Syn- and post-Laramide geology of the south-central Gravelly Range, southwestern Montana
by Ernest Jan Luikart

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

Abstract:
The geologic history of post-Laramide basin evolution in the foreland of southwestern Montana has been a matter of controversy. A complex assemblage of Upper Cretaceous to Tertiary sedimentary and volcanic rocks which record some of that history are exposed on and near the crest of the Gravelly Range. Past interpretations of their relations and tectonic implications conflict. The present investigation of a portion of the southern Gravelly Range crest helps to resolve the physical stratigraphy and ages of the post-Laramide deposits and suggests the following sequence of events: (1) syn- and post-Laramide erosional beveling of the Madison-Gravelly arch; (2) Late Cretaceous deposition of quartzite gravel from a thrust belt source, locally containing Archean metamorphic clasts from a foreland source; (3) conformable transition to deposition of limestone conglomerate derived from the Blacktail-Snowcrest arch, with interbedded siltstone, sandstone and lacustrine limestone, deposited prior to the end of Laramide deformation; (4) final movement of Laramide faults; (5) erosion represented by a 28-38 my-long unconformity; (6) deposition of tuffaceous mudstones beginning in the Duchesnean (40-37 Ma) and proceeding into the Whitneyan (32-29 Ma) interrupted by erosion at about 32 Ma; (7) eruption of basalt flows from local vents between 33 and 30 Ma; (8) minor erosion followed by early Miocene (23 Ma) eruption of an isolated mafic volcanic center; (9) emplacement of Huckleberry Ridge Tuff at 2.1 Ma after erosion or nondeposition of Miocene strata; (10) significant uplift of the range in Quaternary time; (11) Pleistocene deposition of glacial moraines in the deeper valleys, and ongoing mass-movement and colluvial processes.

Conclusions differ from those of previous workers in that the quartzite gravel is older than the limestone conglomerate, both units are Late Cretaceous rather than Paleogene, and basal exposures of Renova mudstones produce a Duchesnean rather than a Chadronian local fauna. The broader Conclusions support disruption of a broad Paleogene depositional basin by the present geometry of basins and ranges in southwestern Montana. Extensional faulting did not predate 30 Ma and has offset the Renova Formation by 3,350-5,300 m (11,000-17,400 ft) relative to adjacent grabens. The dense welding of the Huckleberry Ridge Tuff on the range crest suggests that the 1,100 m. (3,600 ft.) of relief relative to outcrops in the adjacent Madison valley is largely the result of tectonism during the Quaternary.

SYN- AND POST-LARAMIDE GEOLOGY OF THE SOUTH-CENTRAL GRAVELLY RANGE, SOUTHWESTERN MONTANA

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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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Date 4/25/97

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ABSTRACT

The geologic history of post-Laramide basin evolution in the foreland of southwestern Montana has been a matter of controversy. A complex assemblage of Upper Cretaceous to Tertiary sedimentary and volcanic rocks which record some of that history are exposed on and near the crest of the Gravelly Range. Past interpretations of their relations and tectonic implications conflict. The present investigation of a portion of the southern Gravelly Range crest helps to resolve the physical stratigraphy and ages of the post-Laramide deposits and suggests the following sequence of events: (1) syn- and post-Laramide erosional beveling of the Madison-Gravelly arch; (2) Late Cretaceous deposition of quartzite gravel from a thrust belt source, locally containing Archean metamorphic clasts from a foreland source; (3) conformable transition to deposition of limestone conglomerate derived from the Blacktail-Snowcrest arch, with interbedded siltstone, sandstone and lacustrine limestone, deposited prior to the end of Laramide deformation; (4) final movement of Laramide faults; (5) erosion represented by a 28-38 my-long unconformity; (6) deposition of tuffaceous mudstones beginning in the Duchesnean (40-37 Ma) and proceeding into the Whitneyan (32-29 Ma) interrupted by erosion at about 32 Ma; (7) eruption of basalt flows from local vents between 33 and 30 Ma; (8) minor erosion followed by early Miocene (23 Ma) eruption of an isolated mafic volcanic center; (9) emplacement of Huckleberry Ridge Tuff at 2.1 Ma after erosion or nondeposition of Miocene strata; (10) significant uplift of the range in Quaternary time; (11) Pleistocene deposition of glacial moraines in the deeper valleys, and ongoing mass-movement and colluvial processes.

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INTRODUCTION

Efforts to unravel the post-Laramide sedimentary and tectonic history of southwestern Montana have resulted in a number of possible scenarios for regional Cenozoic basin evolution (Reynolds, 1979; Fields et al., 1985; Fritz and Sears, 1993; Ruppel, 1993). Southwestern Montana has been shaped by a complex tectonic history from Late Cretaceous through Cenozoic time. Major episodes of deformation include spatially and temporally overlapping thin-skinned (Sevier) and thick-skinned (Laramide) contractional deformation in the Late Cretaceous to early Tertiary, followed by at least one phase of extension in the mid-Tertiary, and late Tertiary through Quaternary tectonic influence of the passage of the Yellowstone hot spot (Anders and Sleep, 1992; Pierce and Morgan, 1992; Fritz and Sears, 1993). Although most models of regional geologic events share these basic elements, there is ongoing debate about the number, timing, and style of basin-forming episodes during the Cenozoic.

Numerous studies have focused on the stratigraphic record of Tertiary basin-fill in intermontane basins of southwestern Montana as the key to unraveling post-Laramide geologic history. Similarities among basins include homotaxial lithostratigraphic sequences and vertebrate faunal successions, with closely matching radiometric age limits where volcanic rocks are available. This suggests that the individual basins share a common history to a large degree (Fields et al., 1985). It was recognized that this observed "basin unity" (Monroe, 1976) required mechanisms, such as climate, which operate on a

regional scale (Kuenzi and Fields, 1971; Monroe, 1976; Thompson et al., 1982). Other proposed tectonic models and geologic histories propose that the semi-isolated extensional basins which preserve Tertiary basin-fill are not the basins in which those strata were deposited. The "basin unity," at least for the lower part of the Tertiary system, may reflect deposition as a broad, relatively continuous sheet which was subsequently partitioned during one or more extensional episodes (Thompson et al., 1981; Fritz and Sears, 1993; Thomas, 1995). Remnants of the Tertiary system which exist outside of the present extensional fault-bounded basins preserve important clues about the complexity of basin evolution in southwestern Montana.

Purpose of Study

A heterogeneous assemblage of syn- and post-Laramide coarse- and fine-grained sedimentary rocks and volcanic flows overlie an erosional surface between about 2,740 and 3,050 m (9,000-10,000 ft) on the crest of the Gravelly Range in southwestern Montana. Previous conclusions about the tectonic and depositional significance of these rocks vary significantly, because the field relations and ages of the scattered outcrops were interpreted in conflicting ways (Scott, 1938; Atwood and Atwood, 2945; Mann, 1954; 1960; Hadley 1969b; 1980; Gutmann et al., 1989; Ruppel, 1993).

The primary goal of this study is to resolve the chronology of Late Cretaceous through Tertiary geologic events in the southern Gravelly Range based on an in-depth, mapping-based investigation of high-elevation syn- and post-Laramide strata, and to discuss the tectonic implications of that chronology, in the light of proposed tectonic models. On a local scale, the chronology is

relevant to the uplift history of the range relative to adjacent grabens. On a regional scale, it can help test hypotheses of Cenozoic geologic evolution in southwestern Montana. Additionally, newly reported fossil mammal faunas which contribute age control at several localities are recognized as a significant Duchesnean local fauna.

Geologic Setting

The Gravelly Range lies in the Rocky Mountain foreland of southwestern Montana (Fig. 1). This region is bounded on the north by the "southwest Montana transverse fault zone", a 120-km-long east-trending fault zone which forms the southern margin of the Helena salient of the Sevier thrust belt (Schmidt and O'Neill, 1983). To the west, the southwest Montana reentrant of the Sevier thrust belt is characterized by structural overlap and interference of Sevier- and Laramide-style deformation (e.g. 'Dillon cutoff' of O'Neill et al., 1990). The foreland is bounded on the southwest and south by frontal thrust sheets and the Snake River Plain. To the east, the foreland grades into the northern Great Plains.

The present physiography of the region surrounding the Gravelly Range is characterized by broad intermontane basins separated by high mountain blocks (Fig. 2). The underlying extensional structure represents a northernmost extension of the Basin and Range structural province, flanking the northern margin of the Snake River Plain (Reynolds, 1979, but see Ruppel, 1993). The Gravelly Range also lies within a region of tectonic disruption caused by thermal effects of the passage of the Yellowstone hot spot (Anders and Sleep, 1992; Pierce and Morgan, 1992; Fritz and Sears, 1993).

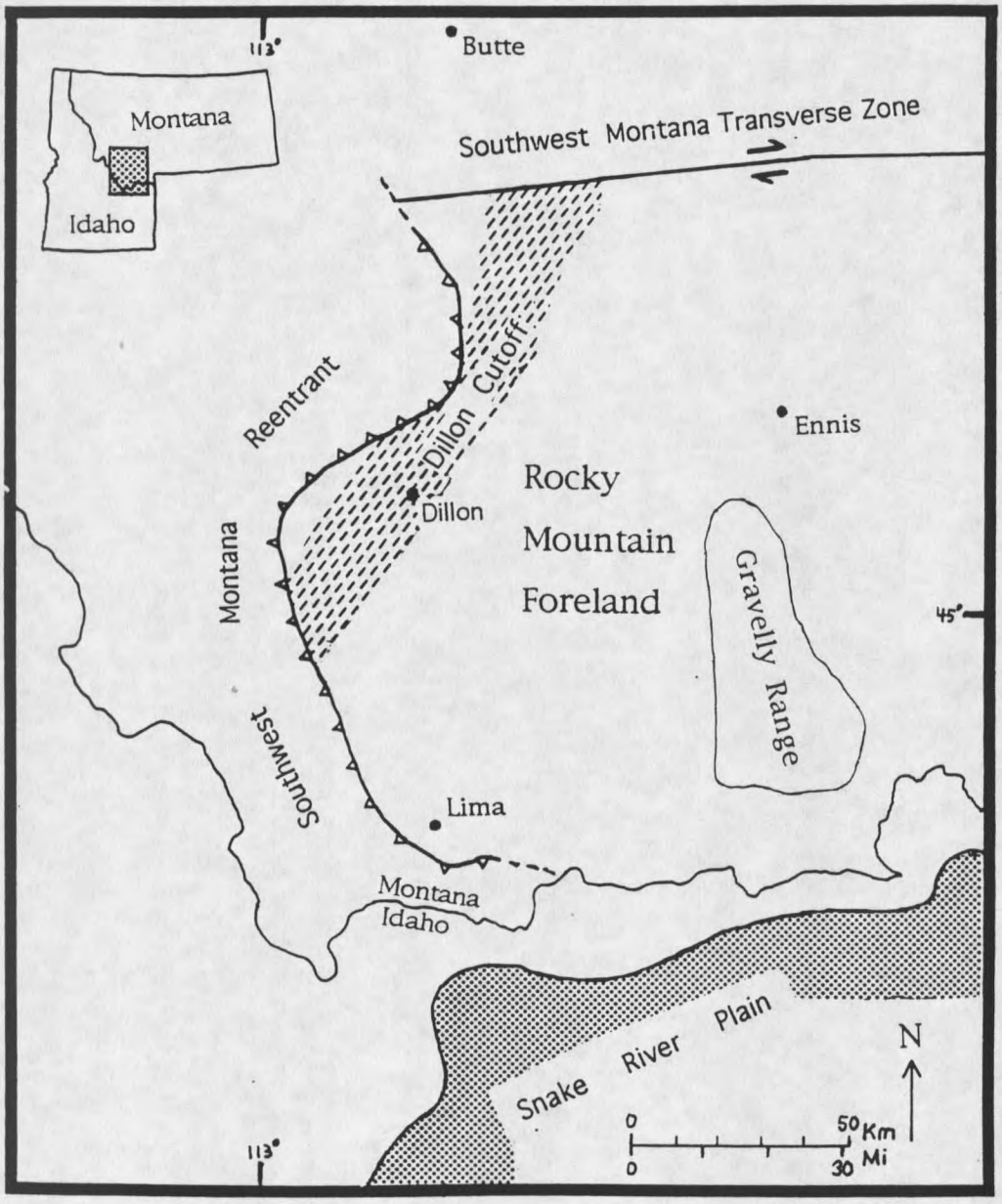

Figure 1. Simplified tectonic map of southwestern Montana showing the Rocky Mountain foreland bounded by the margins of the Sevier thrust belt and the Snake River Plain. Location of Gravelly Range is outlined; other ranges not shown.