



Tectono-sedimentary evolution of a Late Cretaceous alluvial fan, Beaverhead Group, southwestern Montana
by Paul Alex Azevedo

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

The lower conglomeratic member of the Late Cretaceous Beaverhead Group east of Bannack, Montana contains a progressive unconformity which provides a direct link between sedimentation and deformation in the leading edge of the Cordilleran fold and thrust belt of southwest Montana. The recognition of a progressive unconformity within the lower Beaverhead conglomerate along Grasshopper Creek directly ties the deposition of the strata to uplift of the Madigan Gulch anticline. In addition, it provides an alternate interpretation for the structural configuration of the Beaverhead strata in the study area.

Along Grasshopper Creek, the lower Beaverhead conglomerate consists of approximately 354 m of synorogenic pebble/cobble conglomerate with subordinate sandstone and minor volcanic rocks. Consideration of lithofacies types, bed geometries, and facies associations suggests deposition on an alluvial fan characterized by cohesionless debris flows, hyperconcentrated flows, and proximal, braided gravel-bed river processes. The preserved remnants of a large fanhead channel is evidence that the surface of the fan actively went through periods of fanhead entrenchment which probably occurred in response to a tectonic stimulus.

Paleocurrent and clast composition data suggest the source area for the lower Beaverhead conglomerate was the east limb of the Madigan Gulch anticline. Formation of this eastward-verging asymmetrical fold may be related to movement of the Ermont thrust over a subsurface ramp. The progressive unconformity records the kinematic evolution of the fold.

The progressive unconformity is defined by the existence of three wedge-shaped packages of sediment. Each package of sediment formed in response to basinward rotation of the proximal part of the fan during uplift of the Madigan Gulch anticline. The rotative offlap geometry of the progressive unconformity indicates that the rate of uplift was episodic and exceeded the rate of sedimentation.

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APPROVAL

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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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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	iv
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF PLATES	xii
ABSTRACT	xiii
INTRODUCTION	1
Purpose of study	4
Location	6
METHODS	9
Field Procedures	9
Laboratory Methods	12
REGIONAL STRUCTURAL AND STRATIGRAPHIC SETTING	14
GENERAL GEOLOGY OF THE STUDY AREA	17
Local Stratigraphy	17
Local Structural Geology	21
Folds	21
Faults	24
STRATIGRAPHY AND AGE OF THE BEAVERHEAD GROUP	28
LITHOFACIES	36
Conglomerate Lithofacies (G)	36
Introduction	36
Massive, Disorganized, Polymodal Conglomerate (Gcd)	36
Description	36
Interpretation	38
Massive, Disorganized Conglomerate (Gcm)	41
Description	41
Interpretation	43
Horizontally Stratified Conglomerate (Gch)	47

TABLE OF CONTENTS - continued

Description	47
Interpretation	48
Organized, Pebble Conglomerate (Gcp)	49
Description	49
Interpretation	49
Trough Cross-Stratified Conglomerate (Gct)	50
Description	50
Interpretation	50
Sandstone and Mudstone Lithofacies (S/F)	51
Introduction	51
Massive Sandstone (Sm)	52
Description	52
Interpretation	53
Horizontally Laminated Sandstone (Sh)	54
Description	54
Interpretation	55
Ripple Cross-laminated Sand (Sr)	55
Description	55
Interpretation	56
Fine-Grained Lithofacies (Fm/Fl)	56
Description	56
Interpretation	57
Volcanogenic Lithofacies (V)	57
Introduction	57
Volcanic Rocks (V)	57
Description	57
Interpretation	58
LOWER BEAVERHEAD STRATIGRAPHY	59
DEPOSITIONAL SYSTEMS	62
PALEOCURRENTS	69
PETROGRAPHY	71
Conglomerate	71
Texture	71
Composition	71
Limestone Clasts	71
Chert Clasts	72
Sandstone Clasts	72
Modal Composition	74
Sandstone	75
Texture	75

TABLE OF CONTENTS - continued

Composition	75
Monocrystalline Quartz (Qm)	75
Polycrystalline Quartz (Qp)	76
Lithic Fragments	76
Sandstone Petrofacies	76
Chertarenites	78
Calclithites	79
Volcanic Rocks	80
PROVENANCE	82
SYNTECTONIC UNCONFORMITIES	92
TECTONO-SEDIMENTARY EVOLUTION OF THE GRASSHOPPER CREEK ALLUVIAL FAN	102
SUMMARY OF INTERPRETATIONS	117
REFERENCES CITED	120
APPENDICES	130
APPENDIX A: CONGLOMERATE CLAST COMPOSITION DATA	131
APPENDIX B: SANDSTONE DETRITAL MODES	134

LIST OF TABLES

Table	Page
1. Summary descriptions of lithologic units . . .	19
2. Summary of lithofacies	37
3. Formation names and ages for clast lithologies recognized in the lower Beaverhead Conglomerate in the study area . . .	83
4. Probable source formations for unique clast lithologies recognized in hand samples and thin-section	85
5. Conglomerate clast count data	132
6. Conglomerate clast modal percentage	133
7. Sandstone point count data	135
8. Sandstone modal percentage calculated for QFL ternary diagrams	136
9. Sandstone modal percentage calculated for QmFLt ternary diagrams	137

LIST OF FIGURES

Figure	Page
1. Generalized map of southwestern Montana showing location of study area and major regional structures.	7
2. Thesis location map	8
3. Overview of field area and location of measured sections	10
4. Relative stratigraphic position of measured sections in the lower Beaverhead conglomerate	11
5. Major divisions of the Cordilleran fold belt in southwest Montana and east-central Idaho	15
6. Generalized stratigraphic column of study area and northern portion of the Armstead Hills	18
7. Generalized geologic map of study area	22
8. Distribution of Beaverhead Group rocks in southwestern Montana and east-central Idaho	29
9. Stratigraphy of Beaverhead Group east of Bannack, Montana	30
10. Contact between the lower Beaverhead conglomerate and Lombard Limestone on the east limb of the Madigan Gulch anticline	31
11. Ages and stratigraphic relationships of formal and informal units within the Beaverhead Group	34

LIST OF FIGURES - continued

12. Facies Gcd interbedded with thin, discontinuous beds of massive sandstone (Sm)	39
13. Facies Gcm overlain by facies Gch	42
14. Facies Gct overlain by facies Gcd and underlain by facies Gcm	51
15. Generalized vertical lithofacies profile of the lower Beaverhead conglomerate	60
16. Steep walled channel incised into conglomerates (Gcm and Gcd) and sandstones (Sm)	63
17. Large channel incised into deposits of conglomerate and sandstone	67
18. Rose diagrams showing paleocurrent measurements from imbricated clasts in conglomerates	70
19. Modal percentage of conglomerate clasts at each clast count location	74
20. Compositional ternary diagrams of Beaverhead sandstones in study area	77
21. Photomicrograph of chertarenite from the lower Beaverhead conglomerate	78
22. Photomicrograph of calclithite from within the large channel	79
23. Photomicrograph of vitric tuff from deposits in the lower Beaverhead conglomerate	81
24. Photomicrograph of lower Beaverhead conglomerate matrix sample	86
25. QmFLt ternary diagram of Beaverhead sandstones	89

LIST OF FIGURES - continued

26. Overview and sketch of Beaverhead strata on the south side of Grasshopper Creek	93
27. Genetic model of progressive and syntectonic angular unconformities	95
28. Equal-area stereonet of poles to bedding planes from strata within the lower Beaverhead conglomerate	96
29. Cross-sections of three progressive unconformities in the Upper Eocene-Oligocene Montsant conglomerates of the NE Ebro Basin, Spain	100
30. Schematic diagram showing progressive uplift of the Madigan Gulch anticline and deformation of the Grasshopper Creek alluvial fan in response to propagation of the Ermont thrust	108
31. Klippe of Madison limestone truncating a portion of the lower Beaverhead conglomerate on the north side of Grasshopper Creek	115

LIST OF PLATES

Plate	Page
1. Measured stratigraphic sections of the lower conglomerate unit of the Upper Cretaceous Beaverhead Group east of Bannack, Montana .	in pocket
2. Photomosaic and sketch of the lower Beaverhead strata on the south side of Grasshopper Creek	in pocket

ABSTRACT

The lower conglomeratic member of the Late Cretaceous Beaverhead Group east of Bannack, Montana contains a progressive unconformity which provides a direct link between sedimentation and deformation in the leading edge of the Cordilleran fold and thrust belt of southwest Montana. The recognition of a progressive unconformity within the lower Beaverhead conglomerate along Grasshopper Creek directly ties the deposition of the strata to uplift of the Madigan Gulch anticline. In addition, it provides an alternate interpretation for the structural configuration of the Beaverhead strata in the study area.

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INTRODUCTION

Synorogenic conglomerates have long been recognized as a valuable tool in deciphering the tectonic history of their source area (Ryder and Scholten, 1973; Haley, 1985; Lawton, 1986; DeCelles and others, 1987, 1991a, Haley and Perry, 1991). However, incomplete exposures and lack of accurate chronologic markers often make direct links between sedimentation and deformation difficult (Holl and Anastasio, 1993). Recent studies (Riba, 1976; Anadon and others, 1986; DeCelles and others, 1987, 1991a;b) have suggested that synorogenic conglomerates produced in compressional tectonic settings may contain suites of structures that are characteristic of contractional deformation and are directly attributable to deformation of their adjacent source terranes. These structures include intraformational thrust faults, folds, and progressive unconformities.

Progressive unconformities develop as wedge-shaped packages of sediment deposited on the flanks of growing structures such as anticlines, high angle faults and nappe fronts. The geometry of a progressive unconformity is usually interpreted to be directly controlled by the interplay between the rate of tectonic uplift and the rate of sediment accumulation along the flank of the structure (Riba, 1976).

The recognition of progressive unconformities is important because the geometry or stacking characteristics of successive depositional wedges may provide insight into the kinematic evolution of the adjacent source terrane (DeCelles and others, 1991a; Verges and Burbank, 1992; Holl and Anastasio, 1993). However, descriptions of syntectonic sediments containing progressive unconformities are scarce in the geological literature (Riba, 1976; Anadon and others, 1986; DeCelles and others, 1987, 1991a;b; Holl and Anastasio, 1993). Those that have been described are found in alluvial fan deposits adjacent to foreland basin margins and intrabasinal uplifts. These studies suggest that progressive unconformities may be an important characteristic of thrust generated conglomerates that have been widely overlooked. One stratigraphic unit in the North American Cordillera which might be expected to contain progressive unconformities is the Late Cretaceous Beaverhead Group of southwestern Montana.

Strata of the Beaverhead Group comprise the synorogenic Upper Cretaceous to lower Tertiary (?) stratigraphic sequence in southwestern Montana. Beaverhead Group strata are dominated by conglomerates that are thought to have been shed from structural elements which rose in response to contractional deformation in the Rocky Mountain foreland to the east and the fold and thrust belt to the west (Ryder and Scholten, 1973, Haley, 1985). Lithofacies analysis of the Beaverhead Group conglomerates suggest they were deposited on alluvial fans and

in the proximal portions of braided gravel-bed fluvial systems (Ryder and Scholten, 1973; Haley, 1985; Haley and Perry, 1991). Although the depositional environment and structural setting are favorable for the development of progressive unconformities no structures of this type have been described to date in the Beaverhead strata.

East of Bannack, Montana synorogenic strata of the Late Cretaceous Beaverhead Group crop out along Grasshopper Creek. Previous work by Goodhue (1986), Johnson and Sears (1988) and Coryell and Spang (1988) suggests that the lower conglomerate member of the Beaverhead Group in this area may be a promising location to look for progressive unconformities. In this area the lower conglomerate member is dominated by framework-supported limestone-clast conglomerate with interbeds and lenses of sandstone and minor volcanic rocks (Goodhue, 1986; Johnson, 1986; Johnson and Sears, 1988). By analogy with other Beaverhead Group strata in southwestern Montana, Goodhue (1986) hypothesized that the lower conglomerate unit east of Bannack represented deposition on the surface of small alluvial fans and in the proximal portions of braided gravel-bed stream systems. The uplifted structural elements which shed these deposits resulted from compressional deformation in the frontal fold and thrust zone of the Cordilleran fold and thrust belt in southwestern Montana (Johnson and Sears, 1988; Coryell and Spang, 1988).

Purpose of study

The purpose of this study is to explore the question, "Does the lower Beaverhead conglomerate east of Bannack, Montana contain a progressive unconformity?" In testing this hypothesis the following questions were addressed:

1) What depositional environment(s) characterized the lower conglomeratic unit? To date, progressive unconformities have only been recognized in proximal alluvial fan environments adjacent to compressional uplifts. Therefore it is important to establish the depositional environment of the lower Beaverhead strata. Alluvial fan deposits can be recognized by a distinctive association of lithofacies (Miall, 1978; Rust, 1978).

2) What is the provenance of the lower conglomeratic unit? Knowledge of the sediment provenance is important for determining the location and composition of the source area. Paleocurrents from an individual alluvial fan deposit should have a flow pattern radiating outward from the fan apex (Nilsen, 1982). However, this radial pattern may become hard to detect if the fan apex is not preserved. Coalescing of adjacent fan sequences may produce complex paleoflow patterns. Possible paleoflow indicators include channel orientation, cross-stratification in sandstones and conglomerates, and conglomerate clast long-axis orientation. Measurement of the largest clast sizes in alluvial fan sequences may also be a

useful paleoflow indicator. There is generally a rapid decrease in the maximum and average clast size downfan from the fan apex (Bluck, 1964; Lustig, 1965; Bull, 1972; Nilsen, 1982). However, the uniformity of particle size decrease may be greatly affected by the amount of temporary channel entrenchment during the history of the fan (Bull, 1972). Compositional trends in the ^acourse-grained and fine-grained fractions of the sediments may provide additional insight into the structural evolution of the source area. The character of clast compositional trends may be indicative of the structural setting of the source area (Steidtmann and Schmitt, 1988).

3) What evidence can be found in the lower Beaverhead strata which might suggest the existence of a progressive unconformity? Determining the depositional environment and provenance will not in itself document the existence of a progressive unconformity within the lower Beaverhead deposits. Progressive unconformities are recognized in proximal alluvial fan deposits of the Tertiary Ebro Basin, Spain by a series of overlapping, wedge-shape sedimentary packages which thin in an upfan direction (Riba, 1976). Such sedimentary wedges might be documented in the lower Beaverhead conglomerate by recording bedding attitudes throughout the stratigraphic section. It is hypothesized here that uplift of the source terrane, which is integral to the development of a progressive unconformity, should cause the initial sedimentary packages to be deformed to a greater degree than later deposits. However, each

sedimentary package should contain an internally consistent set of bedding attitudes. Plotting bedding attitudes on a photomosaic of the outcrops may also serve to highlight the existence and geometry of individual sedimentary packages. It may also be possible to distinguish individual packages based on lithology and association of lithofacies.

4) If a progressive unconformity is present in the lower Beaverhead conglomerate does its geometry reveal any information regarding the kinematic evolution of the source terrain? When the rate of uplift exceeds the rate of sedimentation along the flanks of the structure the individual sedimentary-wedge packages will offlap each other in a basinward direction (Riba, 1976, Anadon and others, 1986). If the rate of sedimentation exceeds the rate of deformation the sedimentary wedges will onlap each other towards the hinterland (Riba, 1976, Anadon and others, 1986).

Location

The study area is located along Grasshopper Creek in the northern portion of the Armstead Hills approximately 3 km east of Bannack State Park in Beaverhead County, Montana (Figure 1 and 2). The study area covers approximately 6 km² (Sections 8, 9, 16, and 17 T8S; R11W) of the U.S. Geological Survey Bannack 7.5 minute topographic quadrangle.

Beaverhead strata in this area crop out in a north-south trending arcuate band for several kilometers on either side of

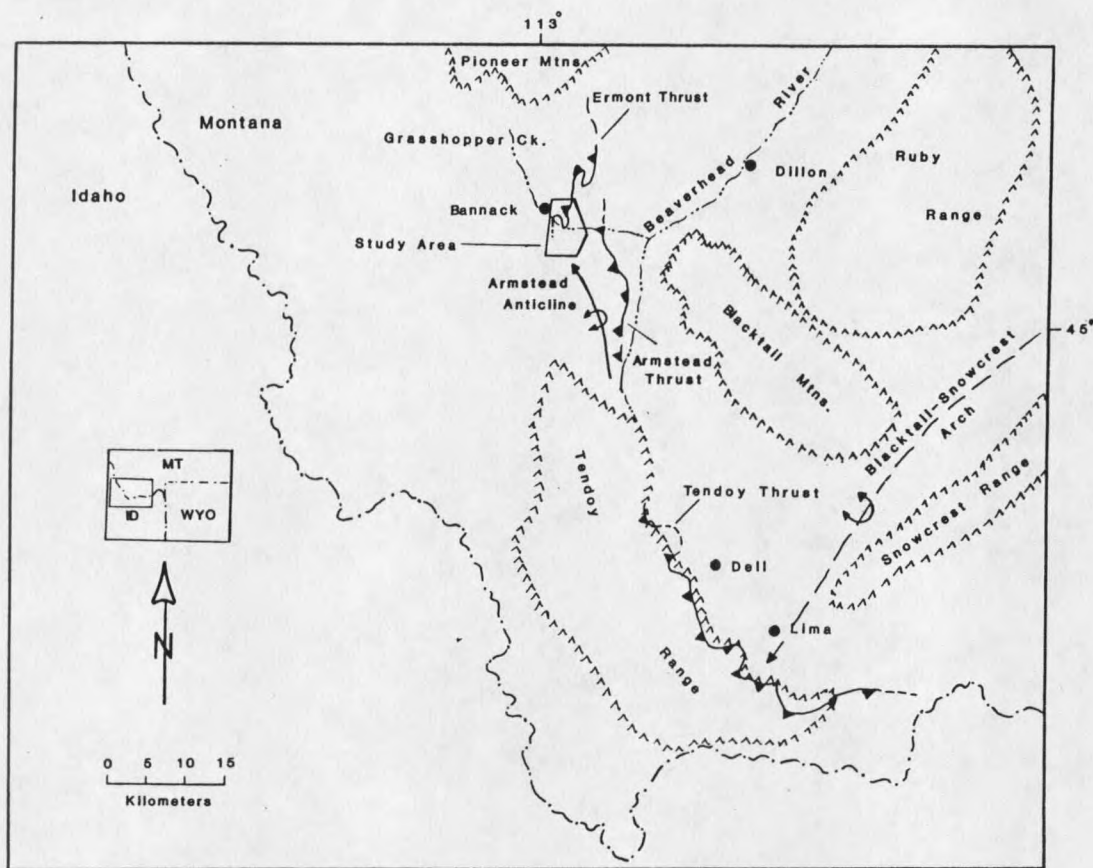


Figure 1. Generalized map of southwestern Montana showing location of study area and major regional structures. Modified from Johnson (1986).

Grasshopper Creek. In general, good to fair out crops are limited to several of the northeast-southwest trending gulches which bisect the area. The most prominent outcrops are located immediately adjacent to Grasshopper Creek where up to 354 m of strata are exposed. These outcrops adjacent to Grasshopper Creek were chosen for the focus of this study because they offered the greatest extent of high quality exposures.

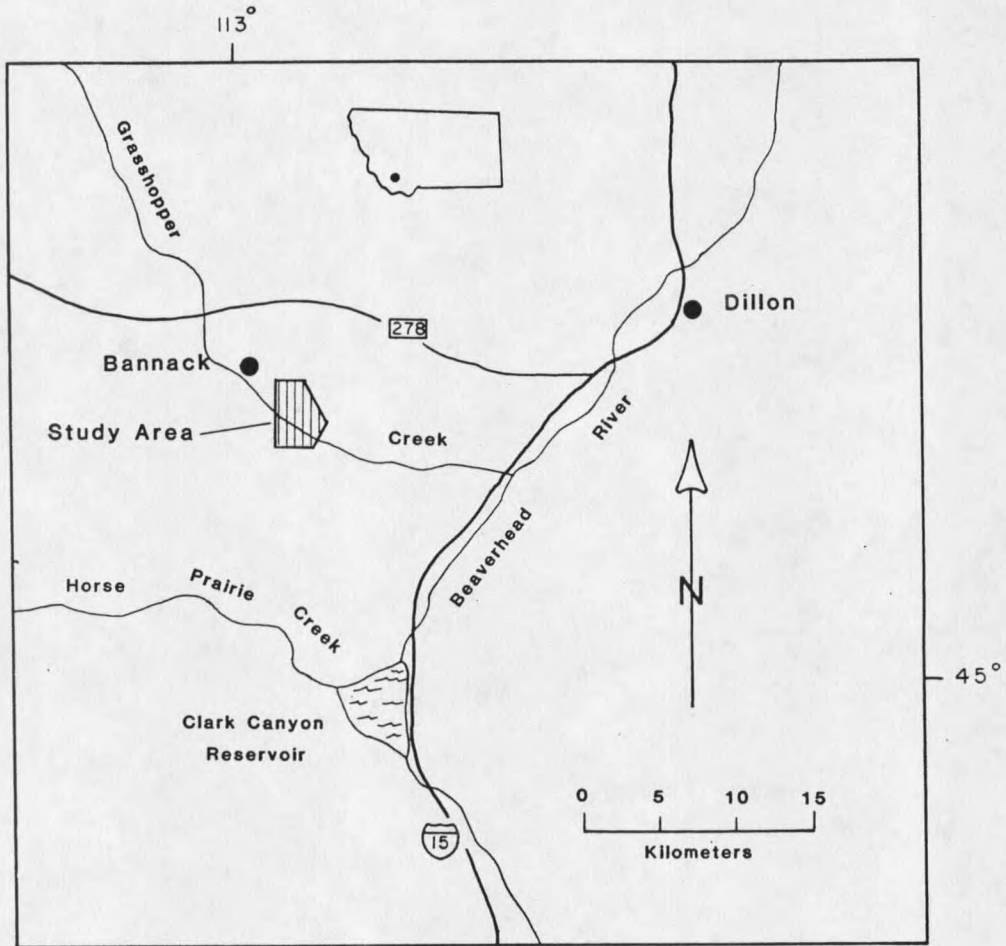


Figure 2. Study area location map.

METHODS

Field Procedures

The lower conglomerate member of the Beaverhead Group in the study area was measured using a Brunton Pocket Transit, Jacob's staff and a 30 m (100 ft) steel tape (Compton, 1962). Seven partial sections were measured and described (Figure 3) (Plate 1). The partial sections were combined by determining their approximate stratigraphic positions relative to each other to form a nearly complete section through the lower conglomerate (Figure 4). The location of each section was chosen as a balance between accessibility and quality of exposures. Descriptions of depositional units within each section included lithology, texture (clast size, clast shape, and sorting), fabric, grading, stratification, bed thickness, lateral continuity of beds, nature of bounding surfaces, bed geometry, and sedimentary structures. A lithofacies classification system based on the system developed by Miall (1977, 1978) and appended by Rust (1978) was used to classify the lithofacies present.

Clast counts were performed on pebble-cobble conglomerates to ascertain the composition of strata exposed in the source area and to illuminate any stratigraphic compositional trends.

