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ISOTOPIC AND ION CHEMISTRY OF WATERS IN THE EAST SHORE AREA, NORTHERN UTAH

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ABSTRACT

Fluid chemistry and stable isotopes of oxygen and hydrogen were used to investigate the origin of thermal waters in the East Shore Area of northern Utah. Water samples were collected from all hot and warm springs, and many of the wells in this area, and analyzed for major cations and anions, and $\delta^{18}\text{O}$ and δD .

The data presented suggest the presence of two distinct hydrologic regimes. One involves deep, fault-controlled circulation of waters derived from high elevations in mountains to the east. These waters evolve into the Na+K and Cl-enriched hot spring fluids that are high in total dissolved salt concentrations (>4000 mg/l). A second hydrologic regime consists of waters derived from lower elevations that infiltrate into the shallow valley sediments. These dilute Ca+Mg and HCO_3 fluids comprise the bulk of the area's ground water supply.

Leakage of thermal waters into overlying cooler aquifers is observed in the vicinity of the hot springs, and is believed to occur in several other portions of the East Shore Area.

INTRODUCTION

The East Shore Area of northern Utah is located between the Great Salt Lake on the west and the foot of the Wasatch Range on the East (Fig. 1). This area extends from the Salt Lake-Davis County line, north to the Box Elder-Weber County line and contains Hooper, Utah and Ogden hot springs. Because recent igneous activity is absent, thermal waters in this area are believed to represent the surface manifestation of waters that have circulated to depth along steeply-dipping faults in a near-normal heat flow regime. Typically, systems of this type are characterized by dilute bicarbonate-chloride springs with total dissolved salt concentrations less than 1000 mg/l and temperatures below 100°C. The discharge rates of the springs are usually small and storage of water in the systems is not large (Ellis and Mahon, 1977).

In order to justify the existence of a viable low-temperature (<90°C) resource beneath this area at reasonable drilling depth, the near-surface

expression of a deep circulation warm-water system must be demonstrated. The evaluation of the chemical and stable isotopic composition of thermal springs, well waters and cold surface waters has proved to be a useful tool in the initial stages of geothermal exploration in such systems. The purposes of this study are to apply these geochemical techniques in the East Shore Area to (1) determine the origin of the thermal fluids and (2) to determine if any of this type of water is present within other portions of the area (i.e. close to population centers).

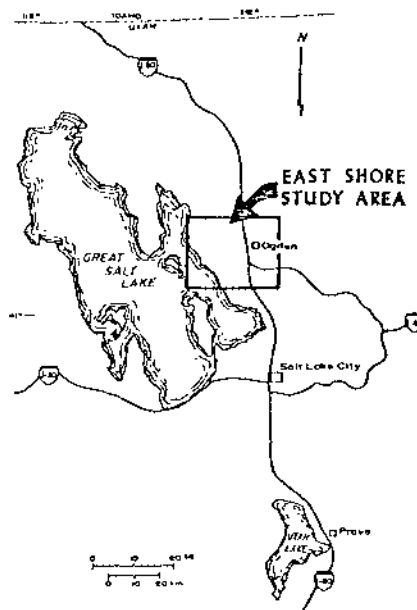


Figure 1. Location of the East Shore study area.

GEOLOGIC AND HYDROLOGIC SETTING

The East Shore Area is a structural graben whose eastern edge is marked by the Wasatch Fault Zone (Goode, 1978). The western side is probably marked by northerly-trending buried faults located east of Little Mountain (near the Great Salt Lake Mineral Co. property) and Antelope Island. The bedrock surface of the graben (Pre-C. granite gneisses, metaseds.) is in the shape of an elongate trough that exhibits a maximum thickness of 2000 to 3000 m. The valley fill consists of

detritus derived from the Wasatch and Uinta Mountains to the east, and brought into the valley principally by the Weber and Ogden Rivers. These deposits are gravel and sand near the mountain front and largely sand, silt and clay as one proceeds farther west, out into the valley. The bulk of the near-surface deposits is comprised of deltaic river sediments formed during the high cycles of Lake Bonneville.

The unconsolidated sediments form extensive aquifers that are largely artesian, so that there is the constant tendency towards upward movement of water (Goode, 1978). Widespread lacustrine clay beds, however, act as confining layers and inhibit this tendency. A regional ground-water study by Feth et al. (1966) indicated the existence of two major aquifers in the area, one at 85 m and a second at 185 m. The interaction of these aquifers with any thermal water component at depth was not established.

BULK COMPOSITION AND ELEMENT DISTRIBUTIONS

The composition of 55 wells and springs sampled in the area between 1979 and 1981 are represented on a trilinear diagram in Figure 2. These data indicate that there are several distinct types of waters present in the East Shore Area. These water types differ not only in their bulk composition, but also in their temperatures and δD contents. Waters sampled from wells located in the center and eastern sections of the study area are relatively enriched in Ca+Mg and $HCO_3 + CO_3$. These fluids are generally low in temperature (<20°C) and ionic strength (0.003 to 0.01), and exhibit δD values ranging from -110 to -126‰.

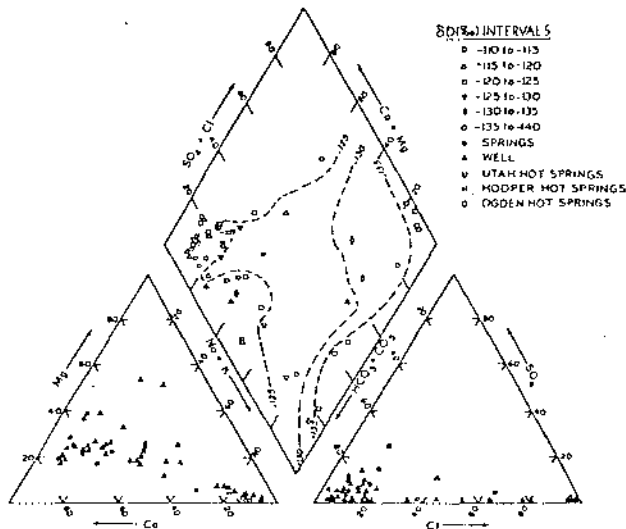


Figure 2. Trilinear diagram showing the chemical composition and δD values of waters from the East Shore area.

A second group of waters is represented by the hot springs (Ogden, Hooper, Utah) and several

warm springs and wells. These waters range in temperature from approximately 30° to 58°C and are enriched in Na+K and either Cl (plotting on the extreme right of the diamond in Fig. 2) or $HCO_3 + CO_3$. δD values for these waters typically range from -135 to -140‰.

Waters of intermediate composition between these two types range in temperature from 20° to 30°C and have δD values ranging from -125 to -135‰. Many of these waters are located within 1 or 2 km from a major hot spring and may be the products of ground water and thermal water mixing.

Ion concentration maps such as the example shown in Figure 3 for chloride indicate extremely variable, but predictable chemical patterns. The Cl plot (augmented with data from Feth et al., 1966 and Good, 1978) suggests the presence of an apparent high Cl (>250 mg/l) plume originating from the Ogden Hot Springs area, trending west. Conversely, two low Cl (<25 mg/l) zones flank this high Cl plume, one on the north originating from North Ogden Canyon and a second on the south originating from Weber Canyon. These low Cl zones are located in areas dominated by low temperatures (15° - 20°C), high concentrations of HCO_3 in waters and high clay plus silt-bearing sediments at depth (Feth et al., 1966). In general, high Cl and Na concentrations are centered on the hot springs, warm springs and wells such as those on the Great Salt Lake Mineral Co. property 17 km north of Hooper Hot Springs.

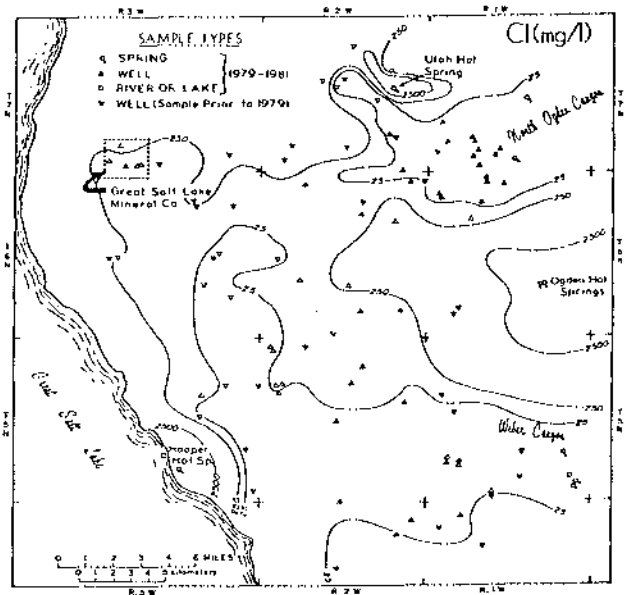


Figure 3. Chloride distribution in the East Shore waters.

STABLE ISOTOPE VARIATIONS

The δD and $\delta^{18}O$ values for over 50 water samples are given in Figure 4. Inspection of data indicates a moderate range in both $\delta^{18}O$ from -18.6

to -14.4‰ and δD from -140 to -110‰ . In this figure, it can be seen that most of the waters fall very near the meteoric water line (Craig, 1961) indicating that they are isotopically unaltered surface waters. Waters plotting on this trend can, however, be divided into two groups, separated by -130‰ δD . The upper group is comprised predominantly of well waters located in the central and eastern portions of the study area with temperatures less than 20°C . The lower group in this figure ($<-130\text{‰}$) ranges in temperature from 20° to 40°C and is comprised of well waters sampled exclusively on the Great Salt Lake Minerals Co. property near Little Mountain. A third group dominated by hot springs waters exhibits $\delta^{18}\text{O}$ shifts of between 2.5 and 3.5‰ with little or no change in the δD values (-135 to -140‰). These $\delta^{18}\text{O}$ shifts are the result of oxygen exchange between rocks and water at depth during fluid circulation. Mg-corrected Na-K-Ca geothermometer calculations on the various hot springs of this area (Cole, in press) suggest aquifer temperatures ranging from 80° to 125°C . Lower temperature waters ($<30^\circ\text{C}$) that also exhibit comparable $\delta^{18}\text{O}$ shifts and geothermometer temperatures may represent fluids that have undergone isotopic exchange with aquifer rocks, but have conductively cooled during ascent to the surface.

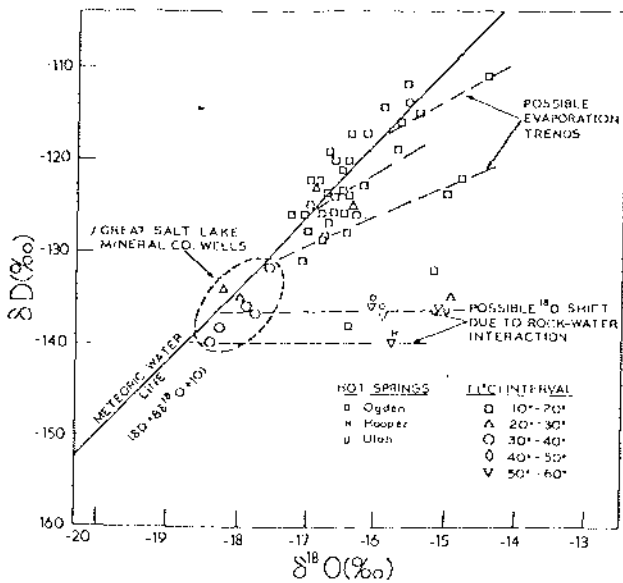


Figure 4. δD versus $\delta^{18}\text{O}$ diagram of waters from the East Shore.

The δD values plotted in Figure 5 display patterns similar to those observed for Cl (Fig. 3) and for temperature, Na and HCO_3 (not shown). Enriched δD waters (-125 to -110‰) are present in a plume originating from North Ogden Canyon (NE corner of map area), in a less definitive zone south of Ogden hot springs, and in the center of the area. δD values of -126 to -140‰ are common for hot springs waters, warm waters from the Great Salt Lake Minerals Co. wells and springs or wells located near hot springs. It is apparent from the

δD distributions in Figure 5 that waters emerging from the hot and warm springs near the major fault structures are depleted in deuterium with respect to waters occupying shallow aquifers in the valley. The exception to this is the presence of a δD anomaly (-126 to 127‰) located approximately 7 km northeast of Hooper Hot Springs.

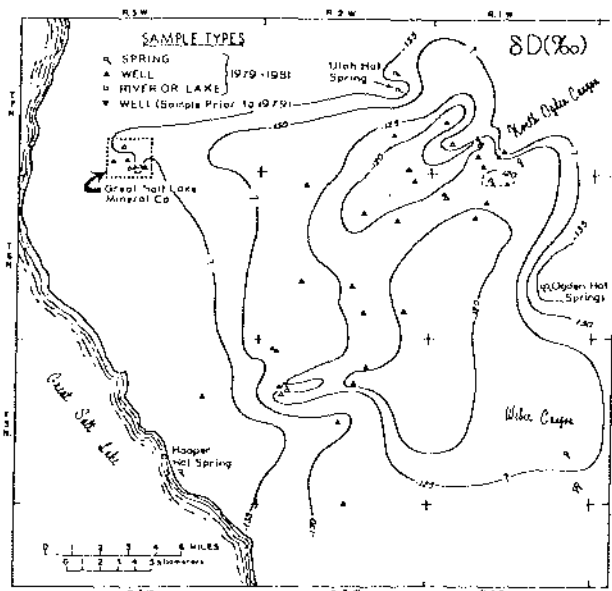


Figure 5. δD distribution in the East Shore waters.

ORIGIN OF ISOTOPIC AND CHEMICAL VARIABILITY

Based on the observations of fluid types, element distributions, surface and subsurface temperatures, and oxygen and hydrogen isotopic compositions, a model of fluid path lines from source region to spring and well locations can be proposed. This model assumes that the source of the thermal energy present in the hot spring waters is from a normal geothermal gradient. Thermal gradient data from the Hill Air Force Base located in the southeast portion of the East Shore Area (Glenn et al., 1980) support this assumption.

Water emerging at the mouth of North Ogden and Weber Canyons and along the Wasatch Front is a Ca+Mg and HCO_3+CO_2 -enriched meteoric fluid with δD and $\delta^{18}\text{O}$ values typically ranging from -110 to -125‰ and -17 to -15‰ , respectively. This relatively cool water ($<20^\circ\text{C}$) is diverted in several directions as it moves into the deltaic-alluvial sediments of the valley and forms most of the shallow subsurface aquifer water found in the area. Some of this water, which originates probably at lower elevations in the Wasatch Mountains to the east, has undergone evaporation (see Fig. 4).

The fluids that emerge as hot or warm springs and wells are derived from higher elevations as suggested by the depleted δD values (-140 to -125‰). Of the fluid that infiltrates to depth

in the mountains, a portion is heated to temperatures no higher than about 125°C and is enriched in Na+K and Cl during rock-water interactions, before returning to the surface along faults (e.g. Ogden hot springs). A fraction of this fluid may continue to circulate to greater depths and subsequently migrates westward along the base of the graben fill or in the bedrock. Seismic interpretations by Glenn et al. (1980) indicate that the bedrock terrain beneath the valley contains overthrust structures that may be a factor in controlling horizontal permeability. This fluid returns to the surface along a steeply dipping fault that demarcates the western edge of the basin near the shore of the Great Salt Lake (e.g. Hooper hot springs).

In all cases, hot spring fluids exhibit characteristic $\delta^{18}\text{O}$ shifts similar to those observed in many other hot springs around the world (Craig, 1963) indicating oxygen isotopic exchange due to rock-water interaction at depth. Preliminary mineral equilibria calculations suggest that the hot spring fluids from the East Shore Area have equilibrated with Ca and Mg montmorillonite, kaolinite, calcite, and chalcedony (Cole, in press). Alteration of feldspar and other detrital minerals to this assemblage has probably resulted in the observed $\delta^{18}\text{O}$ shifts.

Zones of thermal and ground-water mixing are inferred for areas west of Ogden hot springs where a large Cl plume is observed, and northeast of Hooper Hot Spring where well waters exhibit slightly anomalous δD values. These phenomenon may be the result of leakage of thermal waters into the overlying cooler aquifers. Further sampling and isotopic measurements are needed to substantiate this contention.

CONCLUSIONS

Geochemical studies of hot springs and ground waters in the East Shore Area, Utah reveal complex distributions of major ion concentrations, δD and $\delta^{18}\text{O}$. The data presented suggest the presence of two very different hydrologic regimes. One involves deep, fault-controlled circulation of waters derived from high elevations in the mountains to the east of the study area. These waters ultimately evolve into the hot spring fluids present in the area (Hooper, Ogden, Utah). The δD values of these fluids appear to remain unchanged even after transport along deep structures, west across the valley. Oxygen isotopic compositions, however, have undergone considerable alteration as the result of rock-water interaction at elevated temperatures (80° to 125°C).

A second hydrologic regime consists of surface runoff from lower elevations that infiltrates into shallow detrital sediments. This fluid makes up the bulk of the area's ground-water supply. Interaction between these two regimes occurs on a local scale in the vicinity of the hot springs, but by be more widespread such as in areas west of Ogden hot springs and northeast of Hooper Hot Springs.

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