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Scottish chemistry, classification and the late mineralogical career of the 'ingenious' Professor John Walker (1779–1803)

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Abstract. During the first decade of the nineteenth century, Edinburgh was the scene of several lively debates concerning the structure of the Earth. Though the ideas of groups like the 'Wernerians' and the 'Huttonians' have received due attention, little has been done to explicate the practice of mineralogy as it existed in the decades before the debates. To dig deeper into the eighteenth-century subject that formed the foundation of nineteenth-century geology in Scotland, this essay concentrates on Rev. Dr John Walker, the University of Edinburgh's Professor of Natural History (1779–1803). In pursuing this topic, it builds on an earlier *BJHS* article in which I excavated his early career as a mineralogist (1749–79). After first addressing a few historiographical points and the provenance of the student manuscripts upon which this study is based, I explain the method that Walker used to arrange minerals. I then move on to show that, like his younger attempts at mineralogical classification, his mature system was based predominantly upon chemistry. This sets the stage for the last half of the essay where I reconstruct the mineralogical system that Walker taught to the hundreds of students who sat in his natural history lectures from 1782 until 1800. I then conclude with a few observations about the relevance of his mineralogy to the scientific community of late eighteenth-century Edinburgh.

Systems and manuscripts

By the time John Robison published his edition of Joseph Black's lecture notes in 1803, the principle-based chemical nomenclature that his Edinburgh colleague had used during the last half of the eighteenth century was already becoming obsolete. This predicament is clearly evinced in the numerous lists of equivalency tables that he included at the end of Black's discussion of salts. In a footnote to the last page of these tables, Robison avers, 'Unless the chemical reader makes this list familiar to his mind, he must remain incapable of reading with intelligence the writings of all the chemists of

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I wish to dedicate this essay to Roy Porter. It was his initial comments on my doctoral thesis that led me to write it. During 2002 sections of this study were presented to the University of Oxford's Modern History Faculty and at Max Planck Institute for the History of Science (MPI). The final phases were written over the next year when I was a postdoctoral fellow at MPI and the Dibner Institute, MIT. A very special thanks to the anonymous referees of the *BJHS* and to David M. Knight, Ursula Klein, David R. Oldroyd, Robert Fox, Rob Iliffe, David Pantalony, Fred Page, NAHSTE (Navigational Aids for the History of Science, Technology and the Environment in Scotland) and the staff of the following libraries: University of Durham, University of Newcastle, University of Edinburgh, Harvard University, the Dibner Institute (the Burndy Library) and the Max Planck Institute for the History of Science. All archival material is cited by permission of these libraries.

Europe previous to the publication of Mr. Lavoisier's system.'[1] He goes on to emphasize his point by stating,

> Yet those writings contain a vast body of solid chemical knowledge, all of which has a chance of being forgotten, if it have an immediate and palpable dependence on new doctrines. He [the reader] will remain equally ignorant of the writings of the most eminent natural historians and mineralogists, who employed no other language in all their discussions.

Clearly these comments contain a bit of rhetorical flair. Black had died in 1799 and Robison was trying to maintain the centrality of his friend's work in the face of the extraordinary success of the new nomenclature. However, from a historiographical perspective, Robison's assessment has turned out to be quite prophetic. Despite his prescient warning, most chemists soon became 'ignorant' of the old doctrines and, true to his prediction, a great many of the eighteenth century's chemically inclined natural philosophers slowly slipped into oblivion.

Bearing Robison's comments in mind, it is the goal of this essay to read 'with intelligence' the chemically based mineralogical 'system'[2] that was taught in the University of Edinburgh's Medical School by Black's contemporary, Rev. Dr John Walker, the Professor of Natural History from 1779 until 1803. This study follows on from a previous article in which I outlined his early mineralogical system and his career as an aspiring mineralogist (1749–79).[3] More specifically, it reconstructs the system that he taught to his students during his twenty-four years at the university. The place where his thoughts on this topic were most clearly evinced was his mineralogy lectures. Over the past two hundred years they have remained hidden away in a series of student notebooks that are now housed in the University of Edinburgh's Special Collections Department. This essay is based on these manuscripts and I will address their form and content in more detail below. In addition to his lecture notes, I also use his personal papers and his library catalogue.[4]

Walker was a popular lecturer who taught well over seven hundred students during his tenure as professor.[5] Included in this lot were natural philosophers like Sir James Smith, Thomas Beddoes, Robert Jameson, James Hall and John Playfair. In addition to the names included on his class lists, there were those who sat in his public lectures and

1 Joseph Black, *On the Elements of Chemistry Delivered in the University of Edinburgh by the Late Joseph Black, M.D.* (ed. John Robison), Edinburgh, 1803, 499.

2 In what follows, the word 'system' is employed as Walker and other professors in the Medical School used the term in their lectures; that is, a methodological arrangement of data.

3 M. D. Eddy, 'Scottish chemistry, classification and the early mineralogical career of the "ingenious" Rev. Dr John Walker (1749–79)', *BJHS* (2002), **35**, 411–38. In this article I traced Walker's chemical training, his early attempts at mineralogical classification and the travels that he took in the Lowlands, Highlands and Hebrides.

4 A list of Walker's library was published by Cornelius Elliot as *A Catalogue of the Books in Natural History with a Few Others, which Belonged to the Late Rev. Dr. Walker, Professor of Natural History in the University of Edinburgh*, Edinburgh, 1804. In subsequent footnotes, books that appear in this catalogue will be followed by an 'EC' (Elliot's *Catalogue*) and then a number that connotes the book's placement on the catalogue's list.

5 The student lists of Walker's course can be found in M. D. Eddy, 'The University of Edinburgh natural history class lists, 1782–1800', *Archives of Natural History* (2003), **30**, 97–117.

the numerous naturalists with whom he corresponded.[6] One of the advantages of explicating Walker's work is that it provides a clearer picture of what was being taught to these students and what was being discussed within the Medical School. More specifically, his lectures offer a glimpse of the highly complex world of eighteenth-century nomenclature. Systematic arrangement, as understood by its Enlightened practitioners, is often drastically simplified or glossed over by historians. For the early eighteenth-century British scene, due attention has been given to Locke's and Linnaeus's 'kinds' and 'species'.[7] Yet the apparent simplicity often assigned to Enlightenment nomenclature, for both chemistry and natural history, has been subjected to much criticism during the past three decades. For chemical nomenclature, it has been shown that there are many influential chemists to be found outside Lavoisier's historiographical shadow.[8] For natural history, one of the most influential voices concerning the history of classification has been Michel Foucault, but others such as John Dupré and Wolfgang Lefèvre have also addressed this issue.[9] As I will show below, Edinburgh's Medical School favoured authors whose writings were relevant to practical and philosophical questions being raised in Scotland.[10] This meant that its mineralogical canon often

6 A list of Walker's correspondents is housed in the reading room of the University of Edinburgh's Special Collections library.

7 Attention is most often drawn to Locke's comments in Book III, Chapters I–VII, of *Essay Concerning Human Understanding*. See A. J. Cain, 'John Locke on species', *Archives of Natural History* (1997), **24**, 337–60; P. R. Sloan, 'John Locke, John Ray, and the problem of a natural system', *Journal of the History of Biology* (1972), **5**, 1–53. Mayr cites Sloan on species and avers that Locke (along with Leibniz) exercised 'the greatest influence' over the mid-eighteenth-century 'nominalistic species concept'. See Ernst Mayr, *The Growth of Biological Thought: Diversity, Evolution and Inheritance*, Cambridge, MA, 1982, §163, §§263–5. For treatments of Linnaeus's kinds and species see P. R. Sloan, 'The Buffon–Linnaeus controversy', *Isis* (1976), **67**, 356–75 and J. L. Larson, *Interpreting Nature: The Science of Living Form from Linnaeus to Kant*, Baltimore, 1994. Also, just because eighteenth-century authors cited the empirical observations of a systematist did not mean that they agreed with his nomenclature. As J. L. Heller has shown, this was even the case for Linnaeus: *Studies in Linnaean Method and Nomenclature*, Frankfurt, 1983, 115–45.

8 J. V. Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760–1820*, Cambridge, 1992; J. R. R. Christie, 'Historiography of chemistry in the eighteenth century: Hermann Boerhaave and William Cullen', *Ambix* (1994), **41**, 4–19; *idem*, 'William Cullen and the practice of chemistry', in *William Cullen and the Eighteenth-Century Medical World* (ed. A. Doig, J. P. S. Ferguson, I. A. Milne and R. Passmore), Edinburgh, 1993, 98–109. J. R. R. Christie and and J. V. Golinski, 'The spreading of the word: new directions in the historiography of chemistry 1600–1800', *History of Science* (1982), **20**, 235–66; M. Beretta, *The Enlightenment of Matter: The Definition of Chemistry from Agricola to Lavoisier*, Canton, 1993; U. Klein, *Verbindung und Affinität: Die Grundlegung der neuzeithlichen Chemie an der Wende vom 17. zum 18. Jahrhundert*, Basel, 1994; *idem*, 'The chemical workshop tradition and the experimental practice: discontinuities within continuities', *Science in Context* (1996), **9**, 251–87.

9 See the first three chapters of J. Dupré's *The Disorder of Things: Metaphysical Foundations of the Disunity of Science*, Cambridge, MA, 1995; W. Lefèvre, 'Natural or artificial systems? The eighteenth-century controversy on classification of animals and plants and its philosophical contexts', in *Between Leibniz, Newton, and Kant: Philosophy and Science in the Eighteenth Century* (ed. W. Lèfevre), Boston, 2002; M. Foucault, *The Order of Things: An Archaeology of the Human Sciences*, London, 1970.

10 Porter, Teich, Withers and Bensaude-Vincent have pointed out how national contexts influenced the reception and development of scientific ideas during the Enlightenment. See R. Porter and M. Teich (eds.), *The Enlightenment in National Context*, Cambridge, 1981; C. W. J. Withers, *Geography, Science and National Identity: Scotland since 1520*, Cambridge, 2001; B. Bensaude-Vincent and F. Abbri (eds.), *Lavoisier in European context: Negotiating a New Language for Chemistry*, Canton, 1995. Local, national and transnational understandings of science are also addressed in a recent, thought-provoking essay by Lewis Pyenson

placed just as much value (if not more) on works that were critical of writers like Locke or Linnaeus. For instance, even though John Thomson's biography of Edinburgh's Professor William Cullen (1710–90) had kind words for 'Mr. Locke's excellent account of our complex ideas of substances', he qualified this assessment by stating that Scotland's own Dugald Stewart (1753–1828) had made Locke's work much more comprehensible during the late eighteenth century.[11]

The central role played by chemistry within Edinburgh's medical community engendered a wide variety of data, especially in relation to minerals. Faced with bottle after bottle of mineral water, and box after box of stones and materia medica simples, most physicians and naturalists organized their collections around the chemical principles of Earth, Salt and Metal that were promoted both in the Medical School and in the foreign publications that they read. The systems created by these chemists were by no means in agreement and were often influenced by the perceived use of the system.[12] The result was a string of competing mineralogical classifications. However, even though the medical professors in Edinburgh disagreed over the nuances of nomenclature divisions, they were united in their belief that mineralogy should be founded on chemical characters. Such a view of minerals was also held by most practising chemists in Scotland and by members of the aristocracy.[13] This was notably different from the mineral system offered by Linnaeus in his *Systema Naturæ*. It is also different from the systems offered by the English mineralogy texts written by Emanuel Mendes Da Costa and John Hill.[14]

Walker's system was recorded in many forms during the course of his tenure at the University of Edinburgh. There are thirteen known bound manuscript volumes of student notes taken in his mineralogy lectures. This essay is based on these sources. Unlike his geology lectures, those on mineralogy were never published.[15] Most of them are

that investigates broad-ranging historiographical issues relevant to the scientific enterprise in Europe, South America, the Middle East and Asia. See 'An end to national science: the meaning and the extension of local knowledge', *History of Science* (2002), **60**, 251–90.

11 J. Thomson, *Account of the Life, Lectures, and Writings of William Cullen, M.D.*, 2 vols., Edinburgh, 1832, ii, 191. Thomson was specifically referring to Stewart's *Elements of the Philosophy of the Human Mind*, London, 1792 – a book which Walker had in his library (EC 152).

12 For instance, see Prof. Charles Alston's *Index Medicamentorum Simplicium Triplex*, Edinburgi, 1752, 69–70.

13 The best example of this can be seen in the mineralogy collection of John Stuart, Earl of Bute. This was one of the largest in Britain and it contained a wide variety of acids, alkalis and books on medico-chemistry. [Anon.], *A Catalogue of the Great Part of Materials of the Capital Mansion House, Offices, Conservatory and Temples … and Other Effects of the Late Right Hon. Earl of Bute …*, London, 1795. The only copy of this document that I have been able to find is housed in the Bute Family Archives, Mount Stuart, Isle of Bute, BU/173; [Anon.], *A Catalogue (Part First–Third) of Duplicates of Ores, Petrifactions, Spars, Gems, Crystals, &c. Selected from the … Collection of … John, Earl of Bute …*, London, 1793. A copy of this catalogue is housed in the British Library, St Pancras Reading Rooms, 1255.c.15.(1). I must thank the Mount Stuart estate (particularly Andrew McLean) for pointing these sources out to me.

14 Emanuel Mendes Da Costa, *A Natural History of Fossils*, London, 1757; John Hill, *A General Natural History: Or, New and Accurate Descriptions of the Animals, Vegetables, and Minerals …*, 3 vols., London, 1748–52.

15 John Walker, *Lectures on Geology: Including Hydrology, Mineralogy, and Meteorology with an Introduction to Biology* (ed. H. W. Scott), London, 1966. As a boon to the interested reader, Scott's edition (pp. 223–9) contains a transcribed version of Walker's two introductory mineralogy lectures.

housed in the Special Collections Department of the University of Edinburgh Library.[16] Even though he published the heads of his lectures,[17] these only consisted of the actual names that he gave to his classes, orders, genera and species. This means that the empirical data that he used to form his classification categories can only be found in the notes taken by his students. Their notebooks show that even though he tried hard to differentiate minerals based on composition, it seems that some of the classification categories were not mutually exclusive (especially in the case of minerals with problematic compositions). However, this being said, many of the mineralogies in his library contained categories that occasionally vied for the same mineral.[18] Additionally, when reading these notes, it becomes quite clear that the printed texts cited by Walker do not fall within the standard canon of natural history and chemistry books usually mentioned in modern secondary sources concerned with investigating the 'origins' of chemical or Darwinian 'revolutions'.[19] Rather than being interested in theorists like Buffon and Hutton,[20] Walker and his Medical School colleagues paid more attention to

However, these only offer a tiny glimpse of Walker's system because they are undated and were only the preamble to the forty to fifty curricular and extracurricular lectures that Walker gave on the topic over the course of the year.

16 Eleven are housed at the University of Edinburgh, one at the Royal College of Physicians, Edinburgh and one at the University of Aberdeen.

17 John Walker, *Institutes of Natural History; Containing the Heads of Lectures in Natural History; Delivered by Dr. John Walker, in the University of Edinburgh*, Edinburgh, 1792; *idem*, *Classes Fossilium: Sive, Characteres Naturales et Chymici Classium et Ordinum in Systemate Minerali: cum Nominibus Genericis Adscriptis*, Edinburgi, 1787. That the former work was known in British mineralogical circles is evinced by the fact that it is listed in Joseph Banks's library: *Jona Dryander, Catalogus Bibliothecæ … Tome iv. Mineralogi*, London, 1799, 13. It is one of the few Scottish books in his collection. The only copy that I have been able to find is housed in the University of Oxford: OUM Mineral 549/14. This could be the copy used by Walker's student Thomas Beddoes when he was lecturing there in early 1790s. Like Walker, Beddoes collected minerals (with Davies Gilbert) and then used them as illustrations in his lectures. See the 'Introduction' in R. Siegfried and R. H. Dott (eds.), *Humphry Davy on Geology: The 1805 Lectures for the General Audience*, Madison, 1980, p. xix; R. Porter, *Doctor of Society: Thomas Beddoes and the Sick Trade in Late Enlightenment England*, London, 1992, 13.

18 This was a problem for most mineralogists in the eighteenth century. See David R. Oldroyd, *Thinking about the Earth: A History of Ideas in Geology*, London, 1996, 97–100.

19 Often the anachronistic categories of early nineteenth-century conceptions like 'Vulcanism' and 'Neptunianism' are used to characterize mineralogical and geological works written from 1700 to 1800. Notable exceptions to this method are R. Porter, *The Making of Geology*, Cambridge, 1977; R. Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830*, London, 1987; N. E. Emerton, *The Scientific Interpretation of Form*, London, 1984; R. Rappaport, *When Geologists Were Historians, 1665–1750*, London, 1997; D. R. Oldroyd, *Sciences of the Earth – Studies in the History of Mineralogy and Geology*, Aldershot, 1998; G. L. H. Davies, *The Earth in Decay: A History of British Geomorphology, 1578–1878*, London, 1969. For a helpful treatment of the chemistry behind eighteenth-century issues deemed relevant to later 'Vulcanists' and 'Neptunists', see B. Fritscher, *Vulkanismusstreit und Geochemie: Die Bedeutung der Chemie und des Experiments in der Vulkanismus-Neptunismus-Kontroverse*, Stuttgart, 1991.

20 Over twenty years ago R. Porter's *The Making of Geology*, op. cit. (19), pointed out that Hutton was not the centre of Scotland's emerging discipline of 'geology'. In his recent (and brief) essay on this book, Martin Rudwick re-emphasizes Porter's claim that 'Hutton was exceptional and even anomalous' for the Scottish context. 'Roy Porter, historian of geology', *History of Science* (2003), **41**, 251–6. Additionally, the speculative aspects of Buffon's natural history (especially his cosmogonical account) did not resonate with the empirical epistemology of Edinburgh's philosophers and physicians – a point that figured into Walker's bid for the chair of natural history (against William Smellie) and subsequently in his lectures on geology. See

a different group of European authors – especially chemists whose works were obtainable via North Sea trade routes.[21]

Bearing these issues in mind, this essay explains how Walker arranged his mineralogical system. For the most part I will use the twelve-volume set of stenographed notes taken by (Sir) David Pollock in Walker's 1797 lecture series.[22] Of the many bound collections of notes taken by Walker's students, these are by far the most detailed. Yet Pollock was silent on a few issues and in these cases I refer to other sets of notes (this does not occur very often and I include an explicatory footnote when it does). On the whole, the notes of Pollock and other students show that Walker orally explained the lead characters that he used to form his classes, orders, genera and species. Even so, Walker's definitions of these characters are sometimes confusing, incomplete or illegible. These considerations in combination with the tedious nature of the chemistry behind Walker's mineralogy make reconstructing his system an exciting, but challenging, task.

Even though he sometimes changed their sequential number, Walker kept the same class names throughout his time as a professor.[23] A comparison of his personal notes, student notebooks and the books in his library and his museum indicates that his system went through at least three stages. He created his first comprehensive system in 1781 – the year before he gave his first full natural history course. This was called *Schediasma Fossilium* and it consisted of eighteen classes.[24] The second version of his system appeared around 1790 and the number of the classes went up to nineteen. This change was most clearly captured in manuscript copies of his students' notebooks.[25] Although he began to lose his eyesight in the mid-1790s, the final version occurred around 1795 when he decided to create a catalogue for the mineralogy collection that was under his supervision in the University of Edinburgh's Natural

C. W. J. Withers, 'The Rev. Dr. John Walker and the Practice of Natural History', *Archives of Natural History* (1991), **18**, 201–20; M. D. Eddy, 'Geology, mineralogy and time in John Walker's University of Edinburgh natural history lectures', *History of Science* (2001), **39**, 95–119.

21 The importance of Baltic chemistry for English travellers at the beginning of the nineteenth century has recently been traced by B. Dolan, 'Travelling savants: experimental chemistry in eighteenth-century Sweden and England', in *Travels of Learning: A Geography of Science in Europe* (ed. A. Simões, A. Carneiro and M. P. Diogo), Amsterdam, 2003, 115–41. Additionally, like the Scots, the Swedes placed a high emphasis upon the utility of science. See L. Koerner, 'Daedalus Hyperboreus: Baltic natural history and mineralogy in the Enlightenment', in *The Sciences in Enlightened Europe* (ed. W. Clark, J. Golinski and S. Schaffer), Chicago, 1999, 387–422.

22 A law student who would later become Sir David Pollock (1780–1847), Judge Advocate. Pollock was a student at Edinburgh in 1797, but he did not graduate.

23 But there were some changes. He had originally included Fusoria (Class 5) in his 1781 system. But by 1790 he had replaced it with Ponderosa and Amandina.

24 John Walker, *Schediasma Fossilium*, Edinburgh, 1781, housed in Edinburgh University Library, Special Collections Department (hereafter EUL), DC.2.19, and another copy with notations, EUL DC.8.20. This eighteen-class system is reprinted in Walker, op. cit. (15), 230–7. In 1786 he began to amend *Schediasma* by moving around its orders and by listing more characters for each fossil. These corrections were not that substantial and in 1787 he published these augmentations of *Schediasma* as *Classes Fossilium*, Edinburgh, 1787. Part of this was reprinted in the third edition of Robert Jameson's *A System of Mineralogy*, Edinburgh, 1820, pp. xxxiii–xxiv.

25 As demonstrated in [Anon.] (transcriber), *Lectures on Natural History III* (1790), Bound MS EUL DC.2.25, f. 62 and [Anon.] (transcriber), *Lectures on Natural History Vol. III* (1790s), Bound MS, EUL DC.2.19, f. 3.

History Museum.[26] This was named *Systema Fossilium* and it consisted of nineteen classes.[27]

The method of mineralogy

Walker gave an 'Imperium naturæ' lecture every year in his natural history course that discussed the different types of classification that could be used to arrange the three kingdoms of nature.[28] In this lecture Walker stated that there were three basic methods: natural, artificial and mixed. Although the general definitions of these methods remained the same throughout his mineralogy, botany and zoology lectures, he only intended this lecture to be a general summary of the main methods available to a naturalist. One must therefore read his lectures on botany, zoology and mineralogy as individual units to see how he adapted his methods to the data available for each kingdom. In what follows below, I take care to explicate his method of classification solely in relation to how it is represented in his mineralogy lectures. Those who wish to pursue his botanical and zoological methods will need to consult his personal manuscripts and the botany and zoology lecture notes taken by his students during the 1780s and 1790s.[29]

Using the chemistry that he had learned in Edinburgh, Walker modelled his mineralogical system on Torbern Olaf Bergman's *Outlines of Mineralogy* (1783),[30] Johan Gottschalk Wallerius's *Minéralogie* (1753),[31] and Axel Fredrik Cronstedt's *Essay*

26 C. W. J. Withers has treated Walker's supervision of the museum in '"Both useful and ornamental" – John Walker's keepership of Edinburgh University's Natural History Museum, 1770–1803', *Journal of the History of Collections* (1993), **5**, 65–77.

27 John Walker, *Systema Fossilium*, *c.* 1797, bound MS, Glasgow University Library, Special Collections Department (hereafter GUL), Gen. 1061.

28 A reprint of one (undated) 'Imperium Naturæ' lecture can be found in Walker, op. cit. (15), 220–2.

29 By the end of his career (the late 1790s) Walker's interest in mineralogy led him to reduce the space given over to botanical and zoological lectures. His botanical classification was based closely on Linnaeus's *Systema Naturae*. G. Taylor, 'John Walker, D.D., F.R.S.E. 1731–1803. Notable Scottish naturalist', *Transactions of the Botanical Society of Edinburgh* (1959), **38**, 180–203. Botany at this time in Edinburgh was also closely tied to georgics. During the 1790s Walker made an unsuccessful bid to become the Professor of Agriculture. C. W. J. Withers treats this in 'A neglected Scottish agriculturalist: the "georgical lectures" and agricultural writings of the Rev. Dr. John Walker (1731–1803)', *Agricultural History Review* (1985), **33**, 132–43. For zoology, Walker advocated the use of classification characters taken from internal organs, not just those based upon external morphology. This approach is most clearly evinced in the following manuscript lectures taken by his students: *Lectures on Natural History* (1790), bound MSS, EUL DC.2.27 and DC.2.27 and *Epitome of Natural History* (1797), bound MS, EUL Gen 711.D and 712.D.

30 T. O. Bergman, *Outlines of Mineralogy* (tr. William Withering), Birmingham, 1783, EC 131 (all op. cit. references in the footnotes below, unless stated otherwise, refer to this edition). This was originally published as *Sciagraphia Regni Mineralis, Secundum Principia Proxima Digesti*, Lipsiæ, 1782, and it gained further popularity via its translations (and sometimes interpretations) into English (above) and French, *Manual du minéralogiste: Ou Sciagraphie du règne minéral, distribué d'après l'analyse chimique, par M. Torbern Bergman; et traduite et augmentée de notes par M. Mongez*, Paris, 1783.

31 J. G. Wallerius, *Minéralogie, ou description générale des substances du règne minéral …*, Paris, 1753, EC No. 117.

Towards a System of Mineralogy (1770).[32] All three of these chemists were Swedish and their influence upon the Medical School's conception of mineralogical systematics was substantial. In addition to these texts, he possessed numerous copies of their other works in his personal library.[33] Even though the chemical mineralogy presented by these three authors had a profound influence over Walker and other eighteenth-century mineralogists, the impact of this 'Swedish school' has remained relatively unexplored in anglophone histories of chemistry and/or the nascent earth sciences.[34] Instead, attention has been given to the writings of Abraham Gottlob Werner (1750–1817), a mineralogist from Saxony whose work had its most profound impact upon early nineteenth-century European geology. In particular, his internal and external characters[35] are usually discussed in reference to Linnaean classification. However, even these characters were closely tied to Werner's knowledge of chemistry and a close look at his writings reveals that he too was significantly influenced by ideas presented by both Wallerius and Cronstedt. Werner even employed the same terms and nomenclature divisions used by these two authors, though he did choose to recalibrate their ideas in relation to the data at his disposal in Saxony. As we will see, Walker did the same thing in Scotland. Thus, since Werner and Walker lived within different chemical communities and were of two different generations (Walker was twenty years older than Werner), they often drew from the same authors but produced a different type of system.[36] Furthermore, though

32 A. F. Cronstedt, *An Essay towards a System of Mineralogy* (tr. G. Engestrom, ed. E. M. da Costa), London, 1770, EC 407; *idem*, *An Essay towards a System of Mineralogy* ... (tr. G. Engestrom and J. H. Magellan), London, 1788, EC 408.

33 Cornelius Elliot's *Catalogue*, op. cit. (4), shows that Walker owned the following books by these authors: Johann Gottschalk Wallerius, *D.D. Lucubrationum Academicarum Specimen Primum de Systematibus Mineralogicis et Systemate Mineralogico Rite Condendo*, Holmiæ, 1768, EC 5; *Minéralogie, ou description générale des substances du règne minéral* ..., Paris, 1753, EC 4 and 117; *idem*, *Elementa Metallurgiae Speciatim Chemicae Conscripta atque Observationibus* ..., Holmiae, 1768, EC 122; *idem*, *Chemiae Physicae Pars Prima, de Chemiae Natura ac Indole in Genere Ejusdemque Historia* ..., Stockholm, 1760, EC 320; *idem*, *Systema Mineralogicum, 2. tom.*, Holmiae, 1772, EC 401; Torbern Olaf Bergman, *Physical and Chemical Essays*, London, 1784, EC 92 (since both Thomas Beddoes and Edmund Cullen issued translations of this text in the same year, it is hard to tell which edition Walker used); *idem*, *A Dissertation on Elective Attractions by Torbern Bergmann* (tr. Thomas Beddoes), London, 1785, EC 109; *idem*, *An Essay on the Usefulness of Chemistry* ..., London, 1783, EC 11 and 328; *idem*, *Outlines of Mineralogy* (tr. William Withering), Birmingham, 1783, EC 131; Richard Kirwan, *Elements of Mineralogy*, EC 569 – EC gives no publication details for this book, but it is most probably London, 1784.

34 For Scotland's use of Wallerius and Cronstedt's books and articles from the 1750s to the 1770s see Eddy, op. cit. (3). However, there were local factors that influenced how a given community used chemical characters to create classification systems. The nuances of differing national or even linguistic interpretations in chemistry within Scotland and Scandinavia are perhaps best evinced by how each country received the new nomenclature during the 1780s and 1790s. For Sweden, see A. Lundgren, 'The new nomenclature in Sweden: the debate that wasn't', *Osiris* (1988), **4**, 146–68. For Scotland, see A. Donovan, 'Scottish responses to the new chemistry of Lavoisier', *Studies on Voltaire and the Eighteenth Century* (1979), **9**, 237–49.

35 See Abraham Gottlob Werner's 'Introduction' to his *On the External Characters of Minerals* (tr. A. V. Carozzi), Urbana, 1962. This was originally published as *Von den äusserlichen Kennzeichen der Fossilien*, Leipzig, 1774.

36 Additionally, even had Walker been fluent in German, much of Werner's work was published after Walker had created his mineralogical system. English translations or explications of Werner's work appeared after he died. The first of these were J. Mawe (ed.), *A New Catalogue of Mineral Substances. The Arrangement and Classification after Professor Werner's system, to which Is Added the New Names from*

Walker was familiar with a number of Latin and French works written by German authors, I have found no mention of Werner in any of his lectures or personal notes.[37]

Like most mineralogical systems of the time, Walker's system was based on 'characters'; that is, empirical data taken from a mineral that was held to be representative of its structure, form or composition. In general, he held that there were two types of mineralogical character: natural and chemical.[38] Unlike most contemporary botanical arrangements (including his own), Walker did not use essential characters for his mineralogical system.[39] For him, a natural character was a 'part' of a mineral that could be observed plainly on its external surface or by breaking it open. Characters of this type included colour, texture, fracture and shape. As so defined, his conception of a 'natural' character bore a striking similarity to Bergman's definition of an 'external' character: 'the chief superficial marks of any fossil taken together, constitute the *external character*'.[40] Indeed, student lecture notes indicate that Walker used the word 'external' and 'natural' interchangeably.[41] Because natural characters sought to represent a mineral exactly as it existed undisturbed in nature, Walker held that the way in which a mineralogist arranged these characters was by a natural method.

A second type of character was a chemical character, and this was taken directly from principle-based chemistry. Walker's conception of a chemical character also mirrored Bergman's definition of an internal character: 'A collection of those properties on which the leading [chemical] principles depend, is called *internal character*.'[42] This

Professor Haüy, London, 1804, and Charles Anderson (tr.), *New Theory of the Formation of Veins; with its Application to the Art of Working Mines*, Edinburgh, 1809. After these works appeared, several of Werner's works were translated into English.

37 Edinburgh's preference for authors like Wallerius, Cronstedt and Bergman led many of Walker's students to become interested in Werner's work. For example, two who were particularly fond of Walker's course, Robert Jameson and Charles Anderson, went on to translate Werner's works into English and to found the Wernerian Society of Edinburgh in the years after Walker died. Additionally, Thomas Beddoes, another one of Walker's students who endeavoured to learn German, had begun to read Werner's work in the *Bergmännisches Journal* during the 1790s. However, Beddoes seems to have disagreed with Werner's geological conclusions. See 'Observations on the affinity between basaltes and granite. By Thomas Beddoes, M. D.; Communicated by Sir Joseph Banks, Bart. P. R. S.', *Philosophical Transactions of the Royal Society of London* (1791), **81**, 48–70. Furthermore, Walker was quite keen to keep external and internal mineralogical characters separated. For a very insightful article on the state of play between mineralogical methods in the 1790s see 'On the corundum Stone from Asia. By the Right Hon. Charles Greville, F. R. S.' *Philosophical Transactions* (1798), **88**, 403–48.

38 These distinctions have been around for quite a while – especially in mineralogy and early attempts at chemical analysis. See R. Hookyaas, 'The discrimination between "natural" and "artificial" substances and the development of corpuscular theory', *Archives internationales d'histoire des sciences* (1948), **4**, 640–51.

39 The failure to recognize the difference between botanical and mineralogical characters has caused much confusion in histories of eighteenth-century chemico-mineralogical systematics. For more on artificial or natural characters, see E. M. Melhado, 'Mineralogy and the autonomy of chemistry around 1800', *Lychnos* (1990), 229–62.

40 Torbern Olaf Bergman, *Physical and Chemical Essays, Translated from the Original Latin of Sir Torbern Bergman, … To which Are Added Notes and Illustrations, by the translator [and Thomas Beddoes]* (tr. Edmund Cullen), 3 vols., London, 1791, iii, 226. Original emphasis. Walker had a copy of this book in his library and cited it in his lectures.

41 For instance, see [Anon.], *Notes of Walker's Lectures on Natural History* (*c.* 1790), bound MS, EUL DC.10.33, f. 330.

42 Bergman, op. cit. (40), 226. Original emphasis.

similarity explains why Walker used 'chemical' and 'internal' as synonyms in his lectures.[43] Walker held that the process by which a mineralogist arranged chemical characters was called a chemical method.[44] This was his method of choice. He only reverted to natural characters when he ran out of chemical characters, a practice that he called the mixed method.[45] But on the whole, just about all of the classes, orders, genera and species in his system were based on chemical characters. These were obtained via the application of heat, water, acids or alkalis. He was able to employ chemistry in such a manner because he had learned it in the University of Edinburgh's Medical School under the instruction of William Cullen during the 1750s[46] and he had used it to create a rudimentary mineralogical schema during the 1760s.[47]

During the eighteenth century chemical characters in Edinburgh were generated by principle-based chemistry. This form of chemistry used the word 'principle' to represent the most basic forms of matter which could be empirically verified in the laboratory. The principles used by Walker and other contemporary chemists were Salt, Earth, Fire (Inflammables), Metal, Water and (sometimes) Air.[48] When classifying minerals, most early modern chemists (Joseph Black and Bergman included) converted four of these principles directly into mineralogical classes. According to Bergman,

> Avicenna, an Arabian physician of the eleventh century, divided fossils into the four classes of salts, earths, metals and phlogistic [inflammable] bodies. In this division, all substances agreeing whether in external or internal character, are properly enough combined; and, as hitherto no general arrangement has been proposed preferable to this, it is in no doubt of being continued.[49]

Since the base of Walker's mineralogical arrangement was chemistry, this meant that it differed fundamentally from the arrangement popularized by Linnaeus's *Systema Naturæ*. This was because Linnaeus's mineralogy was based almost entirely on external characters (like colour and shape).[50] However, since Walker disagreed with the priority that Linnaeus gave to non-chemical (external) characters, he utilized chemical characters to create a form of binary nomenclature similar to that employed by Bergman and his predecessors (Wallerius and Cronstedt in particular). He used this as a base for a

43 *Lectures on Natural History*, op. cit. (41), f. 330.

44 This method was a slightly reconfigured form of the 'artificial method' discussed by Walker in 'Imperium naturæ', in Walker, op. cit. (15), 222.

45 Thereby following the general definition of this method in his 'Imperium Naturæ' lecture, in Walker, op. cit (15), 222.

46 M. D. Eddy, 'The doctrine of Salts and Rev. John Walker's analysis of a Scottish spa, 1749–1761', *Ambix* (2001), **48**, 137–60.

47 Eddy, op. cit. (3), 411–38.

48 For reasons of clarity, throughout this essay I will use upper-case letters for the words that denote these principles, e.g., 'Earth' rather than 'earth'. As Kim has recently shown with France, the properties and categories of these 'principles' sometimes varied between different chemical communities. M. G. Kim, *Affinity that Elusive Dream: A Genealogy of the Chemical Revolution*, Cambridge, MA, 2003.

49 Bergman, op. cit. (40), 227.

50 Linnaeus did use chemistry (mainly acid and alkali tests) to obtain characters for the lower classification characters. But he usually used this only after he had run out of natural characters. However, during his early career, he had displayed a keen interest in the chemistry of minerals. This can be seen in a manuscript that he wrote in Fahlun during 1734. It was finally printed as *Vulcanus Docimasticus*, Uppsala, 1925.

'Quintuple Division',[51] that is, an arrangement based on classes, orders, genera, species and varieties.

Walker was appointed to the Medical Faculty as Professor of Natural History in 1779. Throughout his first decade of lecturing, he asserted that he did not create new mineralogical classes, orders or genera per se: 'As to the names of the Classes, Orders, and especially those of the Genera, there are none of them new and none of them mine.'[52] As Lefèvre has recently shown, such a preservation of the topmost categories was commonplace in Enlightenment classification systems.[53] This being said, the apparent simplicity of his comment above on the quintuple division is hard to substantiate because neither Walker's personal papers nor the notes taken by students in his mineralogy course give the specific criteria that he used to create many of his classes, orders and genera. Additionally, as will be shown below, Walker's later systems expanded his classes beyond the four chemical principles employed by Black, Bergman and other chemists.

Primary and secondary characters

In basing his mineralogical system on chemistry, Walker followed in the footsteps of Wallerius, Cronstedt and Bergman. In particular, he followed Bergman's dictum that, 'In methodizing fossils, *compounds should rank under the most abundant ingredient.*'[54] In this case, 'abundance' was determined by weight. As Albury and Oldroyd explain it, 'If, for example, substance "xy" contained more "x" than "y", then it should belong to the genus "x".'[55] The unit of measurement was the 'grain' and composition was listed in parts per hundred. This was commonly practised in both chemistry and mineralogy texts of the time.[56] When chemical characters were not enough, Walker reverted to natural characters. His commitment to chemical classification did not change throughout his teaching career and he summed up this belief about five years before he died. In 1797 he reaffirmed that chemistry should be used to form 'the leading Character of the Classes and Orders. … A Method, & properly executed, equally useful

51 David Pollock (transcriber), *An Epitome of Natural History* (1797), bound MS, EUL Gen. 706D, f. 6.

52 Walker, op. cit. (15), 'Mineralogy', 229. *Lectures on Natural History*, op. cit. (41), f. 332.

53 Lefèvre, op. cit. (9), 197–9.

54 Bergman, op. cit. (30), §14. For Bergman and Walker, a 'Fossil' was anything that was dug out of the ground. Original emphasis.

55 W. R. Albury and D. R. Oldroyd, 'From Renaissance mineral studies to historical geology, in the light of Michel Foucault's *The Order of Things*', *BJHS* (1977), **10**, 187–215, 197. The debate concerning Bergman's use of 'equivalent' weights during the 1970s illustrates the linguistic and conceptual difficulties presented to modern scholars when trying to understand eighteenth-century scientific measurement. For comparative weights and measures from this time see T. Thomson (ed.), *Annals of Philosophy* (1813), **1**, 452–7. For more on the debate, see the following articles: J. A. Schufle and G. Thomas, 'Equivalent weights from Bergman's data on phlogiston content of metals', *Isis*, **62** (1971), 499–506; W. A. Smeaton, 'Bergman's "Equivalents": a correction', *Isis* (1973), **64**, 231; J. A. Schufle, 'Reply by J. A. Schufle', *Isis* (1973), **64**, 231; C. S. Smith, 'Bergman's "Equivalents": a further comment', *Isis* (1974), **65**, 393–4; J. A. Schufle, 'Further reply on Bergman's "Equivalents"', *Isis* (1975), **66**, 404.

56 For instance, see William Nicholson's popular *First Principles of Chemistry*, London, 1795.

to the Naturalist and Chemist'.[57] This statement shows that his method of classification worked from the top down. Using this approach, the general structure of Walker's system remained relatively unchanged. Although he made minor adjustments throughout his career, on the whole, his changes mainly concerned genera and species, and not classes and orders.

Walker followed the eighteenth-century tradition of subdividing chemical 'principles' into 'Primary' and 'Secondary' categories.[58] Following Bergman, he held that there were five Primary Earths.[59] He also believed that there were two Primary Salts and six Primary Metals:

Primary Earths	**Primary Salts**	**Primary Metals**
Calcareous	Acids	Iron
Argillaceous	Alkalis	Tin
Magnesia		Copper
Terra Ponderosa		Silver
Siliceous		Lead
		Gold

Most of Walker's mineralogy lectures included instructions on how to use acids and heat to ascertain the composition of a mineral and there are sections where it appears that he was combining his own experimental knowledge with that of colleagues like Cullen, Black and Thomas Charles Hope. This being said, it is unclear how much his acceptance of 'Primary' categories was dependent upon experiments that he performed on his own. During this time, just about every naturalist had to use data that had been recorded (usually in print) by someone else. In Walker's case, the process of determining the relevance of such textual evidence was most probably influenced by his education under Cullen and the chemical community of late eighteenth-century Edinburgh – especially the experimental chemistry being conducted in the Medical School from the 1770s until the 1790s. Student notebooks show that he cited a significant amount of data taken from the writings of Wallerius, Bergman, William Watson, Wilhelm

57 Walker, op. cit. (27), f. 22–4. He made similar statements throughout his lecturing career. For instance, compare the above statement to the following: 'the characters of the Classes & Orders must be formed on Chemical principles. While those of the Genera, Species and Varieties seem to depend chiefly upon their natural marks.' *Lectures of Natural History*, op. cit. (41), f. 330. See also *An Epitome*, op. cit. (51), 706D, f. 35.

58 Bergman argued that these principles were not 'metaphysical' because they demonstrated observable empirical properties. Beretta touches upon this point when discussing Bergman's *chemia sublimior*. See Beretta, op. cit. (8), 134–49. These 'properties' were also closely linked to Bergman's conception of chemical affinity. See A. M. Duncan, *Laws and Order in Eighteenth-Century Chemistry*, Oxford, 1996, 136–45 and 148–53.

59 Since the early part of the century there had been many debates as to the exact number of Primary Earths. Although Johann Gottschalk Wallerius and Axel Frederick Cronstedt had influenced Walker's early mineralogical education on this topic, the 1780s saw him accept the five Primary Earths of Swedish chemist Torbern Bergman: calcareous, argillaceous, magnesia, terra ponderosa and siliceous. Bergman, op. cit. (30), §85.

Scheele, Richard Kirwan and Joseph Priestley – all authors who were frequently consulted in the Medical School. Furthermore, his affinity for Bergman was no doubt linked to the fact that Bergman's chemistry harmonized with the work of Cullen and Black.[60]

Using the characters generated by chemistry to arrange minerals was not without its difficulties, and Walker repeatedly stated this in his lectures. One of the biggest problems was that laboratory techniques and non-standardized solvents and reagents (usually acids and alkalis) made it very difficult consistently to determine the exact percentage of the chemical substances that formed a given mineral's composition. A further complication was that Primary Earths were sometimes so strongly bound to each other that they could not be split apart into primary classification characters. For those stones consisting of two or more Primary Earths 'intimately united', Walker followed the Bergmanian practice of creating a sub-chemical category of 'derivative' Earths. Bergman held that the force that bound them together was a highly localized, non-mechanical expression of chemical affinity, or, in his words, Derivative Earths had 'a mutual attraction to each other, and form combinations more intimate than mechanical ones'.[61] Walker accepted this definition and considered several chemical substances to be Derivative or, as he sometimes stated, Secondary:

Secondary Earths	**Secondary Salts**	**Secondary Metals**
Steatite	Neutral	Pyrites
Amiandina	Acid-Earth	Semimetals
Schista	Alkali-Earth	
Gypsum	Vitriol	
Phosphorus		
Apyrite		
Mica		

As will be shown in more detail in the sections below, all of the classes of his system were not based solely on one empirical 'character' associated with an overarching chemical principle. If this were the case, there would only be four classes: Earths, Salts, Metals and Inflammables (water was not generally considered to be a mineral). In reality, Walker was using six different types of 'lead' chemical character to form his classes.[62] The first was a principle itself and this is why he named Class 15 'Salts', Class 16 'Inflammables' and Class 19 'Metals'.[63] The second was a primary representation of the principle, hence Class 2 (Calcareous), Class 4 (Ponderous), Class 7 (Siliceous). Next there were characters based on the secondary representations of the principle: Class 3

60 Duncan has argued that there was a 'strong probability' that Bergman was influenced by Cullen and Black. See Duncan, op. cit. (58), 127–9 and 146–7.

61 Bergman, op. cit. (30), §83; *idem*, op. cit. (40), 244.

62 I use the word 'lead' here based on Walker's use of a 'leading' character in his lectures. Walker, op. cit. (27), ff. 22–4.

63 There is a full chart of Walker's system as it existed in 1797 at the end of this essay.

(Gypseous), Class 5 (Phosphoric), Class 8 (Steatitical), Class 10 (Zeolitical), Class 11 (Micaceous), Class 17 (Mundicks) and Class 18 (Semimetals). A fourth lead character was a mineral's inability to burn and this produced only one category, Class 9 (Apyrites), and a fifth was the presence of iron – Class 6 (Amandina). For classes 12 to 14, Walker took a different tack in selecting the lead character. These rocks were generally much larger than the minerals mentioned above. In fact, they were quite massive and seemed to be part of what Walker called the Earth's 'primary strata'. For these rocks, the lead character was the type of cement (a chemical formation) that held them together: Class 12 (Petræ), Class 13 (Saxa) and Class 14 (Concreta). Overall, in basing all of his classes on chemistry, this method was technically 'mixed' because it alternated between different types of chemical character.

Though Walker's system was quite comprehensive, his lectures did not clearly explain how he selected the lead chemical character of each class. From a chemical standpoint, using principles and their primary and secondary manifestations was well grounded on the work of Bergman and others. For instance, in his *Outlines*, Bergman listed the five 'Primitive Earths' and then noted, 'And we must believe these to be primitive, until it shall appear by proper experiments that they may be separated into others, still more simple, or changed into one another by art.'[64] Similar statements about Primary and Secondary manifestations of Salts, Earths, Inflammables and Metals can be found in the work of Cullen, Black and other chemists being read in the Medical School (Bergman, Wallerius and Cronstedt in particular). So even though Walker's elevation of lower nomenclatural categories to classes was somewhat innovative, it was firmly grounded on chemical practice.

Stones, earths and strata

In this section and those that follow, I will use Walker's mineralogical appellations to refer to the stones classified in his system.[65] The lecture notes taken by Walker's students in his mineralogy lectures clearly show that Classes 2 to 11 were generally found in secondary strata.[66] Their lead chemical character was either a Primary or a

64 Bergman, op. cit. (30), §86.

65 Identifying how his Stones' names compare to those used in modern mineralogy exceeds the focus of this essay. Two good sources for such a comparison are M. F. Heddle, *The Mineralogy of Scotland Vols. I–II*, St Andrews, 1924, and A. M. Clark, *Hey's Mineral Index: Mineral Species, Varieties and Synonyms*, London, 1993. Heddle's work will have additional interest to those interested in the local Gaelic names associated with several Scottish minerals.

66 Class 1 consisted of different types of soil. Since this arrangement of soils was basically a smaller version of other chemical categories used elsewhere in Walker's system, I will set this class aside and not discuss it. He held that 'earths' (Class 1: Terra) – that is, soils – could not be satisfactorily classified. This being the case, he does attempt to arrange their orders based on chemical characters. For instance, he propounds that this is 'the Class which can have no Place in a Chymical Method; but it is necessary to retain the Earths in a separate Class for the Purposes of Natural History'. *An Epitome of Natural History*, op. cit. 51, 706D, f. 41. In this case, the 'Purposes of Natural History' was no doubt georgics. This suggests that it is quite likely that aspiring farmers audited the first part of his lectures without staying on for the rest of the course. Such a scenario explains why there are three different sets of lecture notes (in different handwriting) on Class 1 alone in *Lectures on Natural History*, op. cit. (41), ff. 332–292.

Secondary Earth:

Class 2: Calcareous	Class 7: Siliceous
Class 3: Gypseous	Class 8: Steatitical
Class 4: Ponderous	Class 9: Apyrous
Class 5: Phosphoric	Class 10: Zeolitical
Class 6: Amandina	Class 11: Micaceous

The exact quantity of each stone's 'Earthy' component was not always recorded in the class notes of Walker's students. Usually composition was listed in order of abundance. The character that had the highest weight was listed first and the rest were listed in descending order (this was often done without any numbers being given to explain the exact percentage of each Earth).

When Walker gave his lectures, he took care to point out the industrial and pharmacological uses of these stones. To this goal, he gave his students instructions on where to find minerals in the Highlands and Lowlands. Since Scotland's physicians applied their mineralogical knowledge not only to medicine (especially materia medica) but also to industry and agriculture, it is no coincidence that most of Walker's classes were of relevance to these subjects.[67] I shall therefore address each class in relation to its chemical composition and its role(s) in commodification. The main component of a Calcareous Stone (Class 2) was (Primary) Calcareous Earth.[68] This type of stone was of crucial importance to the Medical School's interest in lime-water, a solution formed from limestone which was used to dislodge or dissolve bladder stones (also called *calculi*).[69] This ailment (along with gout and venereal disease) ran rampant among the aristocracy and gentry and was therefore the bread and butter of future physicians and surgeons who sat in Walker's lectures.[70] Gypseous Stone's (Class 3) lead character was gypsum, a Secondary Earth formed from Calcareous Earth that had been combined with vitriolic acid.[71] As the 1771 edition of the *Encyclopaedia Britannica* (an Edinburgh publication) succinctly stated, 'The gypsums are much used in plaster, for stuccoing

67 An informative work on the chemical foundations of industry and agriculture in Enlightenment Scotland is A. Clow and N. L. Clow's *The Chemical Revolution: A Contribution to Social Technology*, London, 1952. Walker's chemical contributions are mentioned throughout the book. See also Withers, op. cit. (29).

68 This was qualified by the fact that they could be 'converted into quicklime by Fire'. *An Epitome of Natural History*, op. cit. (51), 706D, f. 160. Earlier in the 1790s, Walker had hinted that presence of Aerial Acid was also a characteristic of these stones, going as far as to assert, 'Of all the Calcareous Earths, chalk contains the largest proportion of Aerial Acid. Mr. Kirwan found no less than 40 per cent in it.' *Lectures on Natural History*, op. cit. (41), f. 343. Because Walker does not give specific composition here, it is hard to tell what percentage of Calcareous Earth or Aerial Acid is needed to determine his conception of a Calcareous Stone. In general there was no consensus on this point at this time. It is for this reason that Walker cites different Calcareous Stone chemical compositions from various mineralogies for every order.

69 M. D. Eddy, 'Set in stone: medicine and the vocabulary of mineralogy in eighteenth-century Scotland', in *Science and Beliefs: From Natural Philosophy to Natural Science, 1700–1900* (ed. D. M. Knight and M. D. Eddy), Aldershot, 2005 (forthcoming).

70 For more on the subject matter of experimental pharmacology see A. H. Maehle, *Drugs on Trial: Experimental Pharmacology and Therapeutic Innovation in the Eighteenth Century*, Amsterdam, 1999.

71 *An Epitome of Natural History*, op. cit. (51) 707D, ff. 7–8.

rooms, and casting busts and statues'[72] – all of which would have been useful for any practically minded physician in the service of a patron.

Phosphoric Stone (Class 5) took its name from phosphorus, a Secondary Earth derived from Calcareous Earth and sulphur[73] (these were also naturally occurring in contrast to other forms of phosphorus made out of urine). As Golinski has shown, this sort of stone had been a 'noble spectacle' in Britain since the seventeenth century; that is, phosphorous was a useful conversational piece for chemists (who were often physicians) seeking to impress patrons or other natural philosophers.[74] As an avid reader of the *Philosophical Transactions*, Walker was no doubt aware of this tradition and emphasized that, when heated without a flame, these stones gave off a 'beautiful Phosphoric Light'.[75] Walker's comments on zeolite, a Secondary Earth and the lead character for Zeolitical Stone (Class 10), were more complicated. Without naming page numbers (which commonly occurs), Pollock's notes cite the work of three authors on this topic: Torbern Bergman,[76] Johann Anton Scopoli and Jean-Baptiste-Michel Bucquet.[77] Each of these authors held a different position on zeolite's chemical composition.[78] Since Walker had been contemplating the composition of zeolite since the 1760s,[79] in the end he seems to have rejected Bergman, Scopoli and Bucquet and concluded that zeolite was formed from Calcareous Earth and Siliceous Earth. Furthermore, his long-standing interest in zeolite suggests that he made it a class in his system because of his familiarity with its composition and because of its popularity with Edinburgh's chemists. Similarly, Walker probably included Ponderous Stones (Class 4) on account of their relevance to scientific discourse. Their lead character was the (Primary) Ponderous Earth that had been proposed by Bergman in 1774.[80] This Primary

72 *Encyclopaedia Britannica* (ed. William Smellie), Edinburgh, 1771, ii, 767.

73 *An Epitome of Natural History*, op. cit. (51), 707D, ff. 29 and 85. However, it seems that Walker could not determine whether the other component was sulphur (Wallerius) or 'Acidum opatosum' (Scheele). See the first volume (§§172 and 176) of Wallerius's *Systema Mineralogicum*, op. cit. (33), and the first volume (§23) of Cronstedt's *System of Mineralogy*, op. cit. (32). These two authors are also cited in the section on zeolite in *Lectures on Natural History*, op. cit. (41).

74 J. V. Golinski, 'A noble spectacle: phosphorus and the public cultures of science in the early Royal Society', *Isis* (1989), **80**, 11–39.

75 *An Epitome of Natural History*, op. cit. (51), 706D, f. 29.

76 Bergman, op. cit. (30), §121, thought it was Argillaceous Earth. On this point, Bergman cites §§108–12 of Cronstedt's *System of Mineralogy*, op. cit. (32) – Bergman was no doubt referencing one of the Swedish editions.

77 G. A. Scopoli, *Principia Mineralogiæ Systematicæ et Practicæ*, Vetro-Pragæ, 1772, EC 209. For more on Scapoli's approach to classification see *Introductio ad Historiam Naturalem Sistens Genera Lapidum, Plantarum et Animalium* …, Vienna, 1772. J. B. M. Bucquet, *Introduction à l'étude des corps naturels tirés du règne minéral* …, Paris, 1771 (not in EC). Even though Walker mentions Bergman, Scopoli and Bucquet in his main lecture section on zeolitical stones, he does not cite them in the bibliographical (further reading) section listed at the end of Pollock's notes. The main authors cited for Zeolitical Earths in that section are, once again, Wallerius and Cronstedt. See *An Epitome of Natural History*, op. cit. (51), 708D, ff. 201–7.

78 *An Epitome of Natural History*, op. cit. (51), 708D, f. 9.

79 Walker had been contemplating the composition of this stone since his 1766 travels in the Hebrides (at the time he thought that it might be a source for talc) and his earlier lecture notes show that he was unsure of zeolite's exact composition. Eddy, op. cit. (3), 425.

80 According to Walker, 'The Fossils of this Class, are chiefly composed of the Terra Ponderosa, or Barytes'. Bergman, op. cit. (30), addresses Ponderous Earth in §§87–91.

Earth had generated a good deal of controversy and debate and its inclusion in Walker's system confirmed his dedication to Bergman's writings.

Class 6 contained Amandina Stones, and it seems that the lead classification character was iron (garnets are part of this class). However, some of the chemical compositions listed for each Amandina genus demonstrate that the ferrous component was quite low. Walker probably thought that iron produced the reddish colour of the rocks and so he therefore included them in this class. The name of Siliceous Stones (Class 7) came from (Primary) Siliceous Earth, which was basically sand.[81] The most obvious point of interest for this class is that it included gems and diamonds.[82] Aside from sand's use for making glass,[83] Siliceous Stones were valued by several industrial practices in Scotland. Sandy gravel, for instance, was used to make artificial phosphorus and was one of the key ingredients in cement. Related to Siliceous Stones were Apyrous Stones (Class 9). Pollock's notes on this class contain a table that demonstrates that they contained a high percentage of Siliceous Earth.[84] Steatitical Earth, which was a Secondary Earth formed from Magnesian Earth and Siliceous Earth (both Primary Earths), was the lead character for Steatitical Stones (Class 8). During his early travels across Scotland, Walker was continually on the lookout for forms of steatite which could be used to make porcelain (this stone also was known to exist in Devonshire and Cornwall). As the *Encyclopaedia Britannica* pointed out, steatite 'afforded the finest earthen-ware ever made … and promises fair, with good management, for equalling any in the world'.[85] Steatitical Stones were therefore important for those in Walker's course who were interested in this industry.[86] The same held for Micaceous Stones (Class 11). Their lead character was mica, which was 'Magnesia, combined with that of Alum'.[87] These Stones were found in Elgin, Nairn and Kincardineshire and were sometimes associated with ceramic production.

The lead characters that Walker used to form classes 12 to 14 were taken from the different types of cement that held them together. At first glance, using cement as a classification character might seem a bit odd. But it is here that we can see how the chemistry of Edinburgh's Medical School, as practised in relation to pharmaceuticals and emerging industrial practices, had direct application to natural history. Since the early part of the century, laboratory experiments on the 'cement' of bladder stones had been a reccurring activity in the school.[88] This research was

81 This is further qualified: 'This class comprehends the Bodies which strike Fire with Steel, and are composed of Siliceous Earth.' *An Epitome of Natural History*, op. cit. (51), 707D, f. 117.

82 *An Epitome of Natural History*, op. cit. (51) 707D, ff. 161–5. This section also refers to Franz Carl Achard's *Chemische Untersuchung verschiedener Edelgesteine* (Chemical Analysis of Various Gems), Berlin, 1778. The specific version that Walker consulted is not known.

83 For Scottish glass, see the chapter on this subject in Clow and Clow, op. cit. (67).

84 *An Epitome of Natural History*, op. cit. (51) 707D, f. 185.

85 *Encyclopaedia Britannica*, op. cit. (72), iii, 626–7.

86 The making of porcelain was also a topic treated in the *Philosophical Transactions* at the end of the eighteenth century. For example, see 'An attempt to make a thermometer for measuring the higher degrees of heat, from a red heat up to the strongest that vessels made of clay can support. By Josiah Wedgwood; Communicated by Sir Joseph Banks, Bart. P. R. S.', *Philosophical Transactions* (1782), **72**, 305–26.

87 *An Epitome of Natural History*, op. cit. (51) 708D, f. 19.

88 Eddy, op. cit. (69).

published in Edinburgh's scientific journals[89] and began to be taken up by chemically trained naturalists interested in the Earth's form and structure.[90] The fact that medical chemistry was being applied to an industrial context during this time is evinced in several books that Walker had in his library. For example, Bergman's *Physical and Chemical Essays* addressed 'Progress for burning bricks'[91] and Brian Higgins gave an account of *Experiments and Observations Made with the View of Improving the Art of Composing and Applying Calcareous Cements* (1780). Drawing from 'the chaste and philosophical productions of Dr. Black',[92] Higgins performed experiments on cementation that had direct application not only to the construction of buildings but also to the chemical composition of strata. At one point, he treats both natural and man-made aggregated calcareous bodies as if they shared the same chemical composition.[93]

Building on his knowledge of cementation, Walker held that classes 12 to 14 were the large rocks that formed the bulk of primary strata, the lowest observable layer of the Earth and the foundation on which all other stones rested. The names for these classes were as follows:

Class 12: Petræ
Class 13: Saxa
Class 14: Concreta

Walker defined Petræ Stone (Class 12) as both 'heterogeneous' and 'Simple'. They were massive 'Rocks … which the naked Eye cannot observe more than one sort of

89 The major scientific journal in the middle of the century was *Essays and Observations, Physical and Literary* (published in 1754, 1756 and 1771). The end of the century saw the foundation of the *Philosophical Transactions of the Royal Society of Edinburgh*. For more on eighteenth-century medical journals in Scotland see F. A. Macdonald, 'Reading Cleghorn the clinician: the clinical case records of Dr. Robert Cleghorn, 1785–1818', in *Science and Medicine in the Scottish Enlightenment* (ed. C. W. J. Withers and P. Wood), East Linton, 2002, 255–79. Edinburgh's medical and scientific print culture are also treated in R. B. Sher, 'Science and medicine in the Scottish Enlightenment: the lessons of the book trade', in *The Scottish Enlightenment: Essays in Reinterpretation* (ed. P. Wood), Rochester, 2000, 99–156.

90 For instance, the surgeon David MacBride built on Black's magnesia alba experiments and argued that fixed air (carbon dioxide) was the 'cementing principle' that held together animal and vegetable bodies. Such a position was directly related to earth's structure in Edinburgh because several of its leading chemists (including Black) held that certain types of limestone were composed of compressed shells. See Eddy, op. cit. (69). D. MacBride, *Experimental Essays … on the Nature and Properties of Fixed Air …*, London, 1764, 254–8.

91 Bergman, op. cit. (40), 376–86.

92 More specifically, he was referring to Joseph Black's 'Experiments upon *magnesia alba*, quicklime, and some other alcaline substances', *Essays and Observations, Physical and Literary* (1756), **2**, 157–225.

93 Bryan Higgins, *Experiments and Observations Made with the View of Improving the Art of Composing and Applying Calcareous Cements and of Preparing Quick-Lime: Theory of These Arts; and Specification of the Author's Cheap and Durable Cement*, London, 1780, 54–5. Walker also owned Antoine-Joseph Loriot's *A Practical Essay on a Cement, and Artificial Stone …*, London, 1774, EC 203. Higgins, Irish by birth, held an MD from Leiden, ran a school of practical chemistry in Greek Street, Soho and was known for his writing on mineral wells: *Synopsis of the Medicinal Contents of the Most Noted Mineral Waters …*, London, 1780. For more on Higgins see his entry in the *DNB*.

Particles',[94] a description which shows that they were a type of hardened cement.[95] Concretion Stone (Class 14) operated on a smaller, more local scale and included concretions of Earths, Water, Fire (inflammables) and Metals.[96] Class 13 was Saxa Stone. Walker held that this class 'forms the greatest Proportion of the Mass of Matter in this Globe, and though it is a subject of much Importance, it is the least cultivated Part of Mineralogy'.[97] Furthermore, he took care to point out that previous chemical mineralogical systems had reduced these stones to an appendix.[98] Saxa Stone, he suggested, was composed of three distinguishable 'Parts': substramen[99] (or Ground), gluten[100] (or Cement) and concretions[101] (or Charge):[102] 'The Substramen and the Gluten compose the cementing or uniting Matter, and the Concretions are the Matter cemented or united.' The only difference between substramen and gluten was their mass. Substramen was 'copious', 'thereby rendering the Concretions at a Distance from one another'. Gluten was 'sparing' and 'the Concretions are near together'. Walker's description of how gluten and substramen held concretions together was no

94 The description is virtually the same as that given for 'Petra' in the definition section at the beginning of the lecture notes. *An Epitome of Natural History*, op. cit. (51) 708D, f. 10. For the structure of Petra Stones, see *An Epitome of Natural History*, op. cit. (51) 708D, ff. 25–6.

95 Class 12 had four orders. Order 2 (Whetstones) was composed of Siliceous Earth and Earth of Alum; Order 3 (Schistic) was made of quartz, mica and shorl; Order 4 (Siliceous) was named after Siliceous Earth. Order 1 (Quadrines) consisted of 'bodies' that were 'disposed in the Earth in Quadrated Masses' and were 'raised in cubical Figures'. These are chemically significant because their cubical shape would have been held to be the product of a chemical reaction. As these shapes resembled large crystalline structures, Walker thought that they were essentially the result of a bygone chemical process. *An Epitome of Natural History*, op. cit. (51), 708D, f. 30. See also his 1760s comments on stone blocks in the Hebrides in the *The Rev. Dr. John Walker's Report on the Hebrides of 1764 and 1771* (ed. M. M. McKay), Edinburgh: 1980, 112, 215.

96 There were four Orders: 'Ordo I. Terrestria, or Concretions formed in the Earth. Ordo II. Aquea. Concretions formed in Water. Order III. Ignigena. Concretions formed by Fire; and lastly, Ordo IV. Metallica, Metallic Concretions.' *An Epitome of Natural History*, op. cit. (51) 708D, 114.

97 *An Epitome of Natural History*, op cit. (51), 708D, f. 55.

98 'It is very evident that this class could never have [a] place in the chemycal System of Fossils, and accordingly we find, that those writers who have attempted to draw up a Chemical System, add the Class of Saxa as a sort of Appendix, which could not be properly arranged in the course of the work.' *An Epitome of Natural History*, op. cit. (51), 708D, ff. 55–6. For instance, at the end of his *Outlines of Mineralogy*, op. cit. (30), §244, Bergman introduces the topic of concreted rocks, but then states, 'Such compositions may well be excluded from the present work, but, upon account of their extensive physical, economical, and metallurgical uses, I propose to give a slight sketch of them.'

99 The *OED*'s only recorded usage of 'substramen' is Rev. James Headrick's *View of the Mineralogy, Agriculture, Manufactures and Fisheries of the Island of Arran …*, Edinburgh, 1807, 56.

100 The *OED*'s first geological usage of this word is John Pinkerton's *Petrology. A Treatise on Rocks*, 2 vols., London, 1811, i, 530. Walker's usage in 1797 lectures demonstrates that it was clearly being used much earlier. It is most likely that the word was imported from its eighteenth-century usage in botany and zoology (which are recorded in the *OED*). Additionally, Walker employed the vernacular equivalent of this word in the field notes that he took in the Hebrides earlier in his career. He used it to describe the composition of Porphyry on the Island of Tiree. This means that the term was being used during the 1760s. See *Walker's Report*, op. cit. (95), 191.

101 Also used in a geological sense in Rev. John Playfair's *Illustrations of the Huttonian Theory of the Earth*, Edinburgh, 1802, 246.

102 The quotations in the next two paragraphs are taken from *An Epitome of Natural History*, op. cit. (51), 708D, ff. 59–63.

doubt influenced by the writings of Black and Cullen and by other chemists in the 'field' like Higgins.

Salts, inflammables and metals

Class 15 contained Salts. As the name indicates, the lead character was the Salt Principle itself (e.g. not a Primary or Secondary manifestation of the principle). The priority that histories of chemistry often give to the implementation of the new French nomenclature sometimes allows scholars to forget that Salts were a vital part of eighteenth-century chemical mineralogy.[103] They played an important role in Lavoisier's own intellectual development[104] and in 1807 Aikin's popular *Dictionary of Chemistry and Mineralogy* asserted that the 'chemistry of salts, taken in the most extended sense, forms by far the largest part of the whole science'.[105] As with Cullen's mid-century tripartite definition of Salts (acid, alkali and neutral),[106] Aikin's *Dictionary* reiterates that they are substances that can be dissolved in water. It then goes on to state that contemporary chemists (*circa* 1800) applied the term 'to all the crystallisable acids or alkalis, or earth, or combinations of acids with alkalis, earths or metallic oxyds. Hence the common and useful distinction *alkaline*, *earthy* and *metallic*'.[107]

Although Walker did not cite Aikin in his lectures, his system demonstrates that he combined this late eighteenth-century view with that of the mid-part of the century. By the 1790s he held that there were two types of Salt: Primary and Secondary. These two divisions were conceptually similar to the role played by Primary and Secondary Earths. But instead of using Secondary Salts to form classes, Walker used them to form orders. His Primary Salts came in two forms: acids and alkalis. These comprised the first two saline orders. He stated that acids had five genera and that these required 'no Explanation, and indeed these more properly belong to the Chymist'.[108] Alkalis had two genera: Natron and Volatile Alkali. Secondary Salts were combinations of Primary Salts with either themselves, Metals or Earths. These combinations formed the last four orders of Walker's saline class: Neutrals, Acid-Earths, Alkaline-Earths and

103 One of the best books on this subject is F. L. Holmes, *Eighteenth-Century Chemistry as an Investigative Enterprise*, Berkeley, 1989.

104 A. Donovan, *Antoine Lavoisier*, Cambridge, 1996. See especially the chapter on Salts.

105 'Salt', in A. Aikin and C. R. Aikin, *A Dictionary of Chemistry and Mineralogy*, 2 vols., London, 1807, ii, 284–5. Bergman's chemistry was also heavily based on saline analysis. See his *A Dissertation on Elective Attractions*, London, 1785, and J. A. Schufle, 'Torbern Bergman, earth scientist', *Chymia* (1967), **12**, 56–97, 87–90.

106 See Eddy, op. cit. (46) and William Cullen, 'A Cullen Manuscript of 1753' (ed. Leonard Dobbin), *Annals of Science* (1936), **1**, 138–56. It should be noted here that William Withering, Cullen's student, included Cullen's definition of 'Salt' in his 1783 translation of Bergman's *Mineralogy*. Withering held Bergman's definition to be inadequate: 'I shall, therefore, offer another, given by Dr. Cullen: – viz. '*Saline bodies* are sapid, miscible with water, and not inflammable.' Bergman, op. cit. (30), §20.

107 Aikin and Aikin, op. cit. (105), 284–5. Original emphasis. Note that the 'oxyd' distinction based on the new nomenclature is being used alongside terms traditionally associated with principle-based chemistry.

108 *An Epitome of Natural History*, op. cit. (51) 709D, ff. 13–14. The five genera were Aerial, Vitriolick, Nitrous, Muriatick, Sparry, Boracic and Phosphoric.

Vitriols:

Primary Salts	**Secondary/Derivative Salts**
Order 1: Acids	Order 3: Neutrals (Acid + Alkali)
Order 2: Alkalis	Order 4: Acid-Earths (Acid + Earth)
	Order 5: Alkali-Earths (Alkali + Earth)
	Order 6: Vitriols (Acid + Metal)

Interestingly, the first three of his saline orders were the exact divisions taught to Walker by Cullen in the 1750s.[109] Black's 1803 *Lectures* also used these three divisions to classify all of the Salts that he presented to his students.[110] However, similar to Aikin's classification, Walker seems to have been a bit more innovative because he also created separate orders for metallic Salts (Vitriols),[111] earthy acids and earthy alkalis. Moreover, it is interesting to note that placing metallic Salts in this acidic category was distinctly different from his 1757 *Philosophical Transactions* paper on Hartfell Spa (near Moffat). There he argued that Salt of iron was alkaline.[112]

The fact that Walker was publishing on the classification of Salts as far back as the 1750s illustrates that he had a long-standing interest in the saline composition of mineral waters.[113] In eighteenth-century Scotland, local spas and wells were a standard testing ground for saline theories that were also applicable to pharmacology and natural history.[114] The medicinal use of these wells was popular at this time and lasted well into the nineteenth century. For instance, the 1797 re-publication of Cullen's 1765/6 *Clinical Lectures* promoted the pharmacological use of wells that contained 'metallic substances' because of their 'tonic power'.[115] Cullen's book, like many publications at the end of the

109 Cullen, op. cit. (106), 144.

110 Joseph Black, *Lectures on the Elements of Chemistry* …, 2 vols., Edinburgh, 1803, i, 347–499. Black was also a student of Cullen.

111 This was a trend at this time. See Bergman on metallic salts in his *Outlines of Mineralogy*, op. cit. (30), §20.

112 John Walker, 'An account of a new medicinal well, lately discovered near Moffat, in Annandale, in the county of Dumfries. By Mr. John Walker, of Borgue-House, near Kirkudbright, in Scotland', *Philosophical Transactions* (1757), **50**, 117–47.

113 Walker maintained a firm interest in Salts throughout his adult life. In addition to general chemistry books, he read several specialized treatises on the subject. The index of the library that he kept during the 1760s (*Index Librorum*, EUL, DC.2.38) contains several *Philosophical Transactions* articles on Salts. Additionally, Elliot's *Catalogue*, op. cit. (4), contains works that address the manufacture of common salt: N. Grew, *A Treatise of the Nature and Use of the Bitter Purging Salt* …, London, 1697, EC 21; J. Collins, *Salt and Fishery* …, London, 1682, EC 257; W. Brownrigg, *The Art of Making Common Salt* …, London, 1748, EC 565; A. Cochrane, *The Present State of the Manufacture of Salt Explained* …, London, 1785, EC 493. Brownrigg and Dundonald's work also was known on the continent. Gerhard Stalla, *Salz in Bayern, eine Bibliographie*, Augsburg, 1995, 9.

114 A good example of this practice can be seen Rev. William Laing's *An Account of Peterhead, its Mineral Well, Air and Neighbourhood*, London, 1793. In addition to addressing the medical benefits of the well, Laing (who also held an MD) based much of his chemical analysis on the work of Torbern Bergman. For more on the therapeutic context of these wells in Scotland, see A. Durie, 'Medicine, health and economic development: Promoting spa and seaside resorts in Scotland c. 1750–1830', *History of Medicine* (2003), **47**, 195–216.

115 William Cullen, *Clinical Lectures, Delivered in the Years 1765 and 1766 … Taken in Short-Hand by a Gentleman Who Attended*, London, 1797, 73–4.

century, utilized saline analysis when testing the composition of such waters.[116] Thus, as a member of the Medical Faculty, Walker, like Black, included a saline class in his mineralogical system because Salts were still a vital part of contemporary chemical practice – especially in therapeutics and experimental pharmacology. In Edinburgh, saline analysis had also become connected to the study of 'airs', specifically in reference to how water could be impregnated with them. At this time, both natural and artificial aerated waters were prescribed by Edinburgh's physicians for stomach and digestive ailments. It was probably for this reason that Walker took manuscript notes on Joseph Priestley's *Observations on Different Kinds of Air* and Karl Wilhelm Scheele's *Chemical Observations and Experiments on Air and Fire* during the 1780s.[117]

Walker's personal manuscripts also reveal that he took notes on the saline composition of mineral waters from the works of John Elliot (who based his work on Priestley) and Bergman.[118] Indeed the preface to Elliot's book was subtitled 'Directions for impregnating water with fixed air' and Walker's notes on Bergman were entitled 'Precipitants for Mineral Waters'. The latter even included a chart that lists which Salts were present in water taken from the spas at Selzer, Bath and Pyrmont.[119] Correspondingly, Walker's library was stocked with related works by Baron Montesquieu, Thomas Short, Donald Monro, Alexander Sutherland and William Simpson.[120] He used saline analysis not only in his mineralogy lectures but throughout all of his other lectures and publications. A good example of this occurred in his hydrography lectures where he cited saline experiments to demonstrate the chemical composition of the ocean, rain,

116 The relevance of medicinal waters in Edinburgh's medical community is treated in Maehle, op. cit. (70), and in A. Durie, 'Medicine, health and economic development: Promoting spa and seaside resorts in Scotland c. 1750–1830', *Medical History*, **47** (2003), 195–216.

117 Walker's notes on Joseph Priestley's *Observations on Different Kinds of Air*, London, 1772, are contained in the bound MS volume entitled *Essays, Transcripts and Other Papers II*, EUL DC.1.58 f. 44. There were many editions of Priestley's book and Elliot's *Catalogue*, op. cit. (4). EC 99 states that Walker owned a 1772 edition and his personal notes suggest that he possibly owned another later one. Walker also had read (*circa* 1782) Karl Wilhelm Scheele's *Chemical Observations and Experiments on Air and Fire. With a Prefatory Introduction, by Torbern Bergman; Translated from the German by J. R. Forster, L.L.D. F.R.S. To which Are Added Notes, by Richard Kirwan*, London, 1780. See *Essays, Transcripts and Other Papers III*, EUL DC.1.59, f. 11.

118 For Walker's notes on Elliot, see *Essays, Transcripts and Other Papers II*, op. cit. (117), f. 42. These are based on John Elliot, *An Account of the Nature and Medicinal Virtues of the Principal Mineral Waters of Great Britain and Ireland, and those Most in Repute on the Continent*, London, 1781. For his notes on Bergman, see *Essays, Transcripts and Other Papers II*, op. cit. (117), f. 40. These are based on Torbern Bergman's *Physical and Chemical Essays*, London, 1784.

119 Interest in the mineral wells at Selzer, Bath and Pyrmont stemmed from Bergman's studies on them in the early 1770s. See the translation of Bergman's *On Acid of Air, Excerpt from K.V.A, 1773. Treatise on Bitter, Seltzer, Spa and Pyrmont Waters and their Synthetical Preparation, Excerpt from KVA, 1775*, Stockholm, 1956.

120 J. B. Secondat, Baron Montesquieu, *Observations de physique et d'histoire naturelle sur les eaux minérales de Dax, de Bagnères, & de Barège, sur l'influence de la pesanteur de l'air dans la chaleur des liqueurs bouillantes, & dans leur congellation. Histoire de l'électricité, &c*, Paris, 1750, EC 19; T. Short, *General Treatise on the Different Sorts of Cold Mineral Waters in England* ..., London, 1766, EC 314; D. Monro, *A Treatise on Mineral Waters*, London, 1770, EC 229; A. Sutherland, *An Attempt to Ascertain and Extend the Virtues of Bath and Bristol Waters by Experiments and Cases* ..., London, 1764, EC 294; W. Simpson, *Hydrological Essayes: Or, a Vindication of Hydrologia Chymica: Being a further Discovery of the Scarbrough Spaw, and of the Right Use thereof* ..., London, 1670, EC 469.

snow and springs. Note his treatment of 'Hard Water': 'These pit springs will not make a lather with Soap; the reason is that they always either contain an earthy or metallic salt, and hence they decompose the soap by the acid in the saline matter attracting the Alkali of the soap and leaving its oleaginous part disengaged.'[121]

The lead classification character for Inflammables (Class 16) was the Inflammable Principle. It had five orders – Airs, Sulphurs, Bitumens, Coals and Electric(al) – and it is unclear if Walker held that these substances were Primary representations of the principle itself. (This being said, Walker was a local expert on the chemical qualities of peat moss.)[122] As the concept of an 'aer' touched on various aspects of his mineralogy (especially in relation to aerial acids and mineral waters), Walker's reading of Priestley's *Observations* and Scheele's *Experiments* no doubt influenced his thoughts on the matter. Additionally, many of the chemical mineralogies in his library emphasized an air's ability to decompose exposed stones. 'Air' at this time was also conceptually linked to electricity because the latter was sometimes thought to be a 'fluid' form of energy that used 'air' as a medium. The attention that Walker paid to 'Coals' also had chemical aspects to it. Its very place in his classification system was dependent upon its ability to burn – which, of course, was a chemical quality. Although he did own books that treated the chemistry of coal composition,[123] his published letter to Colonel Dirom (1800) demonstrates that he was just as interested in its physical placement in strata.[124]

Walker's last three classes (17–19) dealt with the subject of metals. Aside from the metallurgical references made in his mineralogy lectures (which are numerous), his library contained older texts like Agricola's *De Re Metallica* and more recent works like Gellert's *Metallurgic Chymistry* and Jars's *Voyages Métallurgiques*.[125] Other sources for this area were the visits Walker made to Scottish mines early in his career and the experiments being conducted by fellow Edinburgh chemists like Black.[126] The lead

121 Walker, op. cit. (15), 'Hydrography Lecture', 121.

122 John Walker, 'An essay on peat, containing an account of its origin, of its chymical principles and general properties', *Prize Essays and Transactions of the Highland Society of Scotland* (1803), **2**, 1–137. For peat moss's importance to Walker's geology see Eddy, op. cit. (20), 109–10.

123 J. Hutton, *Considerations on the Nature, Quality, and Distinctions, of Coal and Culm*, Edinburgh, 1777, EC 128.

124 John Walker, *Letter to Colonel Dirom, Quarter Master General of Scotland, on the Discovery of Coal*, Edinburgh, 1800 – a copy of this pamphlet is housed in EUL, D.S.h.8.15/5. See also John Williams's section on coal in *The Natural History of the Mineral Kingdom in Three Parts* (Edinburgh: 1789) EC 279.

125 G. Agricola, *De Re Metallica Libri XII …*, Basileae, 1657, EC 181; C. E. Gellert, *Metallurgic Chymistry. Being a System of Mineralogy in General and of All the Arts Arising from this Science* (tr. John Seiferth), London, 1776, EC 100; G. Jars (the Elder), *Voyages métallurgiques: Ou Recherches et observations sur les mines & forges de fer …*, Lyon, 1774, EC 514.

126 Walker's mineralogical travels, including his visits to Lowland mines, are addressed in Eddy, op. cit. (3). E. Vaccari has recently treated how mining contributed to Enlightenment conceptions of the earth: 'Mining and knowledge of the earth in eighteenth-century Italy', *Annals of Science* (2000), **57**, 163–80. Accounts of travels made by naturalists to both homeland and foreign mines, moors and mineral wells, though often hard to find, provide a wealth of information for historians interested in the classification systems. Linnaeus, with whom Walker corresponded in the 1760s, was the archetypical example of such a traveller. His travels are treated in W. Blunt, *Linnaeus: The Compleat Naturalist*, Princeton, 2001, and L. Koerner, *Linnaeus: Nature and Nation*, Cambridge, MA, 1999.

character for Metals (Class 19) was the Metal Principle and its orders were groupings of Primary Metals based on malleability: durable (iron and copper), flexible (lead and tin) and fixed (silver and gold). The lead characters of the two other 'metallic' classes were Secondary Metals: Semimetals (Class 18) and Mundicks (Class 17 – also called Pyrites).[127] The orders of these classes were based on chemical distinctions common in eighteenth-century chemistry – mineralized and calciformed:[128]

Mundicks (Class 17)	**Semimetals (Class 18)**
Order 1: Sulphureæ (mineralized)	Order 1: Sulphureæ (mineralized)
Order 2: Arsenicals (mineralized)	Order 2: Arsenicals (mineralized)
Order 3: Ferreo (calciformed)	Order 3: Fluida (?)
Order 4: Amandina (calciformed)	Order 4: Dubia (?)

Knowledge of metals and semimetals was of direct importance to mining. Physicians were often approached by landowners to inspect mines and to give advice on assaying. Walker's career abounds with examples of the practice. He used his mineralogical knowledge to inspect Lord Hopetoun's mines and to become a scientific advisor to Lord Bute and this experience allowed him to write the letter to Colonel Dirom mentioned above. Finally, metals played a key role in Edinburgh's experimental pharmacology. They were used in many drugs (expectorants and anthelminthics, for example) and figured in therapeutic practices being developed in Edinburgh's Royal Infirmary.

Conclusion

This essay has shown that the mineralogical system taught by Rev. Dr John Walker at the University of Edinburgh was founded upon principle-based chemistry. In focusing on this topic, I have touched upon an area of chemical mineralogy that is often overshadowed by secondary literature interested in excavating the 'forerunners' of Lavoisier, especially his experiments on 'airs'. However, a simple glance at the chemically related articles and chapters in most British, Swedish and German books and journals written during the middle and later decades of the eighteenth century (including the *Philosophical Transactions*) will show that experiments that used the principles of Earth, Salt, Fire, Water and Metal were more numerous than those that investigated air. In fact, even pneumatic chemists transferred the language of mineralogical composition to the study of 'aerial liquids'. For instance, in a 1784 letter written by Charles Blagden to the French translator of Henry Cavendish's 1780s eudiometry

127 Traditionally, pyrites (also called mundicks) included rocks that sparked when struck against steel or other hard bodies. See 'Pyrites' article in Aikin and Aikin, op. cit. (105). This mineral distinction is used to describe marcasites and spars in N. Grew's *Musaeum Regali Societatis*, London, 1681, which is not in the *Catalogue*, but no doubt would have been available to Walker via one Edinburgh's many libraries.

128 For example, see Wallerius's section on metals and semimetals in his *Systema Mineralogicum*, op. cit. (33). Also see J. R. Partington's comments on this aspect of Wallerius's thought in *A History of Chemistry*, 3 vols., London, 1962, iii, 169–72. Walker defines 'calciformed' as 'The Form of Calx, which is where the Metal has been reduced from its metallic or reguline State to a Calx by a particular Solvent. The most General Form of this Sort is that of an Ochre'; whereas 'mineralized' was 'Where it [the metallic substance] is combined either with Sulphur or Arsenic'. *An Epitome of Natural History*, op. cit. (51), 709D, ff. 155–6.

experiments, Blagden used the following mineralogical analogy to explain the 'standard' scale that Cavendish had developed to classify the purity of the air:

> Standard … means properly that fixed measure to which others are compared, but in a more general sense is used by us to express the proportion which any thing bears to a fixed measure: thus if a mixture was made of 3 parts of gold & one of base metal, we might say that the standard of the mixture was 3/4.[129]

Using the characters derived from principle-based chemistry, Walker's final system consisted of nineteen classes and drew from his own knowledge of chemistry, from the expertise of Medical School colleagues and from a pool of publications influenced by continental thinkers.[130] Even though mineralogy was often mentioned in the Medical School's chemistry courses, Walker's lectures were the only ones that offered a comprehensive system. Although Black lectured on limited aspects of mineralogy and geology, he was more interested in discussing basic classification issues that were directly relevant to an introductory chemistry course – a practice that he frankly admitted. When his students wanted to pursue the connections between chemistry and mineralogical systematics, he told them to consult Wallerius, Cronstedt, Bergman, William Withering and Richard Kirwan. Should the writings of these and other authors need to be explained in detail, Black specifically referred them to Walker by stating, 'my colleague, the Professor of Natural History, will give you information of all the particulars. In this [chemistry] course we have not the time to follow the subject so far, but must confine our attention to the most remarkable and distinguished chemical varieties which occur in Nature'.[131]

Throughout this essay I have emphasized that Walker operated within a context that was influenced by the chemically trained physicians who taught in Edinburgh's Medical School. The experiments performed there were often applicable not only to therapeutics and pharmacology but also to the mineralogical composition of geological strata and Scotland's manufacturing and mining industries. Because of their chemical training, Edinburgh's physicians were able to make analogical comparisons between stones taken out of the ground and bladder stones taken out of the human body. On a larger

129 Charles Blagden to Bertrand Pelletier (November 1784), draft, Blagden Letter Book, Yale University. Also quoted in the massive tome of C. Jungnickel and R. McCormmach, *Cavendish: The Experimental Life*, Lewisburg, 1998, 358–9. This book rightly points out that Cavendish had a substantial interest in mineralogy and geology. See Chapter 6, 'Mercury', and Chapter 7, 'Earth', 393–460. I must thank David Pantalony for pointing this source out to me.

130 How the Latin, Swedish, French and German versions of these books ended up in Edinburgh would make an interesting study and would help uncover the routes by which scientific knowledge was transferred between different linguistic contexts. To this goal, C. Warren's recent work in this area is a firm foot forward: 'Charles Elliot's medical publications and the international book trade', in *Science and Medicine in the Scottish Enlightenment* (ed. C. W. J. Withers and P. Wood), East Linton, 2002, 215–54. The 'Short title-list of Charles Elliot's medical publications' on pages 237 to 254 also contains a good number of chemistry books. For a brief look at Swedish books translated into English, see Swedish Museum of National Antiquities, *The Heritage from Newton to Linnaeus: Scientific Links between England and Sweden in Bygone Times*, Stockholm, 1962.

131 Black, op. cit. (110), ii, 20. Black then goes on to give a rudimentary mineralogical arrangement on pages 20 to 169. These sections are more concerned with enumerating experiments that employ minerals than with working out the specific characters of classification.

scale, the role played by medico-chemistry in Enlightenment theories of the Earth remains largely unexplored.[132] Like Higgins's book, the chemical language of Walker's mineralogy lectures was the same as that which was being used in Edinburgh laboratories and suggests that this time period saw no need to differentiate between calcareous mixtures formed in the earth, by masons or in a laboratory crucible. Such a situation is relevant to nascent geological practices because it also implies that Walker and his contemporaries saw little chemical difference between the 'cement' of Highland stratigraphic formations and the 'concretions' of the human body.

Methodologically speaking I have drawn attention to the fact that Walker's mineralogical system depended upon two recurring taxonomic distinctions: primary and secondary. In general, the idea of 'primary' and 'secondary' divisions played a notable role in eighteenth-century natural philosophy. In fact, further treatments of the use of these distinctions would shed much light on a wide variety of early modern classification systems (both for nosology and natural history).[133] From a philosophical perspective, the primary and secondary manifestations of Earths, Salts and Metals bore a striking resemblance to Locke's primary and secondary ideas. Such a situation would have been favourably received in Edinburgh since Cullen discussed *An Essay Concerning Human Understanding* in his lectures[134] and since Locke's epistemology was so prevalent in Scotland.[135] As James McCosh stated in the nineteenth century, 'The Scottish metaphysicians largely imbibed the spirit of Locke; all of them speak with profound respect; and they never differ from him without expressing regret or offering apology.'[136] Yet, as McCosh went on to write, 'the Scottish school never adopted the full theory of Locke' and this led to a wide variety of interpretations. Working out just how many of these interpretations trickled into natural history and chemistry in Scotland is a task that remains to be fulfilled.

132 This would even be the case for James Hutton, whose 1785 Royal Society of Edinburgh papers on his theory of the earth drew from the concepts of bodily circulation that he advocated in his 1749 Leiden medical thesis. Early in the century, the English author William Hobbs summed up a similar approach (*circa* 1716) when he wrote, 'It appearing, by what has been Said, That the Earth cannot be an animated Body, without an internal *Heat and motion*, or pulsation: we Shall therefore endeavour to prove that those Properties or Quallifications, are to be found in the Earth, as certainly as in any other Animall.' Roy Porter (ed.), *The Earth Generated and Anatomized by William Hobbs: An Early Eighteenth-Century Theory of the Earth*, Ithaca, 1981, 61.

133 For chemistry, a good place to start would be Robert Boyle's 'simple' and 'compound' distinctions used by Cullen in the 1750s and Macquer's primary and secondary 'principles' in his *Dictionary of Chemistry* (tr. James Kier), London, 1777. The former distinction was brought forth into mineralogy via Cullen's conception of a 'simple' and 'structured' stone. Additionally, several eighteenth-century chemists – Domenico Guglielmini and Bergman, for example – used the concept of 'primary' (primitive geometrical form) and 'secondary' to classify crystals. See R. Hookyaas, 'Torbern Bergman's crystal theory', *Lychnos* (1952), **16**, 21–54.

134 A. L. Donovan, *Philosophical Chemistry in the Scottish Enlightenment*, Edinburgh, 1975, 42–4.

135 Although it could be argued that these distinctions were gleaned independently via ancient and early modern taxonomical arguments that were often read in the form of Aristotle's *Categories*. For reference, see John Wilkins's *An Essay towards a Real Character, and a Philosophical Language*, London, 1668, or even Robert Boyle's numerous comments on classification in Peter Shaw's collected edition of his works, *The Philosophical Works of the Honourable Robert Boyle Esq.*, London, 1738.

136 James McCosh, *The Scottish Philosophy, Biographical, Expository, Critical, from Hutcheson to Hamilton*, London, 1875, 28–9. Here McCosh used the term 'metaphysician' to denote philosophers like Hutcheson, Hume, Reid and so on, whom he held to be key thinkers of the Scottish Enlightenment.

This being the case, it is interesting to note that Walker applied the primary, secondary and tertiary hierarchical distinctions to the strata of the earth in his lectures on geology. This tradition was also followed by early nineteenth-century geological systems based on both chemical and natural (stratigraphic) characters.[137] Walker's use of chemistry to determine the mineralogical composition of geological strata suggests that histories of the nascent earth sciences that have ignored chemical composition are neglecting a vast early modern experimental culture that viewed the earth in stringently analytic terms. Equally, histories of chemistry have also overlooked this culture because its complex principle-based system does not conform to the later historiographical precedent given to Lavoisier and the new nomenclature. This situation is made even more challenging when one realizes that mineralogists often used several different types of lead chemical character (e.g. those based on principles and primary and secondary qualities). In this essay I have called attention not only to the relevance of Walker's system but also to the many other mineralogists who, like him, would have been happy to defer to a hammer and a crucible when analysing the terraqueous globe.

A comparison of the classes of Walker's mineralogical systems

1781[138]	1790[139]	1795/7[140]
1. Terræ	1. Terræ	1. Terræ
2. Calcarea	2. Calcarea	2. Calcarea
3. Gypsea	3. Gypsea	3. Gypsea
4. Phosphorea	4. Ponderosa	4. Phosphorea
5. Fusoria	5. Phosphorea	5. Zeolitica
6. Silicea	6. Amandina	6. Ponderosa
7. Steatitica	7. Silicia	7. Amandina
8. Apyra	8. Steatitica	8. Silicea
9. Zeolitica	9. Apyra	9. Steatiticea
10. Micacea	10. Zeolitica	10. Apyra
11. Petræ	11. Micacea	11. Micacea
12. Saxa	12. Petræ	12. Petræ
13. Concreta	13. Saxa	13. Saxa
14. Salia	14. Concreta	14. Concreta
15. Inflammabilia	15. Salia	15. Salia
16. Pyritæ	16. Inflammabilia	16. Inflammabilia
17. Semimetalla	17. Pyritis	17. Pyritis
18. Metalla	18. Semimetalla	18. Semimetalla
	19. Metalla	19. Metalla

137 Charles Lyell, *Principles of Geology or the Modern Changes of the Earth and Its Inhabitants*, London, 1875, 58–9; Porter, op. cit. (19), 160–5; A. Geikie, *The Founders of Geology*, London, 1905, 194–5. Humphry Davy also used the same divisions in *Elements of Agricultural Chemistry …*, London, 1813, 167–79.

138 John Walker, *Schediasma Fossilium*, op. cit. (24).

139 *Lectures on Natural History*, op. cit. (25), DC.2.25, f. 62 and *Lectures on Natural History III*, op. cit. (25), DC.2.19, f. 3. This version of Walker's system is also printed as an appendix in Eddy, op. cit. (20), 111.

140 John Walker, *Systema Fossilium*, op. cit. (27), which has a 1795 watermark. This is also the classification presented in David Pollock's 1797 *Epitome of Natural History*, op. cit. (51).