Soil mineralogy used to distinguish solifluction deposits formed under a periglacial environment on the Boulder Batholith, Jefferson County, Montana
by Janette Louise Young Black

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

Abstract:
Using soil mineralogy and relative mineral stabilities, soils formed on stable sites were compared to soils formed on features believed to have undergone mass movement. The mass movement features studied are termed solifluction terraces. The terraces are gently sloping and extend into an arcuate, convex-downslope, steep, rocky front. The presence of Early to Late Wisconsinan glacial deposits in close proximity and at similar elevations to the study area terraces, coupled with the lack of glacial features within the study area, provides evidence that a periglacial environment existed in the area. This study indicates that the terraces were formed by periglacial processes during the Pleistocene. Specifically, the terraces are thought to be formed by solifluction, used here to indicate the slow movement of water-saturated material from higher to lower ground over a frozen substrate in a periglacial environment.

A study of the mineralogical changes in the soils within the study area was made in order to substantiate the solifluction hypothesis. An analysis of the degree of weathering and the distribution of the minerals within the soils found striking differences between the soils of the solifluction terraces and those found on the stable sites. Clay mineralogy analysis demonstrates sharp and erratic changes in the distribution of minerals within the solifluction terrace profile, which contrast sharply with the gradual changes in clay mineral distribution exhibited by the stable profiles. In addition, coarse-size minerals in the stable sites show a gradual decrease in weathering with depth whereas the solifluction soils contain a mixture of fresh and highly weathered minerals throughout the profile. These differences are likely the result of frost heaving and downslope motion in the solifluction terrace soils and support the concept that the origin of the terraces are attributable to the mass movement process of solifluction.

The study demonstrates the utility of integrating soil mineral analysis with geomorphology and that an analysis of mineral texture and distribution within a soil can provide valuable information to distinguish stable landforms from those formed by mass movement processes.

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JEFFERSON COUNTY, MONTANA

by

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APPROVAL

of a thesis submitted by

Janette Louise Young Black

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 May 14, 1984

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ABSTRACT

Using soil mineralogy and relative mineral stabilities, soils formed on stable sites were compared to soils formed on features believed to have undergone mass movement. The mass movement features studied are termed solifluction terraces. The terraces are gently sloping and extend into an arcuate, convex-downslope, steep, rocky front. The presence of Early to Late Wisconsinan glacial deposits in close proximity and at similar elevations to the study area terraces, coupled with the lack of glacial features within the study area, provides evidence that a periglacial environment existed in the area. This study indicates that the terraces were formed by periglacial processes during the Pleistocene. Specifically, the terraces are thought to be formed by solifluction, used here to indicate the slow movement of water-saturated material from higher to lower ground over a frozen substrate in a periglacial environment.

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CHAPTER 1

INTRODUCTION

Purpose of Study

The purpose of this study is to substantiate the geomorphological interpretation of certain landforms on the uplands of the west central Boulder batholith in southwestern Montana. Using concepts from soil genesis and relative mineral stabilities, soils formed on stable sites were compared to soils formed on features believed to have undergone mass movement. A second objective is to demonstrate the utility of soil mineral analysis to aid in distinguishing stable landforms from those which have undergone mass movement.

The mass movement features studied are termed solifluction terraces. The terrace surfaces are gently sloping and extend into an arcuate, convex-downslope, steep rocky front. This study suggests that the terraces were formed by periglacial processes during the Pleistocene Epoch. Specifically, the terraces are thought to be formed by solifluction, used here to indicate the slow movement of water-saturated material from higher to lower ground over a frozen substrate in a periglacial environment.

Soil mineralogy provides the ideal bridge between geology and soil science. It is especially important for the understanding of rock weathering and mass wasting processes. Soils formed on stable sites exhibit a different mineral distribution profile than soils which have undergone mass movement. Mineral texture and distribution in soils found on solifluction terraces are compared to soils found on stable areas within the study area in order to test the solifluction hypothesis.

Because a concentrated study of typical examples would yield more information than a cursory examination of solifluction terraces in a more regional study, a detailed investigation of three representative examples was undertaken in order to determine their origin. The investigation was designed to test the periglacial hypothesis for the origin of the terraces. The principal objectives were: 1) to describe the terraces in detail, 2) to determine the processes responsible for terrace formation by using the mineral distribution pattern within the soil profile, and 3) to provide data and interpretations to aid in the identification and study of mass movement landforms in other areas.

Location

The study area is located in the west-central portion of the Boulder batholith in southwestern Montana. The study area is 8 km west of Boulder, Montana in the southern part of the Boulder Mountains. The area, referred to as Galena Park, is between 1950 and 2000 meters in elevation and is within the Deerlodge National Forest. The study is concentrated in the northwest portion of T5N, R5W and the southwest portion of T6N and R5W. It is accessible by logging roads that extend southward from U.S. Highway 91 (Figure 1).

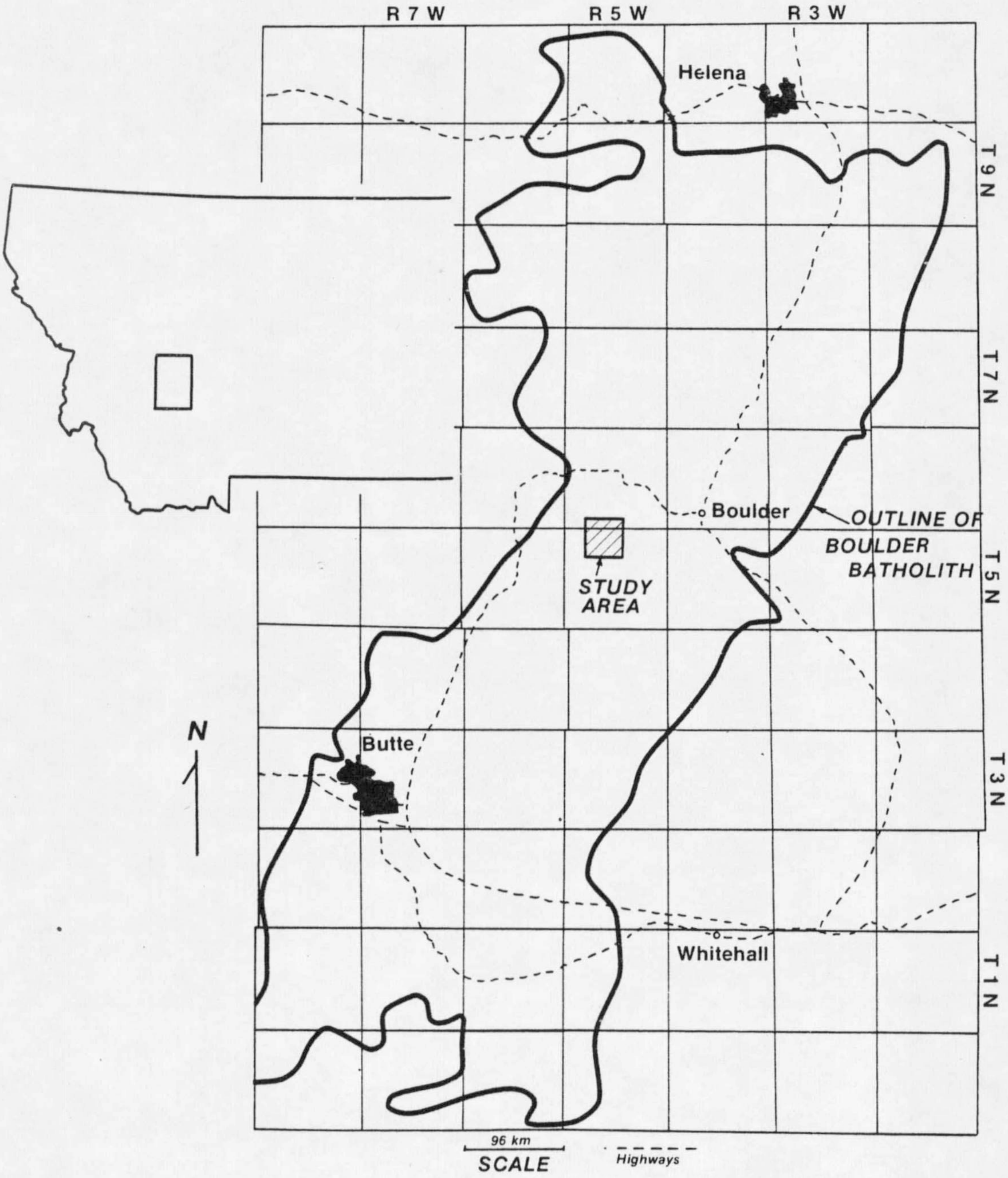

FIGURE 1. Index map showing location of study area and extent of the Boulder batholith (modified from Veseth, 1981)

Topography

The study area lies in the upland region between the Elk Park valley and the Boulder valley. Elk Park is a broad valley located above the Butte Basin on the uplifted block of the Continental Fault. The Boulder valley is a broad intermontane valley trending north-south between the Boulder Mountains and the Elkhorn Mountains. The origin of this valley is not completely understood. Although the Boulder River was larger during the Pleistocene, it is questionable if it could have formed the broad valley. Possibly the valley is formed by a combination of downfaulting and stream erosion (Becraft and others, 1963). Several tributaries to the river show evidence of rejuvenation, with knickpoints, sharp youthful valleys near the river, and sparse terrace deposits (Becraft and others, 1963). The geomorphic expression of the upland region between these two valleys is influenced by the base level established by these drainages. Periglacial processes also appear to have been a significant landshaping force seen in the present landscape.

The Boulder Mountains, on which the study area is located, have no sharply outlined peaks, nor do its hills constitute a well-defined range. The region has moderate relief, with smoothly rounded ridges rising about 300 meters above the major stream valleys. The maximum relief is 1200 meters. There are a few mountains over 2400 meters with most between 2100 and 2450 meters. To the north of the study area, a large ice sheet covered the northern Boulder Mountains during early

Wisconsinan time and subsequently caused nearly all the modern streams in the area to reoccupy glaciated valleys (Ruppel, 1962).

Galena Park is characterized by broad, east-west trending ridges with a series of gulleys and benches extending off both sides to minor tributaries. The benches have tor piles formed by weathering and erosion along joint planes which leave cores of subrounded boulders, usually 6 to 18 meters high, that project above the general land surface (Becraft and others, 1963; Sahinen, 1950). North Boulder Creek, a tributary to the Boulder River, drains the gently rolling uplands of the study area.

Jointing

Physical and chemical weathering is facilitated along joints, and these areas are preferentially weathered. Chemical weathering is enhanced by concentration of water and increased surface area along the joints. Joints also aid the process of frost and ice wedging in periglacial and glacial climates (Thornbury, 1969). In the study area, joint spacing generally falls into two categories, one group with spacing ranging from 0.5 to 2 meters, and another ranging from 4 to 13 meters. As a result, the granite blocks vary in size and shape. Where joints are widely spaced, large, subangular blocks are formed. A finer joint pattern results in increased weathering with the rock often being completely decayed.

In the northern Boulder Mountains, Ruppel (1963) measured nearly 500 joints and mapped two prominant sets, one that trends almost due east and dips steeply north and one that trends north and most commonly dips steeply west. In addition, Ruppel (1963) noted two less prominent, nearly vertical sets that trend N35E and N35W. Smedes (1966) measured 283 joints and found similar trends with the north-south vertical joint set the most pronounced. In the study area, 83 joints were recorded and the dominant joint pattern trends N25W with less prominant sets at N5W and N35W (Figure 2). Smedes (1966) states that the joints are not related to the emplacement or cooling of the batholith, but formed later as a result of regional stresses. Whatever their origin, the joints are the principal controlling feature in the formation of gulleys on the Boulder batholith as evidenced by its strikingly rectilinear drainage patterns (Ruppel, 1963; Klepper and others, 1957).

Climate and Vegetation

The present climate in the vicinity of the southern Boulder Mountains is semiarid with rainfall averaging 38-51 cm per year (Miller and others, 1962). The mean annual temperature is 5.4°C with an average January temperature of -6.9°C and an average July temperature of 16.7°C (Cordell, 1960). The total annual snowfall averages 144 cm. Frost occurs 150 to 180 days of the year. The average depth of penetration of frost is 168 cm (Miller and others, 1962).

Although the annual precipitation is low, the climate is favorable for moderately good soil moisture content due to the occurrence and type of precipitation. Three-quarters of the moisture falls during the months when the ground is not frozen, thus good infiltration is possible. The cool temperatures during the spring and summer also aid