The Bald Mountain batholith contact aureole: geothermometry and phase relations of metamorphosed mafic rocks, Elkhorn Mountains, Blue Mountains Province, Northeastern Oregon

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INTRODUCTION

The Blue Mountains province (Fig. 1) in Northeastern Oregon, Western Idaho and Southeastern Washington consists of four tectonostratigraphic terranes (Silberling and Jones, 1984), the Wallowa, Izee, Olds Ferry and Baker Terranes, believed to have originated at unknown distances from the North American craton. The terranes were accreted during the Mesozoic and Cenozoic and subsequently rotated clockwise approximately sixty-five degrees (Wilson and Cox, 1980). Within the Blue Mountains Province, the Baker Terrane is comprised of subduction complex rock suites including both melange and relatively coherent packages of oceanic sediments and crystalline rocks. This project mapped the geology of the Crawfish Lake Quadrangle (Fig. 2) which is underlain by Baker Terrane lithologies that have been intruded by the relatively dry, Jurassic to Cretaceous, tonalitic magmas (Taubenack, 1995) of the Bald Mountain batholith (Fig. 2). The northwestern section of the Crawfish Lake Quadrangle is unconformably overlain by Tertiary volcanics. This study focuses on the contact aureole of the Bald Mountain batholith, examining temperatures of contact metamorphism as well as phase relations as a function of these temperatures.

METHODS

Forty-eight samples were taken from three types of localities within the Bald Mountain batholith contact aureole: Type 1) <1 to 2 meter thick mafic xenoliths within the Bald Mountain batholith, Type 2) 1 to 3 meter thick mafic lenses that occur within the Permian to Triassic Elkhorn Argillite of the Bellevue Wedge (Fig. 2) and Type 3) large coherent bodies of metagabbro and metadiorite that occur in the western part of the study area. Of these forty-eight samples, thirty-four were cut into thin sections and analyzed for mineralogy and texture. Sixteen of these samples (Fig. 2) were chosen for analysis using an SEM/EDS electron microprobe. For comparison, two samples of metagabbro were also taken at distances of 5 and 15 kilometers from the mapped batholith contact.

All samples contained plagioclase and calcic amphibole. Average plagioclase and amphibole composition were used to determine temperatures of metamorphism using the temperature dependence of partitioning of the plagioclase exchange between plagioclase and calcic amphibole (Holland and Blundy, 1994).

RESULTS

Mineralogy and Mineral Compositions. In hand sample, rocks are black to blackish-green in color and appear massive to foliated. A wide variety of phase assemblages exist and represent a well-defined gradation in metamorphic grade from granulite facies to amphibolite facies to the greenschist-amphibolite facies transition (Fig. 2). Samples from Type 1 localities contain the pyroxene hornfels facies assemblage orthopyroxene-clinopyroxene-hornblende-actinolite-plagioclase ± magnetite and ilmenite. Samples located in Type 2 localities and within 1 km of the Bald Mountain batholith contact contain clinopyroxene-hornblende-actinolite-plagioclase ± ilmenite, titanite and rutile. One sample from a Type 2 locality contains cummingtonite-biotite-plagioclase-chlorite ± ilmenite and pyrite. Samples from Type 3 localities contain amphibolite facies assemblages of hornblende-actinolite-plagioclase ± epidote, ilmenite, titanite and rutile. The samples taken 5 and 15 kilometers from the batholith contact contain assemblages of hornblende-chlorite-plagioclase + spinel, titanite and tourmaline and hornblende-plagioclase-actinolite + ilmenite respectively. In general, modal amounts of clinopyroxene decrease and modal amounts of amphibole increase with increasing distance from the batholith. Modal amounts of plagioclase are 40-50% at Type 1 localities, 5-10% at Type 2 localities and 20-30% at Type 3 localities.

Electron microprobe analyses show that most samples are magnesium rich with atomic Mg/Mg+Fe ratios in pyroxene and amphibole of not lower than 60%. Two samples from Type 3 localities are an exception to this with atomic Mg/Mg+Fe ratios in amphibole of 40-50%. Amphibole compositions in samples vary significantly in aluminum content which ranges from 3-14 weight percent. This variation is complemented by a variation among samples in calcium content of plagioclase which varies from An_{30} to An_{97}.

Fabrics. All samples are fine to medium-grained and massive to weakly foliated in texture except for the sample located 15 kilometers from the Bald Mountain batholith which is pervasively sheared and exhibits a well-defined chlorite foliation. Type 1 locality textures are granoblastic and grains are anhedral and randomly oriented indicating rapid growth. Samples from Type 2 localities also exhibit granoblastic textures and are much coarser grained than samples from other localities. Amphibole and clinopyroxene in these samples are intergrown and contain rare inclusions of plagioclase. In samples from Type 3 localities, porphyroblastic amphibole and chlorite or biotite exhibit a decussate texture (Fig. 3) or are occasionally weakly foliated. Amphibole porphyroblasts in samples from all localities also exhibit complex aluminum zonation with compositions spanning the hornblende to actinolite transition (Fig. 4). Smaller euhedral amphibole laths are also present in plagioclase grains. Plagioclase in all samples is equigranular and has mottled extinction with occasionally irregular twinning.

Geothermometry. Calcic amphibole-plagioclase exchange thermometry (Fig. 2) gives temperatures of 734°C-788°C for Type 1 localities and 494°C-785°C outside of the batholith in Type 3 localities. Amphibole-plagioclase thermometry from Type 2 localities gives unreasonably high values of 850°-1060°C. The sample located 15 kilometers from the Bald Mountain batholith contact also gives unreasonably high temperatures of 854° C. These samples that yield anomalously high temperatures contain extremely anorthitic plagioclase with An contents of 95% or higher.

DISCUSSION

Contact metamorphism produced by the Bald Mountain batholith intrusion overprinted a regional greenschist-amphibolite facies transition metamorphism like that seen in the sample 15 kilometers from the batholith contact. This metamorphism completely reconstituted rock mineralogy and mineral chemistry in the contact aureole, which expands approximately 3 kilometers outside of the batholith contact. Epidote appears in two Type 3 localities on the border of the contact aureole as a mineral indicating original regional greenschist-amphibolite facies transition metamorphism. Epidote also appears as a relict mineral in two assemblages in Type 3 localities. Variations in mineralogy and texture among the three types of localities are a reflection of both variations in temperatures of contact metamorphism and original rock composition. The samples in the Type 2 localities are part of a melange that differs fundamentally in bulk rock chemistry from the metagabbro, metadiorite and mafic xenoliths of Type 1 and Type 3 localities. The anomalously high temperatures in Type 2 localities and some Type 3 localities reflect uncertainties in amphibole-plagioclase geothermometry with An content of 90% or higher (Holland and Blundy, 1994).

The coexistence of actinolite and hornblende in such complex textures in almost all samples indicates later retrograde metamorphism that is breaking down hornblende.

Geothermometry reflects granulite facies and upper amphibolite facies within the Bald Mountain batholith and the Bellevue Wedge to 1 kilometer outside of the batholith contact. Temperature data for metagabbro in the western part of the field area reflects amphibolite facies metamorphism in almost all other samples. This temperature data is for the most part consistent with phase assemblages reflected in the rocks.

REFERENCES CITED

Ferns, M.L., Brooks, H.C., and Ducette, J., 1981, Geology and Mineral Resources Map of the Mount Ireland Quadrangle, Baker and Grant Counties, Oregon: State of Oregon Department of Geology and Mineral Industries, 1982.

Holland, Tim and Blundy, Jon, 1994, Non-ideal interactions in calcic amphiboles and their bearing on amphibole plagioclase thermometry: Contributions to Mineralogy and Petrology, v. 116, n. 4, p. 433-447.

Silberling, N.J., Jones, D.L., Blake, M.C., Jr., and Howell, D.G., 1984, Lithotectonic terrane map of the western conterminuous United States, Pt. C of Silberling, N.J., and Jones, D.L.C eds., Lithotectonic terrane maps of the North American Cordillera: U.S. Geological Survery Open-File Report 84-523, 43 p.

Spear, Frank S., 1993, Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths: Washington, D.C., Mineralogical Society of America Monograph, 799 p.

Taubenack, William H., 1995, A closer look at the Bald Mountain batholith, Elkhorn Mountains, and some comparisons with the Wallowa batholith, Wallowa Mountains, Northeastern Oregon: U.S. Geological Survey Professional Paper 1438, p. 45-123.

Walker, Nicholas W., Tectonic implications of U-Pb zircon ages of the Canyon Mountain complex, Sparta complex, and related metaplutonic rocks of the Baker Terrane, Northeastern Oregon: U.S. Geological Survey Professional Paper 1438, p. 247-269.

Wilson, Douglas, and Cox, Allan, 1980, Paleomagnetic evidence for tectonic rotation of Jurassic plutons in Blue Mountains, eastern Oregon: Journal of Geophysical Research, v. 85, p. 3681-3689.

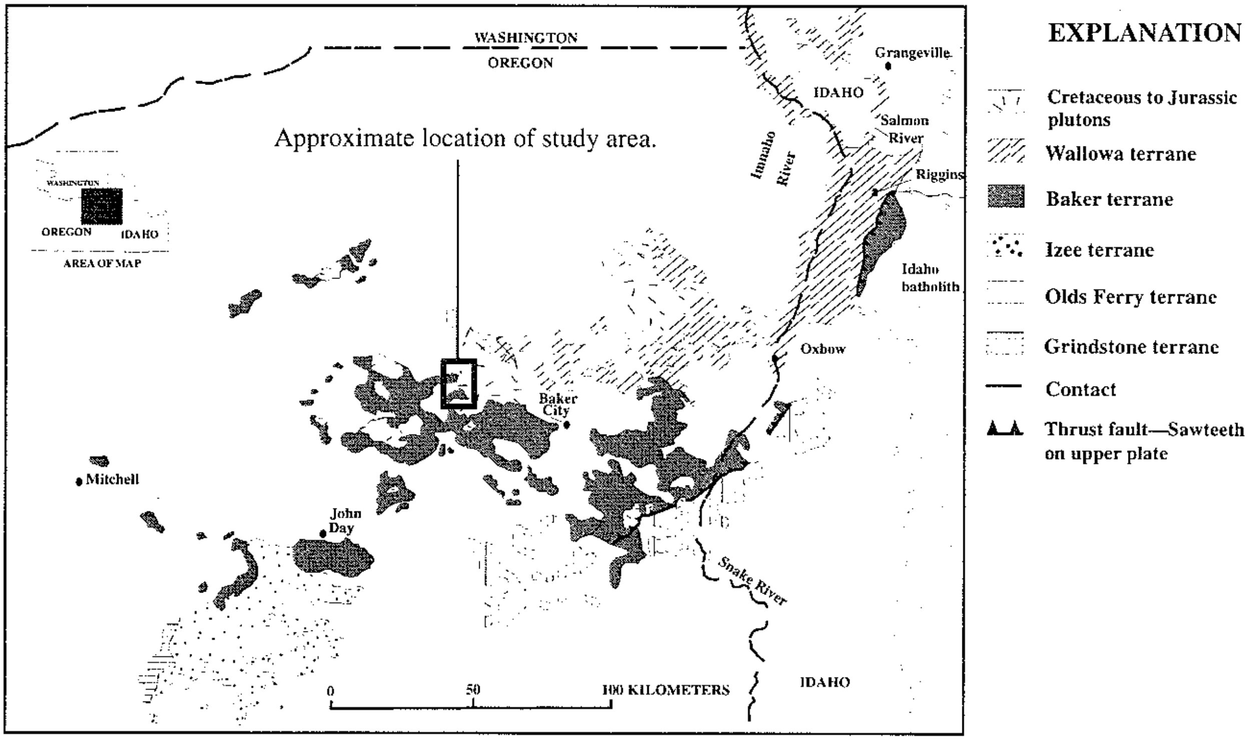

Figure 1—Terrane map of the Blue Mountains Province. (From Walker, 1995.)

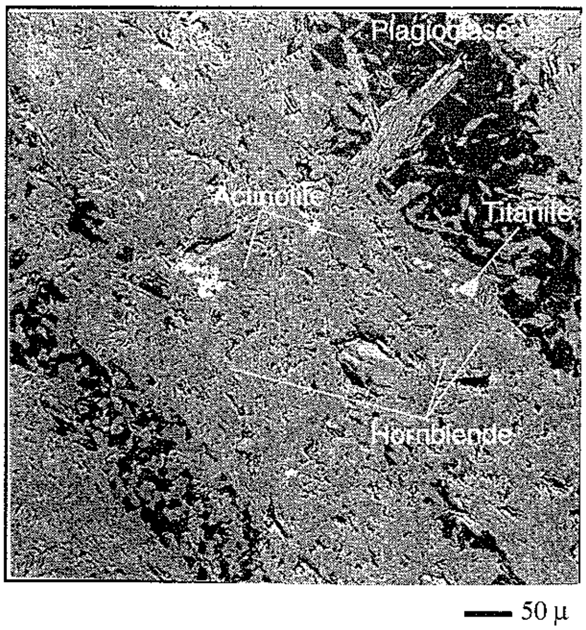

Figure 3—Typical decussate textures seen in the rocks of the Bald Mountain Batholith contact aureole.

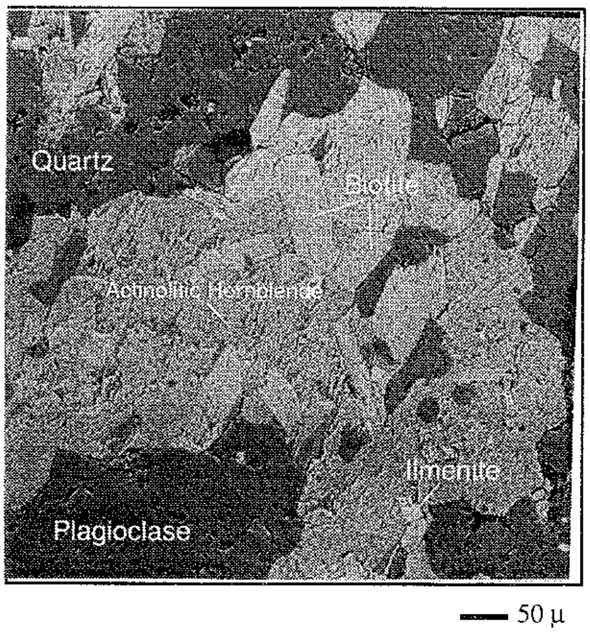

Figure 4—Complex amphibole zonation between hornblende (bright) and retrograde actinolite (dark)..

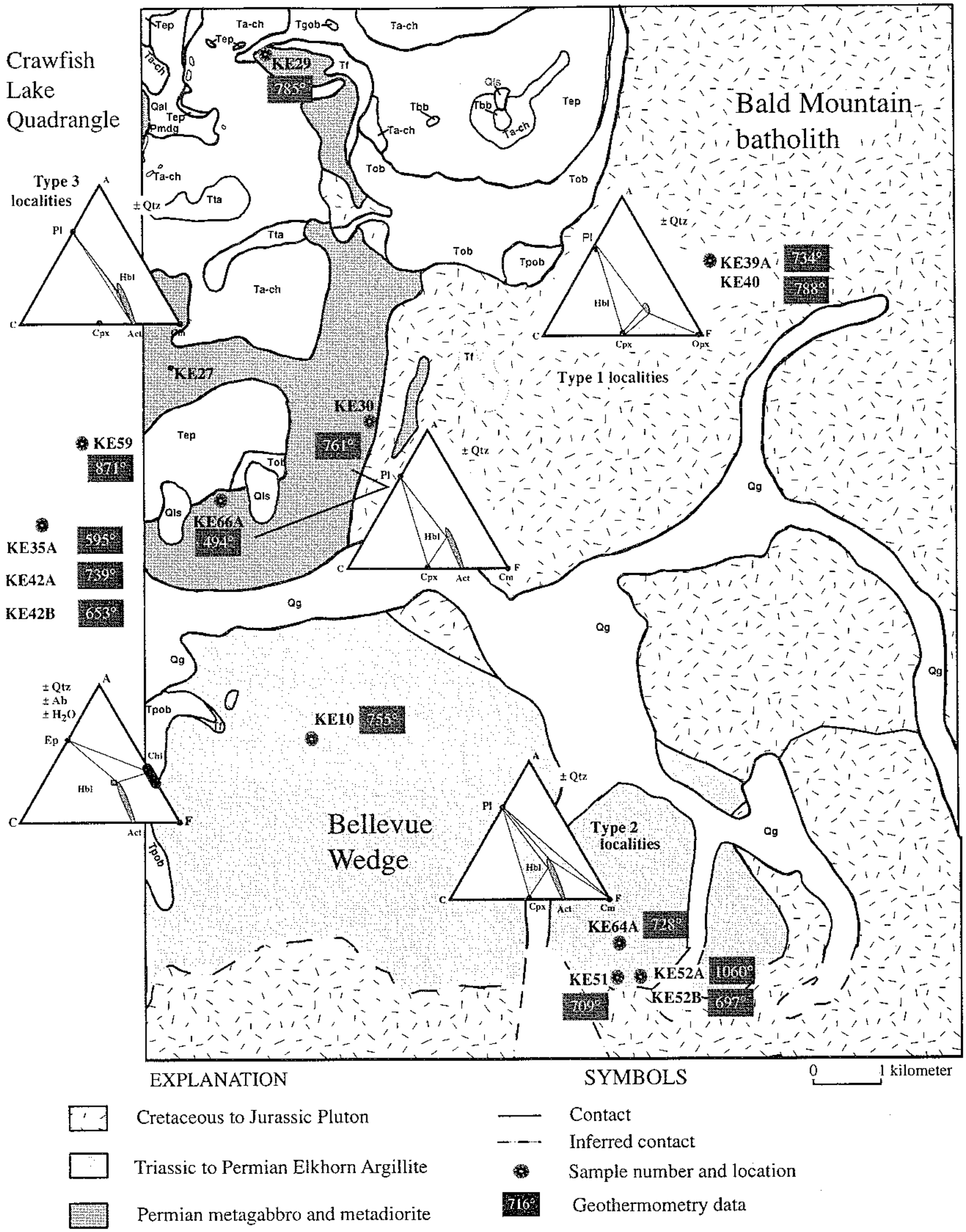

Figure 2—Map of extended field area with sample numbers and locations, temperature data, and equilibrium phase assemblages (modified from Spear, 1993). (Modified from Pogue and others, *in press* 1998 and from Ferns, Brooks and Ducette, 1981.)