ROBERT BOYLE'S INTEREST IN THE KNOWLEDGE OF HUNGARIAN MINES, MINERALS AND MINERAL WATERS

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Received July 8, 1986
Presented by Prof. Dr. F. Szabadváry

Abstract

It is appropriate at the time of the presentation of the third Robert Boyle Gold Medal to *Ernő Pungor* (born Vasszécsény, Hungary, Oct. 30, 1923), the most senior and best known of Hungarian analytical scientists in both teaching and research [1] and via his encouragement of international collaboration [2], to examine Robert Boyle's writings [3, 4] for items of Hungarian interest.

Sources of Information

A surprisingly large number of references to Hungarian mines, minerals, mineral waters and chemicals were found, spread throughout Boyle's works. The information was gathered by Boyle from visitors, correspondents and books of the period since Boyle did not visit Hungary. [5, 6]

It is not clear who were the various visitors with specific knowledge of Hungary due to Boyle's use of vague terms "a chemist who had purposely travelled into Hungary". It is possible that one was Johann Joachim Becher [7, 8] (1635–1682) who came to England in 1679 where he died, London 1682. Becher is known for being the first to construct a theory of Chemistry [9] including introducing the concept of *terra pinguis* (flammable earth) later developed to the concept of phlogiston by Stahl.

The acquisition of this information on Hungary was in no way accidental for Boyle had, in 1666, set up the reporting protocol of information to compose a good natural History [10] from which, in time, might be constructed a solid and useful philosophy. He published a detailed set of 101 enquiries concerning mines [11], followed a year later by 21 specifically directed at Hungarian and Transylvanian enterprises [12] (see Fig. 1). These and other specific enquiries formed the basis of a book [13] "with some material by another hand". Replies came in response to the requests for information for example Dr Edward Brown's 1669 letter [14] to the publisher of *Phil. Trans.*, "concerning Damps in the Mines of Hungary and their effects". A year later quite detailed accounts

Inquiries
For Hungary *and* Tranſylvania.

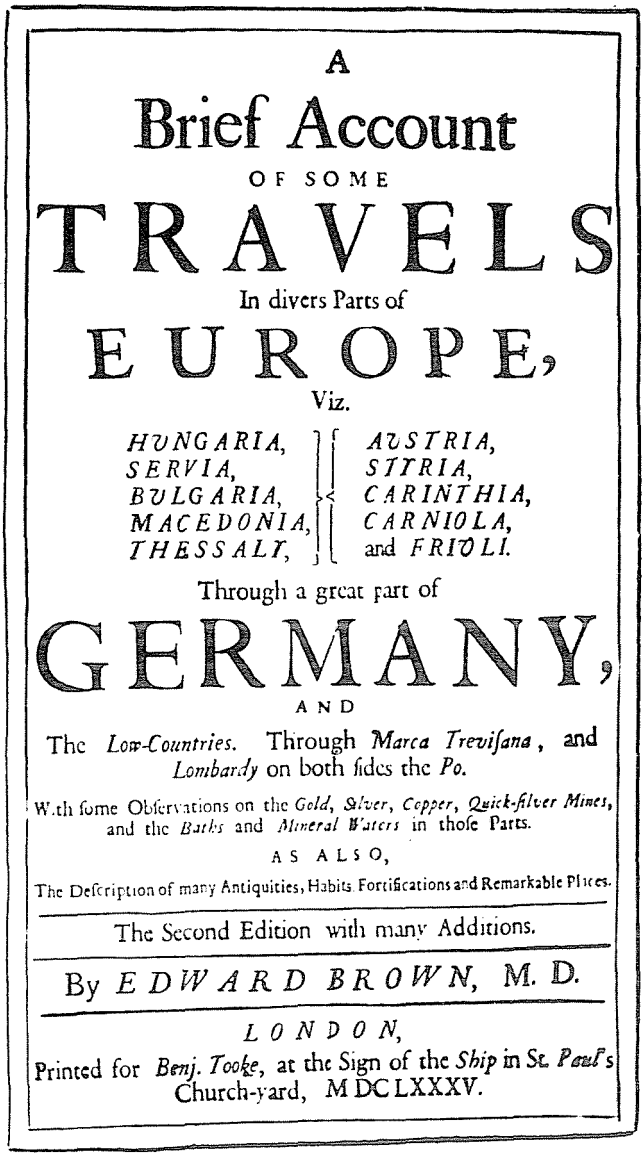
In proſecution of the Engagement, publiſhed Numb. 23. *p.* 414, 422. *we now ſubjoyn ſome other* Inquiries, *and* firſt *theſe, that were very lately recommended to a ſtudious and inquiſitive* Tranſylvanian, *who from* London *returned to his Countrey, and promiſed to procure good Anſwers to the following particulars,* Viz.

Fig. 1. Specific enquiries made in Phil. Trans. about Hungarian Mines, Minerals, Springs, Warm baths, Earths, Quarries, Metals etc. (1667)

"concerning the copper mine at Herrn-ground in Hungary, [15] the Baths of Austria and of Hungary and quarries and rocks of those parts" [16] were presented.

Hungarian Mines

Boyle's three main sources of information on the Hungarian mines were visitors such as, "a very skilful and credible person" who had visited the mines first referred to in *The Sceptical Chemist*, [17, 18a] a French Physician Jo. Baptista Morinus, who gave a detailed account of his visit to the deep mines about 1615 [19, 21a] and referred to in particular by Boyle in *Experimental History of Cold* [20, 21] and in *Cosmicall Qualities of Things* [22, 23] in the tract *The Temperature of Subterraneall Regions*, and Dr. Edward Brown [24] (Fig. 2.). Boyle was aware that gold was found native, [18a] that the temperature increased with depth in the deep mines, [21a, 21c, 21d] and that the atmosphere was corrosive to wood and iron instruments, [21b] and could contain flammable exhalations, [21e] more so near the surface, [25, 26a] which were detectable by the "burning blue of their lights". Boyle next refers to a copper mine using information, "I obtained from a chemist that had purposely travelled into Hungary and other places, to visit the mines. . .". [23a] It is not clear whether or not this was the, "skilful person" referred to in *The Sceptical Chemist*. However, Boyle notes that his report agreed with that of Morinus, [23b] with regard to temperature. Again he notes that the, "exhalations are sulphureous and bituminous . . . and are apt actually to take fire". [23c] The exhalations turned the leaves of trees near the mines a golden colour [23d] and in certain parts of the mine were offensive. [23e] Boyle also cross-checked the



A

Brief Account

OF SOME

TRAVELS

In divers Parts of

EUROPE,

Viz.

HUNGARIA,
SERVIA,
BULGARIA,
MACEDONIA,
THESSALY,
} *AUSTRIA,*
STYRIA,
CARINTHIA,
CARNIOLA,
and *FRIOLI.*

Through a great part of

GERMANY,

AND

The *Low-Countries.* Through *Marca Trevisana*, and *Lombardy* on both sides the *Po.*

With some Observations on the *Gold, Silver, Copper, Quick-silver Mines,* and the *Baths* and *Mineral Waters* in those Parts.

AS ALSO,

The Description of many Antiquities, Habits, Fortifications and Remarkable Places.

The Second Edition with many Additions.

By *EDWARD BROWN,* M. D.

LONDON,

Printed for *Benj. Tooke,* at the Sign of the *Ship* in St. *Paul's* Church-yard, MDCLXXXV.

Fig. 2. Title page of E Brown "Travels in divers parts of Europe..." 2nd edition (1685)

information with Agricola's account of his visit to the deep Hungarian mines. From Agricola [27, 28] we get a very detailed and illustrated account of early mining, metal extractions and assaying (see Fig. 3).

Boyle made specific enquiries among travellers as to "the growth of gold" for example from "a learned traveller who had carefully visited the famous

A—AMPULLAE ARRANGED IN THE VESSELS. B—AN AMPULLA STANDING UPRIGHT BETWEEN IRON RODS. C—AMPULLAE PLACED IN THE SAND WHICH IS CONTAINED IN A BOX, THE SPOUTS OF WHICH REACH FROM THE OPERCULA INTO AMPULLAE PLACED UNDER THEM. D—AMPULLAE LIKEWISE PLACED IN SAND WHICH IS CONTAINED IN A BOX, OF WHICH THE SPOUT FROM THE OPERCULA EXTENDS CROSSWISE INTO AMPULLAE PLACED UNDER THEM. E—OTHER AMPULLAE RECEIVING THE DISTILLED *aqua* AND LIKEWISE ARRANGED IN SAND CONTAINED IN THE LOWER BOXES. F—IRON TRIPOD, IN WHICH THE AMPULLA IS USUALLY PLACED WHEN THERE ARE NOT MANY PARTICLES OF GOLD TO BE PARTED FROM THE SILVER. G—VESSEL.

Fig. 3. G. Agricola, "De re Metallica", (1556). Acid parting of silver and gold

gold-mines of Cremnitz in Hungary". [26a] Growth of metal in mines and mine spoils was a common idea of the time due, no doubt, to improvements in extraction technologies which permitted profitable reworking of mine spoils. [26b]

Medical matters interested Boyle considerably and he wrote on the possible effects of poison sent up into the air from underground as a possible cause of diseases such as *Morbus Hungaricus*, [26c] i.e. consumption, tuberculosis. Boyle continued to work on the *Causes of the Insalubrity and*

Salubrity of the Air and its Effects, a tract annexed to *An Essay of the Great Effects of Languid and Unheeded Motion* [29, 30] in which he discusses the causes of the Plague and the bracing character of certain airs and, earthquakes including one which shook Hungary [30a] and hence a great part of Europe. Boyle's "ingeneous person" that had visited the Hungarian and Bohemian Mines [30b] noted that the air upon the hills was fresh in the morning and that it was possible to detect underground veins of minerals by their smell. In some cases the exhalations were sufficient "to precipitate even the birds, that fly over the caverns, that emit them, [30c] or make one asthmatical". [30d] A few pages later Boyle refers to "the tradition amongst learned men that the leaves of vines, that grow in some places of Hungary whose mines afford gold, are, as it were gilt on the lower side, by ascending exhalations of a golden nature". [30e] This was not confirmed by the learned traveller who was sure, however, "that the kernels of the grapes appear gilt over" a "fact" reported earlier by Parcelsus. [7b, 8b] Boyle's remark in parenthesis about the wine, "Tokay (a place that affords the famousest wine of Hungary, and indeed the best I have drunk)" [30e] is one over which few would dispute.

Arsenic and mercury were also found in a Hungarian mine not far from the copper mine. [30f] The toxic nature of the air in, and above, such mines was also noted.

Boyle made use of specific gravity to examine ores and was aware of rich gold ore that existed in Hungary [32a] but only examined such a gold ore from the East Indies. He noted that poorer ores such as those of the copper mines at Cremnitz produced considerable quantities of gold yearly. [32b] Boyle owned a sample of Hungarian antimonial ore [32c] and recorded its specific gravity, [32d] this is his only recorded quantitative analytical measurement on Hungarian materials. John Locke knowing of Boyle's interest in Hungarian mines made enquiries of a Jesuit [33a] who had been in Hungary and obtained a good description of the extraction of copper from water using old iron. This process was also described by Edward Brown [15] who reported they make handsome cups and vessels out of this copper. "I drank out of one of them . . . it was gilded over and had a rich piece of silver-ore, fastened in the middle of it, and this inscription grav'd on the outside,

"Eisen ware Ich, Kupfer bin Ich,
Silber trag Ich, Gold bedeckt mich"

i.e. "Copper I am, but Iron was of old,
Silver I carry, cover'd am with Gold"

Thus the cup was made from the three products of the mine near Cremnitz, all that it required for completion was to be filled with liquid gold from Tokay.

Minerals and Chemical Products

Prior to the introduction of systematic nomenclature and the acceptance of the reforms of 1787 in *Méthode de Nomenclature Chimique* [34] names of compounds were based on colour, consistency, crystalline form, place names, names of persons etc. and many materials were described by different writers or in different countries by different names. [35] The position was also further confused in that the names often indicated origin and hence quality or purity. In Boyle's works we are particularly concerned with iron (II) and copper (II) sulphate, green and blue vitriol, often called Roman and Hungarian vitriol in Europe but in Britain by the reverse names. The term German vitriol was sometimes applied to the bluish green mineral which contained both copper and iron.

Hungarian vitriol was an article of commerce, for Boyle refers to an acquaintance who had visited the mines of Hungary and dealt much in Hungarian vitriol. [18b] The material was not pure iron (II) sulphate because the residue after calcination the *caput mortuum* or *colcothar*, i.e. iron (III) oxide, contained a deal of good copper, some silver and a trace of gold. The red iron oxide was used for medical purposes and various preparations and purifications are described, [37a, 37b] starting from good Dantzick vitriol (if you cannot get Hungarian or Goslarian). [37a] Later he advises the use of the best Hungarian or if you cannot procure then the best Danzick. [37b] Native iron (II) sulphate in the gold mine at Cremnitz was called the *smaragdine vitriol* [21b] i.e. green vitriol. Boyle knew that the nature of the vitriol affected the *colcothar*. [26e] Hungarian vitriol along with allom and phlegm of vitriol was used to make Boyle's "excellent styptick for stopping of Blood". [39a]

Arsenic compounds were mined and it was possible to find yellow, red or white orpiment i.e. As_2S_3, AsS, and As_2O_3 in the same mine in Hungary. [30f] Similarly more than one colour of vitriol [41a] may be found within one mine at Cremnitz. Boyle was also aware that fossile salt (i.e. rock salt, NaCl) was also dug up in Hungary [41b] and other parts of the world. Antimony was also mined. [32c, 32d] There was also a trade in Hungarian clays used for medicinal purposes, described as *Bolus Tockaviensis*. [37c]

Mineral Waters

Robert Boyle had a long standing interest and great expertise [42, 43] in the examination of mineral waters and clearly kept up with European publications on the subject. When discussing hot springs he refers to a "very small but curious dissertation", *De admirandis Hungariae aquis* [44] (Fig. 4) whose anonymous author he gathered from the tract itself to have been a

DE ADMIRANDIS
HVNGARIAE AQVIS HY-
POMNEMATION.

AD GENEROSVM ET VERE MAGNIFICVM.
D. Sigiſmundum in Herberſtain, Neiperg,
& Guttenhag Baronem, inclyti Roman.
Hung. & Boëm. &c. Regis, D. FER-
DINANDI Conſiliarium, & Fi-
ſci in Auſtria Præfectum.

GEORGIO WERNHERO
AVTORE.

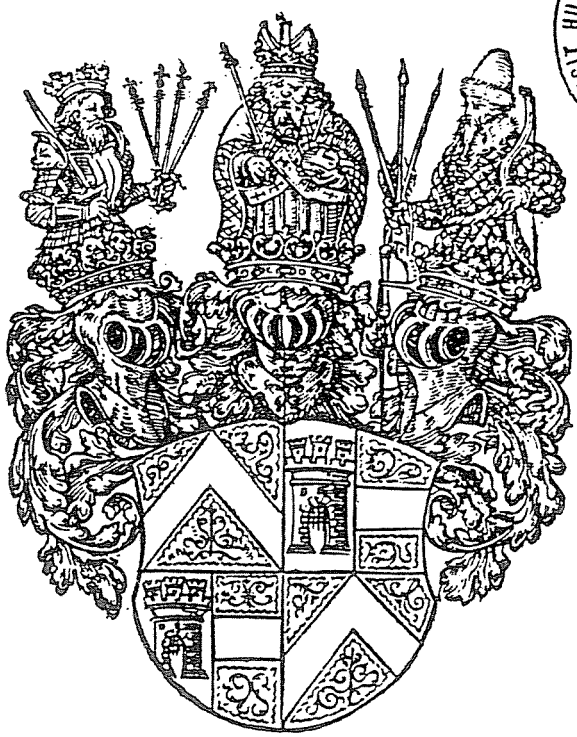


Fig. 4. Title page of Vienna edition, E Aquila, 1551 of G. Wernher "De Admirandis Hungariae aquis"

nobleman, ispán of Sáros. [21e] Boyle dicusses the hot springs of Buda and Istroganum (Esztergom). [21e, 21f] The *Hungariae Aquis* also contains information on mines. [26f] The mineral waters of Hungary were complex and yielded on evaporation "vitriol, a mineral not only compounded but decomposed, as containing in it a saline, a sulphureous, a metalline and an earthy part (which itself, I have found to be none of the simplest bodies); every one of which can be made distinctly to appear". [46a]

Conclusion

It can be concluded that, Boyle had a considerable interest and knowledge of Hungarian natural history of chemical interest and he supported the concept of a world community of scientists so ably argued for by Oldenberg, editor of *Philosophical Transactions*, in his preface to the third year of these tracts in 1666, [47] put as, "the importance of commenting Philosophical Spirits, and of assembly together ingenuities, observations, experiments and inventions, scattered up and down in the world", supported today in the SAC and Euroanalysis series of conferences.

Epilogue

It may be of interest to note that Hungarian chemical matters were not Boyle's sole European dimension, he made a Grand Tour, 1638–44, [48] and additionally visited Holland in 1648. [49] Numerous of his books were published in Continental Europe. [49, 50] Boyle was deeply religious [48,51] and in addition to his scientific writings are those on moralistic, theological and utopian themes many of which contain chemical allusions and illustrations. It was mainly due to his religious beliefs and appointment by the King in 1649 to be a Governor of the "Corporation for the Propagation of the Gospel in New England", that he took a great interest in America. [49]

Detailed study of Boyle's writing has shown that the theme chemical analysis permeates throughout and is a key theme to their comprehension. The term "chemical analysis" almost certainly owes its origin to Boyle. [48, 52] Examination of his writings on this topic and those of his predecessors and contemporaries show him to be the leading exponent of the subject of his period. The major areas of his analytical work are considered to be in solution chemistry, measurement and application of specific gravities and clinical chemistry. [42] Distinguishing features of the work are the detailed and critical approach and in his frequently expressed pleasure in experimental work.

Acknowledgements

The author wishes to record his sincere thanks to his wife for many weeks of assistance in literature searching, the staff of the Science Library and the Special Collections Department of the Main Library at Queen's University of Belfast for locating and obtaining copies of many rare items needed in this study, M. A. Leonard, G. Svehla, F. Szabadváry, W. J. Swindall and W. A. Gabbey for many helpful discussions.

He also wishes to thank the Royal Society of Chemistry for permission to use material prepared as background to the founding and presentations of the A. D., R. S. C. Robert Boyle Medal previously published in *Analytical Proceedings.*

References

1. "Who's Who in Science in Europe", Vol. 3, (3rd edn.), Francis Hodgson, (1978), p 2541.
2. KAY E.: "Men of Achievement", Vol. 10 Melrose Press, 698, (1984).
3. "The Works of the Honourable Robert Boyle. In Five Volumes. To which is prefixed a Life of the Author." A. Millar, London, (1744).
4. "The Works of the Honourable Robert Boyle. In Six Volumes. To which is prefixed a Life of the Author. J. and F. Rivington et al, London, (1772).
5. BIRCH, T., "The Life of the Honourable Robert Boyle", A. Millar, London, (1744).
6. "Life" Ref. 4: Volume I, pp. i-ccxviii.
7. PARTINGTON, J. R.: "A History of Chemistry", Vol. 2. Macmillan, London, (1961). 7(a) Becher 637–652. 7(b) Paracelsus 116–151.
8. SZABADVÁRY F. and SZŐKEFALVI-NAGY, Z.: "A kémia története Magyarországon", Akad. Kiadó, Budapest, (1972). 8(a) Becher p 24. 8(b) Paracelsus p 23.
9. THOMSON, T.: "The History of Chemistry", Vol. I, H. Colburn and R. Bently, London, (1830), p 246, Chap. 7 "Of the attempts to establish a theory in chemistry."
10. BOYLE R.: "General Heads for a Natural History of a Country, Great or Small', Phil. Trans., *1*, 186, (1666).
11. BOYLE R.: "Articles of Inquiries touching Mines", Phil. Trans., *1*, 330, (1666).
12. BOYLE R.: "Inquiries for Hungary and Transylvania", Phil. Trans., *2*, 467, (1667).
13. BOYLE, R.: "General Heads for the Natural History of a Country...", J. Taylor and S. Holford, London, (1692).
14. BROWN, E.: "Concerning Damps in the Mines of Hungary and their Effects", Phil. Trans., *4*, 965, (1669).
15. BROWN, E.: "Concerning the Copper-Mine at Herrn-ground in Hungary", Phil. Trans., *5*, 1042, (1670).
16. BROWN, E.: "An accompt concerning the Baths of Austria and Hungary...", Phil. Trans., *5*, 1044, (1670).
17. BOYLE, R.: "The Sceptical Chemist..." (2nd edn), H. Hall for R. Davis and B. Took, London, (1680).
18. Ref 4: Vol I, pp 458–661; 18(a), Vol I p 568; 18(b), Vol I p 659.
19. MORIN, J. B.: "Nova mundi sublunaris Anatomia", Apud N. Du Fosse, Paris, (1619).
20. BOYLE, R.: "New Experiments and Observations Touching Cold..." J. Crook, London, (1665).
21. Ref. 4: Vol II, pp 462–734. 21(a), Vol II p 588; 21(b), Vol II p 589; 21(c), Vol II p 673; 21(d), Vol II p 674; 21(e), Vol II p 678; 21(f), Vol II p 679.
22. BOYLE, R.: "Tracts. The Cosmicall Qualities of Things...", W. H. for R. Davis, Oxford, (1671).

23. Ref. 4: Vol III pp 290–354. 23(a), Vol III p 327; 23(b), Vol III p 328; 23(c), Vol III p 336; 23(d), Vol III 337; 23(e), Vol III p 338.
24. BROWN, E.: "A brief account of some travels in Europe viz. Hungaria . . . observations on gold, silver, copper, quicksilver mines, baths, mineral waters . . ." T. R. for B. Tooke, London, (1673). (Second edition 1685.)
25. BOYLE, R.: "Tracts: Suspicions about some Hidden Qualities of Air . . .", Printed by W. G. and sold by M. Pitt, London, (1674).
26. Ref. 4: Vol IV pp 79–150. 26(a), Vol IV p 83; 26(b), Vol IV p 84; 26(c), Vol IV p 94; 26(d), Vol 103; 26(e), Vol VI p 99; 26(f), Vol IV p 91.
27. AGRICOLA, G.: "De Re Metallica Libri XII-", Frobens Mark, (H. Frobenium et N. Episcopium] Basileae, (1556).
28. HOOVER, H. C.–HOOVER, L. H.: *Editors and Translators*, "Georgius Agricola De Re Metallica" . . . Mining Magazine, London, (1912). Reprinted by Dover, New York, (1950).
29. BOYLE, R.: "An Essay of the Great Effects of Even Languid and Unheeded Motion . ." M. Flesher for R. Davis, London, (1685).
30. Ref. 4: Vol V pp 1–70. 30(a), Vol V p 14; 30(b), Vol V p 41; 30(c), Vol V p 42; 30(d), Vol V p 43; 30(e), Vol V p 49; 30(f), Vol V p 61.
31. BOYLE, R.: "Medicina Hydrostatica . . . to which is subjoyn'd a Previous Hydrostatical Way of Estimating Ores", S. Smith, London, (1690).
32. Ref. 4: Vol V pp 453–507. 32(a), Vol V p 496; 32(b), Vol V p 497; 32(c), Vol V p 504; 32(d), Vol V p 505.
33. "Letters" Ref. 4: Vol VI pp 35–672. 33(a) Ref. 4: Vol VI p 536.
34. Lavoisier (A. L. and others) Méthode de Nomenclature Chimique proposée par MM. de Morveau, Lavoisier, Bertholet, & de Fourcroy. On y a joint un nouveau Système de Caractères Chimiques, adaptes à cette Nomenclature, par MM. Hassenfratz & Adet. Paris. First edition, Chez Cuchet, Paris, (1787).
35. CROSLAND, M. P.: "Historical Studies in the Language of Chemistry", Dover, New York, (1978) (a report of the 1962 edn with corrections and new preface).
36. BOYLE, R.: "Some Considerations touching the Usefulnesse of Experimental Naturall Philosophy . . .", H. Hall, Oxford, (1663).
37. Ref. 4: Vol II pp 1–246. 37(a), Vol II p 135; 37(b), Vol II p 216; 37(c), Vol II p 120.
38. BOYLE, R.: "Medicinal Experiments; or, a Collection of Choice Remedies . . .", S. Smith, London, (1692).
39. Ref. 4: Vol V pp 312–391. 39(a), Vol V p 336.
40. BOYLE, R.: "The General History of the Air . . .", Awnsham and John Churchill, London, (1692).
41. Ref. 4: Vol V pp 609–750. 41(a), Vol V p 697; 41(b), p 628.
42. BURNS, D.: "Robert Boyle (1627–1691): Part II Literary Style, Specific Contributions to the Principles and Practice of Analytical Chemical Science", Analyt. Proc., *19*, 288, (1982).
43. BURNS, D. T.: "Robert Boyle (1627–1691); Part IV Robert Boyle's Determination of Iron in Tunbridge Water: The Earliest Quantitative Colorimetric Reaction?" Analyt. Proc., *23*, 75, (1986).
44. GEORGIUS, W.: "De admirandis Hungariae aquis" Basel, (1549). It is not clear which edition Boyle consulted, the author is given on the title page of the 1551 edn. (Fig. 5).
45. BOYLE, R.: "An Essay about the Origine and Virtues of Gems . . ." Printed by W. Godbid sold by Moses Pitt, London, (1672).
46. Ref. 4: Vol III pp 512–561. 46(a), Vol III p 541.
47. OLDENBERG, H.: Phil. Trans., *1*, 414, (1666).
48. BURNS, D.: "Robert Boyle (1627–1691): A Foundation Stone of Analytical Chemistry in the British Isles. Part I Life and Thought", Analyt. Proc., *19*, 224, (1982).

49. BURNS, D.: "Robert Boyle (1627–1691): A Foundation Stone of Analytical Chemistry in the British Isles. Part III American and Dutch Connections", Analyt. Proc., *22*, 253, (1985).
50. FULTON, J. F.: "A Bibliography of the Honourable Robert Boyle", Second Edition, Oxford, (1961).
51. BURNS, D.: "Wkład Roberta Boyle'a (1927–1691) Do Teorii i Praktyki Analizy Chemicznej" Historii Nauki i Techniki, *31*, 95, (1986).
52. BURNS, D.: Irish Contributions to European Analytical Chemistry", in D. M. Carroll, D. T. Burns, D. A. Brown and D. A. MacDaeid, Euroanalysis III, Applied Science, London, (1979).

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