

# **Archean Rocks of Southwestern Montana**

## **Workshop**

### **Faculty**

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### **Students**

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William MacFarlane, Colorado College  
Jennifer Martin, Franklin & Marshall College  
Heidi Mohlman, Amherst College  
David Owen, Amherst College  
Ann Pufall, Smith College  
Rebecca Thomas, Williams College  
Caroline Tuit, Beloit College  
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### **Visitors**

Reinhard Wobus, Williams College  
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# Workshop report: Archean rocks of southwestern Montana

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## INTRODUCTION

The goal of the 1993 Montana Archean Rocks Project was to clarify the relationship between two diverse assemblages of Archean rocks exposed in the Tobacco Root Mountains of Montana - the Indian Creek Metamorphic Suite (ICMS) and the Spuhler Peak Metamorphic Suite (SPMS). The ICMS consists of quartzofeldspathic gneiss, hornblende gneiss, dolomitic marble, aluminous schists, quartzite, and iron formation. The SPMS consists of amphibolite, hornblende-plagioclase gneiss, gedrite-garnet-plagioclase gneiss, sillimanite schist, and quartzite. A third major suite of rocks, the Pony-Middle Mountain Metamorphic Suite (PMMMS) suite which consists predominantly of quartzofeldspathic gneiss and hornblende gneiss was not studied in any detail in 1993.

Burger (1966, 1967, 1969) interpreted the contact between the ICMS and SPMS as a fault based on the observation that the Spuhler Peak apparently truncates the large, regionally developed folds in the Indian Creek rocks and what he perceived as different metamorphic histories in the two groups of rocks. Gillmeister (1971, 1972), however, interpreted the contact as an unconformity and believes that the SPMS overlies both the ICMS and the PMMMS. Gillmeister noted, as have others, that the metamorphosed mafic dikes and sills (MMDS) are present in both of these suites but are not present in the SPMS.

Cummings and McCulloch (1992) mapped a series of shear zones that separate the SPMS from the ICMS in a small area near Branham Lakes, located in the southeastern-most part of the area mapped by Burger. One of their shear zones coincides with his fault location, and they interpret the SPMS as a sliver of oceanic crust thrust against shelf sediments (Indian Creek Metamorphic Assemblage). Understanding the actual relationship between the Spuhler Peak and Indian Creek rocks (and the Pony-Middle Mountain) is crucial to unraveling the Archean and Proterozoic history of southwestern Montana, especially if the Spuhler Peak rocks represent allochthonous oceanic crust.

Accordingly, student research projects in 1993/94 concentrated on SPMS geochemistry and metamorphic petrology, comparative petrology of aluminous schists and amphibolites in the SPMS and ICMS, structural relationships along the contact between the SPMS and ICMS,  $^{40}\text{Ar}/^{39}\text{Ar}$  ages on amphiboles from ICMS metamorphosed mafic dikes and sills and SPMS and ICMS amphibolites, and geochemistry of ICMS quartzofeldspathic gneisses.

## CURRENT MONTANA PROJECT

The 1995/96 Montana Archean Rocks Project sought to build on the results of the previous Keck project as well as expanding the scope of the investigation. It became abundantly clear after analyzing 1993/94 results that we required detailed knowledge of the geochemistry and metamorphic history of all three suites and detailed structural information on the nature of their mutual contacts. Therefore, we decided to investigate the geochemistry and metamorphic petrology of the PMMMS, undertake similar work in the SPMS on rocks not sampled in 1993, acquire a more complete data set for ICMS rocks, and expand the structural data base related to the SPMS-ICMS contact and look at the SPMS-PMMMS contact in detail for the first time. It also became clear in 1993/94 that the metamorphosed mafic dikes and sills and meta-ultramafic rocks may hold the key to understanding the tectonic history of these Archean rocks. For this reason we attempted to be sure several projects addressed the geochemistry and petrology of these mafic and ultramafic rocks.

As all of the individual projects contribute to the whole, and as a number of projects are dependent on information from others, we decided a workshop devoted to a discussion of progress and directions for further study was in order. Accordingly, thirteen students from nine Keck schools, Sam Houston State University, and the University of Puerto Rico took part in the 1996 Montana Archean Rocks Workshop. Project faculty are Robert Burger and John Brady (Smith College), Jack Cheney and Tekla Harms (Amherst College), and Kathleen Johnson (University of New Orleans). Reinhard Wobus (Williams College) and Samuel Kozak (Washington & Lee University) attended the workshop as advisers of participating in the project.

Prior to the workshop, students were asked to prepare a 20 minute presentation that summarized their progress to date, detailed the remaining work they planned to do, and posed questions with which they needed help or advice. Student research topics include:

David Owen (Amherst College): SPMS-ICMS (and PMMMS) contact and structures in all three rock suites as exposed close to the contact

Steven Kranenberg (Sam Houston State University): contact relationships, especially geometry and fabrics in quartzites located along the contact trace.

Karl Wegmann (Whitman College): metamorphic history of the Pony-Middle Mountain Metamorphic Suite

Ann Pufall (Smith College): whole-rock geochemical study of felsic and mafic gneisses in the PMMMS as well as the "non-unique" rocks in the SPMS.

Jason Cox (Washington and Lee University): whole-rock geochemistry of amphibolites in the SPMS

Kathleen DeGraaff (Amherst College) and Jillian Hirst (Pomona College): metamorphic P-T-t history of Spuhler Peak rocks in the Branham Lakes and Noble-Sunrise areas, respectively

Jennifer Martin (Franklin & Marshall College): whole-rock geochemical studies of ICMS

Caroline Tuit (Beloit College): metamorphic P-T-t history of Indian Creek rocks, especially in the Indian and Mill Creek drainages

Heidi Mohlman (Amherst College) and Wilfredo Rosado (University of Puerto Rico): whole-rock geochemistry, mineral chemistry, and metamorphic history of metamorphosed mafic dikes and sills

Rebecca Thomas (Williams College): metamorphic history of meta-ultramafic rocks

William MacFarlane (Colorado College): whole rock major and trace element chemistry of meta-ultramafic rocks

### **WORKSHOP ACTIVITIES**

Workshop participants assembled Friday evening, January 19, 1996, at Smith College. Although the weather decided to complicate travel plans, everyone eventually arrived in Northampton on Friday. For those who arrived at a reasonable hour, the evening time was used to become reacquainted, to view slides of the Tobacco Roots from the summer, and to indulge in some high-quality pizza.

Saturday was divided into morning and afternoon sessions. During the first half of the morning, everyone gathered to view video projections of thin sections from the Tobacco Roots so as to be certain important textural and mineralogical relationships were observed by all. Following this session everyone divided into two groups in order to work with computer software relevant to their research. One group concentrated on geothermobarometry software, and the other investigated software designed to aid in interpreting whole rock geochemistry data.

Following a brief "lunch-in-the-lab", each student delivered a summary of their progress to date, their successes and problems, and questions for which they were seeking advice and help. This session was quite beneficial as it forced everyone to assess their current progress and to seek advice at a time when advice was readily available. The afternoon concluded with an open session during which time project faculty interacted with students to examine thin sections, discuss graphs of geochemical data, and acquire necessary resources (map bases, copies of scientific articles, etc.). At approximately 6:00 p.m. we adjourned to dinner at a local restaurant after which the day officially ended.

Sunday morning began with each project faculty member introducing one of the major research areas being studied (protoliths/whole rock geochemistry, metamorphic petrology, structural relationships, meta-ultramafic rocks, and metamorphosed mafic dikes and sills). After rewarding discussions on each of these topics, the remainder of the morning was spent as an open session similar to that of the day before, because project faculty decided a bit more advice and counsel was needed.

At approximately 1:00 p.m. everyone departed for their home campus. Everyone agreed that this time together was invaluable in providing help, gathering a good deal of advice, sharing data, and generating excitement and anticipation for the results to come.

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