

BADEN-BADEN

A FAMOUS THERMAL SPA WITH A LONG HISTORY

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INTRODUCTION

One of the most prestigious and historic thermal spas in Germany can be found in the southeastern part of the country. Located at the eastern border of the Upper Rhine Graben (Figure 1), the city is nestled between vineyards, forests and the plains of the Rhine valley; where, the River Oos leaves the mountains of the Black Forest. The hot springs are known at least since Roman times, and the spa was a social center for the European nobility in the 19th century (the “Belle Époque”). Baden-Baden is still considered as a top place for balneological treatment and society events.

Baden-Baden has an elevation of 161 m (528 ft) above sea level (city center); however, the lowest point in the city is 112 m (367 ft) a.s.l. in the Rhine Graben, and the

highest 1003 m (3290 ft) a.s.l. on Badener Hoehe in the Black Forest. With this location at the foot of the Black Forest, 61.5 % of the area of the city comprise forest.

Several hot springs supply thermal water to the spa facilities, with temperatures ranging from 52 to 67 EC (130-153 EF) and a mineralization of 2680-3522 mg/kg (ppm). Most of the springs are natural; however, in the 1960s thermal water was also found in two drilled wells. The total thermal water production in Baden-Baden is 9.4 l/s (149 gpm). The water has an energy content of ca. 2 MW (ca. 6.8 million Btu/h), but the energy use is not yet complete.

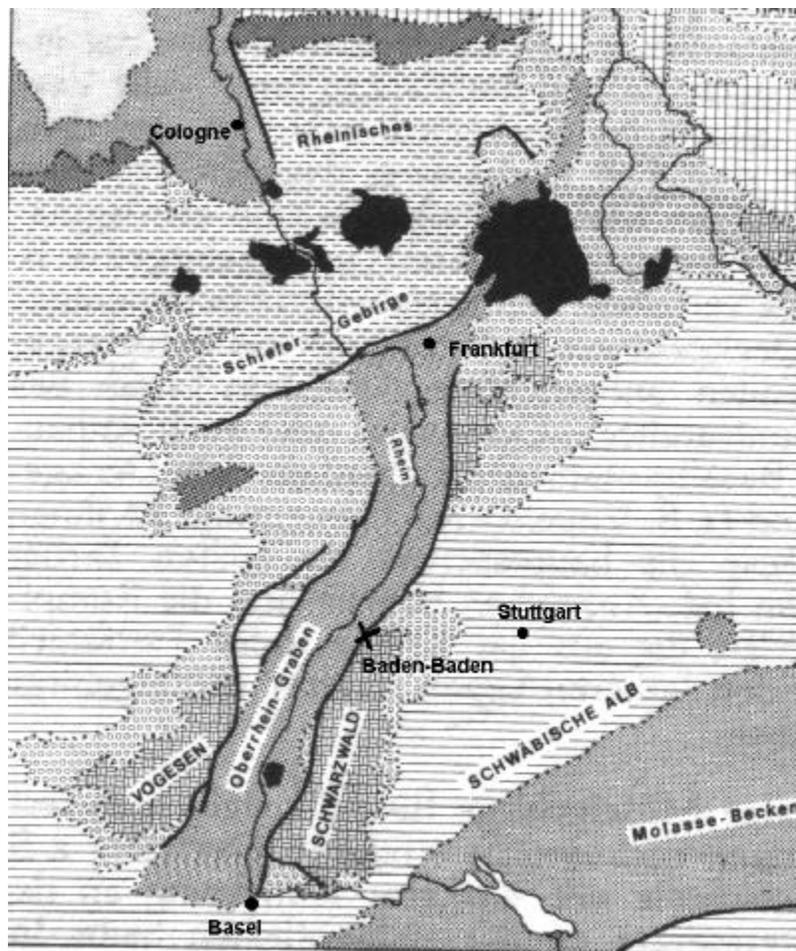


Figure 1. Location of Baden-Baden at the eastern edge of the Upper Rhine Graben (Oberrhein-Graben), map after Henningsen (1976).

HISTORY OF BADEN-BADEN AND THE THERMAL SPRINGS

The earliest traces of human life in the valley of the River Oos date from the stone age, ca. 10,000 years ago. From bronze age, tombs have been found dating ca. 1000 B.C.

Not surprisingly, the Romans made use of the hot springs. The city was founded as "Aquae Aureliae" and their development peaked in the 2nd century A.D. Stately buildings and, of course, the "thermae," coined the image of the city. People, from many parts of the Roman Empire, came in search for mitigation of their sicknesses, including the Emperor Caracalla. After 260 AD, the German tribe of the Alemans invaded the area, and most of the city was destroyed. The thermal bathing ceased for several centuries. However, traces of this first blossom of thermal bathing in Baden-Baden still exist, e.g. in the ruins of a soldier's bath around 2000 years old which have been found in 1847 in the main thermal area.

In the 6th century, the Merovingian king Dagobert III gives the area including the hot springs to the Weissenburg monastery. The first castle (Altes Schloss) was built in 1102 as "Hohenbaden" (destroyed by fire in the 16th century; today ruins). Markgräfin Irmengard installs a monastery in 1245. In 1256 in a document of Markgraf (Earl) Rudolf von Baden for the first time the name "Stadt Baden" (Baden city) is used. From 1384 to 1399, the new castle (Neues Schloss) is built (destroyed by fire in 1689; rebuilt, the form seen today was completed in 1847).

The thermal waters become increasingly important. Markgraf Rudolf III offers a part of the thermal baths to his knights in 1306. In the year 1365, the privilege of secure travel is given to Strasburg citizens for visiting the thermal baths of Baden. In the 15th century, the bathing activities flourish. Emperor Friedrich III visits Baden for bathing in 1473. In 1480, the poet Hans Foltz publishes a "Bäderbüchlein" (baths booklet) describing the hot springs. Markgraf Christoph I controls the bathing activities in 1488 by legal orders. In 1507, he gives a city regulation to Baden and introduces a tax on bathing (Kurtaxe). The court doctor, Dr. Johannes Matthäus, starts in 1601 with mud baths (Fango). A book about the springs is published in 1625 by Johann Küffer, mentioning 12 springs; one of the springs, the "Brühequelle," is used to clean and boil fowl and pig (Küffer, 1625).

In the year 1688, French troops occupy Baden. On August 24, 1689 a huge fire reduces most of the city and the castles to cinder and ashes. The reconstruction of the city did require almost a century. The fire also destroyed the monastery "Kloster vom Heiligen Grab," located directly in the thermal area and founded in 1670 by Markgräfin Franziska. In 1698, it is rebuilt; today, it houses a high school.

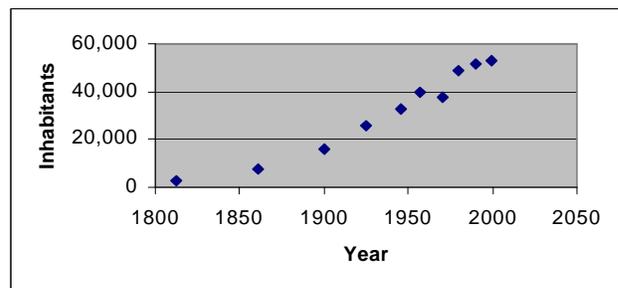
In the neighbouring city of Rastatt, diplomats and highnesses meet in 1797 at the "Rastatter Kongress." They detect the Baden spa, and a new era with the high society of Europe starts for Baden-Baden. 1804 Queen Luise of Prussia visits Baden-Baden to improve her health. Plans for a new spa area are drafted in 1810. In 1811, the building of the college of Jesuits is converted into a casino. A steam bath is constructed in 1819, and a (thermal water!) drinking hall in

1824. The original balneological building (Kurhaus) dating from 1765 is replaced in 1821-23 by the building which exist today. The large, 90 m long drinking hall with Corinthian columns and frescos is completed in 1842. In 1850, Queen Augusta of Prussia, later to become Empress, stays in Baden-Baden for the first time. Another steam bath (Altes Dampfbad) is constructed in 1846-1848, including a hot spring ("Ursprungsquelle") delivering roughly 118 m³ (31,200 gallons) of thermal water with almost 60EC (140EF) per day.

In 1858, Otto v. Bismarck and Cavour stay in Baden-Baden, and the first international horse race is conducted near the village of Iffezheim in the neighborhood of Baden-Baden. 1860-62 a theater is built, following the prototype of the Opera in Paris; a (not successful) ambush on King Wilhelm of Prussia happens, and in 1863 three Emperors met in Baden-Baden in the "Hotel d'Angleterre:" Franz Joseph of Austria, Tsar Alexander of Russia and Napoleon III.

From 1863 to 1875, the annales of Baden-Baden name many VIPs of the time: Dostojewski, Madame Viardot, Clara Schumann, Johannes Brahms, Victor Hugo, Richard Wagner, Friedrich Nietzsche, Queen Victoria of England and Prime Minister Disraeli. In 1877, the Friedrichsbad is inaugurated, 1893 the Augustabad. The presence of nobles from all of Europe is documented by the construction of a Romanian orthodox chapel, built by Leo von Klenze in Greek style in 1863-66 (housing the grave of the Romanian Prince Stourdza), and of a Russian church in 1880-82, planned by Belzer in Byzantine style.

The bathing tradition of Baden-Baden attracts guests also throughout the 20th century. The infrastructure is continuously improved, with a conference center in 1968, the Caracalla spa in 1985 and the latest addition, a festival hall for 2650 visitors in 1998. The growing thermal spa business fueled the economy and resulted in a steady increase in the Baden-Baden population since the end of the 19th century, as the following graph shows (prepared with data from the official website of Baden-Baden municipality, incl. 1999 values):



By the end of 1999, Baden-Baden had a population of 52,627.

THE HOT SPRINGS

The existence of the hot springs is related to the deep faults at the eastern end of the Upper Rhine Graben. The crystalline rocks of the Black Forest are displaced downwards by almost 2 km (ca. 6500 ft) in the graben, and a number of

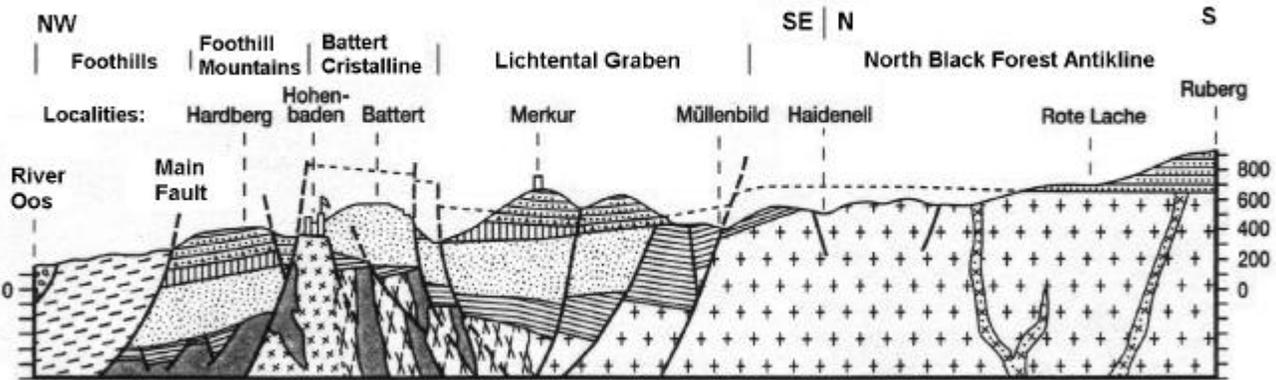


Figure 2. *Geological profile through the faults at the eastern end of the Upper Rhine Graben in Baden-Baden (from Landesarchiv BW, 1995).*

faults delineate blocks in different elevations (Figure 2). The original springs mostly are located close to the Main Thermal Fault (Figure 5) at the SE-slope of the “Florentiner Berg;” where, the new castle (Neues Schloss) is built upon. The springs exist since diluvial (flooding) times. Since then, sinter layers did built up to about 6 m thickness below the springs. Figure 3 shows the location of the springs in use in the middle of the 19th century.

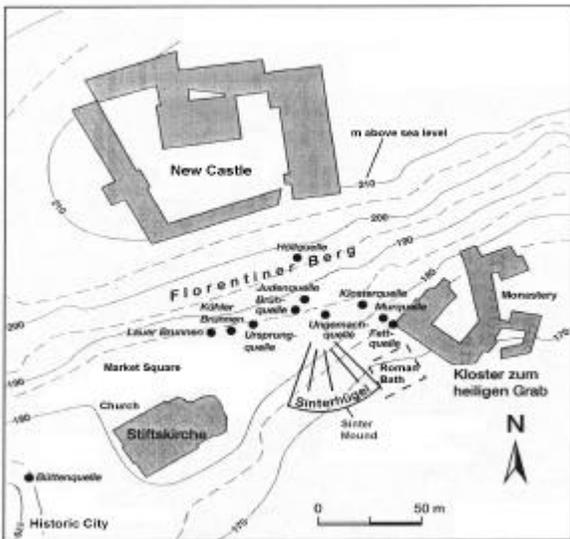


Figure 3. *The hot springs of Baden-Baden prior to the catchment works in 1868 (from Landesarchiv BW, 1995).*

From 1868 on, a system of tunnels was constructed to catch the springs (Figure 4). The goal was to increase production and temperature. Because of the high temperatures, the work was difficult and took until 1871. The system consist of two main tunnel areas, one just below the castle with the “Friedrichstollen” (stollen = tunnel) as main tunnel, the other close to the Marketplace with the “Kirchenstollen” and “Rosenstollen” The total production could be increased by ca. 20%. A new, large bathing facility was built, the “Friedrichsbad” (completed 1877). To make room for the bath, most of the sinter mound had to be removed, with part of the stones cut and used for special building parts.

Between 1894 and 1897, further addition were done to the tunnel system (mainly the new tunnel capturing the “Neue Stollenquelle”). The tunnel system remains unchanged since then and has an overall length of ca. 200 m (660 ft). The thermal water contains mainly sodium chloride (NaCl); an example of an analysis is listed in Table 1. The genesis of the thermal water is not yet clear. A theory is that the water infiltrates in the Black Forest and is heated while passing through the fractures in the crystalline; contents in lithium and fluoride support this theory. However, the sodium chloride can not be accounted for with the crystalline; fragments of mid Triassic evaporates in the fault area may be the source.

DRILLING FOR THERMAL WATER

Increased need for water for new balneological facilities prompted a search for additional resources of thermal water. Geophysical investigations using geoelectrical and geothermical methods revealed a possible field to the north of the “Florentiner Berg;” with a geothermal gradient of 28EC/100 m (15EF/100 ft)! In this location, called the “Pflutterloch.” two boreholes were drilled in 1965-66. One

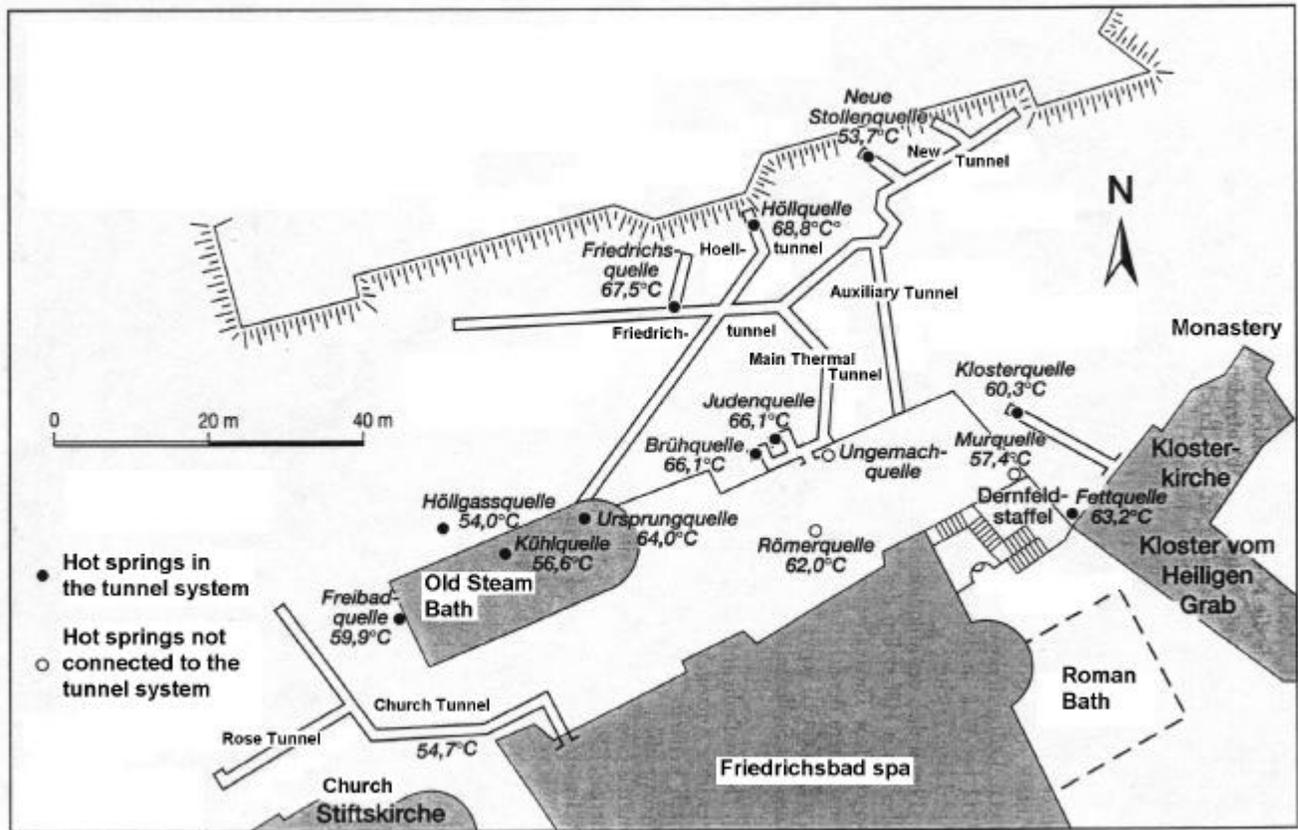


Figure 4. The catchment works and tunnels built from 1868-1902, with source temperatures (...quelle = spring, source; from Landesarchiv BW, 1995).

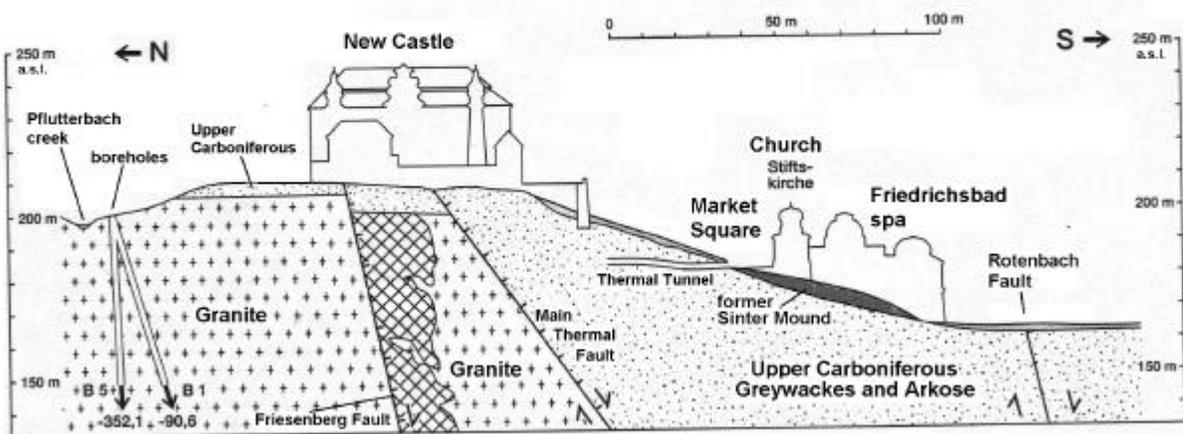


Figure 5. Profile through the main thermal area in Baden-Baden (after Bilharz, 1934; from Landesarchiv BW, 1995).

Table 1. Analysis (selection) of Water from Friedrichs-Tunnel, Sample of July 14, 1987 (after data from Landesarchiv BW, 1995)

Kations	mg/kg (ppm)	Anions	mg/kg (ppm)
Sodium	850.66	Chloride	1437.60
Potassium	75.05	Bromide	3.10
Lithium	9.03	Iodide	0.00
Calcium	129.35	Fluoride	4
Magnesium	2.07	Nitrate	5.40
Strontium	1.71	HCO ₃	0.18
Rubidium	2.50	Sulfate	155.10
Caesium	2.20		152.81

Temperature: 64.6 EC (148.3 EF) pH-Value: 7.47

was drilled with an angle to the south, and the bottom in 301.5 m (990 ft) depth is in fact beneath the court of the new castle (Figure 6). The second borehole is 552.5 m (1812 ft) deep and vertical.

Both wells penetrate other layers than the existing springs come from (north of the Friesenberg-fault, see Figure 6 and cross-section in Figure 5). However, temperature and chemistry of the artesian water found here are similar to the springs. The production decreased from 1.8 l/s (28.5 gpm) in the beginning to 0.94 l/s (14.9 gpm) in 1991. The wells (Florentiner-source) are now part of the thermal water system (Figure 6).

In 1973/74, a deep borehole was drilled in the graben to the west of the city, following seismic profiling (Vibroseis) the year before. The target horizon was Muschelkalk (mid Triassic) limestone, where thermal water was expected. The borehole went through 85 m (279 ft) of Quarternary material, followed by Tertiary material down to a depth of 1855 m (6086 ft). Under a fault, Jurassic sediments were found. At another fault in 2180 m (7152 ft) depth the Jurassic ended abruptly, and lower Triassic sediments followed. From 2440 m (8005 ft) to the bottom of the borehole at 2721 m (8927 ft) depth the metamorphic bedrock was perforated.

Due to the tectonic omission of Muschelkalk, no water could be found. The borehole was filled in 1975, and seismic investigation resumed. In 1976-77, a second deep borehole was drilled. The stratigraphy in this hole was: Quarternary material down to 70 m (230 ft) depth, followed by Tertiary material down to 1040 m (3412 ft). Under a fault, sediments of the Jurassic were found, and from 1311 m (4301 ft) to the final depth of 1502 m (4928 ft) upper Triassic (Keuper) prevailed. From 750 m (2464 ft) depth a small amount of water (0.02 l/s or 0.32 gpm) was produced, with 14910 mg/l (ppm) of Chloride. The drilling was stopped when the rig reached its maximum lifting capacity, and the hole was eventually filled in 1978. After these experiences and a lot of money spent for deep drilling, no further activities were done to explore deep thermal waters.

The geothermal gradient in the second of the deep holes was measured to 5.1EC/100 m (2.8EF/100 ft). This looks promising for the use of geothermal energy, if either water could be found or technologies from the Hot-Dry-Rock-development could be used.

THE BATHS TODAY

The thermal water today is produced by three sources:

- tunnels comprising several former springs
- some remaining individual springs
- two drilled wells

The temperature and production of these sources is listed in Table 2.

Table 2. Properties of the Individual Sources in Baden-Baden, April 1993 (after data from Landesarchiv BW, 1995)

Source	Production		Temp.		TDS*
	m ³ /day	gal/day	°C	°F	mg/kg (ppm)
Tunnels					
Friedrich-tunnel	384	101453	66.9	152.4	3013
Kirche-tunneln	71	18758	54.7	130.5	2778
New tunnel	22	5812	58.9	138.0	2692
Springs					
Ursprungquelle	113	29855	67.1	152.8	2999
Kuehlquelle	29	7662	59.8	139.6	2851
Freibadquelle	9	2378	59.6	139.2	2811
Fettquelle	62	16380	63.7	146.7	3041
Murquelle	6	1585	54.1	129.4	3072
Klosterquelle	10	2642	57.4	135.3	2898
Hoellgassquelle	8	2114	52.6	126.7	2833
Wells					
Florentiner 1	54	14267	60.1	140.2	2680
Florentiner 2	27	7133	51.6	124.9	3522

TDS: Total Dissolved Solids

Two major bathing facilities dominate the activities in Baden-Baden today. One is the traditional Friedrichsbad, serving relaxation and healing since more than a century, and the other is the relatively new Caracalla Spa. Both are supplied with thermal water from the traditional hot springs as well as from the two wells drilled in the 1960s (Figure 7). Thermal water is also delivered to three public drinking fountains and several private users (hotels, hospitals). The annual consumption is shown in Table 3.

Friedrichsbad was opened in 1877 in the traditional hot springs district, just beside the traces of the Roman bath and partly on the site of the former sinter mound of the hot springs (Figures 4 and 5). It features a unique combination of Roman and Irish bathing tradition, initiated by Dr. Barter, an Irish physician, who combined the Roman approach (various types of warm thermal baths) with the traditional Irish technique (hot air baths).

Healing effects of Friedrichsbad's Roman-Irish baths are used to treat chronic disorders, such as arthritis or rheumatism of the joints. Vegetative circulatory disorders, chronic bronchitis, paranasal sinus problems, obesity and

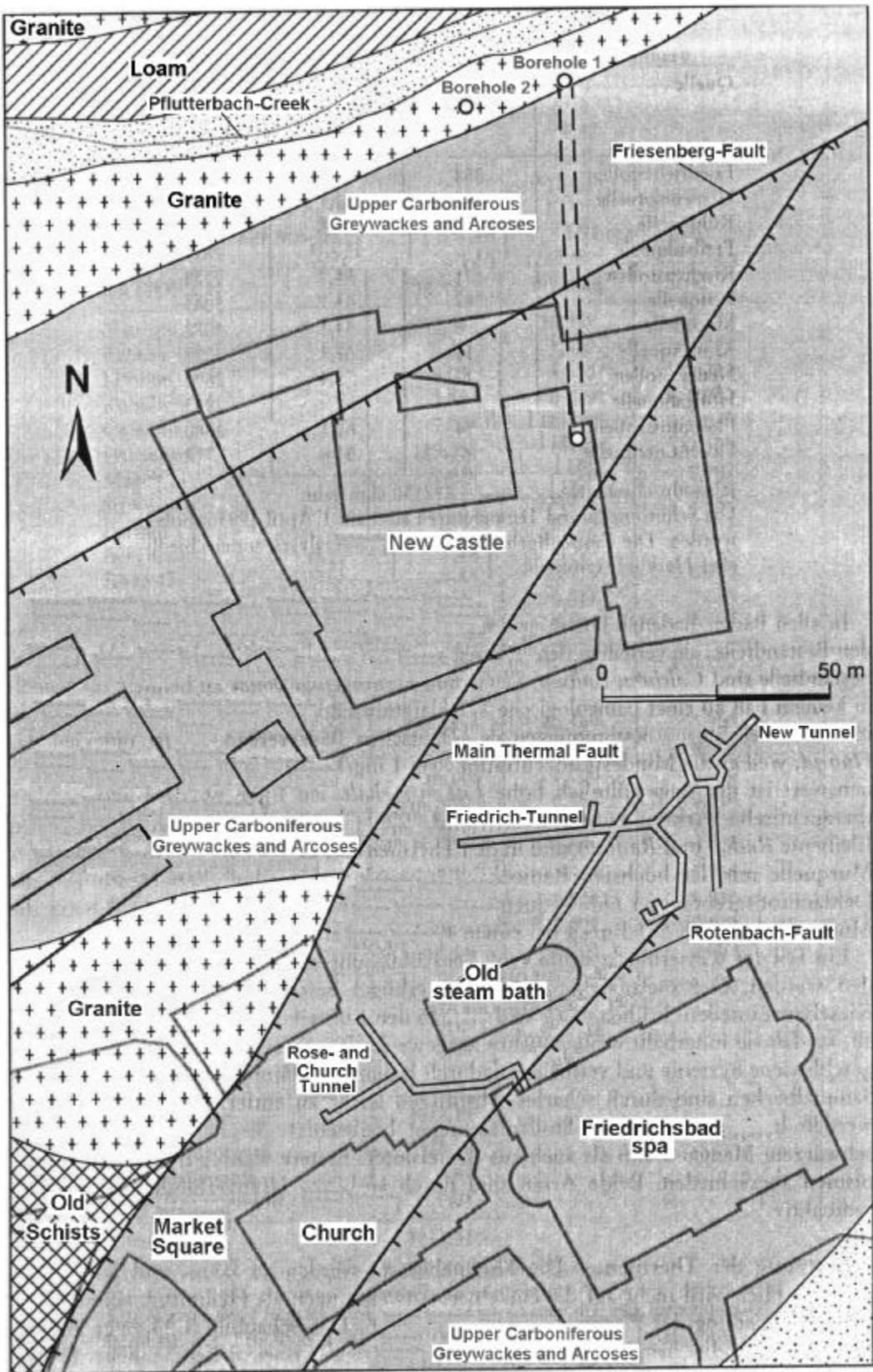


Figure 6. Geological and tectonic map of the main thermal area (after Maus & Sauer, 1972; from Landesarchiv BW, 1995).

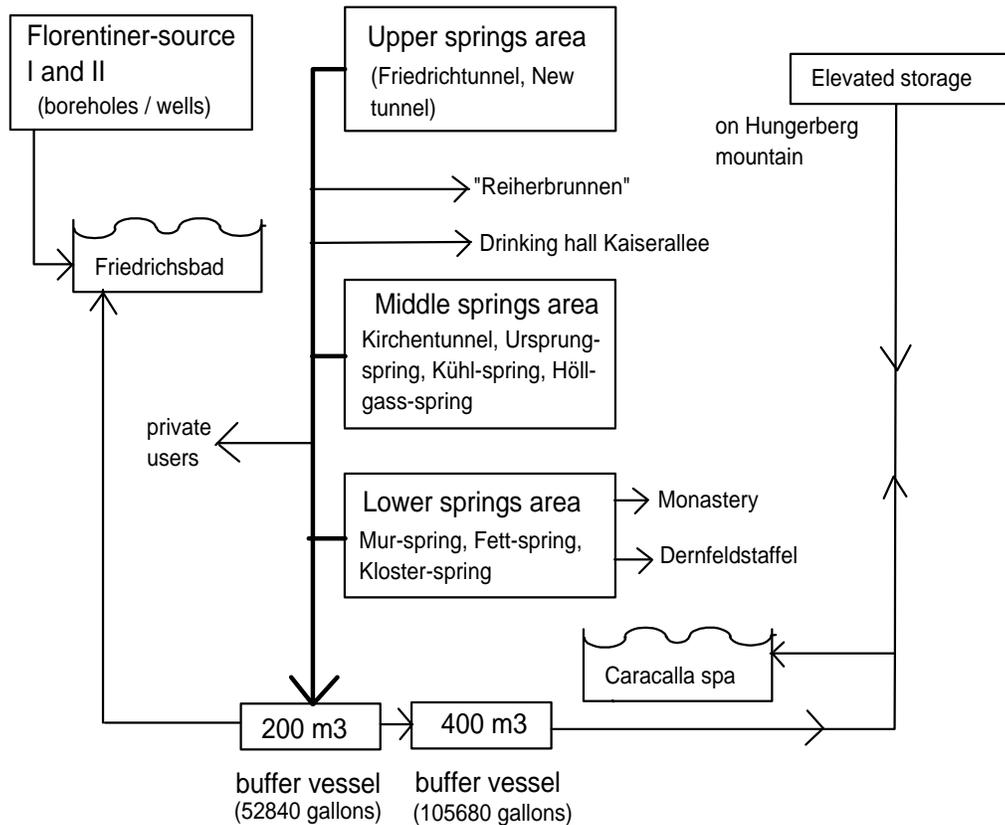


Figure 7. Schematic of the thermal water production and use in Baden-Baden, after Landesarchiv BW (1995).

Table 3. Annual Consumption of Thermal Water in Baden-Baden (after Landesarchiv BW, 1995)

Thermal Water Consumer	m ³ /yr	gallons/yr
Caracalla spa, with drinking well and part of hospital	165,244	43.7 mil.
Friedrichsbad Spa	83,621	22.1 mil.
Drinking hall at Kaiserallee	876	0.2 mil.
“Reiherbrunnen” drinking well, Sophienstrasse	3,311	0.9 mil.
“Fettquelle” drinking well, Dernfeldstaffel	1,167	0.3 mil.
Private users (hotel & hospitals)	37,931	10.0 mil.
Total	292,150	77.2 mil.

various glandular disorders can also be beneficially influenced (information from Carasana Bäderbetriebe GmbH, operators of Friedrichsbad).

The Caracalla Spa, located in the city center and opened in 1985, features a large indoor pool (32EC/90EF) with its own therapeutics area, two open-air pools (30 and 34EC/86 and 93EF), one cold and one hot water grotto (18 and 38EC/64 and 100EF), with a total area of more than 900 m² (9690 sq feet).

ACKNOWLEDGMENTS

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