

A REGIONAL STUDY OF METAMORPHOSED PELITIC ROCKS IN SOUTHWESTERN MONTANA

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INTRODUCTION

The mountain ranges in southwestern Montana are some of the northwestern most exposures of Precambrian basement rock of the Wyoming province. The Tobacco Root Mountains are located in this area and have been extensively studied (Brady et. al., 2004) providing new information and questions about the regional geologic history, particularly during the Big Sky Orogeny at 1.77-1.72 Ga. This project focuses on a regional study of metamorphosed pelitic rocks from the Highland, Ruby, and Gravelly Mountain Ranges, which are adjacent to the Tobacco Root Mountains, in order to record the extent and character of Big Sky metamorphism of rocks of similar bulk composition located in different parts of the northern Wyoming Province.

METHODS

During the summer of 2005, meta-pelite samples were collected across the region. The presence of aluminosilicate minerals, the amount of weathering, and uniqueness of samples were considered when deciding which samples to collect. Most samples came from the Highland and Gravelly Ranges, since more Al-rich rocks were found in these areas, although obtaining a regional distribution of samples was the goal. For each sample a UTM location was recorded with a GPS unit, outcrops were described and field relationships

noted, including strike and dip of foliation and trend/plunge of lineation if apparent. Most samples were collected from outcrops, but a few float samples were taken if the origin was unambiguous. Twenty-six thin sections of the meta-pelites were analyzed using a petrographic microscope to identify the minerals present, their modes, interesting textures, and AFM assemblage.

Two samples have been analyzed for garnet-biotite-quartz-plagioclase thermobarometry using the scanning electron microscope at Smith College. For the samples with the assemblage garnet-biotite-quartz-plagioclase-aluminosilicate, pressures and temperatures were constrained. The program used for these calculations was Spear and Kohn's Program Thermobarometry (2001 version). For biotite-garnet exchange thermometers the Ferry and Spear (1978) calibration modified by Berman (1990) was used. Pressures were obtained using the Hodges and Crowley (1985) garnet-plagioclase barometer. One sample from the Wall Creek area in the Gravelly Mountains and one sample from Camp Creek in the Highlands were sent to the University of Massachusetts for microprobe Th-Pb chemical age dating of monazite grains.

RESULTS

Northern Gravelly Range

Samples were gathered from two locations

in the northern Gravelly Mountains. One sample came from the northernmost area of the Gravelly Range, near the Luzanac mine, and four from the Wall Creek area (refer to Figure 1 for locations). In general, metamorphism seems to be lower grade in the Gravelly Range than in the Highland or Ruby Ranges.

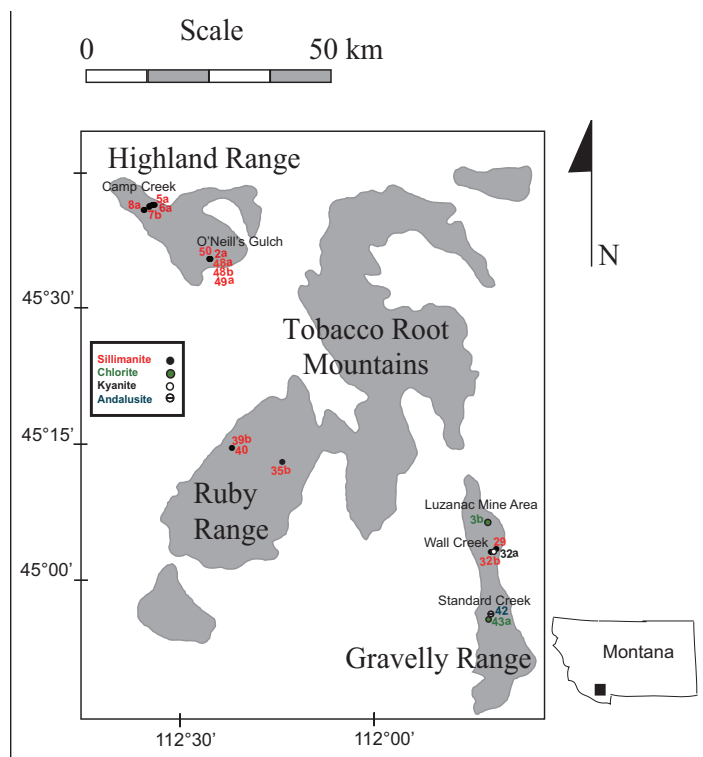


Figure 1. Regional map of mountain ranges with sample locations. Higher grade rocks containing sillimanite are labeled in red, lower grade phyllites are labeled green. Mid-grade rocks containing kyanite and andalusite are labeled black and blue respectively. Sample 29 contains sillimanite, kyanite and possibly kyanite pseudomorphed after andalusite. Modified from Schwab, this volume.

Outcrops from the area near the Luzanac mine are mostly fine-grained, graphite-rich phyllites. Chlorite and biotite can be identified in thin section. Most of the outcrops do not seem severely deformed, but some folds in quartz layers occur. In the thin section studied, original sedimentary bedding seems to be preserved, another reason to conclude that metamorphism is not very high grade in this area.

The Wall Creek area of the central Gravelly Range consists of outcrops of black, fine-grained rock, some with porphyroblasts of aluminosilicate with a chiastolite cross. Although the porphyroblasts were thought to be andalusite, in thin section it is clear that they are actually bundles of prismatic kyanite pseudomorphed after andalusite, indicating an increase in pressure (Fig. 2).



Figure 2. Kyanite pseudomorphed after andalusite in hand sample. Sample from the Wall Creek area of the northern Gravelly Range.

Preliminary results for Th-Pb chemical age dating of metamorphic monazites in a nearby sample yield an age of 2570 ± 45 Ma. In this sample, kyanite, fibrous sillimanite and a crystal seeming to have andalusite's characteristic chiastolite cross occur in close proximity in a single thin section, suggesting a rock that was metamorphosed at conditions near the triple point on the aluminosilicate P-T diagram (Fig. 3). The crystal containing the chiastolite cross is believed to be a kyanite pseudomorphed after andalusite as observed in the sample discussed above.

If so, these textures and the uniform monazite ages suggest a single metamorphic event following a clockwise PT path around the triple point (Fig. 4), with andalusite forming first, then kyanite and finally sillimanite. Another sample

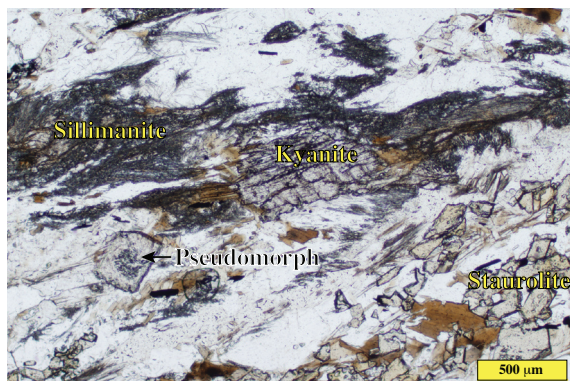


Figure 3. Staurolite, sillimanite, kyanite, and kyanite pseudomorphed after andalusite in thin section (plane light). Sample from Wall Creek in the northern Gravelly Range.

from the area contains prismatic and fibrous sillimanite, as well as staurolite and biotite. This assemblage gives a minimum temperature of about 540°C and a minimum pressure of about 3kb (Spear, 1993).

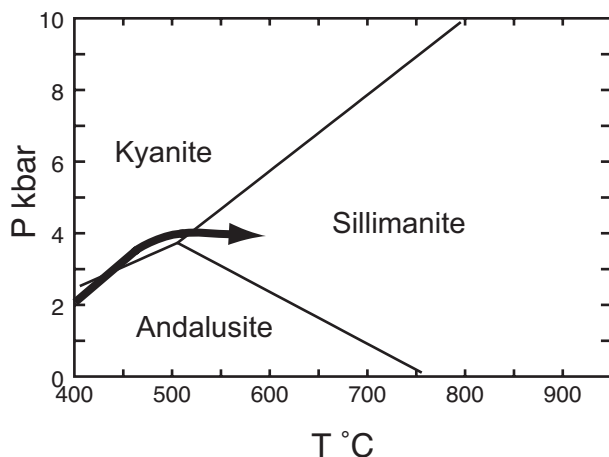


Figure 4. Schematic PT path for the Wall Creek area of the northern Gravelly Range based on the presence of sillimanite and kyanite pseudomorphs after andalusite in close proximity observed in samples from this area.

Southern Gravelly Range

Outcrops in the Standard Creek area of the southern Gravelly Range are highly weathered phyllites, some with black porphyroblasts. Assemblages observed in thin section are relatively low grade, with samples containing garnet, chlorite, staurolite and biotite. Some

contained prominent andalusite crystals, over 2 cm long. This area is about 460 meters from the Standard Creek metagabbro pluton, but because the subsurface extent of the pluton is not well known, the possibility of contact metamorphism should be considered as well as the extent of regional metamorphic events (see Doody, this volume).

Ruby Range

Two samples examined in thin section from the Ruby Range contain biotite-garnet-sillimanite, giving a minimum temperature of about 550°C and pressures from about 2.5 to 6.25 kb (Spear, 1993). Mineral rim chemical analyses of one of these samples show rather variable temperature and pressure data when used with the garnet-biotite-aluminosilicate-plagioclase-quartz thermobarometer (Spear and Kohn, 2001). Temperatures range from about 475-685°C and pressures from about 1.8-5.8 kb (Fig. 5). The lower bounds of the calculated pressures and temperatures are less than that expected for the mineral assemblage of the rock. This could be due to garnet-biotite re-equilibration as the rock cooled.

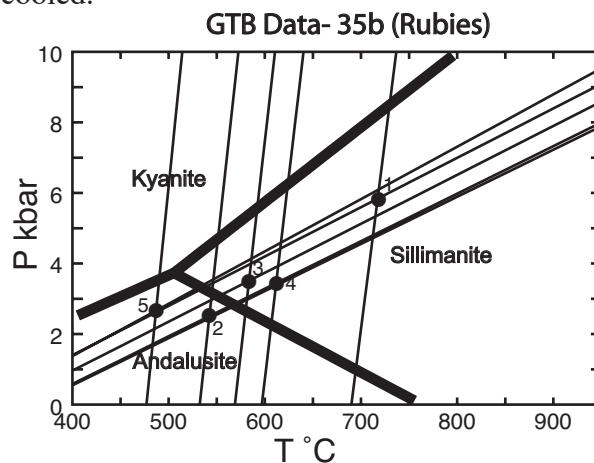


Figure 5. Geothermobarometry data plotted using Spear and Kohn's (2001) Thermobarometry program. The Ferry and Spear (1978) calibration modified by Berman (1990) was used for garnet-biotite temperatures and the Hodges and Crowley (1985) garnet-plagioclase calibration was used for pressure. Each circle represents one of five garnet rim and adjacent biotite chemical analyses. All five

analyses are from the same thin section, a sample from the Ruby Range. The circle does not show the error margin, which was not calculated.

Highland Range

Two areas from the Highland Range were sampled, an area informally called O'Neill's Gulch on the eastern side of the range and Camp Creek on the western side. Preliminary results for Th-Pb chemical age dating of metamorphic monazites in a sample from O'Neill's Gulch show an average age of 1819 ± 28 Ma except for two analyses which show a younger average age of 1737 ± 20 Ma. All samples show evidence of high-grade metamorphism, with many samples containing sillimanite. In O'Neill's Gulch both prismatic sillimanite and fibrolite occur, in some cases within the same thin section. Only prismatic sillimanite is present in thin sections from Camp Creek. In one sample from each location microcline is present. The sample from Camp Creek contains no muscovite, indicating that the reaction muscovite+quartz \rightarrow K-spar has most likely occurred. This constrains the temperature to at least 600°C (Spear, 1993; See also Labadie, this volume). The sample from O'Neill's Gulch contains microcline, sillimanite and muscovite, so perhaps the reaction began but was incomplete. Based on evidence from these two samples it appears that Camp Creek experienced either higher temperatures or lower pressures than O'Neill's Gulch. Mineral rim chemical analyses of a sample from this area yield temperatures ranging from < 400 to about 540°C and pressures of < 1.7 - 3.75 kb. Again these results are lower than those expected based on mineralogy, possibly due to re-equilibration during cooling.

DISCUSSION

Data from this study show that the grade of metamorphism is highly variable between mountain ranges and that there is a general trend of increased temperature in the northern

ranges. The Highland and Ruby Ranges show metamorphism at the highest temperatures and rocks near the Luzanac mine in the northern Gravelly Range show the lowest grade of metamorphism. Many questions remain regarding the metamorphic history of the area. Why do the Luzanac Mine rocks show a lower grade of metamorphism than metapelites in the southern Gravelly Range when regional metamorphic grade seems to increase to the Northwest? What has been the effect of the numerous gabbroic intrusions on this metamorphism? Why do the rocks of O'Neill's Gulch and Camp Creek differ in their apparent metamorphic grade? Were they metamorphosed at the same time? Were all of these rocks metamorphosed during the Big Sky orogeny? A possible explanation for some of the contrast in metamorphic grade is provided by the old ages of monazites in the Gravelly Range. The monazite ages of about 2500-2600 Ma indicate that rocks in the Gravelly Range were metamorphosed earlier in an event that rocks in the Highland Range do not record. Based on the older age of the metamorphism in the Gravelly Range, it seems that the Big Sky orogeny did not have a great effect on the rocks of the Gravelly Range.

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