Chemistry, origin, and potential of geothermal resources of southwestern New Mexico and southeastern Arizona

Chandler A. Swanberg, 1978, pp. 349-351

in:

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INTRODUCTION
The author has visited nearly all of the hot springs in Arizona and New Mexico, recorded the temperature and collected samples for chemical analysis. In addition, the chemistry of several thousand non-thermal ground waters have been used to establish background chemistry for comparison against thermal water chemistry. Standard methods of quantitative and qualitative geothermometry (see Truesdell, 1975 for a summary of techniques) have been applied to all waters and the resulting geotemperatures used to predict the subsurface temperature anticipated for each geothermal prospect area. The most promising geothermal areas are designated in Figure 1. Table 1 contains the chemistry of selected thermal waters from southwestern New Mexico and southeastern Arizona.

On the basis of chemical geothermometry, there appear to be 10 to 20 geothermal prospect areas in southwestern New Mexico and southeastern Arizona.
Mexico and southeastern Arizona whose reservoir base-
temperature approaches the 150°C minimum for economic
generation of electricity. The most promising of these prospect
areas are either associated with Quaternary volcanic rocks or
are located along the margins of the deepest sedimentary
basins. The thermal waters tend to be slightly saline
(1000–3000 mg/k) and enriched in silica and fluoride. The
numerous hot spring areas in the Gila National Forest of
southwestern New Mexico do not appear to have a sufficiently
high reservoir base temperature for electricity generation.
However, the low salinity (<500 mg/Q) and high surface-
discharge temperature (up to 75°C) of these hot springs make
them ideal for non-electric applications.

GEOTHERMOMETRY TECHNIQUES

The concept of chemical geothermometry is that the chem-
istry of geothermal fluids is controlled by temperature-
dependent water-rock reactions within the geothermal reser-
voir and that the water chemistry does not change appreciably
as the water migrates from the geothermal reservoir to the
surface sampling point. The validity of these assumptions is
examined by Truesdell (1975).

The silica geothermometer of Fournier and Ro-
we (1966) can be quantitatively expressed according to the equation of
Truesdell (1975)

\[
T_{SiO_2} = \frac{1345}{5.205 - \log_{10} (Na/K)_{SiO_2}} - 273.15
\]

where \(T_{SiO_2}\) is the silica geotemperature in degrees Celsius, Na, and K are expressed in molar concentrations, and the value of \(f\) is determined by the following tests:

\[
\beta = 4/8 \text{ for } \alpha/Na > 1 \text{ and } T_{NaKCa}((3=4/3) < 100 \degree C
\]

\[
\beta = 1/3 \text{ for } Ca/Na < 1 \text{ or } T_{NaKCa}((3=4/3) > 100 \degree C.
\]

The normal distribution of geotemperatures calculated by
applying equations 1 and 2 to groundwaters of the Basin and
Range province is given in Figures 2 and 3. The geotempera-
tures obtained by applying equations 1 and 2 to selected ther-
mal waters from Arizona and New Mexico are given in Table 1.

Discussion

The most promising geothermal prospect areas on the basis
of chemical geothermometry are shown in Figure 1. Many of
these prospects are located along the flanks of the deep sed-
imentary basins of the Rio Grande rift, an association which
implies a tectonic origin for these thermal waters. These waters
have apparently originated deep within the basin, where they
have been heated by the normal geothermal gradient, and then
migrated to the surface along basin-bounding faults. If this is
the case, the waters may have traveled a considerable lateral
distance en route to the surface so that the locations given in
Table 1 and shown in Figure 1 may not accurately represent
the location of the subsurface geothermal area.

There are at least ten separate localities in the Rio Grande
rift of southern New Mexico where geothermal waters leak to
the surface, most of which are not designated individually in
Figure 1. An additional four areas in west Texas are also

\[
T_{NaKCa} = \frac{15447}{\log_{10} (Na/K)_{Na} + f \log_{10} (Ca/K)_{Na}} - 273.15
\]
shown to emphasize the association with deep sedimentary basins and active faults but are not treated further. These waters are characterized by NaKCa geotemperatures in the 150-200°C range and silica geotemperatures ranging from 80-120°C. The silica data do not appear to reveal much geothermal potential until it is realized that these waters have low silica because they have ascended through a very thick pile (see fig. 1) of sediments saturated by the silica deficient waters of the Rio Grande. Application of mixing models to the Radium Springs data brings the silica geotemperature into agreement with the NaKCa geotemperatures. Thus most thermal areas of the Rio Grande rift are likely to have a reservoir base temperature near or in excess of the 150°C minimum for economic generation of electricity.

A second group of thermal waters worth special mention are those located in the Gila area just west of the Rio Grande rift in southwestern New Mexico. Chemical analyses for several of the hottest springs are presented in Table 1 but are omitted from Figure 1, as their NaKCa and silica temperatures are not sufficiently above regional background (fig. 2, 3; see also Swanberg and Alexander, in press) to suggest the presence of a buried geothermal resource. However, these springs have a high surface-discharge temperature (up to 75°C), very low amounts of dissolved solids (<500 mg/k) and are quite numerous; the Gila area is therefore ideal for non-electric applications of geothermal energy.

Two exceptions to the above generalizations are the Lower Frisco hot springs and the Clifton Known Geothermal Resource Areas (KGRA), located on either side of the New Mexico-Arizona border at about latitude 33°N. Both areas appear to have subsurface temperatures of about 150°C (Table 1).

A final feature of geothermal resources in southwestern New Mexico and southeastern Arizona is the presence of very promising geothermal prospects associated with Quaternary volcanic centers (fig. 1). Examples include Kilbourne Hole, New Mexico; east of Douglas, Arizona; and although it is not included in Figure 1, the Springerville area of Arizona. All of these areas are characterized by sodium bicarbonate water, and NaKCa and silica geotemperatures near 150°C.

ACKNOWLEDGMENTS

I would like to thank the water resources division of the U.S. Geological Survey for making available the WATSTORE file. Chemical analyses were performed by Mr. Andrew Bristol and his staff at the Soil and Water Testing Laboratory Department of Agronomy at New Mexico State University. The work was partially funded by State of New Mexico Energy Institute grant ERB 75-117 and U.S. Geological Survey grant 14-08-0001-G-348.

REFERENCES


