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Title of article Structure and Chronology of the Oval Peak Batholith and Adjacent Rocks: Implications for the Ross Lake Fault Zone, North Cascades, Washington

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see Bulletin v. 102, p. 1361 - 1377

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APPENDIX 1. ADDITIONAL DESCRIPTIONS OF ROCK UNITS

Twisp Valley Schist

In the Scaffold Peak area, strained andalusite, staurolite, and microfolded sillimanite occur within 20 m of the Oval Peak batholith. Recrystallization of the schist elsewhere generally outlasted deformation during metamorphism. Sheets of leucogneiss that are probably related to the Lake Juanita leucogneiss are abundant in the southern part of the envelope of Twisp Valley Schist; in places the schist is present only as screens. The three generations of folds in the schist are distinctly non-cylindrical because of widespread refolding. \( F_1 \) and \( F_2 \) have wavelengths of < 0.5 m. Several orders of \( F_3 \) are common, and generally have wavelengths of 5 cm to 3 m, but locally exceeding 50 m. Crenulations of \( S_{1-2} \) occur in lower-grade rocks.

Skagit Gneiss

Battle Mountain Gneiss

The Battle Mountain gneiss is locally interlayered with sills of Tuckaway Lake gneiss on a scale of 10 cm and in areas with abundant sills the contact is mapped at the last occurrence of the Battle Mountain gneiss.

The dominant metamorphic assemblage is plagioclase (45-50%) - hornblende (10-15%) - biotite (~15%) - quartz (~20%) - sphene (1-2%) \pm\ epidote (0-10%). Foliation defined by biotite, hornblende and sphene wraps around plagioclase
porphyroclasts which show relict oscillatory zoning, synneusis and bent deformation twins. Some porphyroclasts are elongate in foliation. Recrystallized plagioclase (–An₁₆ to An₃₀) forms a fine- to medium-grained mosaic with quartz; the latter displays deformation bands and subgrains. Quartz porphyroclasts and partially recrystallized ribbons occur locally; aspect ratios reach 5:1. Medium- to less commonly coarse-grained hornblende is locally poikiloblastic. Hornblendes in a few samples show pale rims and minor patchy replacement of cores by pale-green amphibole. Epidote locally has allanite cores and simple twins, and forms fine- to medium-grained mosaics with quartz and plagioclase. Medium-grained biotite is weakly bent and undulose; it has replaced hornblende locally. Sphene occurs both as euhedral relics and as smaller metamorphic grains. Amphibolite-facies metamorphism may have been slightly higher grade to the south, as: epidote occurs only in the NW part of the outcrop belt; biotite is deep red-brown in the SE and green-brown in the NW; hornblende is brown-green (Z) in the SE and medium-green (Z) in the NW; and recrystallized plagioclase has a slightly higher anorthite component in the SE.

Tuckaway Lake Gneiss

The dominant metamorphic assemblage is biotite-oligoclase-quartz-opaque ± epidote ± sphene. Foliation in the generally weakly porphyroclastic gneisses is best defined by aligned fine-grained biotite, quartz and plagioclase, and by lenses and layers of biotite and of quartz. Plagioclase (An₂₀ to An₂₄) also occurs less commonly as complexly zoned porphyroclasts. Quartz generally has deformation bands and subgrains. Myrmekite occurs locally in quartz-
plagioclase mosaics. Fine- to medium-grained epidote is concentrated with biotite and sphene, but also occurs in granules within plagioclase porphyroclasts. Epidote locally is poikiloblastic and cored by allanite; it is weakly elongate in foliation.

Enclaves occur rarely in the gneiss. The unit is intruded by undeformed trondhjemites and K-feldspar-rich dikes, including some aplites.

Lake Juanita Leucogneiss

In most leucogneisses, plagioclase (An$_{21}$ to An$_{25}$) occurs both as large relics and as fine- to medium-grained mosaics with quartz. Perthitic orthoclase and quartz commonly are interstitial. Quartz mainly occurs as coarse-grained aggregates; deformation bands, subgrains and recrystallized grains record modest strain. Biotite is fine- to medium-grained, forms stubby and elongate grains, and is commonly red-brown (Z). Medium-grained muscovite is aligned in some samples, but formed by static growth in others. Some large perthites contain inclusions of plagioclase and quartz which define vague zoning. Myrmekitic intergrowths are more abundant than in the Battle Mountain gneiss and Tuckaway Lake gneiss. Sphene is rare, in contrast to the other orthogneiss units of the Skagit Gneiss.

Some areas consist of a locally migmatitic injection complex that shows variably developed foliation. Tonalitic gneiss intruded by the leucogneisses generally is well-recrystallized. Plagioclase (An$_{24}$) in tonalitic gneiss forms a medium- to coarse-grained mosaic and only locally shows oscillatory zoning. Foliation is defined by biotite, elongate quartz and quartz aggregates. Leucogneiss locally is cut by bodies of well-foliated, medium-grained
tonalitic gneiss. In some tonalitic porphyry plagioclase defines glomeroporphyritic texture, and has corroded cores and oscillatory zoning \((\text{An}_{52}-\text{An}_{81})\). Quartz and rare perthite also occur as phenocrysts set in a matrix of quartz and equant plagioclase \((\text{An}_{40})\). Some granite and quartz monzonite pegmatites contain large potassium feldspars, and locally possess small garnets. These pegmatites locally are weakly foliated and rarely folded.

Enclaves within the leucogneiss include medium-grained clots and larger gneissic fragments with higher color indices than the leucogneiss. Most schist enclaves are elongate parallel to foliation in the leucogneiss, and a few are internally complexly folded.

**Oval Peak Batholith**

The overall texture of tonalite in the batholith is hypidiomorphic granular. The biotite-defined magmatic foliation is best developed in the northern finger-like projection of the batholith. Plagioclase shows syneusis and normal and oscillatory zoning; cores are as calcic as \(\text{An}_{55}\) and rims as sodic as \(\text{An}_{10}\). Minor small, generally unzoned plagioclases are interstitial to the larger plagioclases. Large, blocky biotite forms prominent books. Minor strain is recorded in quartz by deformation bands and some subgrains, and there also are local aggregates of recrystallized mosaic. Magmatic epidote in the tonalites either has euhedral boundaries against, or is intergrown with, medium- to coarse-grained biotite. Many epidotes have wormy contacts with plagioclase and quartz, and some contain quartz inclusions. Epidote shows simple twins, and zoned grains with narrow, less ferric rims are common (Libby, 1964). Allanite occurs locally. Epidote occurs throughout the core,
northern "finger" and the northwestern part of the foliated margin, but is scarce to the south. In contrast, hornblende is abundant in the south, but sparse in the northwest. Microcline occurs as an interstitial, fine- to medium-grained phase and rarely is found in mosaics with quartz and as a patchy replacement of plagioclase. Sphene is a widespread accessory mineral. Muscovite and lesser epidote replace plagioclase in some samples. Mafic clots form rare enclaves.

Tonalitic gneiss of the foliated margin displays a mixture of igneous and recrystallization textures. Fine- to medium-grained, unzoned plagioclase typically forms a mosaic with quartz and lesser myrmekite. Some quartz is also coarse-grained and generally shows deformation bands; subgrains and related recrystallized grains are present, but grains showing erratic undulose extinction are also common. Much of the coarse-grained quartz is elongate and aspect ratios of quartz porphyroclasts in mylonites reach 8:1. Some biotites are transverse to foliation, suggesting that recrystallization outlasted deformation. Epidote textures resemble those in the isotropic tonalites. Myrmekite is more abundant in the most recrystallized gneisses.

Some pegmatitic sills contain large plagioclases and K-feldspars surrounded by patches of fine- to medium-grained mosaics of plagioclase, quartz, garnet, K-feldspar, and much myrmekite. In contrast, quartz is very large and only shows deformation bands or erratic extinction in other pegmatites, including some in the strongly foliated margin. Garnet in the pegmatites is fine- to medium-grained, equant and euhedral, and locally forms inclusions in K-feldspar and biotite. Pegmatite dikes are randomly oriented. Tonalite and aplite sills and dikes related to the batholith intrude the Twisp Valley Schist. They typically are 25-50 cm thick and locally occur within
schists of the "tongue" of Twisp Valley Schist for $\geq 35$ m from the contact of the pluton. Minor tonalite porphyries and numerous fine- to medium-grained dikes of intermediate to mafic composition cut the pluton and show little, if any, recrystallization.

**Mylonites in the Foggy Dew Fault Zone**

Intrafolial folds occur rarely in mylonitic gneiss and amphibolite. In mylonitic gneiss, plagioclase best defines S, and C typically is subparallel to compositional layering. Plagioclase porphyroclasts display relict oscillatory zoning and synneusis. Variably recrystallized quartz ribbons are present and aspect ratios of quartz defining oblique foliation exceed 3:1 in some samples. Biotite and muscovite porphyroclasts are medium-grained. In some gneisses, epidote porphyroclasts resemble epidotes in undeformed Oval Peak tonalites and foliation wraps around them in contrast to the recrystallized epidote elongate in C-surfaces. Sphene and hornblende locally form porphyroclasts. Medium-grained hornblende is deep medium-green (Z); a few grains are microboudinaged and connected by blue-green hornblende.

The assemblage in granodioritic and quartz monzonitic mylonites is quartz-muscovite-biotite-plagioclase-epidote. Microcline commonly occurs as strongly bent, microfractured and microfaulted porphyroclasts. In mylonitic pegmatitic granite, medium-grained, elongate fractured orthoclase surrounds microfaulted perthitic porphyroclasts and is itself highly undulose. In contrast to this cataclastic behavior, quartz defines an oblique grain-shape foliation and forms ribbons (aspect ratios up to 8:1) with subgrains and small recrystallized grains on their margins. Plagioclase ($An_{23-26}$) shows
microstructures similar to those in the tonalitic mylonites. Muscovite and biotite occur both as strongly bent "fish" and as much finer-grained, well-aligned crystals. Epidote forms blocky porphyroclasts and sphene occurs as large, euhedral relics.

The mylonitic tonalitic sills and dikes generally are ≤ 2 m thick and consist of quartz-biotite-plagioclase-epidote+muscovite ±sphene. Plagioclase porphyroclasts are probably relict phenocrysts and preserve zoning. Equant, rounded medium-grained epidote is abundant, but does not resemble porphyroclasts in the Oval Peak mylonites. These rocks show type-I and II S-C fabrics and quartz commonly forms ribbons.

Amphibolites are thinly layered. Asymmetric folds in amphibolite have wavelengths of 2-40 cm. These folds lack an axial-planar fabric. Recrystallization outlasted deformation of the amphibolites, as biotite and acicular hornblende have locally grown across foliation, and other phases form fine-grained mosaics. In some amphibolites all hornblende shows strong preferred orientation, whereas in a few others large crystals have subgrains or are recrystallized to fine-grained aggregates. Hornblende ranges from blue-green to medium-green to locally olive-green (Z). In rocks displaying relict gabbroic texture, hornblende displays patchy blue-green to olive-green pleochroism (Z). Relict plagioclase is also preserved in the gabbroic rocks, but shows greater recrystallization to a fine-grained mosaic than does amphibole. Aligned chlorite in a few widely spaced shear bands in the amphibolites may record deformation as temperatures waned.

In metasedimentary rocks, garnet porphyroclasts locally have been fragmented and strung-out along foliation. The assemblage in thinly layered greenschist-facies metavolcanics is albite-chlorite-epidote-quartz-calcite-
sphene-muscovite. Vein quartz shows extreme cataclasis in some greenschists, but in others it forms recrystallized ribbons. Tight chaotic folds of calcite veins and of mylonitic foliation are cut by other calcite veins. Siliceous greenschist possibly derived from sedimentary rocks contains calcite, albite and various combinations of muscovite, biotite and epidote. Subgrains in partially recrystallized quartz ribbons indicate sufficiently high temperatures for dislocation creep to operate.

Mylonites in the Twisp River Fault Zone

Mylonitic gneiss in this fault zone contains plagioclase porphyroclasts and prominent quartz ribbons. The mylonitic porphyries are characterized by relict plagioclase phenocrysts and some contain aligned chlorite. Relict bedding is preserved in some metasedimentary rocks, as best shown by interbedded conglomerate and sandstone. Some of the conglomerate contains abundant shale fragments which may represent rip-up clasts. Relict interbedding of siltstone and sandstone is also preserved locally. In nearby schists of the Twisp Valley Schist it is difficult to distinguish deformation related to the fault zone from that associated with earlier metamorphism of the schists. A component of unidirectional simple shear, possibly related to movement in the fault zone, is suggested by the consistent asymmetry of muscovite tails on garnets.