Metamorphic petrology of pelitic sediments of the Elkhorn Mountains, northeastern Oregon

Sarah Newland

Department of Geosciences, Trinity University, San Antonio, TX 78212

Faculty Sponsor: Diane Smith, Trinity University

INTRODUCTION

Exposures in the Elkhorn Mountains of Northeast Oregon (Figure 1) reveal a complex geologic history described by Taubeneck (1995). The Elkhorn Mountains are part of the Baker Terrane, a regional accretionary complex composed of fore-arc sediments, which were deformed and accreted to North America. The complex was subsequentially intruded and metamorphosed by the Cretaceous tonalitic Bald Mountain batholith. Baker Terrane quartzose metasediments crop out within the Bellevue Wedge (Figure 1) and were contact metamorphosed by the Bald Mountain batholith. Oligocene volcanics, mostly basalt and andesite, cap the northwest corner of the region.

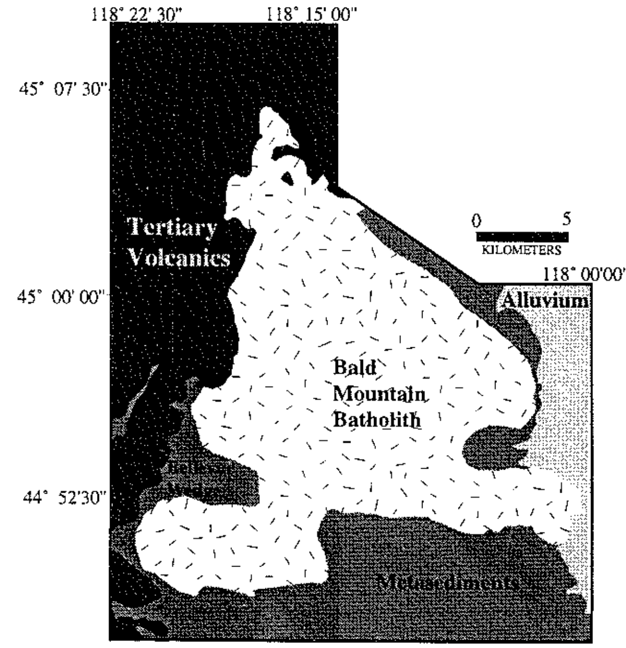

Figure 1. Generalized geologic map showing contacts between the Bald Mountain batholith, the metasediments (including the Bellevue Wedge), Tertiary volcanics, and Quaternary alluvium (after Taubeneck, 1995).

One of the questions addressed during this Keck project concerns the Bellevue Wedge (BW). The outcrop pattern of intrusive contacts bounding the BW suggests that it might be a roof pendant within the Bald Mountain batholith. An alternative hypothesis is that the metasediments were basement country rock to the batholith. In order to test these hypotheses, detailed sampling of the BW metasediments was undertaken. The focus of this study is determination of the metamorphic conditions to which BW metasediments were formed. Mineral assemblages and compositions were used to constrain the temperatures of metamorphism, and to determine whether a quantitative metamorphic field gradient exists across the BW. The existence of such a gradient will help constrain the structural relationships between the Bald Mountain batholith and the BW.

PETROGRAPHY AND MINERAL CHEMISTRY

Field observations show that rocks of the BW are fine grained, quartzofeldspathic gneisses and schists. The rocks are tan to white with black banding and have variable degrees of foliation. Thirty samples were chosen for thin section analysis. The constituent grains average 1 mm and range up to 2 mm, contain no porphyroblasts, and have textures that vary from gneissic, schistose and semi-schistose to granoblastic. Mineral assemblages include quartz, biotite, potassium feldspar, plagioclase, and opaque accessories. Some samples also contain varying amounts of garnet ± muscovite ± tourmaline.

From this initial set of thin sections, a subset was selected for electron microprobe work. All probe work was done at Rice University on a Cameca SX 50 Electron Microprobe. Garnet+biotite pairs were the main phases analyzed, because of their usefulness in geothermometry (Essene, 1982). Table 1 gives representative analyses of biotite and garnet.

Microprobe Analyses											
Mineral	Bio	Bio	Bio	Bio	Bio		Gar	Gar	Gar	Gar	Gar
Sample #	13-9	14-4	14-9	17-8	17-8		13-9	14-4	14-9	17-8	17-8
Weight % oxides											
SiO_2	35.7	35.4	35.0	34.1	33.8		36.9	36.9	36.9	36.3	36.1
TiO_2	1.29	1.79	2.35	3.26	3.07		0.02	0.03	n.d.	0.08	0.04
Al_2O_3	20.8	19.0	19.1	17.2	17.0		20.4	20.4	20.6	20.7	20.9
MgO	10.1	7.24	7.64	5.09	5.03		2.18	1.59	2.18	1.33	1.36
CaO	0.02	n.d.	0.02	n.d.	0.02		1.10	1.04	1.57	1.56	1.56
MnO	0.51	0.45	0.59	0.06	0.09		13.8	11.6	10.6	4.22	4.06
FeO	16.5	21.1	19.8	26.7	26.8		23.9	27.6	27.5	35.2	35.1
Na_2O	0.10	0.15	0.13	0.20	0.19		n.a.	n.a.	n.a.	n.a.	n.a.
K_2O	9.61	9.18	9.39	9.01	8.86		n.a.	n.a.	n.a.	n.a.	n.a.
SUM	94.66	94.43	94.11	95.7	94.89		98.32	99.26	99.32	99.45	99.1
Mg/Fe	1.10	0.61	0.69	0.34	0.33		0.16	0.10	0.14	0.07	0.07

Table 1. Representative electron microprobe analyses of biotite and garnet. n.d. = not detected; n.a. = not analyzed.

GEOTHERMOMETRY

From the microprobe analyses of garnet+biotite occurring in the BW metasediments, metamorphic temperatures were calculated using three calibrations of the garnet+biotite thermometer (Table 2). Ferry and Spear (1978) provided the first calibration of the garnet+biotite thermometer. Since their work, other calibrations have been proposed. Perchuck and Lavrent'eva (1983) proposed a calibration that accounts for high Mn in garnets. Hodges and Spear (1982) proposed another, which corrects for substitutions that affect Fe-Mg mixing in both phases, particularly Al^{vi} and Ti in biotite and Mn and Ca in garnet (Anderson, 1996). These two later calibrations were important to use here because the spessartine component is relatively high in some garnets (e.g., garnet in Sample 13-9). The temperatures calculated from Perchuck and Lavrent'eva (1983) range from ~ 575° to 690° C, which seem high because no evidence of anatexis exists in the BW. Temperatures from the Hodges and Spear (1982) calibration yield results that are the most consistent within any given sample. The range in temperatures in any given sample is ~ 30° to 55° C, significantly smaller than those found with the Ferry and Spear (40° to 120° C) and Perchuck and Lavrent'eva (40° to 100° C) calibrations. However, no matter which thermometer is used, given analytical and calibration errors, the calculated temperatures for all the analyzed garnet-bearing rocks are indistinguishable. Using the Hodges and Spear (1982) calibration, garnet+biotite-bearing rocks within the BW appear to have been heated to temperatures between ~ 500° and 575° C, but show no clear pattern of lateral or vertical distribution (Figure 2). Garnet+biotite thermometry could not be applied to samples from elevations less than 7000 feet

Results		Temperatures in degrees C						Errors based on analytical uncertainty
Calibration	Sample	14-11	14-9	6-7	17-8	13-9	14-4	
Ferry & Spear	high	627	638	522	617	587	637	± 16° C
	low	507	536	481	542	509	524	
Perchuck & Lavrent'eva	high	688	684	626	641	659	680	± 19° C
	low	588	614	585	576	617	612	
Hodges & Spear	high	558	563	532	573	552	563	± 2° C
	low	502	521	500	524	510	516	

Table 2. Temperatures calculated from three calibrations of the garnet+biotite thermometer.

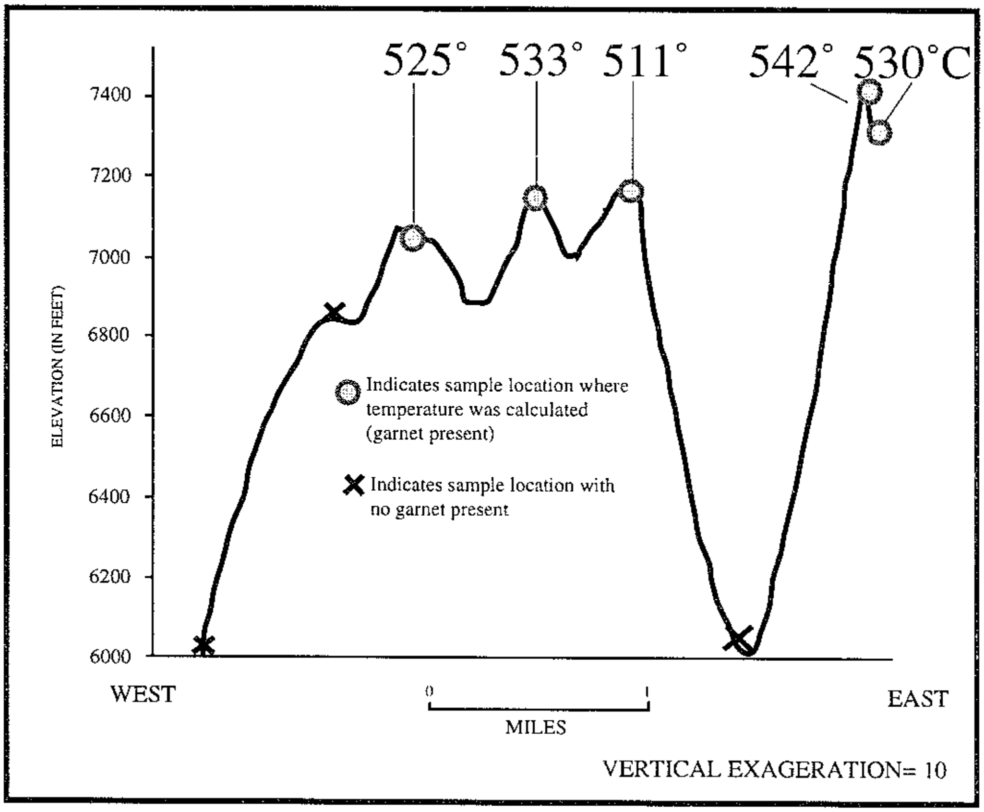

Figure 2. Topographic profile across the BW showing calculated temperatures and sample locations of rocks containing garnet, and those without garnet.

because garnet was not found in rocks at those elevations. Samples containing garnet could have been overlooked due to poor exposure of bedrock in the valleys. If the lack of garnet in topographically low areas is real, this suggests a qualitative metamorphic gradient, in which only the presently elevated areas were heated to temperatures high enough for garnet to form.

IMPLICATIONS FOR STRUCTURAL MODELS

In trying to answer the question of whether the BW is basement to the Bald Mountain batholith (Figure 3a), or is a roof pendant in the batholith (Figure 3b), no definitive conclusion can be reached. If the batholith was emplaced above the BW, the contact metamorphic effects would be strongest along the top of the BW, with temperatures decreasing toward the lower portion of the BW (Figure 3a). In contrast, the roof pendant model would predict the highest and lowest temperatures recorded in rocks of the lowest and highest elevations, respectively (Figure 3b). The distribution of samples containing garnet at the highest elevations in the BW suggests that a vertical metamorphic gradient exists, with higher metamorphic temperatures affecting rocks at the higher elevations, which supports the basement model.

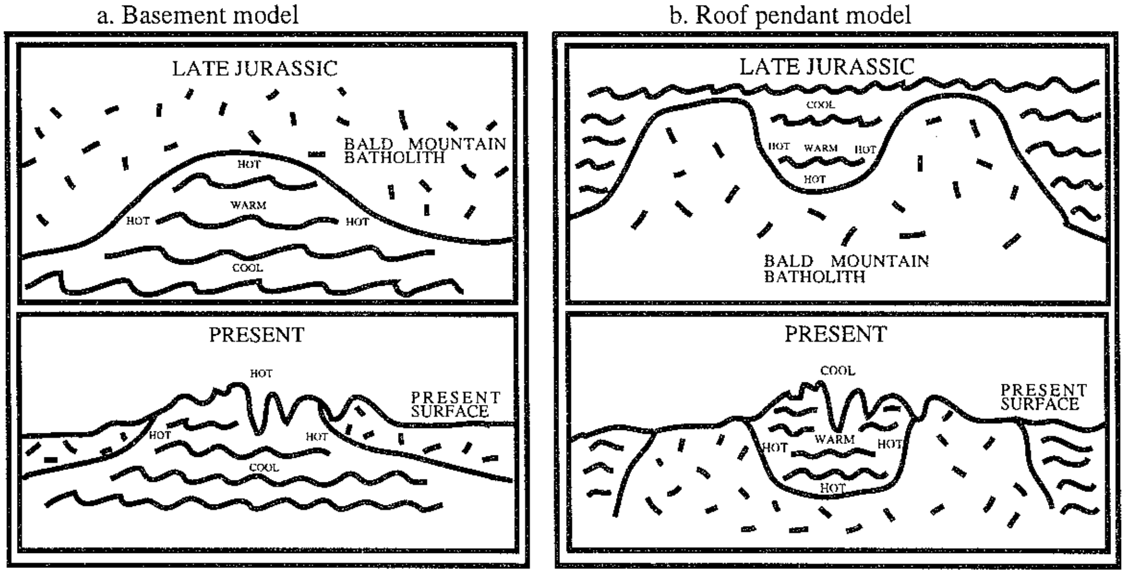

Figure 3. Proposed models of the contact relationships between the metasediments (wavy lines) and the Bald Mountain batholith (tick marks).

ACKNOWLEDGEMENTS

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