GEOLOGISTS AND THE BRITISH RAJ, 1870-1910

by

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ABSTRACT

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The Geological Survey of India (GSI) was a government institution that was created to map the geography and mineral resources of colonial India. British geologists Thomas Oldham and Valentine Ball used the GSI in order to affect policy changes regarding museum ownership, environmental conservation, and railroad construction. All of these policies were intended to impose order on the landscape and streamline the resource extraction process. Their goal was to enrich the British Empire. An Indian geologist named Pramatha Nath Bose, who also worked for the GSI for a time, also worked to enact policy changes regarding education and production. But instead of trying to make the British Empire stronger, he wanted to push it out of India. He left the GSI since he found it too restrictive, and, together with other Indians, restructured geological education at the university level and set up a successful steel manufacturing mill. Both the British geologists and Bose helped lay the economic foundation of India's independence.

The GSI gave geologists power in some situations, but in others it restricted the advancement of the field.

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PUBLIC ABSTRACT

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The British Raj (1858-1947) hired geologists from both India and Great Britain to find valuable resources in India, such as coal. The geologists worked to convince the government to enact policy changes regarding museum ownership, conservation, railway construction, education, and industrialization. But the geologists had different goals based on whether they were Indian or European. The Indian geologists wanted India's independence from Britain, so their education and industrial policy proposals were geared towards making India self-sufficient and globally competitive. The British geologists' goal was to enrich the empire. The British were able to convince the government to accept most of their proposals. However, the Indian geologists were not. They needed to leave the government's employment and recruit local investors before they were able to change the educational system and begin major industrial companies. They helped lay the economic foundation for India's independence.

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CHAPTER 1

INTRODUCTION: ECONOMIC GEOLOGY AND THE BRITISH RAJ

In 1880, Henry B. Medlicott wrote:

> The geologist has an anxious part to play with reference to practical questions. He is instituted more as a concession to what seems but a rising fashion, than from any faith in his knowledge or any understanding of his functions; and thus it happens that he is not consulted when his opinion might be for great service, or, on the other hand, he is called upon to perform what is quite out of his line of business, or twitted for not having done what it would be unwise to attempt unless under special circumstances, and impossible to undertake without special appliances that were not at his disposal. As no one is more aware than himself that the best, if not the only, warrant for his existence is his usefulness, such circumstances are very distressing.[1]

His frustration was understandable. The British Raj had recently replaced the East India Company (EIC) as the government of colonial India in 1858. Their purpose for employing scientists was purely for the economic benefit of the British Empire. In the beginning the Raj did not care about what geologists in India could do to advance the science. Because of its ability to quickly and efficiently bring wealth to the empire, geology swiftly became an essential science in India. No other scientists brought the empire wealth as effectively as geologists, except perhaps botanists. The EIC organized the Geological Survey of India (GSI) in 1851 for the purpose of reporting the mineral resources of India. The Raj expected more from its geologists in India than it did of the

[1] Valentine Ball, *A Manual of the Geology of India, Part III: Economic Geology* (London: Trübner and Co., 1880), v.

geologists in Britain. In addition to surveying India and mapping its mineral resources, they were expected to suggest places to build railways and forts, map the land for military purposes, spy for the British, teach geology at the universities, propose conservation tactics, and explain the economic viability of proposed industry sites. The scientists felt constricted by the unrealistic expectations of the government.

Even though the geologists were subject to the instructions of the Raj, they found ways to use the structure of the survey to change policies, such as museum ownership, conservation efforts, and transportation construction. Though geologists often died soon after reaching India, working for the GSI was an attractive work opportunity for British scientists looking to make a name for themselves. In India, they could make new discoveries and broaden or challenge the theories of the scientists in Britain. They did not have the competition that they would have had in Britain. They were valuable because they were the only link scientists in Britain had to the rest of the empire. Indian geologists did not enjoy the same power, even if they were educated in Britain and were just as or more qualified than the other scientists. They were always treated as inferiors to the British. British geologists did not try to change the entire system of government. However, Indian geologists that wanted India's independence found geology a useful tool as well. The GSI was too restrictive for them to enact meaningful policy changes.

So, the GSI was both an institution that gave geologists power and an institution that stopped the advancement of the field. When it was too restrictive, the geologists had to look outside of it for support. Indian investors, educators, and scientists made a powerful team that was able to change several of the policies that scientists restricted by

the GSI could not. Once they took charge of their own resources and the government benefits, they created some of the most successful systems in the world. Their work provided the economic framework that could support the India's independence.

Soon after the government started the GSI, the geologists began to organize their records and publish them, first in the *Memoirs of the Geological Survey of India* in 1859, and later in the *Records of the Geological Survey of India*, started in 1868. This thesis uses both to determine what policies the geologists proposed. Many of the entries are not just descriptions of minerals in India, but are also proposals, telling the government how profitable each find is based on its location, ease of extraction, and proximity to labor, other minerals, and fuel. Looking at later *Records*, *Memoirs*, and maps help determine whether these proposed policies were implemented. Other sources that include similar information are society records, reports, and books and essays published individually by geologists.

Historiography

Imperial Science

In 1967 George Basalla introduced a diffusionist model of modern science. He defined modern science as the type of science developed during the European Enlightenment, and explained how it spread throughout empires. The model had three phases, 1. nonscientific (read: not Western science), 2. colonial science, and 3. the struggle to achieve independence. In the nonscientific stage, European (or North

American) scientists surveyed the "unscientific" country and reported their findings back to Europe.

At this stage, Basalla said, "only nations with a modern scientific culture can fully appreciate, evaluate, and utilize [phase 1 science]."[2] Colonial science, the next stage, was still heavily dependent on European scientific institutions. Colonial scientists could be either European or indigenous; all that mattered was that they had been trained in European institutions. Often, the education systems and societies in the colonized state were inadequate, and the state lacked a scientific culture. Nevertheless, colonial science had the resources to "challenge or surpass the work of European savants…but its ultimate strength lies in the growing number of practicing scientists whose education and work are supported by an external scientific tradition."[3] In the third stage, scientists in the colonized states tried to become self-reliant and independent of European institutions. Often nationalism was a motivation to move from phase 2 to phase 3.[4] In his conclusion, Basalla asked his readers to consider the importance of local social setting, saying that we cannot understand science as just a successive development of ideas, and that external factors are essential to understanding science, and especially imperial science.[5] Deepak Kumar criticized this overly simplified model writing that Basalla "assumes uniformity and homogeneity where none exist" and claiming that he failed to show how science actually diffuses among the indigenous population.[6] However, Basalla did provide a

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[2] George Basalla, "The Spread of Western Science," *Science* 156, no. 3775 (May 1967): 613.
[3] Ibid., 614.
[4] Ibid., 617.
[5] Ibid., 620.
[6] Deepak Kumar, *Science and the Raj, 1857-1905* (Delhi: Oxford University Press, 1995), 2-3.

useful preliminary model about colonial science's dependence on European institutions and also the struggle for independence from these institutions.

Basalla's article was intended to cover all areas of science, but Lewis Pyenson argued that 'exact' sciences, such as astronomy, were untainted by imperialism since, for example, the German government did not perceive them as valuable to colonizing efforts.[7] He thought that these sciences had been the most powerful and enduring of the sciences, far more than any environmental sciences, since they lacked the imperialist taint.[8] Paolo Palladino and Michael Worboys' article critiqued Pyenson's theory. They contended that this argument was fundamentally flawed, and that the history of Western science and imperialism, for many people, was the history of science.[9] Pyenson referred almost exclusively to cultural imperialism without considering the necessary exploitation and domination of the colonized peoples since his narrative was about the role science played in the 'civilizing mission.'[10] Palladino and Worboys point out that Pyenson failed to provide any evidence to prove his claim. They concluded that, not only was imperialism the history of science, but that Pyenson's categories of 'exact' and 'prescriptive' science were meaningless since science was not perfectly objective, and that Pyenson's 'exact' sciences were affected and guided by external influences as well.[11] Pyenson stood by his argument about the divisions between exact and prescriptive science, calling the relativism that Palladino and Worboys used unacceptable for

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[7] Lewis Pyenson, *Cultural Imperialism and Exact Sciences: German Expansion Overseas 1900-1930* (New York: Peter Lang, 1985), 1-2.
[8] Paolo Palladino and Michael Worboys, "Science and Imperialism," *Isis* 84, no. 1 (March 1993): 92, 100.
[9] Ibid., 102.
[10] Ibid., 96, 98.
[11] Ibid., 102.

historians of science.[12] Although Palladino and Worboys are correct that Pyenson does not successfully argue that 'exact' sciences were untainted by imperialism, he did introduce an important idea in the history of imperial science: the relation between the perceived value of science and colonialism. The more valuable a colonizing country sees a science, or how quickly the science will bring wealth, the more likely it is to be funded and influenced by the government.

M. Anis Alam addressed the idea of the perceived value of science and empire. He argued that capitalism and science were inseparably joined. The first reason they were inseparable was that science developed out of the search for and acquisition of wealth. He rejected the idea that science was constructed independent of the search for wealth and that it developed unaffected by imperialism. He argued that science was the second most important social property "to be turned into an adjunct of capital," with labor being the first.[13] Science, he wrote, proved itself to be one of the most effective means for acquiring capital. Scientific discoveries made it possible to "divide the entire globe into captive markets and to capture sources of raw materials for rapidly rising industrial production."[14] Not only was science tied to capitalism, but the invention of some sciences and schools of medicine were developed directly in response to imperialism. The second reason that science and imperialism are inseparable, he argued, was that wealth maintained the elitism of Western science. He used the example of foreign students from third world countries. Instead of returning to their own countries and helping 'improve'

[12] Lewis Pyenson, "Cultural Imperialism and Exact Sciences Revisited," *Isis* 84, no. 1 (March 1993): 107.
[13] M. Anis Alam, "Imperialism and Science," *Social Scientist* 6, no. 5 (December 1977): 7.
[14] Ibid., 8.

(read: westernize) education, science, and medicine, they became frustrated by the lack of funding and returned to first world countries, thereby reinforcing the "elitist, hierarchical and expert science which perpetuates and reproduces the same exploitive system as before."[15]

Sociologists have added to the field of the history of colonial science by fine tuning the theory of science as merely an instrument of capitalism. Instead they argued, similarly to Palladino, Worboys, and Alam, that capitalism and science are inseparable. For example, Evan Schofer rejected the idea that the empire and its interests were the only driving influences behind scientific institutionalization and argued that the theory of science limited historians from considering other possibilities. He posited that there were also cultural, political, and religious reasons that explain how science was institutionalized across the world. He used Protestantism, scientific associations, and statistics to analyze the spread of science.[16] Scientific associations were, he argued, an effective way to diffuse knowledge across the world. Innovation and new knowledge travelled quickly among societies.[17] He wrote that, "industrial capitalism may not create a functional 'need' for science, but rather may provide the resources and social relations required for the institutionalization of science."[18] According to Schofer, the idea that science was restricted to wealthy and industrialized nations was seriously flawed because third world countries, such as India, possess advanced scientific infrastructures.[19] He

[15] Ibid., 9.
[16] Evan Schofer, "The Global Institutionalization of Geological Science, 1800 to 1990," *American Sociological Review* 68, no. 5 (October 2003): 735.
[17] Ibid., 732.
[18] Ibid., 736.
[19] Ibid.

concluded by saying that science, and specifically geology, was institutionalized around the world through a European-centric society of elite science. They were the most successful in Protestant nations. Countries chose to incorporate science because of culture, not just because of instrumentalism.[20]

Although Pyenson and Alam recognize the importance of the monetary and political value an empire places on sciences like botany and geology, their narrow focus causes them to miss the important moral motivations driving and justifying imperialism. Sociologists address these issues in their works. Read together, they provide a more holistic view of the motivations behind colonial science. Basalla's model, though seriously flawed as Kumar points out, provides a useful framework in which to think about colonial science and scientists.

Imperial Science and the Natural World

Environmental historians have contributed greatly to the history of science and the natural world. Several historians have focused on the institutions behind the natural sciences, and the British Empire and the East India Trading Company (EIC) are popular topics. Environmental historians have addressed the importance of the role of environment, refining Basalla's narrow diffusionist model. Instead of showing just the effects of science on the environment, they also show how the environment shaped science. They also show how the EIC's broad contact with the Indian Ocean and Asia led to a change in their thinking and policies that resembled modern environmentalism.[21]

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[20] Ibid., 752.

[21] Vinita Damodaran, Anna Winterbottom, and Alan Lester, eds., *The East India Company and the Natural*

The East India Company and the Natural World addresses how scientific information was disseminated throughout the Empire. This is where the importance of place comes in. Basalla's model mostly focused on how scientists took knowledge directly from Europe and implemented it in almost the exact same way in the colonies. However, recent work by James Beattie recognized how place shaped scientific ideas in something he called "imperial careering." "Rather than viewing such groups [scientists] as having introduced ideas directly from Europe to the colonies…we can see their experiences, their policies and their attitudes having been accumulated through movement from one place to another."[22] And it was not the only reason that science in the colonies looked different. Extensive polycentric networks of correspondence, more complicated than the ones in Britain, also helped shape the nature of colonial science.[23]

Imperialism and the natural world talks about the applied sciences in imperialism as well as the importance of symbolism. Geological surveying was important to the EIC and British Raj for several reasons, including mining, smelting, construction of railroads and steamboat systems, and land evaluation for building material and the feasibility of colonization.[24] They were most interested in results submitted by the geologists rather than how well they conducted their surveys or in the benefit to scientific knowledge.[25] The attitudes of both technical scientists and gentleman scientists were changing too. In

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World (UK: Palgrave Macmillan, 2015), 4, 270.
[22] Alan Lester, "Introduction: New Imperial and Environmental Histories of the Indian Ocean," in Damodaran, Winterbottom, and Lester, 5.
[23] Rohan D'Souza, "Mischievous Rivers and Evil Shoals: The English East India Company and the Colonial Resource Regime," in Damodaran, Winterbottom, and Lester, 130.
[24] Robert A. Stafford, "Annexing the landscapes of the past: British imperial geology in the nineteenth century," in *Imperialism and the natural world* ed. John A. MacKenzie (Manchester: Manchester University Press, 1990): 73.
[25] John M. MacKenzie, introduction to *Imperialism and the Natural World* ed. John A. MacKenzie, 9.

France in 1873, J. L. Havard, the vice-president of the Central Committee of the Chambres syndicales de Paris, "announced [to the members of the Chambres syndicales] that he had found, 'next to the old current of opinion too exclusively scientific, a current of new ideas from young men who rightly judge that science today can no longer neglect its industrial and commercial applicability'."[26] Most agreed and decided to help trade.[27] The symbolism of surveying and cartography was important to the Europeans as well. Maps "symbolized regularity and improvement: they graphically chartered the European conquest of the peripheral wilderness."[28] Early British geologists, both in Britain and in India, felt not only justified but morally obligated to explore and chart unexplored territory, bringing order to a 'primitive' land.[29] Writing specifically about geologists and imperialism in the nineteenth century, James Secord analyzed Roderick Murchison. Murchison served as the president of the Royal Geological Society off and on between 1843 and 1871 and was the director of British Geological Survey, the Royal School of Mines, and the Museum of Practical Geology. He was a dynamic character eagerly invested in spreading the superiority of British science aggressively throughout the world, which made him an especially popular person to study. Most histories of colonial geology focus on him. According to Secord, Murchison used metaphors of militarism and imperialism in his writing to understand the role that science played in imperial rhetoric. Murchison's disappointing career in the army, his naming system, and disagreements

[26] William H. Schneider, "Geographical reform and municipal imperialism in France, 1870-80," in MacKenzie, 101.
[27] Ibid., 105.
[28] Stafford, "Annexing the landscapes," 73-4.
[29] Richard H. Grove, "Colonial conservation, ecological hegemony and popular resistance: towards a global synthesis," in MacKenzie, 18.

with other scientists both in Britain and around the world changed the way he looked at the landscape and framed his arguments.[30]

His unique perspective, as a former military officer, allowed Murchison to discover a previously unnoticed layer in the earth. He hoped that his fame in geology would make up for his lack of fame in the army. Murchison named his newly discovered layer the Silurian layer, after a warlike group of Ancient Britons that resisted the Roman Empire and supposedly had lived where he discovered the layer.[31] He was desperate to keep this name even when historians disagreed about where the Silurians lived. Murchison rewrote history to extend the land of Siluria to keep the designation "Silurian."[32] For Murchison, Secord says, "the Silurian classification, along with the rest of his stratigraphical work, simultaneously brought honor to himself and to Britain."[33] Murchison adamantly supported his naming system, especially against other parts of the world. He wanted to express the superiority of England by making the English names in science standard throughout the world.[34] He was appalled when U. S. geologists began naming geological layers after Native American words:

> This was one of the possibilities that Murchison had feared, for the importation of stratigraphical names from abroad frequently aroused intense opposition, especially in the United States. Geologists on the opposite side of the Atlantic preferred to name indigenous rocks with Indian tribal names rather than Welsh ones, and to use American localities as types in preference to those imported from England.[35]

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[30] James A. Secord, "King of Siluria: Roderick Murchison and the Imperial Theme in Nineteenth-Century British Geology," *Victorian Studies* 25, no. 4 (Summer 1982): 421.
[31] Ibid., 422.
[32] Ibid., 423.
[33] Ibid., 426.
[34] Ibid., 437.
[35] Ibid., 438.

Murchison's opponents were afraid that his personal and national pride had clouded his judgment and was preventing true science and scientific theory. However, as Secord showed, "method and territory were both clearly legitimate weapons in scientific controversy."[36] Murchison became a national hero not only because he discovered important geological features, but also because he was able, through science, to show the world the supremacy of Great Britain.[37]

Writing more about Murchison's role in imperial science, in 1990 Robert A. Stafford discussed how the British used science to justify racism and environmental determinism. He explained that the main scientific societies "shared an ideology which envisioned science as an instrument of economic policy."[38] They hired several scientists to make maps, which symbolized regularity and improvement, and then charted their conquest of perceived wilderness.[39] Stafford attributed the imperialistic rhetoric of geology to Murchison and stated that "geology in this era was as much a territorial as a historical science."[40] According to Stafford, "Murchison's research alone went far toward establishing the paramountcy of British geology, and he considered the mapping of the earth's surface according to Britain's system of stratigraphic nomenclature as a scientific corollary to the nation's imperial and commercial expansion."[41] His idea of empire was feudal in nature. He wanted to acquire territories to both define the greatness of the British Empire and benefit Great Britain.[42] Britain used the earth sciences to justify the

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[36] Ibid., 437.
[37] Ibid., 440.
[38] Stafford, "Annexing the landscapes," 68.
[39] Ibid., 73-4.
[40] Ibid., 76.
[41] Ibid., 77.
[42] Ibid.

takeover. Since the tropical climates of Africa, India, and Australia reminded the British of the ancient earth, they concluded that everything in those areas must be prehistoric.

Stafford wrote, "The study of ancient environment fostered an impression of the colonies as a primitive place inferior to Europe. Such research contributed to theories of race and environmental determinism which shaped the ideology and practice of imperialism."[43]

Early Imperial Geology in India

Despite encouragement from Britain, in India it took a long time for the British geologists to explore and exploit the subcontinent. Andrew Grout examined geology in India under the East India Company. He explained that the EIC was not eager to exploit India's mineral resources, and often resisted the British government's attempts to get them to start using India's wealth.[44] He described several reasons for their reluctance.

The first was ideological. The British argued that mining had degrading effects on the land, the British Empire, and humanity. Instead, "agriculture was reinforced by arguments influenced by the Protestant work ethic, an ethic which stressed the morality of wealth gained as a result of human toil, as in agriculture, rather than wealth simply found, as gold or diamonds were."[45] But Grout argued that this rhetoric was merely a cover up for a more serious problem that the EIC believed mining would cause:

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[43] Ibid., 84.
[44] Andrew Grout, "Geology and India, 1770-1851. A Study in the Methods and Motivations of a Colonial Science" (Ph.D. diss., London University, 1995), 13.
[45] Ibid., 43.

colonization.[46] They did not want to people to come seeking wealth in India and settle down there. And mining would also make the colony more independent from Great Britain, and that was judged "highly impolitic and also contrary to the maxims of our Government."[47] The second reason was that geology in India lacked structure, skill, and organization.[48] Often, geologists would arrive only to be disappointed because of the lack of funding, unclear instructions, the multiplicity of projects, and a lack of organization in the societies, museums, and personnel. Once the geologists began to figure things out, they would usually get sick and die, and the government and company would again have to search for someone with adequate skills who was willing to come to India. The third reason is that scientists in the nineteenth century were heavily dependent on a patronage system. Without people willing to fund geology, there was little geologists could do. They could not get the necessary money to make any substantial progress since most of the money and patronage went to botany and agriculture.[49] Even if a geologist was able to secure funding and travel to India for an appointment, there was no guarantee that they would continue to receive support from back home. Even de la Beche essentially abandoned one of his geologists once he got to India.[50] Grout ends his analysis by stating that ultimately, the EIC had to change its form of state before it would consider taking responsibility for geological surveys. "The operation of the kind of pan-Indian geological survey envisaged by many could only operate successfully within a new state structure-a

[46] Ibid., 51.
[47] Ibid., 52.
[48] Ibid., 107, 125, 130.
[49] Ibid., 167.
[50] Ibid., 240.

pan-Indian bureaucratic state."[51] However, the establishment of the official Geological Survey of India (GSI) was not necessarily a signal of geology's triumph in India.

Later Imperial Geology in India

Kumar is one of the few historians who specifically addressed colonial science under the administration of the British Raj in his book *Science and the Raj, 1857-1905*. Although his book covers most of the scientific activity in India, some parts of his book focus on the objectives and struggles of the GSI. He argued that geology and geography were important to the Raj and EIC both economically and militarily. The EIC found that a knowledge of the layout of India was just as important to the military as having superior firearms.

Kumar argued that "The East India Company (EIC) was quick to realize that the whole physical basis of its governance depended on a geographical, geological and botanical knowledge of the area it conquered."[52] Though the EIC appreciated the importance of the geological surveys, they were reluctant to spend more than absolutely necessary on the surveys. They were interested in minimizing costs but expected maximum benefits from the work of geologists.[53] Generally, geologists were unhappy with how the government handled geology. Perpetually underfunded and short on staff, geologists often were unable to meet the EIC's demands effectively.[54] They also disagreed with the single purpose of economic geology. Both the geologists in India and

[51] Ibid., 258.
[52] Kumar, *Science and the Raj*, 32.
[53] Ibid., 76.
[54] Ibid., 93.

in Great Britain pushed for more freedom to discover things that were not immediately economically useful, but enriched the general knowledge of the natural sciences.[55] This created a rift between state geologists and the government, but geologists had very little power to push for change since the power structure was so top-heavy. The Secretary of State was quick to refuse requests for funding 'ornamental' geological expeditions and slow to grant funding for 'economic' geological expeditions.[56] Both parties had the common interest of enriching the empire; the EIC and Raj wanted to enrich it through mineral wealth and military knowledge, while the geologists wanted to enrich it through scientific knowledge that could not have been acquired in Europe.

The few scholars that have discussed geologists working for the Raj focus on the top heavy model of science. This model predicts that when a government is as controlling as the British Raj was, scientists have very little influence on the government or its policies. They and their science were subject to the government's heavy handed management. The Victorian imperial government was controlling, but not so much that the scientists had no agency. In fact, they were some of the major driving forces behind policy changes and government decisions. They actively campaigned when they believed it would bring them more power. This thesis hopes to answer the question of how much power they had to change policies, and what their motivations to do so were.

[55] Ibid., 108.
[56] Ibid., 109.

Outline

The second chapter looks mainly at the works of Thomas Oldham and Valentine Ball. Oldham was the third director of the British Geological Survey, which the first director, David Hiram Williams, renamed the Geological Survey of India. Williams died within a few months of arriving in India. John McClelland, a medical doctor, took over the survey until another man could be found. He had been part of the Coal Committee, and had been the first to suggest hiring professional geologists to find coal in India. Until the GSI, army surgeons were the men that typically reported on the mineral finds.

Geology had not yet professionalized in India, so the gentleman amateur naturalist tradition was the EIC's main source of mineral information. They liked McClelland's idea of hiring trained geologists to do the surveys since the army surgeons were rarely able to draw up a thorough and accurate report. Often the reports were overly exaggerated as well. They also did not have an accurate map of India. They realized that they could not extract material efficiently or profitably until they could get a systematic, professional survey done of India and a professional map drawn up. So the EIC established the GSI in 1851, for the sole purpose of mapping and reporting on the economically profitable mineral wealth.[57]

After the EIC found Oldham, they allowed McClelland to retire from his supervisory role. Oldham was one of the most qualified officers they could have found. He was an Irish geologist who worked for the ordnance survey of Ireland. In addition to

[57] See Grout, "Geology and India," 210-11; Stafford, "Annexing the landscapes," 71; and Kumar, *Science and the Raj*, 33-34.

surveying, he was a professor of geology and assistant professor of engineering, a curator and assistant secretary to the Geological Society in Dublin, and an assistant secretary to the Institute of Civil Engineers of Ireland, among other notable appointments. In 1851 the EIC offered him a job as Director of the survey, which he accepted.[58] He was one of the most influential and well-known geologists in both India and Britain.

Ball was a less well-known geologist who also worked for the GSI. He was popular with the English, however, because of his book that he published in 1880 entitled *Jungle Life in India: Or, The Journeys and Journals of an Indian Geologist*.[59] In this book he talked about what he encountered while in India. He was also from Ireland (most of the early notable geologists were) and spent most of his time in the central provinces of India. This was unusual, as most of the geologists were assigned to parts of India closer to the coasts. He assembled the *Manual of Geology* in 1880 as well, which was an important collection of all of the work done by geologists up to that time.

Chapter two analyzes what influence these two geologists had on government policies on museums, conservation, railway construction, and industrialization until 1900. For the most part they were very successful. The one area where they failed to make a difference was in industrialization. Neither were able to convince the Raj that creating large scale iron and steel mills would be economically beneficial.

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[58] "Thomas Oldham." British Geological Survey Website. Accessed April 1, 2016. http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/archives/pioneers/pioneers.cfc?method=viewRecord.

[59] Valentine Ball, *Jungle Life in India: or, The Journeys and Journals of an Indian Geologist* (London: Thos. De la Rue and Co., Bunhill Row, 1880).

Chapter three primarily analyses the work of the Indian geologist Pramatha Nath Bose, who was instrumental in changing the education system and policies regarding native industrialization, something the British geologists had not really considered. Bose was a Hindu who traveled to England to get his education. The British government sent him back to India to be a graded officer in the GSI. He was the first one. While there, he worked on the Siwalik fossil deposit, which was incredibly rich with prehistoric fossils and an important find in the intellectual history of paleontology. He also discovered several important mineral deposits, though the government overlooked most of them. After he resigned from the survey and joined the *swadeshi* movement, he attempted to set up some small scale industries, including a soap factory, which failed. He worked with the Tata family to establish the first large scale steel mill in India, which became and currently is one of the most prosperous companies in India.[60]

Each of these geologists' influence may have been anomalous, but their attitudes and beliefs were representative of major trends in India. The British geologists' goal was to enrich the empire. The only interest they had in developing India was in so far as it helped Britain without competing with it. Bose was primarily interested in developing scientific and technological equality with the British. He wanted to use this not to enrich the empire, but to push it out of India. The chapters are divided by not only themes of

[60] Daniel R. Headrick, "Mining and Metallurgy," in *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford University Press, 1988), 259-303; David Arnold, *Science, Technology, and Medicine in Colonial India*. Vol. 3. The New Cambridge History of India (New York: Cambridge University Press, 2000), 139-140; Jogesh Chandra Bagal, *Pramatha Nath Bose* (New Delhi: Lok Sabha, Parliament House, 1955); and Kumar, *Science and the Raj*, 202-216.

policy changes, but also by the goals of the geologists involved. Each goal required a different approach.

CHAPTER II

BRITISH GEOLOGISTS: MUSEUMS, CONSERVATION, TRANSPORTATION, AND INDUSTRY

Each policy that Oldham and Ball proposed was designed to make resource extraction more efficient. They believed the best way to make it efficient was to impose order: on the landscape, on the minerals, on teaching, on records, on the transportation systems, and on industry.

The few policy changes Oldham affected with regard to geology were focused on organizing and educating. The GSI needed something like a center of operations and a way to categorize and save all of the information it gathered. Unless the reports were organized and published, they were unusable. Geologists, or at least geologists' assistants, needed to be trained in the science, but Oldham did not trust the university to do it. They also needed a place to analyze their material. Paleontologists could estimate the value of coal, but only a chemist could analyze the exact content. Conservation and a type of proto-environmentalism were also indirectly important. Part of the job of a geologist was to analyze soil. Most of the goods Britain was trying to extract were agricultural. Geologists would advise where things could be planted and flourish. They also wanted to promote the planting of 'useful' plants, such as trees, which would help fuel their proposed factories.

Ball's proposals were much more closely tied to geology. He was most concerned with the connection between transportation systems and resources. They were dependent

on each other, and his proposed railway route would take advantage of that dependency. His end goal was to start the industrialization of India. Unfortunately, he was using the wrong tactics to convince the government. It was only later that Indian scientists and manufacturers would be able to convince the government to change its policies regarding private mining.

Museums

By 1841, the Asiatic Society of Bengal, one of the most important scientific societies in India, recognized the need for a geology museum. They had a growing collection of geological specimens but nowhere to put them. During the late eighteenth and nineteenth centuries, museums represented control over an area. According to John Mackenzie, museums gathered all of the unknown and mystical and organized and mapped it, getting rid of its elusive qualities and allowing it to be made useful.[61] They represented tools of empire and also provided visual justifications for colonial expansion. Mackenzie wrote, "The museum itself was a machine for measuring the alleged achievements, or lack of them, of mankind. It was also a key 'imperial archive', both three-dimensional and conventional, through specimens, objects and records."[62]

However, museums served more purposes than just mental conquest. They were connecting points between scientists and the public, collections and theories, and

[61] John M. MacKenzie, *Museums and empire: natural history, human cultures and colonial identities* (Manchester: Manchester University Press, 2009), 2-5.
[62] Ibid., 7-8.

professional and public science.[63] Museums were used to exchange information. Specimens were circulated among museums across the world so that scientists could examine them and come up with theories. Britain guarded its monopoly on museums carefully. They worried that their London museums might be outdone by a museum in India, so they requested that only duplicate materials be kept in India, and the best specimens sent to England.[64] Museums, together with journals, proved to be one of the most important sources and centers of scientific information in the nineteenth century British colonies.[65]

Geological museums were important to geologists, and Oldham was especially interested in museums. One of the first things he did when he arrived in India was establish a museum and laboratory, just as de la Beche had done in England.[66] Typically, the societies and scientists advocated for the same thing from the government: more funding to study science. This meant that they were usually allies. But in a somewhat unusual situation, when it came to museum ownership geologists were opposed to the

[63] Ibid., 1.
[64] Ibid., 237.
[65] Asian Museums, as MacKenzie explains, were different from the rest of colonial museums. "This was partly because the question 'what is the museum for?' never received a precise answer. Scientific and cultural instruction? Economic development? Entertainment and instructions? The imparting of civilised notions to indigenous peoples? The economic rhetoric ought to have been the most potent, but since the practical purposes of museums were never fully worked out and their developmental efficiency proved, they remained vulnerable. In times of recession, they tended to be soft targets for 'cuts'. But, unexpectedly, they quickly came to assume importance for the developing identity of local Asian peoples. Instead of whites, Asians became the principal audience and, to the surprise of European curators, it was soon apparent that people who found themselves in the melting pot of colonial cities found museums to be important places of resort in holidays and free time, in fact places where they could rediscover multiple cultural identities." MacKenzie, *Museums and empire*, 235-36. The rest of the museums, such as the ones in Africa and New Zealand, were rather a showcase of British prowess, but were not made for native people.
[66] Deepak Kumar, "The evolution of colonial science in India: natural history and the East India Company," in MacKenzie, 73.

society. Both the geologists and the society appealed to keep the ownership of the museum, but by 1856 Oldham had convinced the government to give it to the GSI. Oldham did more than support the idea to give the museum to the GSI, as he was the one who "pulled some strings to influence the decision."[67] Most of the Asiatic Society opposed the transfer of ownership since the museum gave them prestige and power. They also felt that by giving that part of the museum to 'economic' geologists, the government was severing the ties between theoretical science and the museum.

Oldham wanted the museum for several reasons. Written descriptions could tell a geologist only so much about a mineral. Scientists began to realize the importance of careful map-making, a highly desired skill which made a scientist indispensable during the nineteenth century. Not only did maps and illustrations give visuals about minerals, but they also provided information about where the mineral came from. This was an important element in scientific education. Geologists needed to know where they were likely to find coal. Previous reports were not always accurate, as they were often based on hearsay, so knowing when and where to look was an essential skill.[68] But illustrations still were not enough. Potential geologists needed to see and handle minerals to become well enough acquainted with them to be able to find them while surveying. British ore looked different than foreign ore, so it was important that students see and handle the type of ore or mineral that they would need to find.[69] Museums became an important part of educating future geologists and mining engineers. Training new scientists improved

[67] Ibid., 56.
[68] Ball, *Manual of the Geology*, 69.
[69] Grout, "Geology and India," 112.

the efficiency of mineral exploitation.[70] Hands-on experience, Oldham believed, was as important as courses in geology and mining. Later, he refused to support the University of Calcutta based on its lack of resources.[71]

Besides being an essential teaching tool, museums were also indispensable repositories. Minerals were kept by the museum, but were poorly preserved. Under the Asiatic Society, the mineral specimens were uncategorized, not arranged in any order, and decaying.[72] Oldham quickly turned things around and carefully catalogued each specimen. Mining and geological survey records were also given to the museum for safe-keeping. There was no system of record keeping set up by the GSI, so a library of their reports prevented needless duplication. GSI geologists spent a lot of their time early on correcting maps and surveys done incorrectly.[73] Sometimes they did not have a map that had been done, but had to go and correct it anyway.[74] Geologists also put their reports with the museum to prevent exaggeration (also a very common problem with pre-GSI surveys) of mineral resources, and to protect their rights as the discoverer from anyone else who "might fancy themselves to be the first discoverers" and take the claim of discovery away from the deserving geologist.[75] Without museums' report repositories, many valuable reports would have been lost, and geologists would have wasted time and funding on re- surveying land.

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[70] Kumar, "Evolution of colonial science," 72.
[71] Deepak Kumar, "Economic Compulsions and the Geological Survey of India," *Indian Journal of History of Science* 17, no. 2 (1982): 296.
[72] Grout, "Geology and India," 107.
[73] British Association for the Advancement of Science, *Report of the Twenty-seventh Meeting of the British Association for the Advancement of Science* (London: John Murray, Albemarle Street, 1858), 85.
[74] *Records of the Geological Survey of India*, vol. 5 (London: Trübner and Co., 1872), 1-2.
[75] *Memoirs of the Geological Survey of India*, vol. 13 (London: Trübner and Co., 1877), 75.

The Museum of Economic Geology served one last major role in geological knowledge: it employed a chemist. By this time, scientists had begun to realize the important contributions chemistry made to the earth sciences. Until about the nineteenth century, minerals had been grouped together by looks and inherent nature rather than by chemical makeup.[76] Chemistry was an essential element to economic geology. It was important to have a chemist in India because it removed the need to send specimens to Britain for analysis. The British Raj needed to know not only what kind of material they were dealing with, but also how useful it was. For example, chemists needed to analyze the quality of coal found throughout India. The calorific value (or the measure of the potential energy of the coal to provide heat) varies based on composition and age. Generally, Indian coal had a lower calorific value than British coal, which meant that they had to burn more to get the same amount of energy. The Raj was looking for coal that was good enough to run steamships along the canals, but especially along the Ganges. It was also used to power the trains on the extensive railway network in India. Chemistry also helped determine what type of technology one needed to work the coal. Coal produces ash, but depending on its makeup it produces either bottom ash, which collects at the bottom of a furnace, or fly ash, which does not settle. Each type of coal requires a different type of furnace. If the wrong coal is put into a furnace, the furnace will be damaged.[77] So, it was necessary to have a chemist not only to determine the

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[76] Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology* (London: MacDonald, 1972), 11-12.
[77] Stanley P. Schweinfurth, "An Introduction to Coal Quality," in *The National Coal Resource Assessment Overview*, eds. Brenda S. Pierce and Kristin O. Dennen (U.S. Geological Survey, Reston, Virginia, 2009), 5-13.

quality of the coal, but also what type of byproducts it produced so that it was used with the correct technology.

Geologists would often collect different specimens of the same deposit. One was for display, and the other (often uglier) was used in teaching and chemical analysis.[78] The chemist also analyzed soil quality. The museum also was important for agricultural decisions as well. Quality and availability of coal and other precious minerals were major factors in securing funding and permission from the government to mine.

Oldham and later superintendents of the GSI guarded their ownership of the Museum of Economic Geology. The Museum was an essential and often underrated part of the success of the survey. It provided the physical center of the GSI where they could educate the public about their efforts, display their success to the government and investors, and teach students about their future careers. They relied on the collections of information at the Museum to avoid wasting time, effort, and money. Beyond saving time, the GSI also relied on the Museum to analyze and catalogue their finds. The Museum helped ensure their success as geologists and empire builders. It was also essential to make sure that their projects would continue to be funded, both by investors in Europe and by the government.

[78] Grout, "Geology and India," 151.

Conservation

Both *The East India Company and the Natural World* and *Imperialism and the natural world* address the emergence of ideas about conservation and proto-environmentalism. Richard Grove contended that environmentalism "rather than being exclusively a product of European or North American predicaments and philosophies, emerged as a direct response to the destructive social and ecological conditions of colonial rule."[79] Conservation was not motivated by any concern to save the earth. There was nothing altruistic about the EIC's and later the British Raj's environmentalism. The goal was to find a way to boost the productivity and sustainability of resources. Vinita Damodaran argued that "the linked themes of exploitation and conservation thus lie at the heart of the environmental history of empire."[80] However, several authors have only addressed how the botanical sciences contributed to conservationism.[81] But the belief that Western control could improve conservation extended to geology as well.

Valentine Ball's analysis of iron-making near the Rajmehal hills provides a good example. In 1876, he surveyed the area and discovered that several Indians known locally as *Kols* were producing iron using pre-colonial Indian methods. Their methods were inefficient, so the output of iron was, as he termed it, inconsiderable.[82] Closer to some villages, a person known as "Mr. Mackey" had established an iron mill about twenty

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[79] Deepak Kumar, "Botanical Explorations and the East India Company: Revisiting 'Plant Colonialism,'" in Damodaran, Winterbottom, and Lester, 28.
[80] Vinita Damodaran, afterword to *East India Company and the Natural World*, in Damodaran, Winterbottom, and Lester, 270.
[81] Ibid., 270.
[82] *Memoirs*, vol. 13, 87.

years before. Most of the Indians began to work for him at his mill, and at one point they were even compelled to stop using any of their own furnaces. But the company struggled and eventually closed its doors. Because of Mackey's mill, "the most complete indigenous system of iron manufacture ever practiced in Bengal was for the time put a stop to."[83] Though Ball thought Mackey's approach to making iron could have been improved, he welcomed the result that the mill had broken up the Indian manufacturers. The inefficiency of their furnaces had left the landscape near unusable. There was no efficient drainage system, which meant that much of the material was unreachable and their small scale excavating left the resources severely underutilized. Ball reiterated what Hughes (another geologist that did a cursory survey of the area a few years earlier) said in 1870. "I would draw attention to the necessity of introducing a rational system of mining when large quantities of ore will have to be raised. An immense waste of labour occurs in mining the ore by ball pits as at present."[84] In addition to the suggestion of a more systematic extraction policy, Ball also advocated, in order for successful mining and iron production to occur there in the future, carefully cultivating trees. In the end, he admitted that a successful iron mill there was impossible, partially because the soil, even with scientific treatment, was too poor to grow the necessary timber.[85]

Ball's conservation plan of the Rajmehal hills was a classic example of what the British thought conservation should look like: ordered according to Western models. Conservation provided justification for any of the Raj's policies that displaced Indian

[83] Ibid., 88.
[84] Ibid., 90.
[85] Ibid., 87-93.

workers. They believed that Indians were incapable of coming up with the best exploitation/conservation models and policies on their own. By replacing the Indians' production with their own, they were able to much more efficiently extract resources and maintain the area's productivity. Geologists' reports and suggestions provided all the justification that was needed to stop Indian industry. Ball's report also shows what geologists were expected to do for a survey.

Geologists were not supposed to merely recount what amount of minerals they found in different places. Their reports were essentially preliminary business or building plans. They would evaluate the resources and provide an estimate of the cost to extract them. When they arrived at an area, they were looking for much more than minerals. The location of the minerals was just as important as the minerals themselves, if not more so. Part of the reason for the survey was to know where everything was in relation to everything else, including transportation systems, metropolitan areas, other minerals, and water sources. Building a steel mill, for example, had to meet several location requirements in order to be worthwhile. A steel mill was,

> …a complex of at least five industrial plants related vertically to each other. It also contains a number of ancillary facilities that are not directly involved in the production of steel but are essential to the mill's operations. A typical steel mill consumes four basic raw materials: coal, iron ore, fluxes, and scrap. It also consumes a number of other essential inputs such as refractories, water, and … power. At least part of the mill's coal may be washed to improve its chemical and physical properties. Washing usually takes place at or near mines. Washed coal is then shipped to the mill where it may be blended with unwashed coal to obtain a mixture most suitable for the mill's coke ovens, the first major unit of a steel mill.[86]

[86] William A. Johnson, *The Steel Industry of India* (Cambridge: Harvard University Press, 1966), 4.

The next parts of a mill were the blast furnace, melt shop, intermediate rolling mill, and the final rolling mill. Each of these required material to fuel them. For a mill to be successful, it needed to be in close proximity to a good source of these materials. It also needed to be close to a transportation system like a railroad or river so that they could ship the raw material in and the finished product out. It was rare to find a place that met all of the requirements.

Conservation added a new dimension to finding a place that was suitable. It was more than justification or imposing order on a disorderly industry. The "environmentalism" practiced by the geologists was to streamline resource extraction. This meant stopping Indians from what they were doing and allowing the land to rest and be replanted or drained. Only then would a company start mining. They would often hire the Indians they displaced. It was about building an ideal situation where an industry could flourish. That is why the geologists could cross over into suggesting policies for conservation and botany, just as Ball did.

Transportation – Railways and Steamboats

The primary purpose of establishing the GSI was to look for coal. The Raj had little interest in other minerals, though they required that geologists report other finds as well. The government determined that their "chief object [was] determining the existence, extent and relative accessibility of the beds of mineral coal in different parts in India and

their immediate applicability to the increasing demands of the steam-navigation of the Ganges and its tributaries."[87] For many years this took up all of their time. Sometimes this meant that they were either verifying or correcting other scientists' works; other times this meant finding and evaluating uncharted territory. Most reports about the existence and richness of minerals were exaggerated. The military surgeons who had done most of the surveying were underqualified and did not have the time to survey the land properly, even if they had known what they were doing. Oldham entered the GSI knowing that he would spend most of his time looking for coal, and the majority of his twenty-five years with the survey was spent charting coalfields. Coal became even more important after the introduction of the railway system in India. Oldham understood the importance of discovering minerals in developing countries, but he was frustrated by the lack of 'pure' science. But "the only idea the Government then had of the duties of a geological surveyor was that he should go about from place to place, and report upon real or fancied discoveries of minerals. The government would always keep on goading the various organizations to work along only economically beneficial lines."[88] The GSI was finally able to produce a full geological map of India in 1877, right after Oldham retired.[89]

The completion of the map was important for the development of geology as a science in India. It not only visually represented the end of the first stage of the GSI, it allowed geologists to move on to other discoveries. The Raj was only marginally

[87] Kumar, "Economic Compulsions," 289.
[88] Ibid., 294.
[89] Ibid., 292.

interested in anything other than coal until the railway network across India was being finished and they knew where all the major coal deposits were. Until 1894, the majority of the geologists worked as economic scientists.[90] After that, half of the geologists in the GSI working exclusively as economic scientists, and most of the others worked in the scientific section, pursuing "purely scientific enquiry."[91]

These maps were essential when the government evaluated where to build railways. There were several factors in deciding where to build, including the needs of the military, the need for better communication, the difficulty of building in specific areas, and overall improvement to the transportation system. But one of the most important factors was the location of coal deposits. The British wanted to build railways along coalfields so that they did not have to transport fuel to trains. Following coalfields significantly lowered the costs of operation. The location of railroads was dependent on the location of coal.

Valentine Ball was one of the most influential geologists when it came to building railroads. In 1880 he assembled a much needed book that consolidated all of the information that geologists had so far collected. It filled a big gap in reference information about Indian mineral wealth. In *A Manual of the Geology of India Part III: Economic Geology*, Ball describes the location and describes the economic viability of almost ninety minerals ranging from coal to jade to clay. Underlying the entire book,

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[90] Kumar, "Economic Compulsions," 294. Paleontologists, surprisingly, were important economic scientists. Their knowledge was used to decide which coal deposits were likely to be better quality. In general, the older the coal the more useful it was because it was subjected to higher temperature and pressure. By looking at fossils near the finds, paleontologists could determine which coals were older and which were younger.

[91] Ibid., 295.

however, was Ball's argument that there needed to be a railway that cut through the central provinces of India and connected Bombay to Calcutta. The 1880 railways system had a train that connected these two cities, but it took a much less direct route, heading north from Bombay to Allahabad and then dropping down into Calcutta (see map 1). He showed that railroads' dependence on coal was not just one way; coal also relied heavily on railroads.

Coal derived its value from four main characteristics: its accessibility, quality, quantity, and location. The British preferred to mine coal that was located close to the surface, since this was the easiest to mine. Sometimes coal was found in a vertical cliff, which was more difficult to extract. The British wanted the minimize the amount they spent mining the coal, so a coalfield that was wide rather than deep or tall was more valuable even if it contained the same amount of coal.

The quality of the coal was also an issue. Because Indian coal was poor quality, the government's hope of fueling steamships with it during the Opium Wars was not fulfilled. The ships would have required so much Indian coal that they could have carried little else. Therefore, the only economically viable option was to ship quality English coal to India and the surrounding areas. But most Indian coal was sufficient to fuel steamboats on the Indian rivers and Indian trains. Quality of the coal became an important issue when the government considered building metalworking industries. Metallurgy equipment requires better quality coal so that it is not damaged. In geologists' reports of coal deposits, they almost always included an estimate of quality of coal. This is an example of how the geologists ranked the coal:

1. Inferior coal … 12 feet not worked.
2. Good cooking coal … 18-20 feet on fire.
3. Good [cooking coal] … 3 feet 4 inches, worked together.
4. Ten feet good [cooking coal] … 12 feet, worked together.[92]

Categorized by quality, the geologist reported what the economic advantages of his coal discovery was. The inferior coal in this example could have been used to power transportation, or it could be used by local Indians for their various needs. The cooking coal (or coking coal) would be more likely to be used by transportation, but it could also be used by an iron or steel manufacturing mill.

Quantity of coal was another factor that the British considered. Some areas in India contained as much as 1.5 billion tons of easily accessible and relatively good quality coal.[93] It was less profitable to mine small deposits since they would be exhausted quicker, and the company would have to relocate equipment and people to another deposit. Frequent relocation would have cut into the costs of production as well.

But these three characteristics of coalfields were insignificant when determining where to mine coal. The most important characteristic was the coal's location. For example, the large 1.5 billion-ton coalfield was not mined, but another smaller field was because of location.[94] The coal's location mattered in two different ways: where it was located in relation to a railway or another mode of transportation, and where it was

[92] Ball, *Manual of the Geology*, 91. The second seam of coal in the Mopani field was accidentally destroyed by fire. The last two seams were both worked at the same time, side by side, by the Narbada Coal and Iron Company.
[93] Ibid., 84.
[94] Ibid.

located in relation to other minerals. Being close to a railway was the single most important determining factor of whether a coalfield would be mined or not. A deposit only became economically important if there was a railway near it to transport it.[95] If there was not an easy way to transport the coal to major centers of export or industry, then the coal was essentially useless. In India there were at least thirty notable coalfields, but because of their proximity to the railway and centers of manufactures, only four to five were worked.[96]

So, when a geologist surveyed a coal field, he recorded how near it was to a railway (or canal or river), major city or port, and labor. Water transport was sometimes cheaper than railway transport.[97] It needed to be close to a city because shipping costs could raise the price of the coal too much to be competitive. Ball gives a formula for the price of coal. In addition to the mining cost, the shipping would add "1/5th pie per maund per mile, or Rs. 2-5 tons per 100 miles."[98] Labor was the last important need. If there were no Indians living nearby to work the fields, then the government would have to import workers, and provide places to live. Indian workers were not paid nearly as much as imported workers and were not provided with places to live.[99] The British tried to reserve imported miners for much more valuable material. They did not want to have

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[95] Ibid., 73.
[96] Ibid., 61.
[97] Ibid., 74, 87, 544.
[98] Ibid., 65. The British Raj decided that a maund (which varied in weight until it was standardized in the 1830s) was about 82 lbs. The pie and rupee (Rs.) were currencies in India. The pie was worth about .5% of a rupee. James Warden Urquhart, *An Introduction to British Indian Book-keeping by Single and Double Entry, according to the Latest Improvements, Designed for the Use of Schools: To which is Added a Series of Mercantile Forms, a Dictionary of Commercial Terms, with Their Appropriate Translations into Hindustani, and a Set of Concise Interest Tables on a New Method* (Calcutta: Baptist Mission Press, 1853), 304.
[99] *Memoirs of the Geological Survey of India*, vol. 33 (London: Trübner and Co, 1902), 61-63.

them work coalfields if unskilled Indians could do it just as well or better. These three factors determined a mineral's value. Coal was just one example; it also applied to precious metals like gold.[100] Smaller, poorer quality, and less easily mined coalfields were often chosen over rich coalfields because of these other factors.[101]

The railways were so important to coal that mining leases were dependent on the railroad. The Narbada Coal and Iron Company obtained a lease from the government to mine coal and to make iron. The iron was of exceptional quality, and required less flux because the ore was "slightly calcareous."[102] Even though the company had never manufactured iron before, they were in close proximity to all of the necessary material. Indians carried the material to the mill in baskets, but since the distance was less than ten miles, the 'shipping' costs were not too high. The government gave them the lease on one condition. They needed to manufacture at least 5,000 tons of marketable iron "within five years of the opening of the railway to Jabalpur."[103] If they could not send the iron to major markets, then the project did not interest the government. The company's survival depended on their ability to get iron to the markets, and the government knew this. Railways dictated the amount of mining that could happen, and because the good's value was based on its ability to be transported, their lease agreement was dependent on the completion of a railway.

It is unsurprising that Ball's suggested train route was through the central provinces. It would come close to several important mineral deposits. The route would be

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[100] Ball, *Manual of Geology*, 187.
[101] Ball, *Jungle Life in India*, 5.
[102] Ball, *Manual of Geology*, 385.
[103] Ibid., 386.

faster than the preexisting line, but the destination was only part of the importance of the rail.[104] The route was just as important as the destination. By putting a transportation route next to mineral deposits, they would become valuable. All of the discoveries that Ball made in the central provinces would be economically meaningful. Ball, along with other geologists, also hoped that the railway would lead to the discovery of more valuable minerals. Railways would not only make the land around it valuable, but the process of making it, they hoped, would reveal more minerals (as making canals did).[105] The government accepted Ball's proposal for the railway route by the time of his death in 1895.[106] They sent many other surveyors to scout out other possible routes, but his proved to be the most economically viable. By 1909, the railway was complete (see map 2).

Industrialization

The government used the railways and resource maps to determine manufacturing policies and projects. In contrast to their success with resource extraction and railway construction, geologists were unsuccessful in their attempts to use the resources for industrialization. Most, if not all, of the geologists recognized the need for the Raj to establish its own metal making industry. But they all had different opinions about how this needed to happen. Sometimes they would advocate for small scale production, but oppose any large scale systemized production. Whatever their opinion, they tried to keep

[104] Ibid., 249, 375.
[105] Ibid., xviii.
[106] F.R.S., F.G.S, and M.R.I.A, "Obituary Valentine Ball, C.B., M.A., and LL.D. (Dublin)," *Geological Magazine* 2, no. 8 (August 1895): 382.

the money within the Empire. They did not consider a mill owned and run by Indians. Any suggestions they had revolved around supporting the current import economy. At least 70 percent of iron was imported from Britain.[107] The Raj did not develop their iron or steel industries quickly or effectively. Headrick explains that,

> The connection between the needs of an industry and the growth of another is known as backward linkage. The success of a backward linkage in stimulating a supplier-industry in the same country as the customer-industry will depend on several factors: the existence of native entrepreneurs, their access to capital and technology, their costs compared with those of foreign competitors, and the policies of the government. When a sufficient demand exists but does not give rise to a domestic industry, there is a leakage of the backward-linkage effect to foreign suppliers, and a loss of what could have been a stimulus to economic development. All countries beginning to industrialize have been conscious of this effect and have hastened to protect their infant industries with tariffs, subsidies, or state enterprises. That India did not was just as much a political choice.[108]

India, though well equipped with natural resources to make iron and steel, did not do so because they were the British metallurgy industries' biggest customers. Mills in India would have been in competition with British mills, and so would not necessarily add to England's wealth. They had occasionally subsidized a few small scale iron making industries, but there was no system of industry and nothing large enough to challenge their dependence on Britain. Other than those few attempts, the British directed their policies against native industry. The Government of India Act required that stores (or manufactured supplies required by the government) be purchased through the India Office. This protected the monopolies that both the government in India and the industries of Britain had. At first this policy was carefully implemented, but several economic factors, including silver depreciation, caused them to relax the policy starting

[107] Headrick, *Tentacles of Progress*, 279.
[108] Ibid., 276-77.

in 1876.[109] Because of several destructive famines, the Indian Famine Commission asked the government to further relax the policy in 1880. The Secretary of State agreed with them and began campaigning to encourage local purchase and foster local industry development.[110] By 1883, the government majorly revised the policy to support local industries.[111] But iron and steel were left out.

Ball, recognizing the need to not compete with England, and later the difficulty of competing with Germany and Belgium, suggested that only a select few mills be developed in strategic locations where it was expensive to import iron and steel. He was suggesting policies for a protected economy. Because of the tariffs and other importation restrictions, he did not have to worry about the potential competitiveness of the steel mill. Instead of competing with England, it was intended to supplement the imports from Britain. He was not concerned with its competition with England; he was concerned about the creation of the steel mill to enhance England's competition with other European nations. Later, Indian entrepreneurs would recognize the fragility of the system and created their mills specifically so that they could compete with England.

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[109] R. K. Hazari, *Essays on Industrial Policy* (New Delhi: Concept Publishing Company, 1986), 5.
[110] Hazari, *Essays*, 6.
[111] Hazari, *Essays*, 7. "The Government of India is desirous to give the utmost encouragement to every effort to substitute for articles now obtained from Europe, articles of bona fide local manufacture or of indigenous origin; and when articles of European and Indian manufacture do not differ materially in price and quality, the government would always be disposed to give the preference to the latter; and the Governor-General-in-Council desires to remind all officers of government that there is no reasons why articles manufactured in India should not be obtained locally, even though the raw materials necessary for their manufacture may have been originally imported from Europe. It is most desirable to bear in mind the distinction between articles of European manufacture and articles produced or worked up in India from imported material; the former should not, save in exceptional cases, be purchased bin the local market, while the latter should by preference be purchased locally whenever the quality is sufficiently good and the price not higher than the cost of laying down the imported article. There are many articles which may not be immediately obtained in the local market but which can be made in the event of government encouraging the manufacture."

An inland factory, located in Raniganj field, would be most useful because it would not be near any ports, Ball argued. It could supply the needs of the railroad within a certain radius, lowering the cost of building for the Raj. It would not be able to compete with Madras or Bombay imports, and would therefore not be a threat to the British economy.[112] He further recognized that too many factories would cause the industrial economy of India to collapse in on itself. Manufacturing too much iron, he hypothesized, would lower the price of English iron. Indian manufacturers would need to drop their prices as well, and they would constantly be undersold until they failed. Then once again imported steel would take the market. It would be nothing but a costly mistake to create an extensive manufacturing industry in India.[113] A major motivation behind Ball's suggested railway route was that it would encourage a manufacturing plant in the central regions of India, but one that would be safely out of competition with British iron.[114]

Part of the reason Ball wanted to open a mill was because it would provide a location that would increase the value of not only the minerals in the immediate area of the mill, but also the surrounding areas. Since mineral value was based on location, building a mill would provide a new location which would make the minerals relevant. Making the central provinces valuable could lead to the development of a center of trade between Calcutta and Bombay.

The British geologists tried to find places that would work for manufacturing, but they were largely unsuccessful. Like coal, the success and value of manufactured goods

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[112] Ball, *Manual of Geology*, 344.
[113] Ibid.
[114] Ibid., 61.

was heavily dependent on location, but with even more considerations. Not only did the mill have to be close to a railway, but it needed to be close to the minerals that the factory would use to manufacture goods. It had to be close to a coalfield which contained a good amount of quality coal so that it would not damage the equipment and would work efficiently. It needed to be close to a supply of water so that they could wash the coal.[115] It would have to be close to a hematite deposit to get the basic materials in making ore. Fluxes would also need to be located in close proximity. A geologist would not suggest starting a mill unless all of these conditions existed or could be made. In 1852, Oldham had been sent by the Court of Directors to the Damuda valley to determine whether a mill could be built there. What he found was a successful group of Hindus and Muslims working the iron. But based on western methods and requirement, "Dr. Oldham finally concluded that the absence of economical fuel and the scanty supply of ore determined the inapplicability of any extended series of operations for smelting and manufacturing iron in the district of Birbhum."[116]

After that, the British showed little interest in starting a mill themselves, other than subsidizing some small scale production. India's production fulfilled two of the three uses for iron in India: tools, hardware, and weapons. Everything else could be imported.[117] The geologists had failed to get the government to start at least one economically significant mill.

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[115] Washing the coal involved crushing the coal up and putting it in a bath. The good material would float, while the useless heavy material would sink to the bottom. The good coal could then be skimmed off and dried for use in the furnaces.
[116] Ball, *Manual of Geology*, 364-65.
[117] Headrick, *Tentacles of Progress*, 276.

Overall, the scientists advocated for policies with the potential to increase the efficiency of resource extraction. Every piece of their proposed legislation was for the purpose of enriching the empire by imposing a systematic order. Ordering the records and collections of the GSI would reduce wasted time and money, and could be used to train new geologists who did not have to be imported from Britain. Imposing a conservation plan would ensure that an area would continue to be productive for years to come. Situating the railroads near major mineral deposits would increase the value of both the railroad and the minerals. The Raj agreed with the geologists on all of these proposed changes, though they were reluctant to begin manufacturing metals. The British continued to rely upon British, German, and Belgian steel and iron imports. They would not realize how fragile this reliance was until WWI.

CHAPTER III

INDIAN GEOLOGISTS: EDUCATION AND INDUSTRY

Even though the Geological Survey of India was a "premier scientific institution,"[118] in some cases it obstructed the development of the geological sciences in India. As a group, the British members of the GSI generally opposed a national education system that taught the earth sciences, whether on a theoretical level or an applied level. Usually this was due to racism. Officers in the GSI, and especially one of the directors, Henry B. Medlicott, believed Indians were incapable of doing any type of sophisticated science. They wished to keep up the reputation and excellence of their institution, and to geologists like Medlicott that meant excluding Indians. Although he was a geology professor at the Thomason College of Civil Engineering at Roorkee (now the Indian Institute of Technology, Roorkee), he spent most of his time surveying. He protested any efforts to educate Indians to be anything other than assistant workers.[119] On the other end of the spectrum, Thomas Oldham opposed education on the grounds that no university in India was capable of teaching geology well enough. The government made some superficial attempts at improving education, but with little support from Britain and none from local geologists, they did not get very far. By the 1870s, an education in science from universities in India was next to useless.

Industry was not much better off, especially the steel industry. The policies had stagnated at this point. The economy benefitted from importing and exporting material,

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[118] Kumar, "Economic Compulsions," 290.
[119] Ibid., 296.

but the British were unwilling to invest such a large amount of wealth into starting a steel manufacturing mill to create steel for their own needs, like railroads. They did little to encourage any mining or development except for coal and precious minerals beyond allowing a few British to open some mills.[120] The mills were unsuccessful and were shut down. The Raj, though interested in having production in India, did not do much to encourage it and sometimes their policies even hampered enterprising efforts. British geologists encouraged the Raj to support mining and refining material, since foreign steel imports from Germany and Belgium began to develop a monopoly in India. But they were hired primarily to find coal, and so could not do much more than to include a report about potential resources they found other than coal. Britain was behind most of the rest of Europe and the United States in manufacturing techniques and equipment, so they did not find it important to import something that would not be very profitable. The government itself was difficult to work with as well. The viceroy and secretary of state were not in office very long, so "the policies of the Indian government moved by fits and starts, from dynamic action to near-paralysis and back . . . [sometimes] a stalemate arose between the viceroy and the secretary of state. The iron industry in particular, which normally needs years to develop, fell victim to these periodic stalemates."[121]

With the government dragging its feet and the British geologists either opposed to or ambivalent about policies regarding education and industry, the task of improving the policies fell to Indians. Pramatha Nath Bose was the most influential Indian geologist of his time. He joined the *swadeshi* movement to promote Indian self-sufficiency through

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[120] Johnson, *Steel Industry of India*, 9.
[121] Headrick, *Tentacles of Progress*, 296.

education and technology. Several other Indian scientists also supported the *swadeshi* movement; however, as a geologist, Bose was in the unique position to find valuable resources that the British had either ignored or not discovered. He used his skills as a geologist and his experience with his English education to improve educational policies and change outdated and obstructive industrial policies. Bose approached education and industrialization differently than Ball and Oldham. He wanted universities to teach earth sciences, and instead of having the Raj build mills, he wanted manufacturing industries to be owned by Indians.

Education

Geology was one of the sciences that promulgated racism and relied on a crude Social Darwinism. When Europeans encountered what they thought were "geological 'lost worlds' [and] 'landscapes of the past,'" they assumed that the primitiveness of the landscape also applied to the native people as well.[122] Reading the landscape as primitive and then applying the primitiveness to its inhabitants influenced British policies.[123] But it went beyond just establishing backwardness as a national characteristic. Geology also morally justified the existence of the British Raj using the same reasons. Racism, and the resulting discrimination, were essential to British policy in India.[124] Kumar argues that this racialism "was a tool, not an end in itself. The end was to legitimize a complete

[122] MacKenzie, introduction, 10.
[123] Stafford, "Annexing the landscapes", 84.
[124] Kumar, *Science and the Raj*, 213.

psychic subordination."[125] The British government in India found geologists' explanations useful when they defined and reinforced hierarchies based on race, and through it, they were able to refine exploitation.[126]

Several of the geologists that worked for the GSI promoted ideas about the inferiority of Indians. Medlicott, who succeeded W. T. Blanford as the President of the Asiatic Society in 1879, and was the director of the GSI after Oldham retired, was especially racist against Indians.[127] He considered them mentally unwilling, if not incapable, of understanding modern science and conducting research.[128] To him and others like him, admitting that an Indian was equally capable, or more so, of learning and conducting Western science was "'suicidal . . . [Europeans] should claim to be superior in everything, and only allow a native to take a secondary or subordinate part.'"[129] Other geologists, like Thomas Oldham, were not as opposed to the idea that Indians would make good scientists. He hired a few Indians to work for him as apprentices in ungraded posts (meaning they were not specialists and received no extra pay for their professional abilities) and required that they attend science classes. Indians were "treated only as minor partners, in case partnership was at all required."[130] Unfortunately, Oldham was in the minority. Most of the British colonial officials were ambivalent about whether Indians should be hired to work as or alongside scientists. The majority of geologists

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[125] Ibid., 190.
[126] Joshua F. Inwood and Robert A. Yarbrough, "Racialized places, racialized bodies: the impact of racialization on individual and place identities," *GeoJournal* 75, no. 3 (2010): 299.
[127] Kumar, *Science and the Raj*, 78-9, and The Asiatic Society, *Centenary Review of the Asiatic Society of Bengal From 1784 to 1883*, (Calcutta: Thacker, Spink and Co., 1885), 93.
[128] Arnold, *Science, Technology and Medicine*, 139.
[129] Kumar, *Science and the Raj*, 222.
[130] Ibid., 189.

were xenophobic, and it was their beliefs that and shaped government policy. Usually the government would suggest that the Indian scientists settle for secondary positions.[131]

However, racism and discrimination against Indian scientists were not always profitable to the British Raj. It was incredibly difficult to procure a qualified geologist from Britain. British geologists in India believed there were few men that were qualified enough to be hired. They preferred the gentleman geologists to "artisans," or men who worked directly with mining rather than focusing on the philosophical or theoretical dimensions of science.[132] During the 1840s, geologists in India attempted to convince Lyell and Murchison to conduct research in India. Lyell seriously considered the offer, but eventually turned it down because he felt that the government would not pay him well enough for his expertise. He was also afraid for his health and family.[133] Geologists from Britain who worked in India usually died within a few years.[134] The GSI also offered poor incentives for anyone to come work for them because of limited funding.[135] Thus, there was little to tempt any British geologist to work in India, and getting a geologist typically took more than nine months.[136] This caused a shortage of qualified British earth scientists in India. The British Raj attempted to solve this problem by hiring Indians to work for the GSI.

Indians had already proven themselves essential to geological research. Each geologist needed a staff of servants during their surveys. The all-Indian staff, usually

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[131] Ibid., 222-223.
[132] Grout, "Geology and India," 110.
[133] Ibid., 226-30.
[134] Kumar, *Science and the Raj*, 45 and Grout, "Geology in India," 230-31.
[135] Kumar, *Science and the Raj*, 187.
[136] Kumar, "Economic Compulsions," 295.

assigned by an Indian clerk, included a doctor, head man, and several domestic servants known as *chuprasies*.[137] The Indian staff helped gather information from locals about the geographic features of an area.[138] European researchers relied heavily on native information, especially in the early years of administration under the EIC. Native informants were an important part of information-gathering networks because the Europeans did not have the time nor the means to rediscover what Indians already knew, but were able to follow up on a tip from Indians.[139] The government declared the knowledge of native informants as public property, especially metal working Indians.[140] Indians were also important for gathering information when a European could not safely (physically or politically) do so. If British geologists felt that their personal safety was threatened, or when they needed information from "independent Indian states where the active presence of a European geologist might be considered as impolitic," they recruited Indians to gather information.[141] For example, Sarat Chandra Das was sent to survey the landscape of Tibet, which would be useful to the military, essentially acting as a spy for the Raj. The government of Tibet was understandably wary of what they perceived to be the beginning of a British invasion, but Das was able to make a few friends who helped gather the information he needed.[142] Besides being useful in politically problematical

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[137] Ball, *Jungle Life in India*, 9-10. Their work varied according to the needs of the group. They cooked, attended to the table, looked after the guns, set up the tents, collected food for and tended to the animals, collected water, etc.
[138] Ball, *Jungle Life*, 9.
[139] Grout, "Geology and India," 74.
[140] Ball, *The Geology of India*, xviii.
[141] Grout, "Geology and India," 75.
[142] Vibha Arora, "Routing the Commodities of the Empire through Sikkim (1817-1906), *Commodities of Empire: Working Paper No. 9* (July 2008): 12 accessed March 29, 2016 and Sarat Chandra Das, *A Journey to Lhasa and Central Tibet* (New York: E. P. Dutton & Company, 1902), vi.

situations, the British also found it beneficial to hire Indians for several other reasons. As Kumar argued, "J. Mulheran, who headed the Topographical Party of Hyderabad Survey, preferred natives as fieldworkers because 'they require less assistance from the local authorities, have greater influence with the people, are more rapidly replaced if they give dissatisfactions, and as a body are more easily managed and directed.'"[143]

The Raj hoped to hire Indians educated as geologists to fill the shortage. But this is where British geologists stood in the way of geology's development in India, since they considered few of these Indian workers qualified geologists. Because of the prejudices among the geologists of the GSI, they often adamantly opposed Indians being hired to work with them. This caused significant tension between men in the government and men working for the GSI. The Secretary to the Government of India, A. O. Hume, even went so far as to request that Medlicott and Oldham be fired so that Indians, who cost less to employ, could be hired.[144] Eventually, the government settled on promising two posts to Indians within the GSI in 1886. Since there was no reliable geology education in India at that time, they felt that two positions provided adequate accommodation for the Indians.[145]

At first, the Raj considered instituting a good education system to teach geology and other earth sciences. The motivation was not just economic. The military was also pushing for more attention to be paid to education.[146] The education system, however, was more of an obstruction for Indians rather than a service. It required that everything be

[143] Kumar, *Science and the Raj*, 189.
[144] Kumar, "Economic Compulsions," 295.
[145] Headrick, *The Tentacles of Progress*, 320.
[146] Kumar, *Science and the Raj*, 50.

taught in English, which made understanding advanced science difficult, and it placed too much emphasis on subjects like language and logic. The government tentatively approached Calcutta University about changing the education system to accommodate geology in the curriculum. But the university did not see a need to teach geology.[147] Oldham had offered to teach students, but then withdrew his offer. He believed that the university in Calcutta lacked the necessary facilities to teach geology adequately.[148] Medlicott completely opposed geology being taught in India since he believed that Indians were physically and mentally incapable of conducting research and coming up with new or valuable science, and that they were completely uninterested in any type of real science.[149] The government was unconvinced that they needed to institute a geology program since it would be expensive to hire a professor from Britain and there was no guarantee that Indian students would have a career after graduating, given the attitudes of the directors of the GSI.

The Raj instead considered hiring Indian students who had studied in England. The Gilchrist scholarship, established in 1865, enabled a few Indian students to get an education in England.[150] P. N. Datta, one of the Gilchrist scholars, came back to India highly recommended by Archibald Geikie. Despite a recommendation from one of the most renowned geologists of the time, Medlicott was upset that he was required to work with an Indian. The government responded by demoting Datta to assistant geologist, and

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[147] Headrick, *Tentacles of Progress*, 320.
[148] Kumar, "Economic Compulsions," 296.
[149] Arnold, *Science, Technology and Medicine*, 139.
[150] "History," Gilchrist Educational Trust. Accessed March 28, 2016. http://www.gilchristgrants.org.uk/New_Folder/history.htm.

he assisted Oldham with his research.[151] Datta was also paid only two-thirds of what others in his post earned. When the Secretary of State noticed the discrepancy, he also discovered that the GSI had not eliminated a clause that made this practice legal. Other departments had gotten rid of it around 1893. Eventually the "Governor-General finally admitted that this clause 'was inadvertently inserted in our office and escaped our observation'."[152]

Pramatha Nath Bose was another Gilchrist scholar who was much more successful than Datta. He graduated from London University in 1877 and continued his study at the Royal School of Mines.[153] While in England, Bose enjoyed the scientific communities and societies that were not present in India. He felt, for the first time, that he belonged to an international scientific community. He faced relatively little discrimination while in Britain.[154] He felt comfortable enough to criticize the British government. As a student he often campaigned for Indian rights. Although he would have preferred to stay in England, his criticisms of the government prompted the British to get rid of him. To get Bose back to India, the British government sent Bose to work for the GSI in 1880. The Secretary to the Government of India was happy to comply with the British government's request, and Bose became the first Indian to receive a graded post

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[151] *Records of the Geological Survey of India*, vol. 18 (Calcutta: Government of India Central Printing Office, 1895), 2.
[152] Kumar, *Science and the Raj*, 216. Datta was frustrated by his treatment. After Datta left the GSI, he joined an independence movement for India. He helped found the Young Hindustan Association of Constantinople and tried to found an anti-British group in Turkey. See Noor-Aiman I. Khan, *Egyptian-Indian Nationalist Collaboration and the British Empire* (New York: Palgrave Macmillan, 2011).
[153] B. P. Radhakrishna, "Pramatha Nath Bose (1855-1934)," *Current Science* 72, no. 3 (February 1997), 222.
[154] Arnold, *Science, Medicine and Technology*, 155.

working as a government geologist.[155] It was also, Bose believed, the first time that the "'Secretary of State exercised his discretion in favour of an Indian in regard to the appointment in his patronage.'"[156] Upon returning to India, Bose was disappointed by the lack of the freedom and sense of community he had enjoyed in Britain. "…the experience of returning to India to encounter racial discrimination, European domination of the services and grudging official recognition for his scientific qualifications was made even more galling by having previously known, and participated in, a more open scientific community."[157]

Bose was also upset by the lack of pure scientific research in India. When he returned to India, most sciences were driven by the state. The government determined which science was important and which was not by their potential for revenue. Several years later, Bose criticized all of Western science for isolating itself. Pratik Chakrabarti explained that Bose felt, "the negative applications of science were possible because Western scientists had successfully insulated their laboratories from political conscience. Even the most liberal scientists were ultimately serving capitalism through their laboratories…What was required was a new political conscience not enfeebled by science."[158] Recently, natural scientists began to find it necessary to include chemistry in the study of geology. Instead of merely classifying rocks and minerals by their looks, they discovered that they could classify them based on their chemical makeup. While

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[155] Kumar, *Science and the Raj*, 215.
[156] Radhakrishna, "Pramatha Nath Bose," 222.
[157] Arnold, *Science, Medicine and Technology*, 155.
[158] Pratik Chakrabarti, *Western Science in Modern India: Metropolitan Methods, Colonial Practices* (Delhi, India: Permanent Black, 2015), 262.

British academics were embracing this idea and chemistry was in its professional stage in England, geologists in India had little use for chemistry except to determine the quality of the coal.[159] Bose was unhappy that there was next to no research about chemistry being done in India, and that India was not really considered anything more than a "vast storehouse."[160]

Bose adamantly supported educating Indians in Western science. However, one principle that set Bose apart from the government was his emphasis on not just adopting Western science, but adapting it to India's needs. As he grew older, Bose became more opposed to the British rule and their version of science and capitalism. Radhakrishna wrote, "He felt that this had only helped the promotion of militarism and forged fresh fetters on the weaker peoples."[161] Bose eventually joined the *swadeshi*, or self-sufficiency movement in India. In 1903 he wrote *A Plea for a Patriotic Movement*, showing that despite India's resources and the capabilities of her people, the British had a monopoly on science, technology and industry. He believed that the West's morals[162] combined

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[159] Headrick, *Tentacles of Progress*, 282. The quality of Indian coal was much poorer than British coal. While British coal averaged "68 percent fixed carbon and produced 7.8 million calories per kilogram, Indian coal had only 52 percent carbon and produced between 6.1 and 7 million calories per kilogram. Indian coal also contained between 10 and 30 percent ash, compared with 2.7 percent for British coal. Yet coal was so abundant in India and labor costs were so low that its price in Bengal feel from 10.5 rupees per ton in the 1840s to 3.4 rupees in the 1890s, while that of imported coal rose from 13.5 to 17 rupees. Indian production rose from 100,000 tons in the late 1850s to 16 million tons in 1914. Though steam engines needed twice as much Indian as British coal to produce the same energy, Indian coal was not only competitive in eastern and southern India, it was also exported to Southeast Asia. Only in western India and the Arabian Sea did transportation costs favor European and South African steam coal."

[160] Kumar, *Science and the Raj*, 179.

[161] Radhakrishna, "Pramatha Nath Bose," 223.

[162] Chakrabarti, *Western Science in Modern India*, 261. For Bose, the problem with British morals lay in their tie to Darwin. He believed the West had taken a scientific hypothesis too far by applying it to their culture. "Bose produced a critique of Darwin in his nationalist discourse on science, arguing that the problem lay in the acceptance of Darwinism as a doctrine of human conduct rather than as a hypothesis: 'The immoral tendencies of the material development promoted by the practical application of Western Science have been deepened and strengthened by the theory of the "survival of the fittest", which of late has obtained such prominence in wester thought.' This was the cause of moral impoverishment: 'Western

with its capitalism lead to Mammonism and militarism, and said that it was possibly the "greatest curse of modern civilization."[163] The three biggest obstacles to India's successful industrialization were lack of capital, technical education, and protection. Bose supported moral and mental education (Eastern, as he terms it) to natural science education (Western), but admitted that India "must march with the Western progress or perish."[164] Thus, Bose asked the Indians to devote their time to learning natural sciences and invest their capital in the *swadeshi* movement. This would provide protection for the development of Indian industry.[165] But at the same time, he also "called for a return to nature and rural simplicity."[166] Though Bose had a romanticized view of India, especially an India untainted by British imperialism, he also heavily criticized practices he thought kept India from progressing in its own way. He mainly blamed the caste system for preventing scientific progress. He pointed out that although their ancestors had not made much headway in natural science, neither had the ancestors of the Europeans.[167] He thought that the "stagnation of the Hindu intellect" was because "caste rigidities led to an isolation of the intellectual class from social realities. This put a stop to their study of material science: 'Directly the caste system prevented in course of time, the spread of

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society is so deeply imbibed with the evolutional, which has come to be synonymous with the gladiatorial view of life, that its estimation of moral qualities is becoming more and more dependent on the measures of cosmic success to which they may contribute.' This 'gladitorialism' had reduced relationships between nations as well as between human beings to brute force: 'the ultimate question between every two nations, even more than between every two human beings still is in highly expressive though somewhat exaggerated language of Carlyle: 'Canst I kill thee, or canst thou kill me?'"

[163] Pramatha Nath Bose, *Essays and Lectures on the Industrial Development of India and Other Indian Subjects (1880-1906)* (Calcutta: W. Newman and Co., 1906), 38.

[164] Ibid., 41.

[165] Ibid., 32-49.

[166] Headrick, *Tentacles of Progress*, 358.

[167] Bose, *Essays and Lectures*, 85-86.

knowledge beyond a small privileged hereditary class and indirectly led to the neglect of the physical sciences.'"[168] Bose's wish was not that the British would negotiate a situation that would work for Britain and for India; he believed that Britain's rule was completely incompatible with India and was unacceptable in any form. According to Chakrabarti, "P.N. Bose ultimately dreamt the extremist Romantic dream of a new industrial culture within an alternative world order."[169]

His attitude towards Western science helped shape his proposed policy changes in education. Rather than simply transplanting British technology, science, and education, each had to be fine-tuned to fit the needs of India. He gave the practical example of soap-making:

> The raw materials available for it here are not all the same as those used in Europe. For its manufacture on a commercial scale we must utilize *our raw materials*; it would never pay to import any of the principal ingredients from abroad. Caustic soda, for instance, may be made from some such substance as *saji*. And for this purpose, this substance has to be analysed, its impurities ascertained, and the *most economical methods* of purification and the preparation of the caustic lye from it *discovered*. All this cannot be done except by a specialist in Chemistry. Similar remarks would apply *mutatis mutandis* to good many other industries.[170]

Bose was one of the most vocal promoters of a more useful education system in India. In an 1886 pamphlet entitled *Technical and Scientific Education in Bengal*, he wrote to the Indian population. Bose called for major changes in university curriculum, especially at Calcutta University. He pointed out that some industries, such as mining, soap-making, tanning, electro-engineering, and sugar-refining, are heavily dependent on

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[168] Chakrabarti, *Western Science in Modern India*, 234.
[169] Ibid., 264.
[170] Bose, *Essays and Lectures*, 68.

science, but that the current education setup did not prepare a student in the sciences well enough to learn the industries. The focus was literary rather than scientific or practical. The universities lacked the resources to teach since the emphasis was on theoretical knowledge. He called for Calcutta University to follow the structure of London University. The first step, he said, was to "introduce better methods of Science teaching in our colleges."[171] To do this, he said that less emphasis needed to be placed on learning English; science students should only be required to know enough practical English to understand science without learning additional prose. Students should be required to write fewer papers focusing on the literary aspects. If students chose to be scientists, then they should not have to write papers in history and logic. He believed that the university was doing a disservice to the students by requiring that they study a lot of information that would be of little use to them in their future careers. One of the most important steps would be to require that "*a practical examination should be held in every subject that admits of it.*"[172] Since he thought that universities would be reluctant to introduce these tests, he suggested that a Technical and Scientific Education Institute or the company with which a student apprenticed with could administer the tests. He also suggested that students serve as an apprentice to help ensure that they would be hired. The government should provide scholarships to students who were unable to afford school or time off to research, since many of them were too poor to stop working long enough to get an education.[173]

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[171] Ibid., 61.
[172] Ibid., 67.
[173] Ibid., 59-78.

His pamphlet was influential, and by the time he wrote *Scientific and Technical Education in Bengal* in 1906, the Calcutta University had instituted many of his proposed reforms, though they kept the requirement that students write more papers on English. Bose was pleased, but he still pushed for the university to be more attentive to following the program.[174] He also criticized other Indians outside of Bengal for not pursuing an adequate scientific education seriously enough. He believed that they needed to much more eagerly push for the universities to organize science programs similar to the one at Calcutta University and London University.

Apart from providing education models to universities, Bose also helped create societies to foster industrial development. Like several other Indians, he wanted to increase scientific awareness and knowledge and technical ability among the Indians. Bose was instrumental in establishing the Bengal Technical Institute (1906), a school focused on teaching primarily technical knowledge. He was made honorary principal of the school but had to leave it after two years to follow his work.[175] The Institute was later turned into the College of Engineering and Technology Jadavpur, and then became Jadavpur University. While there, he emphasized the need for technical skills to be used to gain capitalism. For him, it was a matter of patriotism. The less dependent India's industries were on the British, the better.[176] Besides the Bengal Technical Institute, he formed, or helped form, several other groups: the Indian Industrial Association, the Industrial Conference (1891), and the Society for Development of Indian Industries.[177]

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[174] Ibid., 79-90.
[175] Bagal, *Pramatha Nath Bose*, 102.
[176] Ibid., 109-111.
[177] Arnold, *Science, Technology and Medicine*, 159.

The Industrial Conference and the Bengal Technical Institute were two successes, while the other two quickly folded or became irrelevant. Still, Bose was trying to replace the hierarchy of scientific knowledge in India. Bose was trying to shift the power that came with scientific and technical knowledge to the Indians.

Industrialization

When Bose was first assigned to the GSI, Medlicott, as usual, was unhappy. However, Medlicott began to like Bose, although he was quick to criticize anything he found wrong with Bose's work. Medlicott tested Bose:

> I gave him to begin with an easy work at Nimar in which the leading features were already marked. There were, no doubt, numerous tell-tale blunders in the progress reports of his work, but his final descriptive account of the ground was so well set up that, with needful correction, I passed it for publication. There was indeed a suspiciously unnatural symmetry in his conclusions, but there was no disputing them without a re-examination of the ground which was impossible. The whole performance was undoubtedly clever, so I gave him the benefit of the doubt. As an encouragement I even recommended him before the usual period for promotion to the 2nd grade. When he was afterwards moved to ground in which he had no outline to start with and the formations were new, his scientific helplessness became at once apparent.[178]

Oldham, though he presumably liked Bose as well, also felt the need to correct his work.[179] Typically, when a geologist corrected another's work, he either would provide some explanation, sometimes bordering on an apology, for criticizing a colleague's work or refuse to name whose work he was correcting, which often happened when the

[178] Kumar, *Science and the Raj,* 215.
[179] *Records of the Geological Survey of India Vol. XXVIII,* 2.

previous geologist was not a member of the GSI and had little time to make an adequate map.[180] Apparently, correcting an Indian's work required no such explanation.

Bose continued to face discrimination after he had worked for the GSI for twenty- three years.[181] Seniority was considered "sacrosanct" when considering which geologist to promote to Director of the GSI. This is shown in the case of Thomas Blanford, who, despite a recommendation for his promotion from Geikie, was superseded by someone else on grounds of seniority.[182] However, when it came time for Bose to be promoted to Director, the Raj refused to put an Indian in charge of the Survey. They felt that it would challenge their superiority and would damage the GSI's reputation as a premier scientific institution.[183] In protest, Bose resigned from the GSI to continue pursuing the economic benefits of geology.

While he was a member of the GSI, he discovered a deposit of hematite in the Raipur district in 1887. Because of the emphasis the British Raj placed on coal and precious minerals, he was unable to stay and evaluate how much he had found. Holland, who later superseded Bose as Director of the GSI, decided to check on the discovery. He found about 2.5 million tons of hematite with about 67.5 percent iron content, much higher than ores in Britain, Sweden, Germany, and the United States. It was so pure that "Dorjabji Tata, Weld, and Saklatvala[184] [reported that the hills] rang under their

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[180] For examples, see *Memoirs of the Geological Survey of India* volumes 11 (p. 105), 13 (p. 1-2), 14 (p. 33-35), and 28 (p.119-120).
[181] Radhakrishna, "Pramatha Nath Bose," 222.
[182] Kumar, *Science and the Raj*, 215.
[183] Radhakrishna, "Pramatha Nath Bose," 223 and Kumar, "Economic Compulsions," 290.
[184] Geologists who worked for the Tata family.

boots."[185] Unfortunately, the hematite deposit was not close to any coal deposit, so the project was essentially abandoned.

Once Bose left the survey he found a job working for the Maharajah of Mayurbhanj in 1903. He went back to another area in Mayurbhanj, about 500 km east of the Raipur district and much closer the coal deposits in Bengal, where he had also discovered hematite to investigate its potential usefulness. He properly surveyed Gurumaishini Hill and discovered the richest hematite deposit in the world. Because the hematite was in a hill rather than buried deep underground, it was easier to mine. It was also easier to smelt since it was very low in sulfur and phosphorus.[186] Location, more than accessibility and quality, was more important for steel manufacturing. For a hematite deposit to be practical to mine and refine, there needed to be a "combination of iron ore, coking coal, flux, and water close enough to each other and to major markets to keep transport costs within reason."[187] Gurumaishini Hill had this combination. Instead of contacting the British, Bose immediately wrote to the Tatas, an Indian family that was looking to start a manufacturing company.

The family had already started a highly successful cotton manufacturing business in the 1860s. They decided that they wanted to begin a steel manufacturing company utilizing India's rich natural resources. The British had already tried to start steel companies in India. The first one was intended solely for military purposes. It was only designed to make weapons and thus had little to no commercial significance. The second

[185] Headrick, *Tentacles of Progress*, 288-289.
[186] Ibid., 289.
[187] Ibid.

factory was underutilized, and after a few months of manufacturing pig iron with substandard equipment, the repairs were so costly that the company abandoned its attempts to make steel.[188] There was plenty of demand for steel since the British were trying to build the railways with steel rather than iron. This meant that India relied heavily on imports from other European countries, such as Belgium and Germany, that manufactured better steel more efficiently.

Though the demand for a local steel manufacturing company was high, there were not very many people that could fill it. Starting a steel factory was expensive: "A steel mill requires costly and complex equipment, and it cannot grow from small beginnings but must be built big from the start."[189] The Tata family was one of just a few who were wealthy enough to start a mill. Since they had been planning on opening a mill for a while, they had hired geologists to scout out resources and had traveled throughout Europe and the United States to determine where to buy their equipment. The United States and Germany had the most advanced equipment that could turn out quality steel quickly. Britain, as the Tatas discovered, was seriously lagging behind its competitors.

British equipment lasted longer, but manufacturing was more expensive which increased the cost of British steel. Their expertise lay more in exporting and trading resources rather than manufacturing metal. By 1904, their steel project was underway and they had contracted with an American to build a steel mill for them.[190]

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[188] Ibid., 285.
[189] Ibid.
[190] Ibid., 288, 291.

Naturally the Tatas were Bose's first choice. They had the required wealth, but they also held the same ideals he did. They supported the idea of India being self-sufficient and resented their dependence on the British. Though they were already looking to start a mill, it took Bose quite a bit to convince them. Since a mill required so much investment up front, choosing the correct location with easy access to good quality minerals was imperative. They had considered other places rich in good hematite but decided not to go forward because of poor location. Bose had to convince them that Gurumaishini Hill was as perfect a situation as they could hope for. Eventually they agreed to start a mill in Sakchi (Jamshedpur). When the Tatas first requested permission to mine, they were denied. The policies before the turn of the century regarding individual prospecting were discouraging:

> By the end of the century, individuals – but not companies – could obtain prospecting licenses. Licenses were limited to a 10-square-kilometer area, and a distance of 12.8 kilometers had to separate any two prospecting areas licensed to the same individual. Then, once an area was explored, the government could auction off the mining rights to it. Based on a misguided concept of fairness, the regulations effectively discouraged even the most sanguine prospector.[191]

So the Tatas and Bose and the Raj were stuck in a difficult place. They were able and ready to begin mining and manufacturing steel that the British badly needed, but an injudicious policy kept them from it. They turned to the government in Britain to ask for help. George Curzon, Major Mahon, and George Hamilton were ready to help. Major Mahon sent coal samples to England to be analyzed for their usability. When he found out that scientists had botched the analysis by testing a second-rate, unrepresentative batch of coal that had lain out in a stock yard for months, he sent coal better representing

[191] Ibid., 286.

the resources in India. The results were much more encouraging, and this prompted him to publish the *Report upon the Manufacture of Iron and Steel in India* in which he requested that large-scale steel manufacturing be undertaken, suggesting that Indian workers be trained to be the manufacturers.[192] The Secretary to the Government of India, Public Works Department, sent a copy to the Committee of the Bengal Chamber of Commerce to ask for their advice. They replied that it was a viable idea and that the government should follow through, but neglected to state any specific concessions to make it happen.[193] George Hamilton encouraged Tata in his efforts and essentially told the government in India not to stand in Tata's way.[194] George Curzon, the new viceroy, had high hopes for India. Although he had little faith in Indians and wanted the power to remain in British hands, he cleared the way for the Tatas to begin mining.[195] Geologists from the GSI also advocated for this industry. Holland wrote to Curzon asking him to encourage the Tata Iron and Steel Company (TISCO) because he feared that if no one developed a steel manufacturing plant, then the economy would be subject to imports of German steel.[196]

So the British, both in Britain and in India, supported Indians' efforts to start manufacturing. But they did little more than change the policies to assist them. When the Tatas tried to get the government to promise to buy steel from them, they declined. No funding was forthcoming either. So the Tatas turned to the Indians for funding who were

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[192] "Iron and Steel Manufacture in India," *Journal of the Royal Society of Arts* 48 (1900): 397-398.
[193] "Manufacture of Iron and Steel in India," *Report of the Committee of the Bengal Chamber of Commerce* 1 (1901): 58-9.
[194] Headrick, *Tentacles of Progress*, 287.
[195] Ibid., 286.
[196] Chakrabarti, *Western Science in Modern India*, 121.

more than happy to buy shares. Including the Tata family holdings, Parsis held 36 percent of the shares, and Hindus, Jains, and Sikhs came in at 50 percent of shares. The British only bought around 5 percent.[197] Only after the future of TISCO and the quality of its steel looked solid was the government willing to contract with the company to buy steel from them.[198]

Though the British did not know it at the time, helping to clear the way for and supporting TISCO was one of the best decisions they made during the early twentieth century. During World War I, Britain was cut off from its primary steel supplier: Germany. Since the British steel industry was lagging behind most of the rest of Europe and the United States, they depended heavily on TISCO to provide them with quality steel quickly at a good price. The high demand for steel from India was also a "godsend." According to Headrick, "The Indian government now purchased all of TISCO's output…For several years TISCO grew up in a totally protected seller's market. Though the government paid less than the market price, the lost profits turned out to be a wise investment in government goodwill for the future. No infant industry could have asked for a happier childhood."[199] We begin to see that Bose's recipe for successful Indian manufacturing was correct. Tata Steel was not held back by the three obstacles that prevented most Indian industries from success. They had the capital (first from the Tatas and then from the Indians), the technical education (that Bose, among several others, had

[197] The other investors were Muslims (6%), Jews (2%), and 'others' (1%). Morris D. Morris, "The Growth of Large-Scale Industry to 1947," in *The Cambridge Economic History of India Volume 2: c. 1751-c. 1970*, ed. Dharma Kumar (Cambridge: Cambridge University Press, 1983), 590.
[198] "20,000 tons of steel rails a year for ten years." Headrick, *Tentacles of Progress*, 290.
[199] Headrick, *Tentacles of Progress*, 291.

been working to provide in India),[200] and the protection (provided by the British, but especially by the demand created by the war). By persuading Jamshedji Tata to start his steel and iron industry, Bose "initiated a gigantic step towards Indian industrialization."[201]

For Bose, an excellent scientific and technical education would help lead India into being a successful, modern (Western), competitive industrialized nation. He did not consider this to be progress though. He would have preferred, especially from the time he left the GSI, that India return to the way it was before it was infected with British imperialism and Western science and its associated moral degeneration. However, he recognized that to survive, India would need to compete with the West on its own terms. This required extensive repairs to the education system set up by the British and a network of Indian-run societies dedicated to improving and monitoring technical and scientific education. It also required that the education be applied. India would not only have to be able to be self-sustaining, but to be competitive in at least a few industries.

This was more than a bid for a share in the capital of the world; education and industrial development were a national duty. He thought that industrializing would help the environment, better the employment prospects for the middle class, and help stop the economic drain from India.[202] The industries would need to be owned by Indians. But there was a much more important reason. Bose approached policy issues with urgency because changing education, industrialization, and trade policies were not just convenient

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[200] Johnson, *The Steel Industry of India*, 12. To get the best advice, the Tatas consulted and hired several skilled foreigners.
[201] Chakrabarti, *Western Science in Modern India*, 262.
[202] Bose, *Essays and Lectures*, 30.

or important to getting wealth. Bose believed that the development of self-sufficient industries would prevent exploitation. India's future depended on these policy changes. His end goal was to kill militant imperialism, if not all of Western imperialism in India, with scientific and technological equality. Bose explained:

> The aggressive imperialism of modern Europe is based upon industrialism. It is chiefly in the interest of their industries, that the greater powers of the West are anxious to dominate the peoples of the East. If these peoples made a vigorous well-concerted effort to develop their resources on western methods, and supply their own wants, their markets would cease to be exploited in the way they now are by western manufactures, and their lands would cease to be the happy hunting ground of western enterprise. Western imperialism, would thus die a natural and peaceful death, at least in its present highly objectionable militant form. That is a revolutions so wholesome and far-reaching in the interests both of the East and of the West – that it is well worth a mighty effort on the part of all orientals.[203]

[203] Ibid., 31.

CHAPTER IV

CONCLUSION

Scientists were influential agents of change. Because of geology's nature, geologists held more sway over the government than other scientific disciplines did. The Raj considered them indispensable thanks to their economic usefulness. When budget cuts affected other areas of science, such as zoology, the GSI was protected. Their discoveries, but more importantly, their proposed use of their discoveries helped the government make important decisions. Ball's railway was the most obvious example of this, but many other important changes and decisions were at least influenced, if not directed, by a geologist. By the time they retired, Oldham, Ball, and Bose had accomplished much of what they wanted. Oldham and Ball, besides their success in policy-changing, also received the recognition they wanted. Both retired in Britain. Ball was made a fellow of the Geological Society of London, the Royal Society of London, and president of the Royal Geological Society of Ireland. He also held appointments as a professor at the University of Dublin and director of an Irish museum.[204] Oldham received the prestigious Royal Medal from the Royal Society in 1875, among other appointments as fellow, professor, and museum director.[205] Bose retired to Ranchi, which is west of Kolkata, where he built a large house and spent most of his time gardening. He was awarded several honors from Indian scientists and societies.[206] These geologists had,

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[204] F.R.S., F.G.S, and M.R.I.A., "Obituary Valentine Ball," 382.
[205] "Award Winners: Royal Medal," The Royal Society, 2015, accessed April 29, 2016, https://docs.google.com/spreadsheets/d/1dsunM9ukGLgaW3HdG9cvJ_QKd7pWjGI0qi_fCb1ROD4/pubhtml?gid=1640032608&single=true.
[206] Bagal, *Pramatha Nath Bose*, 124-135.

from both inside and outside of the GSI, shaped how geology was used and taught in India.

Geology was not the only agent that drove policy change. There were several other considerations in each case (except perhaps in the case of the museum) such as military concerns, famine, other scientists' reports, budget, Britain's economy, etc. But it was an important agent. Geologists provided not only information, but proposals for what the Raj should do.

The GSI functioned as the British expected it to. Geologists brought in the results that the British wanted. In this way, the top heavy model of government is correct. The government's control dictated what the geologists could spend their time doing and which minerals were worth investigating and which were not. However, the model neglects to address the way British geologists used the Raj's dependency on their surveys to get what they wanted. Because geologists' importance was tied to the mineral that fueled the nation, geologists were very effective in changing policies that they felt restricted them. But they were not trying to change the entire system of government. Their scope was much smaller than Bose's. They were looking to change policies that would help the GSI directly. Museums, conservation, and extraction were all things that they successfully proved to the government to change in their favor. The government was willing because the GSI's primary purpose (and, for some time, their only one) was to bring wealth to the empire. They were willing to fund the proposals only so far as the geologists proved that a great return would be derived from a small investment. Though Ball and other British geologists were unsuccessful in trying to get the Raj to build mills,

they were able to help get the policies relaxed against private companies. They had helped prime the policies for when Tata and Bose asked the government for permission to start the mill. Unless the government saw an immediate and assured profit in a project, they were reluctant to undertake it. At least the Raj considered manufacture, as shown by when they sent Oldham to investigate a potential area. Part of their reluctance was because Ball was not just suggesting that they build mills; he was suggesting that the government start changing its entire economic set up. Instead of being an economy based on export of raw materials, they would start to become an independent and self-sustaining colony.

In other ways, even though it was a 'premier scientific institution,' the GSI was too restrictive. They had already showed their unwillingness to start a large scale mill, and they were reluctant to spend a lot of time fixing the education system. Bose had to leave before he could accomplish anything significant. Once outside of the GSI, he could use his discoveries as he saw fit. He went back to all of the discoveries that had been deemed unimportant, and, by convincing Indians of their worth, was able to bring the Raj a proposal that they found acceptable. Since the government did not see the immediate need of changing the education system, Bose had to convince Indians that their future as a nation depended on their ability to keep up with Europe. His power lay in convincing his people that they needed to change the system. They would come up with a proposal and present it to the government, who often found it acceptable and useful. Together, the Indian investors and scientists shaped the India's economic framework.

The GSI functioned as both a source of power for British geologists and an institution that stopped geology's development. The British scientists were able to change several policies that brought them, and the empire, more power. But Bose, despite his education and abilities, could not escape the racism within the GSI. After he left, he was able to restructure how geology was taught and what it could be used for. It took scientists, working from both from inside and outside the GSI, to shape the policies in colonial India.

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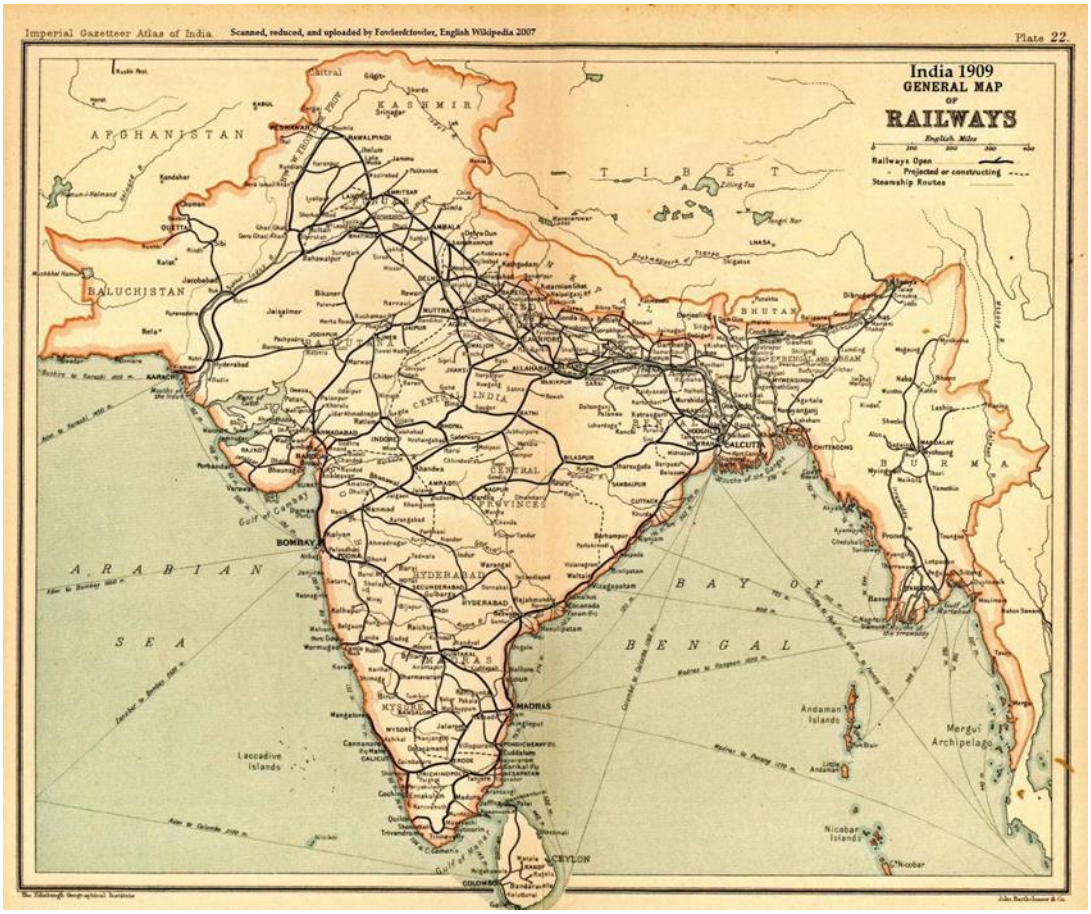
APPENDIX

MAP 1

UK government India Office. *A Map of India*. 1871. April 5, 2009. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:IndiaRailwaysCompletedBy1871.jpg.

This is the map of railways in India completed by 1871. The only way to get to Bombay from Calcutta was to take the train north to Allahabad and then drop down into Calcutta.



MAP 2

General Map of Railways. 1909. September 18, 2007. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:India_railways1909a.jpg.

The railways system by 1909. Ball's railway cuts through the Central Provinces from Bombay to Calcutta.