Stratigraphy and depositional environment of the Upper Mississippian Big Snowy Group in the Bridger Range, southwest Montana
by Gary Eich Guthrie

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

Abstract:
The Big Snowy Group is restricted to a trough which extends from southwest Montana into the Williston basin. Thickness variation of the group on the southern margin of the trough reflects movement of structural elements along an ancient structural weakness located in the central Bridget Range. Field and petrographic data are integrated to determine the depositional environment and stratigraphy of the group and to document the tectonic influence on sedimentation along this zone.

The group is divided into the Kibbey Formation, with two informal members, and the Lombard facies of the Heath Formation. The lower Kibbey is supratidal algal laminated dolostone with dessication features and evaporite solution breccias were deposited at the leading edge of the transgressing Big Snowy sea. Siliciclastic intertidal channels on the sabkha are restricted to the central range where subsidence was greatest. The upper Kibbey and Lombard facies provide further evidence of a trough in the central Bridgers. The upper Kibbey is a regressive shoreface deposit composed of fine grained sandstone at the northern and southern ends of the range. Mudstone and siltstone dominate in the center of the range where deeper water and lower energy conditions prevailed. Ultimately, the Kibbey shoreface transgressed out of the area and the Lombard facies was deposited in a partially restricted shelf lagoon. Shale and lime mudstone accumulated in the center of the range, to the north and south bioclastic wackestones, packstones, and grainstones were deposited in shoaling, higher energy conditions.

All three units of the group are thickest in the central Bridgers and thin north and south onto the Lombard arch and Wyoming shelf.

Deeper water lithologies occur with the thick sections indicating that the central part of the range subsided relative to the Lombard arch and Wyoming shelf during sedimentation. A small positive trend in the central range trough is a local exception to the pattern. This paleotectonic pattern also operated during pre-Amsden uplift and erosion and thinned the group on the positive elements more. Evidence of similar paleotectonic influence on sedimentation along the structural weakness in the Bridgers is also found in Proterozoic and other Paleozoic rocks.

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APPROVAL

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Gary Eich Guthrie

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.

1 Aug 84
Date

Stephen G. Custer
Chairperson, Graduate Committee

Approved for the Major Department

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Date

Stephen G. Custer
Head, Major Department

Approved for the College of Graduate Studies

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Date

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ABSTRACT

The Big Snowy Group is restricted to a trough which extends from southwest Montana into the Williston basin. Thickness variation of the group on the southern margin of the trough reflects movement of structural elements along an ancient structural weakness located in the central Bridger Range. Field and petrographic data are integrated to determine the depositional environment and stratigraphy of the group and to document the tectonic influence on sedimentation along this zone.

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INTRODUCTION

Paleotectonic and Stratigraphic Setting of the Big Snowy Group

Regional Setting

Regionally, the stratigraphy of the upper Mississippian Big Snowy Group reflects the influence of major tectonic elements on sedimentation (Figure 1). It is reasonable to assume this relationship is also true on a local scale. This study attempts to document the influence of paleotectonic activity on sedimentation of the Big Snowy Group in the Bridger Range.

Most of Montana was the site of intermittent shelf or platform sedimentation on the Cordilleran platform throughout Paleozoic time (Sando, Gordon, and Dutro, 1975). The platform was bounded on the east by the transcontinental arch in eastern North Dakota and South Dakota and on the northeast by the Canadian shield. These were continually emergent areas which provided sediment for clastic deposition on the platform. The Cordilleran miogeocline bordered the Cordilleran platform on the west in extreme southwestern Montana, Wyoming, and eastern Idaho. Huh (1967) located and described the craton-miogeocline transition where Big Snowy Group shelf strata grade into equivalent miogeoclinal strata in extreme southwestern Montana. The miogeocline received sediments throughout Big Snowy time (Gutschick, Sandberg, and Sando, 1980).

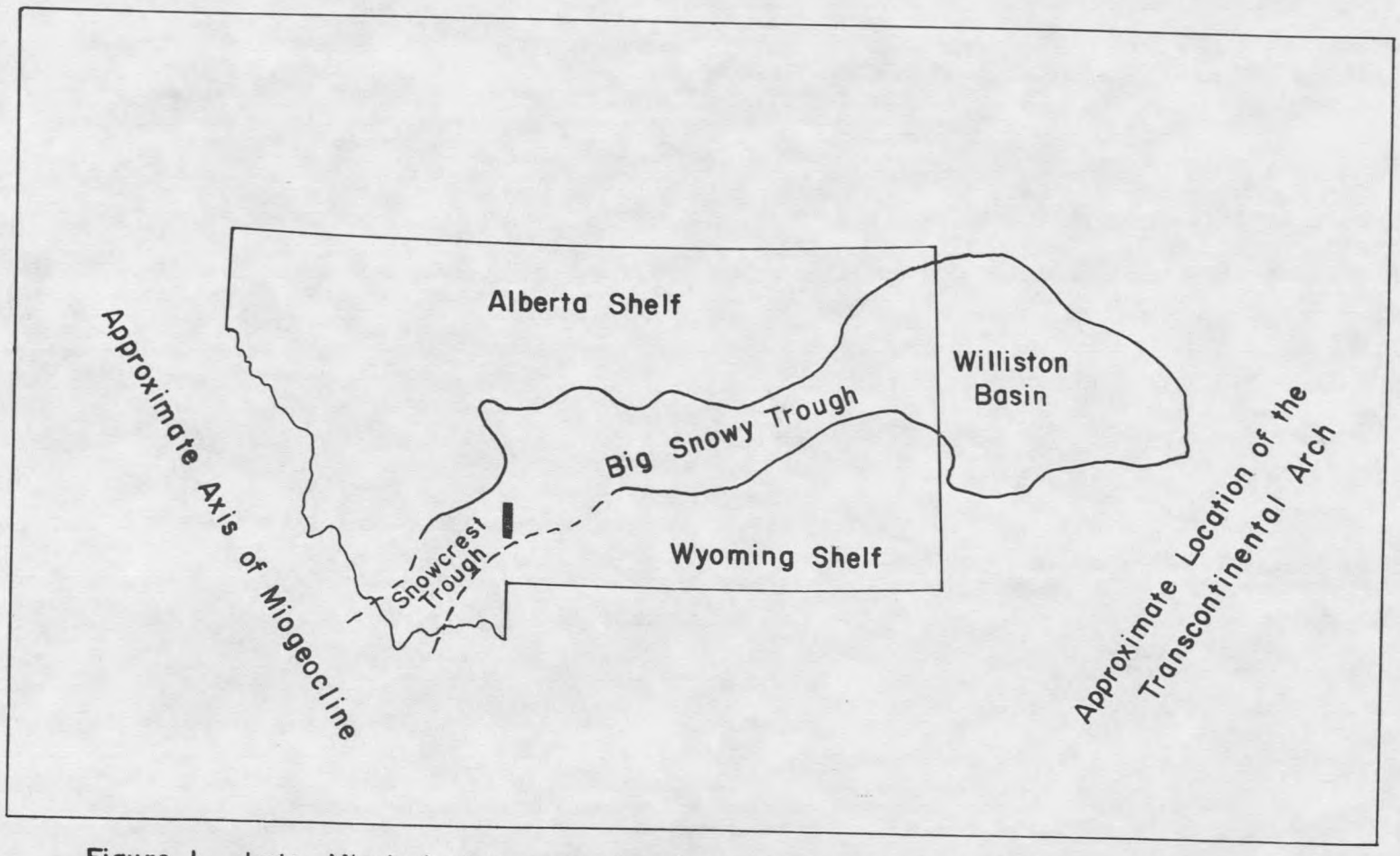

Figure 1. Late Mississippian tectonic elements on the Cordilleran platform in the northern Rocky Mountains.

Stratigraphic studies in Montana indicate that several smaller paleotectonic elements active within the Cordilleran platform itself were particularly influential on late Mississippian and early Pennsylvanian sedimentation (Sando, 1976; Peterson, 1981). An unstable trough connected the miogeocline with the Williston basin and divided the platform into several independent shelves (Figure 1). The east-west part of this unstable trend has been variously described as the Big Snowy basin (Eardley, 1962), Central Montana trough (Roberts, 1975), and Big Snowy trough (Peterson, 1981). Maughan and Perry (1967) named the southwest extension of this unstable trend the Snowcrest trough (Ruby trough of Peterson, 1980). The margins of both troughs correspond closely to the present zero edge of Big Snowy Group sediments (Figure 2). Previous authors have not always restricted usage of the terms Snowcrest and Big Snowy trough to late Mississippian rocks (e.g. Maughan, 1984; Roberts, 1979). In the present report the terms Snowcrest and Big Snowy troughs are used to indicate areas of active late Mississippian and early Pennsylvanian subsidence in which Big Snowy sediments were deposited and preserved.

North of the Snowcrest-Big Snowy troughs, the Alberta shelf was neutral relative to the actively subsiding troughs. Big Snowy rocks are not preserved there (Smith, 1972). Southward, equivalent upper Mississippian rocks are preserved on the Wyoming shelf. The rocks here are thin, however, indicating an intermediate degree of tectonic stability between the unstable Big Snowy and Snowcrest troughs and the Alberta shelf (Sando, Gordon, and Dutro, 1975).

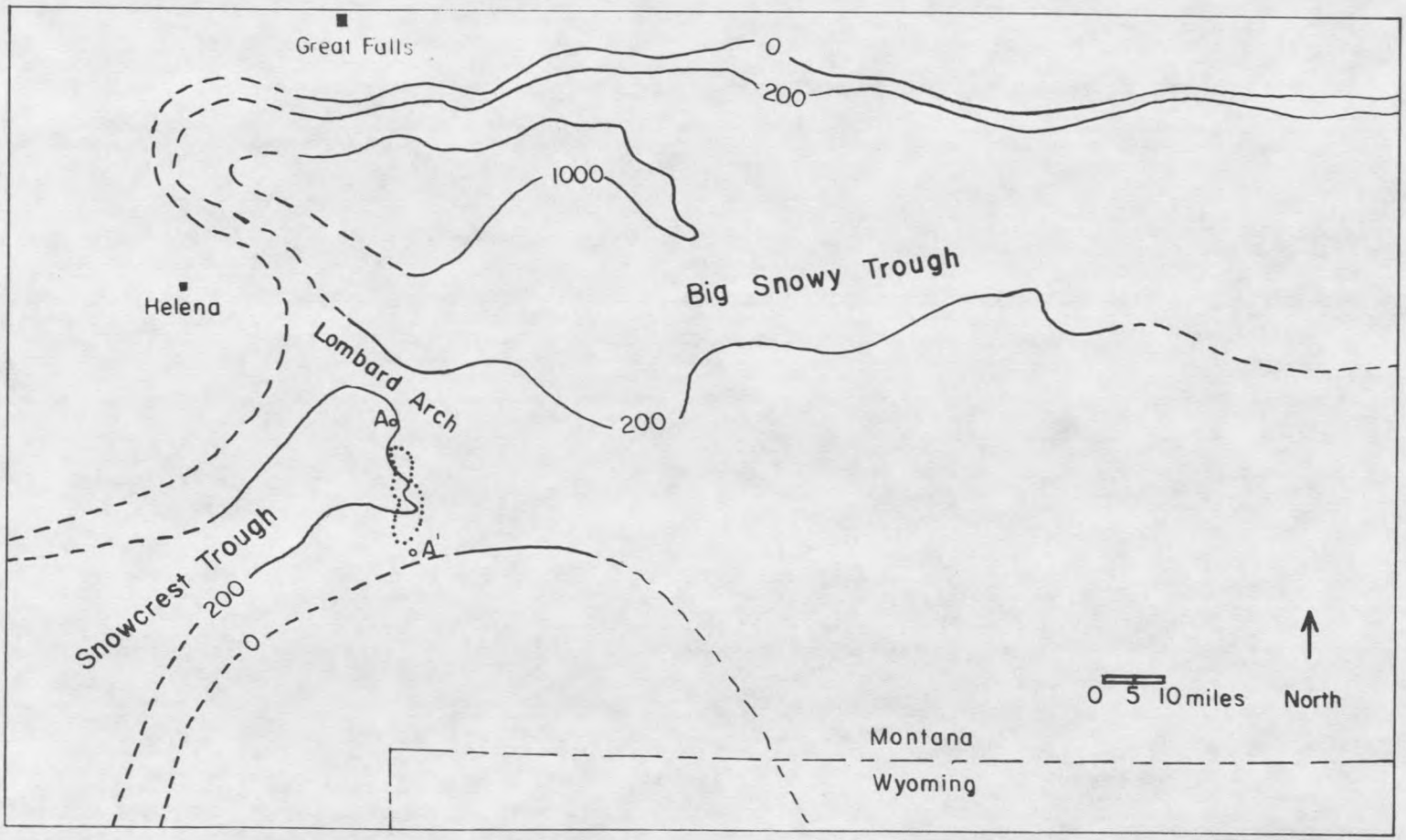

Figure 2. Isopach map of Big Snowy Group showing paleotectonic elements, contours in feet. See Plate I for section A-A', Bridger Range dotted. (modified from Harris, 1972).

Bridger Range Setting

A small positive element separates the Snowcrest trough from the Big Snowy trough (Figure 2). Big Snowy strata thin across this arch-like feature as they are traced from the Snowcrest trough to the Big Snowy trough (Blake, 1959; Harris, 1972). The term Lombard arch is applied in this report to the region between the Snowcrest and Big Snowy troughs where Big Snowy rocks are thin. This region extends approximately from Helena to Livingston, Montana.

Big Snowy Group rocks were first recognized in the Bridger Range by McMannis in 1951. He recognized extreme thickness changes in the group along the length of the Bridger Range. From a zero edge on the Wyoming shelf, which McMannis located in the southern Bridgers, the Big Snowy Group reaches a maximum local thickness in the central part of the range. The group then thins across the Lombard arch in the northern range.

Purpose

Geologists recognize that these thickness variations represent late Mississippian tectonic elements with either differential subsidence during deposition, post-Big Snowy differential uplift and erosion, or both (Harris, 1972; Sando, 1976; Maughan,1984). Unfortunately evidence of depositional thinning, such as gradually shoaling lithofacies, is missing at previously studied locations due to post-depositional erosion. Thus, the original extent of the group and the relative importance of differential subsidence during

deposition and post-depositional erosion is unclear.

The present study was undertaken to determine if thickness variations of the Big Snowy Group in the Bridger Range are due to syndepositional movement of paleotectonic elements.

Study Area

The north-south trend of Bridger Range exposures provides a line of stratigraphic section across a late Mississippian structural trough approximately perpendicular to depositional strike. Also, the range is situated near the intersection of the Snowcrest and Big Snowy troughs which allows examination of the relationship between strata of both troughs as they thin and interfinger across the Lombard arch.

Paleozoic and Mesozoic rocks in the Bridger Range are uplifted approximately 1500 meters above surrounding valleys. They are also thrusted several kilometers east (Dave Lageson, personal communication). The rocks of the Big Snowy Group are well exposed just east of the range crest which is composed of near vertical Madison Group limestone (Figure 3).

Fourteen exposures were analyzed along a line from just south to just north of the Bridger Range (Plate 1). The exposures extended from Rocky Canyon on the south end of the study area to a canyon on the Middle Fork of Sixteenmile Creek in the southern Big Belt Mountains on the north end. Thirteen exposures in the neighboring Horseshoe Hills, Southern Big Belt and Castle Mountains, and northwestern Beartooth Mountains were analyzed in less detail.

Figure 3. Exposure of upper Paleozoic rocks at southeast Sacajawea section (for location see Plate 1). Ridge on right is Mississippian Mission Canyon Formation, next left low interval with trees is Big Snowy Group, non-vegetated interval is Amsden Formation, cliff on left is Pennsylvanian Quadrant Formation.

Methods

During the field season of 1982, exposures of the Big Snowy Group in the Horseshoe Hills, southern Big Belt and Castle Mountains, northeastern Beartooth Mountains, and Bridger Range were located and briefly described. Many exposures were previously cited in the literature. Others were located with aerial photographs and reconnaissance. Literature research and correspondence with geologists working on this stratigraphic interval followed. During the field season of 1983 fourteen complete exposures of the Big Snowy Group in the Bridger Range were measured with a jacobs staff and described in detail. Several other incomplete or poorly exposed sections in the Bridgers were briefly described. Measurements and lithologic descriptions of each exposure are included in the appendix. Samples were collected at each significant lithological change.

Lithologic samples were slabbed and studied using a binocular microscope. Also, over 100 thin sections were prepared and analyzed with a binocular petrographic microscope. Approximately ten percent of the thin sections and slabs were stained with alizarin red solution to determine dolomite content.

Using these data, lithofacies were defined and interpreted. The lithofacies were then correlated between stratigraphic sections plotted on a stratigraphic cross section. Locations of measured sections discussed in the text are plotted on the location map on Plate 1.

The sections were plotted on the cross section shown on Plate 1

using the Big Snowy-Amsden contact as a datum. The contact was initially believed unconformable using field evidence. Conodont data later supported this conclusion and showed that this contact correlates with the regional Big Snowy-Amsden unconformity.

Although the surface is not necessarily a time line and may have had relief prior to Amsden deposition, it is the most appropriate datum for this stratigraphic interval. A line of synchronous deposition within the Big Snowy Group cannot be established unless significantly more biostratigraphic work is done. Therefore, an unconformity represents the next best alternative. The Big Snowy-Amsden unconformity shows the geometry of the underlying Big Snowy Group best. Also, this datum represents an established regional unconformity.

Samples for conodont age determinations were collected from carbonate rocks in the Big Snowy Group and overlying lower Amsden Formation. Sample locations were chosen in order to define the age relations of the Big Snowy Group and to aid in interpreting the contact with the Amsden Formation. Samples were restricted to less than one-third meter thick intervals of strata cropping out in relatively rich bioclastic limestone and dolomite. Eighteen one-kilogram samples were sent to the United States Geological Survey in Denver for preparation and analysis by Bruce Wardlaw. Sample locations and interpretations are included in the appendix with descriptions of measured sections.

PREVIOUS INTERPRETATIONS OF BIG SNOWY GROUP STRATIGRAPHY

Introduction

Three rock packages were deposited by three transgressive-regressive cycles during the Mississippian and early Pennsylvanian. In ascending order, these include the Madison Group, Big Snowy Group, and the Amsden Formation (Figure 4). The duration of the hiatuses separating each sequence is variable. In general, however, the farther from the unstable trough axis, the greater the duration (Smith and Gilmour, 1979). Although the groups are separated by regional unconformities or hiatuses, they are intimately related by common sedimentologic and tectonic controls. Some discussion of the Mission Canyon Formation below and Amsden Formation above the Big Snowy Group is necessary to understand the external tectonic and sedimentologic influences on deposition of the Big Snowy Group and bounding contacts.

Relations of the Big Snowy Group to the Underlying Mission Canyon Formation

The Mission Canyon Formation ranges in age from middle Osage to middle Meramec (Sando, Gordon, and Dutro, 1975). The formation extends throughout Montana except where removed by Tertiary erosion. The diverse rock types of the Big Snowy Group contrast sharply with the underlying relatively uniform Mission Canyon carbonates. The