Geochemistry and provenance of Archean metasedimentary rocks in the southwestern Beartooth Mountains

by Peter Bouck Thurston

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

Abstract:
A thick sequence of Archean metasedimentary rocks is exposed along the southwestern margin of the Beartooth Mountains, Montana.Rock types include quartz-biotite schist, biotite schist, biotite-garnet-staurolite-andalusite schist, iron formation (hornblende-cummingtonite-garnet schist), and dacitic metavolcanic rocks (quartz-muscovite-plagioclase schist). Preliminary chronologic data indicate an age of at least 3200 Ma for these racks (Paul Mueller, pers. comm.). The entire belt is metamorphosed from greenschist to middle amphibolite facies. Peak metamorphic conditions occurred at 550 degrees C and less than 3.8 kilobars. The entire rock package has experienced at least two periods of structural deformation. Early isoclinal folds (F1) are coincident with peak metamorphism (M1). Later open folds (F2) are superimposed on earlier structures. Primary sedimentary structures such as horizontal lamination, graded bedding, cross bedding, wavy bedding, and cut and fill structures are preserved. Analysis of sedimentary structures suggests that the rocks were originally deposited by turbidity currents in an environment similar to the midfan portion of a submarine fan. These data suggest deposition along an active continental margin; geochemical data indicates a provenance with sediment input from at least two different sources, one mafic and one felsic. These rocks are chemically unique in the northern Wyoming Province and were not derived from the adjacent Beartooth Mountains. A chronologically and chemically compatible source terrane has not been identified. The rocks are petrographically and chemically similar to early Archean greenstone belt sediments such as the Fig Tree group of Eriksson (1980). Similar rocks are exposed in central Wyoming (Condie, 1967). The style of metamorphism and deformation is sufficiently different from the surrounding region to classify these rocks as a distinct terrane. Previous work in the region has suggested the possibility of an Archean continental margin along the western edge of the Beartooth mountains (Wooden et al., in press). If this is the case then the metasedimentary rocks of the South Snowy Block could have been tectonically emplaced along this margin.

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Peter Bouck Thurston

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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ABSTRACT

A thick sequence of Archean metasedimentary rocks is exposed along the southwestern margin of the Beartooth Mountains, Montana.Rock types include quartz-biotite schist, biotite schist, biotite-garnet-staurolite-andalusite schist, iron formation (hornblende-cummingtonite-garnet schist), and dacitic metavolcanic rocks (quartz-muscovite-plagioclase schist). Preliminary chronologic data indicate an age of at least 3200 Ma for these rocks (Paul Mueller, pers. comm.). The entire belt is metamorphosed from greenschist to middle amphibolite facies. Peak metamorphic conditions occurred at 550 degrees C and less than 3.8 kilobars. The entire rock package has experienced at least two periods of structural deformation. Early isoclinal folds (F_1) are coincident with peak metamorphism (M_1). Later open folds (F_2) are superimposed on earlier structures. Primary sedimentary structures such as horizontal lamination, graded bedding, cross bedding, wavy bedding, and cut and fill structures are preserved. Analysis of sedimentary structures suggests that the rocks were originally deposited by turbidity currents in an environment similar to the midfan portion of a submarine fan. These data suggest deposition along an active continental margin; geochemical data indicates a provenance with sediment input from at least two different sources, one mafic and one felsic. These rocks are chemically unique in the northern Wyoming Province and were not derived from the adjacent Beartooth Mountains. A chronologically and chemically compatible source terrane has not been identified. The rocks are petrographically and chemically similar to early Archean greenstone belt sediments such as the Fig Tree group of Eriksson (1980). Similar rocks are exposed in central Wyoming (Condie, 1967). The style of metamorphism and deformation is sufficiently different from the surrounding region to classify these rocks as a distinct terrane. Previous work in the region has suggested the possibility of an Archean continental margin along the western edge of the Beartooth mountains (Wooden et al., in press). If this is the case then the metasedimentary rocks of the South Snowy Block could have been tectonically emplaced along this margin.

INTRODUCTION

Archean metasedimentary rocks are exposed in a narrow belt along the southern margin of the South Snowy Block of the Beartooth Mountains in southwestern Montana (Figure 1). These rocks are unique in the northern Wyoming Province (Condie, 1976) because of their low metamorphic grade, excellent preservation of primary sedimentary structures, and distinct chemical composition. Similar metasedimentary rocks are reported from the southern Wind River Range (Condie, 1967), the Owl Creek Mountains, and Rattlesnake Range in the southern Wyoming Province, but comparable rocks are not known to exist in the northern Wyoming Province.

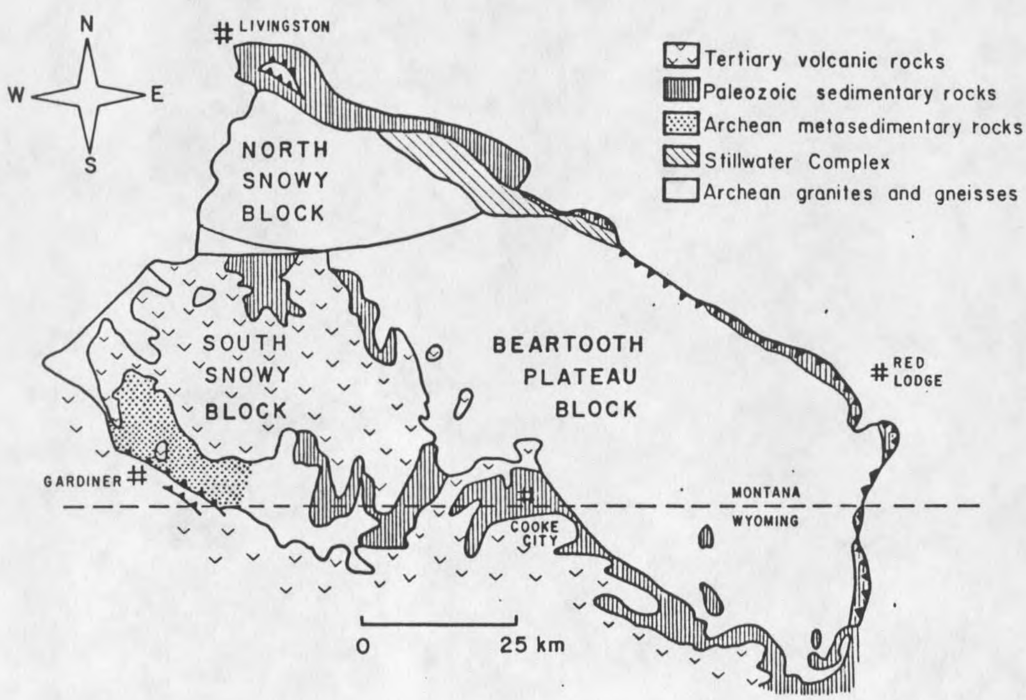

Figure 1. Geologic map of the Beartooth Mountains.

Previous research on Archean rocks in the South Snowy Block in general has been limited to a regional study along the southern margin of the block (Casella et al, 1982). In addition, specific projects concentrated on the gold mineralization in the Jardine area (Seager, 1944, Hallager, 1980) and surface geology of the Gardiner Quadrangle (Fraser et al, 1969).

This study examines metasedimentary rocks from the central part of the belt (Figure 2). The systematic evaluation of the sedimentology and geochemistry presented here suggests that the metasedimentary package was derived from a combination of mafic and felsic sources. The provenance, style of metamorphism, and style of deformation suggest that the entire metasedimentary package was tectonically emplaced in the late Archean.

GENERAL GEOLOGY

Archean metamorphic and igneous rocks of the South Snowy Block are for the most part covered by Eocene volcanic rocks and surficial deposits. Only along the southern margin of the block are Archean rocks well exposed. The metasedimentary sequence is bordered on the east by an Archean batholithic complex (Casella et al, 1982) consisitng of an early quartz-hornblende diorite and younger tonalites and granites (Wooden et al., in press). The minimum age of the metasedimentary rocks is constrained by ages from several of these plutons. The Crevice granite, which intrudes the central part of the belt, is dated at 2,620 Ma to 2,730 Ma by Rb/Sr and K/Ar methods (Brookins, 1968). These data are supported by a Rb/Sr model age on muscovite of 2,740 ± 30 Ma for the Hellroaring Mountain stock (Wooden et al., 1982). A U-Pb zircon age analysis suggests an age of 2,730 to 2,790 Ma for a biotite granodiorite that intrudes the eastern part of the metasedimentary belt (Montgomery, 1982). In the northern and southern portions of the area, these metasedimentary rocks are covered by Eocene volcanic rocks. To the west, the belt is terminated by a ductile shear zone in the Yankee Jim Canyon area (Burnham, 1980). The southwest corner is truncated by the Gardiner Fault, a high angle reverse fault of Laramide age (Fraser et al, 1969).

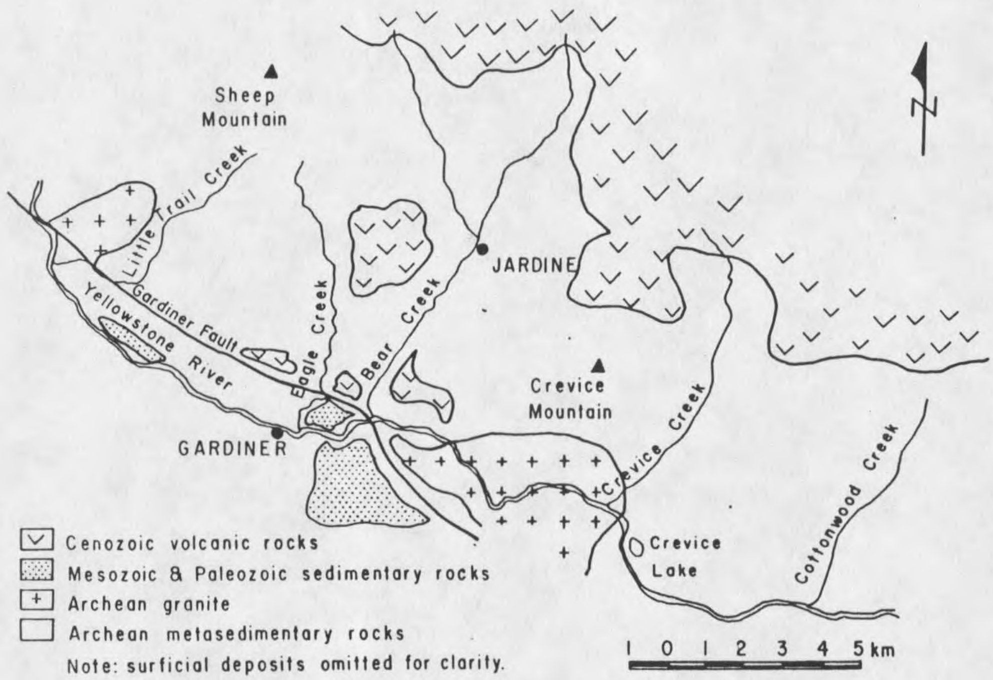

Figure 2. Distribution of metasedimentary rocks in the South Snowy Block.

METASEDIMENTARY ROCKS

Metasedimentary rocks are the oldest lithologic units in the study area. These rocks are metamorphosed from the upper greenschist to middle amphibolite facies with metamorphic grade increasing to the east. A metamorphic foliation defined by parallel alignment of biotite and chlorite is present throughout the region, and is locally very pronounced.

Rock types in the study area include quartz-biotite schist, biotite schist, biotite-staurolite-andalusite schist, garnet-biotite-chlorite schist, iron formation (both silicate and oxide facies), quartzite metaconglomerate, and felsic metavolcanic rocks (quartz-muscovite-plagioclase schist). Each of these lithologies is described in terms of its field appearance and petrography. Selected samples are analyzed for major and trace element geochemistry. For a complete description of analytical methods and listing of data refer to Appendices A and B.

Quartz-Biotite Schist

Quartz-biotite schist is the dominant lithology in the region. In outcrop the rocks are light grey to medium brown in color. Bedding is well exposed in many locations and is defined by abrupt changes in grain size and texture. Individual beds are 5.0 to 25.0 centimeters thick and sedimentary textures and structures such as grading, cross bedding, and cut and fill structures are often preserved. The rock is poorly sorted and is composed of detrital quartz and feldspar grains set in a matrix of quartz, biotite, and chlorite.

Two varieties of detrital quartz grains are present. Monocrystalline quartz grains are the most abundant, and commonly exhibit undulose extinction (Figure 3). Individual monocrystalline quartz grains range in size from 0.1 to 2.0 millimeters and are subrounded to subangular. Polycrystalline quartz grains tend to be slightly larger, have sutured grain boundaries, and are commonly fractured (Figure 4). Individual polycrystalline quartz grains are 1.0 to 2.0 millimeters in size and are subrounded to subangular A gradation between the two types exists. Both varieties of quartz grains are flattened and elongated in the plane of the foliation.

Plagioclase occurs as subrounded detrital grains from 0.5 to 2.0 millimeters in diameter and contain abundant quartz inclusions (Figure 5). Original grain boundaries and igneous textures such as oscillatory zoning and albite twinning are preserved despite metamorphic recrystallization. Compositions determined by optical (Michel-Levy) methods range from An_{24}-An_{31}. Plagioclase grains are also aligned and flattened in the plane of the foliation.

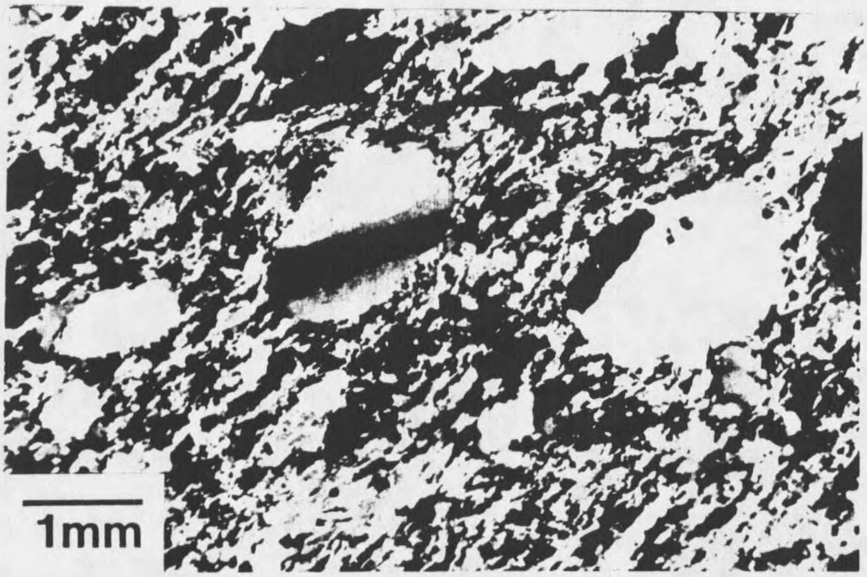

Figure 3. Photomicrograph of monocrystalline quartz grains.

Probable lithic fragments (Figure 6) also constitute a portion of the detrital grains. Angular to subrounded grains composed of aggregates of quartz and plagioclase are 0.5 to 2.0 millimeters in size. The plagioclase occurs as optically discontinuous aggregates of euhedral crystals suggesting an igneous origin. Positive identification of any specific rock type is difficult because of recrystallization, however most appear to be fragments of tonalite or trondhjemite.

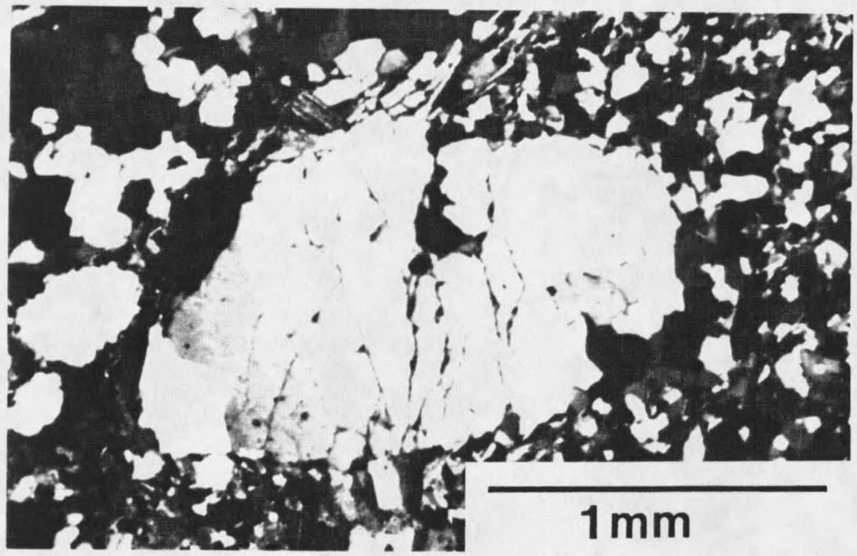

Figure 4. Photomicrograph of a polycrystalline quartz grain.

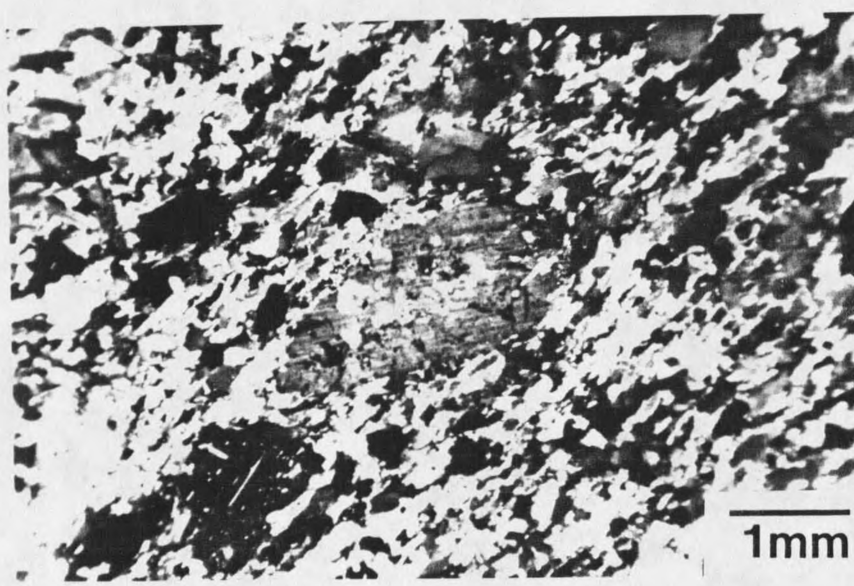

Figure 5. Photomicrograph of a detrital plagioclase grain.