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Geothermal Ground Water in Central Texas

A Potential Energy Resource

C. M. Woodruff, Jr.

Several deep aquifers beneath Central Texas supply low-temperature (up to about 150°F) potable geothermal ground waters. Heretofore, the heat from these waters has been considered a nuisance and, except historically in a few health spas, has not been used. Nevertheless, local municipal and domestic consumption of warm gound water is at such high rates that, if heat-exchange systems were employed, the warm water could supply energy for space heating and water heating. Such use would defray part of the expenditures normally applied to obtain fossil fuels, and the savings might be considerable. For example, during an average January, the Btus from a single municipal water well at Taylor have a potential value of more than $25,000. Because of this possible value, projects to tap this low-temperature geothermal resource are under way at the Torbett-Hutchings-Smith Memorial Hospital in Marlin and at Navarro Junior College in Corsicana.

In Marlin a test well has been completed to a depth of 3,885 feet and, during initial tests, has yielded 300 gallons a minute of 150°F water. This geothermal water will ultimately be produced at a rate of 200 gallons a minute, and a heat-exchange system will be used in supplying space heating and hot water for the Torbett-Hutchings-Smith Memorial Hospital. This test well is funded mainly by the U.S. Department of Energy, with supplementary funding by the Texas Energy Development Fund, the city of Marlin, the hospital, and Central Texas Savings and Loan Co. of Marlin. The Department of Energy appointed J. D. Norris, Jr., T-H-S hospital administrator, as project director for the drilling of the well. The energy obtained from the geothermal waters may reduce by 85 percent the hospital's yearly consumption of natural gas—a savings of approximately 10.2 million cubic feet of gas a year.

The occurrence of warm mineral waters beneath Marlin is no surprise to most people there; for almost ninety years these waters have supplied health spas and resorts, which made Marlin a major medical treatment center before the discovery of penicillin, sulfa drugs, and the Salk vaccine.

This warm water resource is not unique to Marlin; it occurs at various localities along a belt that bisects the central part of Texas from the Rio Grande to the Red River (figure 1-A). Along this belt a convergence of geologic processes has affected conditions of land and water over an enormous amount of time (see box). Moreover, there has been a pronounced human response to the geologic and geographic features of this belt. Fertile soils support intensive agricultural use of the land along this trend, and the area is the site of several Texas cities, including Dallas, San Antonio, Austin, and Waco. Consequently, major industrial and institutional facilities, which consume large amounts of energy, are located within this belt (figure 1-B).

The Fall Line

A similar geologic and geographic trend extends beyond Texas through Mississippi, Alabama, and Georgia and as far north as New Jersey. This larger trend delineates the boundary between continental uplands that are generally resistant to erosion and the more erodible younger coastal plains. In the eastern and southeastern United States, this geologic boundary is termed the *fall line*, because of the waterfalls that occur where rivers flowing toward the coast cross abrupt changes in bedrock. This line marks the upstream extent of navigation on many major rivers, and the waterfalls afforded early sources of power. Hence, mill towns and centers of commerce—including Washington, D.C.; Richmond, Virginia; Raleigh, North Carolina; Columbia, South Carolina; Augusta, Macon, and Columbus, Georgia; and Little Rock, Arkansas—developed along the fall line.

Hot wells and springs that probably indicate areas of high heat and that flow from deep within the earth, major earthquake zones, and mineral deposits formed by the circulation of hot waters occur along this larger trend. The fact that numerous cities occur along or near this trend enhances the potential for using this low-grade energy resource. There is a ready market for the hot water that may

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occur at depths along this geologic trend; however, the quality and quantity of the warm water have not been systematically evaluated outside of Texas.

Prospects for Geothermal Energy in Texas

In Texas, warm water is already being used for domestic, municipal, and industrial needs. Several aquifers along the inner part of the Gulf Coastal Plain produce warm water from their deeper reaches, and in many areas these waters constitute the only available drinking supply (figure 1-A). The water is often purposely cooled before use; yet most homes that use water drawn from deep geothermal reaches of the various aquifers still have gas-fired water heaters. Simple plumbing modifications might allow families to tap the hot ground water directly, circumventing the need for water heaters. Monetary savings from such a modification would be considerable, since approximately 40 percent of domestic energy consumption is for heating water.

Several constraints might prevent the use of geothermal waters as a source of either space heat or hot water. Adverse chemical quality is one problem; it affects the potability of the water and, because of metal corrosion or scale

Geologic Setting

Warm ground waters beneath Marlin are obtained from the lowermost parts of the Trinity Sands, an aquifer (water-bearing stratum) that provides ground water for domestic, municipal, and industrial use throughout much of Central and North Central Texas. The Trinity Sands occur at the ground surface along the western Cross Timbers, which extends from the Colorado River north into Oklahoma (figure 2-A). From this outcrop area, the sand strata dip beneath the earth's surface toward the Gulf Coast. Part of the rain that falls on the sand formations percolates into the ground between sand grains and replenishes the ground water in the aquifer (figure 2-B). The ground water is moved within the aquifer by the prevailing pressure gradient. Water movement in the shallow subsurface is generally downward under the force of gravity. In the deeper reaches, however, fluids rise under pressure, and this upward flow results in artesian conditions.

Near the outcrop area, subsurface waters are generally of moderate temperature, but as the ground water slowly moves deeper the water gradually becomes warmer because of the heat generated inside the earth. With increasing depth and temperature, the concentration of dissolved salts within the water also generally increases, and a decrease in the porosity and permeability of the strata affects the well yield.

The increase in temperature with increasing depth, termed *geothermal gradient*, generally ranges from 1.5°F to 2.0°F for each 100 feet. Water entering the aquifer at an initial temperature of 69°F will thus attain a temperature of between 126°F and 145°F at a depth of 3,800 feet. The deviation of the actual temperature of water obtained at Marlin from the expected values indicates that additional factors may contribute to these ground water temperatures.

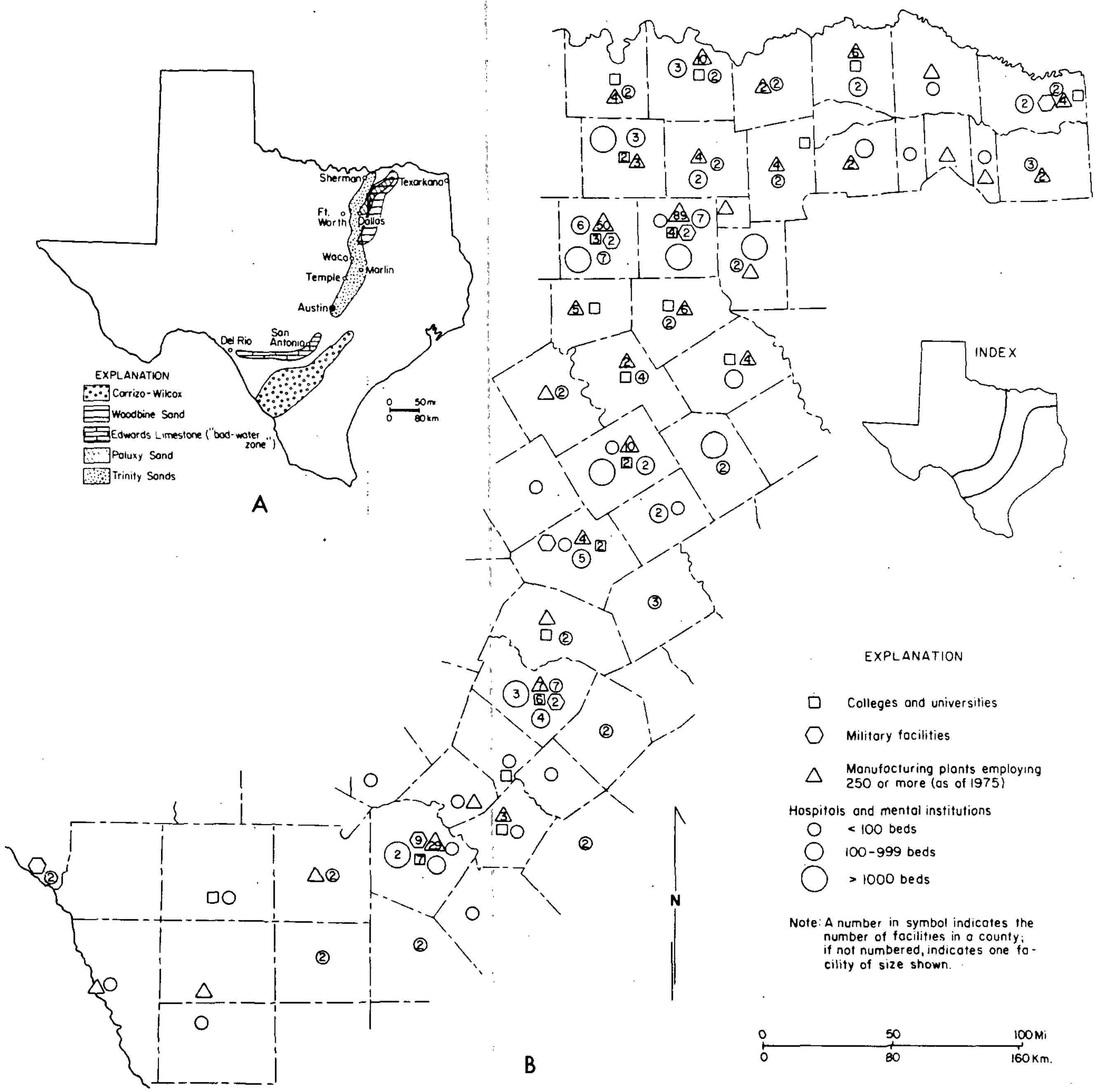
In fact, there are anomalously high geothermal gradients in the region, and geologic factors probably control this phenomenon. The geothermal anomalies may be explained by the fact that a major geologic hinge zone transects Central Texas (figure 2). This hinge zone marks the boundary between the stable continental part of the earth's crust and the downwarped Gulf Coast Basin. There have been repeated major geologic events along this zone; a mountain range was formed and subsided there; North America and Central or South America were probably once joined along this zone but subsequently drifted apart to form the Gulf of Mexico; during several episodes of geologic time major rivers fed deltas along ancient coastlines defined by this trend; volcanoes erupted there; and movement occurred along major fault systems. Today, geologic processes continue to be active as is shown by the high geothermal gradients, locally hot ground waters, local adjustments across faults, the presence of oil and gas fields, and the ongoing deposition of potentially valuable minerals.

The Central Texas hinge zone is delineated at the earth's surface by the Balcones and Luling-Mexia-Talco fault systems and, at depths, by the buried Ouachita Mountains. At one time the Ouachita Mountains stood tall across Texas, but millions of years ago rifting that formed the ancestral Gulf of Mexico subjected this part of the earth's crust to extraordinary stresses. Because of these crustal stresses, North America, South America, and Africa drifted apart, and the Ouachita Mountains sank beneath the Gulf of Mexico. Subsequent tensional forces resulted in the breakage and displacement of overlying strata; fault zones were formed that are noted today by the landscape changes between the Hill Country uplands and the low-relief Coastal Plains.

A correct interpretation of these past geologic events offers an understanding of the high geothermal gradients and, thus, of the warm waters of the region. With a correct interpretation, geologists can more precisely predict where the warm waters will most likely occur and what their attributes will be. Ground water along the Balcones-Ouachita structural belt apparently acts as a natural heat-transfer and heat-storage medium. Two hypotheses are offered to explain this fact. One is that rain water may circulate to great depths along faults, absorb heat, and eventually rise under artesian pressures—essentially what happens at Hot Springs, Arkansas. It is notable that the buried Ouachita rocks beneath Central Texas are of the same geologic origin, structural configuration, and age as those at Hot Springs. The second hypothesis that may explain anomalous increases in water temperature involves an upwelling of deep-seated fluids from either the Ouachita trend or from deep within the Gulf Coast Basin. Upwelling hot brines are, in fact, commonly associated with rift zones, such as the Salton Sea in California or along the Rio Grande in New Mexico. Hence, the geothermal province in Central Texas may be a buried analogue of the hydrologic conditions at Hot Springs, Arkansas, or it may be analogous to the Salton Sea, with anomalous geothermal conditions persisting along the ancient Central Texas rift zone.

Figure 1

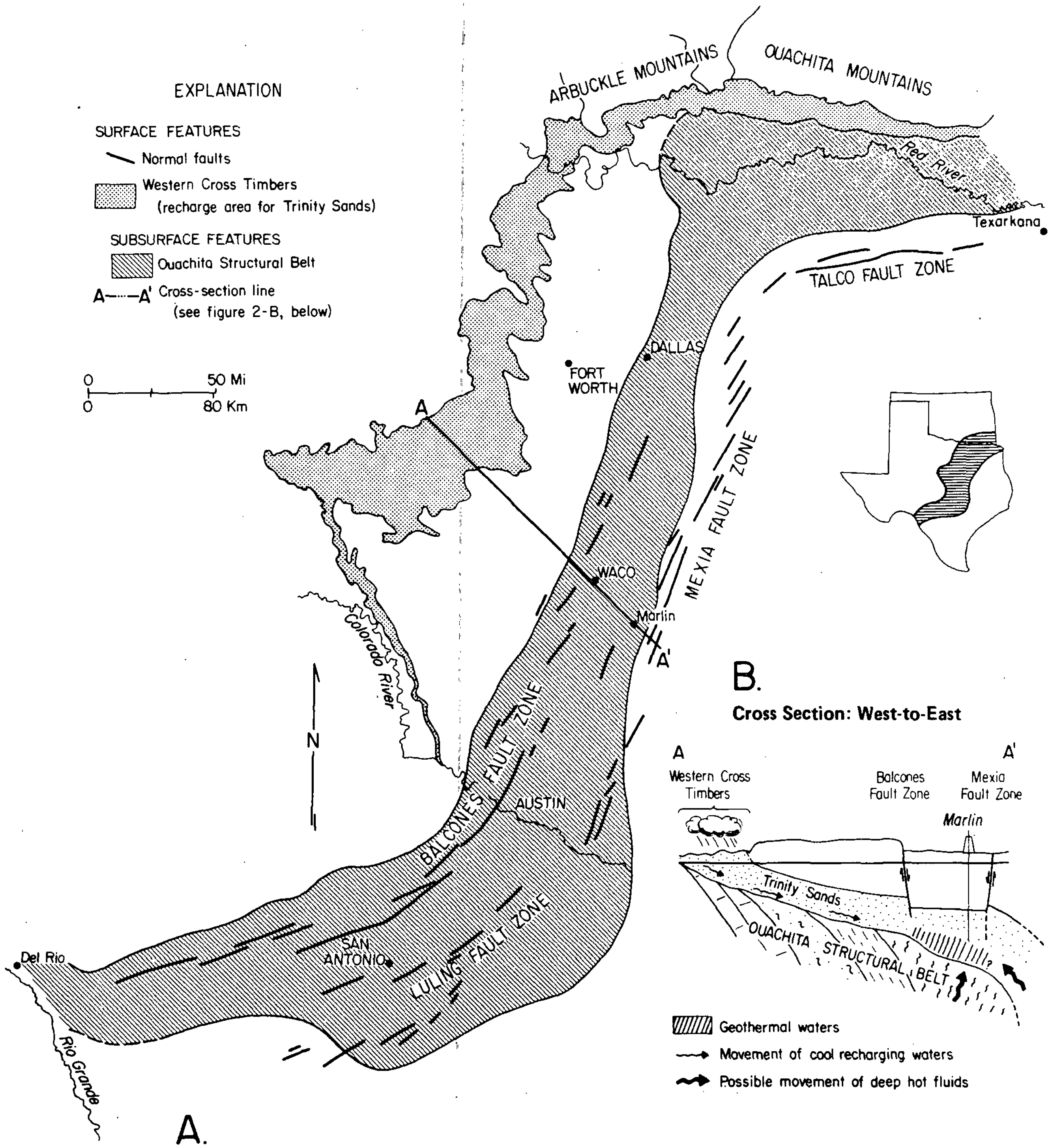
Geothermal Resources and Major Facilities in Central Texas



Source: Modified from Stanley A. Arbingast et al., *Atlas of Texas* (Austin: Bureau of Business Research, 1976), p. 179.

Figure 2

Major Physiographic and Structural Features of Region



Source: Modified from Peter T. Flawn et al., *The Ouachita System* (Austin: University of Texas Publication 6120, 1961), p. 401.

problems with pipes, may effectively preclude the use of heat-exchange systems. Moreover, careful attention must be given to what is a safe pumping rate so that the warm water supply is not depleted. Both water quality and well yield may pose severe limits, because in deeper parts of aquifers there will probably be a consistent trend of increased water temperature, increased dissolved solids content, and decreased well yield. Areas of optimum geothermal potential, however, have been identified for some aquifers. In these areas, water temperatures are anomalously high, yet dissolved solids are in a low to moderate concentration (figure 3).

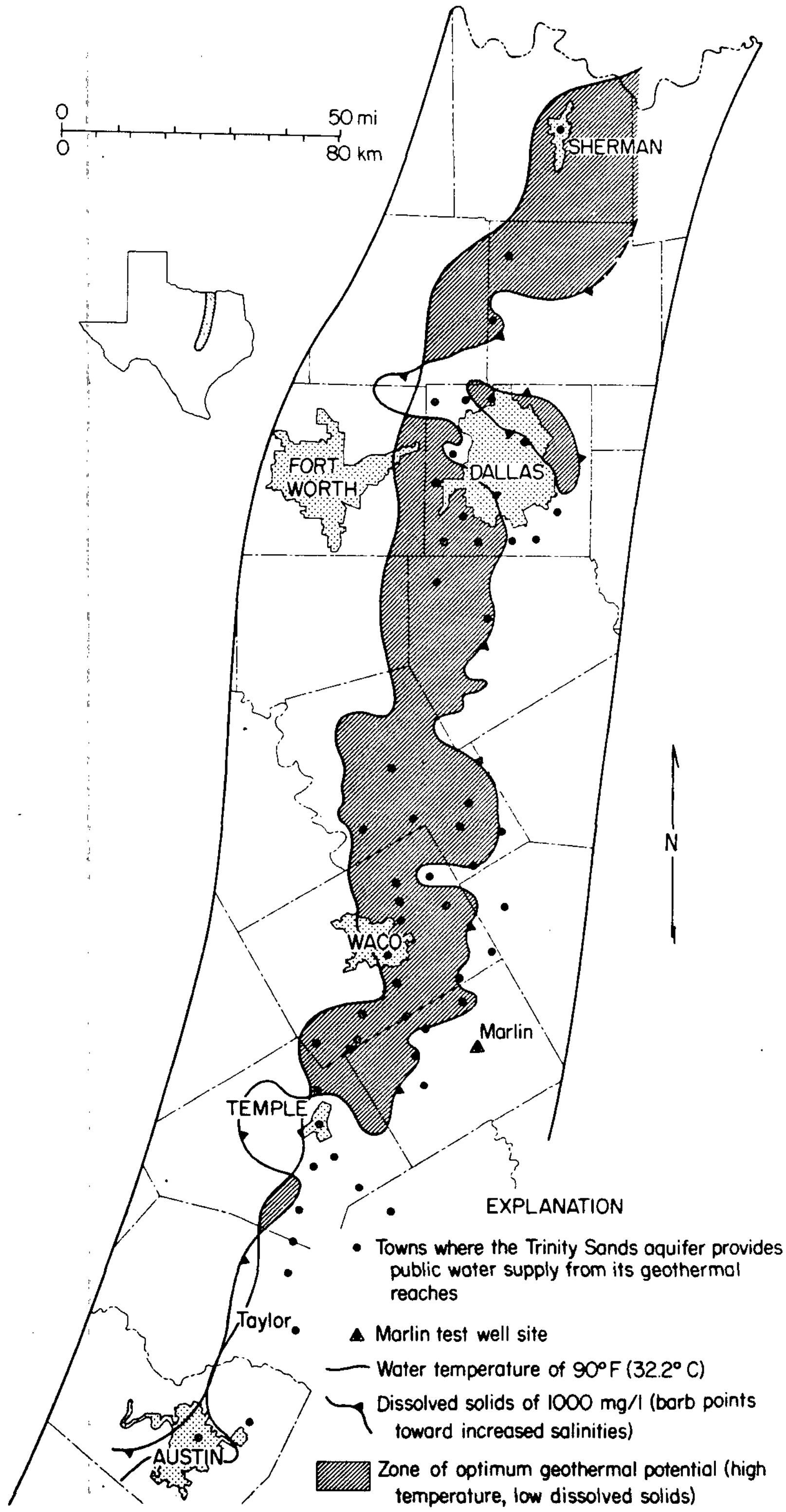
Despite the various limitations, towns and homes that already pump the warm waters are currently wasting an energy resource. Municipalities could designate a recipient (a local school, for example) and install the necessary heat-exchange mechanisms to extract some of this energy before the water goes into the town's distribution system. The initial costs may be considerable, but the ultimate benefit will be a decreased use of fossil fuel at a time when traditional fuels are becoming progressively more expensive.

An example of the heat value of these waters is seen in the average rates of groundwater withdrawal during January from a single municipal well at Taylor. There, an average of 31.5 million gallons of water at a temperature of 116°F is pumped from a depth of 88 feet (the water rises under artesian pressure to this level). This warm water has a heat content of 2.07×10^{10} Btu with a value of more than $25,000, assuming that the heat-exchange system will be 50 percent efficient (an expected efficiency according to Marshall Conover of Radian Corp. of Austin). This dollar value represents the savings for the entire town for an average January, and many towns and homes are already using such water as a potable supply all year. Every Btu not obtained from fossil fuels is money saved and will be increasingly valuable in the future.

A project funded by the Department of Energy is under way at the Bureau of Economic Geology of the University of Texas at Austin and will evaluate the potential safe withdrawal rates for the most promising geothermal aquifers along the Balcones and Luling-Mexia-Talco fault zones. Further regional studies are designed to assess temperature data from deep aquifers throughout Texas to delineate other geothermal sources that have not been recognized before.

Figure 3

Geothermal Potential of Trinity Sands Aquifer



Department of Energy
Washington, D.C. 20585

DEC 5 1979

Mr. David White
Texas Energy and Natural Resources
Advisory Council
800 Executive Office Building
411 West 13th Street
Austin, Texas 78701

Dear David:

I am concerned about the DOE/TENRAC funded program to be conducted by Professor Roy of the University of Texas - El Paso. This concern results from the series of meetings between Duncan Foley and myself with Professor Roy, yourself and the Bureau of Economic Geology geothermal team on November 19, 20 and 21. As a result of these meetings, I believe that the program in West Texas needs redirection. Let me outline the sequence of events that leads me to make such a conclusion.

On November 19 we (D. Foley and G. Brophy) met with Rob Roy in El Paso. At that meeting we pointed out the need for additional geophysics and geology to be done in the Hueco Tanks area, the need to intersect the groundwater table and the need to collect water samples for analysis. I came away with the feeling that Professor Roy is primarily interested in gathering heat flow data over as broad an area as possible, using shallow slim holes from which water sampling would not be possible. It was, to say the least, not a productive meeting.

On November 20 we met with Charles Woodruff of the Bureau to review his program, and then later that morning with you. In the afternoon we (D. Foley and G. Brophy) met with Cris Henry and others to discuss his role in the West Texas program. It was during that meeting that we learned of some additional information concerning the Hueco Tanks area which radically changes the direction that future geothermal exploration should follow.

Cris Henry reported that numerous wells had been drilled by the U.S. Army in the Hueco-Tularosa Bolson, that these wells penetrated into the groundwater zone, that they were drilled within six miles of the Texas-New Mexico border (one right at the border), and several were reported to have abnormally high water temperatures (50°C to 71°C) at depths around 400 to 450 feet. This information comes from the following publication:

McLean, J.S.: Saline Groundwater Resources of the Tularosa Basin, New Mexico; Office of Saline Water, Department of the Interior; Research and Development Progress Report 561

In addition, some information is available from the U.S.G.S. Water Supply Paper 1426. I must admit my chagrin that Professor Roy either did not have the above information or chose to ignore it. In a report to TEAC dated October, 1979, Roy and Taylor use silica geothermometer data from J.M. Hoffer on a map (Fig 2), but do not give any data points. We querried Roy about this and he said he had never seen any locations, even though Hoffer is a colleague at El Paso and should have been asked for that information. We believe that Hoffer must have known of the McLean paper and the U.S.G.S.-WSP 1426, which both contain water analyses from which the geothermometry information could be calculated. What I am saying here is that Roy and his associates apparently did not undertake a thorough literature search before submitting their proposal through your office to us.

The Division of Geothermal Energy (DGE) and your office are seeking alternate energy resources through expeditious exploration program. The program as proposed by Roy does not, in light of the above additional information, meet the program needs of DOE/DGE. I therefore recommend the following:

1. The UTEP team contact the U.S.G.S. El Paso office to find what information they have available (they obviously have not done so as yet) and conduct an exhaustive literature search.

2. Contact the appropriate officer at Fort Bliss to ascertain what information might be available from DOD.

3. Detailed geologic mapping and additional geophysical surveying be completed <u>before</u> any drilling program is initiated.

4. Boreholes be of sufficient depth and diameter to permit water sampling. The well driller should be querried concerning these requirements.

If you agree to the above, and any contract modification is necessary, please contact the Contracting Officer at Idaho Falls.

If Professor Roy is unwilling or unable to conduct such an exploration program in an expeditious manner then I recommend that another group be approached to conduct this effort.

Sincerely,

Jerry

Gerald P. Brophy
Division of Geothermal Energy

cc:
M. Wright, UURI ✓
D. Foley, UURI
C. Nichols, IDO
R. Mink, IDO
R. Gray, HQ