Geologic setting and geomorphic analysis of quaternary fault scarps along the Deep Creek fault, Upper Yellowstone Valley, south-central Montana
by Stephen Francis Personius

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

Abstract:
The Deep Creek fault represents the eastern-most major Basin and Range faulting in Montana. This high angle normal fault forms the western flank of the Beartooth uplift and the eastern margin of the upper Yellowstone (Paradise) Valley in southern Park County, Montana. Initiation of movement along the Deep Creek fault may have begun as early as the Paleocene, in conjunction with uplift of the Beartooth block. A northeast-trending mylonite shear zone along the eastern margin of the Yellowstone Valley appears to have strongly controlled the geometry of the Deep Creek fault.

The fault trace is generally straight, but has several small bends and en echelon breaks.

The western flank of the Beartooth uplift exhibits the great relief common to other normal-fault bound ranges in the western United States, but tectonic landforms (triangular facets in particular) common to many of these ranges are poorly expressed along the mountain front. This relationship may best be explained by the complex glacial history which has strongly affected the northern Yellowstone region, and the resistant nature of the Precambrian crystalline rocks exposed in the footwall of the fault.

Geomorphic and statistical analysis of Quaternary fault scarps revealed three major periods of faulting still preserved in the Yellowstone Valley. A well preserved group of scarps formed 10,000 to 12,000 years BP was preceded by two earlier periods of faulting; these scarps were formed approximately 30,000 to 50,000 years BP, and 100,000 to 200,000 years BP. The oldest scarps are preserved only in the northern part of the valley, beyond the reach of late Pleistocene piedmont ice sheets. Fault scarps in the upper Yellowstone Valley appear to. be the products of single fault movements, or closely spaced multiple movements, separated by quiescent periods of much longer duration. Rate of displacement has been approximately 200-300 m/million years since the early Pleistocene.

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APPROVAL

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Stephen Francis Personius

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 December 10, 1982

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ABSTRACT

The Deep Creek fault represents the eastern-most major Basin and Range faulting in Montana. This high angle normal fault forms the western flank of the Beartooth uplift and the eastern margin of the upper Yellowstone (Paradise) Valley in southern Park County, Montana. Initiation of movement along the Deep Creek fault may have begun as early as the Paleocene, in conjunction with uplift of the Beartooth block. A northeast-trending mylonite shear zone along the eastern margin of the Yellowstone Valley appears to have strongly controlled the geometry of the Deep Creek fault. The fault trace is generally straight, but has several small bends and *en echelon* breaks.

The western flank of the Beartooth uplift exhibits the great relief common to other normal-fault bound ranges in the western United States, but tectonic landforms (triangular facets in particular) common to many of these ranges are poorly expressed along the mountain front. This relationship may best be explained by the complex glacial history which has strongly affected the northern Yellowstone region, and the resistant nature of the Precambrian crystalline rocks exposed in the footwall of the fault.

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INTRODUCTION

Location

The Deep Creek fault bounds the western edge of the Beartooth uplift and forms the eastern margin of the upper Yellowstone (Paradise) Valley in south-central Montana (Fig. 1). This high-angle normal fault trends northeast for approximately 55 km and structurally separates the Gallatin and Beartooth Laramide foreland uplifts. The fault trace is characterized by sporadic Quaternary fault scarps, and is elsewhere buried by surficial debris or inferred by the presence of faceted spurs and other tectonic landforms.

Purpose

The topography of south-central and southwest Montana is dominated by mountain ranges which are commonly bound by steeply-dipping normal faults. These northwest-to northeast-trending structures characterize the extensional Basin and Range deformation which has occurred in this region since Middle (and possibly earlier) Tertiary time. Many of these faults (including the Deep Creek) are considered active today (Reynolds, 1979). The purpose of this study is to describe the tectonic geomorphology of the eastern margin of the upper Yellowstone Valley, and in particular, the

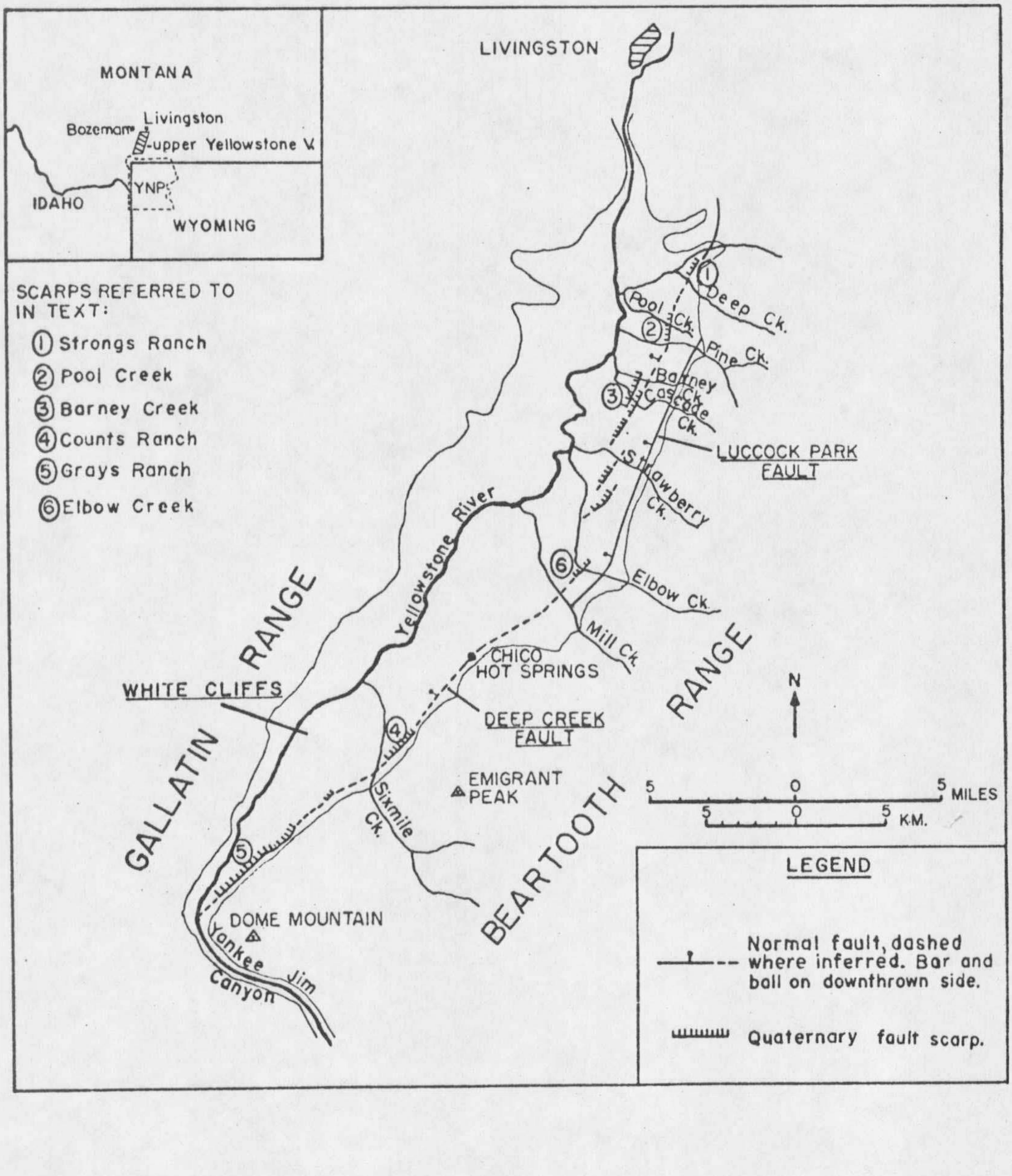

Figure 1. Map showing the outline of the Upper Yellowstone Valley, trace of the Deep Creek and Luccock Park faults, and locations of Quaternary fault scarps. Compiled from Reid and others (1975, Fig. 1), Montagne and Chadwick (1982, Fig. 2), and mapping by the author.

geomorphic expression of the Quarternary fault scarps found along the trace of the Deep Creek fault. This data will then be applied to an interpretation of the history of Quaternary movement along the fault. This interpretation will include the age of fault scarps present in the Yellowstone Valley, recurrence intervals of major faulting, and rate of fault displacement during the Pleistocene. The regional geological setting will initially be developed to explain the relationship between Quaternary features and the structural setting of south-central and southwest Montana.

Previous Investigations

Geologic investigations in the upper Yellowstone Valley date to the late 1800's, when the Hayden Survey followed the Yellowstone River into what is now Yellowstone National Park. Publications from this era (Hayden, 1872a, 1872b; Weed, 1893; Iddings and Weed, 1894) are remarkable, especially considering the reconnaissance nature of these investigations.

The 1930's and 1940's marked a resurgence of investigations in the area, principally by geology students from Princeton University. Excellent studies of the structural geology (Wilson, C.W., 1934, 1936; Wilson, J.T., 1936; Lammers, 1937; Skeels, 1939) and geomorphology (Horberg, 1940) of the region were published during this period.

From the post-war period to the present, investigations of the surrounding Beartooth and Gallatin Ranges were published (Foose and others, 1961; McMannis and Chadwick, 1964; Chadwick, 1969; Reid and others, 1975). The U.S. Geological Survey was active throughout this period, with major studies conducted on the general geology of the region (Richards, 1957; Roberts, 1972; Fraser and others, 1969; Ruppel, 1972). Bonini and others (1972) conducted a gravity survey of the region, which has given major insight into the surface configuration of the Yellowstone Valley. Several Masters and Ph.D. theses have also made contributions to the geology of the region (Van Voast, 1964; Basler, 1965; Bush, 1967; Struhsacker, 1976; Erslev, 1981). The author has recently published a shorter version of this thesis (Personius, 1982).

The most comprehensive investigations of the glacial and geomorphic aspects of the valley have been conducted by John Montagne of Montana State University (Montagne and Chadwick, 1982) and Kenneth Pierce of the U.S. Geological Survey (Pierce, 1979). These works represent the "state of the geologic art" in the upper Yellowstone Valley.

ROCK TYPES AND DISTRIBUTION

Precambrian Rocks

Both the Gallatin and Beartooth Ranges are Precambrian-cored foreland uplifts, characterized by highly metamorphosed crystalline rocks of Archean age (Foose and others, 1961; McMannis and Chadwick, 1964; Reid and others, 1975). Movement along the Deep Creek fault has elevated the Beartooth Range structurally higher than the Gallatin Range, and subsequently more Precambrian rocks have been exposed there by erosion (Fig. 2). The Precambrian rocks are very heterogeneous, and represent metamorphosed equivalents of sedimentary rocks deposited very early in the history of the earth (Reid and others, 1975).

Paleozoic and Mesozoic Rocks

The Paleozoic-Mesozoic sedimentary package representing shelf sedimentation is preserved in several remnants atop the Beartooth and Gallatin Ranges (Fig. 2). The narrow portal forming the northern entrance to the Yellowstone Valley south of Livingston, Montana, is cut through a complex of these rocks ramped onto the northern flanks of the Beartooth and Gallatin Ranges by the Suce Creek thrust system. These represent the best exposures of the section in the valley.