Soil development, morphometry, and scrap morphology of fluvial terraces at Jack Creek, Southwestern Montana
by James Paul Bearzi

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

Abstract:
Analysis of exceptionally well-displayed fluvial terraces and pediments along lower Jack Creek, a modest gradient (0.020) tributary of the Madison River in southwestern Montana, reveals a Late Quaternary chronology of terrace development. Soil stratigraphy of the surfaces reveals two distinct populations. "Higher Group" surfaces (2 terraces and 1 pediment, 40 to 60 m above Jack Creek) are mantled by a loess cap, contain stage III carbonate morphology, and were formed during pre-Pinedale time. All lower surfaces (7 terraces and 1 pediment), termed "Lower Group" surfaces, lack a loess cap, have remarkably similar weakly developed soils with stage I to stage II carbonate morphology, and were formed during late Pinedale and early post-glacial time. Deglaciation of the Madison Range, 15-12 ka (ka = thousand years) ago, initiated downcutting from the late Pinedale (highest Lower Group) terrace.

Mountain front tectonism was not responsible for Lower Group terrace formation; it may have contributed to the formation of Higher Group terraces. Post-glacial climate changes may have influenced the development of steep (~0.030 gradient) Lower Group terraces. Uplift of the Norris Hills throughout Quaternary time has resulted in intermittent damming and subsequent aggradation and degradation of the Madison River. Thus, base level fluctuation has been the primary terrace forming factor at Jack Creek. Jack Creek has been aggrading to the modern floodplain for several thousand years.

Morphologic dating of terrace scarps at Jack Creek shows that slope processes that have operated on the scarps at Jack Creek are much more complex than can be modeled with the diffusion equation. Discriminant function scores define Lower Group scarps as Holocene and Late Pleistocene in age. Linear regression of scarp slope versus scarp height for individual scarps and for aspect groups reveals that scarp morphology at Jack Creek is greatly dependent on height' and aspect.

Jack Creek exhibits a detailed post-glacial terrace flight primarily because the Madison Valley is tectonically active and the Madison River still aggrading. Terraced landscapes in less tectonically active basins are usually of Pleistocene age.

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APPROVAL

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James Paul Bearzi

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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INTRODUCTION

The Problem

Fluvial terraces and mountain-front pediment surfaces are common along both the Madison River and many of its tributaries in southwestern Montana. The terraces are floodplains abandoned through stream downcutting and were formed during periods of equilibrium or threshold conditions of the parent stream (Bull, 1979). As such, they can be used to decipher a chronology of the evolution of the terraced landscape. An understanding of this kind of chronology as well as the factors controlling downcutting in the Madison Valley will shed considerable light on the Late Cenozoic evolution of the area.

Application of graded stream concepts (e.g., Gilbert, 1914; Mackin, 1948; Leopold and Bull, 1979) and terrace analysis in climatically and tectonically diverse areas have proven useful in reconstructing the Late Cenozoic evolution of several large basins (e.g., Ritter,1967; Palmquist, 1983; Reheis, 1984, 1987; Bull and Knuepfer, 1987). An exceptionally well-displayed flight of terraces and pediments along lower Jack Creek (Figure 1), a major tributary of the Madison River, is amenable to this type of

analysis. Since the Jack Creek terraces are the best developed flight in the Madison Valley, a detailed history of landscape evolution can be pieced together at Jack Creek; this is probably not possible elsewhere.

The primary purposes of this study are to determine the timing and causes of major downcutting events at Jack Creek. Establishment of a relative chronosequence (timing) of terrace development at Jack Creek can be obtained by analyzing time-dependent characteristics of terrace development (e.g., soils). Soil development on terrace treads will generally increase with increasing height above the present stream (Birkeland, 1984). The causes of terrace formation can be determined by comparing the timing of terrace formation with that of potential terrace forming activity (i.e., tectonism, climate change, and base level fluctuation) in the Jack Creek area.

The interpretation of pediments is more complex. Pediments are essentially surfaces of transport during periods of basin stability (Mabbutt, 1977) and thus are more subject to reactivation than are fluvial terraces. Morphologically, range-front pediments differ from fluvial terraces in that their gradients decrease dramatically from the mountain zone to the pediment zone to the alluvial zone (Figure 2). Fluvial terraces are subparallel to the master stream throughout their length and have a much less pronounced concave-up profile. Pediments also lack a well-

defined drainage basin upslope and are not directly related to nearby ephemeral or perennial streams (Johnson, 1932).

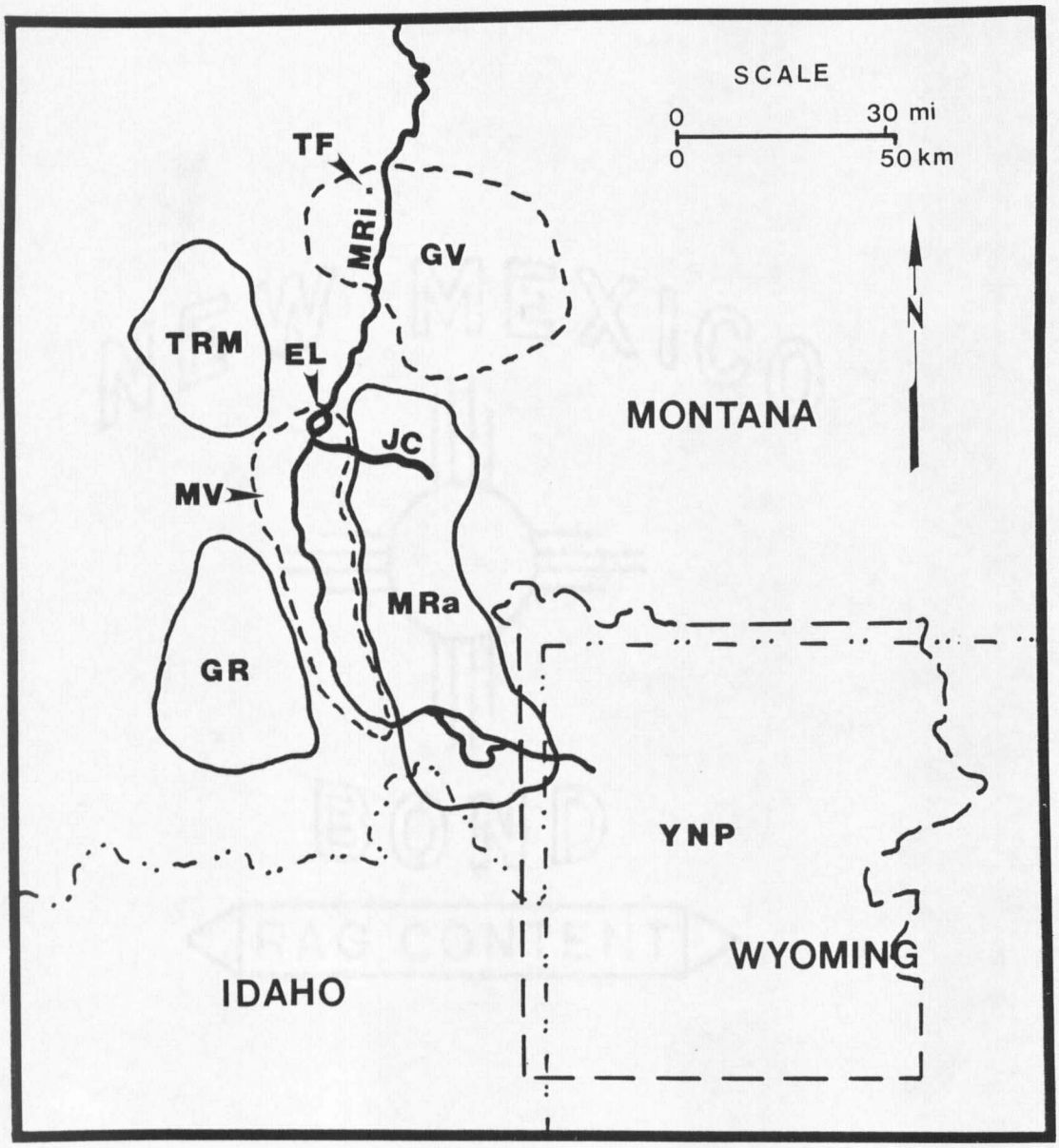

Figure 1. Geographic setting of Jack Creek in southwestern Montana. Solid lines bound mountain ranges; dashed lines bound valleys. JC = Jack Creek; MRi = Madison River; MV = Madison Valley; MRa = Madison Range; EL = Ennis Lake; GR = Gravelly Range; TRM = Tobacco Root Mountains; TF = Three Forks; GV = Gallatin Valley; YNP = Yellowstone National Park.