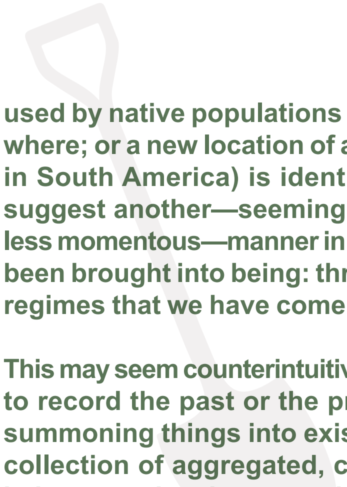
Nineteenth-Century Alchemy: Mineral Statistics circa 1850

Zeynep Çelik Alexander



In the midst of ongoing debates about the burning of fossil fuels, the role of renewable and non-renewable energy sources and the violence of extractive technologies, it might be worthwhile to reconsider a fundamental question: what exactly is a resource? In the popular imagination, a resource—especially when modified with the adjectives "natural" or "physical"—denotes a fixed store of assets waiting to be used by humans as input for productive activities. Yet, economists and geographers have been arguing for a while now that a resource is neither fixed nor merely in potentia.[1] Even early political economists, who privileged land as the origin of wealth and saw all improvement as agricultural improvement, must have perceived the instability of the concept. When David Ricardo endeavored to justify "rent" through the "original and indestructible powers of the soil," for example, he had to perform significant rhetorical acrobatics to posit land as the primordial resource, one that made all others possible.[2] By the time John Stuart Mill discussed "natural agents" (in addition to labor and capital) as essential requisites of production, it had become clear that Britain's wealth was more predicated on coal under the soil than on agricultural production on the surface.[3] Later scholars were therefore more likely to acknowledge, along with Erich Zimmermann who famously wrote that "resources are not; they become," that while resources may seem like natural things, they are in fact *functions* designated as such under particular social, economic, and political conditions.[4] And recent historians have demonstrated how what counts as a resource has changed dramatically over time—as is made clear by the cases of the cochineal bug, guano, nuclear matter, cobalt, and, perhaps most peculiarly, the kind of resource designated as "human."[5]

How, then, does a resource come into existence? Pressures of supply and demand, spells of abundance and scarcity, compulsion to develop and improve, forces of poverty and wealth have all been cited as factors in this historical process—even though these factors have often played out in unpredictable ways.[6] Even most fundamental human needs (such as water) may come in and go out of being a resource depending on historical circumstances. Moments of invention and discovery are privileged in such histories. A source of energy known for centuries (such as coal) becomes central with the development of an efficient steam engine; novel capabilities are created when colonizers find out about a plant (such as cinchona) used by native populations and smuggle and replant it elsewhere; or a new location of a known resource (such as silver in South America) is identified. In what follows, I want to suggest another—seemingly less eventful but arguably no less momentous—manner in which resources have historically been brought into being: through the formation of epistemic regimes that we have come to call "databases."

This may seem counterintuitive at first. Databases are supposed to record the past or the present, not herald the future by summoning things into existence. Defined as a "structured collection of aggregated, commensurable data capable of being sorted and accessed for some purpose of knowledge production," a database is frequently understood today to be a straightforward solution to a practical problem: the modern problem of managing large and complex societies.[7] Although historians have acknowledged its long history, the database continues to be associated with the emergence of electronic computing in the twentieth century. In what follows, I will argue, first, that the past of this epistemic arrangement was intertwined with nineteenth-century imperialism and, second, that its historical role has entailed more than solving the problem of governing the masses. Focusing on the case of the Museum of Economic Geology, which housed a collection of mineral statistics in London after 1851, I will show how collecting, storing, aggregating, and making retrievable statistics about what lies beneath the soil created value for future extraction. I will compare this process of value creation to alchemy, the practice of turning base metals into precious ones, a practice that had become obsolete by the middle of the nineteenth century after having played a crucial role in early political economy. This alchemical transmutation of value, it turns out, necessitated imagining land not as a horizontal surface but rather as extending in the vertical dimension, which was made visible through geological and architectural sections.

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On September 23rd, 1841, when Thomas Sopwith, mining engineer and mineral surveyor, spoke at the Yorkshire Geological Society in England, he began by showing his audience a blank chart.[8] The chart was 15 inches by 20 inches and engraved with a grid at a scale of 40 feet to an inch so that it could be filled in with geological sections. By then the construction of railways and the expansion of the mining industry had become mutually reinforcing phenomena in Britain. Early railcars were designed to carry coal out of mines; the steam engines that now pulled them and ran the pumps that kept flood water out were powered by the same coal.[9] More relevant to Sopwith's argument, these developments meant that British land was repeatedly being cut in dramatic ways for mines and railways, giving geologists unusual opportunities to see earth's mineral composition, formed over millions of years, in section. (Fig. 1) Sopwith argued that the geological information thereby revealed should not go to waste but rather be collected using copies of the blank chart. The sectional information was not only important to the discipline of geology; it was also crucial to identify underground resources that were important for "the future national prosperity" of Britain—for the improvement of agriculture, mining, construction, and so on.[10]

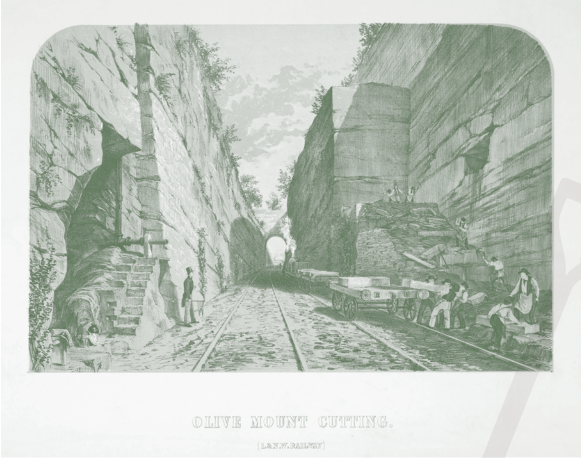

Fig. 1

The chart in question had been printed by the Museum of Economic Geology in London under the leadership of Henry De la Beche, the founder of that institution and the first director of the British Geological Survey. Even though it had been firmly established by the 1820s that earth had a stratified structure, most geological work still primarily consisted of making plans.[11] De La Beche's own career demonstrated geology's representational dilemma: he had started out as a gentleman geologist coloring maps of Pembrokeshire before embarking upon a geological survey of Jamaica during a visit to the island to attend to his family's sugar plantation, which was failing after the Slavery Abolition acts.[12] (Fig. 2) In 1835 when, with the blessing of the Geographical Society of London, he became the first director of the Geological Survey, his primary task was to color and mark maps produced by the Board of Ordnance.

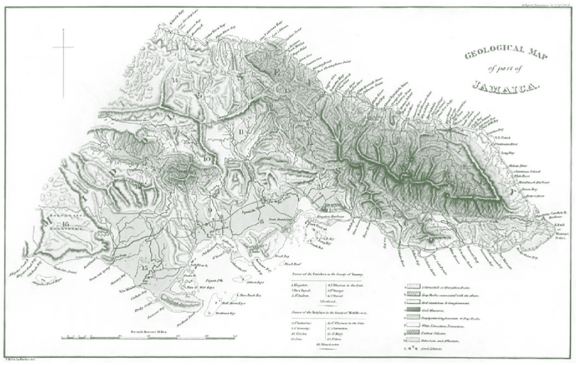

Fig. 2

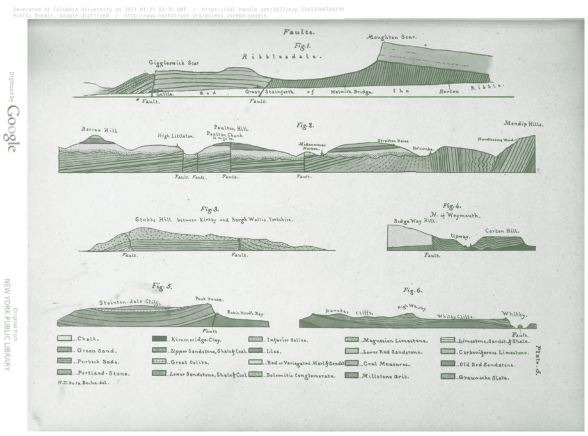

Fig. 3

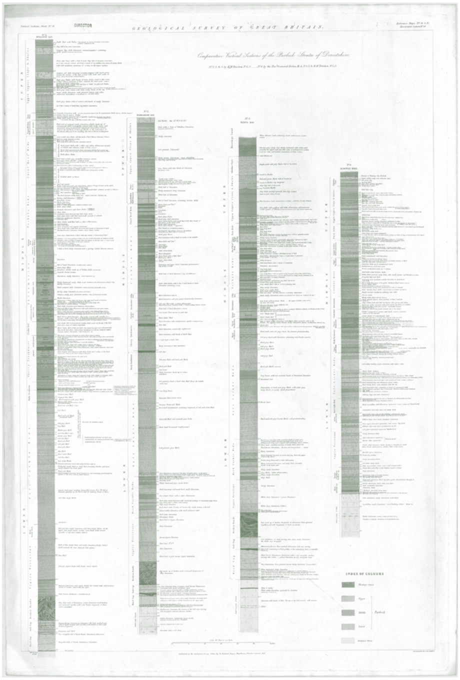

Fig. 4

Yet, De la Beche understood as well as Sopwith that studying earth's structure "sectionally" was crucial.[13] But because sectional information was so hard to come by, he recommended that geologists draw what he called "ideal" or "annexed" sections. These were "horizontal sections" that reconstructed the stratigraphic and topographic transformations of land over long distances. Since geological observation was inherently discontinuous, however, a degree of guesswork was needed when constructing such sections. To construct horizontal sections the geologist had to abstract strata as more or less continuous layers separated into clearly demarcated zones and mark them with colors, letters, and numerals for legibility. (Fig. 3) The kind of sections advocated by Sopwith, by contrast, were vertical; these tall and thin columnar sections showed earth's strata only at crucial points but with far more detail. (Fig. 4) Both kinds of sections made visible what the most meticulously constructed geological plan could not, but vertical sections abstracted horizontal sections further by visually restoring disturbances such as folding or faulting of strata into perfectly parallel layers.[14] Crucially, as we will see, this additional step of abstraction made it easier to aggregate sectional information in an arrangement resembling what we would today call a database. If, reasoned Sopwith, "a regular series of sections of railway cuttings" could be collected in a systematic and standardized manner, the British government could create a central registry to make them available to entrepreneurs interested in agriculture, mining, or railway construction.[15]

Geological and economic thinking were closely related in the early nineteenth century.[16] In 1835, when the Geological Society charged De la Beche with the task of establishing the Geological Survey, its members argued that a systematic survey of Britain's geological resources had countless economic advantages: it would help find coal and precious metals, locate sources of underground water, aid the construction of canals, railroads, and tunnels, and identify chemicals crucial to the artificial improvement of the soil.[17] Yet, as Sopwith explained, mineral wealth was different from other kinds "in the extreme uncertainty of its existence and the difficulty of its discovery," which meant that prospecting for a mineral had conventionally been no different from hoping to win the lottery.[18] Adam Smith's argument that silver riches from American colonies were "a lottery, in which the prizes [did] not compensate the blanks" was repeated countless times in the course of the nineteenth century: some compared the "sure rewards of labour in the fields" to the "lottery of the gem pit" while others cautioned future adventurers against trying their odds in the "mining lottery."[19] With the introduction of systematically arranged "mineral statistics," Sopwith argued that exploiting subterranean resources would become a different kind of endeavor: instead of relying on chance, entrepreneurs could now depend on *data* to make intelligent choices—even in a global economy with unpredictable price fluctuations.[20] According to Sopwith, collecting geological information was more "prospective" than "retrospective"—that is, to the extent that it transformed mining from an aimless treasure hunt to a strategic search for subterranean resources, it was "of far less importance to the present than to future times."[21]

Fig. 5

Reservoir	Region	Storage capacity (Gt CO_2) at different injection times, T (years)										
		$T = 25$	50	75	100	150	200	250	300	400	500	600
Mt. Simon	a	$9.4^{+7.9}_{-2.4}$	$15^{+12}_{-3.7}$	$19^{+16}_{-4.8}$	$23^{+20}_{-5.9}$	$31^{+26}_{-7.8}$	$37^{+32}_{-9.5}$	44^{+37}_{-11}	50^{+42}_{-13}	61 [illegible]	73^{+43} [illegible]	84^{+32}_{-23}
Mt. Simon	b	$4.8^{+4.4}_{-1.3}$	$7.5^{+5.8}_{-2}$	$9.8^{+3.6}_{-3}$	$10^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$	[illegible] $^{+3.3}_{-3.3}$	$10^{+3.3}_{-3.3}$
Mt. Simon	c	$2.7^{+2.5}_{-0.72}$	$4.5^{+4.1}_{-1.2}$	$6.1^{+5.6}_{-1.6}$	7.7^{+7}_{-2}	$11^{+9.7}_{-2.8}$	$13^{+8.6}_{-3.6}$	$16^{+5.9}_{-4.3}$	$17^{+5.2}_{-4.3}$	17 [illegible]	[illegible] $^{+5.2}_{-4.3}$	$17^{+5.2}_{-4.3}$
Black Warrior River	a	$3.8^{+3.2}_{-1}$	$5.6^{+4.6}_{-1.5}$	$7^{+5.8}_{-1.9}$	$8.2^{+6.8}_{-2.2}$	$10^{+8.6}_{-2.7}$	$12^{+10}_{-3.3}$	$14^{+12}_{-3.8}$	$16^{+13}_{-4.3}$	20 [illegible]	[illegible] $^{+19}_{-6.3}$	$28^{+15}_{-9.2}$
Black Warrior River	b	$2.3^{+1.9}_{-0.58}$	$3.7^{+3.1}_{-0.93}$	$5.0^{+4.1}_{-1.3}$	$6.2^{+5.1}_{-1.6}$	$8.6^{+7}_{-2.1}$	$11^{+9}_{-2.7}$	$13^{+11}_{-3.3}$	$16^{+13}_{-3.9}$	20 [illegible]	[illegible] $^{+12}_{-6.2}$	$29^{+7.3}_{-7.3}$
Black Warrior River	c	$2.3^{+2.1}_{-0.65}$	$3.8^{+3.5}_{-1.1}$	$5.2^{+4.8}_{-1.5}$	$6.5^{+6}_{-1.8}$	$8.9^{+8.1}_{-2.5}$	$11^{+5.7}_{-3.2}$	$14^{+3.4}_{-3.8}$	$14^{+3.4}_{-3.4}$	14 [illegible]	[illegible] $^{+3.4}_{-3.4}$	$14^{+3.4}_{-3.4}$
Black Warrior River	d	$3.2^{+2.7}_{-0.87}$	$4.3^{+3.6}_{-1.2}$	$5.3^{+4.4}_{-1.5}$	$6.1^{+5.1}_{-1.7}$	$7.7^{+6.4}_{-2.1}$	$9.1^{+7.6}_{-2.5}$	$10^{+8.7}_{-2.9}$	$12^{+9.8}_{-3.2}$	14 [illegible]	[illegible] $^{+14}_{-4.6}$	$19^{+16}_{-5.2}$
Frio	a	$5.9^{+5.2}_{-1.9}$	$9.2^{+8.1}_{-3}$	12^{+11}_{-4}	$15^{+11}_{-5.3}$	$18^{+8.2}_{-8.1}$	$18^{+8.2}_{-8.1}$	$18^{+8.2}_{-8.1}$	$18^{+8.2}_{-8.1}$	$18^{+8.2}_{-8.1}$	[illegible] $^{+8.2}_{-8.1}$	$18^{+8.2}_{-8.1}$
Frio	b	$3.7^{+3.3}_{-1.1}$	$5.9^{+5.3}_{-2.2}$	$8^{+4.3}_{-4.3}$	$8.6^{+3.7}_{-4.9}$	$8.6^{+3.7}_{-4.9}$	$8.6^{+3.7}_{-4.9}$	$8.6^{+3.7}_{-4.9}$	$8.6^{+3.7}_{-4.9}$	8.6 [illegible]	$8.6^{+3.7}_{-4.9}$	$8.6^{+3.7}_{-4.9}$
Frio	c	$3.6^{+3.2}_{-1}$	$5.5^{+5}_{-1.6}$	$7.3^{+6.6}_{-2}$	$8.9^{+8}_{-2.5}$	$12^{+5.7}_{-5}$	$12^{+5.4}_{-5.4}$	$12^{+5.4}_{-5.4}$	$12^{+5.4}_{-5.4}$	$12^{+5.4}_{-5.4}$	[illegible] $^{+5.4}_{-5.4}$	$12^{+5.4}_{-5.4}$
Madison	a	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$	5.3 [illegible]	[illegible] $^{+2.2}_{-2}$	$5.3^{+2.2}_{-2}$
Madison	b	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$	6.6 [illegible]	[illegible] $^{+2.6}_{-2.8}$	$6.6^{+2.6}_{-2.8}$
Navajo-Nugget	a	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$	5.1 [illegible]	$5.1^{+2.4}_{-2.4}$	$5.1^{+2.4}_{-2.4}$
Navajo-Nugget	b	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$	4.0 [illegible]	[illegible] $^{+1.4}_{-1.4}$	$4.0^{+1.4}_{-1.4}$
Morrison		$7.0^{+6.5}_{-1.9}$	$12^{+11}_{-3.3}$	$16^{+6.8}_{-4.4}$	$17^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$	[illegible] $^{+5.3}_{-5.3}$	$17^{+5.3}_{-5.3}$
Potomac		$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$	3.6 [illegible]	$3.6^{+1.5}_{-1.5}$	$3.6^{+1.5}_{-1.5}$
Fox Hills		$3.0^{+3.1}_{-0.98}$	$4.7^{+3.1}_{-1.5}$	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$	5.5 [illegible]	$5.5^{+2.3}_{-2.3}$	$5.5^{+2.3}_{-2.3}$
Paluxy		$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$	1.5 [illegible]	[illegible] $^{+0.5}_{-0.5}$	$1.5^{+0.5}_{-0.5}$
St. Peter		$1.4^{+0.55}_{-0.41}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$	1.6 [illegible]	[illegible] $^{+0.38}_{-0.38}$	$1.6^{+0.38}_{-0.38}$
Cedar Keys		$2.1^{+2}_{-0.58}$	$3.4^{+3.3}_{-0.97}$	$4.7^{+4.5}_{-1.3}$	$5.8^{+5.6}_{-1.6}$	$8^{+7.7}_{-2.3}$	$9.9^{+9.5}_{-2.8}$	$12^{+11}_{-3.3}$	$14^{+13}_{-3.9}$	17 [illegible]	[illegible] $^{+20}_{-5.8}$	$24^{+23}_{-6.8}$

While the goal of standardization remained elusive, the idea of forming a registry of mineral statistics was realized, at least partially, when dozens of vertical and horizontal sections, along with geological maps to which they were keyed, came together in the Mining Records Office of the Museum of Economic Geology (which was later known as the Museum of Practical Geology).[22] (Fig. 5) The first Museum was founded in London in 1835 in makeshift apartments in Charing Cross to accommodate the assortment of artifacts discovered during the Geological Survey's excavations, but it was formalized into a proper collection when the institution re-opened in 1851 in a building between Jermyn and Piccadily Streets built especially for this program. Situated in a narrow infill site, the building was designed by the architect James Pennethorne for the Office of Works with advice from De la Beche.[23] In addition to exhibition galleries, the Museum accommodated a large lecture hall, chemical and metallurgical laboratories, a library, a model room, and several offices, the largest of which was the Mining Records Office. The lecture hall in the basement served not only the Government School of Mines (which was based in the Museum until 1872) but, for a small fee, also the general public.[24] By 1853 other cities were campaigning to open their own geological museums while De la Beche appealed to the East India Company to set up a branch in India.[25] Bombing during WWI caused structural damage to the building, as a result of which it had to be demolished after its contents were transferred in 1935 to South Kensington.

Historians have compared the Museum of Economic Geology in its second address to natural history museums that came before and to commercial museums that came after, but it was in many ways a different creature. It was, for example, unlike the Old Ashmolean Museum, which displayed mineral specimens like wonders in a cabinet of curiosities. As a visitor remarked in 1851, specimens on display in the Museum were not "selected for the rarity of the form of their crystals, or the

If, as Çelik Alexander notes, "a resource is anything to which humans attribute economic value under particular historical conditions," our current moment ought to be bringing into being some rather particular resources, because we are living in nothing if not a particular time. Sure enough, as fellow Perspecta contributor Gökçe Günel has recently been chronicling, one very unexpected substance has lately been in the process of becoming a resource: carbon dioxide. That's right, global warming's poster child and public enemy number one CO2 is (potentially) emerging as a great holder of economic value.

splendour of their colours, but the *average* produce of the mine, as it is extracted for economic uses."[26] This was "mineralogy in its working, not in its gala dress."[27] In this sense, it was closer in its logic to later natural history museums (such as the natural history branch of the British Museum which would absorb the collections of the Museum of Economic Geology) in which "one wasn't supposed to wonder, one was supposed to learn."[28]

The Museum of Economic Geology was also not entirely like the "commercial museum" type that started appearing in the 1880s in Brussels, Antwerp, Milan, Vienna, Budapest, and Philadelphia and, in the case of Britain, in the Imperial Institute in London.[29] These later museums would display industrial samples ranging from raw materials to machinery and finished products and have bureaus that provided information about prices, tariff arrangements, shipping costs, market conditions unique to a locale, etc. While the Museum of Economic Geology did not have the advanced indexing systems that characterized these later institutions, it did provide to the visitor an abundance of information about materials, manufacturing technologies, and finished products.[30] Such information was especially useful "for gentlemen who are hereafter to inherit mineral property," according to an article published in 1858, which also argued that these gentlemen would have knowledge about "the best mode of managing their property untrammeled by agents or middlemen."[31]

This required information of the kind that Sopwith called for—that is, structured information that was methodically collected, stored, and made retrievable—albeit not always standardized in ways that Sopwith had envisioned. In addition to the collections of the Mining Records Office, which would be absorbed into the Home Office in 1883, the Museum regularly published vast amounts of gray literature—memoirs, reports and almanacs filled with mineral statistics. Furthermore, the design of the displays was determined by an instructional logic that Sopwith noticed even in the earlier Museum in Charing Cross. In a guide from 1843, he pointed out how specimens were arranged "with every reference to instruction and the situations from whence obtained carefully marked, not only on the specimens themselves but also on good maps."[32] This abundance of information was noticed by countless other observers throughout the Museum's history.[33] In this sense the informational function of the Museum of Economic Geology was not confined to the proto-database of plans and sections in the Mining Records Office. The entire building structured geological information in novel ways, especially in section.

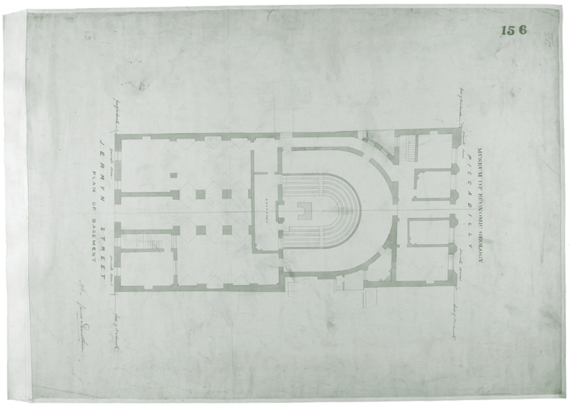

Fig. 7a

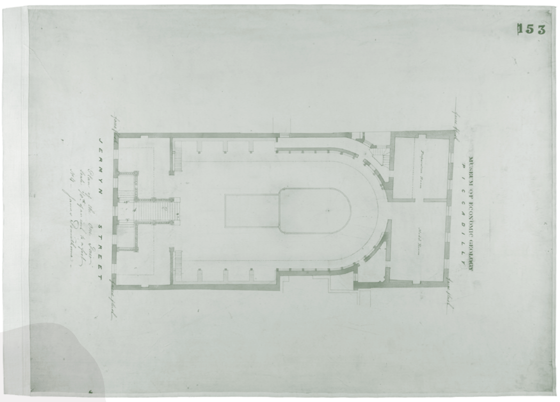

Fig. 7b

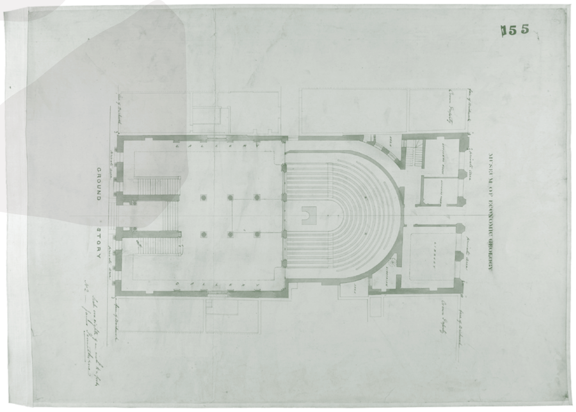

Fig. 7c

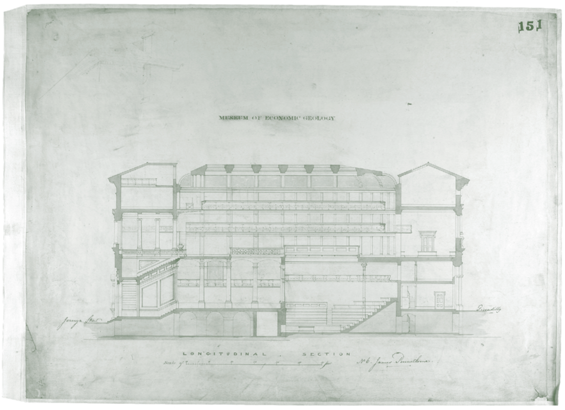

Fig. 6

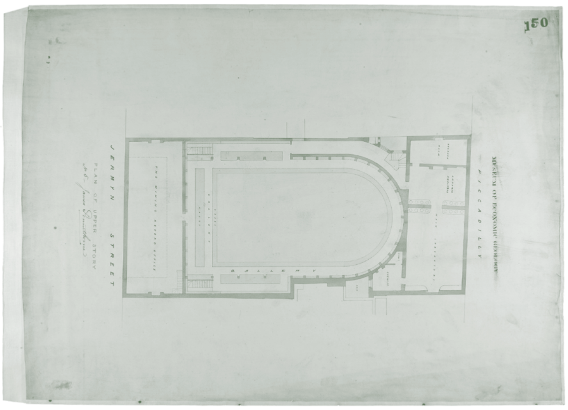

Fig. 7d

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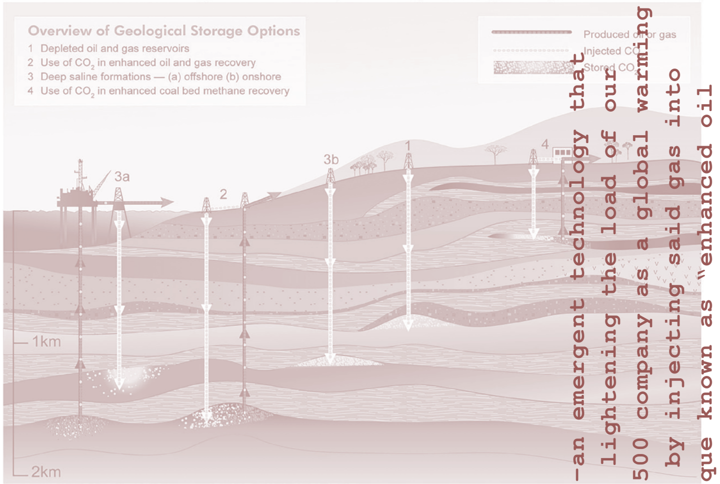
The elaborate section of the Museum of Economic Geology must have been designed in response, at least in part, to the unfavorable lighting conditions dictated by its deep and narrow infill site. (Fig. 6) The primary exhibition spaces consisted of a main floor and two cantilevered galleries that wrapped around a central atrium, illuminated by a 43-foot tall iron-and-glass roof. A horizontal glass plane in the center of the galleries let this light into the 400-person lecture hall in the basement. The horseshoe footprint of the lecture hall determined the spatial arrangement of the rest of the building. The laboratories, a model room, a library, and various offices, including the Mining Records Office, were situated along the Jermyn and Piccadily Street façades in the spaces left over in the plan from the footprint of the lecture hall and the galleries. (Fig. 7a, b, c, d) The building's section was designed such that it could only be accessed from the quieter Jermyn Street. Visitors climbed up two short flights of stairs before entering the ground floor galleries, where a selection of British marbles (famously collected for the Houses of Parliament) were on display. They then ascended a more ceremonious staircase to find themselves in the "great room" of the primary exhibition galleries. (Fig. 8)

Fig. 8

The section of the primary exhibition galleries must have been an impressive sight, a powerful object lesson in economic geology. Historians have pointed out that the galleries resembled a geological section: the display cases were arranged in striated layers as if visitors occupied an oversized model of earth's strata.[34] But the architectural section did not follow the logic of a geological section in a strict manner. In fact, the main floor of the exhibition hall, dedicated to mineralogical and petrographical specimens, had an entirely different spatial arrangement from the cantilevered galleries. As an early guide explained, the organization of the main floor was, "in the first place topographic and in the second place economic."[35] Another observer noted in 1874 that "the specimens [were] admirably arranged in separate lines of cases placed in such juxtaposition that the progress of any one metalliferous mineral may be traced from the geological stratum whence the ore is extracted through the various processes of manufacture till the metal ultimately assumes the forms required for use or ornament."[36] This meant that in every subdivision, the visitor's gaze was meant to move in section up and down from the specimens displayed in the vertical cases toward the horizontal cases exhibiting a range of "economic" products obtained from them. In the foreign minerals section, for example, a cross-section through the display cases revealed the progression of the so-called Siberian vase from the aventurine crystals resourced from the Altai mountains. This visual path was a trip from the past of a raw material to the future of a manufactured product.

Methods for storing CO2 in deep underground geological formations



SRCCS Figure TS-7

If geography dictated the organization of the specimens on the main floor, chronology was the organizational principle of the British fossil exhibits in the two cantilevered galleries. Here Paleozoic fossils in the lower gallery progressed toward the Mesozoic and Cenozoic fossils in the upper gallery. Instead of being arranged as a stratigraphical column, however, the display cases for the fossils wrapped around the two gallery levels, inviting visitors to experience the vertical layers of earth horizontally while making their way from west to east.[37] This was a significant choice. When the Museum opened its doors in 1851, the debate between uniformitarianism and catastrophism, was still heated.[38] At stake was the question of causality with all kinds of theological implications: Was earth the result of gradual evolution or disruptive events? What was the role of God in it? Furthermore, another debate known as the Devonian controversy was only beginning to cool. This one involved none other than De la Beche and Roderick Murchison, his future successor as director of the Museum, who disagreed on the question of how close to earth's surface coal deposits could be found. This was a question that had implications for the nineteenth-century scramble to prospect for new coal deposits around the globe.[39] Fossils were considered to be stratigraphic markers that dated mineralogical and petrographical specimens, so by placing fossils on separate floors, the Museum's curators disconnected the two kinds of specimens, thus suspending the question of mineral historicity. In other

Why would this be the case? As we rapidly approach climate overshoot, carbon capture and storage (CCS)—an emergent technology that allows us to take carbon gathered from the air or from industrial operations and shoot it underground, lightening the load of our overburdened atmosphere—is increasingly being cast by everyone from the IPCC to your favorite Fortune 500 company as a global warming panacea. Shooting CO2 down into the netherworld has a value beyond climate change mitigation, however: by injecting said gas into supposedly tapped oil wells, one can draw out crude reserves that are otherwise inaccessible, a technique known as "enhanced oil words, this was not a natural history museum in which visitors were invited to contemplate the scale of time—regardless of whether that timescale had been imposed by God or Nature. The intended outcome was much more practical: the visitors were to contemplate the future human uses of minerals rather than their formation in an impossibly distant past.

This emphasis on practicality, however, did not mean exactitude. In this sense, the section of the Museum of Economic Geology can be compared to Sopwith's isometrical drawings. (Fig. 9) While De la Beche warned against "the mischief of adopting a scale of height differing from that of length," Sopwith advocated using some exaggeration in geological representations to make visible things such as coal strata.[40] In the short treatise that he wrote on the topic of isometry, he explained that while isometric projection required changing vertical and horizontal dimensions by multiplying them by a coefficient, it had the virtue of being able to represent multiple plans and sections at once.[41] An isometric drawing "fill[ed] up the space between the picture and the plan; between the picturesque beauty of the painter's canvas, and the formality of the designs of the mechanical draughtsman," he wrote.[42] That is to say, while they might not represent exact dimensions, isometical drawings converted discrete vertical geological sections into continuous horizontal ones that could teach the lessons of economic geology more effectively.

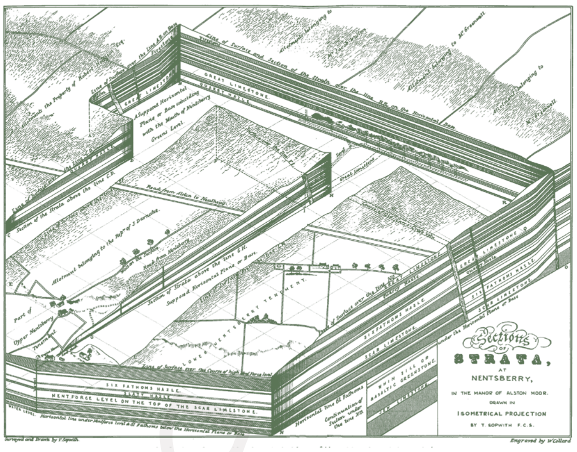


Fig. 9

The design of the Museum, in other words, employed several spatial strategies for structuring information: first, selective sequencing (of geological strata, domestic and colonial minerals, phases of the manufacturing process and separation of fossils from minerals) and, second, measured exaggerating (of the vertical dimension and the clarity of boundaries). A crucial third strategy entailed cross-referencing: the "exposed section," so to speak, of the primary exhibition galleries revealed connections across and beyond the building. This kind of cross-referencing work was done for the most part by labels, which frequently included such information as the scientific and common names of a mineral, its density, chemical composition, the location from which it was extracted and, in some instances, a photograph of its microscopic structure. "The explanatory labels attached to the specimens are also more convenient and useful than any reference to a catalogue could be," wrote one journalist, "inasmuch as the eye rests at once upon the specimen, and its name, locality, and uses; and in most instances, the analysis of the ores and minerals is also given, in order that visitors from different parts of the country may at once become acquainted with the nature and value of the various contents of the museum."[43] Depending on the specimen, this information could be even more detailed. Each building stone on display in the ground floor hall, for example, was cut down to a standard cube six inches by six inches and marked with such information as the amount of water it absorbed and its ability to resist pressure in a hydrostatic press. Also provided alongside a specimen was a list of "the edifices, ancient and modern, which have been built with it."[44] (Fig. 10)

Fig. 10

Even though it was possible by the middle of the nineteenth century to find detailed museum guides and catalogues, information-rich labels—that is, handwritten or printed information meant for visitors rather than for museum officials—were less common. Take the case of the British Museum: while popular guides or handbooks might offer abundant information about antiquities presented in the course of a visit and while the more technical official catalogues of the Museum's natural history collections might provide detailed information that followed a particular taxonomic system favored by researchers, there is little evidence that such narratives in book format were matched by labels with thorough information in the galleries.[45] The situation seems to have been similar across the Channel. According to a comprehensive guide to the collections of Musée royal d'histoire naturelle in Paris, in 1823 plant specimens had labels that merely described "the different names by which the plant had been designated, and the indication of the place where the sample had been collected" while labels to zoological specimens contained only three lines, consisting of a common name, a Latin name, and the name of the donor.[46] Labels in art museums, too, were only beginning to offer more information at this moment. Gustav Waagen, who is sometimes credited with having written the first art museum labels, made extensive catalogues of art collections in Germany and in Great Britain, but while he wrote many an index in book format (and others followed up with indices of his indices), his gallery labels remained relatively simple.[47] It was not until the later decades of the nineteenth century that information migrated in most museums in Europe and North

America from museum catalogues in book format to object labels on the walls or in vitrines—a move that paralleled the transition in libraries from bound to card catalogues.[48]

The Museum of Economic Geology produced information in other formats as well. If visitors wanted to dig deeper into a particular mineral or district, it was possible to find out more in the Museum's library by looking it up in a large volume of gray literature that ranged from official catalogues to reports and from unofficial handbooks to guides that provided more detailed descriptions of the Museum's holdings.[49] And if a particular mineral needed to be traced to a specific location in Britain or in the colonies, the Mining Records Office, which, as we have seen, provided horizontal and vertical sections as well as three-dimensional models that could be cross-referenced to maps produced by the Geological Survey. From 1858 onward, this information became so overwhelming that the Museum started publishing catalogues that indexed its own publications.[50] By 1890 "for a few pence" it was also possible to buy a copy of the numerous colonial reports published by Her Majesty's Stationery; these reports on such locations as Lagos, Ceylon, Newfoundland, Jamaica, Victoria, St. Vincent, etc. contained information about geological opportunities in addition to botanical ones."[51] This thick web of cross-referenced information was meant to produce practical results: in 1852 just before a company was formed to extract coal from an abandoned copper and lead mine in Wheal Alfred, Cornwall, potential investors consulted the sections in the Mining Record Office only to find out that this particular site was prone to flooding.[52] Comparing vertical sections from Northumberland, Robert Hunt, the keeper of the Mineral Records Office for almost four decades, could tell interested entrepreneurs at what depth carboniferous limestone series could be found at a particular location in the region.[53]

It was primarily this comparative function of the Museum of Economic Geology that created new resources: not only by finding unknown uses for known minerals but also by identifying new locations and techniques to obtain known resources. No better example demonstrates this in the nineteenth century than coal. British coal production tripled between the middle of the eighteenth century and the beginning of the nineteenth century and increased fivefold again by the middle of the century.[54] The Museum's move to its new location followed the reopening of the London Coal Exchange in 1849. The comparative function of the Museum was important to the coal trade for two reasons. First, after the public metage system (which entailed public officials weighing coal deliveries to ensure the fairness of a transaction but also to levy taxes) was abolished in 1831, coal's fungibility in London's increasingly "free market" depended on the standardization of *quantity*.[55] The Museum of Economic Geology continued this process by standardizing *quality*. Soon after its opening, for example, the Museum analyzed coal samples to make a recommendation about the kind best suited to the needs of the British steam navy.[56]

Second, the laboratories of the Museum routinely carried out chemical analyses to test the efficiency of coal from around the globe. Comparisons—of, say, specimens from Newcastle to those from Sandy Bay, Patagonia, Chile or Vancouver Island—would be published in the popular press.[57] Comparability implied substitutability: knowing that when a mineral from one resource became unavailable, another could be found made that mineral more easily exchangeable. The information

emanating from the Museum of Economic Geology thus provided assurances for the exchange of minerals in general and for the coal trade in particular, which, at a moment when steam power had become so crucial, was especially prone to speculation. One newspaper article from 1843 went so far as to claim that mineral statistics were therefore "of more importance" to Britain "than all the mines of Mexico and Peru."[58]

This was not mere hyperbole. In the 1840s geologist and future director of the Museum Roderick Murchison predicted, after comparing rock samples from the easternmost regions of Australia to those from auriferous tracts in the Ural Mountains, that there might be gold in the colony.[59] Murchison's prediction came before Edward Hargraves discovered the precious metal in New South Wales in 1851, the same year that the Museum opened its doors in its new building. This meant that once mineral statistics changed mining from a "lottery" to a proper science, the payoff would be no less rewarding than winning the lottery. Thus the Museum of Economic Geology, an institution funded in large part by public funds and in small part by the Geological Society, was put in the service of private entrepreneurs at a moment when free trade was becoming government policy. [60]

It is in this sense that the mineral statistics of the Museum of Economic Geology can be said to have performed an alchemy of sorts. One of the ingenuities of classical political economy was the claim that free trade and practical knowledge (what we would today call "technology") would allow nations to break out of the mercantilist calculation of wealth as a zero-sum game and make infinite improvement possible.[61] As free-trade policies started to be adopted by the British government at mid-century, such exponential creation of wealth seemed within reach. The historian Carl Wennerlind has demonstrated in his study of the Hartlib Circle that early political economy was shaped by alchemy, which also promised a radical transformation by turning base metals into gold.[62] (The only alchemical experiment that succeeded, it turns out, was the creation of paper money.[63]) The spatial arrangement of

recovery." And so, as Günel documents, a number of oil and gas professionals are now attempting to recategorize carbon dioxide not as a waste material but as a commodity.

Whether one is using CCS to draw out that last bit of oil that is playing hard to get or to simply pay off a bit of our carbon debt, the forecasted rise of this technology will in turn create other resources, most notably the saline aquifers that, alongside tapped oil information in the Museum of Economic Geology produced an alchemical effect not only by identifying new resources and new locations for known ones but, more importantly, by providing new capabilities for navigating mineral markets that were increasingly becoming globalized at this moment. The London Metal Exchange, which first traded copper and, later, lead and zinc, officially opened in 1877—even though, like coal, these mineral commodities were being traded in a less formalized manner as early as the sixteenth century.

Early political economists had speculated that infinite improvement would be achieved thanks to free trade and practical knowledge, paying less attention to what historians have come to call "ghost acreages," the land in the colonies whose violently extracted resources exponentially multiplied the "wealth of nations" in Europe.[64] (According to one famous calculation, Britain relied on twenty-three million such ghost acres in 1830 for the cotton that was used in manufacture in Lancashire, a surface area that is almost equivalent to that of the entirety of England.[65]) The primary alchemy of nineteenth-century information storehouses was to create such ghost acreage *virtually*. By comparing the quality of coal from England to that from abroad, by making calculated predictions about tin at home or gold in the colonies, and by suggesting substitutes for a metal that might no longer be available, the Museum of Economic Geology created value simply by projecting future transaction opportunities for the benefit of the entrepreneur. This, after all, was how the thousands of pages of statistics published by the Mining Records Office were meant to be put to use. And, unlike actual ghost acres whose exploitation required a significant outlay of materiel and labor and encountered significant friction and resistance on the ground, the virtual rehearsal of ghost acres of the Museum of Economic Geology required little than the documentation, storage and comparison of information on sheets of paper.

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Such optimism about the infinite resources of the future coexisted with anxieties about the depletion of accumulated resources. Malthus had calculated that while subsistence increased arithmetically, populations increased geometrically, thus setting "natural limits" to improvement.[66] Influenced by Malthus, some expressed fears about the finiteness of mineral resources almost as soon as mining took center stage in British economic life.[67] When geologist and theologian William Buckland critiqued Britain's "wanton waste" of coal, for example, he drew a contrast between the waste of agricultural resources, which, he argued, was morally wrong but not irreversible, and the waste of mineral deposits, which was permanent since it took millions of years for organic matter to replenish itself.[68] Pessimists like Buckland who predicted the exhaustion of Britain's coalfields were countered most frequently by advocates of free trade in the first decades of the nineteenth century.[69]

Thinking in section—rather than in plan—proved crucial to such debates. In 1829 both the House of Commons and the House of Lords established select committees on the state of the coal trade. At stake was the question of how to tax coal and regulate its trade, but, more relevant here, these hearings cast geological sections in an unexpectedly central role. In a testimony in May 1829, Duke Hugh Taylor, owner of mines in Northeast England, offered an optimistic calculation: even after taking into consideration considerable waste, mines of Northumberland and Durham alone would produce coal that would last the nation 1,727 years.[70] A year later Adam Sedgwick, professor of geology at the University of Cambridge, pulled this number down to 300 to 400 years. Sedgwick did not disagree with the surface area that Taylor had included in his estimate—a number Taylor had calculated looking at a plan; he argued that the calculation was simply wrong because Taylor did not take into consideration the varying *section* of the region.[71] The conclusion was clear: it was necessary to engage in sectional thinking to assess the economic value of Britain's coal reserves accurately.

Still, it turns out, there were also ghost acres to be discovered under the British soil. In the 1830s Sopwith was charged by the Crown to be the chair of a committee that collected mineral statistics in the Forest of Dean in western Gloucestershire.[72] In the seventeenth century when the forest was enclosed by the Crown to grow timber for shipbuilding, the local populations were given exclusive rights to mine iron and the coal, some of which lay on the surface. These locals, known as "free miners" used a technique called "galing," which consisted of digging no deeper than 12 feet into the ground. By the end of the eighteenth century, however, it was clear that free miners had neither the machinery nor the capital necessary to extract the coal that lay deeper. In 1838, in the name of improving productivity, the Parliament passed a law which, even as it appeared to be reinstating the old privileges of the free miners, opened up the region to capital. Sopwith's task was to establish rules for awarding the rights of excavation in the region before entrepreneurs with steam engines and locomotives started digging for the coal lying deeper under the forest.[73] The freeminers rioted in response, most significantly in 1831.

Sopwith made sections, plans, and two models of the Forest of Dean in order to negotiate the process of awarding mining rights.[74] The models were then displayed at the Geological Society of London and the Institution of Civil Engineers before being put on permanent display in the Museum of Economic Geology.[75] The smaller of these models, now at the Oxford University Museum of Natural History, was 30 inches by 30 inches, scaled at five inches to a mile; as in Sopwith's isometrical drawings, the vertical scale was exaggerated three times to demonstrate coal veins more clearly. (Fig. 11) It was divided into 36 squares, each of which represented a square mile, and marked with letters and numerals that were cross-referenced to the Museum's other mineral statistics.[76] The model was designed to hinge open to reveal eight additional sections.[77] Sopwith had such models constructed patiently out of the hundreds of vertical sections collected in situ. Next, these vertical sections were connected into horizontal sections (some guesswork was necessary Sopwith acknowledged), which were then "half-lapped" together to form the skeleton of the model.[78]

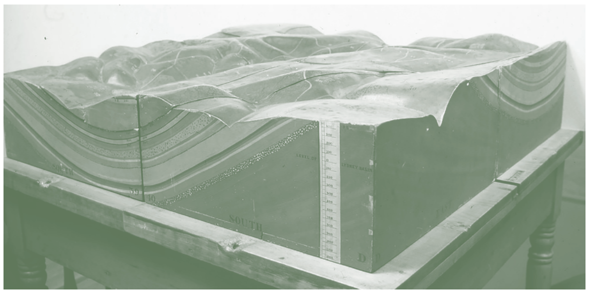

Fig. 11

Making this kind of model might seem labor-intensive and expensive, Sopwith explained, but that “cost was trifling” compared to the benefits, as these representational techniques allowed him to divide up excavation rights between entrepreneurs and freeminers in a relatively peaceful fashion.[79] Even though the free miners did not entirely lose their rights after 1841, most of them ended up having to lease their gales or becoming wage laborers. Still, according to Sopwith, his scientific approach prevented further rioting in the region precisely because it was guided less by old custom and more “by a discretionary power based upon reasonable data.”[80] Plans had been crucial tools as commons and wastelands were enclosed through Parliamentary acts and consolidated in the hands of aristocracy since the seventeenth century. [81] Sections now served a similar role for the *vertical* enclosure of subterranean resources in the name of growing national wealth. In other words, even when a known resource from a well-established location was in question, mineral statistics created abundance out of scarcity and, more importantly, because they did so with the “discretionary power” of data, there was less resistance on the ground.

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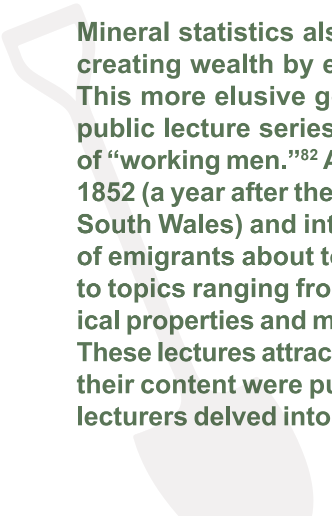
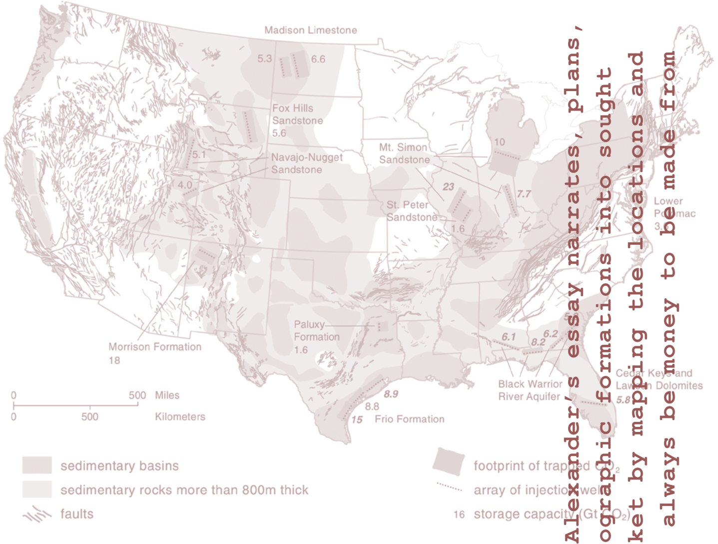


Mineral statistics also delivered the alchemical promise of creating wealth by excavating another resource: humans. This more elusive goal can be discerned in the Museum’s public lecture series, designed for the presumed audience of “working men.”[82] A series on the topic of gold, launched in 1852 (a year after the discovery of the precious metal in New South Wales) and intended primarily for “for the instruction of emigrants about to proceed to Australia, ” was dedicated to topics ranging from the geology of Australia to the chemical properties and metallurgical treatment of gold.[83] (Fig. 12) These lectures attracted so much attention that summaries of their content were published in the popular press. While the lecturers delved into a great deal of detail about geology and the colony, their advice was not limited to discovering gold in Australia. J. B. Jukes, director of the Geological Survey of Ireland, for example, concluded his lecture on the geology of Australia by reminding his audience that gold-digging was back-breaking work that did not always prove lucrative. Still, he hoped that he had offered the audience more than know-how about gold. He told them that the more important lesson to be learned was an attitude that he claimed was embodied in the very act of digging:

MUSEUM OF PRACTICAL GEOLOGY.—DR. LYON PLAYFAIR’S LECTURE.—(SEE NEXT PAGE.)

Fig. 12



> You go out *to dig for gold*, do not *be ashamed to dig for anything else…* Recollect that it is the *avowed object of your voyage*, and the only thing you have to trust to. If you fail to dig up gold, there are lands to be ploughed, sheep to be herded and sheared, cattle to be tended, corn to be sown and reaped: every one of these fully as honourable occupations as digging for gold. Go, then, with a bold and resolute heart, determined to get your own living by the strength of your own arms and the sweat of your own brows; and be assured, that industry and perseverance lead to fortune in Australia with fewer impediments and uncertainties in the way than in any part of the world.[84]

Digging here was not simply digging for a precious metal; it was presented as the alchemical technique that made all other colonial enterprises possible with the promise of infinite improvement—from farming to mining, from construction to husbandry. In the sixth and final lecture of the series on gold in 1852, Robert Hunt reassured the audience: fears that the influx of Australian gold into European markets would diminish the value of the metal, he said, were unfounded.[85] Hunt proved his point in a peculiar manner: by making calculations about how much the fortunes of historical figures would be worth in present-day money. By Hunt’s reckoning, King Croesus had gifted 3 million sterling pounds to the temple in Delphi and Pericles had 1.162 million sterling pounds available in the treasury for the defense of Athens, and so on.[86] This was all to prove that gold retained its value as a metallic currency even during dramatic historical upheavals, a conclusion that might have been challenged after the introduction of paper money, but

`wells, are terrific repositories for CO2 injections. As in the earlier extractive moment that Çelik Alexander’s essay narrates, plans, sections and statistical databases will again be essential to turning these previously valueless geographic formations into sought after resources. Researchers are already hard at work taming the uncertainties of this emerging market by mapping the locations and relative capacities of the world’s aquifers. With the right database in hand, it seems, there will always be money to be made from digging holes in the ground.`

nonetheless served the purpose of calming the nerves of a public encouraged to seek opportunities in the colonies. Hunt, like Jukes, added: colonialists might find no modern El Dorado, but “legitimate occupations of the artisan and the quiet pursuits of the agriculturalist” were, in fact, more reliable sources of wealth.[87]

A few years later when the geologist Warrington Smyth delivered another series of lectures in the Museum on the topic of gold, he advised the audience to economize their most important resource: their bodies, the source of their labor.[88] It was essential, he told them, to know how to calculate one’s own worth. Since the miner was the best judge of the value of his own work, Smyth advised that workers sell their labor through a Dutch auction, a descending price auction which, he argued, would benefit the seller.[89] This was not merely a Lockean possessive individualism that presumed sensations and labor to be one’s first property. Rather at this crucial moment at the beginning of a new phase of capitalism, Smyth and fellow geologists were speaking to a subject imagined as a *homo economicus*, an entrepreneurial subject endowed with intrinsic calculative abilities to seek and achieve future wealth using the environment and the self as resources.[90]

These visitors from the working classes might not necessarily follow the Museum’s trails of information in pursuit of a particular business opportunity, but, as one observer argued, if a “working man” had the intellectual capacity, the dramatic displays of the Museum might “waken up to make him a Watts, a Stephenson, or a Miller”—that is, the building itself could turn him into an enterprising inventor.[91] Whether an entrepreneur hoping to make the right decision when investing in a mining enterprise or a “working man” whose calculation was simply to make a living by selling his labor power, this subject should instinctively infer a favorable ratio between the input of resources and the output of profit. (Fig. 12) A good *homo economicus* knew that anything could be turned into a resource by cleverly operationalizing one’s means toward the future—whether capital or labor did not matter. With the perpetual promise of yet another new resource on the horizon, those limits that worried Malthusians could be avoided and the alchemical promise of political economy be realized.

This meant that a resource was not a fixed asset like coal, which, having accumulated for centuries, had value in the present but rather a function, the ability of the mind to project into the future. Equipped with the power of databases, the human subject, now imagined as a *homo economicus*, could always invent the next resource regardless of any impending limits. Viewing this history in retrospect, of course, it is hard not to be struck by the perverseness of this mid-nineteenth-century calculation. Infinity is a chimera, as we now know, especially when resources such as coal and oil are concerned.[92] And yet the alchemical presumptions of political economy are as alive today as they were in the nineteenth century. That includes the assumption that information technologies can change even the most mundane thing into an economic resource with endless future potential.

Image captions

Fig. 1: Arthur Fitzwilliam Tait, “Olive Mount Cutting.” *From Views on the London & North Western Railway, Northern Division. Bradshaw & Blacklock Printers*, 1848. Science Museum Group Collection Online, 1985-1901/9.

Fig. 2: Geological map of the eastern part of Jamaica as surveyed by H. T. De la Beche in 1824. From H. T. De la Beche, *Remarks on the Geology of Jamaica* (London, 1826).

Fig. 3: Horizontal sections showing faults. From H. T. De la Beche, *Sections and Views, Illustrative of Geological Phaenomena* (London: Treuttel & Würtz, 1830).

Fig. 4: Comparative Vertical Sections of the Purbeck Strata of Dorsetshire. Nos 1, 2 & 3 by H.W. Bristow. No. 4 by the Revd. Osmond Fisher & H.W. Bristow. No. 1. Durlston Bay. No. 2. Worbarrow Bay. No. 3. Mewps Bay. No. 4. Ridgway Hill, railway cutting (1857). BGS Maps Portal, Geological Survey of England and Wales, Vertical sections (Sheet 22). Image courtesy of the British Geological Society.

Fig. 5: Piccadily Street façade of the Museum of Economic Geology (later Museum of Practical Geology), London, designed by James Pennethorne for the Office of Works completed in 1851. From *The Illustrated London News* (April 8, 1848).

Fig. 6: Longitudinal section of the Museum of Economic Geology. From the London Metropolitan Archives, MBO/PLANS/151. Image courtesy of the London Metropolitan Archives.

Fig. 7a, b, c, d: Plans of the Museum of Economic Geology. From the London Metropolitan Archives, MBO/PLANS/150, 153, 155, 156. Image courtesy of the London Metropolitan Archives.

Fig. 8: Interior view of the Museum of Economic Geology. Museum of Economic Geology photograph.BGS image P640481. BGS GeoScenic. Image courtesy of the British Geological Society.

Fig. 9: Isometrical sections of strata at Nentsberry in the Manor of Alston Moor. From Thomas Sopwith, *Treatise on Isometrical Drawing* (London: John Weale, 1838).

Fig. 10: Interior view of the south side of the primary exhibition galleries. BGS image P661605. A watercolour of the Museum of Practical Geology, Jermyn Street, London. Painted by J.P. Emslie in 1875. Image courtesy of the British Geological Society.

Fig. 11: Smaller model of the Forest of Dean by Thomas Sopwith, circa 1837. From the Oxford Natural History Museum.

Fig. 12: Dr. Lyon Playfair’s lecture at the Museum of Economic Geology. *From The Illustrated London News* (February 21, 1852).

1 For a good summary of the literature, see Kathryn Furlong and Amma S. Norman, “Resources,” in *The Wiley Blackwell Companion to Political Geography*, ed. John Agnew, Virginie Mamadouh, Anna J. Secor, and Joanne Sharp (Chichester, UK and Hoboken, NJ: John Wiley & Sons, 2015), 424-437. Also see the three-part essay and especially Gavin Bridge, “Resource Geographies II: The Resource-State Nexus,” *Progress in Human Geography* 38.1 (2014): 118-130.

2 David Ricardo, *On The Principles of Political Economy and Taxation*, ed. Piero Sraffa (Cambridge: Cambridge University Press, [1817] 1986), 69.

3 John Stuart Mill, *Principles of Political Economy: With Some of Their Applications to Social Philosophy*, v. 1 (New York: Appleton, [1848] 1923), 242. On British coal, see E. A. Wrigley, *Energy and the English Industrial Revolution* (Cambridge: Cambridge University Press, 2010).

4 Erich Zimmermann, *World Resources and Industries* (New York: Harper, 1951), 15.

5 See, for example, Steven Topik, Carlos Marichal, and Zephyr Frank, eds., *From Silver to Cocaine: Latin American Commodity Chains and the Building of the World Economy, 1500–2000* (Durham: Duke University Press, 2006).

6 Take the case of the presumed scarcity of oil. Labban argues that the problem is not its scarcity but rather its abundance. Mazen Labban, *Space, Oil, and Capital* (New York: Routledge, 2008).

7 David Sepkoski, “Databases,” in *Information: A Historical Companion*, ed. Ann Blair, Paul Duguid, Anja-Silvia Goeing, and Anthony Grafton (Princeton and Oxford: Princeton University Press, 2021), 392. Databases are distinct from other collections of information in that they are “amenable to some degree of recombination, sorting, and random access.” David Graeber and David Wengrow have argued that this “complexity” argument is deeply ideological. The assumption that modern societies’ complexity can only be managed through hierarchical arrangements such as modern bureaucracies naturalizes the nation-state as the ultimate horizon of human development. David Graeber and David Wengrow, *The Dawn of Everything A New History of Humanity* (London: Allen Lane, 2021).

8 Thomas Sopwith, *On the Preservation of Railway Sections and of Accounts of Borings, Sinkings, &c. in Elucidation of the Measures Recently Taken by the British Association: A Paper Read Before the Geological and Polytechnic Society of the West-Riding of Yorkshire, September 23, 1841* (Leeds: Edward Baines and Sons, 1842), 3. The chart had been conceived in 1840 by a Committee appointed by the learned society British Association at Glasgow. Sopwith wrote elsewhere that the chart had been devised by Professor John Phillips of York, known in the history of geology for having been among the first to theorize the geologic time scale.

9 Rolf Peter Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: White Horse Press, 2001), 124-127.

10 Sopwith, *On the Preservation of Railway Sections*, 4.

11 For a good summary of the primary developments in geology in the nineteenth century, see Mott T. Greene, “Geology,” in *The Modern Biological and Earth Sciences*, ed. Peter J. Bowler and John V. Pickstone (Cambridge: Cambridge University Press), 165-184. For an elaboration of the same themes, see Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World* (Ithaca, NY: Cornell University Press, 1982).

12 On Jamaica, see H. T. De la Beche, *Notes on the Present Condition of the Negroes in Jamaica (London: T. Cadell, 1925) and Remarks on the Geology of Jamaica* (London, 1826). The latter includes a geological plan of eastern portion of the island as well as sections. Also see Lawrence J. Chubb, “Sir Henry Thomas De la Beche,” in *Jamaican Rock Stars, 1823–1971: The Geologists Who Explored Jamaica*, S. K. Donovan, ed. (Boulder, CO: Geological Society of America, 2010), 9–28.

13 De la Beche, *How to Observe. Geology* (London: Charles Knight, 1835).

14 Both kinds of sections can be found today in the collections of the British Geological Survey. See: https://www.bgs.ac.uk/information-hub/bgs-maps-portal/.

15 Sopwith, *On the Preservation of Railway Sections*, 8.

16 Salim Rashid, “Political Economy and Geology in the Early Nineteenth Century: Similarities and Contrasts,” *History of Political Economy* 13 (1981): 726-744.

17 David G. Bate, “Sir Henry Thomas De la Beche and the Founding of the British Geological Survey,” *Mercian Geologist* 17 no.3 (2010), 160-61.

18 Sopwith, *The National Importance of Preserving Mining Records*, 22.

19 Adam Smith, *Wealth of Nations: An Inquiry into the Nature and Causes of the Wealth of Nations* (Ware: Wordsworth Editions, [1776] 2012), 106; Ralph S. G. Stokes, *Mines and Minerals of the British Empire* (London: E. Arnold, 1908), 48; and Thomas Barlett, *A Treatise on British Mining* (London: Effingham Wilson, 1850), 83.

20 Sopwith, *The National Importance of Preserving Mining Records*, 22 and 15.

21 Sopwith, *The National Importance of Preserving Mining Records (London: J. Weale, 1844)*, 49.

22 The horizontal and vertical sections in the archives of the British Geological Section from this period are much larger, typically thirty-nine inches by twenty-seven inches. Sections of the cabinets in which the sections were stored are also much deeper than the dimensions that Sopwith discusses. See “Plan of Upper Story and Gallery,” GSM 1/210, British Geological Survey Archives.

23 The building was one of many designed and constructed to house the growing British bureaucracy in the course of the nineteenth century. The Office of Works, which was brought under the Office of Woods and Forests in 1832, played a major role in this endeavor. Between 1815 and 1832, Office of Works retained a leading architect called an “attached architect”; after that the determination of the leading architect would be left to the market. Pennethorne worked for the Office of Works informally between 1848 and 1856 and then again between 1859 and 1870 when he had a more defined, salaried position. For histories of the Office of Works, see M. H. Port, *Imperial London: Civil Government Building in London 1850-1915* (New Haven and London: Yale University Press, 1995). On Pennethorne, see Geoffrey Tyack, *Sir James Pennethorne and the Making of Victorian London* (Cambridge: Cambridge University Press, 1992).

24 Over time these programs would not fit the small building and space need to be rented out in neighboring buildings. “The Museum of Practical Geology,” *Nature* (July 28, 1934), 130.

25 For calls to open one in Glasgow, for example, see “Museum of Practical Geology,” *The Glasgow Herald* (September 2, 1853), 5. For De la Beche’s appeal to the East India Company in 1841, see De la Beche, “Memorandum respecting a Proposed Museum of Economic Geology in India,” *Gleanings in Science* 124.40 (1 April 1842): 333-339.

26 “A Visit to the Museum of Practical Geology,” *Fraser’s Magazine for Town and Country 43* (June 1851), 628. Emphasis mine.

27 “A Visit to the Museum of Practical Geology,” 628.

28 Carla Yanni, *Nature’s Museums: Victorian Science and the Architecture of Display* (New York: Princeton University Press, 2005), 24.

29 For histories of commercial museums, see Dave Muddiman, “From Display to Data: The Commercial Museum and the Beginnings of Business Information, 1870-1914,” in *Information Beyond Borders: International Cultural and Intellectual Exchange in the Belle Époque*, ed. W. Boyd Rayward (Surrey, England and Burlington, VT: Ashgate, 2014), 259-282, here 260 and Steven Conn, “The Philadelphia Commercial Museum: A Museum to Conquer the World,” in *Museums and American Intellectual Life*, 1876-1926 (Chicago and London: University of Chicago Press, 1998), 115-150. According to the Secretary of the London Chamber of Commerce, Kenric B. Murray, in 1887 there were commercial museums beyond Europe in Argentina, Brazil, and Peru. Kenric B. Murray, *Commercial Geography, Considered Especially in Its Relation to New Markets and Fields of Production for British Trade* (London: T. C. Jack, 1887), 12-15. A commercial museum opened in Calcutta in the early twentieth century.

30 For comparison, see W. Colgrove Betts, “The Philadelphia Commercial Museum,” *Journal of Political Economy* 8. no. 2 (March 1900): 222-233. It seems to be the case, for example, that sections were stored in the Mining Records Office horizontally rather than vertically on their edges. See “Plan of Upper Story and Gallery,” GSM 1/210, British Geological Survey Archives.

31 “Museum of Practical Geology,” *The Times* (May 27, 1858), 12.

32 Sopwith, *Account of the Museum of Economic Geology and Mining Records Office* (London: John Murray, 1843), 1.

33 One need only glance at the handbooks and guides published throughout the institution’s history: Robert Hunt, *A Descriptive Guide to the Museum of Practical Geology, with Notices of the Geological Survey of the United Kingdom, the School of Mines, and the Mining Record Office* (London: G. E. Eyre and W. Spottiswoode for H. M. Stationery Office, 1867); *A Handbook to the Museum of Practical Geology* (London: H. M. Stationery, 1896); *A Short Guide to the Museum of Practical Geology* (London: H. M. Stationery, 1914).

34 For discussions of the architecture of the Museum, see Tyack, *Sir James Pennethorne*, 179-191; Sophie Forgan, “Bricks and Bones: Architecture and Science in Victorian Britain,” in *The Architecture of Science*, eds. Peter Galison and Emily Thompson (Cambridge, MA: MIT Press, 1999) 181-208; Sophie Forgan, “Building the Museum: Knowledge, Conflict, and the Power of Place,” *Isis* 96, no. 4 (December 2005): 572-585; and Yanni, *Nature’s Museums*, 51-61.

35 *A Short Guide to the Museum of Practical Geology*, 19.

36 Bernard H. Becker, *Scientific London* (London: Henry S. King & Co, 1874), 251.

37 Sophie Forgan, “Bricks and Bones,” 197.

38 The terms were coined by William Whewell in 1832 in his review of the second volume of Charles Lyell’s *Principles of Geology*. Whewell saw Lyell as representing uniformitarianism against the mainstream catastrophic view of geology, according to which changes on earth’s surface were due to catastrophic events such as floods, volcanic eruptions, etc. Darwin’s theory of evolution was influenced by Lyell’s views. William Whewell, “Lyell’s Geology, vol. 2—Changes in the Organic World Now in Progress,” *Quarterly Review* 47 (1832), 103-132.

39 Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago; University of Chicago Press, 1988), 63-92. Other seminal works on the development of geology in this context are James A. Secord, *Controversy in Victorian Geology: The Cambrian-Silurian Dispute* (Princeton, N.J.: Princeton University Press, 1986); Martin J. S. Rudwick, *Worlds before Adam: The Reconstruction of Geohistory in the Age of Reform* (Chicago: University of Chicago Press, 2008); David R. Oldroyd, T*he Highlands Controversy: Constructing Geological Knowledge through Fieldwork in Nineteenth-Century Britain* (Chicago: University of Chicago Press, 1990). Murchison’s side won when he discovered evidence for his argument in Russia.

40 De la Beche, *Sections and Views Illustrative of Geological Phenomena* (London: Treutel & Würtz, 1830), 4 and Sopwith, *On the Preservation of Railway Sections*, 11

41 Sopwith, *Practical Observations on the Easy and Rapid Delineation of Plans and Drawings in Isometrical and Other Modes of Projections* (Newcastle: Thomas Sopwith, 1836).

42 Sopwith, *Practical Observations*, 38. He even invented what he called “isometrical drawing paper” to this end, a standardized graph paper representing “17.32040 inches by 14 inches, divided into isometrical squares of half an inch, which are printed in faint lines so as to guide the draughtsman without disfiguring the drawing.” Sopwith, *Practical Observations*, 28. He also gave instructions (strings of numbers) for the drawing of particular shapes on his isometrical drawing paper.

43 “Museum of Economic Geology,” *Chambers’s Edinburgh Journal* (Sep 9, 1843), 267.

44 “A Visit to the Museum of Practical Geology,” 622.

45 See, for example, Henry G. Clarke, *The British Museum: Its Antiquities and Natural History. A Hand-Book Guide for Visitors* (London: H. G. Clarke, 1850) and J. J. Kaup, *Catalogue of Apodal Fish in the Collection of the British Museum* (London: Order of the Trustees of the British Museum, 1856). One strategy was to connect these guides and catalogues to the galleries through marginal annotations that referenced particular display cases. According to one historian, it was not until the 1890s that every specimen received a label in the Oxford University Museum. Małgosia B. Nowak-Kemp, "150 Years of Changing Attitudes Towards Zoological Collections in a University Museum: The Case of the Thomas Bell Tortoise Collection in the Oxford University Museum," *Archives of Natural History* 36, no. 2 (2009), 309.

46 M. Deleuze, *Histoire et description du muséum royal d'histoire naturelle*, vol. 1 (Paris: M. A Boyer, Au Jardin du Roi, 1823), 19 and vol. 2, 436.

47 See several editions starting with G. F. Waagen, *Verzeichniss Gemälde-Sammlung des königlichen Museums zu Berlin* (Berlin: Königliche Akademie der Wissenschaften, 1830). For an index to Waagen's index, see Algernoon Graves, *Summary of an Index to Waagen* (London: A. Graves, 1912).

48 On the transition from catalogues in bound format to index cards, see Zeynep Çelik Alexander, "Stacks, Shelves, and the Law: Restructuring the Library of Congress," *Grey Room* 82 (Winter 2021), 6-29.

49 The list of periodical publications associated with the Museum includes: *Annual Reports of the Geological Survey and Museum, Memoirs of the Geological Survey* (published under different names when dedicated to a particular district, mineral, coalfield, or water supply as well as paleontology and stratigraphical monographs), and *Mineral Statistics of the United Kingdom and Great Britain, Records of the School of Mines* and *Science Applied to the Arts*, among others.

50 Examples are: *A Catalogue of the Contents of the Mining Record Office in the Museum of Practical Geology Consisting of Plans and Sections of Mines and Collieries, Statistical and Other Documents* (London: Her Majesty's Stationery Office, 1858) and *Catalogue of the Maps, Horizontal and Vertical Sections and Other Publications of the Geological Survey* (London: Her Majesty's Stationery Office, 1863).

51 For an example, see G. F. Scott Elliot and Catharine A. Raisin, *Sierra Leone: Reports on Botany and Geology* (London: Her Majesty's Stationery Office, 1893).

52 De la Beche, "Inaugural Discourse" in *Records of the School of Mines and of Science Applied to the Arts*, vol. 1 (London: Her Majesty's Stationery Office, 1852), 11.

53 Robert Hunt, *British Mining: A Treatise on the History, Discovery, Practical Development and Future Prospects of Metalliferous Mines in the United Kingdom* (London: C. Lockwood, 1884), 251-252.

54 According to Wrigley, coal production in England, Wales, and Scotland was 5,230 thousand tons in the 1750s, 15,045 thousand tons in the 1800s, and 74,050 thousand tons in the 1850s. Wrigley, *Energy and the English Industrial Revolution*, 37.

55 Aashish Velkar, "Caveat Emptor: Abolishing Public Measurements, Standardizing Quantities, and Enhancing Market Transparency in the London Coal Trade c. 1830," *Enterprise & Society* 9, no.2 (2008): 281-313.

56 De la Beche as cited in "Museum of Practical Geology," *The Morning Post* (May 13, 1851), 6.

57 De la Beche as cited in "Coals in the New World," *Southampton Herald* (17 February 1849), 6. Coal was not the only material that the Museum's laboratories tested. Of many similar reports, see , for example, Henry Piddington, "Examination and Analyses of Dr. Campbell's Specimens of Copper Ores Obtained in the Neighborhood of Darjeeling," *Gleanings in Science* 2 (May 1854), 477.

58 "Museum of Economic Geology," *Chambers's Edinburgh Journal* (Sep. 9, 1843), 266

59 Hunt, *A Descriptive Guide to the Museum of Practical Geology*, 124.

60 This is sometimes called "constructive imperialism." These were imperialists who advocated tariff reform to realize a stronger, unified British empire. Peter Cain, "The Economic Theory of Constructive Imperialism," in *British Politics and the Spirit of the Age: Political Concepts in Action*, ed. Cornelia Navari (Keele: Keele University Press, 1996),

61 For an account of how the Hartlib Circle borrowed the idea of infinite improvement from alchemy, see Carl Wennerlind, "The Alchemical Foundations of Credit," in *Casualties of Credit: The English Financial Revolution, 1620-1720* (Cambridge, MA: Harvard University Press, 2011), 44-79.

62 Wennerlind, *Casualties of Credit*, 44-79 .

63 Carl Wennerlind, "Credit-Money as the Philosopher's Stone: Alchemy and the Coinage Problem in Seventeenth-Century England," *History of Political Economy* 35 (2003): 234-261.

64 The concept was introduced by the neo-Malthusian Georg Borgström in *The Hungry Planet: The Modern World at the Edge of Famine* (New York: Macmillan, 1965) and was later taken up by Eric L. Jones in *The European Miracle: Environments, Economies, and Geopolitics in the History of Europe and Asia* (Cambridge and New York: Cambridge University Press, 2003).

65 Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton: Princeton University Press, [2000] 2021), 315.

66 T. R. Malthus, *An Essay on the Principle of Population; or, A View of Its Past and Present Effects on Human Happiness* (London: J. Johnson, [1798] 1803) which went through various editions and remains influential to this day. Contrast this with Ricardo who speculated on the "elasticity of steam" in Ricardo, *On the Principles of Political Economy, and Taxation*, 53, 63, 65.

67 According to Sieferle, British anxieties about the exhaustion of coal reserves can be traced back to the sixteenth century, when the English Parliament considered an export ban on coal. Sieferle, *The Subterranean Forest*, 184-191. Wrigley discusses how the energy regime of fossil fuels, on the one hand, allowed breaking out of organic energy regimes and, on the other, triggered anxieties about the finiteness of subterranean riches in Wrigley, *Energy and the English Industrial Revolution.* Among the first to apply the Malthusian logic to coal was Chalmers who defended a self-sufficient nation. Thomas Chalmers, *An Enquiry into the Extent and Stability of Natural Resources* (Edinburgh: John Moir, 1808). The best-known nineteenth-century text on coal exhaustion is Jevons's, *The Coal Question*, which went through several editions. See Nuno Luis Madureira, "The Anxiety of Abundance: William Stanley Jevons and Coal Scarcity in the Nineteenth Century," *Environment and History* 18, no. 3 (August 2012): 395-421. But as historians have demonstrated, the question preoccupied geologists, mine owners, and politicians alike starting in the 1820s. Fredrik Albritton Jonsson, "The Coal Question Before Jevons," *The Historical Journal* 63, no. 1 (2020): 107-126.

68 William Buckland, *Geology and Mineralogy as Exhibiting the Power, Wisdom, and Goodness of God*, vol. 1 (London: Bell & Daldy, [1836] 1869], 448.

69 Coal did not only stretch land's limits, according to some; it literally multiplied its surface area. In an analysis of the "economy of the coal-field," the Scottish mineralogist J. F. W. Johnston argued that coal made Britain doubly rich. "Our minerals are stored beneath," he reasoned, "while agriculture is still rewarded for her surface toil." James F. W. Johnston, *The Economy of a Coal-Field* (Durham: Andrews, 1838), 9.

70 Hugh Taylor in *The Evidence Taken Before the Select Committee of the House of Lords*, 48. Taylor's calculation had important immediate implications: there was no urgency to changing the existing system of measurement, on which much waste was blamed, and coal exports did not need to be restricted.

71 Adam Sedgwick in *Report of the Select Committee on the State of the Coal Trade*, 234-237.

72 For a history of the Forest of Dean, see H. G. Nicholls, *The Forest of Dean: An Historical and Descriptive Account, Derived from Personal Observation, and Other Sources, Public, Private, Legendary, and Local* (London: John Murray, 1858). Also see Di Palma, "Forest," in *Wasteland: A History (New Haven: Yale University Press, 2014)*, 177-229.

73 Sopwith started working in the Forest of Dean at the end of 1833 and beginning of 1834. Benjamin Ward Richardson, *Thomas Sopwith: With Excerpts from His Diary of Fifty-Seven Years* (London: Longmans, Green, 1891), 95-104. He wrote the report on behalf of the commission although he was the commissioner on behalf of the Crown. The miners's interests were represented by John Probyn and the mine owners' by the entrepreneur John Buddle. Sopwith, *The Award of the Dean Forest Mining Commissioners under the Act of 1 and 2 Victoria, cap. 43 as to the Coal and Iron Mines in her Majesty's Forest of Dean and the Rules and Regulations* (London: John Weale, 1841), 7-8.

74 Richardson, *Thomas Sopwith*, 106.

75 Fredrik Albritton Jonsson, "Abundance and Scarcity in Geological Time, 1784-1844," in *Nature, Action, and the Future: Political Thought and the Environment*, ed. Katrina Forrester and Sophie Smith (Cambridge and New York: Cambridge University Press, 2018), 70-71.

76 Sopwith, *Account of the Museum of Economic Geology*, 69-70.

77 See the description in Turner and Dearman, "Thomas Sopwith's Large Geological Models," *Proceedings of the Yorkshire Geological Society*, 14.

78 "Mr. Sopwith's Model of the Forest of Dean," *Proceedings of the Geological and Polytechnic Society of the West-Riding of Yorkshire* (June 4, 1840), 29.

79 "Mr. Sopwith's Model of the Forest of Dean," 30 and Sopwith, *The Award of the Dean Forest Mining Commissioners*, 29.

80 Sopwith, *The Award of the Dean Forest Mining Commissioners*, 25. Also see Ian Wright, *The Life and Times of Warren James: Free Miner from the Forest of Dean* (Bristol: Bristol Radical History Group, 2008).

81 On the relationship between enclosure and map making, see Roger J. P. Kain and Elizabeth Baigent, *The Cadastral Map in the Service of the State: A History of Property Mapping* (Chicago and London: University of Chicago Press, 1992), 236-254.

82 "Museum of Practical Geology," *The Times* (May 27, 1858), 12. From what I could gather, the first lecture series took place in 1852 and the second in 1859. For reports of these, see "Museum of Practical Geology," *The Morning Post* (July 1, 1852), 5; "Museum of Practical Geology. Lectures on the Gold of Australia," *The Morning Chronicle* (July 1, 1852), 3; "Museum of Practical Geology," *The Morning Chronicle* (July 10, 1852), 7; "Museum of Economic Geology," *The Morning Post* (January 26, 1859), 3; and "Museum of Economic Geology," *The Morning Post* (February 9, 1859), 3.

83 These lectures were published as J. B. Jukes et al., *Lectures on Gold for the Instruction of Emigrants About to Proceed to Australia* (London: David Bogue, 1853). Because more permanent settling with families was the goal here, one can assume that women were encouraged to attend.

84 J. B. Jukes, "The Geology of Australia," J. B. Jukes et al., *Lectures on Gold*, 37. Emphasis in the original.

85 Robert Hunt, "The History and Statistics of Gold," in J. B. Jukes et al., *Lectures on Gold*, 170. Hunt's lecture was reported in "Museum of Practical Geology," *The Morning Chronicle* (July 10, 1852), 7.

86 Hunt, "The History and Statistics of Gold," 176, 178.

87 Hunt, "The History and Statistics of Gold," 170.

88 Warrington Smyth cited in "Museum of Economic Geology," *The Morning Post* (February 9, 1859), 3.

89 Warrington Smyth cited in "Museum of Economic Geology," *The Morning Post* (January 26, 1859), 3. Also see "Museum of Economic Geology," *The Morning Post* (Feb. 3, 1859), 3.

90 When British economists started using the term homo economicus in the 1880s, they turned to a passage from an essay published by the philosopher John Stuart Mill in 1836. John Stuart Mill, "On the Definition of Political Economy; and on the Method of Philosophical Investigation into that Science," *London and Westminster Review* (October 1836), 12-13. Although Mill never used the term and found the assumption that human individuals were endowed with intrinsic calculative abilities to seek and achieve wealth absurd, he nonetheless subscribed to such an idea of human nature in an attempt to save political economy. On this, see Charles H. Hinnant, "The Invention of homo oeconomicus: A Reading of John Stuart Mill's

‘On the Definition of Political Economy,’” *Prose Studies* 21, no. 3 (December 1998): 51-68.

91 Edward Forbes, “On the Educational Uses of Museums,” *American Journal of Sciences and Arts* 54 (Nov. 1854), 345.

92 Take one contemporary calculation: 89 metric tons of ancient plant matter were required to produce 1 gallon of gas or, put differently, fossil deposits from the last 500 million years have been providing cheap energy for humans for only the past 250 years. Jeffrey S. Dukes, “Burning Buried Sunshine: Human Consumption of Ancient Solar Energy,” *Climactic Change* 61 (2003), 38, 40.

1 Gökçe Günel, "What Is Carbon Dioxide? When Is Carbon Dioxide?” *Political and Legal Anthropology Review*. 39, iss. 1 (May 2016).

2 Michael L. Szulczewski et al., "Lifetime of carbon capture and storage as a climate-change mitigation technology,” *Proceedings of the National Academy of Science of the United States of America* vol. 109, no. 14 (March 2012).