Contrasting soil development on the sedimentary Kootenai Formation and granitic Boulder batholith in southwestern Montana
by Roger Joseph Veseth

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in SOILS
Montana State University

Abstract:
Characteristics of soils on the Kootenai Formation and Boulder batholith were compared to demonstrate relationships between soils and geologic units in Montana. The Early Cretaceous Kootenai Formation includes clayey shale, fine-grained sandstone, limestone and a basal conglomeratic sandstone. The batholith is composed of a uniform coarse-grained granitic rock, 25 pedons on each parent material were selected by point intercept transects for description, sampling and laboratory analysis.

Thirty of 44 soil properties contrasted sharply between the two parent materials. Boulder batholith soils have sandy loam or loamy sand textures; 40 percent higher frequency of a C horizon in the upper 100 cm; mean pH 0.6 unit higher; larger structure size and weaker grade; and 2-22 percent coarse fragment content. Kootenai Formation soils are more variable, having 7 textural classes ranging from sandy loam to clay and a clay content range of 3 to 74 percent. They have 20 cm greater mean solum thickness; more variable consistence; redder color hues; and a 0-65 percent coarse fragment content. There are 6 family textural classes identified in Kootenai Formation soils compared to 2 on the Boulder batholith.

Less than 10 samples (generally < 5) are required to estimate mean pH; coarse fragment content; sand fraction contents; and sand, silt and clay contents in all horizons of Boulder batholith soils within + 5 units (0.5 for pH) about the mean. Thickness of the B2t and C horizons and depth to the C are the most variable properties, requiring up to 50 samples. In Kootenai Formation soils, about 25 percent of these horizon properties require 10-35 samples and 25 percent require > 30 samples. Coarse fragment content, depth and thickness of the B2t and C horizons, and fine sand, total sand and clay contents of the C horizon require 34-72 samples; clay content being the most variable.

From laboratory analyses of five soils on each parent material, Kootenai Formation soils have 1/3 larger available water holding capacities in the B2t and C horizons; higher extractable Ca, CEC and percent BS; and more variable clay mineralogy ranging from dominantly montmorillonite to kaolinite, illite and interstratified 2:1 clays. Boulder batholith soils are dominated by illite clay with < 25 percent montmorillonite.

This documentation of soil differences related to geologic units will allow more accuracy and efficiency in soil mapping and management .

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Date April 17, 1981

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by

ROGER JOSEPH VESETH

A thesis submitted in partial fulfillment
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in

SOILS

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April, 1981

ACKNOWLEDGMENTS

The author wishes to express his deep appreciation and gratitude to Dr. Clifford Montagne for his constructive criticism, continual support and friendship throughout the pursuit of this degree.

A sincere thanks is also extended to Drs. Gerald Nielsen, Paul Kresge and John Montagne for serving on my graduate committee and providing invaluable suggestions and guidance.

A special thanks to my family and to Claire Barreto for their unending support and cheerful encouragement, to whom I dedicate this thesis.

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Chapter 1

INTRODUCTION

The importance of geologic parent material in soil development has long been recognized, being included by Jenny (1941) as one of the five independent soil forming factors. However, lack of knowledge of geologic weathering products and soil-geology relationships in Montana has limited the potential value of this factor in predicting soil properties. The influence of geologic parent material on soil physical and chemical properties is most pronounced in cool, dry regions and in the early stages of soil development (Birkland, 1974; Stauffer, 1935). Montana's young, often glaciated landscapes and relatively cool, dry climate should provide for a strong expression of geologic parent material properties in soils.

The writer did not find any studies that statistically compare the properties in soils developed on contrasting geologic parent materials. This study documents two contrasting examples of geologic parent material influences on soil development in Montana. It statistically compares the predictability and range in variation of selected properties in soils derived from the two parent materials. Efforts are made to explain the occurrence and variablilty of soil properties in relation to properties of the parent materials.

The granitic Boulder batholith was chosen as one of the parent materials because its relatively uniform composition should be reflected in uniformity of some soil properties. This study also provides baseline information for the recently initiated Butte-Whitehall soil survey which includes portions of the batholith exposure. The data are applicable to other exposures of geologic materials of similar origin and composition in the State.

The Early Cretaceous Kootenai Formation, in contrast, contains a variety of lithologies including clayey shales, sandstones, limestones and conglomeratic sandstone, and should contribute to greater soil variability. Although the Formation contains a variety of rock types, it remains fairly consistent in most exposures in the State. Soils on the Kootenai Formation elsewhere in Montana should have properties similar to those of this report.

This study will hopefully stimulate further interest in soil-geology relationships for their potential value as predictors of soil properties.

Chapter 2

LITERATURE REVIEW

Description of the Geologic Parent Materials

The Boulder batholith is an intrusive igneous body formed by the intrusion of molten magma into older geologic materials and subsequent slow cooling beneath the surface. It covers over 2850 km^2 of western Montana, extending 113 km along the Continental Divide between Butte and Helena (Knopf, 1957). Emplacement of the magma occurred during late Cretaceous time, roughly 78-69 million years ago (Knopf, 1957; Robinson et al., 1960; Tilling et al., 1968). Subsequent erosion, mainly during the Eocene Epoch of the Tertiary Period, removed up to 1.6 km of the overlying rock, exposing the igneous rock beneath (Perry, 1962). Figure 1 shows the exposures of intrusive rocks in Montana.

A review of the geologic studies in the area show that the most extensive rock type in the Boulder batholith is quartz monzonite with subordinate granodiorite (Becraft et al., 1963; Klepper et al., 1957; Knopf, 1957; Roberts and Gude, 1953; Robertson et al., 1960; Ruppel, 1963; Smedes, 1966). Rock mineral composition is typically plagioclase and potassium feldspar, with about 20 percent quartz and 15 percent biotite mica and hornblende. The most common grain size is very coarse sand (Wentworth scale), typically 1-3 mm (Becraft et al., 1963; Roberts and Gude, 1953; Ruppel et al., 1963).

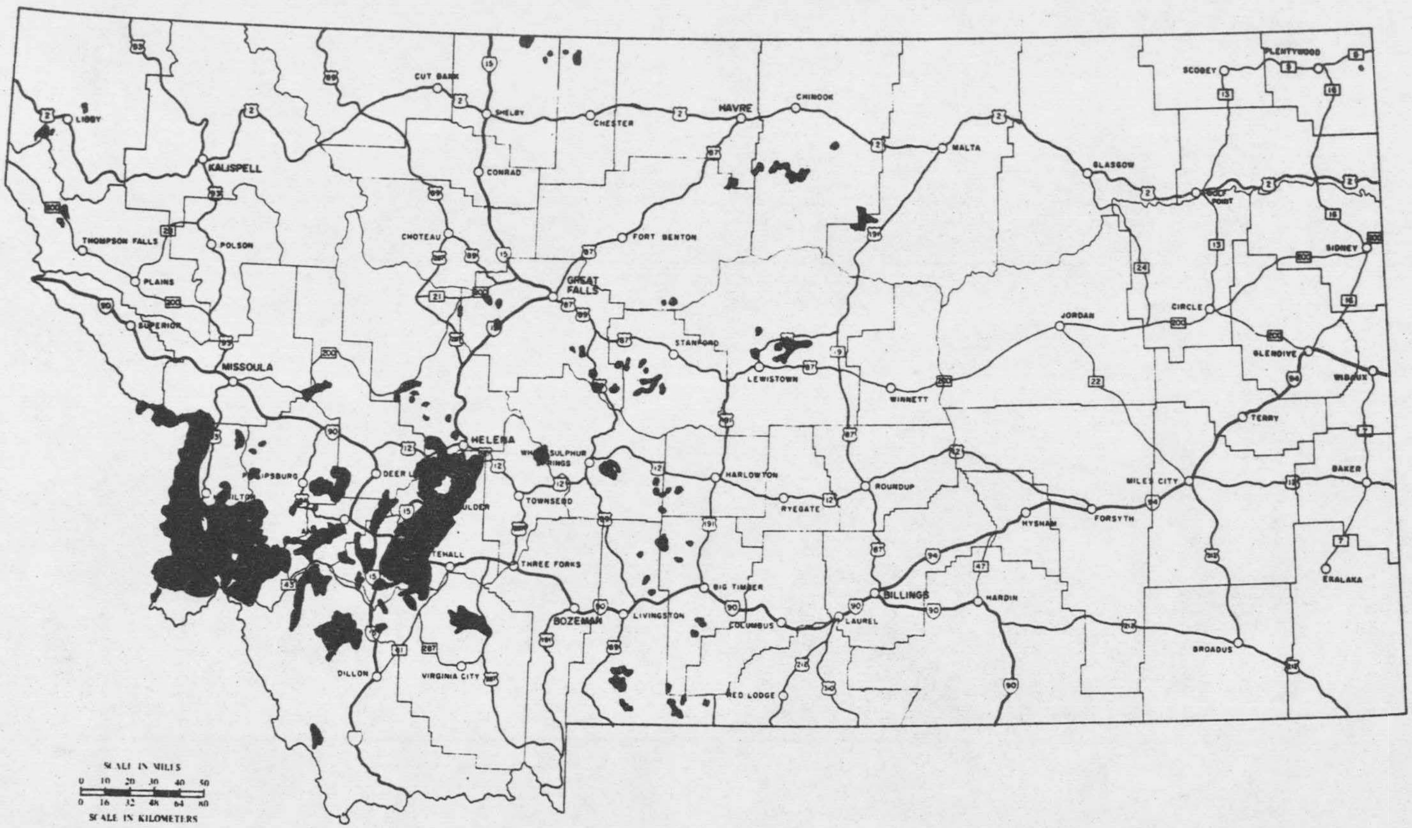

Figure 1. Exposures of coarse- to medium-grained intrusive igneous rocks in Montana (Veseth and Montagne, 1980).

Near the margins of the batholith, the rock composition tends to change somewhat. It becomes darker with an increasing content of iron, calcium and magnesium due to the assimulation of these elements from the "country rock" the igneous rock was intruded into (Perry, 1962; Sahinen, 1950; Tansley et al., 1933). The quartz content decreases and rocks become more basic, grading into granodiotite, diorite and other rock types.

Weathering and erosion along joint planes leave cores of sub-rounded boulders called tor piles, which project above the general land surface (Becraft et al., 1963; Sahinen, 1950). On a larger scale, the batholith landscapes are usually gently rounded, grass and forest covered mountains and foothills. A typical landscape is illustrated in the schematic block diagram in Figure 2.

The rocks have been variably affected by hydrothermal alteration resulting in a variable resistance to disaggregation and erosion (Becraft et al., 1963; Ruppel, 1963). Potassium feldspar and mica are often partially altered to clays by the hydrothermal activity and natural weathering processes (Becraft et al., 1963; Clayton, 1974). The batholith rock commonly disaggregates to a coarse, loose material called grus from mechanical weathering (freeze-thaw, wetting-drying, etc.) and expansion due to clay formation (Arnold et al., 1975; Becraft et al., 1963; Clayton, 1974). On the Idaho batholith to the west, illite, kaolinite and halloysite clay materials predominate in