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## 4. Geothermal Energy Utilization in the Jordan Valley between Lake Kinneret and the Dead Sea: A View from Antiquity

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*Abstract:* In the Hellenistic, and mainly in the Roman and Byzantine periods, four major thermo-mineral spring systems were utilized intensively for bathing and therapeutic purposes in the Jordan Rift Valley, between the Dead Sea to the south and Lake Kinneret (Sea of Galilee) to the north. Two of them, Tiberias and Hammat Gader, are still (or again) in use, while a new spa has been developed recently in the Zarqa Ma'in Wadi near the abandoned spring cluster of Zara (Kallirhoe). Along with a short outline of their geological situation, this chapter discusses the utilization of these springs in Antiquity within the framework of their historical, cultural, and religious backgrounds.

### INTRODUCTION

**A**N ORIGINAL MIDDLE EASTERN EXPLANATION OF THE NATURE of geothermal energy is suggested in one of the numerous, charming and almost always meaningful, timeless, and archetypal Solomonic legends, some of which are still told by mothers and grandmothers to their children in this region.

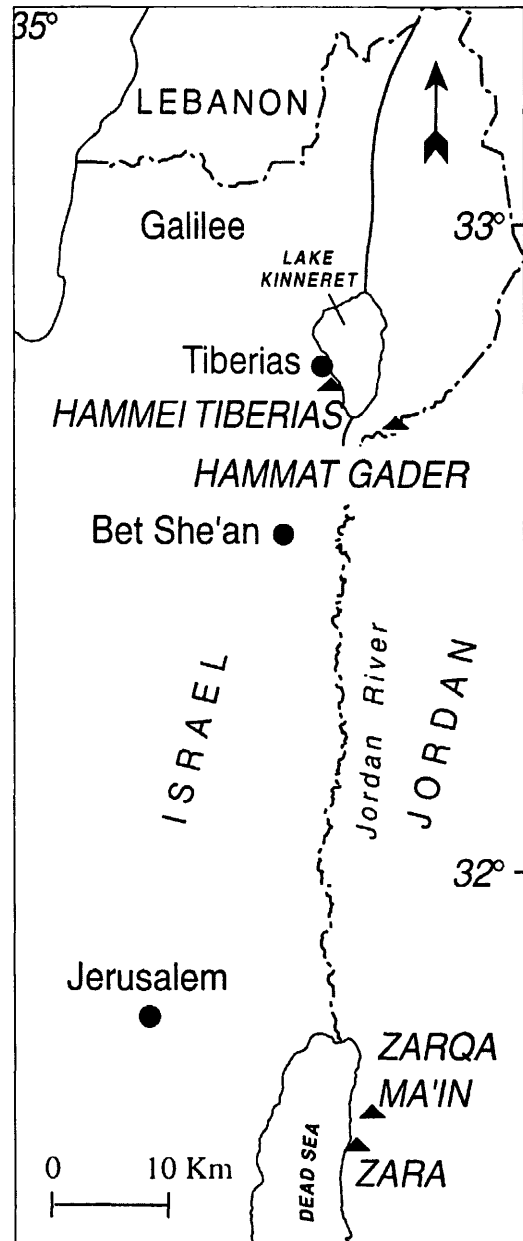
One of the legends relates that, once upon a time, while preparing for his wedding with the Queen of Sheba, King Solomon wanted her to take a hot bath. So he sent one of his demons to a large cold spring near the shore of the Lake (or "Sea") of Tiberias, also called Lake Genesareth or Lake Kinneret, and instructed him to heat the water (photo at left). The Queen traveled to Tiberias, took her warm nuptial bath, married the wise king, and, so the legend goes, they lived happily ever after. The demon enjoyed his work so much that he remained in Tiberias and has been heating the water of the same spring ever since.

Hammei Tiberias was, and still is, only one of the thermo-mineral springs used for bathing in the Jordan Valley (see map). Along with a short review of their geological background, the purpose of this chapter is to describe how thermal springs were used in ancient times for bathing and medicinal purposes in this history-laden part of the world.

#### UTILIZATION OF THERMO-MINERAL SPRINGS IN ANTIQUITY: A GENERAL OUTLOOK

**T**HE MAIN THERMO-MINERAL SPRINGS IN THE Jordan Valley (see map) were utilized essentially for bathing and medicinal purposes during the Hellenistic, Roman, Byzantine, and Islamic periods (Dvorjetski, 1992a, 1992b, 1996a, 1996b; Weber, 1997). At present, Hammei Tiberias, Hammat Gader, and Zarqa Ma'in are still actively utilized for the same purposes, while Zara (Kallirhoe) has been abandoned since the Byzantine period.

Even in earlier periods, people living in this region most likely understood the peculiar nature and healing properties of the hot springs and may have developed cultic and ritual practices besides bathing. But archaeological proofs of this are not available for prehistoric times. However, based on findings from the early excavations made in Hammat Gader in the Yarmuk Valley, it can be said that the Tell Bani ("the mound of the bath"), the top of which has remains of a 5th century A.D. synagogue, was already inhabited during the Bronze Age I-III (Sukenik, 1935). Also considering the fact that the valley of the Yarmuk River is a particularly lush and fertile region, it is likely that the hot springs were known already to early settlers and possibly used by them (see End Note on the Yarmukian Neolithic culture).



Location of the main thermo-mineral springs used in Antiquity in the Jordan Valley.

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## REGIONAL GEOLOGICAL SETTING AND THERMO-MINERAL SPRINGS

The Jordan Valley forms a part of the Dead Sea Transform fault system (DST) that affects the northernmost part of the Afro-Arabian Rift (AAR). The DST is a major transform fault that extends from the northern tip of the Gulf of Eilat-Aqaba (Red Sea) to the Beqa'a Valley in Lebanon (Barjous and Mikbel, 1990; Bender, 1974; Freund and Garfunkel, 1981; Girdler, 1990; Hatcher et al., 1981; Picard, 1970; Quennell, 1982). Taken as a whole, the Jordan Valley represents the deepest depression on Earth, reaching -210 m (below sea level) at Lake Kinneret and -400 m at the Dead Sea. Hence, all the hot springs considered in this chapter (see map) are well below sea level.

In the Biblical *Old Testament*, the Jordan Rift Valley was referred to as the "Great Deep" (*Genesis 7:11*). The DST marks an interplate boundary along which the Arabian Plate slips to the north relative to the Israel-Sinai part of the African Plate. An 107 km sinistral strike-slip displacement has accumulated there since the Late Cretaceous, and its motion is widely believed to have continued through the Holocene and Recent. Long-term mean rates of total slippage range from 6 to 12 mm/y. While details of segmentation are not clear, geological and seismological evidence indicates a complex pattern of strain accumulation and release along the DST; therefore, rather than a single dislocation, the DST appears to consist of co-linear or offset segments with bends and stopovers. Transgressive raised blocks and transtensional rhomb-shaped grabens have been identified at the restraining and releasing bends, respectively. Two rhomb-shaped grabens (the Dead Sea and the Sea of Galilee) form the most prominent features of the DST.

The last stage of the rift development occurred in the past 4-5 million years (Freund et al., 1970; Freund and Garfunkel, 1981), during which the change in the poles of plate motion led to the development of oblique stresses and to the formation of the DST trough-morphology.

The rift-fill, consisting of clastic, fluvial, limnic, and evaporitic sediments, is more than 10 km thick (Schulman and Bartov, 1978). A remarkable amount of clastic sediments has been discharged into the recent structure of the rift by numerous streams, as evidenced by the large alluvial fans seen along the margins of the depression; however, the rate of subsidence in the rift is greater than the rate of filling (Begin and Zilberman, 1994).

Recent fault traces run across the alluvial fans. In the northern part of the rift, this tectonic activity was accompanied by large-scale basaltic volcanism, which occurred mainly at the uplifted shoulders. The volcanism began during the Middle to Upper Miocene in the west and continued in the Pliocene on both the eastern and western shoulders of the rift. Volcanism, however, took place in younger times in the northeast, away from the rift. The geological features on the two flanks of the DST display an interesting asymmetry, which cannot be explained entirely by the significant north-south displacement. In the Dead Sea area, for instance, the eastern flank is raised 1-2 km.

On the western shoulder, the sediments are essentially Cretaceous in age. East of the Dead Sea, however, the sedimentary formations are considerably older than the Cretaceous: they range from Jurassic-Triassic to Paleozoic-Mesozoic in the Nubian sandstones, and even to Lower Paleozoic (Cambrian) in the Zarqa Ma'in region. Basalt flows on the western flank almost reach Bet She'an in the south, while on the eastern flank similar flows can only be seen near Lake Kinneret. East of the lake, however, in the Golan Plateau, these flows reach their maximum development. In the Zarqa Ma'in region, eight post-Eocene to Recent olivine basalt plugs and several flows of similar rocks are to be found, while across the Dead Sea, volcanic formations are unknown.

*cont.....*

Finally, major east-west faults (of which the Zarqa fault is the most prominent with its 50 km length) affect the eastern shore of the Dead Sea; these faults, however, do not exist at all on the western flank of the DST.

Numerous small and a few major hot springs are the main manifestations of geothermal energy in the Jordan Valley. Since only four major thermo-mineral springs are known to have been utilized intensively in Antiquity, this review will be restricted to their description: Tiberias on the western flank and Hammat Gader, Zara (Kallirhoe), and Zarqa Ma'in (Barou) on the eastern flank (see map).

Much information about these springs has been provided by the regional studies in the Lake Kinneret and the Dead Sea areas. The economic importance of these conspicuous fresh and saltwater springs spurred vigorous hydrological, hydrogeological, and hydrogeochemical investigations, as well as studies in related fields, such as isotope geology and heat flow (Eckstein 1979a, 1979b; Gat et al., 1979; Galanis et al., 1986; Gavrieli and Bein, 1995; Bein, 1976; Mazor et al., 1980; Serruya, 1978; Vengosh et al., 1994).

The existence of well-developed rift fracture-zones accounts for an easy ascent of the thermal waters from deep layers and for their outflow at the surface. The variability that has been documented in temperature and chemical concentrations among the various spring systems, and also among the individual springs in a given spring cluster, leads one to think that different confined aquifers with thermal water exist at depth and that a variable dilution of this water occurs with colder water of meteoric origin circulating in shallow aquifers (see map).

Preliminary studies on the low-enthalpy geothermal potential of the thermo-mineral springs in question, and of the confined aquifers existing in their surroundings, have been carried out and submitted with specific recommendations for further work, mainly on the eastern flank of the Jordan Valley. However, funds for drilling in specific target areas have not been available as yet (Abu-Ajamieh, 1980; Abu-Ajamieh et al., 1989; Allen, 1988; Galanis et al., 1986; Myslii, 1988; Tournaye, 1990, 1992).

*Geological and physical-chemical characteristics of the thermo-mineral springs in the Jordan Valley*

	Hammei Tiberias (a)	Hammat Gader (b)	Zara (Kallirhoe) (c)	Zarqa Ma'in (d)
Number of springs	17	5	45	54
Type of aquifer	Kurnub sandstone	Ajlun/Kurnub sandstone	Nubian/Kurnub sandstone	Kurnub sandstone
Age of aquifer	L. Cretaceous	U.-L. Cretaceous	Cambrian-L. Cretaceous	L. Cretaceous
Total yield (m <sup>3</sup> /y)	1	22	17	19
Temperature (°C)	27-62	25-50	42-62	34-63
TDS (mg/l)	30,941	1,444	1,001	1,651
Chemical type	NaCa-Cl	NaCa-HCO <sub>3</sub>	NaCa-Cl	NaCa-Cl

(a) Eggel, 1839; Buchmann, 1957; Bein, 1976; Mazor et al., 1980

(b) Noetling, 1886; Parker, 1970; Levitte et al., 1978; Starinski et al., 1979; Mazor et al., 1980; Mazor et al., 1981; Arad and Bein, 1986

(c) Allen, 1988; Swarieh and Massarwieh, 1996

(d) Truesdell et al., 1983; Rimawi and Salameh, 1988; Abu-Ajamieh et al., 1989; Salameh and Bannayan, 1993

Undoubtedly, however, the peak utilization of thermo-mineral waters took place during the Roman Empire. To understand the love for bathing during this period, it may be appropriate to quote a graffito, scratched on the pavement of the forum in the Roman veterans' colony of Timgad, in the heartland of Numidia, Algeria, "*venari, lavari, ludere, ridere: hoc est vivere,*" which means "hunting, bathing, joking, and laughing: that is living" (Dunbabin, 1989; Yegül, 1992).

Several, often complementary, kinds of sources about the history of the Jordan Valley springs are available. References to these springs are to be found in numerous classical works by Roman and Byzantine historians, chroniclers, and geographers from the 1st century B.C. to the 6th century A.D., such as Strabo, Pliny the Elder, Josephus Flavius, Origen, Ptolemaeus, Jerome, Epiphanius, Eusebius, Eunapius, and Antoninus of Placentia. These authors described at length the healing properties of these thermo-mineral springs and their popularity for the treatment of many diseases, particularly leprosy.

After the destruction of the Second Temple and the Bar Kochba revolt, Galilee became the main region where Jews settled, prospered, and established their religious institutions. Thus, references to localities and events in this region are frequent in the *Talmud* (often referred to as "rabbinical literature"), including the description of thermo-mineral springs and their healing properties, together with recommendations for sufferers from skin diseases, leprosy, ailments of the urinary and digestive tracts, rheumatism, arthritis, and nervous diseases (Dvorjetski, 1996a, 1996b). The therapeutic properties of the *piloma*—a kind of thermo-mineral mud or "fango"—were also recognized and utilized in Hammei Tiberias (Buchmann, 1960).

After the end of the Byzantine epoch, at the beginning of the Early Islamic period in the 7th century A.D., the area under review lost its geopolitical importance and the whole region underwent impoverishment. For many centuries, however, the spas continued to be visited—but only by local people. This is attested to by many well known Arab and Jewish travelers and geographers, such as Al Ishtahi and Al Muqaddasi (10 century), Benjamin de Tudela and Ali Mehirat (12th century), Yaqut (13th century), Bassola (16th century), and Hasselquist and Yerushalmi (18th century).

From the beginning of the 19th century, historical exploration in the Middle East, particularly the Holy Land, became fashionable. Many European voyagers traveled in the region, accurately observing and recording ancient remains (Buckingham, 1821; Seetzen, 1859; Guérin, 1868;

Conder and Kitchener, 1881; Tristram, 1873). Particular mention should be made of Burckhardt (1822), well-known for the discovery of Petra, a very important town in pre-Christian times and the unsuspected capital of the Nabataean Kingdom in the 4th century B.C.

Finally, recent archaeological excavations, coupled with the study and the interpretation of epigraphic material, have shed new light on the structure of bathing establishments in the region and also on its religious, social, and cultural background and significance. Some highlights follow for each of the main thermo-mineral springs of this area.

### *HAMMEI TIBERIAS*

IN THE *TALMUD*, TIBERIAS IS IDENTIFIED WITH THE BIBLICAL HAMMATH, A FORTIFIED CITY IN THE territory of the tribe of Naphtali, which was located in the northern part of ancient Palestine (*Book of Joshua* 19:35). However, this identification is not certain, as no remains older than the Hellenistic period were discovered during archaeological excavations conducted in the area. What is certain, though, is that the town proper of Tiberias was founded only around the year 20 A.D. as the capital of Galilee by Herod Antipas, who named it after the Emperor Tiberius. The thermo-mineral springs are situated just at the southern edge of the town. Their appearance toward the end of the 19th century is seen in the illustration.

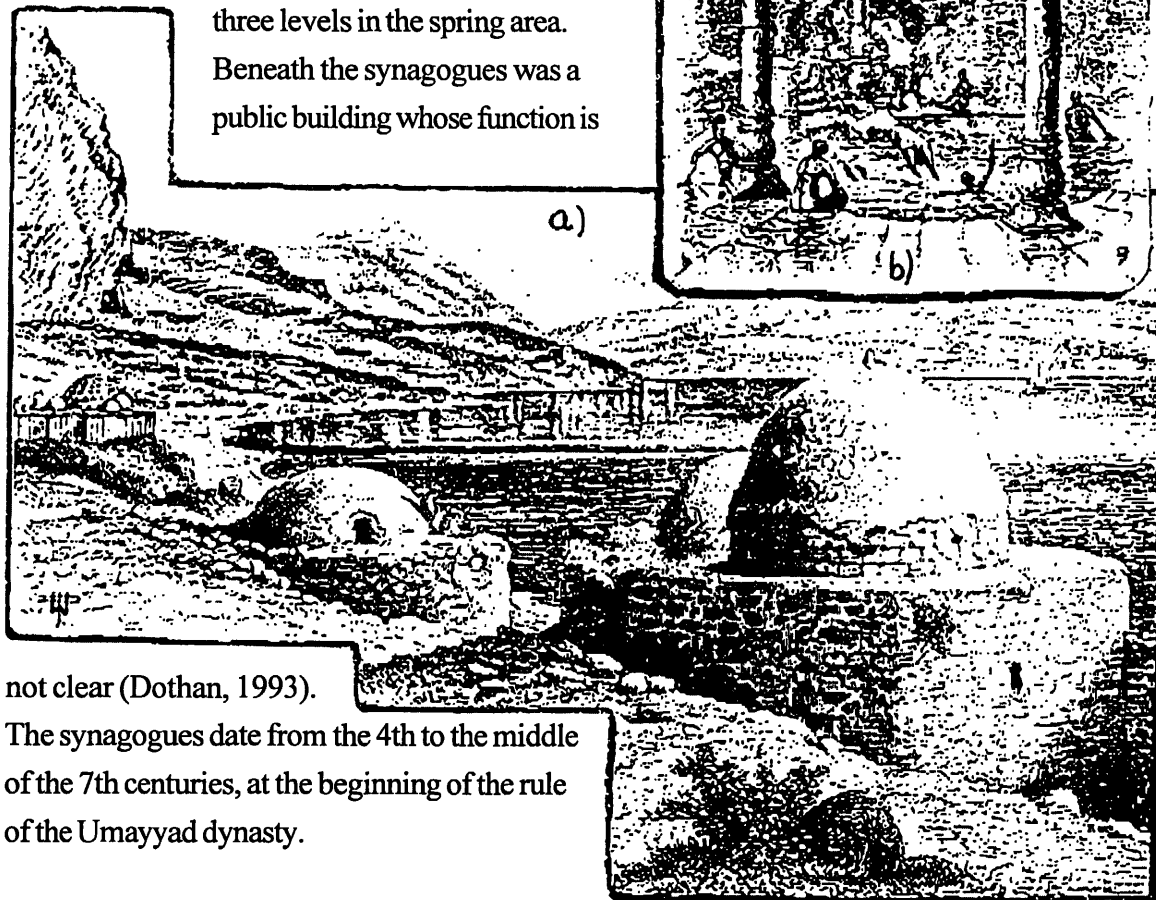
Tiberias was a Jewish town that gradually assumed great spiritual and religious importance. The Academy, which succeeded the *Sanhedrin* (or *Synhedrion*) as the supreme religious institution, was founded in Tiberias; it continued to function well after the Arab invasion in the Early Islamic period, probably until the 10th century. The bulk of the Palestinian (Jerusalem) *Talmud* was written in this institution.

It is thus not surprising that, while the baths essentially had a curative purpose, religious factors were also of great importance. The strong influence exerted by religion on balneological practices can be easily drawn from many documents of the period, which contain in-depth discussions on the religious opportunity to bathe, especially on the Sabbath (Saturday), and on the moral consequences of taking baths in thermal establishments where the indiscriminate and contemporaneous presence of men and women was allowed. In particular, the rabbis strongly opposed the practice of thermal bathing, not only for religious reasons but also because it was customary to erect idolatrous statues inside the spas, such as the statue of the Emperor Hadrian. The *jeunesse dorée* of Tiberias reacted to such limiting factors by preferring to visit the more

festive Hammat Gader thermal spa, where men and women were allowed to bathe together in the same pools.

Excavations also attest to the strong impact of the religious way of life prevailing in Tiberias: several superimposed synagogues were found on at least

three levels in the spring area. Beneath the synagogues was a public building whose function is



not clear (Dothan, 1993).

The synagogues date from the 4th to the middle of the 7th centuries, at the beginning of the rule of the Umayyad dynasty.

The floors of these synagogues are decorated with mosaics inscribed in Aramaic and Greek. Two beautiful mosaics of high artistry were discovered on the synagogue floor on the level

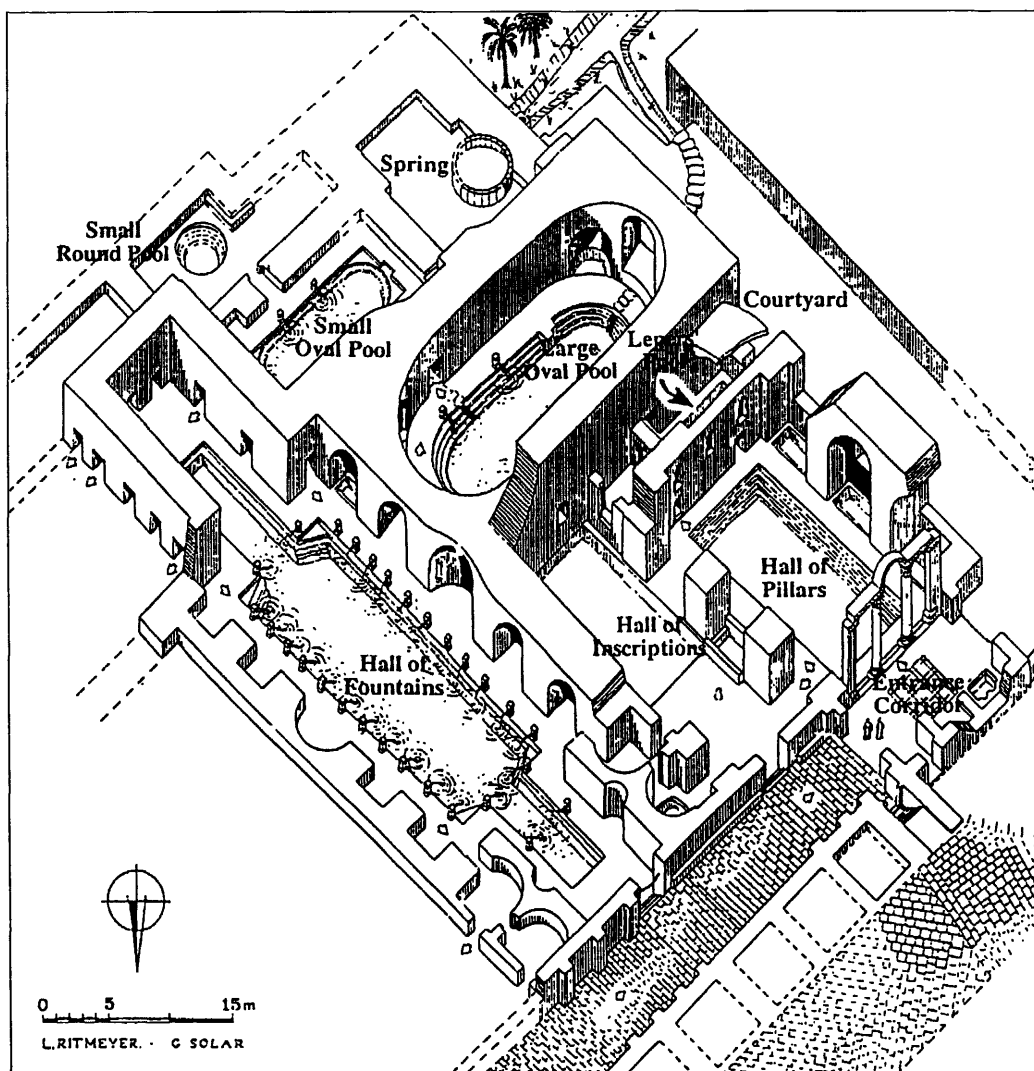
labeled IIA; one depicts the Torah ark with various cultic objects. However, the most beautiful and relatively well preserved mosaic floor on this level portrays Helios, the Greek representation of the sun deity, riding on his chariot surrounded by a zodiac. The free artistic expression displayed in the nude representation of the signs of the zodiac, as well as the frequent use of Greek in the accompanying inscriptions, clearly indicate a strong Hellenistic-Roman influence in the life of the Jewish capital of Galilee.

The thermal establishment of Hammei Tiberias toward the end of the Ottoman period (Wilson, 1880, vol. 2, p. 65): (a) general view; (b) detail of the interior of the public bath. Note the pierced dome.

A modern, fully equipped spa now is operating at Hammei Tiberias.

### HAMMAT GADER

THE HAMMAT GADER THERMO-MINERAL ESTABLISHMENT (SEE MAP), RECENTLY EXCAVATED BY the Hebrew University of Jerusalem, is one of the largest baths in the Roman world, second only in importance to Baiae, in the Phlegraean Fields near Naples (Hirschfeld, 1984, 1993 and 1997; Yegül, 1992). Patients flocked here from distant regions, as faraway as Athens. It was an imposing rectangular architectural complex, covering 3500 (50 x 70) m<sup>2</sup>. The overall plan of the establishment indicates a functional juxtaposition of five major and one minor hall, all interconnected and each containing a large pool. One of the most intriguing areas of the establishment is



The Hammat Gader bathing establishment, axonometric restoration. *By Ritmeyer and Solar in Yegül 1992; slightly modified and reprinted with permission*

the narrow pool between the Oval Hall and the Hall of the Pillars. It may have been used as a special unit for the treatment of leprosy. The spa was well known as a place of licentiousness and frivolity, a unique and rather successful combination of fair, amusement center, and social meeting place where prostitution was a common phenomenon (Dvorjetski, 1994a, 1997a, and 1997b).

At the end of the Byzantine period in the 7th century, the baths were severely damaged by a major earthquake. An inscription in Greek commemorates the renovations undertaken by the Caliph Mu'awiya, the founder of the Umayyad dynasty, shortly after he ascended the throne in Damascus and took over the region from Byzantine rule in the 7th century. The text of this inscription has been interpreted as a clear sign of the tolerance prevailing at the beginning of the Early Islamic period. However, the importance of the baths gradually diminished, although local inhabitants continued to frequent them for cures during the following centuries.

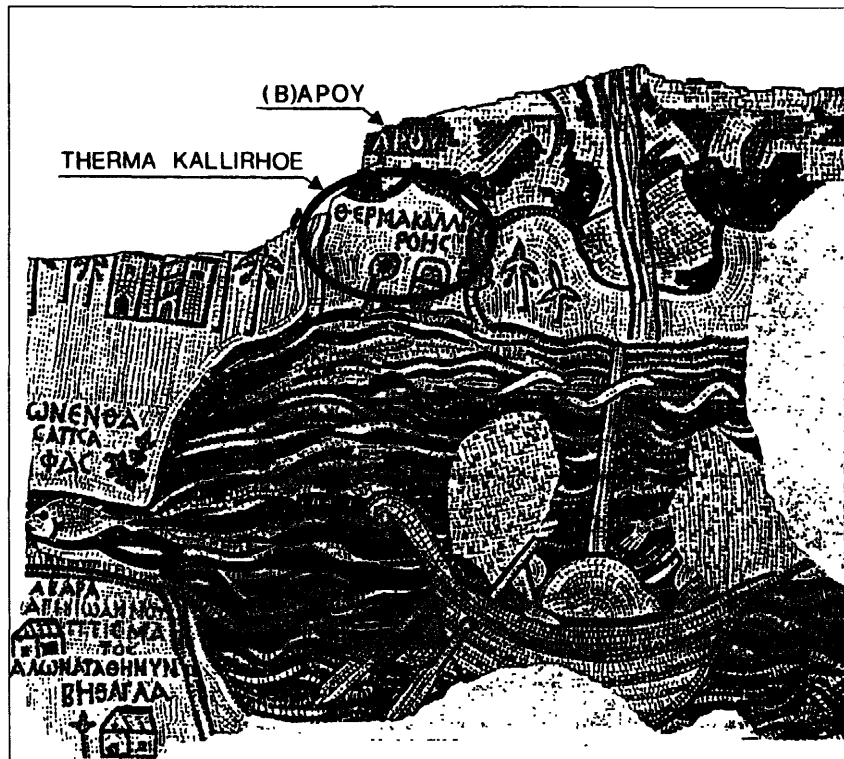
A modern balneological establishment, opened in recent years, is functioning successfully today at Hammat Gader.

#### *ZARA (KALLIRHOE) AND ZARQA MA'IN (BAROU)*

**Z**ARA IS BETTER KNOWN UNDER ITS HISTORICAL GREEK NAME OF KALLIRHOE, "THE BEAUTIFUL spring," and both names will be used in this section. Dunbabin (1989) suggests that the meaning of Kallirhoe is also well reflected by the German term "Schönbrun." Due to its extreme summer climate and its relative inaccessibility on the eastern shore of the Dead Sea, Zara was never a well developed spa. Its claim to fame stems from the description given it by the renowned Jewish historian and military commander Josephus Flavius (1st century A.D.) in relation to the death of Herod the Great. The importance of Kallirhoe is also attested to by its depiction on the famous mosaic of Madaba (near Mount Nebo in the Amman area). The mosaic, which covers the floor of a Byzantine church built toward the second half of the 6th century (Avi Yonah, 1954; Piccirillo, 1993; Dvorjetski, 1994b), represents a geographical map of the Holy Land. It is somewhat paradoxical to note that at the time of the execution of the mosaic, the use of Kallirhoe had practically halted and that it has not been in use since.

In his usual accurate and elegant style, Josephus Flavius (*De bello judaico*, I, 656-657) narrates the death of Herod the Great, an extremely cruel but fascinating tyrant. This king was already a 70-year-old, despondent, and moribund ruler when he decided to visit the Kallirhoe

springs, whose waters were “potable and sweet,” in the hope of some relief from his various illnesses, of which a realistic but somewhat unpleasant list is provided by Josephus Flavius. Learned commentaries have been written on this subject, and modern medical opinions are divided on the possible diagnosis of the illnesses affecting Herod the Great. These illnesses could have been any one or a combination of cancer



Kallirhoe on the Madaba mosaic. Above the name “Therma Kallirhoe,” the locality of (B)apoy (pronounced “Barou”) can be seen. It may well correspond to the Zarqa Ma’in (Barou) springs. Note that the faces of the persons sailing on the Dead Sea were expunged during an iconoclastic episode. Piccirillo, 1993

of the bowels, cirrhosis, and severe diabetes, as well as arteriosclerosis and thrombosis in the abdominal region, complicated by terminal cirrhosis. Under these circumstances, the stay of the king at Kallirhoe apparently was rather unsuccessful. So, he sailed again across the Dead Sea and returned to his winter palace in Jericho, where he arrived in a “melancholy state.” However, he went on plotting as usual, as he had done most of his life; he still managed to have his third son, Antipater, killed after a new and terrible fit of anger overtook him in his poor state of health, and he finally died five days later, in 4 B.C.

The Zara region was studied extensively and excavated by German archaeologists (Clamer, 1989 and 1997; Donner, 1963; Strobel, 1966 and 1989; Strobel and Clamer, 1986; Kraus, 1995, map of Kallirhoe; Weber, 1997). It appears that in Antiquity Kallirhoe was never a popular spa but rather a luxurious and exclusive holiday residence with private bathing facilities for the king and the aristocracy during the reigns of Herod the Great and his son Herod Antipas, the Tetrarch of Galilee. An ancient Kallirhoe pier, still visible at Zara, supports the evidence that Kallirhoe was connected by boat to the western shore of the Dead Sea and from there to the Jericho region.

A road connected Zara with the Zarqa Ma'in thermo-mineral springs; it probably continued from there to the fortress of Machaerus, where at present the village of Mekawir is located, about 8 km south-southeast of Kallirhoe (Khouri, 1988; Dvorjetski, 1996b). Machaerus was Herod's hilltop palace, built to protect his kingdom against the incursions of the Nabataeans. It was the palace where Salome danced in front of Herod Antipas so successfully that she obtained the head of St. John the Baptist.

Archaeological evidence indicates that Kallirhoe was occupied during Roman times but abandoned in the 2nd century after the Bar Kochba revolt, during which the Machaerus castle was destroyed. It was reoccupied in the 4th century by the Byzantines and was used in trade on the Dead Sea, as the Madaba mosaic map indicates (see illustration). Kallirhoe was probably reabandoned in the 5th century, or shortly thereafter, thus falling into oblivion.

The Zarqa Ma'in spring area is situated in a deep gorge, some 3.5 km northeast of the Zara (Kallirhoe) springs (see map). The area is easily accessible from Amman by a good road, which, however, does not continue to the Dead Sea shore; therefore, the two spring systems of Zarqa Ma'in and Zara are practically without communication between them.

The Zarqa Ma'in springs may have been visited for balneological purposes during Antiquity, but archaeological and historical evidence of their use is lacking. For a long time, these springs have been confused with those of Zara (Kallirhoe), but now it is believed that they rather correspond to the ancient springs of Baris (or Barou; [B]apoy on the mosaic), an important group of springs about which very little is known.

Recently, the main Zarqa Ma'in springs have been harnessed to serve a well frequented hotel with bathing and curative facilities. They supply at present the largest thermo-mineral establishment in the whole Middle East.

## CONCLUDING REMARKS

**O**BVIOUSLY, NO QUANTITATIVE DATA ARE AVAILABLE ON THE UTILIZATION IN ANTIQUITY OF thermo-mineral springs in the Jordan Rift Valley. There is, however, sufficient information to surmise that conditions and applications have not changed significantly over the last 2,000 years. Quite to the contrary: the spas just described were far more important in Antiquity than in the last few centuries and at present.

It can be reasonably assumed, though, that a major change may take place in the next century. Then the geothermal potential of the springs area and of the whole surrounding region is expected to be harnessed, not only for classical balneological purposes but for new and challenging low-enthalpy applications.

[*End Note:* The Neolithic village of Sha'ar Hagolan, on the northern bank of the Yarmuk River, is located less than 5 kilometers downstream from the Hammat Gader springs. It is one of the most important Neolithic settlements in the entire Middle East and the type locality of the Yarmukian culture that flourished some 8,000 years ago (6400 to 5800 B.C.). This culture is known from at least 20 other localities in Israel, Jordan, and Lebanon (Garfinkel, 1993 and 1999).]

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16th century Ottoman miniature of a Turkish bath. The dome on the right arches over the entrance to the bath, the cold section where customers arrived. Customers would disrobe in the narrow rectangular room on the lower right, seated on raised banks of earth that were covered with blankets and rugs. They left their clothing in piles, including any clean clothing brought for later. Seven bundles of clothing are depicted, including turbans. Customers also carried their own towels and dried themselves here after the bath.

The man in the small room above is sitting with his bag containing items needed for the bath, such as a razor, loofah, and soap. An employee hangs items out to dry on the roof.

The hot bath itself is on the left, covered by a dome encrusted with colored glass balls where light streams through. The customers are here, enjoying their bath. Interpretation by the College of Fine Arts. *Printed with permission of the Topkapı Palace Museum, Istanbul*