. Q, quartz; A, alkali feldspar; P, plagioclase feldspar. Field boundaries after Streckeisen (1976): (1) syenogranite; (2) monzogranite; (3) granodiorite; (4) tonalite; (5) syenite; (6) quartz monzonite; (7) quartz monzodiorite and quartz monzogabbro; (8) quartz diorite and quartz gabbro; (9) monzodiorite and monzogabbro; (10) diorite and gabbro. In (C) the open symbols and Xs represent modes of younger fine-grained rocks (microgranite), and the solid symbols represent modes of older medium-grained, inequigranular rocks. The Long Alec Creek granodiorite of the Devils Elbow suite occurs as large xenoliths in the Long Alec Creek pluton (Charles Knaack, Washington State Univ., oral commun., 1988). (From Holder and Holder, 1988; with permission. Geological Society of America Bulletin, v. 100, p. 1971-1980.)
The Sanpoil Volcanics are composed primarily of lithoidal, porphyritic andesite and dacite lava flows, volcanic breccia and tuffs, and minor glassy lava flows and epiclastic sediments (Muessig, 1967; Pearson and Obradovich, 1977; Moye, 1984). The thickness of the Sanpoil Volcanics in the Republic graben exceeds 2,500 m (Muessig, 1967). K-Ar ages from the Sanpoil Volcanics range from 53.8 to 49.6 Ma (Pearson and Obradovich, 1977, as corrected by Fox and Beck, 1985).

The Klondike Mountain Formation consists of interstratified fine- to coarse-grained fossiliferous epiclastic sediments and minor andesite flows overlain by glassy lava flows (Muessig, 1967; Pearson and Obradovich, 1977; Gaylord and others, 1987, 1988). Recent research suggests that the total thickness of Klondike Mountain Formation strata in the Republic graben exceeds 1,000 m (D. R. Gaylord and S. M. Price, unpub. data). K-Ar dates from this stratigraphic sequence are inconclusive but suggest that deposition occurred during the Eocene between about 53.8 and 49.6 Ma (Pearson and Obradovich, 1977, as corrected by Fox and Beck, 1985).

Extensive dike swarms and small hypabyssal bodies of older high-K rhyolite and younger high-K hornblende dacite and andesite also occur within and adjacent to the Republic graben. The rhyolite dikes riddle plutonic rocks of the Keller Butte suite but predate the Devils Elbow suite (Atwater and Rinehart, 1984; Holder, 1986) and are thought to be the intrusive equivalent of the O’Brien Creek Formation (Pearson and Obradovich, 1977). The dacite and andesite dikes are correlative with the Scatter Creek Formation (nomenclature of Parker and Calkins, 1964), which is a hypabyssal intrusive equivalent of the Sanpoil Volcanics (Muessig, 1967).

Several lines of evidence lead to the conclusion, inferred by Moye (1984), that the Devils Elbow and Herron Creek suites are largely coeval and possibly comagmatic with the Sanpoil Volcanics and rhyolite domes that intrude the Sanpoil. The evidence includes: (1) the Devils Elbow and Herron Creek suites postdate the biotite rhyolite dikes but predate Klondike Mountain Formation volcanism (Muessig, 1967); (2) both the Devils Elbow suite and the medium-grained quartz monzonite intrusions of the Herron Creek suite grade into the hypabyssal Scatter Creek Formation (Muessig, 1967; Carlson, 1984; Moye, 1984; G. M. Holder, 1985; Holder, 1986); (3) the younger microgranite intrusions in the Herron Creek suite cut across the hornblende dacite bodies in several locations (Muessig, 1967; G. M. Holder, 1985; Holder, 1986), suggesting the microgranite may correlate with rhyolite domes that intrude the Sanpoil (Moye, 1984); and (4) the Devils Elbow suite and medium-grained quartz monzonite intrusions of the Herron Creek suite are chemically similar to the Sanpoil Volcanics (Moye, 1984; G. M. Holder, unpub. data). Klondike Mountain Formation sedimentation and volcanism appear to postdate any recognized plutonic activity. Deposition of sedimentary strata in the lower part of the formation appears to have been restricted to local basins whose original margins are, in many places, obscured by postdepositional faulting.

**Structural Relations of Plutonic, Volcanic, and Sedimentary Rocks with Associated Graben and Gneiss Dome Structures**

Keller Butte suite intrusives were largely emplaced during Paleogene regional mylonitic deformation that formed the gneiss domes (Waters and Krauskopf, 1941; Pearson, 1967; Fox and others, 1976; Atwater, 1985; R. W. Holder, 1985), although some may predate dome formation. As a result, they commonly display the penetrative, generally west-trending mineral lineation characteristic of high-grade metapelitic rocks of the domes. In addition, at least one Keller Butte suite intrusion, the Coyote Creek pluton (Fig. 2), was emplaced during contemporaneous development of the Okanogan gneiss dome and the Republic graben (Atwater, 1985). Other suspected Keller Butte suite intrusives are so intensely deformed that they form layers of granitic ortho-gneiss within the high-grade metamorphic rocks of the domes.
Field evidence indicates that emplacement of the Devils Elbow suite was also contemporaneous with the formation of the Republic graben and Okanogan and Kettle gneiss domes. Intrusive contacts of this suite and associated Scatter Creek dikes commonly strike parallel to graben-bounding faults (Fig. 2) (Atwater and Rinehart, 1984; Moye, 1984; Holder, 1986), reflecting structural control by the graben on their emplacement. Some of the graben faults remained active long after solidification of the Devils Elbow suite, truncating both Devils Elbow suite and Herron Creek suite rocks (G. M. Holder, 1985; see below). These field relations require that the graben faults were active both before and after emplacement of the Devils Elbow suite, related Scatter Creek dikes, and any Sanpoil Volcanics coeval with the Devils Elbow suite and that the grabens must be, at least in part, Eocene in age.

Both the Swimptkin Creek and the Kettle Crest plutons of the Devils Elbow suite cut across deformed rocks in adjacent gneiss domes (Fox and others, 1976; Singer, 1984; G. M. Holder, 1985; Holder, 1986). However, both the western part of the Swimptkin Creek pluton adjacent to the Okanogan dome and the southern and southeastern parts of the Kettle Crest pluton adjacent to the Kettle dome are deformed along with the rocks they intrude. Locally, they are thoroughly mylonitized. The deformed rocks have mineral lineations parallel to the characteristic lineations of the gneiss domes (Singer, 1984; G. M. Holder, 1985; R. W. Holder, 1985, 1986). The observation that these two intrusions both cut and are deformed along with gneiss dome rocks suggests that the Devils Elbow suite was emplaced during the waning stages of mylonitic deformation associated with the domes. This indicates that dome formation extended well into Eocene time, and confirms Atwater’s (1985) conclusion (noted above) that the Okanogan gneiss dome and Republic graben are contemporaneous.

The Herron Creek suite intrusions and those Scatter Creek dikes and upper Sanpoil Volcanics flows thought to be coeval with the Herron Creek suite predate the last movements along graben-bounding faults. However, these rocks are nowhere revealed any hint of deformation related to gneiss domes and may postdate dome formation.

It follows from the discussions above that the early biotite rhyolite intrusives and those Scatter Creek dikes and Sanpoil Volcanics flows correlative with the Devils Elbow suite were intruded or erupted during deformation of the gneiss domes. Though these dikes have not been observed to have been affected by dome-related regional mylonitic deformation, the extensive dike swarms flanking the east side of the Republic graben on the Colville Indian Reservation strike and dip perpendicular to stretching lineations in adjacent foliated granite in the Kettle gneiss dome (Holder, 1986). Tertiary regional extension in the central Okanogan Highlands was apparently accommodated by largely simultaneous regional ductile stretching (gneiss domes) and brittle development of extension fractures (grabens and dike swarms) with parallel ductile stretching and fracture dilation. In summary, intrusion of the Keller Butte and Devils Elbow suites, deposition of the O’Brien Creek Formation and the Sanpoil Volcanics, core complex emplacement, and Republic graben development are broadly contemporaneous and largely of early Tertiary (Paleogene) age. Extrusion of the upper Sanpoil Volcanics, intrusion of the Herron Creek suite, epiclastic sedimentation associated with Sanpoil volcanism, and Klondike Mountain Formation deposition apparently postdate regional mylonitization but predate the final stages of graben subsidence.

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REFERENCES CITED


Road Log
Cumulative mileage is given on the left, interval mileage in parentheses.

0.0 (0.0) Start at the junction of Washington State Routes (SR) 20 and 21 N, 3 mi east of Republic. Set odometer to 0. Drive 6.8 mi east on SR 20 to the O’Brien Creek Road. Turn right (south) and proceed 1.0 mi on the O’Brien Creek Road.

7.8 (7.8) STOP 1. O’Brien Creek Formation.
Gray-white epiclastic and pyroclastic rocks of the O’Brien Creek Formation, which form the white flaggy bench midway up the slope 100 m north of the road, are the oldest of the Paleogene sedimentary and volcanic strata in the Republic graben. O’Brien Creek rocks are characterized by tuffaceous sandstone and conglomerate that unconformably overlie Paleozoic and Mesozoic metasedimentary units. Dark gray, angular, granule-sized slate and phyllite clasts are abundant in the O’Brien Creek sequence. Alteration of the ash obscures stratification and makes distinction between epiclastic and pyroclastic sequences in this unit difficult.

At this stop, the O’Brien Creek Formation exhibits evidence of rapid deposition and loading, including massive to crude stratification, normal grading, and flame structures. Elsewhere in the graben, O’Brien Creek Formation sediments are generally poorly sorted and crudely stratified. Primary sedimentary structures and lithofacies associations suggest that deposition occurred primarily in subaerial (probably alluvial) settings. The O’Brien Creek Formation at this exposure, as in many other places near the graben margin, is intruded by a Scatter Creek dike. The Scatter Creek forms gray cliffy exposures upslope of the O’Brien Creek Formation. The contacts and chill zones between these two units are not well exposed; however, xenoliths of O’Brien Creek Formation have been incorporated in the Scatter Creek dike.

Continue south on the O’Brien Creek Road 3.0 mi. Turn right (west) onto the Snow Peak Road (unlabeled, T-junction). Drive 0.7 mi to the junction with the Hall Creek Road (FSR 2050). Turn left (south). Bear right at Y-junction (2.0 mi) onto the Ninemile Road (FSR 2053). Drive 4.5 mi along the Ninemile Road to the junction with the Refrigerator Canyon Road. Turn right (north) and continue 0.1 mi.

(10.3) STOP 2A. Sanpoil Volcanics.
Sanpoil Volcanics form the bulk of exposures in the Republic graben. One of several displays of columnar jointing in andesitic to dacitic Sanpoil lavas is present across the small valley to the east. This exposure and localized horizontal colonnades visible in cliffs along the Sanpoil River and its side canyons may represent in-tracanyon flows that filled drainages eroded into older Sanpoil flows. Continue north on the Refrigerator Canyon Road for an additional 1.0 mi.

(1.0) STOP 2B. Sanpoil Volcanics.
On the cliff to the east, the dip of the Sanpoil flows is highlighted by bands of columnar-jointed lavas. The structure of the Sanpoil Volcanics in the Republic graben is complex. However, in general, the central part of the Republic graben, from just north of Republic south to the Colville Indian Reservation, forms a poorly defined, asymmetric, north-trending syncline, the axis of which roughly corresponds to the Sanpoil River valley (Muessig, 1967).

Continue north on the Refrigerator Canyon Road 1.0 mi to the junction with the Hall Creek Road. Turn left (west) and drive 1.75 mi to SR 20. Turn left (west) onto SR 20 and drive 7.7 mi to the intersection of 6th and Clark Streets (at the flashing yellow light) in the center of the town of Republic. Turn left on SR 20 (toward Tonasket) and continue 0.55 mi to the outcrop on the right (north) side of the road.

(11.0) STOP 3. O’Brien Creek Formation and upper Sanpoil Volcanics.
The bleached, tuffaceous, epiclastic sediments of the O’Brien Creek Formation also seen at the first stop are well exposed along this part of the roadcut. Note the abundance of angular, granule-sized phyllite and slate clasts in the sandstones and conglomerates of these gently dipping strata. Brown-gray intrusive rocks of Scatter Creek, with near-vertical contacts, cut O’Brien Creek strata in this exposure.

Walk along the north side of the road east toward town. The NNW-trending valley you traverse corresponds with the trace of the Eureka fault, a major intragraben structure along which an
estimated 500 m of displacement between the O’Brien Creek Formation strata (footwall) and Sanpoil Volcanics (hanging wall) has occurred. Highly altered strata of the upper part of the Sanpoil Volcanics, including a thick sequence of altered sandstones and cobble and boulder conglomerates, are exposed in the roadcut closest to town.

Return to the vehicles and drive 0.55 mi east on SR 20 back to the intersection of 6th and Clark Streets (flashing red light) in the center of Republic. Turn left at this intersection and drive 0.15 mi to the T. Turn left at the T and drive 0.15 mi along the Trout Creek Road. Park on the left (west) side of the road.

(0.85) STOP 4. Contact of the Sanpoil Volcanics and Klondike Mountain Formation.

The 10-m-high roadcut across the road from where you are parked exposes strata just above the contact between the Sanpoil Volcanics and the Klondike Mountain Formation (following the stratigraphic guidelines of Muessig, 1967). As noted by Muessig (1967), the contact is nowhere well exposed in the Republic Mining District. The conglomerates at the base of the exposure contain reworked pebble- to boulder-sized andesite and dacite clasts of the Sanpoil Volcanics. These conglomerates are overlain by laminated and thin-bedded mudstones and siltstones of the lowermost strata of the Klondike Mountain Formation. The conglomerate beds are alluvial in origin, whereas the mudstones and siltstones reflect dominantly lacustrine sedimentation.

Exposures of the Klondike Mountain Formation in the Republic graben are concentrated in two areas. The first encompasses approximately 50 km in the Republic Mining District and the second covers about 100 km2 (15 km to the north) near Curlew, Washington. Klondike Mountain Formation strata in the Republic Mining District are apparently conformable with the underlying Sanpoil Volcanics (Fig. 5). Detailed sedimentologic studies of the Klondike Mountain Formation have been undertaken only in the Republic Mining District. The limited extent of Klondike Mountain Formation strata in the graben largely reflects preferential preservation due to intragraben faulting. Gold mineralization (in older strata) commonly occurs beneath areas where Klondike Mountain Formation strata are preserved.

Sedimentary strata of the Klondike Mountain Formation coarsen upward from mudstones and siltstones in the lower one-third to sandstones in the middle one-third, to conglomerates and interstratified coarse sandstones and conglomerates in the upper one-third of the unit (Fig. 5). An episode of erosion and fluvial incision that followed deposition of the coarse-grained sediments in the upper part of the unit produced a local topographic relief of at least 150 m. Laterally extensive, black, glassy andesite flows cap the Klondike Mountain Formation sequence in this area and preserve the underlying paleorelief. The total composite thickness of the Klondike Mountain Formation in the Republic Mining District is approximately 1,000 m (D. R. Gaylord and S. M. Price, unpub. data).

Continue north 0.4 mi on the Trout Creek Road to the Couse Road (a private road). Turn right and drive 0.15 mi past the building. Park vehicles and walk approximately 150 m along the abandoned drill site access road.

31.50 (0.55) STOP 5. Fossiliferous beds in the lower part of the Klondike Mountain Formation.

The mudstones, siltstones, and some heterolithic sandstones from the lowest one-third of the Klondike Mountain Formation are renowned for
their preservation of abundant plant, fish, and insect fossils. Wolfe and Wehr (1987) have identified 24 species of dicotyledonous plants in equivalent (Eocene) strata in the Republic and Toroda Creek grabens. They surmise that the flora grew in an upland microthermal mixed coniferous forest 700 to 900 m above sea level.

Drive back 0.15 mi to the Couse Road-Trout Creek Road intersection and turn right. Proceed 0.9 mi to the county road with a sign ‘Not the Mine Entrance’ on the right. Turn right and drive 0.3 mi along the county road (past the baseball field on the right) until you reach the T-intersection. At the T, turn left onto the gravel mine road and proceed 0.4 mi uphill to the tailings pond.

33.25 (1.75) **STOP 6. Lacustrine and turbidite deposits of the Klondike Mountain Formation.**

The lake basins in which much of the Klondike Mountain Formation accumulated were subject to periodic rapid infilling by sediment-laden streams. As a result, the fine-grained suspension deposits of the lakes are intercalated with both proximal and distal turbidites. Coarse-grained turbidites are most common in the middle third of the Klondike Mountain Formation sequence (Fig. 5). A number of 10- to 15-cm-thick (Bouma) ABE turbidite sequences (Bouma, 1962) are visible in this exposure. Notice that mafic dikes and sills have baked, intruded, and altered this epiclastic sequence.

Drive back along the mine road 0.4 mi to the T-junction. Continue east past the T along the county road. Turn left (north) 0.3 mi from the T in order to continue along the county road. Drive for 2.8 mi on the county road past the radio tower at the crest of the ridge.

(3.5) **STOP 7. Conglomerate beds and glassy volcanic flows of the Klondike Mountain Formation.**

The conglomerates and coarse-grained sandstones that characterize the upper one-third of the Klondike Mountain Formation typically are poorly exposed. This stop is no exception. However, as you walk toward the black, glassy, andesite flows prominently exposed on the ridge crest you will see a matrix-supported pebble, cobble, and boulder conglomerate exposed on the surface. The andesite and dacite clasts were derived from erosion of the Sanpoil Volcanics. Deposition probably occurred on alluvial fans. Fluvial incision during a subsequent hiatus created deep valleys into which the overlying andesites flowed. The flows are less than 100 m thick in the Republic Mining District but are two to three times thicker in the northern Republic graben and in the Toroda Creek graben (Parker and Calkins, 1964; Pearson, 1967). Return to the Trout Creek Road intersection (3.4 mi), turn right and drive 2.1 mi north.

(5.5) **STOP 8. Bacon Creek fault zone.**

The scarp of the Bacon Creek fault is clearly exposed on the east side of the road. The graben margin fault juxtaposes rocks of the Herron Creek suite (to the west) against Sanpoil Volcanics (to the east). The fault zone is characterized by intense brecciation of wall rocks; slickensides are visible on the overhanging surface of the outcrop. The lithology and composition of the fragments within the fault zone are difficult to determine due to alteration.

Drive north 250 ft, turn left onto a logging road through the green metal gate, and continue 0.5 mi to outcrop on left (west). Climb 15 ft to natural outcrop exposure above the roadcut.

(0.50) **STOP 9. Quartz monzonite and microgranite of the Herron Creek suite.**

Both principal rock types of the Herron Creek suite are well exposed on the eastern slope of Stormking Mountain adjacent to and west of the Bacon Creek fault; Herron Creek suite microgranite intrudes Herron Creek suite quartz monzonite. The contact here is a textbook example of a chilled margin, but the contact is more commonly gradational over a few inches or is sharp, without chilling (see below).

Chlorite-filled fractures with slickenside striations at the base of the outcrop reflect proximity to the Bacon Creek fault.

Return 4.5 mi to the stoplight in Republic. Drive 2.5 mi west on SR 20; turn left (south) at junction with Swamp Creek Road. At 9.8 mi, turn right onto FSR 5314. Bear right at Y-junction at 5.0 mi, odometer reading 54.25, and follow directions to Swan Lake (FSR 5330). After 1.8 mi on FSR 5314, turn left (east) onto a small spur road (FSR 5314-450) and drive 0.1 mi into the quarry floor.

61.25 (18.45) **STOP 10. Leucocratic biotite granite and granodiorite of the Keller Butte suite.**

The Keller Butte suite consists of large plutons of light colored biotite granite and granodiorite with locally abundant and common garnetiferous aplo-pegmatite (Figs. 2, 3). Penetrative mineral fabrics are characteristic of these intrusions adjacent to or within areas affected by mylonitic deformation associated with the Kettle and Okanogan domes and are largely absent away from these areas. In this
quarry on the eastern edge of the Okanogan gneiss dome, main phase granodiorite with a well-developed mineral fabric is cut by several pegmatite veins and dikes. Both the granodiorite and pegmatite contain garnet. Garnet in the main phase of Keller Butte suite rocks is atypical. Xenoliths of garnet-biotite schist in various stages of digestion have been observed in this area and suggest the garnet in the main phase may be xenocrystic.

Return 0.1 mi to FSR 5314, and drive south (left) 4.5 mi to the Scatter Creek Road (FSR 53). Turn right and continue 7.3 mi to the junction with SR 21. Turn left (north) and drive 7.0 mi. Turn right at the junction with SR 20; drive 3.0 mi. Then bear left at breakoff of SR 21 north to Curlew. After 19.0 mi, turn right onto the West Deer Creek Road (unlabeled) across from the Blue Cougar Café. At 0.3 mi, keep right and follow arrow to U.S. Highway 395, bypassing the town of Curlew on the east. Park at the east end of the roadcut on the spur road on the north side of the road, 9.55 mi past the junction with the fork into the town of Curlew.

120.00 (50.75) **STOP 11. Herron Creek suite microgranite and quartz monzonite of the Long Alec Creek pluton.**

The largest known mass of microgranite in the Herron Creek suite makes up most of the Long Alec Creek pluton (Fig. 2). Xenoliths of quartz monzonite of the Herron Creek suite are included in the microgranite. Basaltic dikes of unknown age, representing a very late episode of magmatism in the Okanogan Highlands, cut both the quartz monzonite and the microgranite.

Continue east on the West Deer Creek Road 1.8 mi to Deer Creek Summit. Walk about 150 ft along the road to the large outcrop on the left.

113.80 (1.8) **STOP 12. Quartz monzodiorite of the Devils Elbow suite.**

At the Deer Creek Summit, microgranite dikes of the Herron Creek suite cut medium-grained, equigranular biotite-hornblende quartz monzodiorite of the Devils Elbow suite. Devils Elbow suite rocks have a remarkably uniform texture and composition throughout the region. The large outcrops of Devils Elbow suite at this stop are thought to be slope blocks in the Herron Creek suite Long Alec Creek body (Charles Knaack, Washington State Univ., oral commun., 1988).