Investigating the site of Newton's laboratory in Trinity College, Cambridge

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'Mr Newton intends not to publish anything, ... and prosecutes his Chemical Studies and Experiments.'[32]

IT IS NOT GENERALLY KNOWN THAT OVER THE course of some thirty years, Isaac Newton carried out around four hundred chemical experiments in a private laboratory located in the walled garden immediately below his rooms in Trinity College, Cambridge. The exact location of his laboratory has long been a source of conjecture and this article describes a survey undertaken to determine both the possible site of the laboratory as well as that of the rubbish pit in which Newton would have disposed of the waste materials generated in his chemical experiments. The results are believed to be of sufficient interest to justify continuation of the investigation.

Historical background

Newton the laboratory chemist

Isaac Newton (1642–1727) was a man of the most extraordinarily diverse interests — a member of that tiny band of scholars such as da Vinci and Goethe who were active and creative in a wide variety of fields. He is of course principally remembered for two great works, both of which are widely recognized as landmarks in the history of Western science: his *Philosophiæ Naturalis Principia Mathematica* ('the Principia'), published in 1687, and the *Opticks*, published in 1704. In the former work, Newton demonstrated his incomparable ability as a theoretician, while in the latter he provided indisputable evidence of his remarkable skill in conceiving, planning and carrying out a set of original experiments relating to the '*Reflections, Refractions, Inflections and Colours of Light*', as the subtitle of the work states.

Newton's great achievements in mathematics and physics have tended to so overshadow his other scholarly activities that the traditional accounts of his life have, until recently, made comparatively little mention of his intense interest in alchemy, chronology, biblical prophecy and theology. However, both the contents of his library of several thousand volumes and his extensive manuscript legacy provide powerful evidence of the intensity and depth of his interest in what would today be classified — even dismissed — as esoterica.

Even less well known than Newton's interest in the 'non-scientific' areas mentioned above is his performance during much of his thirty-year period in Cambridge (1666–1696) of a long series of frequently complex chemical experiments. The written records of these commence in 1678 and end in 1695, not long before Newton moved to London to take up the post of Warden of the Royal Mint. However, as he had purchased chemicals and apparatus as early as 1669 — and perhaps even as early as 1665, when he was a young man of 23 — Newton's period as a practising chemist in Cambridge must in fact have extended over the much longer timespan of thirty or more years. Detailed study of these experiments is just commencing and it is not yet clear in what way they related to his preoccupation both with alchemy and his longstanding interest in matter theory as a whole. There can be no doubt, however, that this experimental work was carried out with extraordinary diligence and attention to detail.

The manuscript accounts of Newton's experimental work in chemistry, recorded in a small leatherbound notebook[1] and a set of some 50 loose sheets of paper,[2] are to be found in the University Library, Cambridge, having been donated to the university in 1888 by the 5th Earl of Portsmouth, to whom they had descended via Newton's niece, Catherine Barton. Although these experiments, some 400 in number, have not as yet either been published in full nor described in detail, they have been discussed in general terms by the Halls[3] and Spargo,[4] as well as by some of Newton's biographers such as Westfall.[5] However, what is clear from even the most cursory examination of these records is that Newton had at his disposal in Cambridge a well-equipped laboratory where he performed a wide variety of chemical experiments using apparatus such as furnaces, retorts, egg-glasses, fire-shovels, funnels, crucibles, glass 'phials', and a diverse set of materials, including metals such as antimony, bismuth, iron, copper and lead, and reagents such as oil of vitriol (sulphuric acid), *aqua fortis* (nitric acid), fullers earth and vitriol [copper(II) sulphate].

Every chemical laboratory has always produced significant quantities of waste materials: broken glassware and earthenware (retorts, flasks, containers, etc.), cracked crucibles, unused or spent reagents, solid or liquid reaction products, etc. Newton's laboratory would undoubtedly have been no exception and in fact the records of his experiments contain numerous references to accidents in his laboratory: 'I broke my egg-glass by y^e volatile stiptick vitriolick salts w^{ch} arose in the digestion'[6]; 'Upon letting y^e glass fall and breaking it, the liquor spurtled like molten pitch or antimony & some of it (by reason of its fluidity) ran into round globules'[7]; '& afterwards began to boyle though not so much as before & y^n y^e glass broke'[8]; 'In a new crucible I melted'.[9]

It is worth noting that the charcoal-fired furnaces used so extensively by Newton in his chemical work would not in fact have produced much waste material, as one of the characteristics of laboratory charcoal, which was usually produced from hardwoods such as oak, is that when used as a fuel it generates only a very small quantity of ash — as opposed to coal, which, depending of course upon its quality, frequently produces a substantial amount of ash.

Seventeenth-century chemical laboratories

While we possess a number of descriptions, both in printed and manuscript form, of the design and equipment of the chemical laboratories in use in the period before 1700, our knowledge of the actual locations of such early laboratories, as well as examples of the laboratory artefacts which have survived from that period, is distressingly small. There are in fact no more than a handful of published descriptions of such locations and their associated apparatus,[10–14] and therefore any site which is strongly associated with a pre-1700 laboratory is not only of intrinsic historical importance but clearly also merits the most serious consideration with respect to excavation. Such is the site of Newton's chemical laboratory at Trinity College, Cambridge.

The site of Newton's laboratory

That assiduous Victorian collector of information on Newton's life, Joseph Edleston, records that in October 1667, when Newton was still a Minor Fellow of Trinity College, he was allocated a room known as the 'Spirituall Chamber'.[15] We are still uncertain as to where this was located — or even whether Newton ever actually occupied the room. However, there is little doubt that near the end of 1673 he moved into the chambers he was to occupy, first shared with fellow undergraduate John Wickins and then alone, until he left Cambridge for London in 1696. These were the rooms on the first

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floor of the range lying between the Great Gate and the chapel, that is, immediately to the north of the Great Gate of the college (Fig. 1).[16,17] The wonderfully detailed set of engravings of Cambridge buildings made by David Loggan and published in 1690 fortunately includes one of Trinity College viewed from the east, providing us with a sharply focused picture of the appearance of this part of the college when Newton was living there (Fig. 2).[18]

Projecting from Newton's set of first-floor rooms was a wooden loggia containing a staircase which provided direct access to a fairly substantial — and noticeably well tended! — garden immediately below his rooms. As one can see from Loggan's engraving, the privacy of Newton's garden was ensured in that not only was it surrounded by a high wall but it also could not be entered from the ground floor of the range. A noteworthy feature of this neatly laid out garden is the pump in the corner near the staircase and which was presumably the source of the water required by Newton in his chemical experiments.

Fig. 1. Ackermann's 1815 view of the Great Gate of Trinity College, Cambridge.[23] The high wall surrounding Newton's private garden, in which his laboratory was situated, is clearly visible to the right of the gate.

Of particular interest in Loggan's engraving, however, is the small, clearly wooden structure in the corner between the chapel and the main range. It has long been assumed by Newton scholars such as Dobbs that it was in this shed that Newton undertook his chemical experiments: 'But the laboratory shown in the print was undoubtedly, the one that Newton used',[19] no doubt influenced by the words of Humphrey Newton, Newton's amanuensis from 1685 to 1690, that:

> On the left end of the garden was his elaboratory, near the east of the chapel, where he at set times employed himself in with a great deal of satisfaction and delight.[20]

There are, however, a number of objections to identifying this shed as Newton's laboratory, particularly given Loggan's reputation for 'conscientious accuracy'

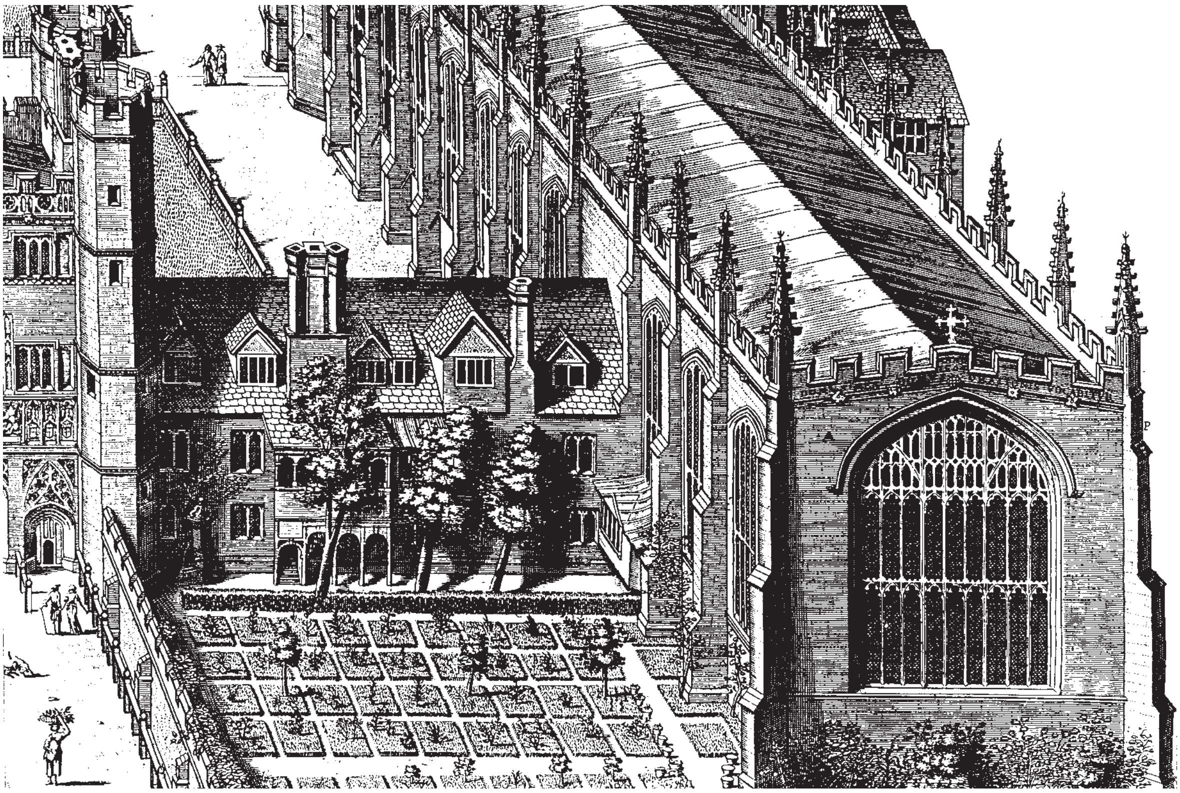

Fig. 2. Loggan's 1690 engraving of the east front of Trinity College, Cambridge, showing part of the Great Gate on the left, Newton's private garden in the centre, and the chapel on the right.[18] Newton entered the garden from his first-floor rooms, using the staircase in the wooden loggia.

as an engraver for, in the words of the authors of the standard work on the architectural history of the university, in Loggan's work 'Every detail of the buildings, the courts, and the gardens, is carefully noted, so that they present not merely a record of the architecture, but of the life of the period.'[21] Firstly, the structure is clearly shown to be 'floating' above the ground, rather than resting on it. This would be totally out of keeping for a laboratory which we know from the records of Newton's chemical experiments to have contained heavy brick-built furnaces. Secondly, the structure does not appear to contain an entrance door from the garden and was presumably entered from the inside of the chapel. Finally, the chimney that would inevitably have been part of a laboratory containing one or more furnaces is noticeably absent. For these reasons it must be concluded that, whatever tradition may have decreed, this structure was highly unlikely to have been Newton's laboratory and was more likely related in some way to the structure and work of the chapel.

Returning to Humphrey Newton's description of Newton's laboratory quoted above, it would be logical to assume that any person describing the location of the laboratory would base his description as he entered the garden from the staircase. Thus the 'left of the garden' would indicate a site somewhere along the wall of the chapel, while 'near the east of the chapel' would clearly indicate the most easterly of the three bays formed by the buttresses of the chapel — that is, the bay on the southeast corner of the chapel (Fig. 4). (It is of interest to note that Newton also contemplated using his garden at Trinity as the site of experiments relating to the acceleration of bodies due to gravity, for in the record of his visit to Newton in *c.* July 1694 the Scottish mathematician David Gregory noted that 'He is choosing the place for contriving his experiments [on falling bodies] from the top of Trinity College Chapel into his own garden on the right as one enters the College.'[31] As far as we know, these experiments were never carried out.)

'Newton's Garden' since 1696

What we may designate as 'Newton's Garden' is of considerable antiquity, being clearly visible in Hammond's map of 1592 (Fig. 3), appearing not very different from what it was in Newton's time — and indeed as it is today.[22]

After Newton vacated his rooms in 1696, the high wall surrounding his garden remained in place for at least a century and a half, being clearly visible in Ackermann's lovely painting of 1815[23] (Fig. 1) and in Le Keux's engraving of 1847 (Fig. 5).[24] From these illustrations it is notable how large the trees in the garden had grown since Newton's time; also clearly visible is a narrow gate cut in the garden wall close to the Great Gate, presumably used for access to the site by a gardener.

Sometime between 1847 and the turn of the century, the wall surrounding the garden was demolished, being replaced by a slatted wooden fence.[25] Later still, this too was removed, leaving the situation as it is today, with the garden being surrounded on two sides by a low 'wall' only a few bricks high with the bases of the set of columns which supported the original wall clearly visible in the portion

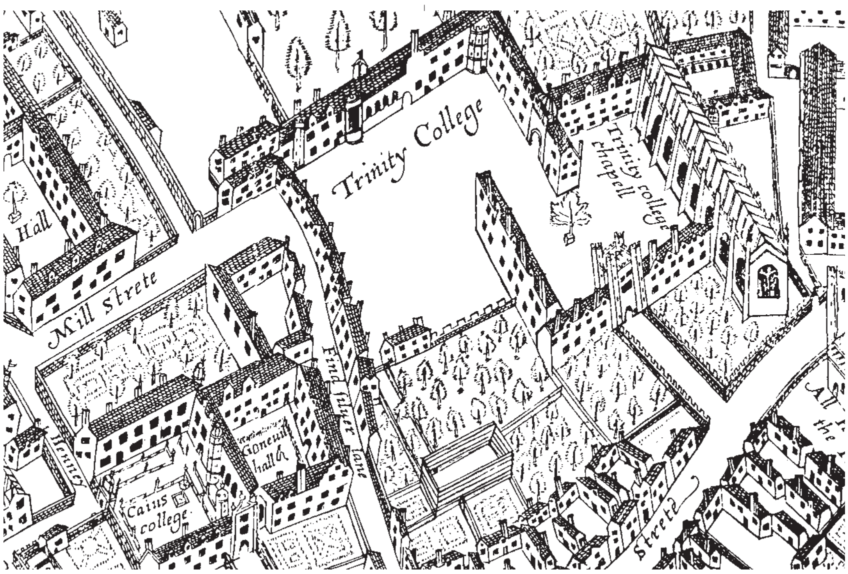

Fig. 3. Hammond's 1592 map of Cambridge, showing what was to be 'Newton's Garden' already in existence as a walled enclosure.[22]

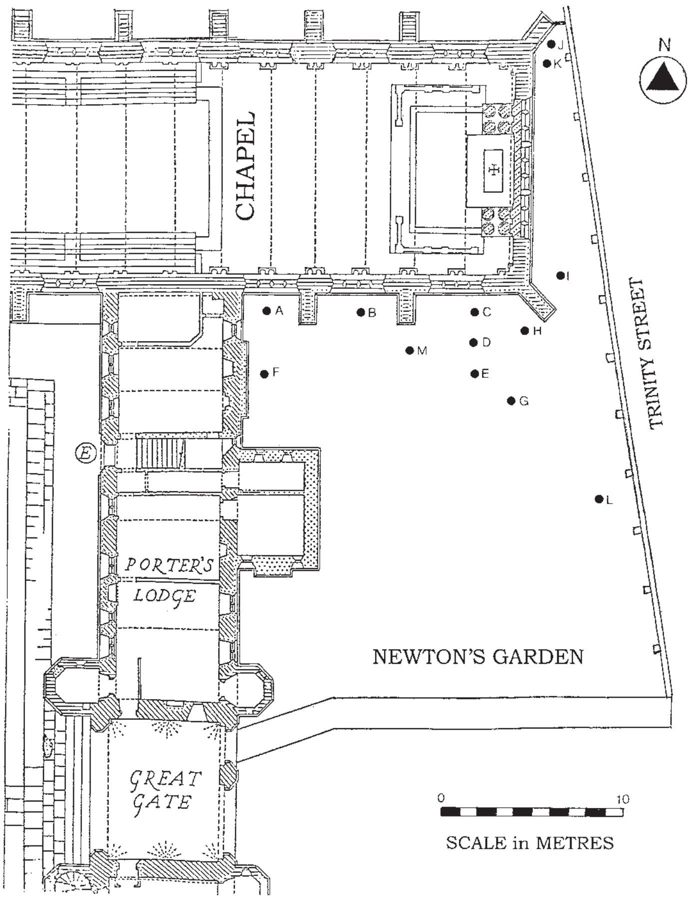

Fig. 4. Plan of the site of 'Newton's Garden' as it appears today, showing locations of the thirteen cores. (After Royal Commission.[27])

running along Trinity Street.

The exterior of the range in which Newton's rooms were situated has also been much altered since his departure for London in 1696. This is mentioned briefly by Pevsner[26] and in greater detail by the Royal Commission on the Historical Monuments of England:

> The length N. of the great gate has been entirely refaced on both sides, on the E. in 1856 by Salvin, who altered the former character The doorway from the Porter's N. room into the E. annexe is cut through an original window with moulded jambs and square head; the annexe is Salvin's replacement of the earlier arcaded annexe, presumably of the 17th century shown in Loggan's engraving.[27]

It is therefore reasonably certain that the wooden loggia (or 'arcaded annexe') containing the staircase used by Newton to gain access to his garden was removed in 1856 and replaced by that portion of the porters' lodge which today projects into the garden. It is also probable that the wall surrounding the garden was removed at the same time. No information has been found relating to the removal of the small wooden 'shed' in the corner where the north range meets the chapel nor when the large trees visible in the 19th-century prints were removed and replaced by the present uninterrupted stretch of lawn.

It should be noted that in 1991 a sondage 0.8 m × 1.5 m was excavated in the southeast corner of the lawn now covering 'Newton's Garden' in order to obtain information relating to the stratigraphic sequence in that area. This extremely interesting excavation resulted, from the bottom, in the discovery of Saxo-Norman pottery, small shards of green glazed ware and, in the uppermost layer, in small fragments of coal and medium and large fragments of tile.[28]

The investigation

Following a 1994 proposal by Spargo,[29] the Trinity College authorities were approached, in the first instance, by R. G. W. Anderson, then director of the British Museum, and subsequently by the author, for permission to investigate the area we have called 'Newton's Garden' (Fig. 4) in the hope of locating the site of his laboratory. After a protracted series of discussions, permission was eventually granted for an exploratory investigation to be undertaken. This was limited to carrying out a general, non-intrusive, geophysical survey of the area concerned and the removal of approximately a dozen soil cores. Permission was not granted to carry out any form of excavation other than soil coring.

In order to provide information which would assist in determining the positions of the core sites, it was decided to undertake two preliminary geophysical surveys in the survey area as we hoped these would locate the extent of ground disturbances below the current surface, or any other anomalies, within this area. The first was a soil resistivity survey covering the whole area of interest, followed by a ground-penetrating radar (GPR) survey based upon the results of the soil resistance survey. These were carried out in December 1997 by GSB Prospection of Bradford.

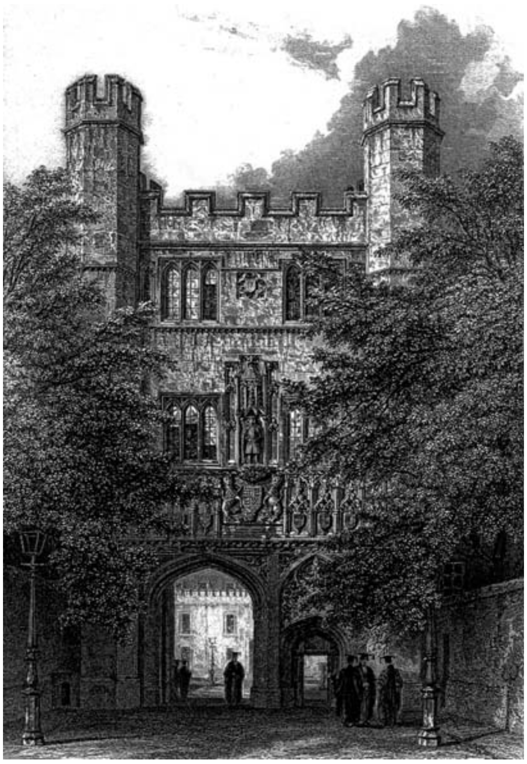

Fig. 5. Le Keux's 1847 engraving of the Great Gate of Trinity College.[24]

The soil resistivity survey

A 1 m × 1 m grid of total size 20 m ×20 m was set out on the grassed area between Trinity Street and that portion of the college range lying between the Great Gate and the chapel. Resistivity measurements were carried out using a Geoscan Research RM15 instrument, sampling at 1 reading per metre, intersecting distances being 1 m. After capture in the RM15, the data were downloaded into a portable computer, thereby enabling an overall resistivity plan of the surveyed area to be produced (Fig. 6).

From the results of this survey, it can be seen that four main areas of high resistance were located. The two substantial areas along the west edge of the survey area, probably caused by soakaways, subsurface drains or buried manhole covers, were not considered to be significant. Nor is the area running along the east edge of the survey area parallel to Trinity Street as this almost certainly indicates the foundations of an early, since-demolished garden wall. However, the high resistance in the most easterly of the three bays running along the side of the chapel is particularly interesting in view of the fact that we have shown above that this is the area that best accords with Humphrey Newton's 17th-century description of the location of Newton's laboratory.

The GPR survey

The ground-penetrating radar survey was carried out using a 500-MHz antenna on a grid divided into sections 1 m × 2 m. Throughout the area surveyed, the results (Fig. 7) revealed a reflector at a depth of between 2 and 2.5 m, believed to represent hard reflecting material such as bedrock. A weaker reflector was obtained at about 1–1.5 m, probably indicating a soil horizon. The two areas of strong reflection along the eastern edge of the survey area are not considered to be significant, probably being caused either by buried services of modern origin or the foundations of the early, since-demolished garden wall mentioned above in relation to the resistivity survey. However, once again the area of high reflectivity in the most easterly bay of the chapel is noteworthy, indicating as it does the possible existence here of a floor or compacted area.

Soil coring

Taking into account both the known history of the site and the results of the geophysical surveys described above, it was decided to remove twelve soil cores, designated A–K and M, together with a control core, L (Fig. 4). The position of the last in the southeast corner of the site was of course determined by the need for it to be separated from the working site. Coring took place in January 1998 and the 13 cores, *c.* 5 cm in diameter, were removed intact to a maximum depth of *c.* 1 m and, after wrapping in aluminium foil in order to preserve their stratigraphy, were inspected on site and the soil profiles recorded (Fig. 8).

The position of cores J and K requires additional comment. Newton was by nature an extraordinarily private person and we know that his chemical experiments, in particular, were conducted in almost total secrecy. It would therefore seem entirely reasonable to assume that, in order to maintain secrecy, he instructed his assistant Humphrey Newton — or perhaps the college gardener — to bury the waste material generated by his laboratory investigations on site, rather than have it removed for disposal elsewhere as was probably the case with the ordinary garden refuse. Thus, in Spargo's original 1994 project proposal,[29] it was proposed that the location of rubbish pits should also be sought on site, with the greatest likelihood of finding such a pit being in the narrow out-of-sight area next to the northeast corner of the chapel, that is, where the Trinity College property meets that of St John's College. Hence the decision also to take two cores (J and K) in this latter area.

Analysis of the cores

The thirteen soil cores were in the first instance analysed for Sb, Pb and Cu by the Department of Scientific Research at the British Museum, London. An initial qualitative analysis carried out using energy-dispersive X-ray fluorescence was followed by one using atomic absorption spectrophotometry, a more sensitive technique.[30] Finally, the samples were re-analysed for Sb, Pb, Cu, Fe, Co, Zn, As, Ag, Sn, Au, Hg, and Bi using the laser ablation–inductively coupled plasma–mass spectrometer facility in the Department of Geological Sciences at the University of Cape Town. No significant discrepancies were found between the two sets of results for Sb, Pb and Cu, although the last method naturally gave a substantially higher degree of accuracy. The results of the final analyses are presented in Table 1, with each core being indicated by a capital letter and the lower case letters (a–d) indicating increasing distance from the surface.

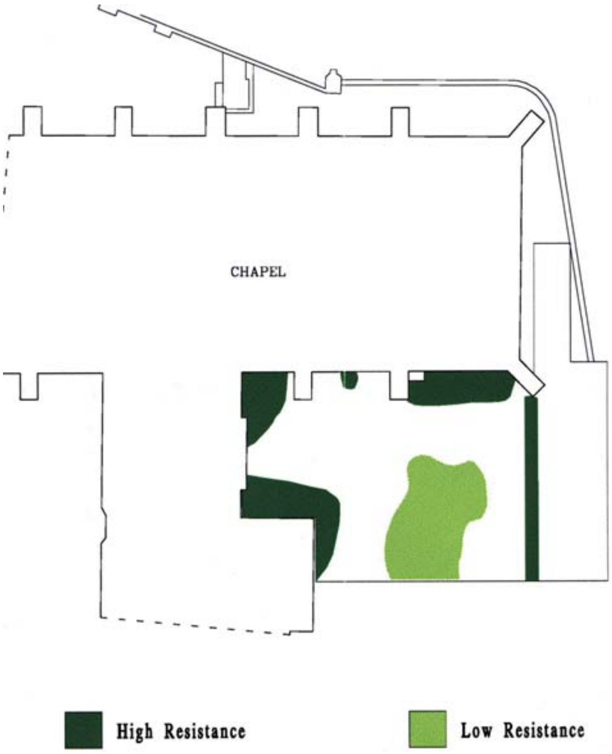

Fig. 6. Results of the resistivity survey.

Discussion and conclusion

By its very nature, the survey described here cannot be expected to provide a definitive answer to the question of the location of Newton's laboratory. However, the results of both the soil resistivity and the GPR surveys, together with the elemental analysis and stratigraphy of the core samples, clearly indicate that within the overall survey area there are two particular locations of especial interest with respect to Newton's chemical activities.

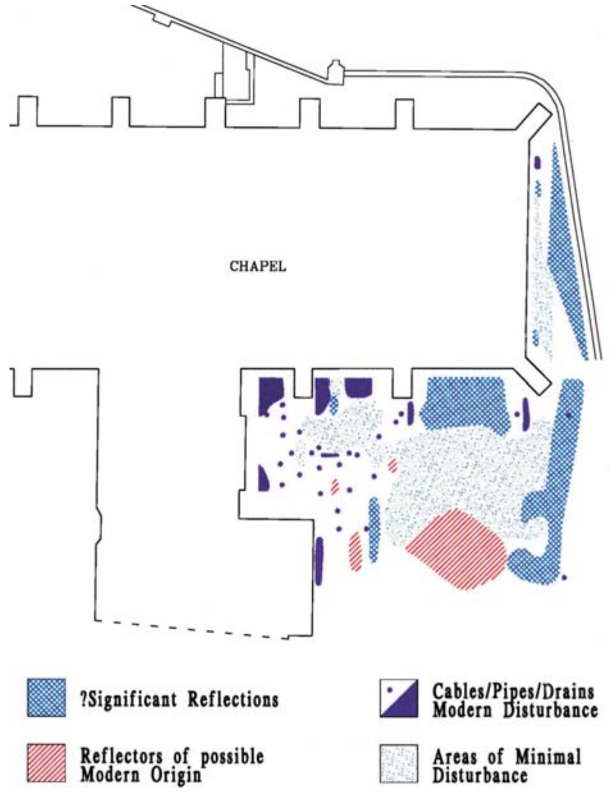

Fig. 7. Results of the 500-MHz GPR survey.

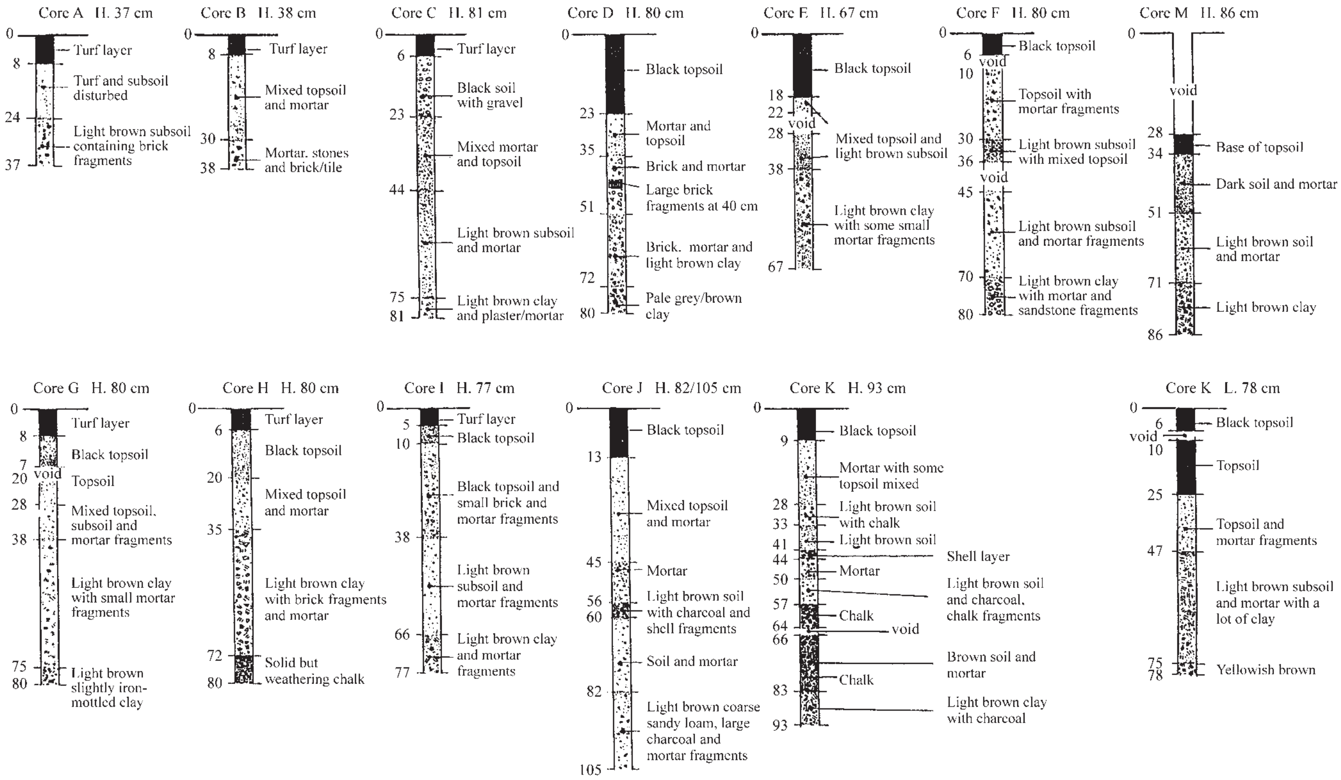

Fig. 8. Soil profiles of the cores.

The first is the most easterly of the three bays of the chapel, which, as we have seen, the contemporary historical record indicates as being the most likely location of Newton's laboratory. This contention is supported by both the resistance and GPR surveys, showing as they do the presence here of an area of high resistance and reflectivity, strongly suggesting the possible existence of a floor or compacted area. Hence the sub-surface soil in this area might be expected to contain higher concentrations of metallic residues than in other areas. This is indeed the case, with cores C or D showing the highest

Table 1. Elemental analyses* of the core materials.

Core:	A		B	C		D			E		F		G		H	
Sample:	a	b	b	b	c	a	b	c	b	c	b	c	b	c	b	c
Fe (wt%)	1.7	1.6	1.9	2.0	1.6	1.8	1.7	1.9	1.8	1.8	2.0	1.4	2.1	1.9	2.1	1.7
Co (ppm)	7.7	6.7	7.3	6.9	7.5	7.6	6.3	7.0	7.8	7.9	7.4	5.5	7.9	7.8	6.8	6.3
Cu (ppm)	45	37	37	31	54	57	26	32	33	32	36	27	41	37	26	21
Zn (ppm)	662	259	526	212	85	239	90	93	100	74	121	71	99	80	76	65
As (ppm)	24	11	14	26	12	26	22	13	13	10	23	10	18	9	13	8
Ag (ppm)	0.75	0.65	0.70	0.47	0.83	0.80	0.50	0.75	1.01	0.74	0.89	0.54	0.77	0.66	0.48	0.46
Sn (ppm)	30.7	41.4	12.0	22.7	3.1	21.9	7.9	5.8	8.1	3.6	6.2	2.0	6.9	19.0	2.4	1.3
Sb (ppm)	2.1	0.9	4.8	1.6	0.5	1.1	1.6	0.5	0.7	0.5	0.5	0.4	1.7	1.0	0.4	0.3
Au (ppm)	0.058	0.077	0.033	0.031	0.026	0.19	0.054	0.023	0.051	0.023	0.031	0.019	0.036	0.026	0.018	0.013
Hg (ppm)	0.053	0.023	0.038	0.12	0.075	n.d.	0.082	0.015	0.062	0.041	0.018	0.049	0.040	0.021	0.026	0.010
Pb (ppm)	1337	788	1227	211	241	621	293	362	222	145	626	422	211	95	315	153
Bi (ppm)	0.27	0.13	0.18	0.19	0.13	0.29	0.16	0.14	0.28	0.15	0.14	0.10	0.25	0.10	0.09	0.07

Core:	I		J				K				L (control)			M		Ave. cont'l crust	Ave. upper cont'l crust
Sample:	b	c	a	b	c	d	a	b	c	d	a	b	c	b	c	–	–
Fe (wt%)	1.9	1.6	1.7	1.8	2.0	2.1	1.5	2.0	1.4	2.1	2.2	1.8	1.9	1.5	1.8	5.18%	3.50%
Co (ppm)	7.4	6.5	6.4	8.7	8.9	8.8	5.4	7.7	5.7	7.6	8.1	7.9	8.2	6.7	7.7	25 ppm	10 ppm
Cu (ppm)	59	26	43	49	53	54	22	37	46	39	63	37	39	29	26	24	25
Zn (ppm)	128	78	119	112	115	115	69	109	66	105	185	90	87	98	83	74	71
As (ppm)	19.2	11.0	20.9	15.8	17.9	16.4	10.1	9.7	5.9	11.3	31.2	16.2	10.1	10.7	9.6	3.1	1.5
Ag (ppm)	0.75	0.57	0.54	1.17	2.12	1.33	0.48	0.60	0.43	0.68	0.91	0.67	0.62	0.63	0.58	0.052	0.05
Sn (ppm)	429	6.0	10.9	39.7	24.1	30.9	20.9	7.9	17.3	7.7	19.1	9.3	2.4	11.3	9.4	1.5	5.5
Sb (ppm)	1.44	1.06	0.88	4.33	6.88	8.37	1.43	2.22	1.40	3.13	1.46	0.99	0.30	0.85	0.78	0.2	0.2
Au (ppm)	0.10	0.067	0.029	0.084	0.067	0.045	0.035	0.044	0.018	0.39	0.10	0.035	0.019	0.027	0.030	0.003	0.0018
Hg (ppm)	0.055	n.d.	0.041	0.044	0.12	0.10	0.010	0.031	0.11	0.070	0.033	0.020	0.14	n.d.	0.084	0.009	0.0123
Pb (ppm)	452	158	280	349	325	495	173	222	389	113	538	214	96	507	808	12.5	20
Bi (ppm)	0.90	0.12	0.18	0.98	1.14	0.70	0.09	0.13	0.13	0.09	0.38	0.17	0.10	0.14	0.12	0.27	0.127

n.d. = not detected. *Performed in the ICP–MS facility, Department of Geological Sciences, University of Cape Town.

concentrations of copper, arsenic, gold and mercury in all of the areas sampled other than the assumed site of the waste pit (i.e. core J), while in the case of zinc core D showed the second highest concentration (Table 1). This conclusion is also strongly supported by the existence in cores D and H of fragments of brick and mortar at a depth of some 40–70 cm below the current ground level, which one would expect if this were indeed the site of Newton's laboratory (Fig. 8). The ground below the 'floating' wooden shed shown tucked against the chapel in Loggan's 1690 etching shows neither high reflectivity nor significantly high concentrations of metallic residues (core A) and thus the longstanding assumption that this was the site of Newton's laboratory can now reasonably be put to rest.

The second area is that sampled by cores J and K, that is, in the extreme north-east part of the survey area. Here significant concentrations of nine metals which one might expect to find in the residues of a chemical laboratory, Fe, Co, Cu, Ag, Sn, Sb, Hg, Pb and Bi, are to be found. The likelihood that these would have originated in normal domestic waste must surely be low. It is also significant that in this core particles of charcoal and a small fragment of pre-modern glass were also found, producing additional evidence of the existence at that point of the rubbish pit believed to be in the vicinity.

From the above, it is reasonable to conclude that the location of Newton's laboratory, as well as that of the pit used for the disposal of the waste products of his numerous chemical experiments, have in all likelihood been located. There can therefore be no doubt that further systematic, more extensive excavations of this extremely interesting — and, in the history of science, perhaps unique — historical site is called for.

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