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THE COAL QUESTION BEFORE JEVONS*

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ABSTRACT. *In the early nineteenth century, political economists, politicians, and geologists debated the size and duration of the British coal supply. For mineral Malthusians, the argument about a dwindling supply sharpened anxieties about population pressure, fuel demand, and limited resources. They introduced a new sense of geological limits and long-term obligations into the theology of atonement. But for cornucopian liberals, the shift to a mineral energy regime supplied a powerful refutation to the Malthusian forecast. Inexhaustible coal promised growth without end.*

I

The Great Exhibition of 1851 was, most scholars would agree, a self-conscious display of British manufacturing power. Indeed, the organizers designed the spectacle to educate the public about the sources and forms of industrial production. The exhibits were divided by Lyon Playfair and the executive committee into four sections and thirty classes. These four sections were meant to illustrate the basic stages of the manufacturing process, guiding visitors from displays of raw materials and machinery to finished manufactures and fine arts. In Playfair's schema, mining and quarrying operations held pride of place as the first class of the first section. *The official descriptive and illustrated catalogue of the Great Exhibition* reminded the public that Britain's 'present commercial and productive greatness' derived principally from its 'exhaustless stores' of iron and coal. The wealth of the nation was a gift from the underground.[1]

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[1] Eric Auerbach, *The Great Exhibition of 1851: a nation on display* (New Haven, CT, 1999), pp. 92, 99; *The official descriptive and illustrated catalogue of the Great Exhibition* (3 vols., London, 1851), I, p. 119.

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Awash in the sea of objects, the crowds at the Great Exhibition in 1851 were perhaps not always aware of Playfair's didactic designs. But few visitors would have missed the gigantic slabs of coal from the mining districts lining the western end of the building. The largest specimen, a 'noble column' of bituminous coal, extracted in a single piece from Coed Talon and Leeswood collieries in Flintshire, weighed 16 tons. In the southern enclosure of the Crystal Palace were other megaliths of this sort along with a large *Sigillaria* fossil – an arborescent lycopodiophyte – from the lower coal measures of Cwm Cely and Blaina iron works. Inside the building, visitors could inspect coal from around the world in the many galleries dedicated to minerals. There were also a large number of geological maps, sections, and models on display. Lyon Playfair had specifically requested these visual aids so that visitors would be better able to appreciate the significance of the coal samples. The prince of Wales contributed a touch of royal whimsy in the form of a garden seat carved out of cannel coal from Wemyss in Fife, showed in the south transept of the building. In a lecture at the Royal Society of Arts, geologist Henry De la Beche praised the objects submitted by various Northumberland and Durham collieries. These included 'specimens of the various coals, the rocks by which they are accompanied … sections of pits, and the machinery in them' as well as geological maps and a 'beautiful model by Nicholas Wood' which 'exhibited the methods of working coal in the northern counties'. As a reminder of the organic origin of coal, the Newcastle committee also displayed thirty-six kinds of Carboniferous fossil ferns found in local mines.[2]

The Great Exhibition is often said to have formed a decisive turning point in British middle-class attitudes towards industrial society. Martin Daunton sees it as the moment when deep-seated Malthusian anxieties about population growth finally yielded to a more sanguine view of the future. Likewise, Boyd Hilton suggests that the 'celebration of English manufacturing supremacy' at the Great Exhibition had a revelatory effect: 'the old ambivalence about economic growth quickly gave way to the view that it was both natural and inevitable'. For both Daunton and Hilton, the spectacle of 1851 forged a new kind of self-consciousness about the revolutionary consequences of industrialization. From this point onward, Malthus's fear that improvement could not keep up with population growth lost its hold on the middle-class imagination. Yet this stress on a dramatic rupture overlooks an important question. When and how was coal recognized as the linchpin of the new industrial economy? The narrative of a decisive turning point around 1851 has to reckon with the lengthy debate about coal exhaustion, which culminated in William Stanley Jevons's *The coal question* (1865) and the Royal Commission on coal supplies (1866–71).

[2] *The official descriptive and illustrated catalogue*, I, pp. 115–16; Henry T. De la Beche in *Lectures on the results of the Great Exhibition* (London, 1852), pp. 35–6; Auerbach, *The Great Exhibition*, p. 90. De la Beche called the exhibits 'illustrations' – drawing attention to the new visual language of geology.

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Rather than a quick and triumphant rupture, the discovery of the fossil fuel economy seems to have been a conflicted and contracted process, where fears of exhaustion and scarcity may have played as great a role as a growing faith in improvement.[3]

The story of how the coal question entered into Victorian political economy has not yet been told in full. Many scholars have insisted on a connection between economic thought and geology in the 1820s and 1830s, but the importance of fossil fuel in this context remains a neglected topic. For the period after 1860, there is an excellent body of research on the context of William Stanley Jevons's work *The coal question* (1865), though it has focused almost exclusively on the immediate circumstances surrounding the publication of Jevons's work. Among environmental and economic historians, there is of course a long-standing and deep interest in the mineral basis of the Industrial Revolution, including the intellectual and cultural question of when and how people came to recognize coal as the driver of fundamental change. In a well-known argument, E. A. Wrigley suggests that fossil fuel provided a crucial means for growth beyond the limits of the organic economy but that Victorian observers only belatedly came to appreciate the revolutionary properties of coal and steam. He describes the anxious obsession of classical political economists with the physical limits to growth – a fear about the finite national supply of agricultural land inherited from T. R. Malthus – as a kind of intellectual hangover from the pre-industrial 'organic economy'. Timothy Mitchell has also stressed the persistence of pessimistic ideas about exhaustion and scarcity. Mitchell goes so far as to claim that economists only freed themselves from this Victorian gloom in the twentieth century. But such a binary arguably distorts the historical record, missing important cues about how growth was understood in earlier periods.[4]

The debate about coal exhaustion carried on by Jevons and others in the 1860s was in fact a continuation of an earlier controversy in the 1820s and 1830s when the extent and duration of coal reserves first became an object

[3] Daunton in Colin Matthew, ed., *The nineteenth century: British Isles, 1815–1901* (Oxford, 2000), pp. 42–3; Boyd Hilton, *A mad, bad, and dangerous people? England, 1783–1846* (Oxford, 2008), p. 630.

[4] M. J. S. Rudwick, 'Poulett Scrope on the volcanos of Auvergne: Lyellian time and political economy', *British Journal for the History of Science*, 7 (1974), pp. 205–42; Salim Rashid, 'Political economy and geology in the early nineteenth century: similarities and contrasts', *History of Political Economy*, 13 (1981), pp. 726–44; Boyd Hilton, *The age of atonement: the influence of evangelicalism on social and economic thought, 1785–1865* (Oxford, 1988), pp. 148–52; Michael White, 'In the lobby of the energy hotel: Jevons's formulation of the postclassical "economic problem"', *History of Political Economy*, 36 (2004), pp. 227–71; Nuno Luis Madureira, 'The anxiety of abundance: William Stanley Jevons and coal scarcity in the nineteenth century', *Environment and History*, 18 (2012), pp. 395–421; E. A. Wrigley, *Energy and the English Industrial Revolution* (Cambridge, 2010); Rolf Peter Sieferle, *The subterranean forest: energy systems and the Industrial Revolution* (Cambridge, 2001); Timothy Mitchell, *Carbon democracy: political power in the age of oil* (New York, NY, 2011), p. 234; William Cavert, *The smoke of London: energy and the environment in the early modern city* (Cambridge, 2016).

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of concern in politics and popular culture. A key figure in the dispute was the conservative Anglican geologist William Buckland. In scientific terms, Buckland is best known for his 'catastrophist' interpretation of the fossil record, but his interests also extended into subjects like political economy and agricultural improvement. He was a close ally of Sir Robert Peel and like him an advocate of Liberal Tory ideology with its mixture of Malthusian anxieties and evangelical belief. Buckland voiced a pessimistic view of resource waste and natural limits in his testimony to the 1830 House of Commons select committee on the coal trade and again in his Bridgewater treatise *Geology and mineralogy considered with reference to natural theology* in 1836.

This natural theology of coal clashed with cornucopian arguments about the inexhaustible nature of the coal supply. Liberals like George Poulett Scrope rejected talk of coal scarcity as a misguided revival of Malthus's political economy. Scrope's ally the radical Whig Joseph Hume suggested in his 1833 speech on the corn laws that the manufacturing sector could grow without limit if free trade in grain was permitted. Superior machinery along with the 'easy supply of coal' presented the means of overcoming problems of subsistence. When and if domestic food shortages arose, imports from abroad could make up the difference. British manufacturing profits made it possible to outsource food production. Yet for pessimists like Buckland and Robert Torrens, precisely this increasing reliance on coal threatened to create a new kind of scarcity. Rising coal prices would make British manufacturing less competitive and bread more expensive. In effect, the pessimistic perspective on coal connected the problem of the limits to food production with a geological concern about the finite extent of the coal supply.[5]

This debate extended and transformed Malthus's concern with forecasting resource strain. For both sides, coal inspired a new interest in the long-term future. Sir Robert Peel went so far as to insist that parliament had a responsibility that reached several centuries forward in time. Cornucopian liberals in turn defended laissez-faire as a project of infinite expansion. The coal question thus allows us to see the legacy of Malthusian ideology in a new light. For pessimists, the argument about a dwindling supply sharpened anxieties about population pressure, fuel demand, and limited resources. Coal consumption introduced a new sense of geological limits and long-term obligations into the theology of atonement. But for optimists, the shift to a mineral energy regime supplied a powerful refutation to the Malthusian forecast. Inexhaustible coal promised growth without end.

[5] Hume quoted in *Parliamentary Debates*, Third Series, xvii (17 May 1833), p. 1360. Christopher Otter sketches a political and environmental history of coal and wheat in his brilliant essay 'Liberty and ecology: resources, markets and the British contribution to the global environmental crisis', in James Vernon and Simon Gunn, eds., *Peculiarities of liberal modernity in imperial Britain* (Manchester, 2011), pp. 182–98.

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II

The first warnings about the limited extent of the coal supply surfaced in the late Enlightenment. John Williams declared in his *Natural history of the mineral kingdom* (1789) that national stocks in Great Britain were heavily depleted. Williams's warning set off a rash of rival calculations about the extent of coal seams among naturalists and mining viewers. Some predicted collapse while others insisted that the supply was inexhaustible. Yet these controversies did not necessarily strike a chord with contemporary political economists. T. R. Malthus's account of scarcity in the *Essay on the principle of population* (first edition 1798) was strictly concerned with the produce of surface land rather than underground resources. He maintained the same position in all six editions of the *Essay* from 1798 to 1826. While Malthus recognized the general dynamism of the manufacturing sector, he did not connect technological improvement with coal for the most part. A rare exception was a brief remark about the importance of steam engines to textile production in the *Principles of political economy* (1820): 'In carrying on the late war, we were powerfully assisted by our steam-engines, which enabled us to command a prodigious quantity of foreign produce and foreign labour.' But if Malthus was becoming more aware of the place of fossil fuel in the economy in later years, this growing realization did not move him to consider revising the *Essay of the principle of population*. We find a similar reluctance to engage with issues of energy in Malthus's friend and correspondent David Ricardo. The latter briefly considered the question of rent in coalmines and identified the 'elasticity of steam' as a gift of nature on par with water or air. Yet, much like Malthus, Ricardo did not offer any detailed considerations about the broader function of coal or steam in the economy. Instead, we must turn to the next generation of students of Malthus and Ricardo for explicit discussions of the coal economy.[6]

The first follower of Malthus to address the question of the coal supply was probably Thomas Chalmers in his 1808 book *An enquiry into the extent and stability of natural resources*. Written before Chalmers's conversion to Evangelical Presbyterianism, the book explored the importance of agriculture to the national economy and the best method of managing the 'redundant

[6] Fredrik Albritton Jonsson, *Enlightenment's frontier: the Scottish Highlands and the origins of environmentalism* (New Haven, CT, 2013), pp. 181–7; [T. R. Malthus], *An essay on the principle of population* (London, 1798); T. R. Malthus, *Principles of political economy: variorum edition*, ed. John Pullen (2 vols., Cambridge, 1989), I, p. 577; for mineral exhaustion in Malthus, see 'Malthus diary of a tour of the Lake District', in J. M. Pullen and Trevor Hughes Parry, eds., *T. R. Malthus: the unpublished papers in the collection of Kanto Gakuen University* (2 vols., Cambridge, 2004), II, p. 40; Patricia James, ed., *The travel diaries of T. R. Malthus* (Cambridge, 1966), pp. 111–12, 115; David Ricardo, *On the principles of political economy and taxation*, in Piero Sraffa, ed., *The works and correspondence of David Ricardo* (11 vols., Indianapolis, IN, 2004), I, pp. 169, 331–2; Ricardo discussed the value and labour of steam engines with McCulloch in 1820, see Ricardo, *The works and correspondence of David Ricardo*, ed. Sraffa, VIII, pp. 171, 192, 389–90.

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population' of Britain. Chalmers also attacked the political preference for mercantile wealth and overseas trade in favour of national self-sufficiency. For Chalmers, this autarkic ideal included not just foodstuff but also coal. He linked the emergence of new manufacturing districts to the natural advantages of easy access to coal and waterpower. To drive home his critique of mercantile policy, Chalmers asked the public to imagine who would suffer if the coalmines in Britain were exhausted. This counterfactual was intended to clarify the relation between specific economic interests and the national welfare. Coal, like food, was an essential resource. While Chalmers touched on the coal question only to score a theoretical point, he expected the argument to startle and persuade the reader. 'It is the consumer who is the principal sufferer, and the suffering is of so serious a kind, that even in spite of our mercantile delusions, we allow it to engross the whole of our sympathy.' The concept of coal collapse was so potent an idea that it could strip away false attachments to trade and produce a more accurate picture of national wealth.[7]

Robert Slaney's *Essay on the beneficial direction of rural expenditure* in 1824 drove home the importance of coal with a different image. Thanks to the invention of steam, he observed, the nation had gained a vast new force of labour: 'one hundred million pair of hands, which required no food to support them' and which laboured 'without intermission, day and night'. Expanding on Malthus's suggestion, he also insisted that steam engines had been the most important factor in paying for the war effort and keeping the government from bankruptcy during the long struggle with France. Though Slaney dismissed the need for national autarky, he shared with Chalmers and Malthus a strong concern about the dangers of accelerating population growth. Without education and good morals, improvident habits might take root in the labouring classes, undermining the economic gains produced by the manufacturing economy. Coal and steam alone could not deliver lasting progress.[8]

The next liberal political economist to tackle the issue directly was Ricardo's student John Ramsay McCulloch who gave coal a central place in the history of British development in *Principles of political economy* (1825). McCulloch listed as the technological hallmarks of 'an advanced and refined period' ships, muskets, cotton-mills, and steam engines. He argued that districts with an 'abundant' supply of coal (along with sea access and good 'internal navigation') were the 'natural seat of manufactures'. He refined the old argument about Britain's comparative advantage in cloth production, to include not just the quality of wool and the skill of British workmen but also new machinery and 'our command of coals'. All prudent economic policy should capitalize on those

[7] Thomas Chalmers, *An enquiry into the extent and stability of natural resources* (Edinburgh, 1808), pp. 25–6; Stewart J. Brown, *Thomas Chalmers and the Godly commonwealth in Scotland* (Oxford, 1982), pp. 36–7.

[8] Robert A. Slaney, *Essay on the beneficial direction of rural expenditure* (London, 1824), pp. 9, 19–22, quotation on p. 22; Paul Richards, 'R. A. Slaney, the industrial town, and early Victorian social policy', *Social History*, 4 (1979), pp. 85–101.

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'branches' of 'our capital and industry' that took full advantage of 'our inexhaustible supplies of coal and our improved machinery'. He capped off his argument with a blistering attack on Adam Smith's notion that nature only assisted human labour in agriculture and not in manufactures. On the contrary, he exclaimed, 'the fact' was 'nearly the reverse'. 'The powers of water and of wind, which move our machinery, support our ships, and impel them over the deep, – the pressure of the atmosphere, and the elasticity of steam, which enable us to work the most stupendous engines, are they not the spontaneous gifts of nature?' In fact, McCulloch asserted that fossil fuel provided the foundation of a new form of growth. The 'bounty of nature' in manufacturing had 'no limits'. Coal here entered classical political economy as a cornucopian force.[9]

Yet, however heated his rhetoric, McCulloch's proclamation did not in a single blow reshape public opinion. Instead, we should see the arguments of Chalmers, Slaney, and McCulloch as early forays into a long and hard-fought campaign about the fate of the manufacturing nation. Indeed, the question of steam and coal took on a quite different significance during the public hearings on the coal trade in 1829 and 1830. Both the House of Lords and the House of Commons established select committees at this time to investigate the problem of fraud and waste in the coal trade. Issues included the desirability of domestic duties on coal, the fate of the Newcastle system of cartel production, the standardization of weights, the frequency of mining accidents, and the persistence of fraud in the regulatory regime in London. Criticism of the system was animated in part by a liberal impulse, which sought to reduce regulation and taxation in the coal trade. But the hearings also gave voice to conservative concerns about the reliance of the country on a finite resource and the need to safeguard it for the benefit of future generations. In effect, they recast the Malthusian question of population in the new framework of mineral stock.[10]

To understand how political economy became intertwined with geology, we must first consider the technical process of coal extraction in this period. The Northumberland coal viewer and mining engineer John Buddle presented a case for fuel economy in his 1829 testimony to the select committee on the state of the coal trade. Buddle attacked the practice of screening coal to discard smaller pieces (another witness dated the origin of this custom to the 1780s). Such scraps could not be sold profitably on the London market

[9] John Ramsay McCulloch, *Principles of political economy: with a sketch of the rise and progress of that science* (Edinburgh, 1825), pp. 119, 124, 136, 150–1; D. P. O'Brien, *J. R. McCulloch: a study in classical economics* (London, 1970), p. 280; E. A. Wrigley, 'The supply of raw materials in the Industrial Revolution', *Economic History Review*, n.s., 15 (1962), p. 3.

[10] Aashish Velkar, *Markets and measurements in nineteenth-century Britain* (Cambridge, 2012); Michael Flinn, *The history of the British coal industry*, II: *The Industrial Revolution* (Oxford, 1984), pp. 283–5; on 7 Mar. 1828, a committee of representatives of the Northumberland Collieries, which included Buddle, decided to lobby both houses of parliament regarding domestic and foreign duties, see North of England Mining and Mechanical Engineers Institute, Buddle Atkinson papers, box 5, fo. 41.

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because coal was valued by measure rather than by weight. Some remainders were sold at greatly reduced prices domestically and abroad, but the vast majority of 'small coal' was simply left underground or burned in heaps by the pitside. Buddle estimated that upwards of one fifth of the coal was lost this way in the Newcastle region. If one included the small coal left underground because it was unprofitable to mine, the loss might be as high as one third. For Buddle, this waste was a consequence of the convention of selling by measure. Because coal tended to break up in transport, only the largest coals were selected for sale. But he also recognized that small coals had a market abroad and that exports might help bolster sales.[11]

Waste was not the only problem haunting the select committee. It also interviewed Hugh Taylor, the agent to the duke of Northumberland, regarding the duration of the coal supply. Taylor produced an estimate of the seams in Durham and Northumberland by calculating the surface area at 837 square miles. He deducted one eighth from this amount as already excavated (105 square miles). At an average thickness of 12 feet for the coal strata, each square mile contained 12,390,000 tons. The total for the region amounted to 9,069,480,000. Taylor then deducted one third for small coal, dykes, and other obstructions. This left more than 6 billion tons of coal in the ground, which would last 1,727 years, if production held steady at the current rate of 3,500,000 tons per year. He also computed consumption for the nation as a whole at 15,580,000 tons per year, on the assumption that Newcastle production amounted to one third of total consumption for 15 million people.[12]

The last witness at the hearings in 1829 was the Northumberland colliery owner Charles Perkins. Perkins brought to his testimony a remarkable table that showed, perhaps for the first time in British history, the relative rise in per capita consumption of coal over three decades. Perkins employed demographic data from the censuses of 1801, 1811, and 1821 to construct a table of coal demand between 1801 and 1828. His calculations showed that per capital consumption of coal had risen from 1.05 chaldrons per head in 1801 to 1.156 in 1821 (see Figure 1). There were two ways to read Perkins's table. In the first interpretation, demographic growth was the driver of energy demand: the larger the population of Britain, the greater its consumption of coal. But Perkins's table also hinted at a different and more radical idea. Perhaps coal itself had become the engine of population growth? From these two interpretations flowed competing ideologies. Some observers saw cheap coal as a solution to the Malthusian problem of subsistence. Coal had liberated the country from the shackles of agricultural autarky. Others worried that

[11] *Report from the select committee of the House of Lords appointed to take into consideration the state of the coal trade in the United Kingdom* (London, 1830), pp. 39–40, 48; Anne Orde, ed., *Letters of John Buddle to Lord Londonderry: 1820–1843* (Woodbridge, 2013), pp. 183–4.

[12] *Report from the select committee of the House of Lords appointed to take into consideration the state of the coal trade in the United Kingdom*, pp. 77–8.

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A STATEMENT of the adjusted Importation of Coals to London since 1801, and the probable Population in each Year, for the sake of showing the Consumption per Head. The Consumption in 1801 appears small, because the Import of 1800 was very large.

	Chaldrons of Coals.	Population.		Chaldrons per Head.
1801 - - -	859,738	818,129	Census of 1801 -	1.05
1802 - - -	881,031	8[illegible] 628	- - -	1.06
1803 - - -	902,324	84[illegible] 27	- - -	1.07
1804 - - -	923,617	858,626	Presumed annual Rate of Increase about 1.65 per cent.	1.07
1805 - - -	944,910	872,125		1.08
1806 - - -	966,203	885,624		1.09
1807 - - -	987,496	899,123		1.09
1808 - - -	1,008,789	912,622		1.105
1809 - - -	1,030,082	926,121	- - -	1.112
1810 - - -	1,051,375	939,620	- - -	1.118
1811 - - -	1,072,668	953,276	Census of 1811 -	1.12
1812 - - -	1,093,959	972,184	- - -	1.125
1813 - - -	1,115,252	991,249	- - -	1.125
1814 - - -	1,136,546	1,010,314	Presumed annual Rate of Increase about 2 per cent.	1.124
1815 - - -	1,117,034	1,029,379		1.08
1816 - - -	1,149,650	1,048,444		1.09
1817 - - -	1,182,266	1,067,509		1.107
1818 - - -	1,214,882	1,086,574		1.118
1819 - - -	1,247,498	1,105,639	- - -	1.127
1820 - - -	1,280,114	1,124,704	- - -	1.18
1821 - - -	1,312,730	1,144,531	Census of 1821 -	1.146
1822 - - -	1,345,345	1,163,596	- - -	1.156
1823 - - -	1,377,961	1,182,661	Presumed that the same Rate of annual Increase has continued.	
1824 - - -	1,410,577	1,201,726		
1825 - - -	1,443,193	1,220,791		
1826 - - -	1,475,809	1,239,856		
1827 - - -	1,508,425	1,258,921		
1828 - - -	1,541,041	1,277,986		
	32,580,515	28,868,085		

Fig. 1. Coal and population in London, 1801–1828
Source: Report from the select committee of the House of Lords appointed to take into consideration the state of the coal trade in the United Kingdom (London, 1830), p. 102.

population growth was now dependent on fossil fuel and that such reliance might deplete the national coal supply over time.[13]

The testimony compiled by the 1829 committee elicited considerable public interest. Buddle's friend John Sykes produced an edited version of the report in Newcastle to inform the coal lobby about the outcome of the hearings. Ricardo's student John Ramsay McCulloch published a favourable opinion of Taylor's estimates in the *Edinburgh Review*. Most importantly, a new select

[13] Ibid., p. 102.

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committee was organized in the House of Commons the following spring and summer. These hearings included not just Buddle, but also two eminent academics from Oxford: Adam Sedgwick, the Woodwardian professor of geology and his colleague William Buckland, reader in mineralogy and geology and dean of Christ Church. The two geologists were brought in to offer expert advice regarding Taylor's calculations.[14]

Sedgwick was summoned to comment specifically on Hugh Taylor's calculations regarding the coal supply. Evidently, he did not take much time to prepare. He told the committee that he had only read Taylor's testimony after he arrived in London for the hearings. But such short notice did not stop Sedgwick from offering a detailed critique of Taylor's estimate. Using geological maps by George Bellas Greenough and William Smith, he challenged Taylor's calculations of the surface area. The maps presented a more or less consistent notion of the direction and limits of the seams. Sandstone marked the lower level of the coal strata. Taylor's main error was his assumption that magnesian limestone escarpments contained coal, which had led him to exaggerate the western boundary of the field. In this way, Sedgwick injected into Taylor's abstract space the particularities and unevenness of geological strata. He reduced both the extent and the duration of the field dramatically, from Taylor's 732 square miles and 1,727 years to 435 square miles and no more than 350 or at most 400 years. Sedgwick's relative pessimism was sharpened by his concern with waste. Like Buddle, he estimated that one third of all coal was routinely discarded and lost to the consumer. Evidently, the select committee found his case persuasive. The queries to Sedgwick were respectful and well informed. Many of the questions revealed a modicum of geological knowledge, for example on the importance of sandstone as a boundary of the coal strata.[15]

Buckland's testimony extended and reinforced Sedgwick's argument. Buckland's connections with colliers like Buddle influenced his understanding of the practical side of the industry. Buckland first seems to have become interested in the economic question of coal mining when he learned about the practice of burning small coal on the side of the pitheads in the north. This waste deeply offended Buckland's Liberal Tory principles. From a Malthusian perspective, it is hard to imagine a more flagrant example of excess production and market glut than the large-scale destruction of small coal. Tellingly, Buckland suggested in his Bridgewater treatise that the difficult access to coal deposits served as a providential form of rationing. God had located coal at different depths in order to prevent the market from becoming glutted all at once.[16]

[14] *Select committee of the House of Lords appointed to take into consideration the state of the coal trade* (Newcastle upon Tyne, 1829); McCulloch in *Edinburgh Review*, Apr.–July 1830, pp. 190–2; McCulloch, *Observations on the duty on sea-borne coal* (London, 1831).

[15] *Report of the select committee on the state of the coal trade* (London, 1830), pp. 231, 233, 236, 238.

[16] Buckland, *Geology and mineralogy considered with reference to natural theology* (2 vols., London, 1836), I, p. 554. For Buckland's natural theology, see Martin Rudwick, *Bursting the limits of time:*

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The problem of waste overlapped with the question of duration. Buckland rejected Taylor's estimate for the duration of the north-east coalfields, calling it 'egregiously exaggerated'. The total should be reduced by three-fourths to 400 years. Buckland observed that the geological maps misrepresented the extent of coal on the western frontier of the district. Rather than continuous seams, there were only a few pockets of low-quality coal surrounded by barren sandstone and shale. While Taylor was correct about the average thickness of the seams, he had failed to take into account the effect of denudations. Many of the best upper coal beds had been washed away by prehistoric floods. Buckland relied on his contacts among local coal viewers for these observations. But he applied the lens of geological time to interpret the evidence. The banks of the Teame formed one extensive 'valley of denudation' where the 'action of water' had 'excavated and carried bodily away' the original continuous coal beds, sometimes to the depth of '30 fathoms' leaving behind 'rubbish and gravel filling a bread and deep trough of the carboniferous strata'.[17]

For Buckland, the geological question of how the coal strata were formed intersected with his conservative vision of the nation. He explained to the select committee that the geological maps of England made by William Smith and George Bellas Greenough had revolutionized the public understanding of the limits of supply. The evidence of the maps strongly suggested that all extant coalfields had already been discovered, eliminating the prospect of 'unknown districts'. This 'moral certainty' in turn led Buckland to a political conclusion. While the coalfields were bountiful enough that they would last many more generations, the finite nature of the supply imposed on the public an obligation to conserve stock. Reflecting on Buckland's recommendations, the select committee asked whether it was 'wise policy in the State to interfere and enforce the economical use of the coal?' 'Most assuredly I think it is', Buckland responded. He added, 'it is a duty we owe to posterity'. In practical terms, such a long-term threat required a Malthusian commitment to prudential economy and self-sufficiency. Buckland endorsed Buddle's estimate that one third of all coal was discarded. To waste all this fuel of the best quality was nothing short of a national disgrace. The best remedy would be to prohibit by law the screening of small coal at the pit mouth. Buckland also wanted to ban

the reconstruction of geohistory in the age of revolution (Chicago, IL, 2005), pp. 610–11. For the concern with glut in Liberal Tory ideology, see Hilton, *Age of atonement*, p. 118. On the synchronicity of Thomas Chalmers's Malthusian political economy and Buckland's geology, see Nicholas Rupke, *The great chain of history: William Buckland and the English School of Geology, 1814–1849* (Oxford, 1983), pp. 256–7. This article leaves to the side the question of how Malthusian thought may have shaped Buckland's understanding of population checks in the economy of nature.

[17] *Report of the select committee on the state of the coal trade*, pp. 241–2, 244. Buckland and Buddle arranged to meet to discuss the 'probable duration of our coal-field' on 5 May 1830, the day before Buckland's testimony to the select committee; see Oxford University Museum of Natural History, Buckland papers, box 4, section 3, fo. 60.

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the export of coal from Newcastle to foreign countries. 'It is permitting foreigners to consume the vitals of our own posterity.' Coal provided the 'stamina upon which the manufacturing prosperity of the country primarily depends'. It was 'our duty not to spare one ounce of coals to any person but ourselves'. 'The coal of all England should be entirely reserved.'[18]

The quarrel between Taylor, Sedgwick, and Buckland set the stage for a series of confrontations in the House of Commons. In the spring of 1831, the free-trade proponents won a great victory when the domestic duties on seaborne coal were abolished. Emboldened by this success, they sought a reduction in export tariffs on coal in July 1831. On the reform side was the chancellor of the exchequer Lord Althorp (Henry Spencer) and his ally Charles Poulett Thomson, MP for Dover (later Manchester) together with Sir Matthew Ridley, Whig member for Newcastle upon Tyne and Joseph Hume, the Radical MP for Middlesex. Against them stood a curious mixture of conservatives and radicals, including John Charles Herries, Conservative MP for Harwich, the political economist Robert Torrens, Whig MP for Ashburton, and the philosophical radical Henry Warburton, MP for Sittport. Lord Althorp opened the debate by proposing substantial reductions in the duty on coal exports.

In his February speech on the budget he had called the prevailing 17*s* duty on round coals a virtual ban on exports. For Warburton, this was exactly the point of the tariff. Parliament had a duty 'not to facilitate the exportation of coals' and to 'prevent it by restrictive duties as much as possible'. While Warburton was favourable to free trade in other respects, he saw coal as a vital exception. High tariffs were a necessary precautionary measure, since 'a time would come when our present mines would be worn out'. Warburton's argument in turn provoked two distinct responses. Speaking for the coal interest, Sir Matthew Ridley rejected all talk of limits. He gave 'no credit to the fears' of exhaustion. Ridley's faith in abundance required no arithmetic: 'Our coals [will] last as long as the world itself.' In contrast, the radical Joseph Hume argued that the welfare of the common people should be the guiding principle of all tariff policy. 'To lay a tax of this nature upon coals, was to lay a tax upon an article necessary to manufactures; and every tax of that description hurt the lower orders, by keeping them out of employment.' In an earlier speech attacking the corn laws, Hume had observed that the 'abundance of our coal and fuel' was one of the crucial factors in making British manufactured goods competitive in foreign markets. But he skirted the problem of supply with a defence of free trade that was focused on present welfare. It was the immediate well-being of the 'lower orders' that mattered, not the condition of coming

[18] *Report of the select committee on the state of the coal trade*, pp. 244–5, 247. While Buckland's Bridgewater treatise would cast geology in an explicitly religious frame, Buckland did not mention providence in his testimony but spoke instead of the position of coal beds as the 'accidental and successive accumulations of drifted vegetables'; cf. ibid., p. 247.

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generations. For Warburton, in contrast, the emphasis was entirely on the future prospect of the coal supply. This orientation was hardly a coincidence. Warburton had a long-standing interest in geology and counted among his friends and associates many of the leading geologists of the period, including Buckland, Sedgwick, and Lyell. William Conybeare's letter to Warburton on the extent of the Welsh coalfields was published as an appendix to the 1830 select committee report on the coal trade. All of this may help explain why Warburton saw the question of free trade through the lens of geology and understood coal on time scales well beyond the immediate future.[19]

Lord Althorp and his allies won the debate. The 17*s* export duty on large coals was reduced to 6*s* 8*d* per ton in foreign ships and 3*s* 4*d* for export with British ships. This victory encouraged the reformers to push for further cuts. In early July 1834, George Poulett Thomson proposed to abolish the export coal duty wholesale. Lord Althorp observed that the Newcastle coal interest was distressed and that the termination of export duties would inject new vigour into the coal trade. When Warburton showed his displeasure with the idea, Thomson mocked him as a deluded visionary. There was no reason to expect that 'stock of coal' in the country would be exhausted, even 'after a period of 1,400 years'. Warburton responded by shifting register from the long term to the present. He accused Thomson and Althorp of violating sound economic principle in their eagerness to please 'members for northern places'. He pointed out that none other than David Ricardo had warned that the abolition of export duties of this sort was 'most impolitic' since the 'effect of removal would be to put our foreign rivals upon the same footing as ourselves'. Robert Torrens lent his support to Warburton, stressing as well that 'the exportation of coals would be injurious to our manufactures'.[20]

III

When the debate commenced again on 25 July, Sir Robert Peel took up the question of the coal supply in a remarkable speech. Like Warburton, Peel cultivated ties to the leading geologists, including a close friendship with Buckland. Peel reflected and expanded Buckland's vision of coal users as a multi-

[19] *Parliamentary Debates*, Third Series, II (11 Feb. 1831), p. 415; *Parliamentary Debates*, Third Series (1 July 1831), pp. 595–7; for Hume and the abundance of coal, see John Henry Barrow, *The mirror of parliament for the third session of the eighth parliament*, III (London, 1829), p. 1725; the 'coal interest' also included Wharncliffe, Ravensworth, Londonderry, Russell, and Bell, see North of England Mining and Mechanical Engineers Institute, Buddle Atkinson papers, vol. 5, fo. 55; on Hume's ideology, see Ronald K. Huch and Paul R. Ziegler, *Joseph Hume, the people's M.P.* (Philadelphia, PA, 1985); for Warburton's geological interests, see Cherry Lews and Simon J. Knell, *The making of the Geological Society of London* (London, 2008). For Conybeare's section, see *Report of the select committee on the state of the coal trade*, p. 394.

[20] *Parliamentary Debates*, Third Series, XXIV (2 July 1834), pp. 1084, 1087; Richard Cowling Taylor, *Statistics of coal* (Philadelphia, PA, 1848), p. 266; David Alfred Thomas, *The growth and direction of our foreign trade in coal during the last half century* (London, 1903), p. 7.

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generational moral community. While the abolition of export duties would bring 'temporary relief to certain distressed interests in the North', this policy deprived 'the country of one of its greatest natural advantages – the almost exclusive monopoly of coals'. Like Buckland, Peel observed that coal by nature was finite and incapable of regeneration on a human time scale. 'He was not satisfied that the supply of coals in this country – he meant of coals lying so near the surface as to be procured upon cheap and moderate terms, was so abundant as some hon. Gentlemen supposed.' To protect the mineral basis of the manufacturing economy, Peel demanded that the 'Legislature' rise above 'the present interests' and 'look forward even for a period of 400 to 500 years'. Such a long-term perspective was a moral imperative for true statesmen: 'In matters of legislation or of fiscal arrangement, the interests of remote periods ought always to be considered, unless some immense immediate advantage was to be gained.' Since free trade in coal was unlikely to yield any such 'immense immediate advantage', it was best to limit exports as much as possible. Peel added that the existence of coalfields on the continent actually strengthened the need for restriction. With 'coal of their own', these countries were more likely to 'establish manufactures to rival ours'.[21]

At the heart of Peel's view of coal was a Liberal Tory vision of the fossil fuel economy. He spoke of mineral stock as a bond between past, present, and future that had to be carefully nurtured and protected. There was a distinct echo here of Edmund Burke's notion of organic community from *Reflections on the revolution in France* (1790). Burke famously defined society as a 'partnership' in science, art, and virtue that required 'many generations' to be fully developed. It was a pact 'not only between those who are living, but … those who are dead and those who are to be born'. Each generation held in 'trust' a legacy of social liberty far more valuable than the perverse ideal of 'solitary, unconnected, individual, selfish liberty' celebrated by radicals. Burke imagined this extended community both as a constitutional tradition and an entailed aristocratic estate to be transmitted intact to posterity. Peel's push to limit coal exports extended the Burkean concept of moral community to the fossil fuel base of the economy. This was not merely an organic energy economy founded on aristocratic agriculture but also a mineral energy economy, to borrow E. A. Wrigley's terms. Peel reframed Burke's sense of temporal horizon by borrowing the new arithmetic of limits from the Malthusians and

[21] *Parliamentary Debates*, Third Series, xxv (25 July 1834), pp. 533–4; reprinted in *The speeches of the Late Right Honourable Sir Robert Peel …* (4 vols., London, 1853), ii, pp. 862–3; for Buckland and Peel, see Hilton, *Age of atonement*, pp. 23, 78 n. 23, 150–1; idem, *A mad, bad, and dangerous people?*, p. 340. Buckland advised Peel on economic questions and matters of science regularly, see for example British Library (BL), Add. MS 40403, fo. 83; BL, Add. MS 40429, fos. 4, 49; BL, Add. MS 40504, fo. 387; BL, Add. MS 40560, fo. 40. See also the Peel–Buckland correspondence in the Beinecke Library, Osborn d61. For conservative protectionism more generally, see Anna Gambles, *Protection and politics: Conservative economic discourse, 1815–1852* (Woodbridge, 1999).

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the geologists. The scale and vigour of industrial and imperial expansion made it possible to imagine processes of rapid exhaustion and deterioration at the national level. Peel's speech suggested that coal consumption had altered the basic nature of the public interest, extending it deep into the geological past and the distant future.[22]

The House convened to debate the coal duties again on 1 August 1834. Robert Torrens now joined Peel in condemning the lifting of coal tariffs as 'contrary to every sound doctrine and principle of political economy'. 'It is the cheapness of fuel', Torrens added, 'which counter balances the dearness of food in this country, and enables us to complete with the foreign manufacturers.' By permitting duty-free coal exports, parliament would raise the price of fuel at home while making it cheaper abroad. Like Peel, Torrens saw the British coal supply as the foundation of national prosperity and a stable social order. But he avoided the temporal and intergenerational questions about coal that Peel had raised. Henry Warburton, in contrast, compressed the timetable of exhaustion to make its consequences seem (relatively speaking) urgent rather than remote. According to Hansard's account, Warburton warned that the abolition of export duties would have the 'effect of expediting the period when coals nearest the surface and nearest the sea would be exhausted'. As mine owners were forced to go deeper and further inland, employing more machinery, 'consumers and manufacturers at home' would bear the brunt of the change by paying 'a higher price for coal' while French and Dutch manufactures 'would get our coals cheaper'. Barrow's *Mirror of parliament* added two important details to this narrative. Warburton rested his objection on arguments made by coal proprietors to the 'Coal Committee'. The exhaustion of the easily accessible coal had been occurring over the 'last forty years' and he expected that the 'same will happen during the next forty years'. Instead of appealing to the very long-term future like Peel and Buckland, Warburton pointed out that exhaustion was an ongoing process and that its consequences could already be felt and would be worse still in a single generation. There was perhaps en echo here of Charles Lyell's idea that geological processes were continuous and uniform. One might also see Warburton's argument as a return to the more compressed time scale of Malthus's original forecast of scarcity.[23]

[22] Edmund Burke, *Reflections on the revolution in France* (London, 1790), pp. 47, 69, 144; E. A. Wrigley, *Continuity, change and chance in the English Industrial Revolution* (Cambridge, 1988). One of Peel's early speeches in parliament, regarding the function of the speaker of the House of Commons, defined the office as a bond between the past and the future, whose performance affected 'even the remotest posterity', see *The speeches of the Late Right Honourable Sir Robert Peel*, I, p. 107.

[23] *Parliamentary Papers*, Third Series, XXV (1 Aug. 1834), pp. 907–8; Barrow, *The mirror of parliament for the second session of the eleventh parliament*, IV (London, 1834), p. 3185. Warburton allied with Lyell rather than Buckland in the Geological Society of London disputes, see Mrs Lyell, *Life, letters, and journals of Sir Charles Lyell, Bart* (2 vols., London, 1881), I, p. 38.

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Yet these warnings proved futile. Once again, the liberal reformers won the battle over tariff reform. After August 1834, a simple *ad valorem* duty of 10 per cent applied to British ships and a flat 4*s* per ton on foreign ships. The substance of the argument is worth considering in detail. Against Warburton's forecast, Lord Althorp insisted that there were 'still vast fields of coal near the surface' in the north of England. The member for Tyneside and North Shields, George Frederick Young, invoked the expertise of 'scientific men' against Peel and Warburton. He reminded the House of Commons about Taylor's assessment in the 1829 select committee report on the coal trade. The two counties of Durham and Northumberland could afford an 'adequate supply of coal for 1,700 years'. Young also brought up Robert Bakewell's verdict that the Welsh coal seams added another 2,000 years of supply. Ironically, Young's line of argument conceded the importance of Peel's long-term perspective. Instead of rejecting Peel's 400-year limit as irrelevant to the world of contemporary politics, Young pushed the calendar of exhaustion deeper into the future. Since the British coal supply could be expected to last upwards of 3,700 years, there was no reason to oppose the export of coal in the present; by this logic, the more distant the point of exhaustion, the stronger the case for laissez-faire. Forecasts that spanned over millennia rather than centuries seemed to offer more assurance that free trade could be pursued with impunity. Where Peel, Buckland, and Warburton understood the coal question as a problem that required government at least a modicum of oversight and regulation, the liberal reformers employed the idea of long-term abundance to reject tariffs and intervention.[24]

This battle over the future was also waged outside parliament. John Ramsay McCulloch's 1830 pamphlet on the coal duties relied on Taylor's coal estimates to attack tariffs. He doubted the 'expediency' of 'any duty upon the export of coal' when the supply of coal could be considered, for all practical purposes, 'as infinite'. He proposed that British coal exports might serve as a weapon to keep other nations, such as the United States, dependent on the British supply, thus discouraging them from opening their own mines. In *The statistical account of the British empire* (1837), McCulloch delegated the chapter on British geology to George Bakewell who repeated his estimate that the South Welsh coalfield would last 2,000 years.[25]

For the geologist and political economist George Poulett Scrope – the brother of Charles Poulett Thomson – the idea of physical limits to growth was a chimera. Scrope had made his name in the field of volcanic geology before he became an MP for Stroud in 1833. His work was an important influence on

[24] Barrow, *Mirror of parliament*, IV, p. 3185; Roy Church, *The history of the British coal industry*, III: *1830–1913: Victorian pre-eminence* (Oxford, 1986), p. 65.

[25] McCulloch, *Observations on the duty on sea-borne coal*, pp. 4–5; idem, *The statistical account of the British empire* (2 vols., London, 1837), I, p. 89; cf. Aeneas Mackenzie, *Historical, topographical and descriptive view of County Palatine Durham* (Newcastle upon Tyne, 1834), p. cxiii. In later life, McCulloch changed his mind and embraced export duties; see O'Brien, *J. R. McCulloch: a study in classical economics*, p. 126.

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Charles Lyell's theory of uniformitarian change. In *Principles of political economy deduced from the natural laws of social welfare and applied to the present state of Britain* (1833), Scrope attacked Malthus and his followers by arguing that they had profoundly underestimated both human ingenuity and natural abundance. 'There have been in truth few grosser fallacies of the economists', Scrope raged, than the notion of the 'decreasing fertility of the soil'. On the contrary, the productiveness of soils was 'daily increasing'. Human ingenuity constantly expanded the extent of cultivation. The history of mankind was a story of indefinite progress, with no end in sight. Scrope also argued that the natural world remained virtually unexploited. The frontispiece of *Principles of political economy* contained what may be the first published map of comparative population density. According to Scrope's map key, the vast majority of the land on the planet was still virtually uninhabited with less than one person per square mile. The globe had an 'unlimited capacity' for the production of food.[26]

Scrope was equally confident about coal. One of his favourite examples of future potential was the frontier of the Ohio basin, which he claimed had upwards of 500 million acres of fertile land and coalfields big enough to cover half of the European continent. Like William Buckland, Scrope regarded the mineral endowment of Britain and America as part of a providential arrangement. Iron, coal, and other useful minerals had been distributed throughout the surface of the earth to encourage higher forms of industry and civilization. The coal strata were the 'remains of plants of a former world' created through the deposition of an 'immense' quantity of 'fossil remains of plants'. For Scrope, the assumption of benign design – a natural order arranged to encourage fossil fuel civilization – obviated talk of exhaustion and the arithmetic of supply. In his 1848 work on the future of Irish improvement, Scrope declared coal and iron virtually 'inexhaustible' (implying at the same time that mineral poor Ireland should have a fair share in the carbon wealth of Great Britain).[27]

Two years after the 1834 vote about coal export duties, William Buckland published his magnum opus *Geology and mineralogy considered with reference to natural theology* (1836). Like the other contributions to the Bridgewater series, Buckland's book was well received and reached a wide audience in the middle classes. While Buckland's treatise was first and foremost a work of

[26] George Poulett Scrope, *Principles of political economy deduced from the natural laws of social welfare and applied to the present state of Britain* (London, 1833), pp. 265, 272–3; M. J. S. Rudwick, 'Poulett Scrope on the volcanos of Auvergne', pp. 205–42; Rashid, 'Political economy and geology in the early nineteenth century', pp. 726–44; Hilton, *Age of atonement*, pp. 153–4; David Stack, 'The "secret concatenation" in the mid-nineteenth century: the case of George Poulett Scrope, a still neglected political economist', *History of Political Economy*, 32 (2000), pp. 553–84.

[27] *Quarterly Review*, 56 (1836), Scrope, 'Geology considered with reference to natural theology', pp. 36, 39, 64; George Poulett Scrope, *A plea for the rights of industry in Ireland…* (London, 1848), pp. 39–40.

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geological research, it also included numerous references to economic matters. This should come as no surprise. After all, one of the aims of the Bridgewater bequest was to demonstrate how God had fashioned the natural world in the service of mankind. Take for example the opening pages of Buckland's treatise. Readers were asked to reflect on the economic and social effects of geology on population and economic development in Great Britain. Primary and transition rocks defined the sparsely populated highlands; red sandstone and Carboniferous strata dominated in the manufacturing districts; limestone and chalk shaped the character of the arable low country. For Buckland, demographic density, occupational trends, public health, and morals could be deduced directly from geological conditions. 'The numerical amount of our population, their varied occupations, and the fundamental sources of their industry and wealth, depend in a great degree, upon the geological character of the strata on which they live.' A little later in the book, Buckland meditated on the need for a new comportment towards coal. He reminded his readers that they were in 'immediate connection' with the geological past 'almost every moment of [their] lives' through a myriad of acts. By making middle-class readers aware of the geological origin of the economy, Buckland sought to instill a novel ethos of 'personal concern' towards fossil fuel. He repeated his arguments from the 1830 hearings about the duty of the present generation to conserve coal in the interest of posterity: 'Let us help ourselves abundantly, and liberally enjoy these precious gifts of the Creation; but let us not abuse them, or by willful neglect and wanton waste, destroy the foundations of the Industry of future Generations.' As a remedy, Buckland suggested a parliamentary ban on screening for small coal in the mining districts. All coal had to 'be shipped in the state in which it came from the Pit'. He also repeated his plea for limitations on exports. 'A densely peopled manufacturing country like our own' could not sustain 'any extensive exportation of Coal'. The prosperity of the new machine economy depended on 'native Coal Mines' and could 'never survive the period of their exhaustion'. Buckland's theology of nature makes a striking contrast with Scrope's 1833 work. The two geologists drew their arguments from the same fount of geological research, but with fundamentally different ideological aims. Scrope's book articulated a sharp critique of evangelical Malthusians, whereas Buckland as we have seen was quite closely aligned with the pessimistic tenor of Liberal Toryism.[28]

[28] Buckland, *Geology and mineralogy considered*, I, pp. vii, 1–4, 66–7, 536–8; Buckland collected a great deal of material on coal in preparation; see Oxford University Museum of Natural History, Buckland papers, 'Notes for the Bridgewater Treatise', box 2 and box 4; Jonathan Topham, 'Science and popular education in the 1830s: the role of the "Bridgewater Treatises"', *British Journal for the History of Science*, 25 (1992), pp. 397–430; on the theology of nature, see Jonathan Topham, 'Science, natural theology, and the practice of Christian piety in early nineteenth-century religious magazines', in Geoffrey Cantor and Sally Shuttleworth, eds., *Science serialized: representations of the sciences in nineteenth-century periodicals* (Cambridge, MA, 2004), pp. 37–66.

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In the fifteen years between Buckland's Bridgewater treatise and the Great Exhibition of 1851, the coal question surfaced repeatedly in a variety of contexts. Buckland's ally the Newcastle engineer Thomas Sopwith constructed a series of large-scale models of collieries and mining districts to educate the public about the structure of the coal supply. His model of the Forest of Dean became a popular sensation when it was displayed in London during the winter of 1841. Several of Sopwith's models were housed at the new Museum of Practical Geology, founded by Henry De la Beche in 1838. In the political realm, Sir Robert Peel succeeded in reviving export tariffs on coal in 1842, provoking a flood of protests and petitions, some of them expressly cornucopian in their defence of duty-free exports. Peel asked his peers to consider carefully the geological map of Britain and France before casting their vote – a telling sign of the popular importance of the new science.

Thomas Milner's *The gallery of nature* (1846) incorporated the full visual repertoire of Victorian geology, such as traverse and columnar sections along with images of fern fossils and colliery work. The Congregationalist Milner echoed Buckland's providential view of coal. God had arranged the mineral resources of Great Britain for the maintenance of civilized society. Milner predicted that the end of coal would impose conflicting demands on arable land, making it impossible to grow enough food and fuel to sustain a 'numerous population'. 'It is impossible to conceive of a greater and more disastrous change than that which an exhaustion of coal would produce.' Though Milner's warning came at a moment of liberal reform. Peel ushered in the repeal of the corn laws in 1846. The previous year, he had reversed his position on coal exports and abolished remaining duties. This liberal optimism was enshrined in the new Coal Exchange inaugurated by Prince Albert in 1849. The building gave material expression to the idea of coal as the foundation of British wealth and power. Painted panels along the upper walls showed miners at work. In the dome were figures of fossil plants found in the coal measures. The Coal Exchange was, in the words of a speaker at the inauguration, the fountain of 'inexhaustible enterprise'. Yet such confidence proved short-lived. Even the triumph of the Great Exhibition did not dispel the spectre of coal exhaustion from intellectual and political life. The pessimists returned in full force in the 1860s.[29]

Parliament took up the question of coal exports once again during the negotiations over the Cobden–Chevalier trade treaty with France in the summer of

[29] Diary of Thomas Sopwith 1828–79, Newcastle University Library, Special Collections, microfilm, journal 26, p. 256; journal 27, pp. 293–4, journal 30, 1842, pp. 43–5; S. Turner and W. R. Dearman, 'Thomas Sopwith's large geological models', *Proceedings of the Yorkshire Geological Society*, 44 (1982), pp. 1–28; *Parliamentary Debates*, Third Series, LXIII (14 June 1842), pp. 1576–7; J. R. Greg, *Observations on the proposed duties on the exportation of coals* (London, 1842), p. 17; Thomas Milner, *The gallery of nature* (London, 1846), p. 691; cf. Aileen Fyfe, *Science and salvation: evangelical popular science publishing in Victorian Britain* (Chicago, IL, 2004); *Daily News*, 31 Oct. 1849; J. Ewing Richie, *About London* (London, 1860), p. 35.

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1860. A year later, the surveyor Edward Hull issued a new estimate of the national coal supply. William Armstrong used his bully pulpit as president of the British Association for the Advancement of Science to warn about coal exhaustion in 1863. Growing public disquiet turned into veritable panic with William Stanley Jevons's book *The coal question* (1865). The intellectual force of the book came in no small part from Jevons's self-conscious synthesis of Malthus's political economy with the language of popular geology. Drawing on statistical evidence, Jevons argued that coal consumption increased by an average of 3.5 per cent per annum and that this trend would bring about rapidly rising prices within a mere generation or two. Jevons thus transposed Malthus's notion of exponential growth into the realm of coal consumption. Leading liberal figures John Stuart Mill and William Gladstone endorsed Jevons's forecast and urged parliament to investigate the issue. Following an initiative by the Welsh MP Hussey Vivian, a royal commission was formed to assess the extent and duration of the British coalfields. After five years of work, it concluded in 1871 that Jevons's pessimism was unwarranted. But ironically, coal prices began to soar shortly afterwards, triggering new fears of a general 'coal famine'.[30]

How do we explain this seesaw movement between panic and confidence in the politics of coal? The sociologist Nicholas Xenos has suggested that abundance and scarcity operate as conceptual twins. In traditional societies, ideas of feast and famine, Carnival and Lent, are mutually constituted. It is perhaps not far-fetched to see such cycles at least in part as a reflection of the material conditions of the organic economy: fair and foul weather, seasonal changes, sickness and health, good harvests and dearth. But for a fossil fuel economy such as Victorian Britain, the metaphor of steam locomotion seems to offer a more fitting model: the faster the movement of the train, the more catastrophic any crash. As novel forms of technology and energy consumption began to reshape the economy, new kinds of breakdown and collapse became possible to imagine. Such worries about limits in turn gave rise to counter-arguments about the deficiencies of pessimism. In intellectual and cultural terms, accelerating change produced competing forecasts. The persistence of the coal question can be understood as a double movement: two ideologies feeding on each other, generating alternate fossil futures.[31]

[30] *Parliamentary Debates*, Third Series, CLVII (9 Mar. 1860), pp. 247–330 (debate about coal exports in Cobden–Chevalier treaty); Edward Hull, *The coal fields of Great Britain: their history, structure and resources* (London, 1861); *Report of the thirty-third meeting of the British Association for the Advancement of Science held at Newcastle-upon-Tyne in August and September 1863* (London, 1864), pp. lii–lv; William Stanley Jevons, *The coal question: an inquiry concerning the progress of the nation and the probable exhaustion of our coal mines* (London, 1865), pp. 213, 215; *Parliamentary Debates*, Third Series, CLXXXIV (12 June 1866), p. 241 (Vivian's motion for a Royal Commission); *Report of the commissioners appointed to inquire into the several matters relating to coal in the United Kingdom* (2 vols., London, 1871); Martin Daunton, *Trusting Leviathan: the politics of taxation in Britain, 1799–1914* (Cambridge, 2001), p. 120; Madureira, 'The anxiety of abundance'.

[31] Nicholas Xenos, *Scarcity and modernity* (London, 1989), p. 35.

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