GL04017

WATER CHEMISTRY AS AN AID IN RECONNAISSANCE EXPLORATION FOR A LOW-TEMPERATURE GEOTHERMAL SYSTEM, ARTESIAN CITY AREA, IDAHO

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ABSTRACT

Water geochemical data can be usefully applied in the reconnaissance stage of exploration for low-temperature geothermal systems. This paper presents the use of these data in conjunction with the hydrologic and geologic interpretation of Struhsacker et al. (in prep.) to predict recharge areas, flow paths, and subsurface temperatures of thermal water in the Artesian City area, Idaho.

The source of recharge of the thermal water was determined to be meteroic water derived from the Rock Creek Hills and heated by the geothermal gradient. Interpretation of Na-K-Ca(-Mg) and SiO_2 geothermometer temperatures in the context of proposed flow systems and fluid sources indicates that the predicted temperatures are high and that the thermal water probably cooled from temperatures not much higher than their discharge temperatures.

INTRODUCTION

In the last several years interest has increased in the utilization of low-temperature geothermal systems (<100°C) for direct heat applications. Geochemical techniques commonly used in exploration for high-temperature systems can not always be applied to low-temperature systems due to complications caused by the sluggishness of reactions rates at low temperatures, and the lack of distinctive chemistry. This paper illustrates how water analyses, coupled with geologic mapping and hydrologic data have been used in reconnaissance level exploration of the low-temperature geothermal system near Artesian City, Idaho, to estimate recharge areas, flow paths, and subsurface temperatures of thermal water. The geochemistry of the Artesian City area described in this paper is part of an integrated geological, hydrological, geophysical and geochemical study (Struhsacker et al., in prep.) funded by the U.S. Dept. of Energy under contract no. DE-AC07-80ID12079 to ESL/UURI.

The Artesian City area geothermal system is located in south-central Idaho approximately 10 km southeast of Twin Falls. Numerous wells and a few springs occurring at the base of the Rock Creek Hills, south of Artesian City, produce warm water at temperatures up to 39°C. Through comparison of water temperatures measured in this area, water greater than 28°C is defined as warm (Struhsacker et al., in prep.).

GEOLOGIC SETTING

The Artesian City area as described by Struhsacker et al. (in prep.) lies on the southern margin of the Snake River plain and the northern edge of the Basin and Range Province. A lowland of alluvium-covered (Qf,Qal) basalt flows (Tb) extends southward from the Snake River to the east-west trending front of the Rock Creek Hills (Fig. 1). A thick sequence of gently dipping Tertiary rhyolitic volcanics (Tiv, Tal), forms the

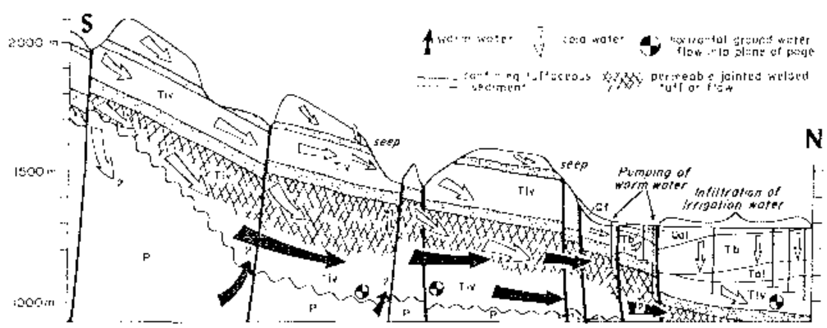

FIG. 1. Generalized geologic and hydrologic cross section through the Rock Creek Hills and Lowlands taken from Struhsacker et al. (in prep.).

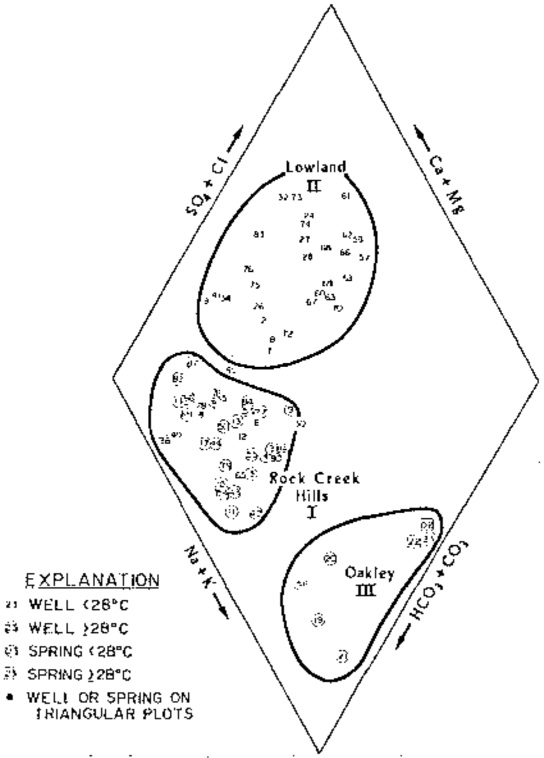

FIG. 2. Trilinear diagram showing the chemical character of Artesian City area water.

Rock Creek Hills. Normal faults bound the northeastern, northern, and northwestern margins of this upland. The Tertiary volcanic rocks lie unconformably on late Paleozoic marine limestone, shale and quartzite (P).

GROUND-WATER CHEMISTRY

Different water types can frequently be distinguished by comparing the proportions of cations and anions on a trilinear diagram (Hem, 1970). A trilinear plot completed for water samples collected from the Artesian City area indicates three water types (Fig. 2). These compositional groupings also define three clear geographic regions, which include the Rock Creek Hills (type I), Lowlands (type II), and Oakley (type III) areas (Fig. 3). Temperature further characterizes these water types. Type I includes both thermal and nonthermal waters with temperatures ranging from 4 to 39°C, type II contains only nonthermal water (less than 28°C), and type III contains only thermal water with temperatures greater than 40°C.

Type I (Rock Creek Hills) water includes all Artesian City area warm wells and springs sampled, several nonthermal wells, and all cold springs (Fig. 3). These waters, although having similar proportions of anions and cations, become more concentrated in total dissolved solids (T.D.S.)

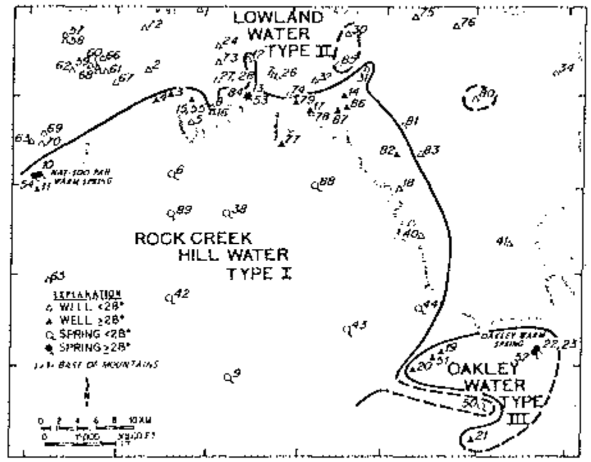

FIG. 3. Locations of sampled wells and springs.

with increasing temperature (Fig. 4). They are dilute, near-neutral bicarbonate ground waters with average T.D.S. contents varying from 141 mg/l in cold springs to 200 mg/l in thermal wells. The pH also changes with temperature from a low of 6.2 in the coldest, 4°C water, to 7.9 in the hottest, 39°C water (Fig. 4). SO_4 and Cl are both present in consistently low concentrations of less than 20 mg/l. Ca followed by Na, both ranging in concentrations from 3 to 43 mg/l, are the dominant cations present in the majority of Rock Creek Hills water samples.

Type II (Lowland) water includes the majority of wells sampled in the lowlands north and northeast of the Rock Creek Hills (Fig. 3). This water is nonthermal and exhibits a large variation in composition, ranging from slightly basic, calcium or sodium bicarbonate to calcium or sodium bicarbonate-sulfate or bicarbonate-chloride ground water. In contrast to the Rock Creek Hills water, 90% of the Lowland water samples have temperatures under 20°C. They also have higher T.D.S. concentrations and pH values, averaging 518 mg/l and 7.7, respectively. Concentrations of SO_4 and Cl in the Lowland water average 137 and 86 mg/l, respectively.

Oakley thermal water (type III) is found southeast of the Artesian City study area (Fig. 3). This water has a sodium bicarbonate to sodium bicarbonate-chloride composition. It differs from both the Rock Creek Hills and Lowland waters by having higher temperatures, ranging from 41° to 49°C, higher pH values and Na concentrations, averaging 9.0 and 73 mg/l, respectively, and lower Ca, averaging 6 mg/l. The chemical composition of Oakley water indicates that it is probably not related to the thermal water which discharges just south of Artesian City which is the focus of this study. The Oakley water, therefore, will not be considered further in this report.

SOURCE OF THERMAL WATER

The low concentrations of dissolved solids in Rock Creek Hills water of less than 200 mg/l, the compositional trends of increasing T.D.S. and pH with increasing temperature (Fig. 4) and the uniformity of composition (Fig. 2) suggests that the source of both thermal and nonthermal Rock Creek Hills water could be meteoric water derived from the Rock Creek Hills. As meteoric water, which is very dilute (<10 mg/l) and slightly acidic (pH from 5 to 7), flows through and reacts with silicic rocks, its pH and T.D.S. will increase as a result of feldspar dissolution reactions (Helgeson et al., 1969). The deeper rain and melt-water infiltrates, and therefore the longer it reacts with the host rock, the higher its pH and concentration of T.D.S. will become as it approaches chemical equilibrium with the host rock. In addition, the deeper this water infiltrates, the higher its temperature will become as a result of the geothermal gradient. The similar chemical character of both the cold and warm Rock Creek Hills waters which suggests a common set of reactions with the dominant silicic volcanic rock type in the Rock Creek Hills further supports this proposed flow path.

This proposed source for the thermal water is in agreement with the hydrologic interpretation of Struhsacker et al. (in prep.) (Fig. 1) which indicates the source of thermal water is deep circulation within the Tertiary rhyolitic volcanics of meteoric water derived from the Rock Creek Hills and heated by the local thermal gradient estimated to be approximately 60°C/km.

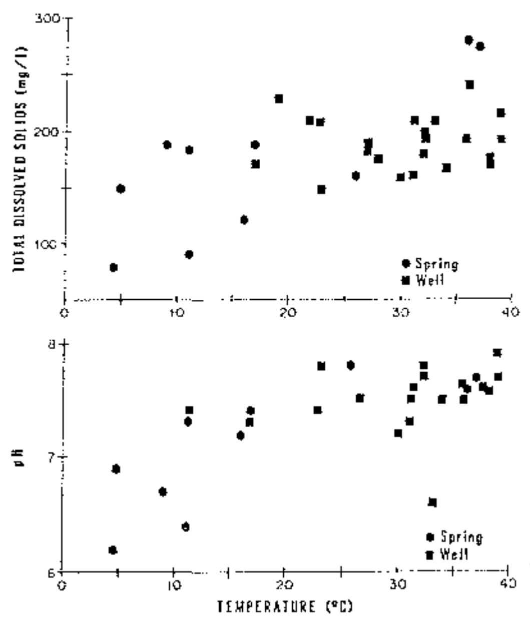

FIG. 4. Total dissolved soilds and pH vs. temperature diagrams for Rock Creek Hills water.

SUBSURFACE TEMPERATURES

Geothermometers based on temperature-dependent mineral-fluid equilibria are routinely used to approximate subsurface temperatures of thermal fluids. The utility of these geothermometers is contingent on the attainment of equilibrium between thermal fluid and the host rock. The slow reaction rates at low temperatures, therefore, suggest that these geothermometers may not be applicable in a low-temperature geothermal system (Fournier, 1973, 1979).

Geothermometer temperatures were calculated for all water samples collected from the Artesian City area employing the Na-K-Ca (Fournier and Truesdell, 1974), with Mg correction (Fournier and Potter, 1979), and silica (Fournier, 1977) geothermometers. The silica geothermometer employed for each sample was that of the least supersaturated polymorph, thereby predicting a minimum geothermometer temperature. The majority of the water samples analyzed are supersaturated with beta-cristobalite and amorphous silica (Fig. 5). The range of geothermometer temperatures for each water group are listed in Table 1.

TABLE 1

GEOTHERMOMETER TEMPERATURES (°C)

	Na-K-Ca(-Mg)	SiO_2
Rock Creek Hills (Type I)		
Cold Springs	25-72	44-65
Nonthermal Wells	50-68	40-72
Thermal Wells and Springs	34-76	37-65
Lowland (Type II)	11-74	29-65

Measured temperatures for all Artesian City area waters are below 100°C, therefore their estimated geothermometer temperatures are suspect

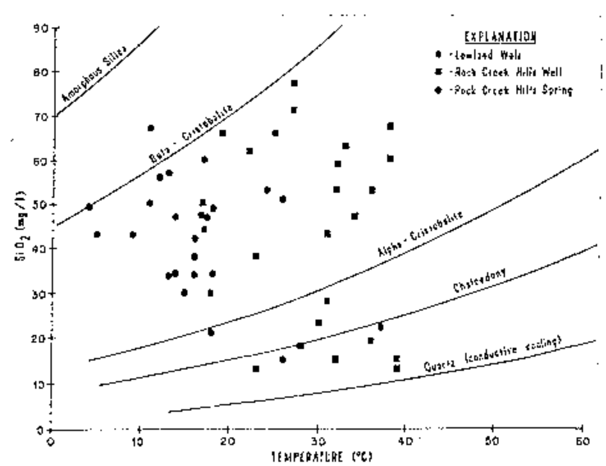

FIG. 5. Silica concentration vs. temperature diagram of Lowland and Rock Creek Hills water. Mineral solubilities are taken from Fournier (1977).

despite the apparent agreement between the two geothermometer temperatures for each water group. Review of the chemical character of these waters in the light of the proposed hydrologic regime of each water type allows further comment on the reliability of these predicted temperatures.

Hydrologic and geochemical data strongly suggest that Rock Creek Hills cold springs produce shallow circulating rain and melt-water derived from the Rock Creek Hills. The low concentration of T.D.S. in these waters, ranging from 81 to 192 mg/l, supports this suggestion of shallow circulation and thus short residence time within the host formation. The Na-K-Ca(-Mg) and SiO_2 estimated temperatures of up to 72 and 65°C, respectively, for the cold spring water are therefore probably too high. The enriched silica concentrations in the cold spring samples that yield high estimated SiO_2 temperatures could be the result of rapid dissolution of volcanic glass (alpha-cristobalite) present in the silicic volcanics (Paces, 1972). The anomalously high Na-K-Ca(-Mg) temperatures could be due, on the other hand, to nonequilibrium in the cold spring water as a result of its short residence time within the host formation.

Water compositions (except SiO_2), fluid sources, and the range of predicted temperatures (Table 1) of thermal and nonthermal Rock Creek Hills well water are similar to those of the cold spring water. Thus, Na-K-Ca(-Mg) temperatures calculated for the Rock Creek Hills well waters may also be too high. The estimated SiO_2 temperatures for the Rock Creek Hills thermal and nonthermal wells are also suspect. In this case, the SiO_2 concentrations in the well waters are believed to be controlled by equilibrium with clay minerals rather than an SiO_2 polymorph considered by the geothermometer. This is supported by the tendency of the pH of these waters to be buffered just below 8 (Fig. 4), which could result from kaolinite and montmorillonite equilibrium (Helgeson et al., 1969).

Geothermometer temperatures for Lowland water are questioned because their source of recharge is suggested by hydrologic data to be downward infiltration of irrigation water (Struhsacker et al., in prep). This downward percolating water is most likely not in equilibrium with the alluvium because of concentration by evaporation, reaction with the soil layer, and short residence time in the formation.

CONCLUSION

Interpretation of the water chemical data from the Artesian City area in light of the hydrologic and geologic data of Struhsacker et al. (in prep.) supports the conclusion that the source of thermal water is artesian flow of rain and melt-water from the Rock Creek Hills heated during deep circulation. In addition, these waters have probably cooled from temperatures not much higher than their discharge temperatures, despite higher estimated geothermometer temperatures. While this model could be strengthened through the use of stable isotope data and mineral-equilibrium calculations, acquisition of these data is generally not practical within the cost and time limitations of a reconnaissance exploration program for low-temperature geothermal systems.

A few cautions should be taken in interpretation of water chemical data. For example, water compositions will be effected by: lithologic variability within the flow system; mixing with waters from different sources; changes in the hydrologic regime due to pumping; and seasonal and long-term climatic variations.

ACKNOWLEDGEMENTS

Thanks are owed to J. N. Moore, D. R. Cole, E. M. Struhsacker, and D. Foley for critical review of this manuscript.

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