# DISTRICT HEATING ON THE HIGH PLAINS OF PAQUIMÉ

**Susan F. Hodgson**
**California Department of Conservation**
**Division of Oil, Gas, and Geothermal Resources**

## INTRODUCTION

For a brief 56 years, around 1205 to 1261 A.D., Paquimé, Mexico (also called las Ruinas Casas Grandes) was in its prime, a city about 280 km northwest of Chihuahua in a basin on the vast high plains of northern Mexico. Paquimé relied upon many innovative hydrological systems—perhaps including a geothermal district heating system begun around 1060 A.D. If this proves true, the Paquimian system is the oldest geothermal district heating system in the world.

How the city came to be as it was—and why its golden era was so brief—are integral parts of a complex hydrological story that includes geology and cultural history.

## GEOLOGY

As late as Eocene time, northern Mexico was cut by the Laramide orogeny. Large fault blocks of Mesozoic and Paleozoic rock—including rugged volcanics—became mountain ranges stretching northwest-southeast, usually between 1,000 and 2,000 meters above sea level, their bases hidden in basins of Cenezoic sediment where hot springs sometimes bubbled up.

The parallel pattern of basins and ranges formed a great corridor, a north-south frontier passage where animals and humanity ebbed, flowed, and intermingled through millennia, including mankind who arrived about 10,000 B.C. in the shadow of Pleistocene megafauna.

## CULTURAL HISTORY

Paquimé, Mexico, is near the center of what is called the Casas Grandes Archaeological Zone in northern Mexico and the southwestern United States (Figure 1). Vast and inexact, the zone equals about 170,521,470 sq km.

The zone was populated by Chichimecans, rugged individualists from all accounts. They included several mixtures of Mexican peoples, depending on the chronicler, so the exact composition is unsure. The Chichimecans lived in small hunting groups for hundreds of years longer than their southern neighbors, unable to risk agrarian communal living without irrigation in a climate such as theirs.

The great art and urban architectural traditions of Mesoamerica, including skills such as irrigation, evolved in the highly organized, agrarian cultures in southern Mexico, where between 1900 and 1500 B.C., people became full-time agriculturists.

## PAQUIMÉ: THE BEGINNING

Chichimecans began living together at the site we call Paquimé between 700 A.D. (±50 years) and 1060 A.D. (Figure 2). This may have been inspired by contacts with


***Figure 1.*** ***Paquimé, Mexico, at the center of the Casas Grandes Archaeological Zone (after Di Peso, 1974a).***

southern merchants, for by now long trading caravans moved throughout southern Mexico and then northward, exchanging products and ideas. Highly civilized southern Mexico had reached its *Classic Period*. In general, this was a time of change in both southern and northern Mexico—destruction of civilizations and power shifts in the south and growth of communities in the north. Gradually life in Paquimé altered, and architecture and artifacts became more complex. By the mid-11$^{th}$ century, the dominion of Paquimé had grown to include over 220,150 sq km of land and several thousand satellite or culturally associated villages.

These socio-cultural interrelationships were created and nurtured by southern merchants based on their own direct economic ties to one or more older southern cities. The merchants, called *puchtecas*, were commoners—chosen as advisors and war captains to kings, merging military and trading activities in southern Mesoamerican society. A merchant in a frontier post was under the direct control of a home merchant with military, religious, and mercantile responsibilities. The *puchtecas* provided information about new areas, new customs, and trails and raw materials. They negotiated trade treaties and guided conquering armies.

Archaeologists assume *puchtecas* came to Paquimé from a relatively complex hydrological culture (or cultures) in Mesoamerica. The first sent were—naturally—in disguise to gather data about the town. Turning Paquimé into a major trading center was a major undertaking, and *puchtecas* carefully calculated risks and benefits. They considered the amount of exploitable raw materials available; the hydrological potential—at least one major water source was


*Figure 2.* ***Paquimé, Mexico. The letter "A" is by the fork of the acequia madre and the acequia lateral 1, and "B" is by Reservoir 1. Compare the photo with Figure 6 to trace the paths of the acequias. Courtesy of The Amerind Foundation, Inc., Dragoon, Arizona.***

needed to feed a hydrological system; the climate—a complete plant growth cycle was critical; the acreage of fertile soil accessible to irrigation; and geography in terms of transportation. Paquimé was near the center of all the Chichimecans, on the southern edge of a turquoise-producing area and in an important north-south corridor with enough people to support economic growth. The *puchtecas* negotiated "rights-of-passage" treaties with enemies on all sides of the city, safely linking Paquimé to both the raw materials needed to make goods and the markets to sell them.

**PAQUIMÉ: ITS PRIME**

Under the helm of the *puchtecas*, Paquimé was rebuilt from the ground up. It became a dazzling planned, model city that reached a pinnacle of prosperity from 1205 to 1261 A.D. Influenced by its merchant "professional rulers," the city "…changed from a conglomerate of single-storied, ranch style house-clusters to a massive, multistoried, high-rise apartment house covering some 36 hectares (Figure 3). The former were either razed, remodeled, or abandoned; the earlier city water system was revamped to accommodate the remodeling; and the city planners surrounded this new housing complex with a ring of ceremonial structures including effigy mounds, ball courts, a market place, stately open plazas, and other specialized edifices. Obviously, the Paquimian authorities had not only the power to relocate the inhabitants, but control of the required labor and building materials to carry out this change" (Di Peso, 1974b).

***Figure 3.*** ***Looking eastward across a portion of the dwellings at Paquimé (the walls were once several stories high).***

In 1584, Obregón described Paquimé in its prime, writing, "…this large city…contains buildings that seemed to have been constructed by the ancient Romans. It is marvelous to look upon. There are many houses of great size, strength, and height. They are of six and seven stories, with towers and walls like fortresses for protection and defense against the enemies who undoubtedly used to make war on its inhabitants. The houses contain large and magnificent patios paved with enormous and beautiful stones resembling jasper. There were knife-shaped stones which supported the wonderful and big pillars of heavy timbers brought from far away. The walls of the houses were whitewashed and painted in many colors and shades with pictures of the building" (Hammond and Rey, 1928, *in* Di Peso, 1974a). The name "Paquimé" may come from the Náhuatl language: pa ("big"), ki ("house"), mé ("s").

Thousands of hours were probably spent rebuilding the city, cutting and transporting timbers and gathering construction mud and other supplies. Probably this fascinating architectural rebirth occurred only at Paquimé, not in surrounding areas. However, hundreds of mountain and valley satellite villages around Paquimé helped supply its needs, freeing Paquimians to create "…architectonics, ceramics, jewelry, and lithic [objects]" (Di Peso, 1974b). City life now meant exciting daily markets, busy workshops for pottery and other trading goods, ball games, and ceremonial pomp.

**PAQUIMÉ: THE FALL**

By the mid-13$^{th}$ century times had changed again, and in the city itself "…two and one-half generations sat idly by and watched the magnificent city of Paquimé fall into disrepair. Artisan-citizens continued to produce an abundance of marketable goods, but civil construction and public maintenance all but ceased. The populace crudely altered public and ceremonial areas into living quarters. The walls of the city crumbled and, apparently unconcerned, people laid rude ramps over the rubble to reach still usable upper rooms" (Di Peso, 1974b).

"The city water and reservoir system was no longer maintained, but left choked by debris and used as a burial area. More hopeless were the cistern drains, which emptied the enclosed plazas of rainwater. These, too, were permitted to go out of commission. The remaining population stole the capstones of the drains and buried their dead in them" (Di Peso, 1974b).

Were these last years ones of economic depression when export markets were lost? Were there natural calamities like earthquakes? Were Paquimians characteristically casting off social oppressors, retrenching to better survive (Di Peso, 1974b)? No one knows.

Whatever the cause, the bitter end for Paquimé came around 1340, when unknown enemies attacked the city. Igniting the first-floor master beams, they destroyed Paquimé, collapsing it upon itself like a house of cards. Hundreds were killed inside the houses and in the public areas. Objects on altars were defiled and thrown into the walk-in well, part of the abandoned city water system. Breeding macaws and turkeys were left to die in their pens and boxes. Only scavenging animals cleaned the slaughter. Through the years, earthquakes, desertion, and ruin have left Paquimé an abandoned, one-storied maze of brown adobe walls.

Some suggest the end was part of a chaotic and widespread frontier revolt against sophisticated Mesoamerican overlords and their practices, possibly triggered by a long drought (Di Peso, 1974b). In any event, the destruction coincided with the general collapse of established centers throughout the Gran Chichimeca.

## THE WATER SYSTEMS OF PAQUIMÉ

The city of Paquimé included two innovative water systems—both with multiple parts: one outside the city and one inside.

These systems supported a city built in reverse of most in southern Mesoamerica, which typically had ceremonial and public architecture at their centers and dwellings around the edges. The style chosen for Paquimé, with dwellings in the center and public and religious areas on the periphery, certainly maximized hydrological efficiency in dwelling areas.

That the city was torn down deliberately and rebuilt just before its prime explains a fundamental puzzle about the amazing water systems at Paquimé. Clearly, they were preplanned and in place before structures covering them were built. Yet, the systems themselves are so sophisticated, they came late in the culture.

### Outside the City: Surface Water- and Soil-Retention—Plus Irrigation

Paquimé, wrote Obregón in 1584, "… is located in some fertile and beautiful valleys surrounded by splendid and rich mountains and small mountain ridges. It is situated on the shores of the river. This is the most useful and beneficial of all the rivers we found in those provinces. It can readily and at little cost be utilized for irrigating the fertile shores" (Di Peso, et al., 1974).

On the slopes around Paquimé, *puchtecas* designed an elaborate, effective, surface water- and soil-retention system, finishing as an irrigation system. The public project enhanced, protected, and irrigated the land, especially the 750 to 800 sq km of deep, rich bottom lands in the lower Casas Grandes Valley, one of the finest valleys in the northern frontier" (Bartlett, 1854, *in* Di Peso, 1974b). An unforeseen benefit was increased agricultural land on the upper slopes because so much moisture and soil were retained there. Some 12,000 sq km of a dendritic hydrological system were involved, an area of 80,000 hectares once subject to violent runoffs from high mountain thunderstorms.

The system controlled "…every raindrop which fell upon the mountainous southern and western borders [of the city]" (E.L. Hewett, 1908, *in* Di Peso *et al.*, 1974 ). To do this, stones were arranged in linear borders, terraces, check dams, and grid borders (Figure 4) (Herold, 1965, *in* Di Peso *et al.*, 1974). Slope angles and erosive features determined placement. Some stones were piled in tiers and some aligned in single rows. The complex system, built as a unit, delivered clear water to irrigation canals that ran through fields in the rich lower valley—and to the river itself.

The interlocking system so safeguarded the rich valley-bottom farmlands from erosion and annual flooding that satellite farming villages were built there. Today, such a choice is out of the question for people living around Paquimé, as the entire water- and soil-retention system is in disrepair. Angle by angle and rock by rock, it was custom-made to the terrain. Each part depended on the rest, and once maintenance ended, the system failed.

### City Water and District Heating—the Oldest System in the World

The people who lived in Paquimé from about 700 A.D. (±50 years) to 1060 A.D. were first to collect domestic water from Ojo Vareleño, the nearby thermal spring. Archaeologists believe the first city water system channeling domestic water into Paquimian houses was built around 1060 A.D., and I believe the water warmed the rooms it flowed through, the world's first geothermal district heating system (Figure 5).

***Figure 5.*** ***Thermal domestic water flowed through this channel lined with flagstone-like rock in the dwelling area of Paquimé. The small pit has been identified as a tub for bathing. (Photo by Susan Hodgson)***

From 1205-1261 A.D., as *puchtecas* rebuilt and ran the city in its prime, the original city water system was expanded and improved—along with the *de facto* geothermal district heating system (Figures 6 and 7).

The district heating theory depends on the waters of Ojo Vareleño in the low-lying volcanic foothills of the Cerro Prieto Mountains. The spring is 3.65 km northwest and up slope of the northern edge of Paquimé, as measured from the fork of the *acequia madre*, the main water channel of the city system, and the *acequia lateral 1*, the first lateral channel. The fork is visible on all photos and maps of the site. The spring had a flow rate of 11,400 liters per minute in 1960 and is about 1501 m above mean sea level (Di Peso, 1974b).

In 1960, a concrete dam at the spring ran "…north-south across the mouth of the Ojo de Vareleño arroyo below the spring's source, forcing the water to rise to the level of the *acequia madre* outlet, located 1.75 m above and on the southern side of the Ojitos Arroyo. A similar contrivance, perhaps made of earth and destroyed by the modern dam, must have been used originally to perform this hydraulic action" (Di Peso, 1974b).

How hot was the water? Spring water temperatures, sometimes described in the literature as "hot" and sometimes as "warm," today are about 82°F. The water is no longer from

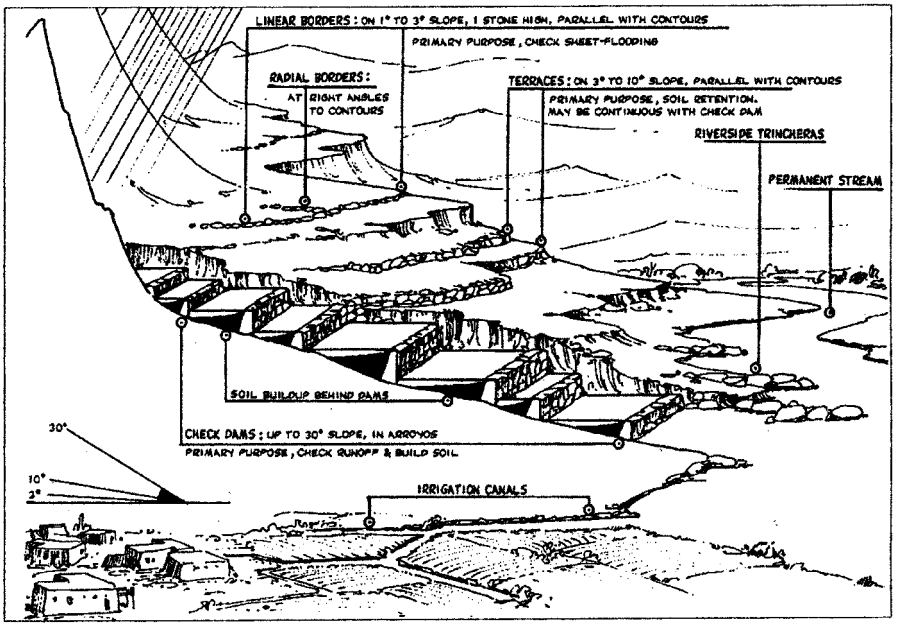


*Figure 4.* *Schematic view of the water-control and soil-retention system on the slopes around Paquimé, Mexico. Courtesy of The Amerind Foundation, Inc., Dragoon, Arizona.*

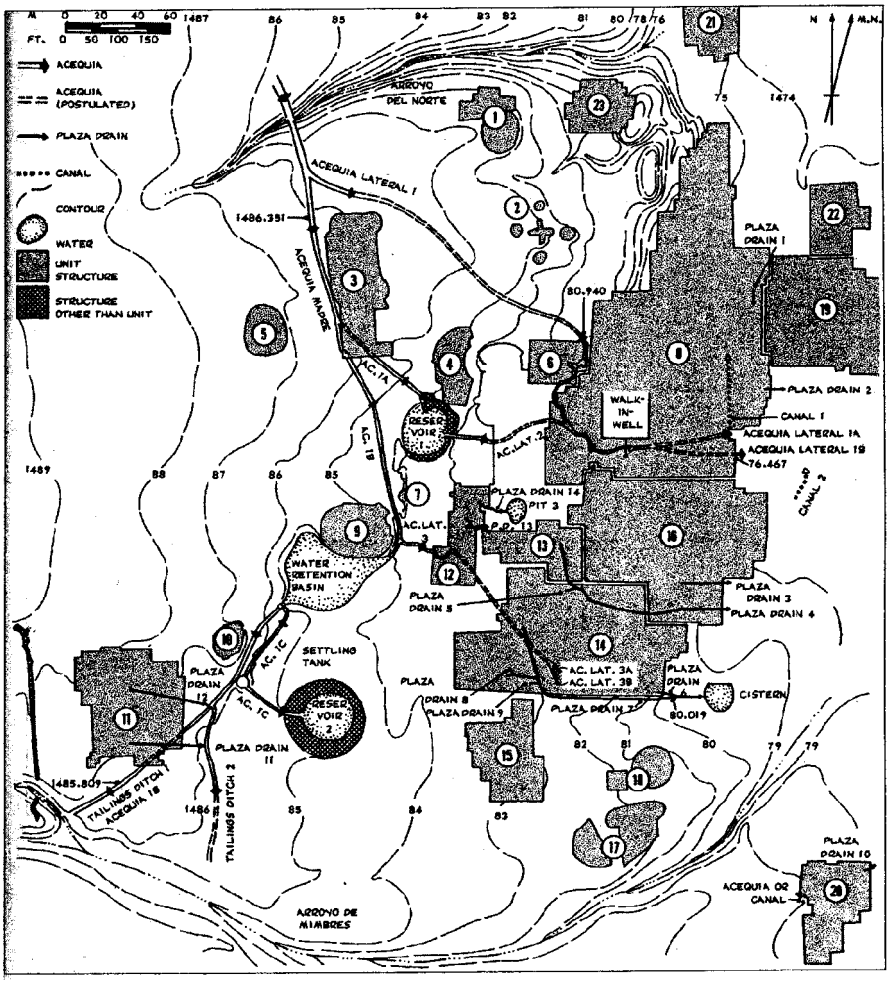


*Figure 6.* *Sketch of the city water system at Paquimé, Mexico. The domestic water flows from a hot/warm spring 3.65 km northwest of the fork at the upper left, where the acequia madre meets the acequia lateral 1. Water reaches the housing areas through the acequias laterales 1, 2 and 3. Courtesy of The Amerind Foundation, Inc., Dragoon, Arizona.*

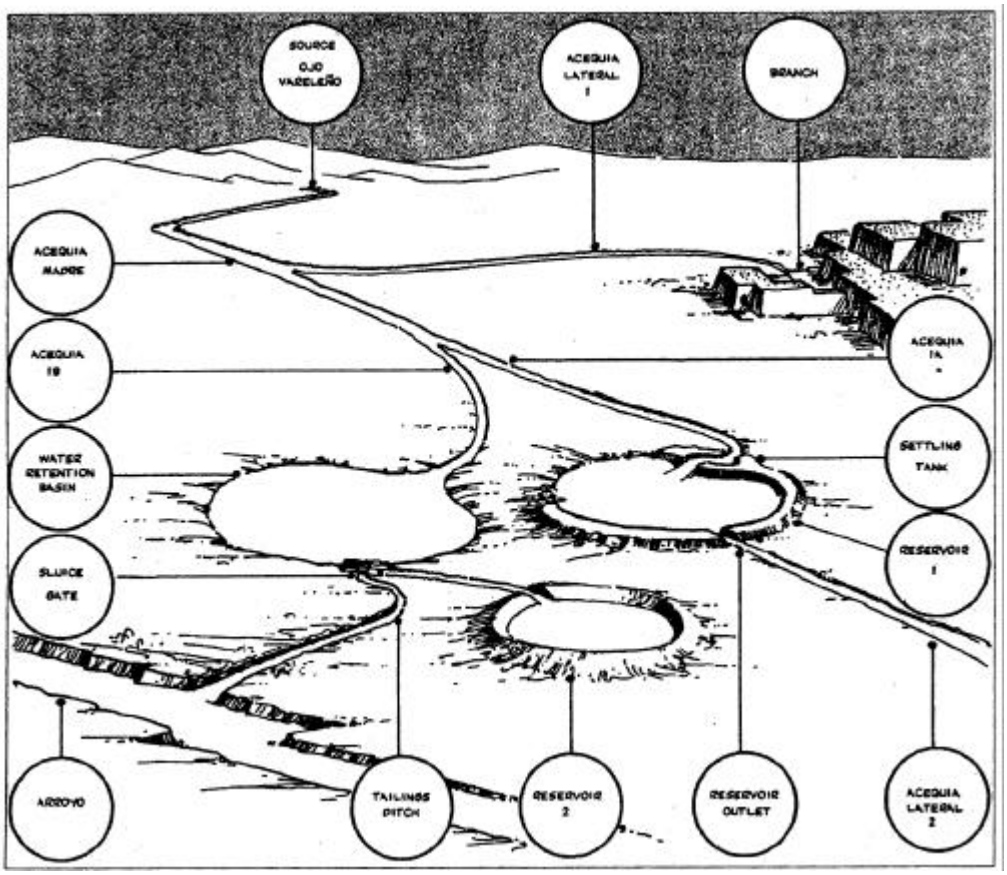


***Figure 7.*** ***Schematic view of the city water system at Paquimé, Mexico. Not all Figure 6 elements are included. Courtesy of The Amerind Foundation, Inc., Dragoon, Arizona.***

one large spring but from a cluster of smaller ones in the same area. Today, the water is collected, filtered and piped to nearby Viejo Casas Grandes, a town abuting the eastern edge of Paquimé. The thermal water is hot enough when it arrives here to make further heating unnecessary for much of the year. True, the thermal spring temperatures may have changed over the last 900 years or so, but experts say this is rare.

Stable isotopic analyses—or other geochemical tests run on spring water deposits on the rocks lining the *acequias* and channels at Paquimé—may tell us the water temperatures in the spring when the domestic water/district heating system was operating. Such analyses are made on sea shells to find the water temperatures of their natural habitats (Churchill, 2001).

At Paquimé, all the *acequias* were empty of water from about 1854 on in the literature I read. (A search of Spanish accounts from the end of the 1500s might prove otherwise for earlier times.) Much information about the *acequia madre* was noted by famed archaeologist Adolph Bandelier, who wrote in 1892, "The *acequia* is best preserved on the terrace northwest of the ruins. There its course is intercepted by gulches, and the section is therefore very plain. It seems that at a depth of about four feet below the present surface, a layer of calcareous concrete (caliche) formed the bottom of the shallow trough through which the water was conducted. It was carried on a steady and very gradual incline by means of artificial filling. The calcareous concrete forming the bed of the *acequia* may be artificial" (Di Peso, et al., 1974).

In 1890, Bandelier said portions of the *acequia madre* near the spring were 10 feet wide, and "...show traces of filling and of cutting. It is no longer the primitive method of slavishly following sinuosities of the ground in order to avoid obstacles. The ditch…runs almost straight…It rests on a bed of stones" (Di Peso, 1974b). Di Peso himself called the a*cequia madre* "stone- and adobe-lined" (1974b). The *acequia madre* was graded with a "delicate drop" of 0.4 cm per meter.

Water reaching the city flowed east from the *acequia madre* through three lateral *acequias* to various housing clusters, there passing into narrow channels incised in various ground-floor rooms (Di Peso, 1974b)(Figure 8). (Not all ground-floor rooms have channels and naturally none of the upper story rooms did.) In the Paquimé museum, an archaeologist showed an exhibit of a channel about 25-30 cm wide, made of flagstone-like rock on all four sides. All stones but those on top were cemented, possibly with caliche. If the water channels were like this and people inside rooms lifted loose stones at floor level to extract water for domestic use, I suggest they did so to adjust heat in these areas, as well.

***Figure 8.*** ***A channel for thermal domestic water cut in the floor in the dwelling area of Paquimé. The door at the top of the photo has the typical shape used in the city. Note the smaller door shape incised in the wall, photo right. (Photo by Susan Hodgson)***

This was possible because water flowing from the spring probably retained its heat for the distance to the dwellings. Hydrologists designing systems for Paquimé were too brilliant to have disregarded the heat, and a few heated rooms in the winter would be too welcomed to ignore. If this is true, Paquimé was the first city in the world to develop a geothermal district heating system.

New geologic and archaeological studies, combined with modern hydrological calculations, can help verify this. New measurements are needed of the flow rate; ancient and current spring temperatures; length of the *acequia madre* from the spring to the city; *acequia madre* width and gradation—a grade is given, but I don't know how much of the *acequia madre* was measured to find it; grades of the *acequias laterales* and channels in the rooms; and annual air tempera-tures at Paquimé. Other data may be necessary, as well.

The city water system included three more features attesting to the hydrological genius of the city builders. One was a sewer system and one an extensive plaza-drainage system, built to empty water from the completely enclosed plazas after torrential cloudbursts. Drainage systems are not unknown in ancient Mesoamerican and southwestern sites, but they are not common (Di Peso, et al., 1974).

The third was a "walk-in well," a large multistoried room built under Plaza 3. The only such structure in the Americas, the room is well shored and vented for good air circulation. Stairways wind down to the water table at the bottom—a second urban water supply completely apart from the *acequias*. Halfway down is a detour to a secret room, perhaps built for religious reasons.

## CONCLUSIONS

People with great hydrological imagination and skill developed the effective and innovative water systems at Paquimé. Outside the city, these included a surface water- and soil-retention system, and inside the city a "walk-in well" unique to the Americas and what may be the world's first geothermal district heating system.

At Paquimé, channeling thermal spring water for domestic use through dwelling floors meant channeling heat. Housing residents could get water and change the air temperature by adjusting rocks over the channels. Thus, the geothermal district heating system and the domestic water system may have worked together. New geological and archaeological studies may help prove this is so.

Most people are unaware of geothermal district heating systems. The possibility of finding one probably didn't occur to archaeologists studying Paquimé, and I didn't find the topic mentioned in the Di Peso volumes. Although the volumes discuss the *acequia madre* and *acequias laterales*, the large channels bringing water to the city from the thermal springs—these are not studied in the same detail as many other aspects of city life. There was no reason to do so if a geothermal district heating system was not at issue.

Studies by geothermal and geological experts are underway to pinpoint the nature of the geothermal waters enjoyed so long ago at Paquimé.

## ACKNOWLEDGMENT

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***Note:*** Except for comments on geothermal district heating systems, information about Paquimé comes from the volumes by Di Peso, and Di Peso *et al.*

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