

ARTICLES



William Edmond Logan's Geological Apprenticeship in Britain 1831-1842¹

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He seems to have been mostly self-taught, though no doubt he learned much from the practical mining engineers with whom he came in daily contact (Flett, 1937, p. 40).

SUMMARY

William Logan was recently voted Canada's most important scientist. But the origin of his scientific interests has been a mystery. He attended university but not geology classes; he then became an accountant, far removed from geology. In 1833 Logan became joint manager of a copper-smelting works near Swansea, south Wales, at that time the world copper-smelting centre. Logan's

smelting operations depended on coal, a great variety of which was then available here, with anthracite soon used in iron making. With such motivations, Logan enthusiastically set to work to make a comprehensive study of coal, iron and other mineral seams in the vast South Wales Coalfield. Logan's surviving notes reveal a considerable debt to the many mineral and land surveyors and colliery viewers and engineers who were already active in the area. Such people have been written out of the history of geology, as they published little or nothing, but their part in Logan's meteoric rise as a geologist deserves recognition.

RÉSUMÉ

Récemment, William Logan a été nommé le scientifique le plus important du Canada. Toutefois, la cause première de son intérêt pour les sciences demeure encore un mystère. Bien qu'il ait fréquenté l'université, il n'y a pas suivi de cours de géologie. En 1833, il est devenu codirecteur d'une fonderie de cuivre près de Swansea, dans le sud du pays de Galles, alors le centre mondial de la métallurgie du cuivre. Les activités métallurgiques qu'il dirigeait étaient tributaires de l'approvisionnement en charbon et, le Canada en recelait une grande variété, dont l'anthracite qui allait bientôt être utilisé dans la fabrication de l'acier. Ce sont là les grandes lignes du contexte dans lequel Logan commença une étude exhaustive des couches de charbon, de fer et autres substances minérales du vaste bassin houiller du sud

du pays de Galles. Les notes de Logan dont on dispose encore montrent que son étude est fortement tributaire des contributions de nombreux arpenteurs-géomètres, minéralogistes, ingénieurs et chroniqueurs houillers de la région. Comme ces gens ont peu ou pas publié, ils ont été exclus de l'histoire géologique, mais il demeure que le rôle qu'ils ont joué dans la carrière de géologue de Logan mérite d'être reconnu.

INTRODUCTION

William E. Logan (1798-1875), the first director of Canada's Geological Survey (1843-1869), has long, and rightly, been a man of great appeal to all interested in geology and in particular, Canadian geology. This is best demonstrated by the recent poll by *Maclean's Magazine* of the "Most important Canadians in History" which placed him as the most important scientist in Canada's history, "a man whose imprint remains on the land and whose surveys made it possible to tap Canada's treasury of minerals" (Anonymous, 1998, p. 39). Logan has the highest mountain in Canada named after him; rather appropriately, this has proved to be the fastest rising mountain in North America (*Episodes*, June 1992, v. 15, n. 2, cover).

But Logan is symptomatic of a major problem in history, and not just that of geology. He travelled and trained outside the country of his birth (he was born of Scottish parents in Montreal on 20 April 1798) and he also died "abroad," having returned from Canada to be near his geological training grounds in south

¹ This paper sheds new light on the question of how William Logan acquired his initial skills in geology, while immersed in the commercial world of accounting and managing a large copper-smelting operation, yet following his interests in geology to the point of obtaining the recognition of the British academic and scientific community of the day. Hugh Torrens gave the paper orally at the symposium "Hutton, Lyell, Logan and their influence in North America", held at the 1998 Geological Society of America Annual Meeting in Toronto (Conference Report, *Geoscience Canada*, 1998, v. 25, p. 185-188). Although Logan lacked formal training in geology, study of a hitherto almost unknown 1850 report by Logan on his work in Canada in the 1840s (Smith, *Geoscience Canada*, v. 26, p. 111-120, this issue) shows just how skilled Logan had become by 1850, and what major contributions he was making in Canada. R.W. Macqueen, editor.

Wales, where he died on 22 June 1875 at Castle Malgwyn, in Pembrokeshire (Winder, 1965). Such travel-filled lives complicate the historian's task, as records of them get split, separating across, in this case, the drifting continents of Europe and North America. Separate expertises, and considerable finance, are needed to deal with such records now preserved in widely separate archives.

Conscious of this difficulty I determined to seek out what I could of records in the United Kingdom to shed light on the thorny problem of when, where, and how Logan first learned the geology, at which he proved so proficient, on his permanent return to Canada in 1843. But, if only to illustrate the extent of the problem outlined above, I have not been able to use Canadian archival sources. I hope some future Canadian scholar may be able to build on these foundations.

AT EDINBURGH UNIVERSITY

Logan entered Edinburgh University for the academic year 1816-1817 intending to study medicine. In the event, he only spent this 1 year at the university. Professors here had to earn their livings by the numbers of students they attracted (Smith, 1976, v. 2, p. 760; Shapin, 1976, p. 17). University records show that Logan took classes in logic from Professor David Ritchie (died ca 1842), in chemistry from Professor Thomas Charles Hope M.D. (1766-1844), (whose class that year had 522 students; such numbers thus prove not to be a new phenomenon!), and in mathematics from a Mr. Nichol. But Logan left the university in 1817 to work at the counting house of his uncle Robert Hart Logan (1772-1838, hereafter Hart) in London. Hart was elected an MP for Suffolk in 1837 just before he died (Stenton, 1976, p. 242).

Gordon Winder has claimed that an earlier statement that Logan was not exposed to geology at Edinburgh University is probably not now correct, since Logan's mentor in chemistry was Hope "...an ardent supporter of the Neptunists" (geologists who believed that rocks formed by the action of water alone), so that "Logan probably was exposed to some geological concepts in his university course" (Winder 1965, 123-4). But Hope, whatever he may have taught Logan — and this certainly included some geology — was always

a devoted Plutonist (or Huttonian), never a Neptunist. Winder was misled by a confusing letter from Louis Albert Necker (1786-1861), the Swiss Neptunist, who was expressing the wish that Hope might change his mind, when he wrote about him in 1807 (Eyles, 1948, p. 100-102). Hope instead believed, with his Edinburgh associate James Hutton (1726-1797), that the role of fire and heat in the production of some rocks, like granite and basalt, and in the consolidation of others, had been both crucial and central. It was in that cause that Hope was "not less zealous," to quote Necker.

Hope's true allegiances are proved by many sources, from G.B. Greenough's (the soon-to-be first president of the Geological Society of London in 1807) 1805 *Scottish Journal* (Rudwick, 1962, p. 124-125) to David Brewster (1781-1868) who insisted, some years later, that Hope was "a Huttonian philosopher" ([Brewster], 1837, p. 10). Hope's own lecture notes survive (Anderson, 1978, p. 37), as do others taken by an attending German student in October 1798 (Oxford, Bodleian Library, MS Eng. Miscellaneous d. 197). These were made by the later distinguished diplomat, linguist and historian Barthold Georg Niebuhr (1776-1831), (Bunsen *et al.*, 1852, v. 1, p. 106-107, 124, 128). Final confirmation comes from surviving lecture notes and other sources quoted in Jim Secord's analysis of Charles Darwin (1809-1882)'s attendance at Hope's lectures in 1825-1826. These further prove that "Dr. Hope thinks the Huttonian better accounts for the appearance of Nature than the Wernerian" (Secord, 1991, p. 139-142).

I believe we should continue to take seriously the claim by Logan's biographer, Bernard Harrington (1883, p. 9) that "teaching [at Edinburgh] probably had nothing to do with Logan's future devotion to geology." All available evidence still points to this being the correct view. But there is now evidence that Logan was soon busy as a collector of fossils. Several labelled specimens of fossil bivalves that he collected in Suffolk, where his uncle's estate was situated, probably in the 1820s, still survive in the Royal Institution of South Wales (RISW) collections, now at Swansea Museum. They deserve further research. Logan was soon busy extending such investigations. This is shown by his excursion to examine the

London Clay formation (Eocene) on the Isle of Sheppey during an enforced stay in London in 1833 (Harrington, 1883, p. 55-58). Such rocks were close in geological age to the rocks from which he had already collected in Suffolk.

It might be tempting to see parallels between the geological apprenticeships of Darwin and Logan, since both took up the serious study of geology at much the same time. But I believe this would be misleading. Darwin was much influenced by his university careers, at both Edinburgh and Cambridge, while Logan was not. Darwin left us a mass of manuscript material on which the "Darwin industry" is now based, while Logan's have been hopelessly scattered or lost. Darwin was influenced all along by "gentlemanly" attitudes to geology, and those aspiring to these, at the Geological Society of London. Logan was instead in business, and could never be the leisured amateur (in its original sense) that Darwin remained. Logan's profession depended on his acquisition of geological knowledge. Gordon Winder asked the crucial question, "did [Logan] acquire geological knowledge through the business transactions of his uncle's company?" (Winder, 1965, p. 108). The answer is yes.

IN SOUTH WALES

Logan was first based in London after his studies in Edinburgh, and from 1827 took charge of his uncle's business affairs at his counting house there, leaving Hart to enjoy his Suffolk estates. Harrington noted that Logan's "study of geology [as opposed to fossil collecting] was apparently not begun until after he went to live in South Wales." This was early in 1831 (Harrington, 1883, p. 49), not 1829 (Christie, 1994, p. 169). It was Logan's first cousin William Logan Edmond (1808-1877) who had arrived here in 1829 as metallurgist to the Forest Copper Works, near Swansea (Dahne, 1971, p. 131). Logan certainly had earlier south Wales connections, such as those revealed by his visits to the Gower family at Castle Malgwyn between 1822 and 1829. These must have helped lead to the marriage of his youngest sister Elizabeth (1799-1866) to Abel Lewes Gower (1796-1849) on 2 September 1828 (not 1837 as Winder, 1965, p. 10-5). Such connections in turn explain why Logan was to die there (Crisp, 1917, p. 51; Phillips, 1867, p. 142). Gower had been elected a Fellow

of the Geological Society of London (FGS), well before Logan, on 12 June 1833 (Anonymous, 1833, p. 486). Gower was thus in a good position to advise Logan on the best geological reading available.

By the spring of 1833, Logan was using Conybeare and Phillips's fine 1822 textbook, which concentrated on uncovering the "regular succession and order in the arrangements of the mineral masses constituting the Earth's surface" (Eagan, 1992, p. 327). He was also quoting the third volume (1833) of Lyell's new *Principles of Geology* (Harrington, 1883, p. 56; Winder, 1965, p. 109). Logan's new Gower brother-in-law had been based at 31 Finsbury Square, London while Logan shared a house at nearby 47 Finsbury Square with Dr. Robert Dickson (1804-1875) MD Edinburgh 1826, (see Dictionary of National Biography). Both Gower and Dickson would have been able to help Logan discover "which are the best works in

geology and mineralogy" (Harrington, 1883, p. 50) before Logan departed for south Wales.

At Swansea, or "Copperopolis," between 1800-1890, 90% of British copper was smelted using coal, and by 1845, 55% of the world's copper was being smelted here (Newell, 1990, 1997). A good description of the processes involved there was given by the Freiberg Bergakademie-trained metallurgist and geologist John Henry Vivian (1779-1855) in 1823 (Vivian, 1823). Vivian had been a honorary Member of the Geological Society from its foundation in 1807. One of the many smelting firms involved at Swansea was the Forest Copper Works at Morriston, 3 miles upstream from the port of Swansea (Fig. 1).

These works had been purchased on 11 May 1827 by the firm of Osborne and Benson, whose partners were Henry Osborne and Thomas Starling Benson (1775-1858). By the end of that decade

Benson had enlisted the financial support of Logan's uncle Hart, who soon joined the partnership. Members of the Benson and Osborne families also intermarried on 18 October 1831 (Anonymous, 1831a, p. 464). New records give useful data on the timing of Logan's business activities in south Wales. The articles of a new partnership, now between Starling Benson, Jr. (1808-1879) and Logan, dated 2 February 1839 (West Glamorgan Archives, D/D SB 12/13), show how Osborne and Benson next leased another copper premises and copper slag near Melyncriddan, Neath from 28 February 1829, while the firm was newly named Benson, Logan and Company from 20 April 1833 (Bayliffe and Harding, 1996).

Logan first joined these Forest Copper Works in 1831, as manager in charge of accounts, but he soon became concerned with all aspects of copper smelting, which of course involved locating and purchasing supplies of both



Figure 1 Swansea and the Harbour in 1848 (from the *Illustrated London News*, 19 August 1848, v. 13, p. 109).

the many types of copper ores, which had formerly come largely from Cornwall but which could now be imported from Ireland (Knockmahon), South America and Europe, and of coal, which was available in great abundance locally, again in various types, but of which 2 tons were needed to smelt every ton of ore. On 1 February 1833 the first of seven patents assigned to Nicholas Troughton R.N. (died 1844; see *Cambrian*, 21 December 1844, the local newspaper published in Swansea) for "preparing materials for, and producing, a... Metallic Cement" (British Patent number 6303, dated 8 September 1832) was assigned to Benson, Logan and Company. This the firm also started to manufacture, under new articles of partnership signed on 20 April 1833. In these, Benson, Sr. transferred some of his shares to his son, and Hart Logan, part of his shares to his nephews William E. and Henry Logan. In 1834 the old Forest Works were demolished and rebuilt as part of Benson and Logan's major improvement scheme (Grant-Francis, 1881, p. 111). It is likely that while at Swansea, Logan lived at Cambrian Place (Fig. 2), sharing the residence of his friend and colleague, Starling Benson, both partners in the firm from 1833 (Bayliffe and Harding, 1996).

Logan started to take fuller managerial responsibility in these south Wales operations from April 1833. Exactly how the two partners separated their responsibilities remains unclear but Logan, clearly with an already extant interest in geology, was undoubtedly the more involved with supplies of coal and copper while Benson was more interested in their transport by rail, and in shipping improvements through the crucial development of Swansea Harbour, in which, however, Logan was also a Trustee (*Cambrian*, 19 August 1843). We should moreover recall that, long after Logan had left Swansea, Benson was also competent enough as a geologist to report to the British Association for the Advancement of Science (BAAS) in 1848 both "on a Boulder of Cannel Coal found in a vein of common bituminous coal" (Benson, 1849a) and to deliver a very significant paper on the relative positions of the various types of coals found in south Wales (Benson, 1849b).

As one immediate result of this new partnership, we find Logan writing to another brother James, in June 1833,

of how "the study of the ores of copper had gradually led me to that of mineralogy and geology, and of specimens in both I have become a bit of a collector... I attend to nothing else but the making of copper and [the] digging of coal from morning to night" (Harrington, 1883, p. 50). This was the reason Logan was absent for several months in 1834 in France and Spain (see Logan to De la Beche, 14 April 1838, National Museum of Wales, Cardiff, Geology Dept. archives, letter 868; see Sharpe and McCartney, 1998, p. 67; Harrington, 1883, p. 58-59). He was seeking new supplies of copper ore in Spain. A large amount of documentation, and some specimens, from this search survive in the collections, publications and archives of the RISW, Swansea.

WELSH INFLUENCES ON LOGAN'S GEOLOGICAL KNOWLEDGE

The major influences that facilitated Logan's now professional interest in geology were first formed at Morrision, site of the Forest Works. This had been earlier the home of the first geological pioneer of the soon-to-be enormous South Wales Coalfield, the forgotten but important mineral engineer and land surveyor Edward Martin (1763-1818) (Torens, in press). In 1806 he first published his ground-breaking, and much reprinted, *Description of the Mineral Basin of South Wales*, which contained a detailed stratigraphic log, listing all known coal seams within the Swansea part of this coal basin (Fig. 3).

We know that Logan was directly influenced by Martin's work in at least two ways. First, in 1838-1839, Logan do-

nated a now apparently unique copy of a 1809 Swansea reprint of this paper, printed by T. Jenkins, to the library of the RISW (Anonymous, 1839, p. 57), where it survives. Second, Logan's Welsh geological MSS, as now preserved in the archives of the British Geological Survey (BGS) at Keyworth, Nottingham, quote several of "Old Martin's" notes and sections. These include 1. "Old Martin used to say that the Lansamlet [coal] Veins are to be found over at Aberavon" (in Notebook 1 (1837), p. 11, Logan's unnumbered field notebooks 1837-1842, numbered 1 to 13, BGS archives).

2. "Details of Pembray seams from Messrs Martin and Davies" (Logan's notes and sections relating to the South Wales Coalfield 1836-1842, BGS archives, 1/218, p. 27-28, 459). [Martin's son-in-law, the surveyor David Davies (1786-1819), see *Cambrian*, 12 June 1819, was Martin's business partner from 1807].

3. Geological section near Pont Yates with "distances measured from a section by Old Martin" (*ibid.*, p. 467-468). Martin's youngest son, the barrister and local land owner Joseph Martin (1807-1850), was also the author or source of several other sections and notes in Logan's manuscripts. This other Martin was also elected a Fellow of the Geological Society on 3 November 1841 (Anonymous, 1841, p. 545).

While Logan was busy gathering details of the occurrence of coal seams in the South Wales basin and of their correlation across it, as revealed by these notes, he came across a number of others who had preceded him in such work.



Figure 2 Cambrian Place in the 1830s with the Benson, Logan house on the left (from Bayliffe and Harding, 1996, p. 49) by kind permission of Dorothy Bayliffe.

One, but of whom we have no evidence yet of any direct influence on Logan, was the English land and mining surveyor Richard Cowling Taylor (1789-1851), who emigrated as a surveyor and engineer to North America (Philadelphia) in 1830 just before Logan arrived in south Wales. Taylor had been a pupil of the geological pioneer William Smith (1769-1839), also in south Wales in 1810. From 1825 Taylor made detailed and pioneering 3-D models of all the coal and iron seams exposed in the vicinity of Pontypool, at the eastern end of the coal field (Taylor, 1835). These won Taylor the Gold Medal of the London Society for the Encouragement of Arts, Manufactures and Commerce in 1830. Logan seems certain to have

known of this work (Fig. 4).

Others known to have more directly helped and influenced Logan were members of the Kirkhouse family, who had long held important places in south Wales engineering and iron making (Wilkins, 1888, p. 236-239; Hughes, 1990, p. 127-131). William Kirkhouse, Sr. (ca 1785-1873; see *Cambrian*, 16 June 1873) had been employed by Osborne, Benson and Co. from early in 1830 to improve their copper works and then to examine the potential for, and then sink, a new colliery at Penclawdd (due west of Swansea), which they then leased (see W. Kirkhouse letters dated 15 July 1831 to Osborne, Benson and Co., and 1 November 1834 to Benson, Logan and Company, letter book, West Glamorgan

Archives Office, SL 14/1 = Swansea Public Library MSS 466, p. 46, 68; Harrington, 1883, p. 388). William's brother Henry (ca 1781-1866; see *Cambrian*, 22 June 1866), who was manager at the important Cyfarthfa Iron works, later also contributed geological data to Logan by providing a geological section at Cyfarthfa, which Logan later annotated "correct" (Logan's numbered field notebooks 1 to 13, 1837-1842, BGS archives, v. 1, 1837, p. 103-106).

Others directly involved include "David Williams and Son, land and mineral surveyors" of Swansea. These two, on 24 March 1835, prepared a detailed "Report on minerals at Clyn Ithrim farm, Llanyfelach" with a map, which still survive in Logan's MSS papers (BGS archives, 1/67, v. 1). The senior Williams (died 1856; see *Cambrian*, 21 November 1856) was a land and mineral surveyor in Swansea by 1828 (*Cambrian*, 20 December 1828) as well as the engineer who had started the engine for Richard Trevithick's first experiment with a locomotive here in 1804 (Owen-Jones, 1981). He was soon joined by his land surveyor son David Hiram Williams (ca 1812-1848; see *Cambrian*, 2 January 1849).

LOGAN'S GEOLOGICAL MAPPING FROM 1835 AND HIS WORK FOR THE GEOLOGICAL SURVEY FROM 1838

Logan's systematic survey of the South Wales Coalfield is claimed to have started as early as 1831, by the metallurgist John Percy (1817-1889), an old friend of Logan's, writing in 1862. Exactly when this work first came to the attention of the Director of the Geological Survey, Henry De la Beche (1796-1855), seems uncertain. De la Beche himself only arrived at Swansea on 16 December 1837 (Sharpe, 1985, p. 6). Ramsay has pointed out how De la Beche

... well knew that the purely practical and possibly money-making part of the [Geological Survey] business would, at first, at all events, make most impression on the government and on the public, [if] he decided to commence this work in the important [metal] mining districts of Cornwall and Devonshire... Having finished [this], Sir Henry wisely saw, that the best thing to do was to begin on another [coal] mining region, and accordingly he transferred himself, for that was all the staff in those days to Glamorganshire (Ramsay, 1877, p. 365-366).

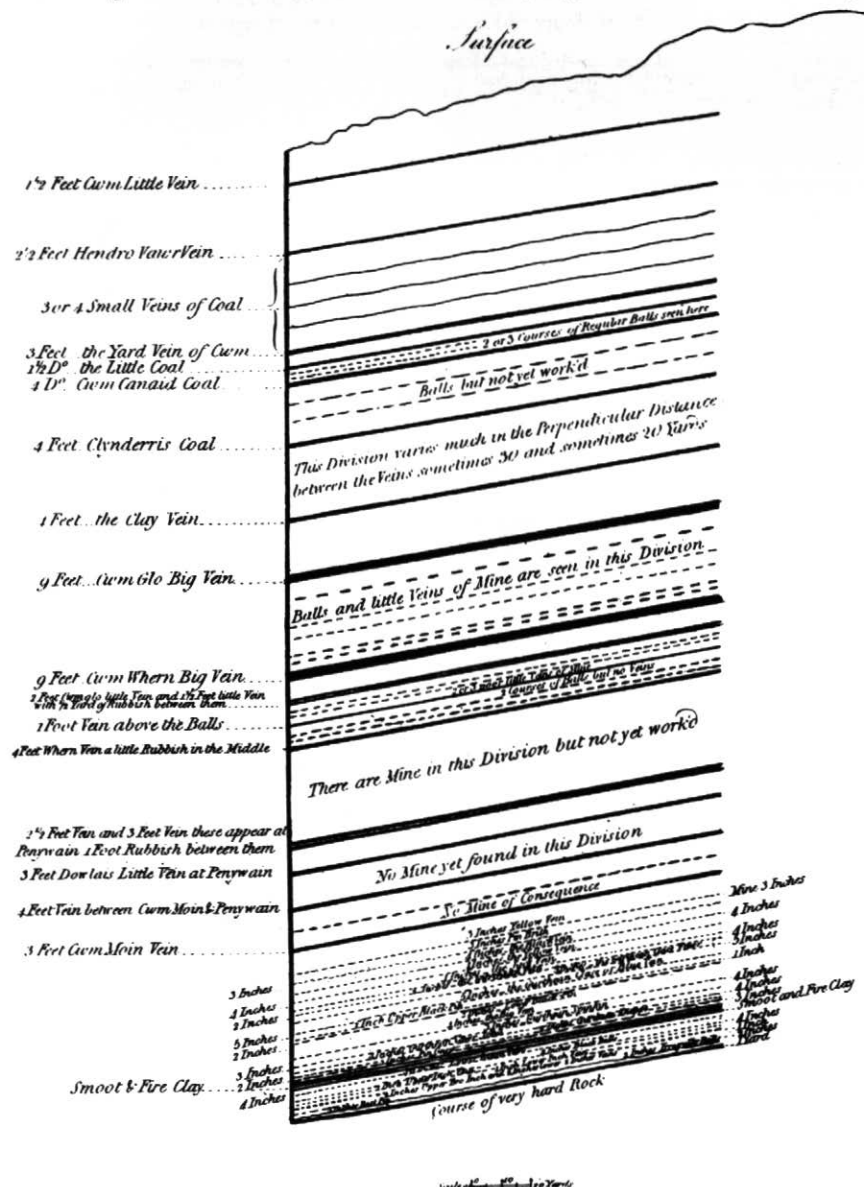


Figure 3 Edward Martin's detailed section of the Coal Measures as known in the South Wales Coalfield in 1806 (from Martin, 1806, plate 14, n. 2).

But Logan's unofficial work, later much used by the Geological Survey, had started well before this. 1836 is the first date in Logan's "Notes and sections relating to the South Wales Coalfield 1836-1842" (in BGS archives, 1/218) on paper also watermarked 1836. The first section in these is of a coal "section of the Bedwelty [Bedwellty] minerals adjoining Ebbw Vale property of the Monmouthshire Iron and Coal Company" dated 1836 (BGS 1/218, p. 3-7). The Third Report of the RISW for 1837-1838 published in June 1838 specifically notes (Anonymous, 1838a, p. 17) "Logan has already exhausted three years in laying down on Ordnance Survey sheets... the coal basin between Kidwelly and the Vale of Neath." So Logan must have started his comprehensive geological mapping here in the summer of 1835. He was thus busy mapping in

the area of his future Geological Survey work, well before he was elected to the Geological Society of London early in 1837, and his application to join the latter must have been inspired by the former.

It is thus impossible for this detailed mapping work to have already "directly contributed to scientific debates within the Geological Society of London," as Christie claims Logan's work did (1994, p. 162). In any case, its Fellows spent their time arguing "violently and at length, about coal seams and mineral veins... but their disputes concerned the nature of coal, the origin of mineral veins, *not where to find them*" (italics here added; Porter, 1973, p. 323). Logan's interest as a copper smelter was to find more coal. The availability of local coal was the single, simple reason that Swansea copper smelting then led

the world. It was entirely based on the close proximity and great abundance of coal supplies. Logan's geological life in Wales thus far had been in search of better materials for his smelting works near Swansea, in which he was a partner from 1833.

It should not be thought, however, that the Geological Survey was entirely parasitic on Logan's growing knowledge of the South Wales Coalfield (Fig. 5). The Survey in turn duly improved Logan's operations. In December 1839 Benson, Logan and Company published an earlier July 1839 joint Report by the Survey's chemist, and curator of their Museum of Economic Geology in London Richard Phillips (1778-1851), and William Carpmael (1804-1867), the leading patent agent in London. Their Report was on improved processes for smelting copper ores, the subject of

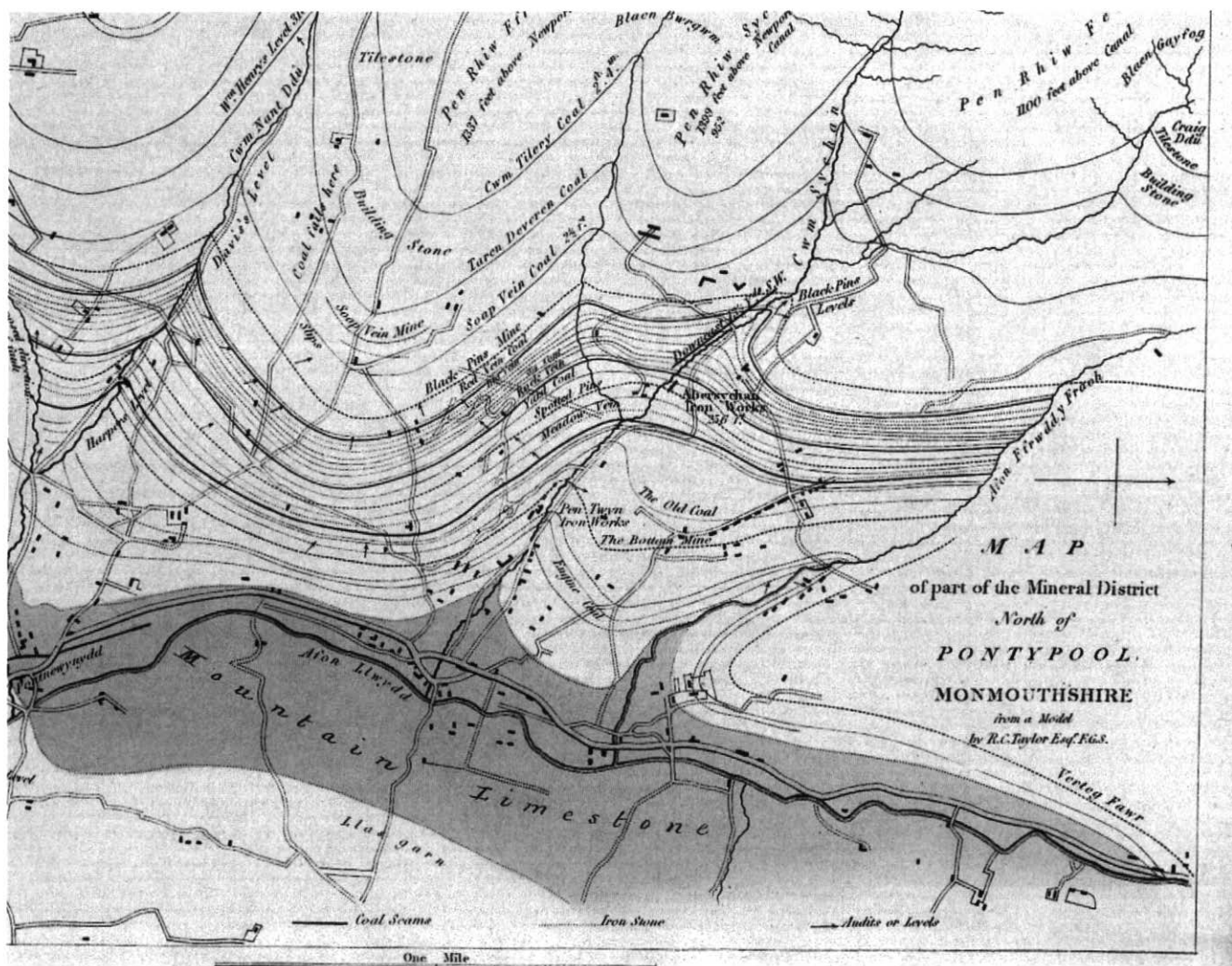


Figure 4 Richard Cowling Taylor's map (from his detailed and pioneering three dimensional model) of the coal (=solid) and iron (=dotted) seams, north of Pontypool, at the eastern end of the Welsh coal field (from Taylor 1835).

three other patents granted to Nicholas Troughton between 1835 and 1839 (British Patent numbers 6965, 7779, 8075). These, also in use by then at the Forest Copper Works, tried to prevent the wholesale escape of noxious vapours during the calcining of copper ores. This detailed Report concluded that these inventions were "new, useful, and decidedly successful" (see *Cambrian*, 28 December 1839).

Logan himself later noted of his time in south Wales:

... my whole connection with Geology is of a practical character. I am by profession a Miner and Metallurgist and for many years was one of the active managing partners in an establishment in Wales, where we annually melted 60,000 tons of copper ore, and excavated 60,000 tons of coal. It was my constant occupation to superintend and direct the minutest details of every branch of the business, A due regard to my own interest forced me [italics here added] into the practice of Geology, and it was more particularly to the economic bearings of the Science that my attention was devoted (Logan, 1855, p. 39).

MORE WELSH MINING CONNECTIONS

Before and after his Geological Survey commission, Logan remained in touch with other mineral surveyors and the colliery overmen and viewers who were now such an important part of the burgeoning South Wales Coalfield. South Wales discovered a new market for its anthracite coal, as result of the technical advances made by George Crane (ca 1784-1846). He was the first, at least in Britain, to smelt iron with local anthracite fuel, using hot blast methods at his Ynisedwin Iron Works from early 1837 (Brough, 1836; Anonymous, 1837, 1846). Such men were papyrophobic, being doers not writers. They are thus too easily forgotten by today's historians, who rely too much on printed records. Lynn White, Jr. made the point best in 1962 when he noted how "history is a bag of tricks which the dead have played upon historians. The most remarkable of these illusions is the belief that the surviving written records provide us with a reasonably accurate facsimile of past human activity" (White,

1962, p. v). He might well have been thinking of such mining professionals.

Logan's survey of the South Wales Coalfield reveals at least one direct debt to such men. Logan naturally first became familiar with the Swansea area when he started his work, as this was where his works were sited and for which he needed coal. When he moved westward to survey the Llanelli coalfield, he was instead obliged to seek other sources, such as those revealed by the MSS "Extracts from the observations of B. Jones - gathered from the long experience of his father Rees Jones as a mineral surveyor, accompanying a Plan of the courses of the Seams in the Llanelli district made in 1835," which survive in Llanelli Public Library, but without the plan (Thomas Mainwaring Commonplace Book). The Llanelli Copperworks Company had commissioned a report in 1835 on the coal districts it then leased. Rees' son, Benjamin Jones, was chosen to prepare this, and his Report also survives (National Library of Wales, Nevill MS XVIII, January 1836). These sources reveal the in-

The Coal Field of Sth Wales & its surrounding Beds of Limestone

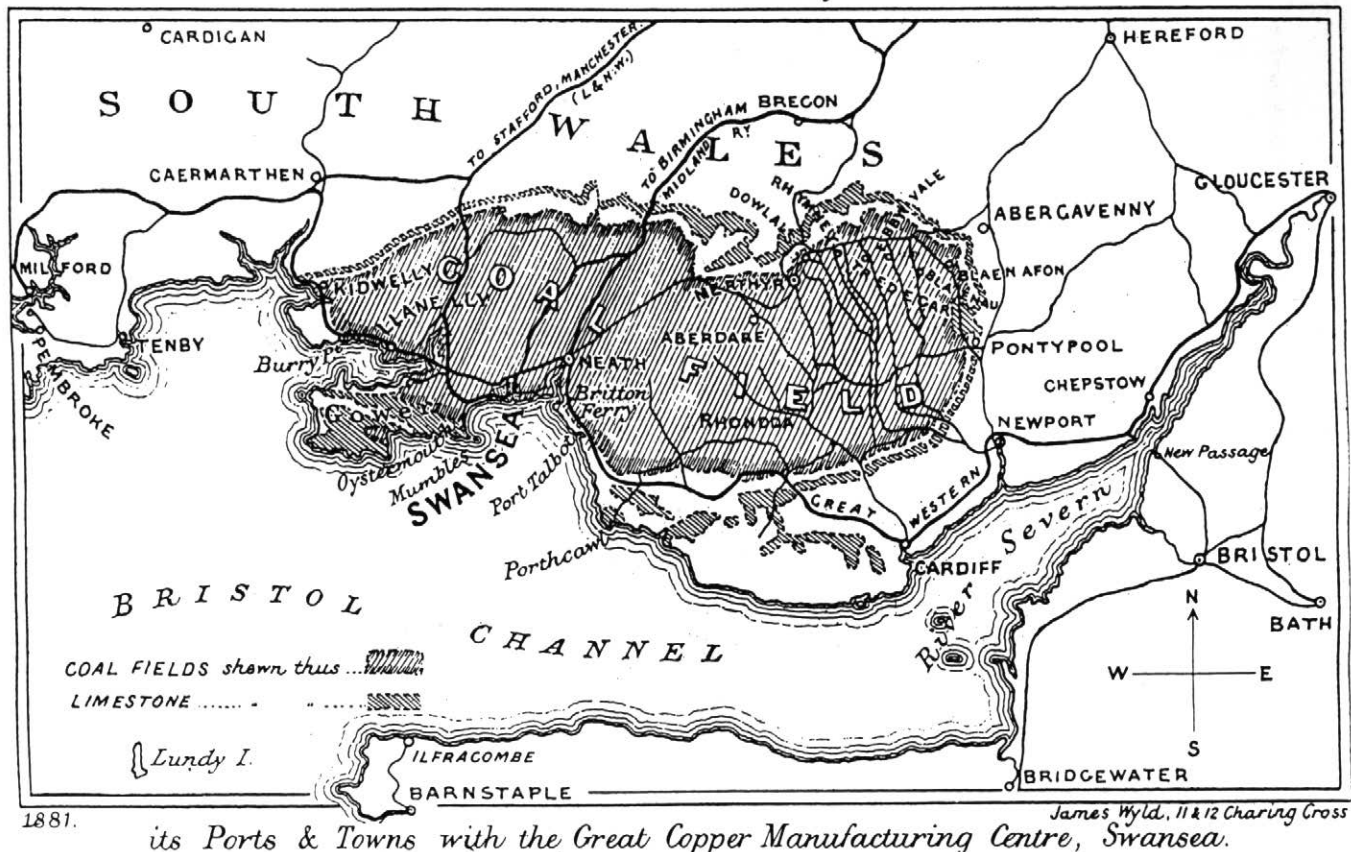


Figure 5 The South Wales Coalfield and Copper Works (from a sketch by Grant-Francis, 1881).

terplay between coal mining and geology which already formed part of the practice of the local coal viewers here (Symons, 1989, p. 70). They prove that Logan obtained much of his information on this coalfield (see his MSS notes BGS 1/218, 1836-1842) from these sources (Symons, 1979, p. 19, 24-25).

The Jones's were another typical dynasty of south Wales land and mineral surveyors. Rees Jones (*ca* 1769-1836; see *Cambrian*, 26 June 1836) was another land and mineral surveyor and engineer, who flourished from at least 1804 when he was active in Brecon and throughout Glamorgan. He had three sons, of whom the above Benjamin (1809-1891), third son, had "constructed the [railway] line between Wigan and Preston under [Isambard Kingdom] Brunel" and was "on the staff which completed the ordnance geological survey of South Wales," before becoming a solicitor in Llanelli in 1838 (Anonymous, 1891). Another son was Rhys William Jones (1804-1864), who was also active as a railway engineer after he too had been trained as a land surveyor (Bendall, 1997, v. 2, p. 283).

Logan's representations of this information were duly incorporated into the first 1 inch to 1 mile Geological Survey maps of that area. Logan's name appears as a joint author of Sheets 37, 41 and 42 SW. Parts of the different editions of Sheet 37 have been reproduced in black and white by Winder (1965, p. 114) and Bassett (1969, p. 22-23). Some 21 of Logan's original field slips have also been preserved (see Bassett, 1967, p. 45-46). These show in detail the coal seams and faults which Logan had so carefully investigated. Bailey has pointed out how much Logan's methods, using theodolite and chain, influenced Geological Survey mapping practice from the early 1840s (Bailey, 1952, p. 32-33; Secord, 1986, p. 207-208). A.C. Ramsay, who was on the Geological Survey staff from 1841, recorded his own impressions of these maps. They were

... in a style of such beautiful detail, that no map of any coal-field that had been done before, approached it in excellence". Logan's mapping was done "with such excessive detail, that it enabled all interested in such subjects, not only to judge of the lie of the beds of coal with great accuracy, but to judge of the precise nature of the strata that they would have to sink through, in their attempts to seek for coal in regions where coal pits had not previously existed (Ramsay, 1877, p. 367).

We can see here the day-to-day routine of land and mining surveyors being transmitted into the normal practice of geologists. Ramsay gave further confirmation of the economic rationale behind Logan's mapping, and proves that his work was not "merely" to advance "scholarly" enquiry. Christie is completely wrong to claim that "Logan's interest in the coal bearing strata [here] bore no relation to their economic value" (Christie, 1994, p. 171).

Further confirmation of the respect that Logan was held in by the mining community here comes from the 1837 law suit at the King's Bench, London, which was referred to Logan alone for arbitration. The owner of the Penybailey estate in Loughor claimed that the Broadoak Colliery owed him royalties. Evidence was presented to Logan between April 1837 and November 1837. The owner of the Penybailey Colliery was the aforementioned Rhys William Jones, with whom Logan was already involved. The conclusion to be drawn from this is that Logan must have been regarded as well informed on such mining matters. He cannot have been seen as just a "scholarly gentleman geologist." He must also have been sufficiently trustworthy for the owner of the Broadoak Colliery to have accepted his arbitration, when it was known he was already in contact with Jones (Llanelli Public Library, Local Collection, MSS 46). Unfortunately, the outcome of this case remains unknown.

Another practical man who tried to help Logan was Thomas Richards, whose quaintly worded letter dated 2 March 1837 to "William Logan Esq, one of the company with Benson Esq at Graigola Colliery" survives (BGS 1/67 ii). This colliery was in the parish of Cadoxton, 4 miles from their smelting works, where in March 1831 Osborne, Benson and Logan had leased coal and other seams of culm and fireclay (Bayliffe and Harding, 1996, p. 22). This became Graigola Colliery (a useful map for naming and locating collieries in this coalfield is given by Brown, 1874) and was another pioneering venture of Logan and Benson's. Here William Kirkhouse had again earlier examined and reported on the facilities, the tramway, trams, and wharf that would be needed to transport this coal to their Forest Works. It was one of the first collieries at which the dry steam coals of the semi-anthracite series in this coal field

were worked for the new steamship market. By 1840 experiments had been made to ascertain the calorific value of this coal, against Welsh anthracite and bituminous coal from Scotland (*Mining Journal*, v. 10, n. 274, 21 November 1840, p. 371) when Graigola coal was reported to be "decidedly the most powerful steam coal in the world" (see also John, 1950, p. 120).

Richards tried in 1837 to offer advice on how to improve the working of this coal on behalf of Logan's coal company. The reason for the survival of this letter may well only be its quaintness, but we should recall that when Richards wrote in English, this was in — for him, a Welsh collier — a foreign language. Logan had to check other such advice, like that of William Morgan of Penclawdd in 1837, more carefully. As Logan noted, "Mr. Morgan it must be remembered never hesitates to permit his invention to supply the deficiencies of his memory!" (BGS 1/218, p. 72). These were problems only to be expected in a mining culture that did not yet see any real need to commit such information to paper, and had great difficulty in doing so when it tried. To have been the first to put down this information on paper throughout the South Wales Coalfield so effectively was undoubtedly Logan's greatest achievement during his apprenticeship there.

Another who helped Logan with mineral surveying was William Price Struve (1809-1878; see *Cambrian*, 19 April 1878; Anonymous, 1878). Struve provides an interesting case study. On 8 July 1838 he and Logan measured a section at Penclawdd together (BGS 1/218, p. 92-93). Struve had been born on Jersey in 1809 and was articled in 1832 to his brother-in-law Henry Haberley Price (1794-1839), born a Quaker but forced from their Society when he married a non-Quaker, Struve's sister Julia in 1824 (see *Cambrian*, 11 December 1824). From 1818 Price had been a partner in the innovative Neath Abbey Iron Company, which had supplied a rotative stamping engine to Osborne, Benson and Co. in 1830 (Ince, 1984, p. 29, 105). Price was yet another local Member of the Geological Society of London, from 1825 (Woodward, 1907, p. 284).

Struve, after being managing partner of the local Millbrook Iron Works from 1834 until the partnership was dissolved in 1835 (*Cambrian*, 21 March 1835),

had become consultant mining engineer to the Swansea collieries by 1838. His obituarist recorded that "his zeal for the interest of the Geological Survey was very great, and although he had plenty of other professional work, he nevertheless found time to render useful aid to Mr. Logan" (Anonymous, 1878). Logan employed Struve early in 1842, when Logan was trying hard to finish his geological mapping (see Logan to De la Beche, 3 February 1842, National Museum of Wales, Cardiff, Geology Department archives, letter 878; Sharpe and McCartney, 1998, p. 68). Logan was, however, unsuccessful in recommending Struve as Keeper of Mining Records in London to De la Beche in 1839 (see Logan to De la Beche, 27 November 1839, National Museum of Wales, Cardiff, Geology Department archives, letter 872; Sharpe and McCartney, 1998, p. 67). Struve is now best remembered for his important work in ventilating coal mines, patent 11,127, in March 1846 (Hinsley, 1972, p. 31, plate 1).

THE ROYAL INSTITUTION OF SOUTH WALES (RISW)

Before he joined the Geological Society, Logan had played an important role in the local Swansea Philosophical and Literary Institution founded in 1835 (Beanland, 1935). In 1839 it became the RISW, and it survives there in its magnificent restored building as the Swansea Museum (Fig. 6). Intriguingly, it had had a predecessor several years before, of which nothing has been recorded, the

Cambrian Geological Society. This was founded in 1821 (*Cambrian*, 13 October, 20 October 1821) and was apparently only active until about 1823 (*Cambrian*, 11 November 1823). In 1835 its collections and library passed to this new Swansea Institution.

Logan was a founding member of this, and in June 1835 he was elected to its 10-man General Purpose Committee. At the first annual meeting in 1836 Logan was made its Honorary Secretary (Bayliffe and Harding, 1996, p. 50). He was also the Honorary Curator of its Geology Section. Its surviving donation books are full of Logan's donations of minerals, fossils, birds, reptiles, entomological and archeological specimens, as well as of books and surveying instruments. The specimens had come first from Wales and England, then from Spain, and Germany, and latterly Mexico and Canada (see Donations Books, 1835-1842 in RISW archives, and RISW Annual Reports 1836-1842). Logan also read a number of papers to the RISW (Logan, 1838a, 1840).

THE GEOLOGICAL SOCIETY OF LONDON (GSL)

Christie has wrongly claimed that "throughout his career Logan pursued fieldwork in geological strata that directly contributed to scientific debates within the Geological Society of London" (Christie, 1994, p. 162). Such a claim completely fails to acknowledge that his earlier work — of at least 5 years' duration — had been instead a direct contri-

bution to the success of his own Swansea copper smelting firm before this. It was not until 13 December 1836 that Logan was proposed as a Fellow of the GSL (elected 18 January 1837). It is instructive to discover (especially in view of Christie's equally extraordinary claim that "Logan's interest in the coal-bearing strata bore no relation to their economic value" (Christie, 1994, p. 171), that all three of his sponsors were entirely "economic" in their geological interests.

The first, who had to recommend Logan from personal knowledge, was Richard Janion Nevill (1785-1856), builder of another major copper-smelting works at Llanelli in 1805 (Symons, 1979, p. 148-156; Torrens, 1984, p. 56). Nevill had been elected as a Member in 1817 (Woodward, 1907, p. 279). The second was John Taylor FRS (1779-1863), who was the Treasurer of GSL from 1823-1843, as befits such a truly "economic geologist." Taylor had been elected a founding honorary member as far back as 1807 (Woodward, 1907, p. 43, 269, 298). He was the leading light in British and foreign mining geology throughout his distinguished career (Burt, 1977).

Logan's third sponsor was the hitherto misidentified W. Loughtrey (Winder, 1965, p. 118). He was in reality William Long Wrey (1792-1883), a member of a landed family from Devon (Townend, 1970, p. 2881). Wrey, after only matriculating at Cambridge University in 1811, had gone into the Army, but had retired by 1824 when he is again mis-recorded as "Mr. Ling Urey." He had now taken "a lease of extensive mineral tracts from Lord Cawdor, [John Frederick Campbell (1790-1860) of Castlemartin] upon which he established collieries" along the Gwendreath valley (Wilkins, 1888, p. 40), but with whom he was involved in lawsuits by 1830 (*Cambrian*, 3 April 1830). By 1831, Wrey was living at Thornhill Farm, Great Mountain [Mynydd Mawr], west of Ammanford, Carmarthenshire when he was elected FGS (Anonymous, 1831b, p. 351). His publication record in geology may extend only to a local newspaper article (Wrey, 1840), but this demonstrates both his acquaintance with south Wales geology and his considerable investment in anthracite mining. This article was issued as a branch line railway to his collieries off the Llanelli Railway was being completed (Price, 1992,

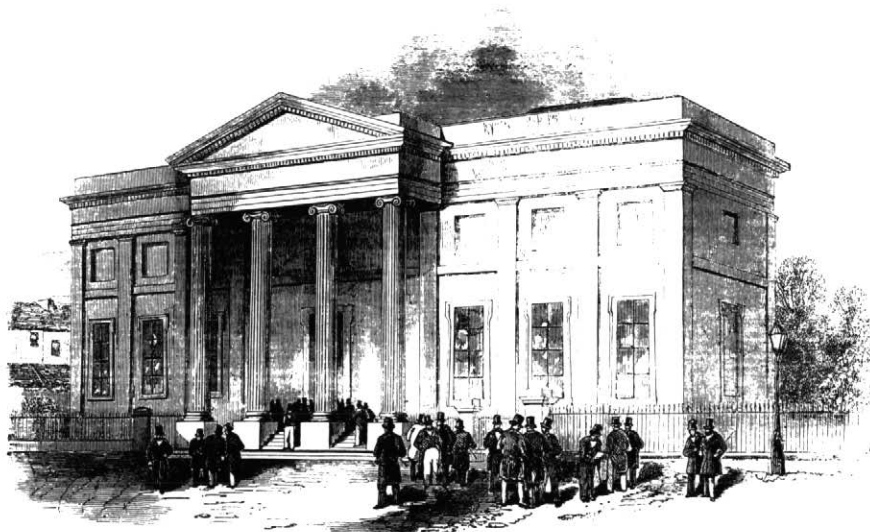


Figure 6 The Royal Institution of South Wales in 1848 (from the *Illustrated London News*, 19 August 1848, v. 13, p. 109).

p. 28). His son and heir was born at Thornhill in 1826 (*Cambrian*, 25 May 1826). Wrey had a riding accident in 1840 (*Cambrian*, 14 October 1840). In 1843 Thornhill was sold, and in 1867 he or his son published a pamphlet on New Zealand and its investment potential, in London, and so one or other may have emigrated there. Records at GSL merely record his decease in 1883 (Anonymous, 1884, p. 14).

Logan's only GSL paper from his Welsh period was read to the GSL on 26 February 1840 (Logan, 1842). It concerned the beds of clay below coal seams, there commonly called underclays, with which "the miners of the district are so well acquainted [that] scarcely any would fail to recognise this material." Furthermore they "would as soon expect to live in a house without a foundation as work a coal seam that did not rest upon underclay." These are powerful testimonies to the unwritten knowledge already held in these mining communities. Logan had certainly come across the phenomenon of the underclay by the time, late in 1837, the Geological Survey arrived here (De la Beche, 1846, p. 145). Logan's paper analysed the wide occurrence of these underclays and pointed out they proved that coals must have originated in peaty swamps and not, as some supposed, as driftwood. This was a matter of real economic significance, as it meant that coal seams should prove more widespread and laterally extensive. It also established that coal had been formed *in situ* and was seen by Logan's GSL colleagues as a matter of real theoretical, and thus "gentlemanly," significance, although it soon emerged that another, equally practical, coal viewer and owner in Leicestershire, Edward Mammatt (1766-1835), had earlier made and published many of these same observations (Mammatt, 1834, p. 73-74). The second part of Logan's GSL paper discussed the occurrence of boulders or pebbles of coal in clay, which Logan had first noticed in 1833. Such coal pebbles gave Logan further insight into how such coal seams had formed (De la Beche, 1846, p. 193).

Logan's third coal discovery was of specimens of erect-standing fossil trees (*Sigillaria*) preserved in growth position. Lewis Weston Dillwyn FRS (1778-1855) noted Logan's discovery of these on 3 April 1838, thus:

Four large *Sigillariae*, rising vertically

through strata of shale and sand stone, as if they had grown on the spot, were this day discovered by my friend, W. E. Logan Esq., in Cwm Lech, near the head of the Swansea valley, and a short account of the discovery, accompanied by an illustration, is given in the Third Report of our Philosophical and Literary Institution (Dillwyn, 1840, p. 54).

These were illustrated in an 1838 lithograph ([Logan], 1838a, p. 33) (Fig. 7) and again in 1846 (De la Beche, 1846, p. 183-184) and 1851 engravings (De la Beche, 1851, p. 577-578; the latter two from a sketch by Logan).

Two of these specimens, excavated

under the superintendence of De la Beche, were taken to the RISW where they still stand in the grounds of Swansea Museum (Fig. 8).

Another such tree was later deposited in the Museum of the Cornish Geological Society by John Vigurs of Rosehill, Penzance who owned another local copper smelt works at Cwm Avon. These are not the earliest such trees to be discovered even in the British Coal Measures, as others had been found in 1837, during railway excavations in Lancashire (Torrens and Cooper, 1986, p. 258-259).



Figure 7 Logan's specimens of Carboniferous fossil trees (*Sigillaria*), preserved in life position at Cwm Llech, Vale of Swansea, as he discovered them on 3 April 1838 (from Logan 1838a).

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (BAAS)

The BAAS meeting in 1837 was held in September at Liverpool, and at this meeting Logan both exhibited his geological map of the South Wales Coalfield between Neath and Kidwelly and read a paper in explanation (Logan, 1838b). This was his only paper read to the BAAS in this period, contrary to Christie (1994, p. 173) who wrongly reports earlier "timely papers" to both the GSL and BAAS, and that "Logan exhibited his first maps of the coal region of Swansea before the Liverpool meeting of the British Association for the Advancement of Science (BAAS)" in 1831! Logan's 1838 paper discussed the pattern of faulting which controlled the distribution of coal here in a very precise way. He also accurately outlined the geographical distribution of bituminous and non bituminous coals in south Wales. This paper was also published in the *Welshman* and *Cambrian* newspapers.

FINANCIAL PROBLEMS

Benson, Logan and Company underwent a series of crises in 1837 and 1838. First Abel Anthony Gower (1748-1837), founder of the large trading firm of Gower, Nephews and Co., died in August 1837 (Montgomery-Massingberd, 1972, p. 389) leaving £400,000, at least on paper, to two relatives, one of whom, Abel Lewes Gower (1796-1849) was Logan's brother-in-law (Roberts, 1969, p. 224). Then both Logan's uncle Hart (Anonymous, 1838b) and his brother and partner Henry Logan (Anonymous, 1838c) died in April 1838. This brought about a change in Benson, Logan and Company, with Logan now holding all the Logan shares, amounting to 21/48, while Starling Benson held the remaining 27/48. Hart Logan left £5,000 and Henry left £10,000 (Public Record Office, London, PROB 6/214, folios 197 on). These deaths were the reason Logan could resign his salaried position at Swansea in 1838 (Evans, 1876, p. 76), but he did not sever his connection with the company,

remaining a partner until at least 1850-1851 (Bayliffe and Harding, 1996, p. 83-85). His Forest Works at Morrision had passed, under a new lease, to the new English Copper Company in March 1845 (Grant-Francis, 1881, p. 112), but were only finally sold in 1851. They were converted to the manufacture of zinc in 1867 (Grant-Francis, 1881, p. 111).

By 1835 this company had become indebted to the Gowers for £50,000, and by the end of 1838 the Gowers were recalling the payment of this enormous debt, so that the "financial affairs of the Logans were [already] far from healthy... [Benson and Logan's] financial problems were, however, far from over; in 10 years' time they were to face even greater trials" (Bayliffe and Harding, 1996, p. 80). These financial problems, which were so soon to hit the whole Swansea copper industry, involved the creation of a new controlling English Copper Company, formed in 1841, but which soon had to be bailed out by the Bank of England when it was hit in turn by the financial crisis of 1847 (Roberts,



Figure 8 "Logan's Trees" as they stand today outside Swansea Museum. These two fossil trees (*Sigillaria*) were discovered in 1838. The taller is 13.5 feet high and the shorter, 4 feet (photos by H.S. Torrens).

1969). These several crises had begun well before Logan finally left Britain in 1843 on being appointed, the previous year, to conduct a geological survey in Canada. Logan cryptically referred to these in 1843 when, feeling seasick on his way back to Canada, he wrote "the fact is that Coleman Street [the investment and financial centre of London] has made me bilious. What I gave [then] to the fishes was as yellow as gold" (in Logan notebook titled "Chaleur Bay-Bay of Fundy", National Archives of Canada, R.G. 45, Geological Survey of Canada, v. 158: Field Notebook 2606; a reference I owe to Charles Smith). Under such impossibly complex financial situations, it is by no means clear that Logan was already as "independently wealthy" when he left Wales for Canada, as Christie implies (1994, p. 168-169). One might instead see good reasons why Logan was now so actively looking to new, and helpfully distant, horizons in Canada!

In the autumn of 1841 Logan had gone to visit the coal fields of Pennsylvania and Nova Scotia, a visit which also helped to stimulate his aspiration to geologically survey his native country. For it was then he learned that a geological survey of Canada was to be funded by the newly united legislature of the colony in September 1841, and decided to apply for the position. While in the Americas, he also met Henry Darwin Rogers (1808-1866) of Virginia. At this time Logan "even talked of settling in the United States as a coal-viewer" (Harrington, 1883, p. 110), a position for which his expertise with Welsh coal would certainly have qualified him highly.

LOGAN AND THE GEOLOGICAL SURVEY OF INDIA

A further tribute to Logan's coal field work in south Wales is given in letters between him and De la Beche written in 1844 and 1845. Logan's first letter (see Logan to De la Beche, 11 November 1844, National Museum of Wales, Cardiff, Geology Department archives, letter 884; Sharpe and McCartney 1998, p. 68) gives a wonderfully vivid description of the horrors he had met with on geological field work in Canada

I have received one letter from you... on my return from the depths of the Forest, where for three months & a half I had no other bed than the moss which covered the ground, where my food in the way of flesh has been

partridges, bears, porcupines, & otters, and when to protect myself from those little entomological devils, worse than all the other devils of hell, the black flies, I was under the necessity of constantly keeping my head in a bag with a gauze window in front; to be removed however whenever it become necessary to take a sight with my prismatic compass or measure an angle with my pocket sextant... it was necessary every now and then to climb the highest tree in the vicinity & there to submit to the martyrdom these virulent insects inflict, grinning & bearing it, restraining my breath & leaving some hundreds of them to bite at once & at will, each drawing blood while I steadied my body... The little devils too like to bite under cover, so where ever they can find an opening they creep under your clothes, up your sleeves, down your neck, and up your trousers & when a man comes to look at his body - which in the woods is not very often - he finds it is spotted from head to foot with the effects of their operations.

De la Beche's response asks if Logan would go to India to form a Geological Survey there to examine the country for coal, at the princely salary of £1200 per year for at least 3 years (see De la Beche to Logan, 29 March 1845; Harrington, 1883, p. 228-229), perhaps hoping that Logan would find less excitement there. Logan replied:

I have your dispatch on India affairs, which renders it necessary that I should inform you of the position on my campaign in Canada... in the matter connected with the East India Coal, I fancy you will see that the Chances are I am tied to Canada... [but this will] shew my Canadian friends that geological investigations are something thought of in other parts and that if I do not accept pecuniary terms more advantageous than they give, they must not think the less of me (Logan to De la Beche, 12 May 1845, Harrington, 1883, p. 229-236; National Museum of Wales, Cardiff, Geology Department archives, letters 885, Sharpe and McCartney 1998, p. 68).

The Indian Geological Survey was duly founded in 1846 (Fox, 1947). This followed the search for a geologist to make a "survey of those districts in which coal fields are situated," with the new urgency of fuelling Britain's new steam-driven navy. After Logan's refusal, the choice, in December 1845, fell on the equally practically qualified David Hiram Williams (*ca* 1812-1848), (Grout, 1995, chapter 5), the Swansea-born son of the land surveyor David Williams, Sr., both of whom had helped Logan there in 1835. This son was the first of De la Beche's official geological assistants in England from April 1839, and who was described by De la Beche as "a very

clever hand and a regular good one" (North, 1939, p. 255; North, 1936, p. 65-71). Williams soon returned home to work on the South Wales Survey.

After Williams' later tragic death from "jungle fever" (malaria?) in India in 1848 (see *Cambrian*, 12 January 1849), Charles Lyell called Williams the "best of [De la Beche's] practical men" (Lyell, 1881, v. 2, p. 153). Williams' case again demonstrated that it was men with actual knowledge of the *practice of coal mining* who were appointed by the British Government to direct the Geological Surveys in both Canada and India. Williams, Jr. also worked in Borneo for Rajah James Brooke (1803-1868) while based in India (*Cambrian*, 17 March 1848).

FINALE

It was a copy of a letter from Williams Jr., dated 1 November 1841, concerning the scientifically uninformed and doomed attempt to find impossible Welsh coal at Shirenewton, near Chepstow (Williams to De la Beche, 1 November 1841, National Museum of Wales, Cardiff, Geology Department archives, letter 2116; Sharpe and McCartney, 1998, p. 141), which the Professor of Geology at Oxford University, William Buckland (1784-1856), chose to send to the new Prime Minister, Sir Robert Peel (1788-1850), on 10 November 1841. This was in an attempt to get Peel's further support for the new Geological Survey of Great Britain (British Library Add MSS, 40494 folios 16-17). Williams's letter demonstrated, said Buckland, "the practical value of the work [De la Beche's team] is doing. It is one of the endless cases of searching for coal where it is impossible to be found. I am sure that from 5 to 10 thousand pounds a year are wasted in England in similar fruitless attempts which the Geological Survey will put an end to." Logan's work in south Wales had been in exactly this same practical, improving tradition.

The technical value of Logan's other work as a copper smelter in Wales was also demonstrated as late as 1864 when the *Mining and Smelting Magazine* suggested the adoption of his better formula for calculating the "returning charge" on copper ore, to cover the costs of transporting the ore from mine to smelting works. This vital figure was used to determine miners' wages and to regulate ore purchases (Newell, 1986). It

should have pleased, at least, the mining and metallurgical communities in which Logan had learned his practical skills that these skills were proving useful over 20 years after he had left south Wales for Canada.

CONCLUSIONS

I hope this study has illuminated another historiographic problem, involving the treatment of Logan's Welsh work by historians. This concerns the slight attention they have given to the history of "applied, practical and/or economic" geology. As Paul Lucier has noted,

...the neglect of applied geology speaks to how historians have studied [this] science... To maintain a strict division between the science of [the well studied] gentleman-specialists and the random searching of [unstudied &] untrained prospectors amounts to simple stereotyping of social groups as well as to reinforcing a dichotomy between ornamental and economic geology that might not have existed. Historians of science thus should attend to the relations of geology and industry. In future studies, it can only be hoped that applied geology will receive the careful attention that it surely deserves (Lucier, 1999).

Logan would surely have been the first to agree with such sentiments.

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