



The Hot Springs of Bath: Geology, geochemistry, geophysics

A review of knowledge relating to the Hot Springs of Bath, and summary of the research and investigations commissioned by the Bath Spa Project (Bath & North East Somerset Council), 1999 – 2002, as part of the Thermal Resources Project.



Introduction

The Council's decision, in 1996, to part-fund and deliver a new spa, based on the supply of natural thermal water, made it vital to gather as much knowledge regarding the geology and mechanism of the Hot Springs in order to physically protect the source during this and other developments, and, of course, to ensure a continued, adequate supply of hygienic water for the operation of the spa itself.

For this reason, the Bath Spa Project team established a Thermal Resource Project. This was funded by Bath & North East Somerset Council, by money from the main grant supplied by the Millennium Commission for the Spa Project itself, and with a significant contribution from Hanson Quarries under the terms of the Section 106 agreement relating to Whatley Quarry.

The popular theory regarding the source of the Hot Springs of Bath is that they are composed of water that fell as rain up to 10,000 years ago on the Somerset Mendip Hills, sank to sufficient depth to be heated to over 50⁰C by geothermal heat, and finds its way up to the surface through faults in the limestone beneath Bath.

In fact, quarrying in the Mendip Hills was limited during the 20th century because of this theory, and an Act of Parliament – the County of Avon Act – was passed in 1982 to ensure that the waters were protected from any engineering development that might impact on the spring system.

The Thermal Resource Project aimed to test this and other theories regarding the source of the Hot Springs of Bath.



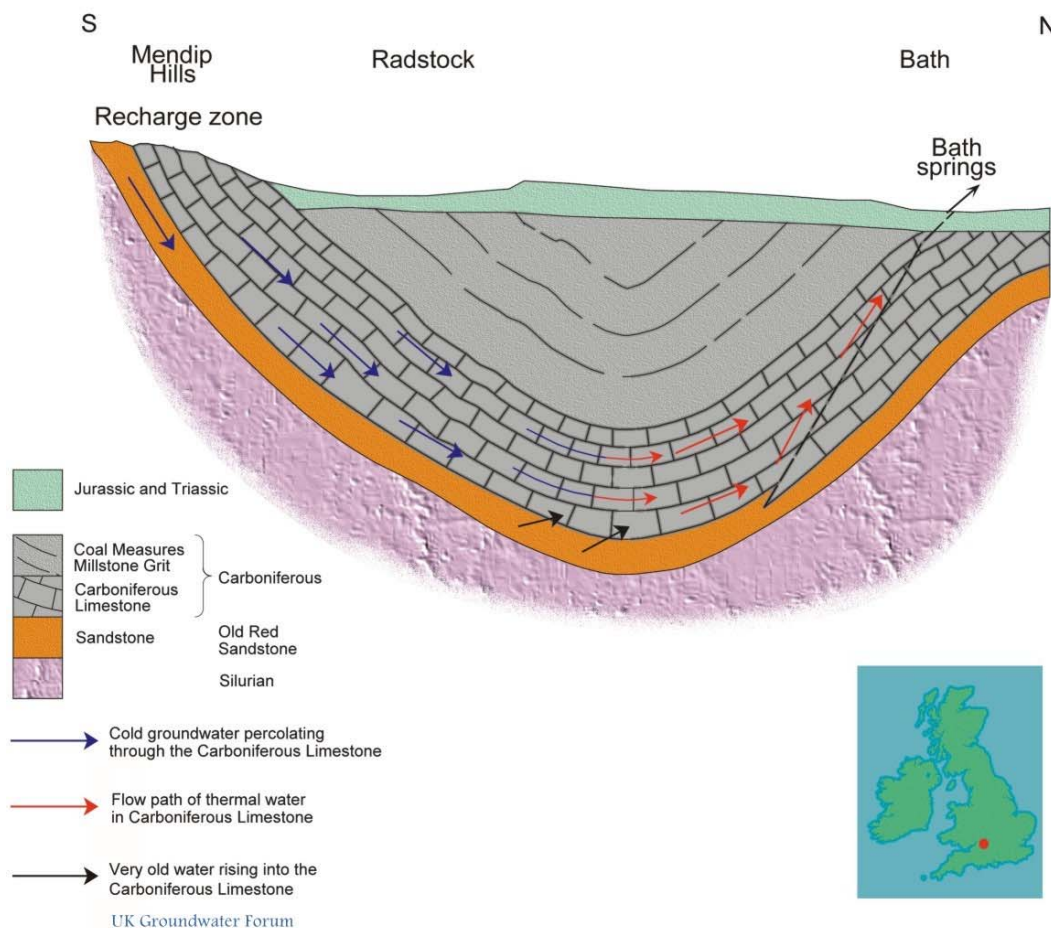
The Cross Spring prior to restoration. © Giles White

The Hot Springs of Bath: Facts

The main rock at depth beneath Bath and the surrounding area is Carboniferous Limestone. Beneath Bath itself, the limestone is concealed by younger rocks and river deposits. The Hot Springs of Bath reside in, and pass through, fractures in this limestone on the way to the surface.

There are three hot springs in the centre of Bath – the King's Spring, Cross Spring and Hetling Spring. A number of boreholes have been sunk in and around Bath as part of various investigations over the years. Water that is used for drinking or bathing at the Spa is taken from boreholes that by-pass the near-surface layers in order to ensure its purity.

This picture is taken from the UK Groundwater Forum's recent book "*Groundwater - our hidden asset*". The images were created by Chris Wordle and are copyright of the **British Geological Survey**



The Hot Springs of Bath: Facts (ctd)

The cumulative flow of the Hot Springs is 1.3 million litres each day at an average temperature of 45⁰C, most of which runs to natural waste.

The dominant flow is from the King's Spring which accounts for some 80% of the total flow of water.

Since regular measurement of the Hot Springs began, there have been only minor variations in temperature and flow rate.

The chemical composition of the spring waters has been examined at intervals for over 100 years. During that time the composition has remained fairly constant. The water contains over 42 minerals and trace elements. Those with the highest concentrations are:

- ❑ Sodium (195 mg/l)
- ❑ Calcium (358 mg/l)
- ❑ Sulphate (1015 mg/l)
- ❑ Chloride (340 mg/l)
- ❑ Bicarbonate (193 mg/l)
- ❑ Magnesium (57 mg/l)
- ❑ Silica (42 mg/l)
- ❑ Iron (0.6 mg/l)

Source	Centigrade	Fahrenheit	Flow (litres per day)	Flow (m ³ per hour)
King's Spring	45 ⁰	113 ⁰	972,000	40.5
Hetling Spring	45.3 ⁰	113.5 ⁰	86,400	3.6
Cross Spring	43.7 ⁰	110.7 ⁰	192,000	8

The Thermal Resource Project

The aim of the Thermal Resource Project was to gather as much knowledge as practicable regarding the Bath's Hot Springs system in order to better understand how to protect the source and ensure a continued, adequate supply of hygienic water for the operation of the new Spa.

The Project has achieved these aims, but, so far, has fallen short of pinpointing the exact mechanism of the Hot Springs.

At a meeting held in Bath on 12 September 2002, the Project team presented the following review of the work of the Thermal Resource Project team.

First Phase Geophysical Research

There are few deep boreholes with which to investigate the deep geology of the area around Bath, and complicated land-slips make it difficult to unravel the near-surface geology.

Therefore, for the first phase of geophysical research, a seismic-reflection survey was designed, to map the sub-surface structure of the aquifer, the Carboniferous Limestone, over an area of about 42 km² in and around Bath. The survey – tracing coherent reflectors to about 3.5 kilometres below the surface – was undertaken by IMC Geophysics in 1999.



© Giles White

One of the specially-equipped vehicles used to map the geological structure to depths in excess of 1,000 metres below Bath.

The structure of the Carboniferous Limestone was further defined using existing reflection seismic data shot during the 1980s (as part of an oil-exploration programme). This data was reprocessed to modern standards and interpreted.

In combination with the new data from the IMC Geophysics survey, an area of 1,500km² around Bath has been mapped.

The seismic data confirmed that the top of the Carboniferous Limestone dips steeply away from Bath towards the south-west, reaching a depth of at least 2.6 kilometres below Ordnance Datum (OD).

The Thermal Resource Project (ctd)

From these investigations and data, the Thermal Resource Project team extrapolated two speculative models of the springs:

A SPECULATIVE MODEL OF THE SPRINGS, 1

- ❑ The entire 480 km³ of the basin, of low porosity, low permeability Carboniferous Limestone, is the reservoir
- ❑ The reservoir is recharged from the surface outcrops of the limestone around the whole basin
- ❑ The surface water flows slowly through the reservoir via fractures, reaching a depth of over 3 kilometres and achieving a temperature of > 70°C

A SPECULATIVE MODEL OF THE SPRINGS, 2

- ❑ The hot water rises up slowly through fractures in the Carboniferous Limestone, cooling in the near-surface layers to about 50°C
- ❑ The hot water reaches a fracture system in the limestone to the west of Bath and rises rapidly along this high transmissivity path
- ❑ The hot water travels along a high permeability, fracture or (?)karstic system to the springs

Geochemical Analysis

In August 2000, as part of the Thermal Resource Project, water samples were obtained from the Stall Street borehole and the Cross Spring for geochemical analysis by the British Geological Survey.

Chemical and isotopic analyses were carried out to provide the most authoritative and comprehensive interpretation to date of the origins, age and circulation history of the thermal springs.

The British Geological Survey concluded that:

- At least 95% of the water that emerges has an age in excess of 1,000 years, and no more than 12,000 years.
- The water is most likely to be between 6,000 and 10,000 years old.
- The water may contain up to 5% of modern water (less than 20 years old) – probably derived some tens of metres below the surface.
- For the water to reach the temperature at which it emerges (45⁰C/116⁰F), it must have reached a depth of at least 2 kilometres. The maximum circulation depth of the water is estimated to be about 3 kilometres.
- The maximum temperature the water has reached is estimated to be approximately 69⁰C. The temperature loss of more than 20⁰C suggests the water follows an indirect pathway.

The Thermal Resource Project Team

The following consultants contributed to the Thermal Resource Project

Dr G.A Kellaway, consulting geologist
Professor Clive McCann, geophysical research
Professor David McCann, geophysical research
Andrew Mann, geophysical research
Professor Mike Edmunds, geochemical research
Dr George Darling, geochemical research
Dr Ramues Gallois, geological research

Further Reading

Dr Geoffrey Kellaway's book, *Hot Springs of Bath*, published in 1991 remains the most complete and authoritative study of the spring system. It also records the important works directed by Dr Kellaway from 1977 when the original Spa facilities were closed, by the City Council, to 1987 when a number of drilling operations were completed. Dr Kellaway remained as consulting geologist to the local authority until 2003. His authority and knowledge were critical in ensuring the viability of the Bath Spa Project.

Bath & North East Somerset Council: Custodian of the Hot Springs of Bath

Bath & North East Somerset Council is the custodian of the Hot Springs of Bath, under the terms of the County of Avon Act, 1982.

The responsibility for complying with this Act lies with Environmental & Consumer Services. This department tests and monitors the water issuing from the Stall Street Borehole, which is a designated 'Natural Mineral Water' under the Natural Mineral Waters Regulations 1985.

Water quality is analysed on a weekly basis. Temperature and flow-rate data is collected at 10-minute intervals by a data logging system located within the Roman Baths.

As part of the Bath Spa Project, the Council entered into a 'Water Supply Agreement' with Thermae Development Company Ltd.

Boreholes

There are a number of instances of thermal water having been encountered in wells, shafts and borings in and around Bath, from the sinking of the Batheaston Colliery Shaft in 1804, to the Lower Bristol Road sewer tunnel in 1979. The main boreholes drilled specifically for the purpose of investigating the Hot Springs are:

Kingsmead Borehole (1981)

The 112.2 metre deep Kingsmead borehole was sunk in 1981 in the public car park near the Square as part of the geological investigations that followed the closure of the Spa in 1978.

The site was chosen, in part, because of the existence of records relating to the notorious 'Pinch's Well' which was sunk by a local brewer in 1835. In this case, the borehole impacted on the flow of water in the King's, Hetling and Cross Springs, and the brewer was ordered to close it.

In 1981 the purpose of the borehole was to provide evidence as to where contaminants might have entered the Hot Springs. It showed the water to be entirely free of contamination when taken from depth, supporting the theory that boreholes beside the King's, Hetling and/or Cross Springs would enable the City to utilise the mineral water for drinking and bathing. It was not designed as a permanent source of thermal water for spa use, but is fitted with a pressure gauge and flowmeter for monitoring purposes. It was also useful in proving the sub-surface structure of Carboniferous Limestone.

Pulteney No. 1 Borehole (1982)

The Pulteney No. 1 borehole was sunk in 1982 on the Recreation Ground beneath the area now occupied by the Sports Centre.

It had been hoped that this borehole would be used to feed the swimming bath at the Sports Centre, but the water that was extracted was, at 21°C, too cold for bathing, and the saline taste unsuitable for drinking. This borehole was subsequently sealed.

Stall Street Inclined Borehole (1983)

The Stall Street borehole was sunk in 1983, to a depth of 77.46 metres alongside the King's Spring, and at an angle in order to intersect the Carboniferous Limestone at depth and avoid possible damage to the spring system. It is used to this day to supply hygienic thermal water to the Pump Room drinking fountain, and now the new Spa complex.

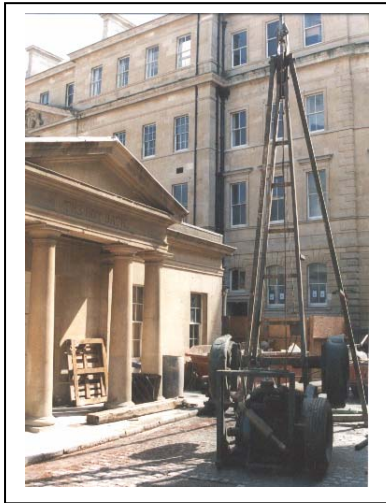
Cross Bath Inclined Borehole (1987)

The Cross Spring borehole was drilled in 1987 to a depth of 109.2 metres. It is now used to supply hygienic thermal water to the new Spa complex.

Boreholes (ctd)

Hetling Borehole (1999)

The most recent borehole – in Hot Bath Street – was sunk in 1999 to a depth of 74.85 metres, as part of the Bath Spa Project, alongside the Hetling Spring. It is now used to supply hygienic thermal water to the new Spa complex.



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