Geology and hydrology of hot springs in the Jefferson Valley, Montana
by Daniel Peter OHaire

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

Abstract:
This report discusses the origin of Silver Star, Renova, Pipestone and New Biltmore hot springs in the upper Jefferson Valley of southwest Montana. Thermal water circulation was examined using geologic mapping, geochemical sampling, and shallow resistivity and seismic data.

Cold meteoric water is believed to circulate by hydrothermal convection to depths of 2 or 3 km in fractured crystalline rock or deeply buried aquifers where it warms to the temperature of the local geothermal gradient. The hot water ascends rapidly to the surface in fault zones or aquifers. A regionally high heat flow and geothermal gradient, in combination with numerous high angle faults with significant vertical permeability, provide a setting where hydrothermal convection may develop. Cenozoic block faults bound the valleys, which contain thick sequences of Tertiary basin fill.

The geothermal gradient may be increased locally by the blanketing effect of relatively low thermal conductivity basin fill.

Geothermal potential of the hot spring systems in the upper Jefferson Valley appears to be limited because of low estimated base temperatures, probable small reservoir capacity, and the prohibitively high cost of drilling and extraction. The present use of the hot waters for space heating and bathing is appropriate.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature Daniel O'Haire

Date Dec 14, 1977

GEOLOGY AND HYDROLOGY OF HOT SPRINGS IN THE JEFFERSON VALLEY, MONTANA

by

DANIEL PETER O'HAIRE

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Earth Science

Approved:

Robert A. Chadwick
Chairperson, Graduate Committee

Milton J. Edie
Head, Major Department

Henry L. Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bózeman, Montana

December, 1977

ACKNOWLEDGMENTS

The author extends his gratitude to his advisor, Dr. Robert Chadwick, for his helpful advice and review of this manuscript. Professors Stephan Custer, Donald Smith and John Montagne of the MSU geology staff were very helpful in lending assistance with geologic interpretations and thesis format.

Funding for summer field work and miscellaneous expenses were provided by the United States Geological Survey under the Extramural Geothermal Research Program, Montana State University, Grant Nos. 14-08-0001-G-238 and G-334. Dr. Robert Leonard of the Geological Survey Water Resources Division office in Helena, Montana, coordinated the project and provided helpful advice concerning hydrologic problems.

Special thanks go to Leota Kane for typing the rough draft and being a steady source of encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report discusses the origin of Silver Star, Renova, Pipestone and New Biltmore hot springs in the upper Jefferson Valley of southwest Montana. Thermal water circulation was examined using geologic mapping, geochemical sampling, and shallow resistivity and seismic data.

Cold meteoric water is believed to circulate by hydrothermal convection to depths of 2 or 3 km in fractured crystalline rock or deeply buried aquifers where it warms to the temperature of the local geothermal gradient. The hot water ascends rapidly to the surface in fault zones or aquifers. A regionally high heat flow and geothermal gradient, in combination with numerous high angle faults with significant vertical permeability, provide a setting where hydrothermal convection may develop. Cenozoic block faults bound the valleys, which contain thick sequences of Tertiary basin fill. The geothermal gradient may be increased locally by the blanketing effect of relatively low thermal conductivity basin fill.

Geothermal potential of the hot spring systems in the upper Jefferson Valley appears to be limited because of low estimated base temperatures, probable small reservoir capacity, and the prohibitively high cost of drilling and extraction. The present use of the hot waters for space heating and bathing is appropriate.

CHAPTER 1

INTRODUCTION

Objectives and Procedure

This paper discusses the origin of hot springs in the upper Jefferson Valley, Montana. The thermal springs of the upper Jefferson Valley are of interest because of a regional concentration of hot springs and because the area lies astride a north-south trending line of hot springs in a deep and narrow valley along the eastern margin of the Boulder batholith. Silver Star and Renova hot springs received detailed attention while Pipestone and New Biltmore hot springs were the objects of brief reconnaissance.

A primary objective of this investigation was the establishment of a pattern for the circulation of thermal water. A preliminary assessment of the geothermal potential of the upper Jefferson Valley was a secondary objective. Conclusions are based on field evidence and a review of the scientific literature.

Geologic maps of the Silver Star and Renova areas were prepared. In addition, shallow subsurface geophysical investigations were conducted in the two areas. Dr. Robert Leonard of the United States Geological Survey investigated the geochemistry of these and other hot springs.

Location and Physiography of Study Area

Field investigations for this report were confined to the upper Jefferson River Valley, Montana, and adjacent hills between Pipestone and Twin Bridges, a distance along the valley of about 40 km (Fig. 1). The valley may be viewed in profile from Interstate 90 near Whitehall. The Tobacco Root Mountains border the valley on the east; the mountain front rises abruptly in a nearly straight line from the valley. The Highland Mountains rise gently on the west.

An alluvial fan complex slopes from the mountains to the valley. Hidden under the fan complex is a range front fault along which the mountains were uplifted and the valley dropped down. The upper Jefferson River meanders north through the valley along the edge of the alluvial fan to join the Missouri River at Three Forks, Montana.

Gullies have formed on the fan complex. During the Oligocene and Phiocene, a deposition dominated over erosion and the fan complex achieved a great size (Thornbury, 1965). In the Quaternary, erosion has exceeded deposition. Lesser cycles of deposition and erosion account for smaller features such as benches.

The physiography is similar in many ways to the block faulted terrain of the Basin and Range province. Block faulting, erosion, and deposition have worked to create the landscape which we see today. If not for the intervening Snake River Plain and differences of climate, the upper Jefferson Valley and adjacent parts of southwest Montana

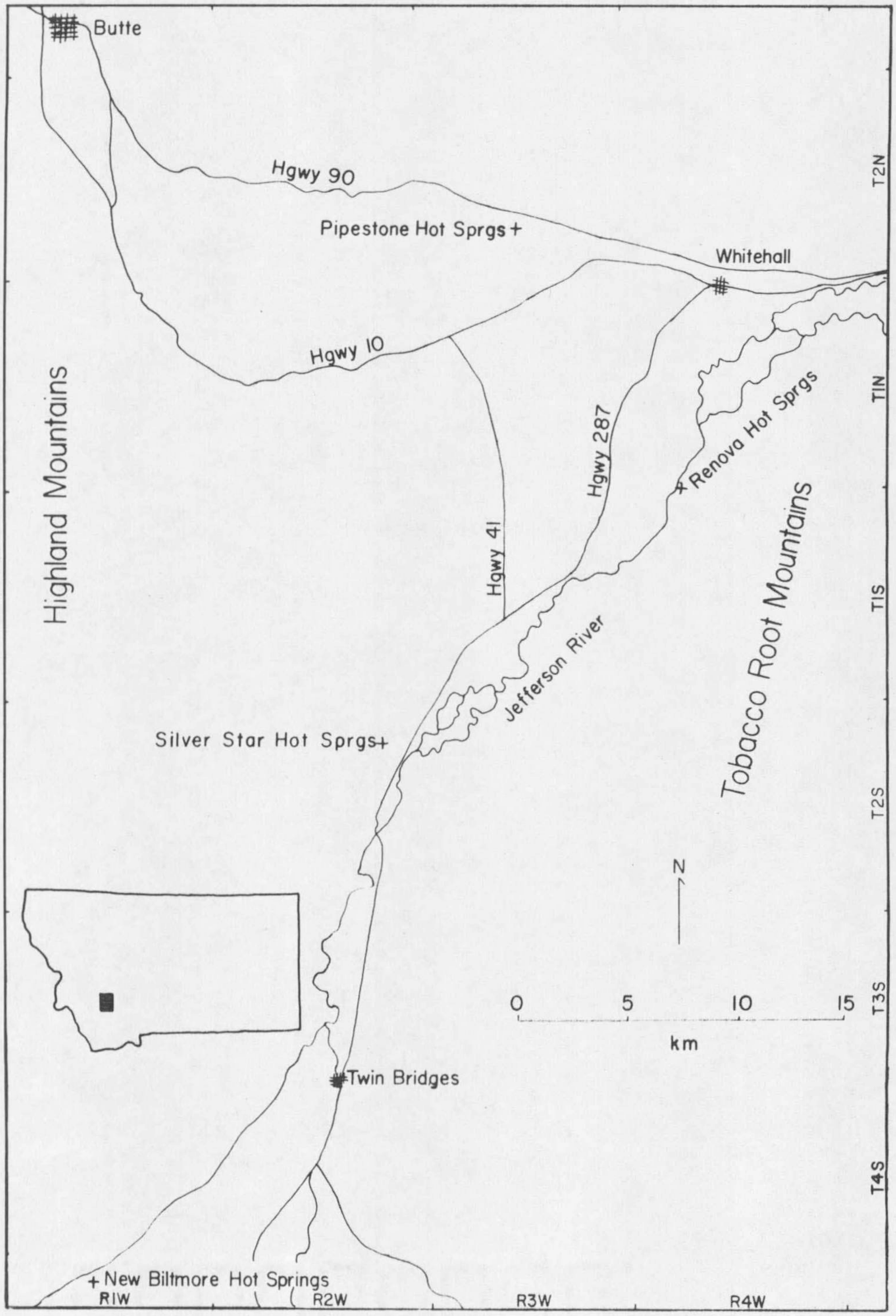

Figure 1. Index Map Showing Location of Hot Springs Studied and Geographic Features.

might well be included in the Basin and Range physiographic province. The relationship can be seen on the geologic map of the United States. That "army of caterpillars marching north out of Mexico" (first described by Fenneman, 1931) can be seen to project under the Snake River Plain and into southwest Montana.

The climate of the upper Jefferson Valley is temperate and semi-arid. Average annual precipitation is 25-35 cm. The temperature varies from an average of -7°C in January to an average of 18°C in July. The adjacent mountain ranges are cooler and receive more moisture than the valley. Elevations range from about 1500 m on the valley floor to 3000 m on the mountain peaks.

The most important economic activity in the upper Jefferson Valley is agriculture. Ranchers raise cattle and feed crops such as hay and alfalfa.

Previous Investigations

Tansley, Schafer and Hart (1933) discussed the structural geology and geologic history of the Tobacco Root Mountains and vicinity. Their work still serves as a good general reference for the area. Later reports on the northern Tobacco Root Mountains and vicinity include papers by Reid (1957) and Schmidt (1975). Berg (1959) in a masters thesis described the geology of the area around Renova Hot Springs. The geology of the Jefferson Valley was investigated by Kuenzi and Fields (1971). Their work was based on the Tertiary stratigraphy and paleontology.

Geophysical investigations of the basin fill include a regional gravity survey by Burfeind (1967), a seismic study by Wilson (1962) and a resistivity study by Malik (1977) in the vicinity of Silver Star Hot Springs. Localized shallow seismic and d.c. resistivity surveys were conducted by Montana State University personnel (1976 and 1977, unpublished data) near Silver Star and Renova hot springs. A soil temperature survey was conducted by M.S.U. personnel at Silver Star in 1975.

The Highland Mountains and its mining districts were described by Sahinen (1950). Fritzche (1935) and McMillan (1939) reported on the geology of the Silver Star Mining District in masters theses.

The Boulder batholith was described by Pinckney (1958), Hamilton and Myers (1967) and Klepper, Robinson and Smedes (1971).

Hot springs in southwest Montana have been the subject of reports by Williams (1971), on the Bearmouth area, and Struhsacker (1976), on the Gardiner area; Kaczmarek (1974) reported on the geochemistry of selected hot springs, and Galloway (1977) investigated the circulation of hot water in fractured crystalline rock.

The geochemistry and structural controls of selected Montana hot springs were discussed by Chadwick and Kaczmarek (1975). Geochemical data on Montana thermal springs has been provided by White and

Williams (1975), Mariner and others (1976), Leonard (unpublished) and others of the U.S. Geological Survey.

CHAPTER 2

GENERAL PRINCIPLES OF HOT SPRINGS

In order to decipher the pattern of thermal circulation and to assess the geothermal resource, an understanding of basic hot spring principles is required. A discussion of hydrothermal convection and of the probable heat source is presented here for the reader.

Hydrothermal Convection Systems

In a hydrothermal convection system, heat is transferred primarily by the convection of water or steam, rather than by conduction through solid rock. In Fig. 2, heated water rises buoyantly because it is less dense while cooler; more dense water sinks to take its place.

Most hydrothermal convection systems are believed to contain liquid water rather than steam as the dominant pressure-controlling fluid (Renner, White and Williams, 1975). In these systems, water transfers most of the heat. Some vapor may be present, however, as bubbles in the more shallow parts of the system.

Surface temperatures of hot springs generally do not exceed the boiling point of water, which is 100°C at sea level and slightly less at higher elevations. An exception is a group of springs in Yellowstone National Park which are superheated by 1° to 2°C. Nearly all hot springs in Montana have surface temperatures below 80°C.