The Source of the Woodhall Spa Mineral Water

Michael Czajkowski

Abstract. For over 80 years the town of Woodhall Spa developed around a unique source of water rich in iodine and bromine, which was found during sinking of a trial coal shaft in 1821. No attempt was made to determine the source of the water, until the Spa was established and the shaft had flooded. Various published suggestions for the source of the water included a direct marine connection and origins in beds from Triassic to Upper Jurassic. Lining of the shaft has prevented direct examination. Assessment of the often conflicting documentary and well log information available, suggests a source of the Woodhall Spa mineral water, in the Kellaways Sandstone. Much unpublished material only became available with the creation of the Woodhall Spa Cottage Museum archive.

The village of Woodhall Spa lies three kilometres east of the River Witham midway between Lincoln and Boston, with the sites of the Spa Bath and various wells and boreholes within and close to the village (Fig. 1). The Woodhall Spa Bath shaft was the last of several sunk in pursuit of coal resources under Lincolnshire in the early 19th century (Czajkowski, 2001).

It was started in 1821, and was lined with brickwork for most of its 256 m depth. There was no contemporary record of the beds passed through during the excavation, and the shaft was abandoned in 1823, after additional boring had reached a total depth of 366 m. Afterwards, the shaft quickly flooded, largely due to inflow from a fissure encountered during the sinking.

The water rapidly gained a local reputation as a healing spring for gout-related illnesses and arthritis, after the overflow had supposedly cured cattle who were drinking it. This prompted the Lord of the Manor to build a small bath house, completed by 1834. Later, under the advice of Dr. A. B. Granville, author of *The Spas of England and Principal Bathing Places* (1841), he had the water analysed, and found that it was strongly saline and was unusually rich in iodine and bromine (see below, Table 4).

With the expansion of the railways, the embryonic Spa rapidly gained a national reputation for its curative properties, and by 1860 had developed into a major spa complex, around which the modern village developed. In the 1880s, increased usage and slow recharge of the spa water into the shaft prompted attempts to increase the supply by excavating horizontal adits from the shaft. After the First World War the spa water industry declined, but the Woodhall Spa Baths continued in use. The National Health Service operated the site as a rheumatism clinic, using the saline spa water until 1971, supplemented by mains water until the collapse and infilling of the shaft in 1983. Currently the site is derelict. Debris from the spa buildings were bulldozed into the shaft as fill.

Following the unexpected initial success of the original Spa Bath Shaft, other wells were sunk to obtain the mineral water. A deep bore was also drilled nearby, in a search for oil in the 1940s. These have all contributed towards resolving the conflict between the various theories on the geology of the Spa Bath Shaft and the source of the Woodhall Spa mineral water.

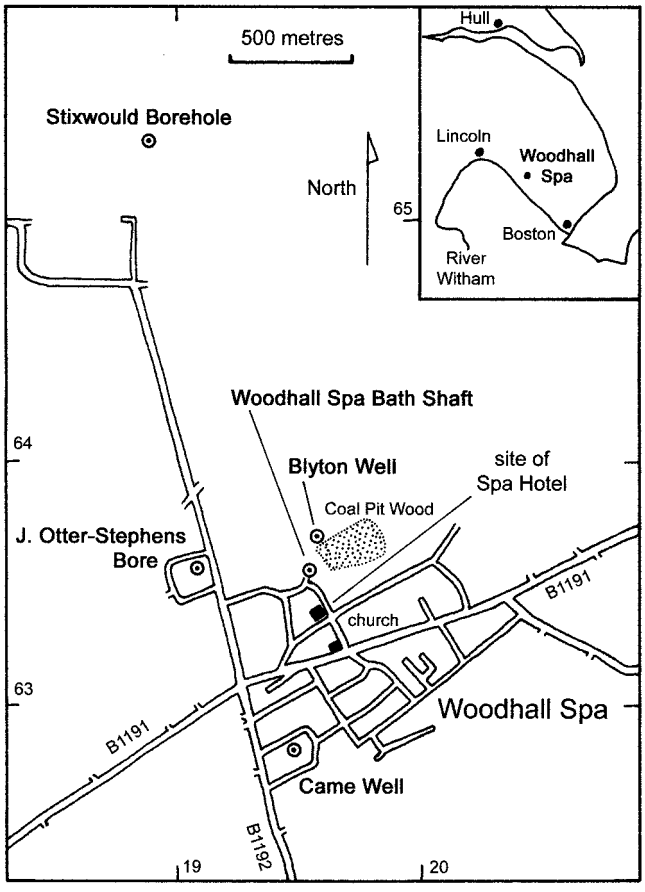

Figure 1. Locations of the shafts and boreholes referred to in thetext, in relation to the modern village of Woodhall Spa.

The Woodhall Spa Bath Shaft

The original shaft

This lies on the north side of the village (at NGR 197636, 8.6 m OD; Fig. 1). The earliest published record on it is from Granville (1841), who gave the depth of the well shaft as 280 yards, which was then bored for a further 120 yards (365.8 m in total). He stated that the source was "a brine spring encountered at about 170 yards" (155.5 m), and also that "17 or 18 feet is through a soft freestone rock from whose surface brine-water has been seen to percolate constantly". It was this water that became the Woodhall Spa mineral water.

Granville seems to have been a careful researcher and when he visited the Woodhall Spa Baths in 1838-39, presumably to gather material for his book, stimulated Mr Hotchkin, the Spa Bath owner, to have the water origin investigated and analysed. Two statements by workmen (Belton and Cheeseman, 1839), who worked to contain the flooding, were recorded at that time.

Cheeseman stated that the shaft was 303 yards deep (277 m), and the base of the source rock was at 180 yards (164.6 m). He also stated that water oozed from every part of the source rock, but especially from a deep fissure, the water flowing east-west, and "This rock which was a soft spongy grey stone and easily cut with a knife, in fact it kept continually falling in masses into the shaft during the operation and is 18 yards thick". The source rock section of the shaft was lined with cemented brickwork, and a conduit was built to convey the water around the back of the shaft. lining. At this stage, the shaft was a coal exploration venture and the water was not welcome.

Belton confirmed the depth at which the brickwork commenced and that they built it upwards for 18 yards (16.5 m). He gave the direction of the fissure of SE by E to NW by W (on a bearing 034°).

The Geological Survey's Lincoln Memoir (Usher *et.al*, 1888) gives an account of the Spa Bath Shaft, mentioning Granville, with an interpretation of the geology by Jukes-Browne (Table 1). The depth of 1,020 ft seems to originate from Skertchly (1877), who agrees with Granville on the depth of the spa water source, but published a total depth of 1,020 feet which was later conceded by Jukes-Brown to be a possible misprint for 1,200 feet (Well box 115/27). However, Jukes-Browne concluded that "the spring of saline water issued at a depth of 530 ft. and therefore appears to be in the Inferior Oolite" (*of which the Lincolnshire Limestone forms the main part*). The shaft was lined with brickwork to this depth.

	feet	m
Gravel and boulder clay	10	3
Kimmeridge and Oxford Clay	350	106
Kellaways Rock, blue clays, Cornbrash limestone, Great Oolite Clay and Limestone, Upper Estuarine	140	43
Lincolnshire Oolite and Northampton Sands	140	43
Lias, (Upper, Middle and Part of the Lower)	380	116
total	1020	311

Table 1. Geological log of the Woodhall Spa Bath Shaft by Usher *et al.* (1888).

These memoirs were written before the sinking of the other spa wells. With today's information on the deep geology of Lincolnshire, the rocks of the Woodhall Spa Bath Shaft might have been recorded differently. It is unfortunate that it is the Survey's conclusions that have been quoted in later publications.

When exploration for coal was abandoned, the flooded shaft became the spa water source. Flow rates were soon insufficient to satisfy demand for the developing Spa Baths, and storage tanks holding 156,640 gallons (712 m^3) were built to store water abstracted over the winter when the baths were closed. Some indication of original flow derives from the fact that Cheeseman and his colleagues were able to dig some distance below the fissure before they started to line the shaft and construct their conduit. It is possible that the water flow was a considerable nuisance near the limit of their pumping ability rather than the cause of any serious flooding, and they decided they had to solve the problem before digging deeper.

The deep adits

The inflow was measured in December 1886 at 1000 gallons per day (about 4500 litres per day, or less than a gently flowing tap), at the time when ways of increasing the flow were being discussed. This resulted in breaking through the brickwork built by Cheeseman and Belton and excavating adits (roughly horizontal tunnels) at the level of the supposed fissure (Well Box 115/27). Woodward (1904) mentions that the well "yealds 1100 gallons per hour", but this probably refers to abstraction rather than natural flow. Natural recharge after the adits had been partly excavated is estimated at about 1300 gallons (5910 l) per day, based on water levels during non-abstraction in February 1897.

It is these surveys concerning the depth and digging of the adits that supply most of the information on the actual geology of the well and the nature of the source rock. Drilling holes in the brickwork described by Cheeseman and Belton suggested that all the water came from rock situated between about 504 and 528 feet (154 - 161 m) from the surface (Hill, 1889).

By 1888 the initial adits had been dug with their ceilings at a depth of 520 ft (158.5 m), and their entrances cut through the cemented brickwork which Cheeseman stated extending down to about 540 ft (165 m). Earlier correspondence from Latham, one of the surveyors, had suggested that the

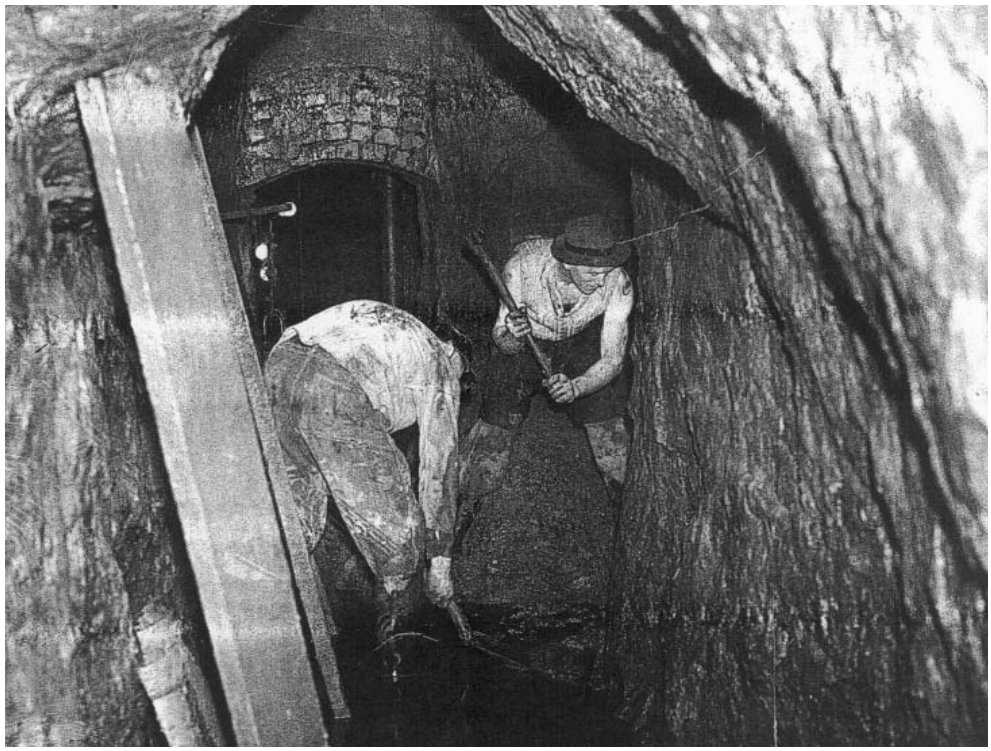

Figure 2. Clearing out the Spa Bath Shaft adits in the winter of 1952-3. (Woodhall Spa Cottage Museum)

source of the water was in the Kimmeridge Clay, but Whitaker, who wrote a report in 1898, probably with Jukes-Brown's survey in mind, suggested the Lincolnshire Limestone and associated beds formed the source. However, Whitaker was concerned with discrepancies between his observations and those of Jukes-Brown. After correspondence, Jukes-Brown admitted some amendments to his depths and thicknesses of the strata published in the Lincoln Memoir. Though his corrections complicate, rather than resolve, the situation they illustrate the difficulties experienced by these early surveyors.

Wilson (1899) surveyed the well in 1899 claiming to give the first accurate measurements of the shaft (Table 2). The adit entrances were 5 ft. 6 ins (1.7 m) high. Wilson also concluded from drilling 70 holes through the cemented brickwork that most of the water from the 'spring' entered the adits from between the floor of the northeast adit and 10 feet (3 m) above (presumably the adit top). He referred to only minor flows from the top and base of the underlying 7 ft. 11 ins. thick rock layer, but no water emanated from within that rock layer.

	feet	m
surface to the floor of the adits	506 ft 6 in	154.38
beneath which is		
cemented brickwork	10	3.05
rock	7 ft 11 in	2.41
un-cemented brickwork	20	6.10
rock**	24	7.32
alternating brickwork and rock to	750	229

Table 2. Log of the Woodhall Spa Bath Shaft by Wilson (1899). **His written report states 24 ft. for this layer, but his accompanying section shows the layer only 12 ft. thick.

This report gives the adit position as 19 feet (5.8 m) higher then that given by other surveyors. In 1889 Hill surveyed the depth of the Spa shaft as 786 ft, having measured the depth below the adits and adding it to Wilson's adit depth. Unfortunately the inconsistency between Wilson's plan and report must produce a question mark on these measurements. Adding 5.8 m to Hill's measurements gives 245.5 m, and natural infilling plus adit spoil could easily make up the rest of the shaft depth recorded by Granville (1841) of about 840 ft (256 m). The borehole drilled 120 yards (110 m) beneath that, would have been easily filled and not subsequently measured.

From 1889 to 1953 (Adit reports) extension and cleaning of the adits continued, in order to find more productive areas of flow and collect brine-rich mud, which was used in a hot poultice treatment called “fango”. The adits were easily excavated with pick and shovel, though there is the occasional reference to dynamite. The adit report of 1906/07 mentions that after tunnelling for 80 ft (24 m) along and upwards in a SSW direction they came up against a hard blue rock.

Many local people went down the well at the time of the last clearance in 1953, and John Sowerby reported (1992, pers. com.) that “the adits were roughly hewn out of the soft, grey, sandy rock, and there was a sizzling noise as the water slowly seeped in”. A photograph taken at this time (Fig. 2), shows

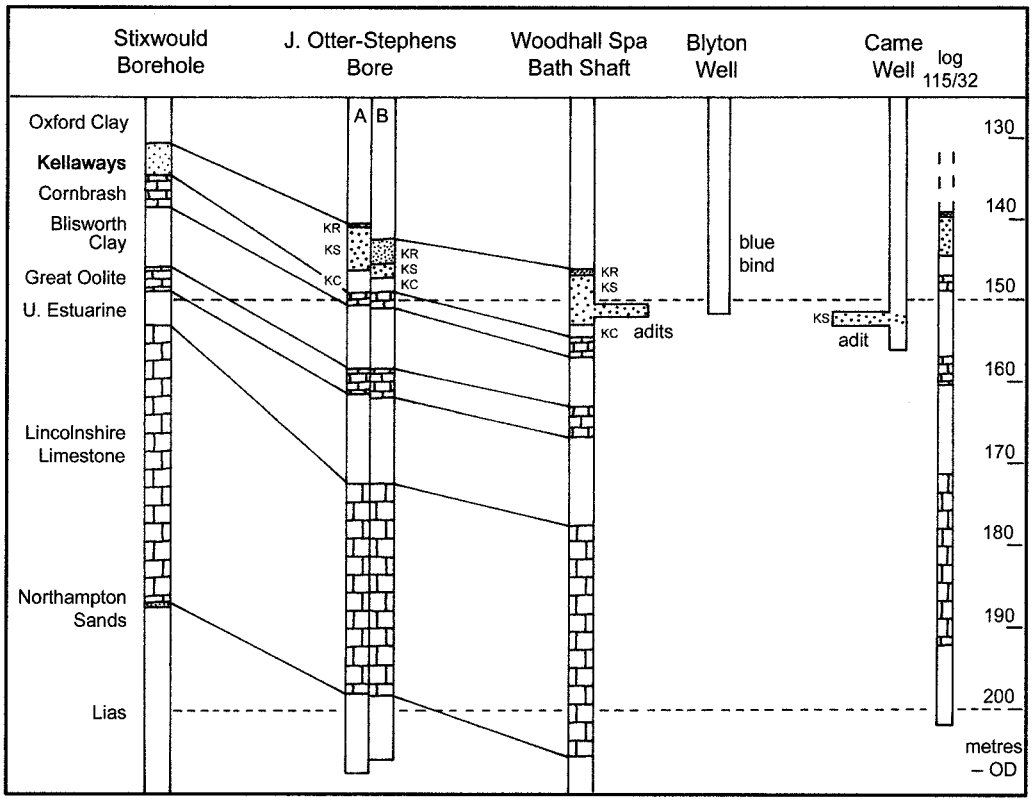

Figure 3. Logs of the boreholes and shafts around Woodhall Spa. The Kellaways may be divided into an upper rock unit (KR) above a sandstone (KS) above a clay (KC).

how the rock was easily working by pickaxe. This suggests that it is not in any limestone, including the Lincolnshire Limestone, of the Inferior Oolite, as indicated by Jukes-Brown.

The J. Otter-Stephens Bores

In 1897-98, J. Otter-Stephens, the secretary of the Woodhall Spa Company, commissioned a borehole to find an additional source of spa water. This bore was sited 300 m west of the Spa Bath Well (at NGR 191636, 4.9 m OD) (Well box 115/31).

Whitaker (Well box 115/27) commented that the rock samples extracted were reduced to a state of a sort of coarse sand. A log of the Otter-Stephens bore was published by Woodward (1904) and is shown as log A in Figure 3. A trickle of water was found at a depth of 490 ft. (149.3 m) in "a sandstone with iron pyrites" (Conway-Walter, 1905). This is most likely the horizon for the spa water, the higher level being accounted for by the regional dip.

A similar unpublished log (in the B.G.S. Well box), was prepared by Isler & Co., and dated 'about 1900' (log B in Fig. 3), but its location and datum are not recorded. Above the Upper Estuarine beds it gives depths slightly different to those in log A (Table 3), though below that they are nearly identical, suggesting that this is probably the same bore (Well box 115/31A). It appears that two shafts were sunk, because the first one was abandoned after the loss of the head gear when it was 91 m deep. This may explain the existence of two different but comparable logs (Well box 115/31). Whitaker's comments on the extracted rock samples suggest that measurement of the boundaries may not have been precise. Either log may be correct. Data on the Kellaways beds from log A fits better with the records from the Woodhall Spa Bath Shaft, and is therefore probably the more reliable.

Log A	ft. in		Log B	ft. in
Kellaways Rock	1 6		sandstone	9 0
sandy blue clay of Kellaways Sands	17 6		sandy blue clay	5 6
Kellaways Clay	6 6		Kellaways Clay	4 6

Table 3. The two logs of the J. Otter Stephens bores.

The Blyton Well

Woodward (1904) quotes a well log, his No. 4, described as "200 yards north of the Spa Hotel", also known as the Victoria Hotel and now demolished. Local legend suggests that this well was situated a few metres northeast of the Spa Baths, near the corner of Coal Pit Wood (close to NGR 195636; Fig. 1). The well was sunk by Mr Blyton, a local entrepreneur, in about 1877 (Conway-Walter, 1905) to create a rival to the Spa Baths.

It is recorded as 520 ft (158 m) deep, with the last 120 ft (37 m) described by Woodward as "blue blind, with beds of sandstone from 2 to 3 feet thick, and 12 to 14 ft apart", which he labelled as "Kellaways Beds, Cornbrash" etc. The position of the well close to the Spa Baths Shaft suggests that it

might have reached the Kellaways beds, but most of the sandstone beds appear to be those in the lower part of the Oxford Clay, as in the Stixwould bore, or may be large nodules.

The Came Well

This well was dug (at NGR 195628, 8.2 m OD, Fig. 3) to supply spa water for R. A. Came's own spa at his Royal Hotel. It had reached 240 ft (73 m), when recorded by Woodward (1904), still within the Oxford Clay. On completion in 1905, adits were excavated with their roofs at 158.8 m depth. These were 1.8 m high, draining into a sump 2.7 m below.

The well yielded a good supply of spa water chemically similar to the Spa Baths, especially with respect to the iodine and bromine contents, suggesting it was from the same source (Table 4). The source rock was described by S. V. Hicks, the successor to the Came estate, as a "spongy sandstone, the yield slow, the water oozing out through layers of rock" (Well box 115/32). Conway-Walter (1905) recorded "water struck in soft spongy stone at 492 feet" (150 m), but gives shallower depths than Hicks for the other measurements. Conway-Walter used second-hand information, while Hicks, as the trustee of the Came estate, could refer to the well sinkers' records. Hicks' information should be more reliable. A sample of rock supposedly from this aquifer, examined by the Geological Survey in 1934, was recorded by "C.W." as "bluish crumbly sandstone with a belemnite" and "certainly Kellaways sandstone" (Well box 115/32).

These depths in the Came Well suggests that the adits were probably cut at the base of the Kellaways Sand, slightly below the level of the Spa Bath Well adits (which were cut first by trial and error), possibly to obtain the maximum drainage from the source rock. The adits are probably floored by the Kellaways Clay, with the sump in the Kellaways Clay, though water may have been lost if this had entered the Cornbrash, as its depth could imply, and was not subsequently backfilled.

Among the data for this well is a copy of a log titled 'Woodhall Spa', which has the Geological Survey reference number 115/32, the same as that used by the Survey for the Came Well. This was found in a series of papers given to the Woodhall Spa Cottage Museum archives in 1999. It cites the same location as the Came well, but at an altitude of only 6 m, while the Came well is at 8.2 m. This log is included on Figure 3 for comparison, but it is difficult to reconcile it with other data, and it must be considered suspect.

The Stixwould Borehole

In 1944, the D'Arcy Exploration Company drilled a series of boreholes in the hope of finding exploitable reserves of oil. These included the Stixwould Well No. 1 (at NGR 188653, 7.6 m OD, Fig. 1). The upper part of this log is included in Figure 3.

Swinnerton and Kent (1976) record different depths in the Stixwould borehole. They quote about 200 feet for the Amphill Clay, while the D'Arcy log shows 166 ft for this and possible the Kimmeridgian. They cite 249 ft for the Oxford Clay while the log shows 261 ft, and they have 21 ft of Kellaways beds while the log records only 13 ft. They also commented on the regular development of the Kellaways beds throughout Lincolnshire, where they are rarely less then 25 ft or more than 35 ft thick (Swinnerton and Kent, 1949). Kent would certainly have known about the Stixwould bore since he worked for D'Arcy Exploration, who sunk the well, and data on the Jurassic rocks in the boreholes was published by Lees and Taitt (1946).

The figures from Swinnerton and Kent (1949) make the depth to the Kellaways about 478 ft (146 m), when surface gravels are included, rather then the 456 ft (139 m) given in the D'Arcy log. The lower depths would fit better with data from the other wells, but the Stixwould bore is further from the others, so differences may be due to undulation and bed thickness variations. The regional dip is about 1 in 75 almost due east.

The borehole record was based on mud samples and drilling rates only, since electric logging was not then in use (Field, 1989). We might speculate that Kent had had access to unpublished information in 1949, but his sources are not recorded. The data in Figure 3 is therefore based on the D'Arcy well log.

Geology of the Woodhall Spa Bath Shaft

A best assessment, based on evaluation of the various records, of the geological sequence within the Spa Baths Well is shown in Figure 4.

Measurements of the rock and brickwork by Wilson (1899) correlate better with the other borehole data when added to Whitaker's adit depth measurement of 520 ft (158.5 m). His 7 ft 11 ins (2.4 m) of exposed rock beneath the cemented brickwork, is then most likely to be the Cornbrash. The 20 ft (6 m) of uncemented brickwork beneath passes through the Great Oolite (Blisworth) Clay, and the rock layer below is the Great Oolite Limestone. This suggests that the thickness of 12 ft shown on Wilson's sketch is correct, and not the 24 feet given in his report. Wilson's measurements for the thinner beds are probably more reliable, since these would be easier to measure than the full depth.

The reference by Belton and Cheeseman (1839) to encasing '18 yards of soft spongy rock', within the Spa Bath Shaft, has often been interpreted as referring to a thicker rock (such as the Upper Estuarine Series between the Great Oolite and the Lincolnshire Limestone), or as a misprint for

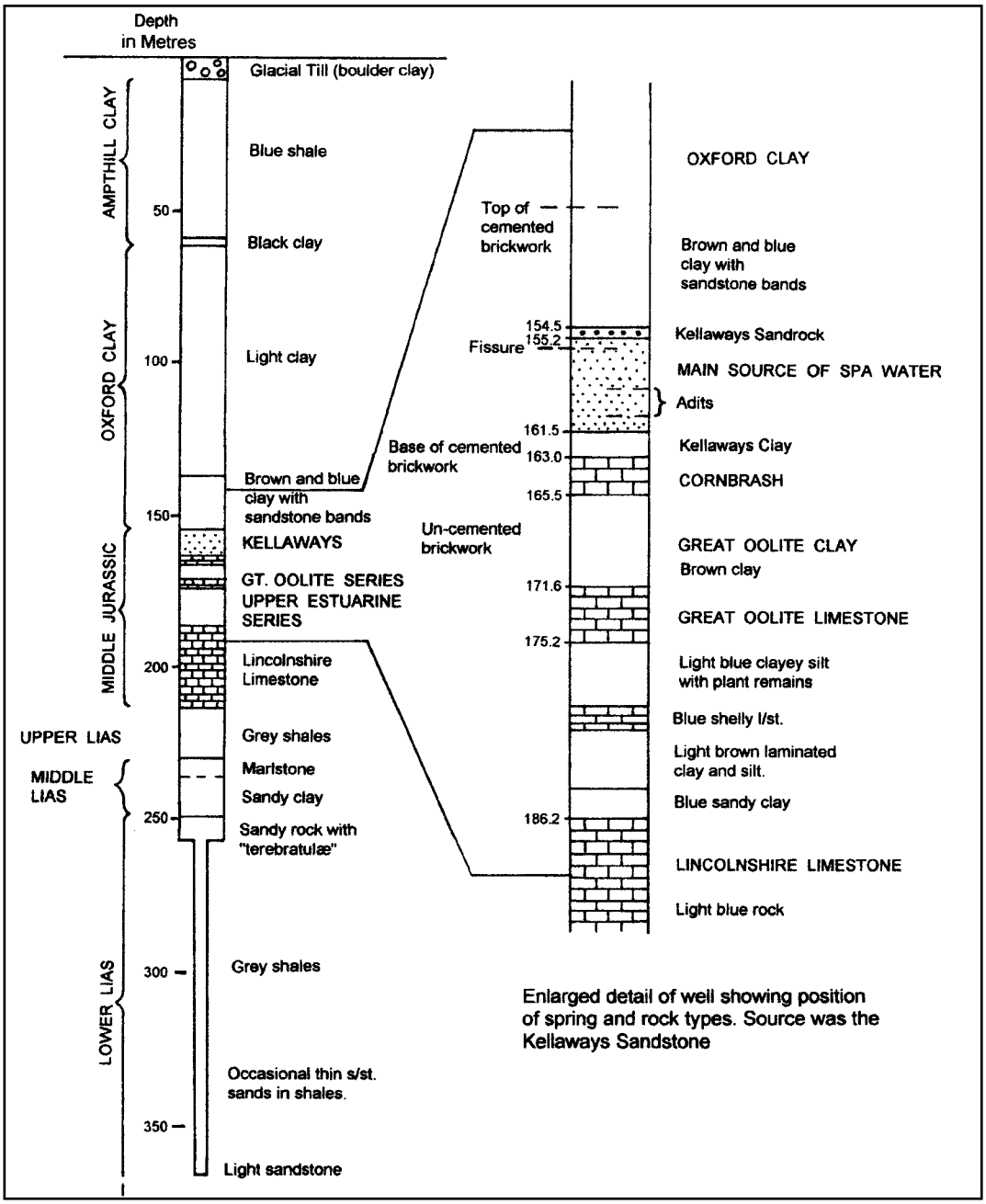

Figure 4. Geological log of the Woodhall Spa Bath Shaft. The narrow lower part is the bored hole, while the upper part is the excavated shaft 2.4 m in diameter.

Granville's '18 feet', despite the clarity of the hand-written statements. It is likely that this refers to the lining through more than one bed. The well sinkers would not have worked higher than necessary, but would have sealed anything that was producing a flow. This could include silty sandstones within the lower Oxford Clay, as described in the Stixwould and Blyton bores. The well sinkers worked upwards with speed and probably in poor light to prevent further flooding, and started from the solid ledge afforded by the Cornbrash, thus also encasing the Kellaways Clay. This is more logical then lining through hard limestone such as the Cornbrash, which Wilson states only yielded a minimal flow of water. If the Cornbrash was covered within the 18 yards of cemented brickwork, it would probably have been remembered and described as a distinct interruption to the normal friability of the source rock, that is mentioned in their accounts.

The water noted by Wilson (1899) entering from up to 10 feet (3 m) above the adits in the Spa Baths Shaft suggests that the aquifer extends upwards to at least that level. This confirms Granville's description (1841) that the source was about 170 yards (155 m) deep, and the hard blue rock encountered when digging the adits in 1906/7 was probably the Kellaways Rock. This would allow a thickness of about 6 m for the Kellaways Sand as the source rock, with 1.5 m of Kellaways Clay beneath, above the Cornbrash exposed beneath the cemented brickwork. Granville's thickness of 17 to 18 feet

(5.2-5.5 m) for his source rock is a reasonable approximation to this, in view of the fact that he obtained the data from men employed to fix the pipes to pump up the water and not by direct measurement. Granville discusses only the source of the 'spring' (1841), and not other beds that might occur behind the cemented lining.

It would appear that Granville's description is essentially correct,and the source rock for the spa water was the Kellaways Sands. In Figure 4, the depths to beds beneath the Lincolnshire Limestone are taken from the Stixwould bore.

The source of the spa water

A number of analyses of spa water are quoted in the literature. Pre-1920 analyses are reported as a hypothetical mixture of salts which, if dissolved in water, would produced the observed chemistry. Such presentation is completely artificial, and the analyses have been recalculated as individual ions, and presented in Table 4. Most refer to the Spa Bath Shaft, but there is one analysis of water from the Came Well. The analysis quoted by Edmunds et al (1969) appears be of a sample collected in 1953 when the Spa Bath Shaft was last cleaned out.

All the spa water analyses show elevated concentrations of iodine and bromine. A comparison with the composition of average seawater (Table 5) shows that Na/Cl and Br/Cl ratios are close to those of seawater, whereas there is an iodine enrichment of two orders of magnitude in the spa groundwater. Although the high bromine content is probably a reflection of the high salinity of these groundwaters, possibly derived from mixing with old formation waters within the Kellaways Sand, the high iodine concentrations cannot be explained by simple mixing. Iodine enrichments relative to seawater are not uncommon in British aquifers and both the Chalk and the Lincolnshire Limestone have enhanced iodine concentrations. The source of iodine is thought to be associated with the breakdown of marine-derived organic matter (Edmunds et al, 1989).

chemical ratio	Na/Cl	Br/Cl	I/Cl
Spa Bath Shaft water	0.51	0.0035	0.00042
Seawater	0.55	0.0034	0.000003

Table 5. Comparison of the Spa Bath Shaft water with seawater. Average values of 7200 Na, 14000, Cl, 5.9 I and 50 mg/l Br have been used, against the values for average seawater given in Table 4.

The composition of groundwater from the Came Well differs slightly from that of the Spa Bath Shaft. Although bromine and iodine concentrations are still high, the overall salinity is reduced, and calcium and sulphate concentrations are higher. It has already been suggested that the Came Well adits were cut slightly below the Spa Bath Shaft adits at the base of the Kellaways Sand, and the chemical differences may reflect mixing with groundwaters of slightly different composition. Iodine occurs mainly as iodate (IO3) in oxidising groundwaters. The presence of ammonia and dissolved iron in some of the analyses, and the faint smell of H2S reported in the Lincoln memoir (Usher *et al*, 1888), suggest that these waters are reduced, and that iodine will be present as iodide.

Acknowledgements

The author is grateful to the British Geological Survey for access to well logs and notes from their various well

source	WSBS	WSBS	WSBS	WSBS	Came Well	WSBS	WSBS	seawater
analyst	Frankland	Wright	Wanklyn	Frankland	Trotman	Thorpe	?	average
date	1874	1883	1886	1891	1908	1911	1953	
reference	Skertchley	Ussher	Woodward	Woodward	Luke	Luke	Edmunds	
Na		6 089	6 907	7 693	5 712	7 245		10 500
K		46		9		28		380
Ca		549	571	555	1 285	544		400
Mg		280	329	301	230	156		1 350
CO_3		68	86	116	135			
Cl	14 250	11 114	14 141	13 514	11 569	14 246		19 000
SO_4		112	3	79	1 857	68		2 700
I	8.8	5.2	5.6	5.7	12.0	5.9	6.0	0.06
Br	63	50	49	47	57	34	38	65
SiO_2		2.6		8.5	28.0	9.8		6.4
iron etc		1.3	tr	2.9	19.0	5.3		0.1
NH_3	8.1	6.0		9.4				
tds	23 612	20 200		22 624	20 851	22 325		

Table 4. Analyses of the Woodhall Spa water. All figures are given as mg/l; tds = total dissolved solids; tr = trace; WSBS = Woodhall Spa Bath Shaft.

boxes and for helpful advice, to Prof. John Mather for advice on the water chemistry, to B. Osbourne for the Came Well water analysis, to John Sowerby and G. Overton for local information, to David Robinson for advice and data from his personal reference collection, and to Woodhall Spa Cottage Museum for access to unpublished research material.

References

Adit reports, 1889-1953. Various annual reports on extending and clearing out the Woodhall Spa Baths adits. Woodhall Spa Cottage Museum Archives.

Belton and Cheeseman, 1839. Workman's statements, 6th and 7 October, 1839. Bundle of papers from Hotchkin family. Woodhall Spa Cottage Museum Archives.

Conway-Walter, J., 1905, *Records of Woodhall Spa and Neighbourhood*, W. K. Morton, Horncastle.

Czajkowski, M.J., 2000. The Kirkstead (Woodhall Spa) Coalfield. *Lincolnshire History and Archaeology*, **35**, 50-56.

D'Arcy, 1944. *Stixwould Well No. 1, Log from the Triassic upwards*. D'Arcy Exploration Co. Ltd (British Petroleum Developments), unpublished.

Edmunds, W.M., Taylor, B.J. and Downing, R.A., 1969. Mineral and thermal waters of the United Kingdom. *Report of 23rd International Geological Congress, Czechoslovakia (1968), Proceedings Symposium 11, Mineral and Thermal Waters of the World*.

Edmunds, W.M., Cook, J.N., Kinniburgh, D.G., Miles, D.L. and Trafford, J.M., 1989. Trace-element occurrences in British groundwaters. *British Geological Survey Research Report*, SD/89/3.

Field, M., 1989. (British Petroleum. Exploration) *Pers. comm*.

Granville, A. B., 1841. The *Spas of England and Principal Bathing Places*, H. Colburn, London.

Hill, W., & Co., 1889. Report and correspondence to the secretary of the Spa Baths, September and December 1889. Woodhall Spa Cottage Museum Archives.

Lees, G. M. and Taitt, A. H., 1946. The geological results for the search for oilfields in Great Britain. *Quarterly Journal Geological Society*, **101**, 255-317.

Luke, T.D., 1919. *Spas and Health Resotrs of the British Isles*. A & C Black, London

Skertchly, S.J.B., 1877. *Geology of the Fenland*. Memoir of the Geological Survey, H.M.S.O..

Swinnerton, H.H., and Kent, P.E., 1949. *The Geology of Lincolnshire*, Lincolnshire Naturalist Union, 1st. edition.

Swinnerton, H.H., and Kent, P.E., 1976. *The Geology of Lincolnshire*. Lincolnshire Naturalist Union, 2nd. edition.

Ussher, W.A.E., Jukes-Browne, A.J., and Strathan, A., 1888. *Geology of the Country around Lincoln*. Memoir of the Geological Survey, H.M.S.O..

Well box 115/27. Various notes, correspondence and map tracing relating to the Woodhall Spa Bath Well. British Geological Survey.

Well box 115/31. Various notes relating to J. Otter-Stephens well log recorded in *Water Supply of Lincolnshire*, (1904). British Geological Survey.

Well box 115/31A. J. Otter-Stephen's well log from C. Isler & Co., received November 1939. British Geological Survey.

Well box 115/32. Various notes relating to the well sunk by Richard Adolphus Came in 1904-5. British Geological Survey

Wilson, G., 1899. Sketch of Spa Bath Well and report, 9th November 1899. Woodhall Spa Cottage Museum Archives.

Woodward, H. B., 1904. *Water Supply of Lincolnshire from Underground Sources*. Memoir Geological Survey, H.M.S.O..

Michael Czajkowski,
96 Tor O Moor Road,
Woodhall Spa LN10 6SB.