Archean geology of a part of the northern Gallatin Range, southwest Montana
by Karen Anne May

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
The northern Gallatin Range in southwest Montana is predominantly composed of regionally metamorphosed Archean quartzofeldspathic gneisses with minor amounts of metabasites. This study characterizes the petrography, petrology, and structure of Archean rocks exposed in a part of the northern Gallatin Range to determine the Archean tectonic evolution of this part of southwest Montana. Metamorphism in the study area ranges from epidote-amphibolite to transitional granu-Iite facies. These rocks are believed to have initially experienced a transitional granulite facies metamorphic event (M1) followed by epidote-amphibolite facies conditions (M2). Retrograde assemblages in the study area rocks may be indicative of a greenschist thermal event (M3?). A dominant N45E structural grain is expressed by foliation strikes and fold hinge line trends. Polyphase deformation is evident based on the identification of two fold generations. Isoclinal folds were produced during an earliest (M1) event. Coaxial open folds were subsequently produced during M2. The tectonic setting for study area rocks is best represented by an ensialic basin depositional environment that was subsequently deformed via A-type subduction processes.

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APPROVAL

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Karen Anne May

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Signature Karen Anne May

Date December 18, 1985

To my parents, for twenty-nine years of patience and support.

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ERRATA

The following corrections should be noted:

The location abbreviations S-13 and S-14 found on the following pages should instead read S-12 and S-13, respectively:

page 48
page 51 (text only - figure caption on this page is correct).
page 55
page 84

Thin section label S-13 on table 7, page 91 should instead read S-43.

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ABSTRACT

The northern Gallatin Range in southwest Montana is predominantly composed of regionally metamorphosed Archean quartzofeldspathic gneisses with minor amounts of metabasites. This study characterizes the petrography, petrology, and structure of Archean rocks exposed in a part of the northern Gallatin Range to determine the Archean tectonic evolution of this part of southwest Montana. Metamorphism in the study area ranges from epidote-amphibolite to transitional granulite facies. These rocks are believed to have initially experienced a transitional granulite facies metamorphic event (M1) followed by epidote-amphibolite facies conditions (M2). Retrograde assemblages in the study area rocks may be indicative of a greenschist thermal event (M3?). A dominant N45E structural grain is expressed by foliation strikes and fold hinge line trends. Polyphase deformation is evident based on the identification of two fold generations. Isoclinal folds were produced during an earliest (M1) event. Coaxial open folds were subsequently produced during M2. The tectonic setting for study area rocks is best represented by an ensialic basin depositional environment that was subsequently deformed via A-type subduction processes.

INTRODUCTION

Foreword and Statement of Purpose

The northern Gallatin Range in southwest Montana lies in the northwestern part of the Wyoming Archean Province (Figure 1) and is predominantly composed of regionally metamorphosed Archean quartzofeldspathic gneisses with minor amounts of metabasites. The metamorphic grade of these rocks ranges from epidote-amphibolite to transitional granulite facies. The nature of protoliths and a tectonic setting for Archean rocks in southwest Montana is currently speculative and incompletely understood. As a result, our present state of knowledge of Archean evolution of continental crust in this area is limited. The study area is located near the transition from predominantly igneous and meta-igneous rocks in the Beartooth Range to the east and a predominantly metasupracrustal terrane in the ranges to the west (Figure 2, Mogk et al, in review). This study provides additional petrographic, petrologic, and structural detail for a part of the Archean rocks in this critical transition area. Mylonites, migmatites, and transitional granulites present in the study area provide details vital to an analysis of the Archean tectonic evolution of southwest Montana.

The objectives of this research are threefold: 1) to describe the lithologies and structures of the Archean basement rocks present in the study area, 2) to characterize their petrogenesis and subsequent

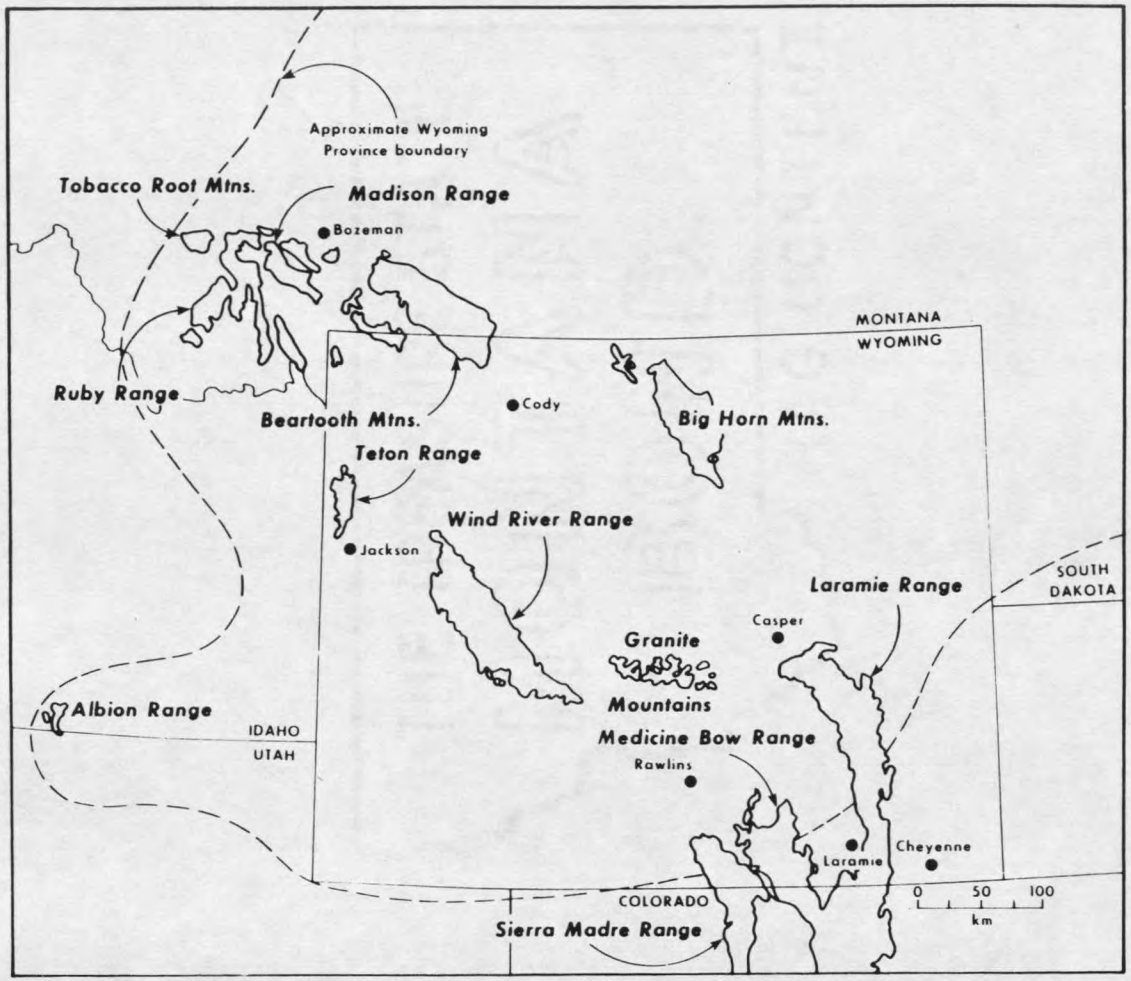

Figure 1. Wyoming Archean Province (after Condie, 1975).

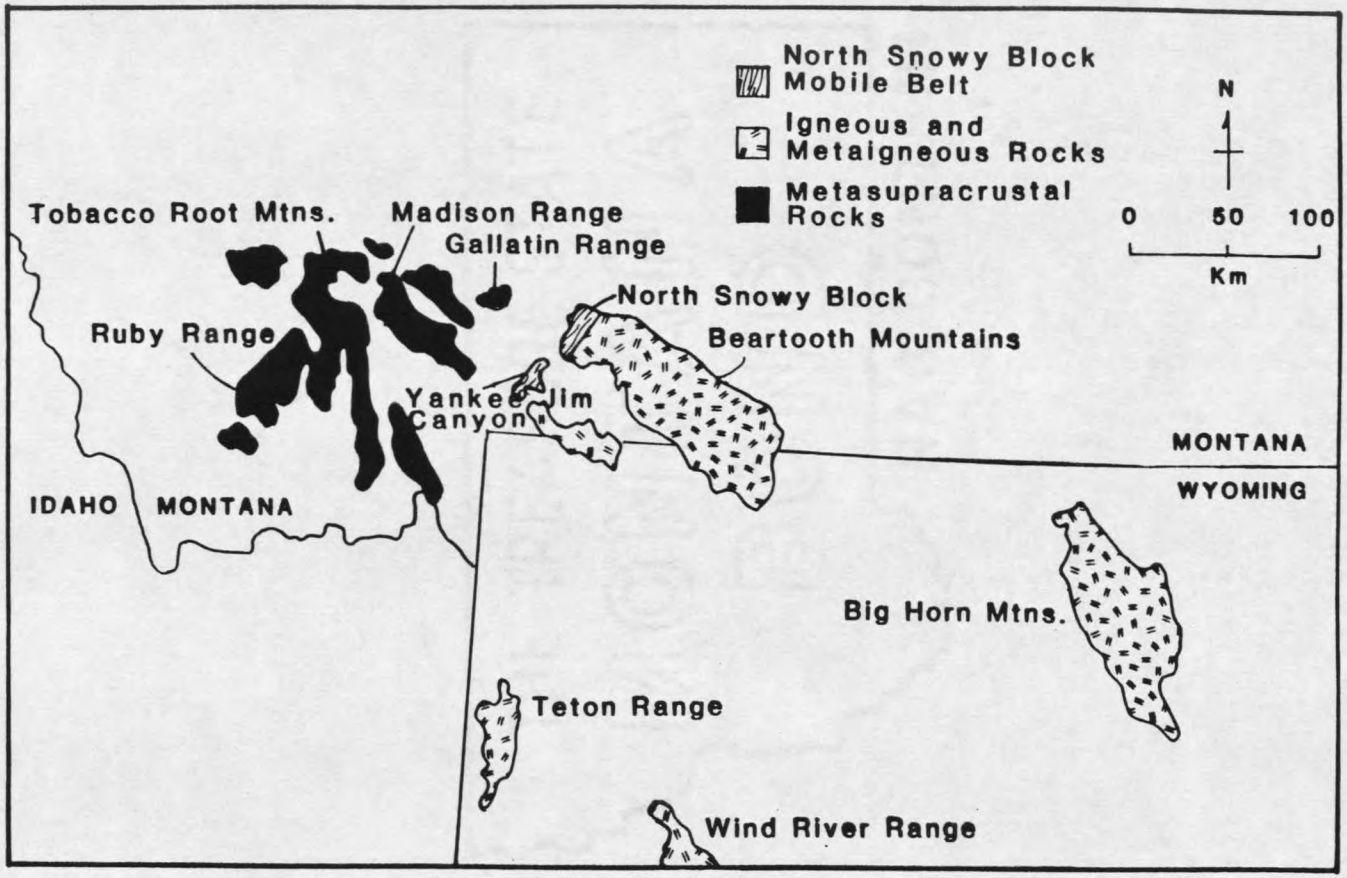

Figure 2. Index map of the northern portion of the Archean Wyoming Province. The North Snowy Block mobile belt serves as a local boundary, separating predominantly igneous and meta-igneous rocks to the east from predominantly metasupracrustal rocks to the west (from Mogk, et al, in review).

style of deformation, and 3) to place them in the context of a regional Archean setting and develop a tectonic interpretation.

Methods of Investigation

The summer field seasons of 1982 and 1983 were spent collecting rock specimens, structural data, and observations of field relationships. The sporadic nature of exposures did not warrant lithologic mapping of the study area. About 100 outcrops were observed, though most were too small or insufficiently exposed to yield valuable data. Four unique outcrops substantial enough in size were studied in detail as separate domainal units and are representative of lithologies and structures observed throughout the study area. These outcrops are highlighted throughout the text (locations of these major outcrops appear in Appendix A). One hundred and forty-seven rocks were collected and 57 thin sections representative of the major lithologic units and unique lithiologies were prepared for detailed petrographic study. X-ray diffraction was used to identify the mineralogy of one rock. Structural data were plotted on stereonets to aid in the analysis of structural elements.

Location and Access

The study area lies in the northern Gallatin Range about six miles south of Bozeman, Montana and is covered by the U.S.G.S. Bozeman 15-minute quadrangle (Figure 3). It is bounded by Hyalite Creek on the west, Sourdough Creek to the east, the Gallatin Valley to the north, the rest of the Gallatin Range to the south, and encompasses an

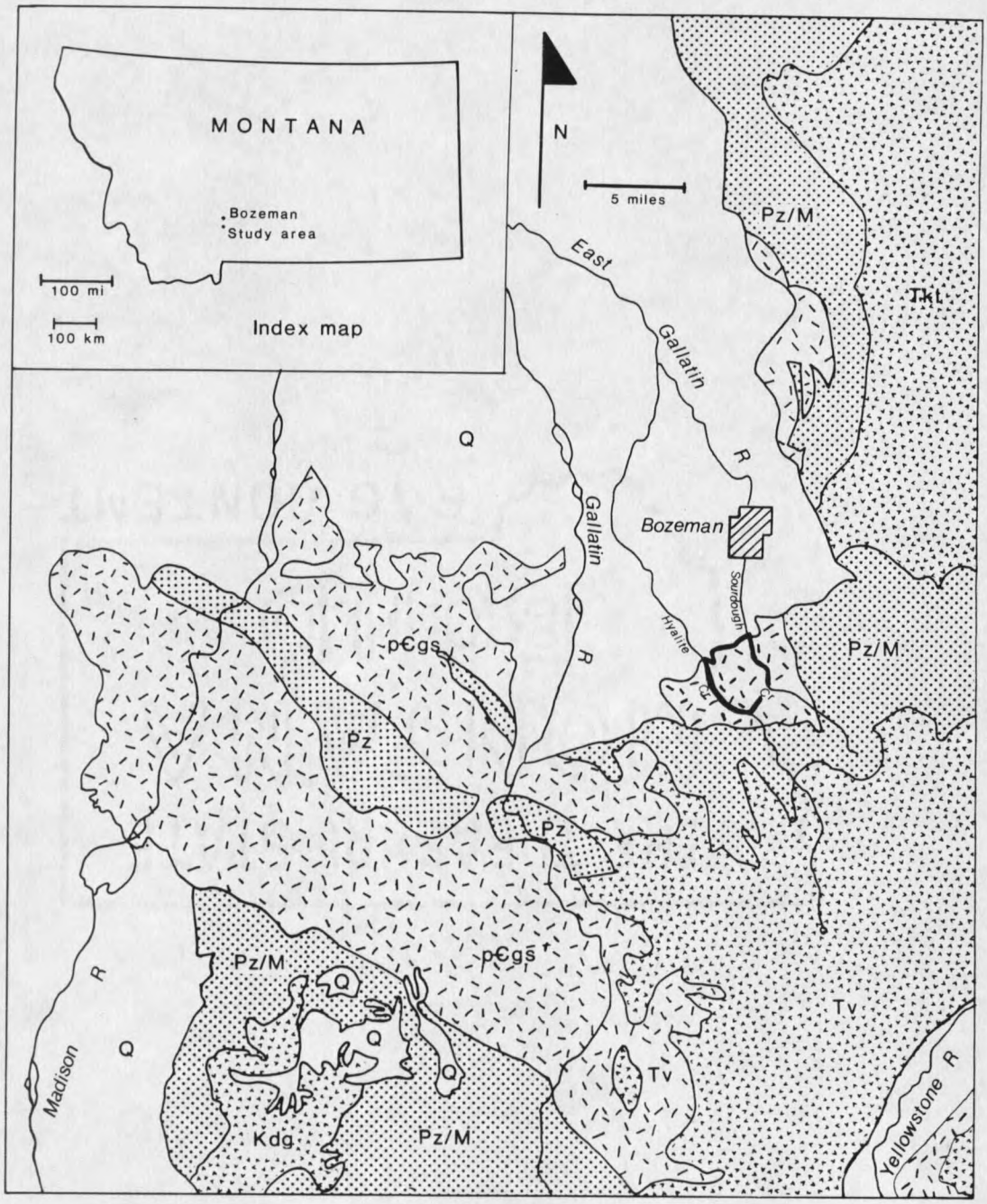

Figure 3. Generalized geologic and index map for study area (after Ross, et al, 1955). Lithologies are: Precambrian gneiss and schist (pЄgs), Paleozoic and Mesozoic sedimentary units undifferentiated (Pz/M), Cretaceous diorite and gabbro (Kdg), Tertiary water-laid volcanic material (Tkl), Tertiary volcanics (Tv), and Quaternary alluvial deposits (Q). Heavy outline indicates study area.

area of about seven square miles. The area was chosen because of the presence of Archean rocks, proximity to Bozeman, and ease of access. Access to the study area was gained by permission of private landowners and through the use of Forest Service and public roads.

Previous Studies

A limited amount of information is available on Archean rocks exposed in the Gallatin Range. Master's theses from Montana State University have included cursory descriptions and limited mapping of the Archean rocks in this area (Mifflin, 1963; Weber, 1965; and Tysdal, 1966). A brief description of Archean lithologies to the southwest of the study area accompanies a map of the Garnet Mountain quadrangle (McMannis and Chadwick ,1964). Spencer and Kozak (1975) mapped and described a part of the Archean rocks of the Gallatin Range along the Gallatin River Canyon as well as the Spanish Peaks area in the northern Madison Range. Giletti (1966, 1968) and James and Hedge (1980) have reported age dates from the Gallatin Canyon area.

REGIONAL GEOLOGIC SETTING

The Gallatin Range lies in the northwestern part of the Wyoming Archean Province (Figure 1; Condie, 1975). Two fundamentally distinct terrains exist within the Archean basement of this province (Figure 2). The North Snowy Block in the Beartooth Range locally defines the boundary between these two terrains (Mogk, et al, in review). To the east of this boundary the Beartooth Range and other exposures of Archean rocks are predominantly composed of late Archean andesites and granitoids with inclusions of older supracrustal rocks (Peterman, 1979; Henry, et al, 1982; Mueller, et al, 1985). The terrane west of the North Snowy Block predominantly consists of high-grade metasedimentary rocks (Spencer and Kozak, 1975; Garihan, 1979; Vitaliano, et al, 1979; Erslev, 1983). These rocks are composed of quartzofeldspathic gneisses and metabasites, as well as subordinate amounts of marbles, quartzites, sillimanite schists, and iron formations. Meta-igneous and ultramafic rocks are also locally present. The metamorphic grade throughout these exposures in the western terrane ranges from greenschist to granulite facies, with upper-amphibolite facies predominant (Spencer and Kozak, 1975; Garihan, 1979; Vitaliano, et al, 1979; Erslev, 1983). Two major generations of folding have been recognized (Spencer and Kozak, 1975; Garihan, 1979; Vitaliano, et al, 1979; Erslev, 1983). The first

deformation cycle produced isoclinal folds. These folds were subsequently deformed to produce large open folds.

James and Hedge (1980) reported Rb-Sr data from Archean rocks in southwest Montana yielding a 2.75 B.Y. age date for metamorphism in the area. Gilletti (1966, 1968) reported 1.6 B.Y. age dates from Archean exposures west of the Gallatin River, representing a regional thermal event that reset K-Ar isotopic clocks. A shear zone in the Portal Creek area of the Gallatin Range marks the transition zone that separates the 1.6 B.Y. terrane to the northwest from an older terrane (~2.7 B.Y.) to the southeast. At present no age dates younger than 2.1 B.Y. have been recognized southeast of the transition zone (Giletti, 1966).

Unconformably overlying the Archean basement in the northern Gallatin Range are Paleozoic and Mesozoic sediments and Eocene volcanics (Figure 3; Chadwick, 1969). Archean terranes in southwest Montana have been exposed through Cenozoic block faulting.

PETROLOGY

Quartzofeldspathic Gneisses

The northern Gallatin Range is composed predominantly of quartzofeldspathic gneisses. The majority of these gneisses exhibit primary compositional layering on a centimeter-scale. These are stromatic migmatites, defined by McLellan (1983) as migmatites with a small-scale layered structure. A minor amount of quartzofeldspathic gneisses exhibit evidence of leucosome mobilization. These migmatites are discussed in a following section. With the exception of the presence of epidote and a minor amount of sillimanite, most of the quartzofeldspathic gneisses lack bulk chemical compositions necessary to give rise to index minerals. Forthcoming observations, however, suggest that the gneisses initially attained transitional granulite facies grade followed by an epidote-amphibolite facies overprint.

Field Occurrence

Quartzofeldspathic gneisses exhibit pervasive compositional layering of millimeter to centimeter-scale, alternating leucocratic, amphibole + biotite-rich, and hybrid layers with a salt and pepper appearance (dark mineral percentages are 1%, >10%, and 10%, respectively). Compositional layering is parallel to mineral foliation. Leucocratic units occur within the quartzofeldspathic gneisses as conformable millimeter to centimeter-scale lenses, coalescing porphyroblasts, and isolated intrafolial folds.