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RLO-2426-T2-2

PART I

PHASE ZERO STUDY RESULTS - GEOTHERMAL POTENTIAL OF THE MADISON GROUP AT SHALLOW DEPTHS IN EASTERN MONTANA

FINAL REPORT

J. L. Sonderegger, R. N. Bergantino, and M. R. Miller

Montana Bureau of Mines and Geology
Montana College of Mineral Science and Technology
Butte, Montana

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TASK AGREEMENT NO. 2

INTRODUCTION

The study of shallow geothermal potential in the Madison Group limestone aquifer was started to provide information about large-volume, low-temperature reservoirs that could have potential for space heating or for extended-crop-season irrigation. The report summarizes data available from federal and state sources. To date, eighty-one hot or warm springs are known in Montana. Twenty-nine of these springs are believed to originate in limestone of the Madison Group.

DATA SUMMARY

Table 1 presents the data currently available for the springs believed to originate in the Madison Group. The springs are listed alphabetically and numbered sequentially. Some spring names have been changed to eliminate confusion (there are at least ten "Warm Springs Creeks" within Montana); for example, the three "Big Warm Springs" in sec. 24, T. 26 N., R. 2 E., have been redesignated Lodgepole no. 1, 2, and 3.

The system for locating springs is based on the U.S. Bureau of Land Management system of subdivision of the public lands using the Montana Principal Meridian system. The first segment of a data-point number indicates the township north or south of the baseline; the second, the range east of the principal meridian; and the third, the section in which the spring is located (Fig. 1). The letters A, B, C, and D, following the section number, locate the point within the section. The first letter denotes the 160-acre tract; the second, the 40-acre tract; the third, the 10-acre tract; and the fourth, the $2\frac{1}{2}$-acre tract. The letters are assigned in a counterclockwise direction, beginning in the northeast quadrant. It is important to note that the order of quarter-tract designations is exactly reversed from that commonly used by surveyors; here the order begins with the largest quarter and progresses to the smallest. Thus, in Figure 1, the designation 2 N. 41 E. 13 ABCD identifies a spring in the SE$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 13, T. 2 N., R. 41 E.

Information on spring discharge is presented in gallons per minute (gpm). If discharge rates for a specific spring differ, the best available maximum and minimum flows are listed. Similarly, the highest and lowest reported temperatures are presented. Comments on the reliability or range of the data are included at the end of the table.

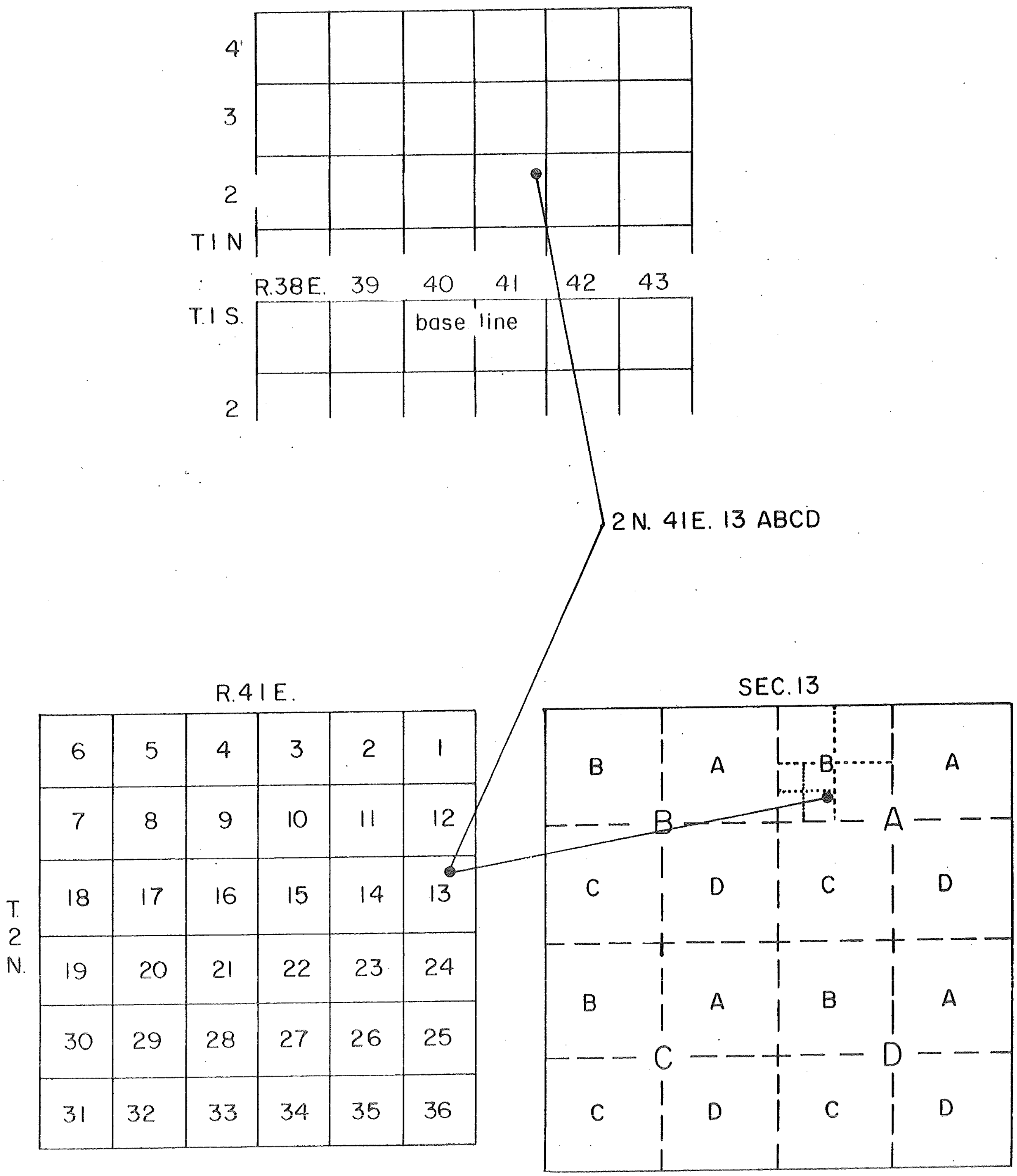

Figure 1. Spring location

The energy available as heat in the water was calculated from a metric base assuming: (1) that the energy released, per degree centigrade, in cooling the spring water to the reference temperature was the same as that released in cooling the same weight of water from 15.5°C to 14.5°C; (2) that one liter of water at the field temperature had a mass of 1 kilogram and a volume of 0.252 gallons; (3) that the cited discharge and temperature are constant; and (4) that the average year has 365.25 days. The equation used is

$$H = (T_{obs} - T_{ref})^{o}C \times Q(gpm) \times 525{,}960(min/yr) \times 3.785(l/gal) \times 3.968(Btu/kcal)$$

where H is expressed in British Thermal Units (Btu's) per year, $(T_{obs} - T_{ref})$ is the difference between the observed field temperature and the reference temperature in degrees Celsius, Q is the discharge in gallons per minute, 525,960 is the number of minutes in an average year, 3.785 is the number of liters per gallon, and 3.968 is the number of Btu's in one kilocalorie. The two reference temperatures employed in the calculations, 18°C(64.4°F) and 10°C(50°F) were judged to be the lowest temperatures applicable for space heating and for extended crop seasons utilizing flood irrigation, respectively.

Under "comments and source", springs for which chemical analyses are available are denoted; comments dealing with source depict our knowledge based upon a survey of existing data unless noted otherwise. Additional information is being gathered on springs numbered 26, 27, and 28. An explanation for the inclusion of springs numbered 7, 8, 24, and 30 is developed below, based upon the water chemistry.

Table 2 presents the currently available chemical data for 16 of the 29 thermal springs. Where such springs issue from an indeterminate source (such as Tertiary sediments) and the Madison Group crops out near the spring, the chemical composition of the spring water was used to interpret whether the water has passed through a carbonate aquifer. A carbonate aquifer "imprint" was assumed if the calcium content was greater than or equal to the sodium content (in milligrams per liter (mg/l), which is equivalent to 1.15:1.0 expressed as milliequivalents per liter). This assumption can be justified on the basis of the analytical data contained in the U.S. Geologival Survey Open-File Report 76-480, which contains analytical data for 21 hot springs in Montana. Figure 2 is a log-log plot of sodium versus calcium for these hot spring waters. Although the trend lines are located only approximately, it is evident that the plot contains points representing two different chemical types of water. The New Biltmore sample

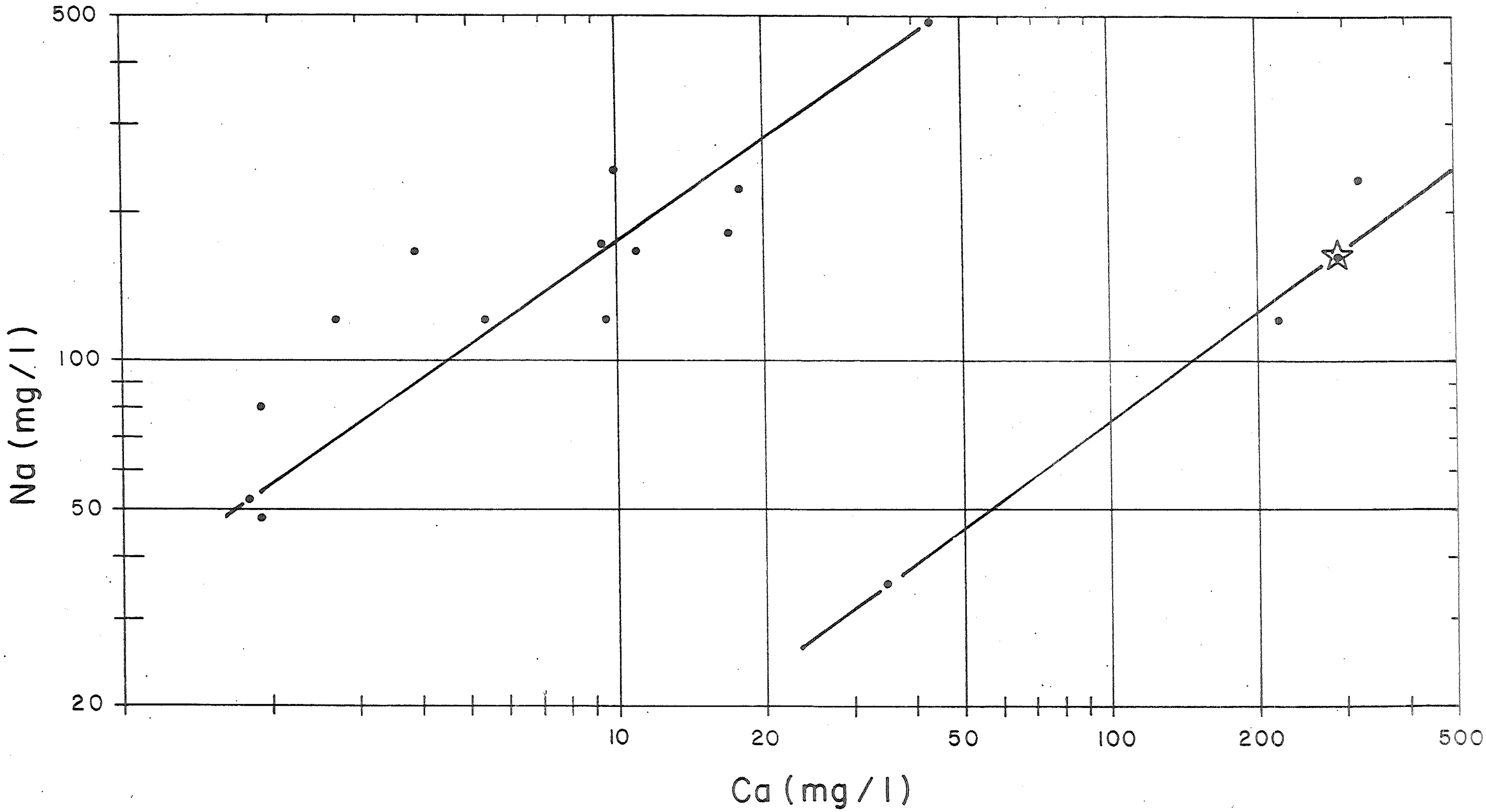

Figure 2. A log-log plot of sodium versus calcium for the spring water analyses in "Chemical characteristics of the major thermal springs of Montana (U.S.G.S. Open-File Report 76-480).

(star) is the only one of the four samples on the lower trend line known to issue in an area mapped as Madison.

The Ca/Na ratios range from 1.0 to 39.1. A plot of these ratios versus temperature, presented in Figure 3, suggests to the authors that only three of the springs (numbers 1, 5, and 9) represent waters that were almost exclusively in contact with carbonate aquifers. The other spring waters are believed to have acquired their sodium content by interaction with sodium-containing minerals or as a result of the mixing of carbonate and noncarbonate waters prior to spring discharge.

DISCUSSION

In terms of available Btu's based upon temperature and flow data, the most promising area for shallow geothermal potential in the Madison Group seems to be the Little Rocky Mountains area (Plate 1). The Landusky, Little Warm and Lodgepole spring series are all located on the southern and eastern sides of this mountain range. These springs are currently known to release 890 billion Btu's per year that could be used for space heating (ΔH_1).

Three different locations are believed to have a second level of geothermal potential. The Brooks warm spring (no. 5) releases a very large flow (68,000 gpm) of low-temperature ($\simeq$ 21°C) water. Because this water is interpreted to have had little contact with noncarbonate aquifers, and because the spring is just north of the South Moccasin Mountain Tertiary intrusive mass, we conclude that there is only a very low probability of significantly warmer water at shallow depth. Durfee Creek number 2 (spring no. 10) also has a large flow (15,000 gpm) and low temperature (22°C). There is no known heat source in that general area, suggesting either deep circulation or a shallow buried intrusive body as the heat source.

The high flow and low temperature suggest that dilution occurs in the Madison. The evaluation of this location is that there is only a slight possibility of significantly warmer water at shallow depth. The Staudenmeyer springs area is currently under investigation as an additional task associated with this study. A preliminary interpretation of potential in this area will be presented in Part II of this report, upon completion of the September field work.

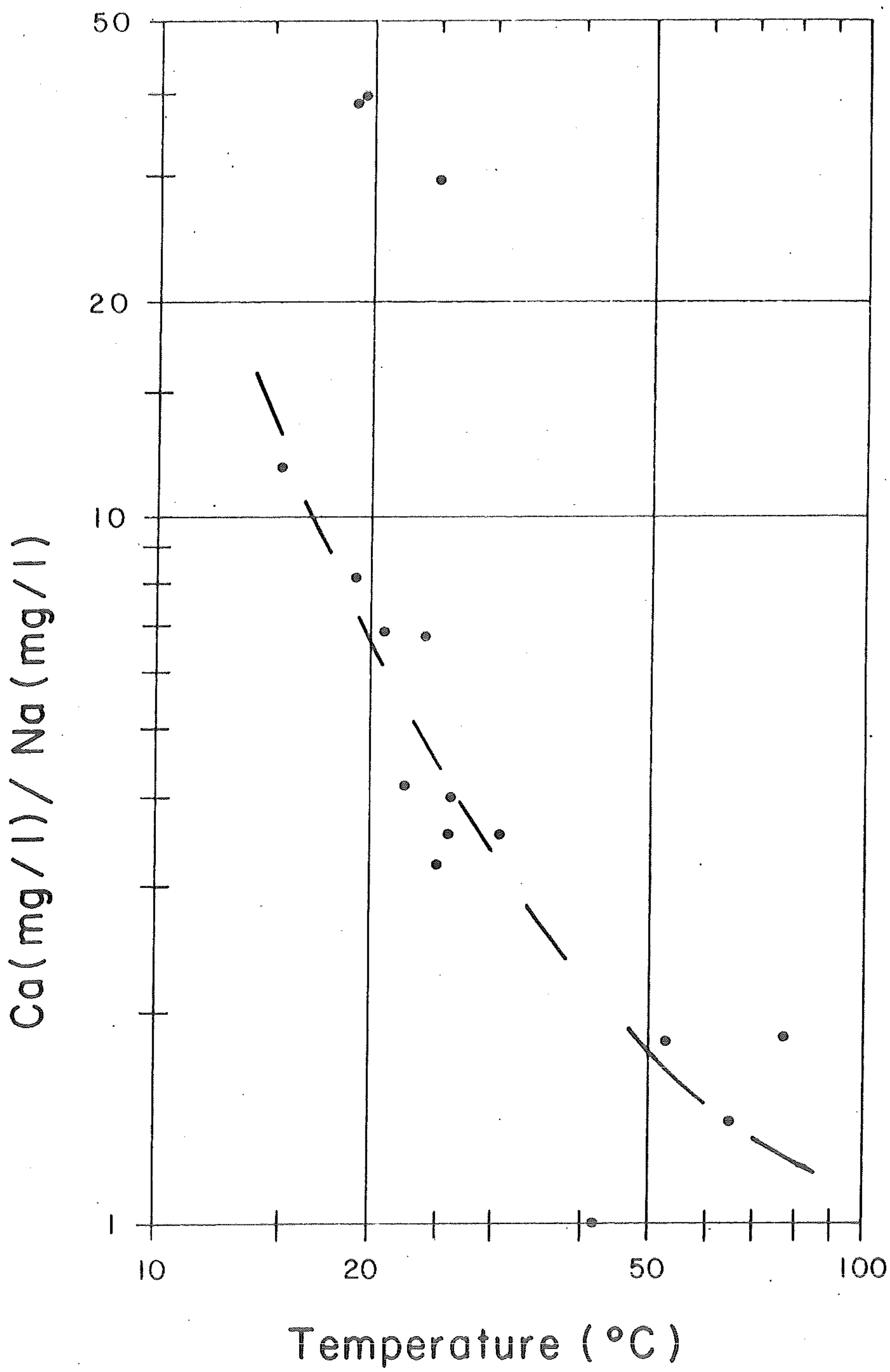

Figure 3. Plot of Ca-Na ratios versus temperature for the data in Table 2.

The Corwin (La Duke) area has already been designated as a Known Geothermal Resource Area (KGRA). The reader is referred to Robert Leonard of the U.S. Geological Survey (Helena, Montana) for a current assessment of the area.

REFERENCES CITED

Mariner, R. H., Presser, T. S., and Evans, W. C., 1976 Chemical characteristics of the major thermal springs of Montana: U.S. Geological Survey Open-File Report 76-480, 31 pages.

PART II

A RECONNAISSANCE STUDY OF GEOTHERMAL POTENTIAL IN THE UPPER PARTS OF RED ROCK CREEK AND MADISON RIVER VALLEYS, SOUTHWESTERN MONTANA

PRELIMINARY RESULTS

W. M. Bermel, J. L. Sonderegger, and D. T. Glasser

Montana Bureau of Mines and Geology
Montana College of Mineral Science and Technology
Butte, Montana

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Introduction

The study of shallow geothermal potential in the Upper Red Rock Creek Drainage and the Lower Madison River Drainage is being conducted to evaluate the geothermal prospects of the area for any possible space-heating potential.

This report includes some of the hydrologic field data obtained during the months of July through September, 1977, when 47 streams (Table 1), and 46 springs were field inventoried (Table 2).

Also, there is discussion of geologic mapping and an aerial thermal scan conducted during this same period.

Discussion

The last two and one half (2½) months were spent doing a hydrologic investigation and geological mapping of the study area (Fig. 1). This includes locating all streams, springs, and wells in the valleys and their perimeters. In the early summer, streams were monitored at 47 sites for flow, temperature, and specific conductance (Table 1), and each of the sites will be remeasured during the last week in September to obtain the lower flow information for the area.

In conjunction with the stream monitoring, 46 springs in the area were located and field inventoried for: discharge, temperature, specific conductance (using a Yellowsprings S.C. meter), silica (SiO_2) (using Hach chemical kit model SI-5), and fluoride (F) (using Hach chemical kit model FL-3).

Values obtained from the field silica and fluoride tests will be used to determine which springs to include on the high-priority list for water-quality sampling. All springs in which SiO_2 content is 20 parts per million (ppm) or more or fluoride content is 2 ppm or more will be sampled. After deciding on the streams and wells to sample, an areal-distribution sampling will be conducted, using the entire 125 samples allocated for this fall.

Of 42 wells in the area, 32 were inventoried according to U.S. Geological Survey System 2000 (Ground Water Site Inventory System) specifications and forms.

This procedure includes recording the following information if available: total depth, static water level, flow, diameter, pump type, etc.

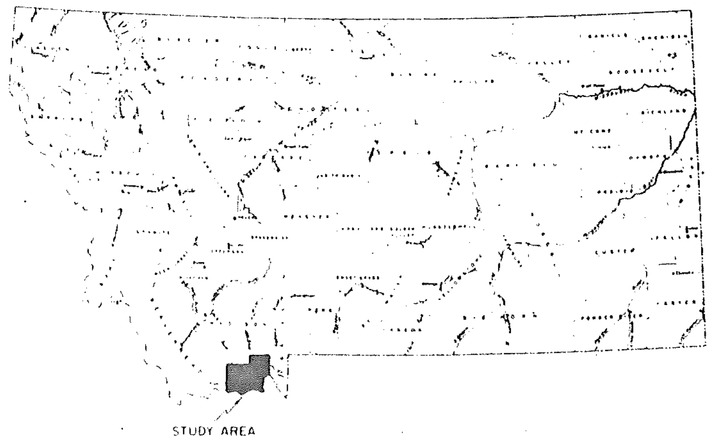

Figure 1. Location of study area.

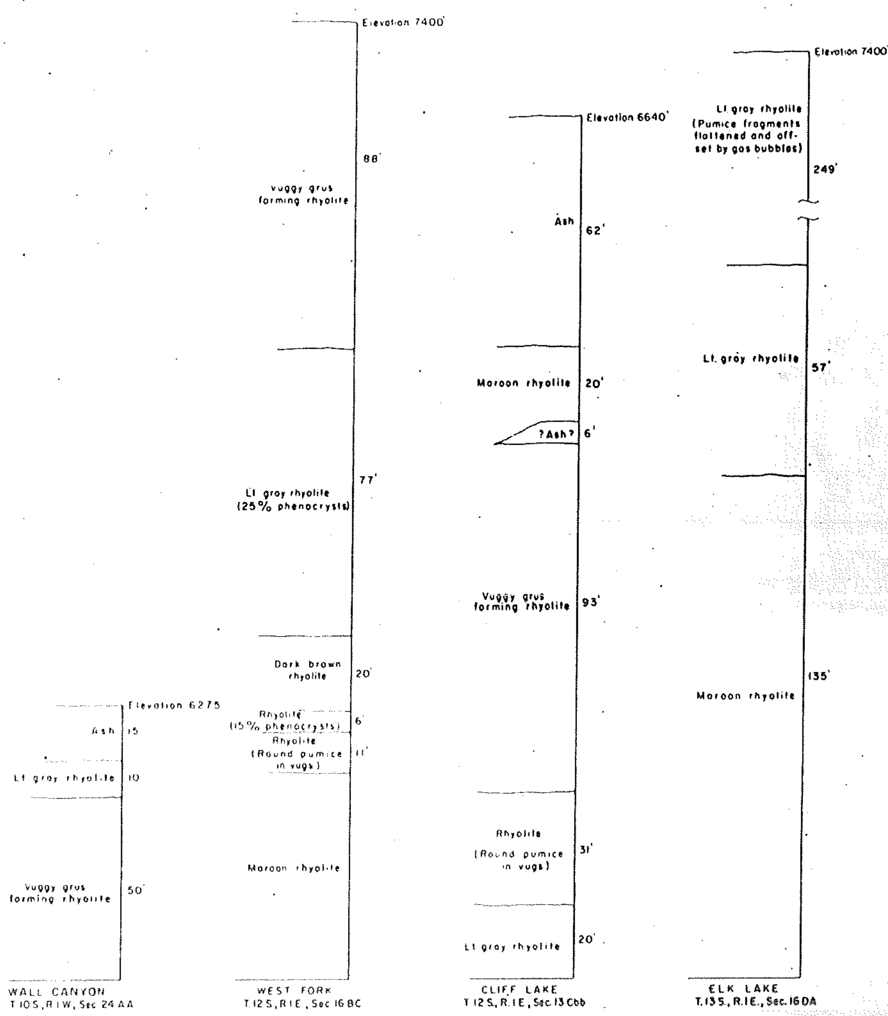

Figure 2. Stratigraphic sections of young volcanic rocks.

Several weeks were spent measuring the stratigraphic thickness of the Huckleberry Ridge Welded Tuff, which is the youngest volcanic unit (1.9 m.y.) in the study area and a potential heat source. Figure 2 shows the thickness and sequence of beds within the Tertiary volcanic rocks.

The only warm ground water found in the Centennial Valley is located on Les Staudenmeyer's property (T. 13 S., R. 2 W., sec. 17 and 18), where water temperatures range from 22 to 29°C; this water is used to extend the grass-growing season in the pastures.

Mapping of the area north of Staudenmeyer's land indicated a small anticlinal structure passing over the warm springs and the Staudenmeyer ranch. Explanations of the relationship between the anticline and the warm water have not been completely evaluated and will be withheld until the submission of a later report.

A reconnaissance map is being done for the north half of the Lower Red Rock Lake 15' Quadrangle (60% complete) and we hope to also complete the Upper Red Rock Lake 15' Quadrangle, which will tie into I. J. Witkind's U.S. Geological Survey map I-943.

Gerald Weinheimer, a graduate student at Montana State University, is assisting with the work in the Madison Valley portion of the research area. We have provided financial support for his field work, have provided aerial photos of his area, and have allocated part of our analytical budget for his water samples. The results of Gerald's thesis work will be incorporated in the final report, on which he will be a coauthor.

Conclusions

At this time it can be stated that:

(1) Faults along the north side of the Centennial Valley have appreciable displacement, exposing rocks of Mississippian age.

(2) The young volcanic rocks, which dip into the Centennial Valley from the north, are not continuous, as older rocks are exposed where the ash-flow tuff has been breached by erosion.

(3) The application of warm waters in this area will probably be restricted to space heating and agricultural use.