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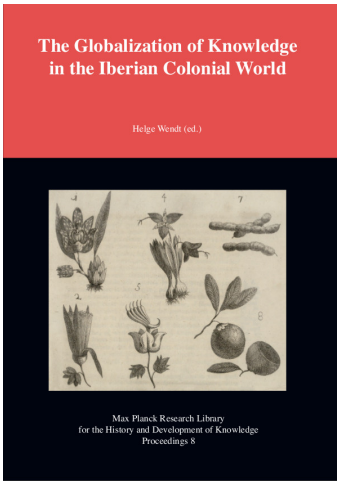

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Chapter 10
Coal Mining in Cuba: Knowledge Formation in a Transcolonial Perspective

Helge Wendt

> No flash of genius of a Crompton or a Watt could transform coal mining. Better methods had to be slowly forged form the painful experience of common men, and only gradually did a new idea or a new device spread from pit to pit, or from one coalfield to another. Development came with the growth of markets and the emergence of new uses for coal, rather than with changes in technique, though these new markets and new uses themselves depended upon technical changes in transport – upon the development of roads, canals, and, above all, of railways. (Ashton and Sykes 1929, 12)
>
> In developing her coal fuel technology, Britain built up a broad band of techniques in furnace design, building and ventilation, in the choice and use of refractories, in boiler making, in the production of large iron plates and castings, in the provision of cokes, and in the important but now obscure craft techniques of furnace management. There was already by the eighteenth century a number of important coal-using processes which could not be used with other fuels. (Harris 1976, 168)

Introduction

The coal that was found in Cuba in 1828 turned out to be of rather bad quality. The history of coal mining in Cuba is thus very short—maybe too short in time and too limited in personnel for knowledge from other coalfields to have influenced the island's coal industry. Nevertheless, this short history has led to an investigation of alternative ways of industrialization. As is well known, at this time the production of sugar dominated the Cuban economy. Additionally, from the 1830s on, new industries appeared such as copper mining, steam engine transportation and machine construction. The island was still under Spanish colonial

rule and the political sector was divided into conservative loyal, progressive loyal and progressive independent parties.

The particular situation of Cuba in the nineteenth century impedes an exclusive concentration on the Spanish colonial empire. Any analysis of the colonial situation cannot focus solely on the limits of the political space set down by colonial powers. The bonds between the colonizing political entities and the colonized areas were not so tight as to be considered the only valuable relationships to exist, nor have colonial boundaries proven to be so potent as to form a closed spatial entity. On the contrary, colonial territories were extremely open spaces and hosted relatively open societies in which processes occurred that in the so-called "mother countries" would have been unthinkable. Thus, relationships endured the military conquest and reached far beyond the newly set political and social borders, altering the political intentions of colonial powers and setting off multiple processes like *métissage* (Gruzinski 2004), political opposition to colonial domination (P. Chatterjee 1993; Mignolo 2000) and economic emancipation (Bayly 2004; Osterhammel 1997).

The transfer of knowledge, which is one of the lessons to be drawn from previous historical globalization studies, has to consider those relationships that trespass geographical and political borders and limits formerly taken for granted (Werner and Zimmermann 2006). This perspective questions the exclusiveness of the access European mother countries claimed to have to their colonial territories and subordinated people. The economic history of black markets (Böttcher 2011), the colonial history of Christian missions (Wendt 2011), the history of scientific development (Baracca 2014) and of mining (Bakewell 1971; Brown 2012; Hausberger 2009) all deliver various transcolonial examples of how colonial borders were permeated by individuals, companies and other social entities.

The transfer of knowledge, at least as emphasized by post-colonial inspired scholars, occurred not only between European countries and their colonies, but also between different colonies. The coal issue exemplifies such transcolonial transfers of knowledge. Often, knowledge in the colonies was gained despite colonial domination. The colonial situation was much more diverse than the much-discussed opposition between the colonizers and the colonized. Various groups were acting in the fields of politics and economics: there were (in colonies other than Cuba) different indigenous groups that tried to preserve a certain political, social and economic status by maintaining relationships to other indigenous groups, to the colonial administration and to different social groups (such as merchants, missionaries, *criollos*, etc.). The *criollos*, descendants of European migrants to the Americas, had different degrees of affinity to the colonizing power.

This situation means that only parts of the colonial society were able to exploit and reassemble circulating information with the aim of creating new knowledge. We are dealing furthermore with a lack of information on the character of knowledge in the colonial intercultural situation. Knowledge and knowledge formation processes are culturally different; they vary locally and differ in the aspects of innovativeness and further diffusion. When in the late 1820s a small but promising coal deposit was found near Havana, the Cuban society, the Spanish authorities and potential investors and buyers of that coal had to develop and employ knowledge that for them was new, even though coal mining was already a well-established tradition in other parts of the world. The problem these people faced had potentially long-term effects, although the economic impact of coal in Cuba was relatively small.

In this paper, I rely mainly on documents from the Spanish National Historical Archive in Simancas.[1] Some treatises on mineralogy and coal from the beginning of the nineteenth century, written in Spain, France and Great Britain, have also provided precious information that allowed an overview to be established of what was known about coal at that time.

Coal in Modern History

Different Forms of Industrialization

Talking about coal in modern history often relates to the history of industrialization and thus to modernization. I use the term industrialization to designate changes in a large number of processes in socio-economic systems. Those changes comprised the production of goods, their consumption and the energy available to increase production rates.

Jan de Vries has focused on the consumer revolution that began in the late sixteenth century and comprised ever more people in a mass-movement of individuals (Vries 2008, 36). Their demand for goods that were once considered luxury items led to an ever-greater need for larger amounts of energy and energy-rich resources (Vries 1994; 2008; Bayly 2004). This was not just a European phenomenon but also occurred in the colonized world, as well as in parts of the world that were independent of European domination, such as China or India (Wright 1984; K. K. Chatterjee 2008; Ranade 1906).

Other global processes included the so-called “industrious revolution” and “globalized,” terms coined by Jan de Vries (1994) and Christopher A. Bayly (2004), respectively. These terms were picked up, for instance, by Robert C. Allen and Jacob L. Weisdorf in restructuring the narration of the industrialization

[1] Available online at http://pares.mcu.es.

process. And Sheilagh Ogilvie (2010) proposed to decenter both objects of research from the North Atlantic environment and investigate "both revolutions" in other European regions.

Taking up the research of Akira Hayami, Kaoru Sugihara (2004) has stressed the difficulties in comparing Northwestern European and Japanese histories of industrialization on a global scale. In contributing to a comparative history of industrialization, Sugihara researched the issue of governmental politics and the industrious revolution during the Tokugawa shogunate in Japan. To establish a typology of how industrial processes changed in Japan, Sugihara focuses on the East Asian history of technologies where a more efficient production method was evident, as well as an accumulation of "human capital" in the form of skilled and literate workers. In contrast, as Sugihara underlines, Jan de Vries (1994) suggested that Europe concentrated on demand, and Kenneth Pomeranz (2000) proposed to research processes of capital accumulation (Sugihara 2004, 8).

This short discussion about early industrialization processes is important to indicate alternative ways of industrialization. This means that the way in which changes occurred in different social-economic systems differed from the socio-economic organization and the resources available. The Japanese path to industrialization in the eighteenth and nineteenth centuries, for instance, relied less on the accumulation of capital or increasing mass-consumption, but instead on the efficient organization of labor processes related to restricted land and labor.

Efficiency and (Global) Industrialization Processes

The history of coal is not confined to the (Northwestern) European history of industrialization that often considered coal as a substitute for timber and the substance that made changes in production processes possible. David Landes (1969; 1998) and Eric Hobsbawm (1975), for instance, treated coal and iron as being intertwined in a co-evolutionary process. Putting coal into a global history framework, Kenneth Pomeranz (2000) has repeatedly referred to this motor of industrialization and to the importance this combination had for Chinese and Japanese modernization processes (Pomeranz and Topik 2006).

Another argument should be made when investigating the history of coal use in different regions of the world, even if these regions were under European colonial domination or integrated into a "Western" economic system and culture. In regions of the world where historiography is typically related to a Western model of industrialization, coal is often put in the context of iron. But that is to argue that many more production processes can be considered in which coal was a useful combustible for increasing production rates and ameliorating efficiency of production. The use of coal comes from a long history that began in the seventeenth

century when all demands for energy were met almost exclusively with organic materials. As Richard Adams (1975) emphasizes, in the seventeenth and eighteenth centuries the European economies were developing from an agricultural to a paleotechnical phase. Instead of "agricultural phase," authors Deléage and Debéir (Debeir, Deléage, and Hémery 1986) employed for the same era the term "organic époque," when exclusively organic energy resources, mostly produced during agricultural processes, were converted into power. Almost the entire mass of energy was extracted from organic materials at this time. Corn, human and animal power, wood and water or wind were the only raw materials used for obtaining energy.

In the late eighteenth century, a change in the energy system took place which affected, among other things, the production of manufactured objects. In a time span of one hundred years, fossil energy resources like coal and later petroleum gradually but profoundly changed the economic and social landscape throughout the world. At the same time, the second green revolution (after the first, the Neolithic revolution) of the late eighteenth century transformed cultivation and husbandry in European and American countries (Overton 1996). The changes in agriculture relied partly on experiences and materials from the European colonies, which were then partly transferred back to the colonized regions. This process affected the social, scientific (Sigaut 1998) and economic contexts in rural areas by helping to produce an ever-increasing mass of organic energy resources like meat, vegetables and fodder for animal husbandry.

Both production sectors—manufacturing and agriculture—were related to one another, but a large part of the labor force now left the agricultural sector to seek manufacturing jobs in workshops and factories. This growing class of workers was nourished by the increased agricultural output. The industrial sector produced instruments and machines, and later also fertilizer for agriculture. The second green revolution thus comprised a mechanization of parts of the agricultural working cycle. In addition, by using new or combined breeding methods, much more efficient species of plants and animals could be created in comparison to traditional species. New types of wheat were able to bear ten to fourteen kernels, rather than the usual eight. This signified a considerable increase in energy production of between 20 and 40 percent per acreage of land. Here we find a third reason why the energy question became so relevant in the late eighteenth century: higher agricultural yields were related to Malthusian theories of limited population and economical growth, which could only be surmounted by an increase in agricultural production. Paolo Malanima comments on the European situation:

> We can summarise the different levels of consumption in the European agrarian society and in other 18th-century societies by saying that, while in European society these were around 15,000 kcal per

> capita per day, in non-European societies they were between 5 and 10,000 kcal.
>
> The European agrarian civilisation, characterized by short growing seasons with one, mainly low yield harvest of cereal, such as wheat, per year, needed a higher average consumption per capita, with its numerous working animals and the long months of low temperatures. It was therefore more vulnerable than other agrarian civilisations to the increase of demographic pressure, with the growing demand of energy that this entailed. (Malanima 2009, 85)

While today the Malthusian trap is disputable, throughout the nineteenth century the conversion of energy became a major catalyst for inventions in areas as diverse as industrial and agricultural production, economic organization, urbanism and individual-state-relations.

The conversion of black coal into heat was therefore important as it helped to match the expectations of increasing production. Steam engines could help to raise water from mines that extracted minerals and metals from ever-deeper strata. Coal gas, obtained after distilling the mineral, illuminated factories and public spaces. When the construction of railroads spread throughout the world and more and more steamships navigated coastal waters, large rivers and later the oceans, coal was needed to move them. To supply the increasing coal trade, the first mining centers in England, France, Germany, Spain, the United States, South Africa and Australia shipped coal to the remotest parts of the world. Deposits were created and continually restocked (Duncan 1972).

This black backbone of industrialization permitted, for instance, an increase in iron production, which in turn became the basis for the construction of steam engines and railways and demanded an ever-greater amount of coal. Consequently, the demand for products requiring coal for their production process stimulated the search for new coal deposits, the advancement of pits in ever-deeper strata and also promoted the irreversible progress in production and knowledge economies relying on coal. The turnaround of fossil resource energy through the massive exploitation of coal and its application in production processes and transportation thus added an additional stratum in the energy supply of European, Asian and American societies.

Coal in the European Context around 1800

Early Developments in England

It seems that the use and knowledge of coal cumulated over a period of several hundred years. From the beginnings of the coal trade in England from the fourteenth century on, there were many obstacles in history to the diffusion of coal use. To name a few, there were several restrictions on its sale in London, coal mining in northern France was under both English and French rule. Paolo Malanima states that by 1620, the economic status of London already depended entirely on access to black coal:

> Coal in England had become more important than wood as a provider of thermal energy by the 1620s. The proportion of coal in total energy consumed was 12 percent in 1560, 20 in 1600, and 50 in 1700. (Malanima 2009, 61)

Since the reign of Elizabeth I and James I, coal had become a vital resource, for example, in heating houses and for use in forges (Crouzet 1966, 53–56). Coal could be used in other processes, for example, from the mid-eighteenth century in iron-smelting processes after Abraham Darby and Henry Cort discovered how to desulfurize pit coal to produce coke. During the seventeenth and eighteenth centuries, the sectors of production where pit coal could be used had multiplied and some of these were only able to develop thanks to this mineral. Transnational transfers of knowledge on the use of coal made such developments possible in the first place, among others, the "invention" of the steam engine (Nef 1966, 243).

John Nef, author of *The Rise of the British Coal Industry*, also mentions that there was a shortage of timber for producing charcoal, and also that it was widely believed that black coal had a lesser impact on the environment and deforestation (Nef 1966, 195). The observation that by using pit coal instead of charcoal, the forests and woods could be better preserved was ascertained knowledge from the seventeenth century on. This development of substituting timber with coal (and later with petroleum), as E. A. Wrigley has pointed out, was a *longue durée* process: "It took a quarter of a millennium for coal to change from supplying a tenth of the energy consumed in England and Wales to nine-tenths" (Wrigley 2010, 243). From a history of science perspective, these 250 years wherein a change in energy supply took place was also a period of newly developing knowledge (Wrigley 2010, 99).

Besides the use in households and forges, and in mines to fuel engines and raise water, the English development of coal usage comprised processes of knowledge formation that can be observed, for instance, in the writing of Robert Boyle.

In the second part of his *Natural Philosophy* published by Thomas Birch in 1777, he wrote:

> And that, which was very convenient in this contrivance, was, that whilst the pit-coal was charring, it afforded him a very intense heat to meal or calcine the minerals, he had occasion to expose to it: and he confess to me, that by this method, he saved three parts in four of the charges the keeping such great and constant fire, with common charcoal, would cost him. (Boyle 1777, 141)

In this chapter, Boyle referred to the potential for pit coal to act as a substitute for combustibles such as charcoal because of its newly discovered abundance and the characteristics that made it accessible for an extended period of time. Boyle could already rely on a broad knowledge of black coal and even referred to some knowledge of economics.

The co-evolution of a social activity, such as production and consumption, and of a new epistemic field—the investigation of possible forms of black coal usage—already encompasses features of the future age of the Anthropocene. Herein, the exploitation of natural resources and the employment of ever-higher amounts of energy to increase production rates are already visible patterns of thought and action. To substitute one resource with another to preserve the former and to obtain an economic advantage also belongs to that logic.

Coal in the Economic Contexts of France and Spain

In the late eighteenth century, England was a model for all those in Europe and abroad who wished to develop a mode of industrialized production. Writers in Catholic societies in France and Spain commented on the new production modes in England and made some efforts to implement comparable forms of production in their own societies, which also used coal. Anne-Robert-Jacques Turgot wrote, for example, that coal could be a useful economic medium. He referred to the case of England, in particular of Newcastle. Comparing the English case to that of the French, the statesman and famous physiocrat stated that French coal was inferior in quality to English coal. This would have been the reason why in France the use of coal in the mid-eighteenth century was rather rare and only a limited legal system directing the coal economy existed. In a short treatise "Mémoire sur les mines et carriers," Turgot wrote:

> The coal mines of Saint-Étienne en Forez (Loire, France) did not wait to be regularized in 1744 to provide the manufactures of that city with an enormous quantity of coal; they have prospered because of the liberty they have taken. (Turgot 1844, 158)

When English coal was imported into France, Turgot was convinced that English coal mining had accumulated knowledge that could be useful for the economic development of France, too, even though past experiences in France could have served as a model for the further co-evolution of industry and the mining sector (Crouzet 1966). This was the argument given by a member of the French Academy of Sciences, veterinarian and coal mining expert, Jean F. C. Morand, when he wrote extensively about coal mining in northern France. It was due to a lack of knowledge in the French territories about current coal mining practices that this mineral was used by only a few industries. For the French case, Morand (1776) stated that this was due to an absence of communication of knowledge for improving the coal mining industries in France. Although Morand aimed to underline the importance of French coal mining, he conceded the much longer experience and leading position of English coal industries.

Similarly, the Catalonian director of the Botanical Garden in Barcelona, Joseph Comes, reflected on the question of why England had become such an economic power. The short historical overview of his report entitled *Memoria sobre el carbon de piedra para persuadir y facilitar su uso en Cataluña* began with the English laws that prohibited the cutting down of trees. Comes saw this law as the reason why in England a combustible was sought with substitutive potential. Consequently, the English began to employ black coal in a wide range of economic fields, which he lists: "domestic firing, combustion in factories and finally the smelting of metals" (Comes 1786, III). Comes considered this variety in the use of black coal as a reason to begin exploiting coal mines in Spain.

Comes understood that the French physiocratic principles of agriculture as the backbone of the national economy meant that no agricultural product, such as wood, should be wasted in producing a material that could be provided by another sector of the same economy. This was the case for black coal, which contrary to timber or vegetable charcoal, did not rely on agricultural production cycles and the man power necessary for a prospering rural economy; it was an economic branch in its own right (Comes 1786, IV–V). As Comes stated in 1786, although many coal mines were being exploited in Catalonia, the use of coal in northwestern Spain was rather limited. Despite the fact that coal mining was of rather low importance in Spain, some coal mining regions did appear from 1800 on.

One center of coal mining in Spain was Villanueva del Río, around 50 kilometers northeast of Seville (García Montoro 1997; Alvárez 1987). Villanueva del Río, for instance, had a royal coal mine concession from the 1770s and produced around 500 tons of coal per year. When in 1792 the concession was revoked, private activities undertaken until 1799 increased production to 1,500 tons per year. In Asturias, the Navy, which produced iron bars for ballast in ship construction,

mostly exploited coal. At the turn of the century, a total of only 15,000 tons of mineral coal were extracted annually from Spanish coal mines (Coll Martín and Sudrià i Triay 1987, 39; Gómez 2005, 259–260). It is worth comparing here the annual consumption of coal by the copper mines of Río Tinto in Andalusia in 1855, which was approximately 230,000 tons per year (Anciola and Cossio 1856, 148). Most of this coal was imported from England and transported via the port of Huelva to the copper furnaces of Río Tinto. Coal mining in Spain could thus only partly contribute to the industrialization process, as many authors have pointed out (Terán Troyano 1999, 24–25).

Other examples of transcolonial economic interaction are the powering of transatlantic navigation and the global commercialization of coal. At the turn of the century, these signaled the very beginnings of economic interaction but became a major factor in the organization of transoceanic dominion. Geological knowledge of where to find coal, of the different characteristics of the various types of coal and the possibilities of its use in production processes evolved over that long period of time. Spanish policy makers, in their transcolonial analysis of the political situation, were conscious of this new geopolitical field and tried to keep up with the changing situation.

Coal in Colonial Spanish America around 1800

A Short Historiography of a "Rare Mineral"

Black coal in the Iberian colonies is a rather undervalued issue. Modesto Bargalló (1955) in his basic study on mining and metallurgy in colonial and post-colonial Mexico does not even mentions coal mining. Nevertheless, Bargalló hints at how important coal had become for the Mexican national economy. Reviewing the foundation of iron smelting companies in the state of Durango from the mid-nineteenth century, he states that one of the furnaces was forced to close down because coal for the smelting process was too expensive. Related to the same problem, other companies were sold several times and often passed from Mexican to US or British proprietors who could access black coal more easily and at better prices.

Generally it can be stated that during the nineteenth and early twentieth centuries, coal was a precious commodity in Latin America, but because the coal mined there was often of poor quality, it had to be imported from distant regions (Glade 1997, 52–53). Such statements can easily be traced to Alexander von Humboldt's writings about black coal in Mexico, a country he visited at the beginning of the nineteenth century. Whenever Humboldt made mention of any deposits, he described them as being scarce and dispersed. Coal was rarely found

in the Cordillera, therefore the main sources were in New Mexico, Texas and Louisiana (Humboldt 1822). All three of these regions became US American territory during the nineteenth century. From the early 1830s, several expeditions in the Rio Grande area had given indications of coal deposits (J. A. Adams 2008). But it was only after the US Mexican War (1846–1848) and the expulsion of hostile Indians from that region that it became possible to mine coal on both sides of the river (Calderón 2000, 133) and US-dependent companies began to exploit coalfields south of the Rio Grande around 1900 (Bernstein 1952). It was only at the turn of the twentieth century that coal was exploited at different sites in Coahuila (Boletín Minero 11, 5 (1927), 627–709).

In contrast to the history of coal mining in Mexico, in Chile coal mines were in operation from the 1840s. Luis Ortega mentions Las Vegas de Talcahuano, the first coal mine to be regularly exploited from 1841. This mine was run by the British citizen John Mackay who sold the mineral to navigation companies (Ortega 1982). The main development of Chilean coal mining, comprising as many British as Chilean entrepreneurs, was due to the increasing sector of copper mining. To implement a national smelting industry, large amounts of fuel were needed and this could only be covered in part by wood and charcoal (Folchi Donoso 2001; Veliz 1975, 648). In 1859, more than 172,000 tons of coal were mined in Chile, mostly from the mines of Talcahuano and Coronel (Ortega 1982, 9). Other Spanish-American areas to develop coal mining in the late nineteenth century were El Cerrejón in eastern Colombia or Río Turbio in Argentina.

In the late nineteenth century, the US government demanded that its consuls in all of the Latin American consular districts report the importation and regional exploitation rates of black coal. This demand and the reports sent to Washington show the extent of global interconnectivity of coal trade at the end of the nineteenth century, as well as the transcolonial relations that were influencing the young independent states. Thirty-two of a total of eighty-three pages of the consuls' report were dedicated to Mexico (Special Consular Reports 1891). From the 1880s on, the charcoal that had previously dominated the heat-intensive production processes in Mexico was progressively replaced by black coal (Rankine 1992). In 1890, when the consuls' report was established (it was published in 1891), coal that was used by Latin American nations mostly originated from England, the United States or Germany. But some consuls reported on regional production, which potentially endangered US influence on the national economies.

Spanish-American Mining —Independent from Coal

There are several reasons why coal in the Spanish speaking countries of Latin America did not play the role it did in the US or in Europe. Black coal had only limited value in the Spanish colonies because the industrialized parts of the colonial economy already worked well without it. These branches of industrialized production could rely on rather still abundant organic fuels and had developed production processes that diminished the quantities of used fuels. In colonial times, the main industry was the mining and smelting of silver. In pre-Spanish and early colonial times, the smelting process relied on the relatively high temperatures achieved in special stoves in which a fire was maintained in the lower parts using wood or charcoal the ore was smelted in the upper parts. To reach the high temperatures, natural winds or blow tubes were employed. When the Spanish learned the amalgamation technique of mixing the ore with mercury (Teich 1975), first used in 1554 in Mexico and from 1572 in Potosi (Hausberger 2009), high temperatures were no longer needed for the smelting process (Ramírez 1994, 102).

After this technological of amalgamation, the Amerindians were no longer able to compete with the Spanish mine owners, who could now produce much higher quantities of silver using less fuel. Nevertheless, they still needed wood and charcoal for the increasing silver smelting activities (Bakewell 1997, 119–120). The implementation of the amalgamation method in the main silver industry areas, Otis E. Young underlines, should be considered a technological innovation, comparable to methods commonly used in Europe. Here, a large amount of fuel was used to reach the high temperatures needed for smelting silver ores (Young 1994, 115). The reduced quantities of wood and charcoal needed because of the use of mercury in the amalgamation process meant that no long lasting interest in natural black coal deposits evolved. Thus, the amalgamation process, a relatively fuel-efficient and low-cost technology, became established in all parts of the Spanish American Empire. In Huancavelica, where wood for heating the amalgam became scarce, timber was substituted by *icho*, a type of grass (Moore 2003; Studnicki-Gizbert and Schecter 2010). In the Zacatecas silver mining region, there was no lack of timber as charcoal could be obtained from the surrounding canyons (Bakewell 1971, 146–147).

Mercury was mined in Huancavelica in Peru, in the so-called “death mine” near the largest silver mines in Spanish America. Before mercury was discovered in Huancavelica, another important mercury mine, located in Almadén in Spain, supplied the silver regions of New Spain (Bakewell 1997, 120–122). In Almadén, the first Spanish mining school was founded in 1774. This new school quickly became part of a transcolonial network of knowledge exchange, mostly with the

German mining schools of Banská Štiavnica (Schemnitz) in Austrian Slovakia (1735, resp. 1770), Freiberg in Saxony (1765) and Clausthal in the Harz-region (1775), which had been founded in the same period. This European network of mining knowledge transfer was comprised of French and British academies and mining schools. All of them concentrated mostly on geological surveys, the construction of galleries, drainage and how to employ machines for these purposes. The treatises and curricula dealt mostly with silver, mercury, copper and iron, but neglected the geological and mineralogy characteristics of black coal and the technologies of coal mining.

The dark side of the extensive use of mercury (and lead) in Spanish silver production was the enormous impact it had on the health of humans and animals, and the contamination of rivers and surrounding landscape (Brown 2012). The silver industry profoundly reshaped the Andean landscape, as great amounts of water were needed to wash away the waste from the mix of silver, mercury, rock, sand, chalk and other ingredients (Moore 2003). From the seventeenth century, the industrialization of the silver industry was accelerated with huge investments of public capital; private capital was accepted only when submitted to the regime of concessions. Concessions did not allow investors to act in their own right but rather allowed the official authorities to take precedence over private investors. Furthermore, the Crown held a monopoly on mercury, impeding its exploitation anywhere other than in Almadén and Huancavelica. It also blocked the importation of much less expensive mercury from outside the Spanish Empire (Trabulse 1988), and a royal decree from 1694 expulsed the Fuggers—a German trade and bank company to which the Spanish Crown had become heavily indepted to—from Almadén (Bakewell 1971, 167). Here, transcolonial interrelations were banned by a strong governmental act against mercury importation.

One of the main features of Spanish mining history is that, since all mines belonged to the Crown, concessions accorded to private capital investors were very strictly associated with estimated yields and renovation work. In contrast to the British situation, mining industries in the Spanish domains did not represent an economic sector where private investors could expect to accumulate massive capital (Chastagnaret 2001). Nevertheless, silver mining in Spanish America can be seen as an "industry" that expanded to many Spanish American areas with silver deposits. Besides Huancavelica, Zacatecas should also be mentioned as the other most important Spanish silver region (Bakewell 1971; Brown 2012).

With the arrival of steam engines, economic activities in the colonies began to diversify and coal became an important factor for sustaining these new developments. The Peruvian case shows that more or less abandoned silver mines were reopened with the help of steam-driven pumps (Boase 1818).

Cuban Coal

The Unfortunate History of the Analysis of Cuban Coal

The history of coal in Cuba started in 1828 when the first black coal was extracted. It was discovered by Ramón de la Sagra, who in 1828 published an account of his findings near Havana, at a site called Guanabo. The director of the Botanical Garden of Havanna refers to this discovery in a journal he published, *Anales de ciencia, agricultura, comercio y artes*. He combines the description of the coal deposits with a description of copper sites—a combination I will come back to later in this article. The nine-page article by de la Sagra seem to be extracted from a lecture or series of lectures he had given to "the youth of Havana" in a newly founded section of the Economic Society of that town. De la Sagra reports that a piece of coal was given to him, which he first analyzed optically. The botanist could identify a density of 1,18 g/m^3 and a composition of 72 percent coke and 24 percent bitumen. By combustion he obtained the following results:

Matière volatile..	28, 00
Charbon.	60, 00
Cendres et résidu..	12, 00
	100, 00

Figure 10.1: Sagra 1828 (reproduced in Sagra 1842, 132).

De la Sagra was not the only one who was optimistic about the discovery of coal. Two geologists published a paper in the *Transactions of the American Philosophical Society* in 1839, referring to the carboniferous deposits. The authors were the Briton Richard Cowling Taylor and the US American Thomas Green Clemson, who apparently came to Cuba as mining experts for British copper mining companies. Before his sojourn on the Caribbean island, Clemson had studied at the Royal School of Mines in Paris. He then worked for some years as a mining engineer in the United States. After his Cuban experience, which lasted at least from 1838 to 1842, he returned to the United States where he became a renowned agricultural advisor and founded the Clemson University in South Carolina. His British colleague, Richard Taylor, had a less academic career. The author of *Statistics of Coal [...] on the American Continent* (1855) approached geology and mining in a more practical manner, guided by the famous self-made geologist William Smith before working as a mining engineer in the United States.

Together, they published the article *Notice of a Vein of Bituminous Coal, Recently Explored in the Vicinity of the Havana, in the Island of Cuba*. Herein, they concluded:

> The foregoing examination of this bituminous coal, fixes definitively the respective proportions of its component parts; consequently, it determines the applications to which that combustible would be the best adapted. Its quality of burning with a long, licking flame, gives it many advantages for evaporating, heating surfaces, &c., over many combustibles, which contain smaller quantities of volatile matter. For the generating of steam power, for the boiling or concentrating, the juice of the sugar cane, or for the manufacture of gas, this coal is singularly well adapted. As it contains no sulphuret of iron, the gas manufactured would be free from that very deleterious portion or admixture, which it is so difficult to separate from those gases usually manufactured from bituminous coals containing sulphur. It might also be employed with advantage in manufacturing lamp black (noir de fumée). (Taylor and Clemson 1839, 195)

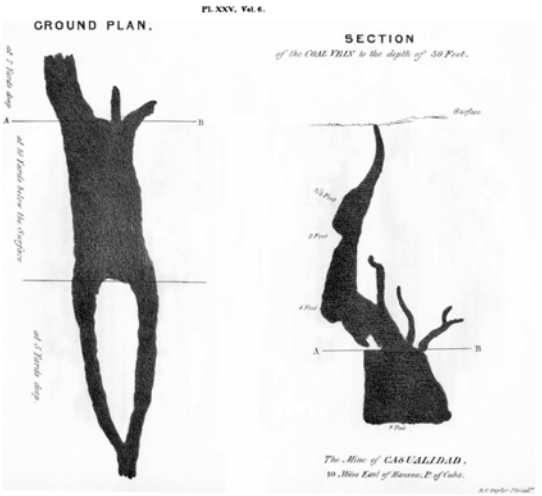

Figure 10.2: Plan of the coal deposit (Taylor and Clemson 1839).

In 1842, only three years after this paper had been published, Clemson became a member of a commission assembled by Cuba's governor who ordered the commission to report on all mining activities in the country. The conclusion of the final report differed greatly from the positive conclusion Taylor and Clemson had reached in 1839. The commission wrote that when used to heat a steam engine or a smelting furnace, the so-called coal glued up the smelter or furnace. The committee proposed to employ the highly bituminous material instead to produce coke and coal gas. The commission's report finally concluded that these circumstances made the exploitation of the mine La Prosperidad of utmost importance for the city of Havana. It was only a matter of time before the necessity of introducing coal into the economic sector of public and private lighting would become evident (AHN Ultramar 77, Exp. 4).

The analysis by Clemson and his colleagues from the commission of the chemical properties of the matter extracted at La Prosperidad differed from previous analyses, as for instance in 1839 when they concluded: "We have here, in the strictest sense of the word, a coal vein, and unlike any we have before witnessed in any part of the world!" (Taylor and Clemson 1839, 193).

Thus, the report of the commission, as well as a comment on this account by the inspector of mines in Cuba, Joaquin Ezaguirre, stated that the coal of La Prosperidad contained too many bituminous parts in its chemical composition (AHN Ultramar 77, Exp. 4) for it to be used directly in any kind of production.

Ramón de la Sagra, who at that time was living in Paris, asked some of his contacts in Cuba to send him some samples of coal and copper from the Caribbean island. After having analyzed them anew, either by himself or with others, he corrected his results from thirteen years earlier in his most famous work on the physical, political and natural history of Cuba in 1842 (Sagra 1842, 72–73):

Matière volatile.	**63, 00**
Charbon.	**34, 97**
Cendres et résidu.	**2, 03**
	100, 00

Figure 10.3: (Sagra 1842, 131).

De la Sagra mentions Taylor and Clemson's paper of 1839 and accuses them of mistaking a fissure for geological strata, when they wrote that a unique geological structure could be observed there (Sagra 1842, 130). In his description, the Cuban

botanist includes a more profound geological observation than Taylor and Clemson did, or as he stated in 1828, it would be hard to call the bituminous deposit a "strata" in a geological sense. Sagra admits that the matter could be reduced to "light and voluminous coke" which after combustion would leave only a little ash (Sagra 1842, 131–132).

The erroneous chemical analysis was only one aspect that hindered the flourishing of the coal mining industry. The commission of 1842 suggested that to produce coal or coal gas from bituminous coal, as was the aim in the context of globalized economies, was to make such a matter usable for any commercial purpose. The council was obviously referring to the fast growing economic sector in Europe and the United States. Since William Murdoch had installed the first lighting system in the cotton manufacture of Philips and Lee in Manchester, and published the results in the *Philosophical Transactions of the Royal Society of London*, many factories and workshops (Murdoch 1808), some private homes and streets in London, Baltimore and elsewhere were lit by lamps running with distilled coal gas (Tomory 2011). Still, the installation of public lighting would first be introduced in Havana in the 1870s (Altshuler 1997) and this kind of asphalt found in different deposits on the island would be commercialized only at the beginning of the twentieth century when US companies gained full access to Cuban mining industries (Monthly Summary of Commerce 1901).

Obstacles in the Establishment of Coal Mining

One important problem that Cuban coal miners envisaged was that no proper legislation existed on the island for the mining of coal (AHN Ultramar 14, Exp. 4, 4–4). Under the direction of Fausto Elhuyar, a new mining law was approved in 1825 for all Spanish territories, but its implementation was discussed in many cases. This legislation demanded that a special court be implemented before any real activity could begin (Chastagnaret 2001; Whitaker 1951). Thus, Cuba had no special tribunal that dealt with mining activities. A similar situation emerged in Biscaya and Asturias when the first small, opencast coal mines were exploited by private persons (Gómez 2005, 259).

The problem mining companies encountered within the Spanish legal system are maybe best described in the words of two engineers, Fernando Bernaldez and Ramón Rua Figueroa, at the mines of Almadén:

> The corpus of rules of this important public enterprise is comprised today by a heterogeneous series of rules and regulations. Some of them were made in response to momentary necessities, suggested by the political requirements of our unhappy epoch, revised with an almost entire lack of a stable and systematic foundation that should

> define without alteration the operations of these industrial and administrative establishments. (Bernaldez and Figueroa 1861, 81)

Another administrative obstacle was an ongoing dispute between the *Inspector de Minas*, Joaquín Eizaguirre and the Cuban civil and military government, appointed in 1842. Eizaguirre was appointed inspector of mines on the island and claimed to have the right to inspect the entire islands of both Cuba and Puerto Rico. The civil and military government of Cuba contested this right. This Caribbean conflict seems to be the same as the one in Spain, where a dispute between administrative authorities and the mining engineers corps had remained unresolved since the early 1840s (Chastagnaret 2001). The civil authorities of Cuba contested the claims of the Ministry of Finances, which in 1842 had planned to end an exemption from taxes that favored copper mining companies (AHN Ultramar 77, Exp. 4).

A further obstacle that from the very beginning hindered the rapid growth of the coal mining economy in Cuba was a lack of infrastructure to transport the minerals from the mines. The easiest and shortest transport routes were usually from the mine directly to a harbor. But the condition of these routes was very poor and railway construction was in its infancy. In 1848, members of the Economic Society of Friends of the Country in Havana stated that the reason why workshops and factories to further process the coal were often concentrated at the same location was due to Cuba's deficient infrastructure. The effort and costs involved in transporting the coal were simply too high to disperse the various stages of production to more appropriate locations (Memoria 1848, 36).

Nevertheless, the economic and infrastructural environment for coal mining showed some positive features. The scarce historiography available underlines the fact that the few railways to be constructed in Cuba were developed mostly in dependence on the sugar industry. Michael Zeuske stresses that the first railway was used to transport sugar, and possibly also slaves, and to explore remote parts of the island (Zeuske 2012). The Catalan entrepreneur Miquel Biada i Bunyol, who had a close relationship with the governor Miguel Tacón y Rosique, promoted the construction of the first railway in Cuba, which after its inauguration in 1837 became the first railroad in a Spanish territory. After this success, Biada i Bunyo returned to Catalonia where he contributed to the first European-Spanish railway, which ran from Mataró to Barcelona (McDonogh 2009, 64). In 1854, Policarpo Cía mentioned in his geological report a railway from La Regla to Guanabacoa, which spanned a distance of around six kilometers (Cía 1854, 11). The importance of this facility for transporting people is shown, for instance, in the order that the governor issued to the railway company to waive the transportation fees for pupils of the Mechanical School of Havana (AHN Ultramar 30, Exp. 32).

An important copper mining industry had existed on the island since the late 1820s. Thanks to large amounts of invested capital, mostly of English origin, more than 30 copper mines were working in the region of Santiago de Cuba (AHN Ultramar 77, Exp. 4). The Spanish Cuban government granted concessions for mining for these foreign enterprises with an additional privilege that exempted them from export taxes for a duration of ten years. Shortly before this privilege was phased out, after an intense discussion between the Cuban government, the inspector of mines and the Spanish ministries of Ultramar and of Hacienda, the decision was made in 1842 to prolong the exemption for two more years. During this time, the copper mine owners were required to invest in copper furnaces in Cuba, which at that time were still very rare. Because of the investment capital from England and the tax-free export of crude copper ore, this material was shipped to Britain and smelted in the Swansea area. Thus, no proper copper industry developed on the Caribbean island, but once presumptive coal was found there, the Cuban authorities envisaged a next step in the industrialization process.

The Economic Development Related to Coal

From some of the archival sources, it can be read that great hopes were invested in the exploitation of coal mines. After Spain had lost most of its Latin American colonies, which the empire relied upon for natural resources, the recently discovered Cuban coal raised the shrinking transatlantic power's expectations for the future. The government and the enlightened forces on the island, still allied with Spain, hoped that the use of coal could help to stabilize the economic and political situations in Cuba. They were well aware of the increasing importance of using coal in heating, industry and transportation in many European countries. Coal mined in Cuba could diminish the dependence on transatlantic coal transports from northern Spain, or the import of coal from England or the United States.

The uses of coal were well known in Cuba. In 1841, the Mining Administration of Havana expected the exploiters of the coal mines in Cuba

> […] to adapt the exploitation if possible to a scale necessary for the different applications in craftsmanship, and the large consumption for navigation and even for domestic issues […] (AHN Ultramar 14, Exp. 4)

As the correction of the results of the chemical analysis revealed, there was a lack of geological knowledge on the island. Between 1842 and 1844, the only known coal mine was La Prosperidad and although this mine had been exploited for around twelve years and had since been partly depleted, no further geological or mineralogical examination had been undertaken. Only in 1854 did the mining

engineer and geologist Policarpo Cía describe the deposit, situated only five miles from the center of Havana, as follows:

> The mine Prosperidad, […] presents the same qualities of combustible, even if in earlier times this was not believed. At that site, for the first time, the bituminous mineral had been shown to be constituted of quite homogenous layers and to be of some importance. (Cía 1854, 15)

Previously referring to La Prosperidad, Cía described bituminous deposits near the ancient coal mine:

> Between Bacuranao and el Puente, two leagues east of Regla, near the route to that location, I was able to observe on crumbly terrain without stratification […] a cut of 14 varas width ending on a bank of asphalt which in two cuts turned out to be one half and three-quarters of a meter thick. […] There is no trace of stratification of that combustible at the beginning, but it is divided into different directions. With regard to its structure, this resource has two characteristics: one part is compact when fractured; united, homogenous and brilliant; reflects many circles of different diameter. When rubbed a bituminous smell can be perceived as well as electricity, which is evident. When put into contact with the fire of a heater plug, it starts to smelt and then catches fire. When put onto iron at a temperature of 130° it will also smelt entirely. Because of these characteristics, it thus becomes evident that this substance is asphalt and not bituminous lignite, as it was once believed to be. (Cía 1854, 14–15)

By the time Cía visited the site of La Prosperidad, the company that had founded the mine had dissolved ten years earlier.

A report from August 1844 (AHN Ultramar 77, Exp. 4) states that as a result of the small production rate of La Prosperidad, the enterprise of Prudencio Casamayor and Joaquín (de) Arrieta went bankrupt. The company's mining concession, obtained for extraction in 1832, was meant to bring other investments into this new economic sector. From the 1820s on, Casamayor was already engaged in the copper mining branch. Arrieta was one of the Spaniards who fled from Santo Domingo to Cuba during the wars of independent Haiti against the Spanish-dominated part of the island between 1822 and 1824. Casamayor founded a commercial business in Santiago de Cuba and in 1827 started his first copper mining business (AHN Ultramar 6, Exp. 7). At the end of the 1820s, Joaquín de Arrieta owned three mining businesses in the region of Santiago (Roldán de Montaud

2008, 362). These men first became associated with one another in 1830 when, in collaboration with other entrepreneurs, they founded a copper mining enterprise. Apparently, the capital used to set up that company was mostly of English origin for reasons mentioned above. But this Spanish-Cuban initiative became more autonomous from its English investors when it split from the Consolidated Copper Mines of Cobre Association in 1841 and founded the enterprise Cubana Cobrera (Roldán de Montaud 2008, 363–364).

All of this indicates that the entrepreneurs of La Prosperidad were in no way new to the mining industry, but part of a respected and influential group of mining entrepreneurs who began to defend their economic interests with political and administrative initiatives. They were in a much better economic and political situation than Ramon Villota and Juan Pujol, the founders of the carbon mine La Prosperidad, who are reported to have found the coal and initiated its exploitation (AHN Ultramar 14, Exp. 4, 7).

The company that ran La Prosperidad had asked the Cuban governor to act on its behalf in dealing with the Ministry of Overseas Affairs (Ministerio de Gobernación de Ultramar) and the Bureau of Mining in 1841. The aim was to obtain permission to increase its production. At the same time, the governor was asked to promote a tax increase on imported coal. Although the secretary and the Bureau of Mining were receptive to both propositions, the administration remained skeptical of the company's capability to produce enough coal to cover its consumption on the island at that time. As long as this was not proven, the Ministry of Overseas Affairs was reluctant to increase taxes on the import of coal (AHN Ultramar 12, Exp. 7).

The Environmental Implications of Coal Use in Cuba

In petitioning the Ministry of Overseas Affairs and the Bureau of Mining, the company highlighted the importance of coal consumption in the island. From the 1848 memorandum of an industrial exposition, held in 1847 at the seat of the Economic Society of Friends of the Country of La Havana and organized mainly by that organization, we are aware of a wide range of machines and engines in various sectors of industry that ran on coal. We also learned of forges in different towns in Cuba where coal was used. Some of them, or at least for some of the smelting processes, used pit coal. Others used the charcoal that was produced on the island. In an account published in 1866, the historian Jacobo de Pezuela gives some data regarding the production of charcoal in various places. In Las Pozas, 130,000 *sacos* (sacks) of charcoal were produced annually (Pezuela 1866). This represents around fifty tons of charcoal whose production would have required burning a quantity of timber ten times higher. Maybe Las Pozas was the largest of

Cuba's charcoal production sites, but it was not the only one mentioned by Pezuela in his dictionary on the geography, statistics and history of Cuba (Pezuela 1866). Some authors claimed that consumption of vast amounts of wood was detrimental to the island's environment and economy. The Cuban author and statesman, José Antonio Saco, who for many years lived in Europe after criticizing the Spanish government in Cuba, illustrated this relation between forest and economic development:

> It is useless to evoke the necessity of forests for the construction of boats, buildings and other kinds of indispensables. Everyone is convinced that this is appropriate, but as long as the particular circumstances of Cuba have not been studied, the amount of efforts needed will remain unknown. Although the island is large, its territory is small compared to continental states; its population is small but is increasing fast; almost all of its riches come from agriculture, especially from the cultivation of sugar, which could not be produced without the use of combustibles. No coalmines have been discovered until now […] It seems imperative to conserve the forests and to establish new ones in view of the smallness of its territory and its quick increase in population and agriculture, especially its peculiar character, the absence of combustible minerals and, above all, the need to constantly maintain substantial naval forces. If in brief nothing is done to avert this dangerous calamity, the day won't be far away that when constructing a house in Cuba the timber has to be solicited from foreign countries. In this, Cuba will become tributary and a miserable slave […] Luckily, some efforts have been made to establish forests, but their scarcity is mostly felt by the *ingenios* […] (Saco 1860, 45–46).

Some of the mechanical devices could be run on charcoal or even timber, but most of the engines imported from Europe and the United States needed a high proportion of mineral coal, which in some cases could be mixed with charcoal. The trains ran partly on coal, and were partly hauled by mules (Zanetti Lecuona and García Alvarez 1998). Pezuela mentions among other engines two dredgers working at the port of Havana (Pezuela 1871, 130). To fuel the mail boats, coals from Asturias and England were mixed together (AHN Ultramar, 434, Exp. 15). But the largest consumer of mineral coal would still have been the sugar industry, where a number of steam-engine driven machines were employed (Moreno Fraginals 1964). Unfortunately, insufficient research has been done in this area to ascertain the number of steam engines on the island at the time or the amount of combustibles with which they were fed.

A Co-Evolutionary Relationship: Copper and Coal

The question of increasing taxes on imported coal mentioned earlier was related to the flourishing copper industry on the island. Copper mining and smelting in Cuba is another neglected issue in historical research, as Inés Roldán de Montaud stated some years ago. Most of the copper mines situated in the district of Santiago de Cuba were in the hands of English investors (AHN Ultramar 77, Exp. 4). In February 1833, the Spanish government issued the investors with a ten-year tax exemption for the export of crude copper. Furthermore, instead of paying 10% tax on processed copper, as was the case for colonial silver mining in New Spain, in Cuba copper entrepreneurs were charged only 5%. Thus it is not surprising that in 1836, one third of all imported copper in Great Britain (6,425 of a total of 19,466 tons) came from Cuba. The total output of Cuban copper mines doubled between 1833 and 1834, and Roldán estimates the output in 1845 at around 39,000 tons (Roldán de Montaud 2008).

Because of the investment capital from England and the tax-free export of crude copper ore, this material was shipped to Wales and smelted in the Swansea region—the so called "Copperopolis" (Hughes 2000; Miskell 2003; Newell 1990). In this domain, Cuban copper suffered the same fate as Chilean and Peruvian copper: at that early stage of global economies of resources, copper as a raw material was transported from all around the world to be smelted and processed in Wales. Thus, no proper copper industry was developed on the island (Roldán de Montaud 2008; Valenzuela 1992).

The issue of copper and coal became more relevant in the 1840s when the tax exemption was about to expire. Within ten years, as the data shows, copper mining had become an important economic factor in Cuba. Although the authorities hoped that this evolution would continue, even without the tax exemption, they still inquired as to how more stable capital investments could be secured for the copper mining industry. After months of discussions, the Ministry of Finance, the Ministry of Overseas Affairs and the Cuban government decided to extend the tax exemption for a further period of two years. Within these two years, the copper enterprises were expected to construct furnaces for smelting the copper ore. The Spanish-Cuban authorities were hoping to develop not only the mining sector itself, but related industrial branches as well such as the smelting and construction industries (AHN Ultramar 77, Exp. 4).

This administrative reasoning, leading finally to an economically motivated decision, was the primary reason why coal once again became a major issue for the island. In order to smelt the copper ore in Cuba, more coal was needed to supply the furnaces. But the English investors were having a hard time themselves and could barely cope with the political situation on the island. Reports dating from the beginning of the 1840s showed increasing xenophobia against

the British in the copper mining sector. At the same time, it was denied that the group managing La Prosperidad was at all dependent on English capital (AHN Ultramar 77. Exp. 4). This fear of foreign investment in the Cuban economy was by no means limited to the copper and coal mining business, but was also present in the tobacco industry as well. The employment of steam-driven machines for the processing of tobacco in England disturbed the finishers in Cuba. In future, they stated, instead of buying the finished tobacco product, the British should exclusively import raw tobacco and process it in British tobacco factories. This had devastating consequences for the Cuban tobacco industry, leading entrepreneurs to demand consistent sanctions. Both a technological advancement in Cuban tobacco production processes and a levy of export taxes for raw tobacco would be needed to protect domestic tobacco production (Memoria 1848, 38). One of the initiatives of the coal mining entrepreneurs was to demand from the Cuban government an increase in coal importation taxes. They also asked for a scientific survey from a Spanish engineer familiar with coal mining and for permission to extract a larger amount of coal than was originally agreed upon.

Other sectors of the Cuban economy prevailed. The sugar industry can be regarded as a catalyst for innovation when referring to technological means of production (Dye 1998, esp. 41–48; Edquist 1985). This was shown in the 1847 exposition, mentioned earlier, during which awards were given to outstanding products fabricated in Cuba (Memoria 1848, 5). One silver medal was granted to the School of Machinery, which had been founded by the Society. Under the supervision of their instructor, Pedro Teodoro Vaurigaud, pupils had constructed a turning lathe and various mechanisms for steam engines (Memoria 1848, 52), which could be employed in different sectors such as sugar refinement. In Havana, it seems to have been possible to work iron for such purposes as the construction of machines or machine parts or the amelioration of imported engines. At the port of La Regla, iron-smelting furnaces could be found, and the jury at the exposition expressed its desire to increase the production of iron —"the king of all metals"—on the island (Memoria 1848, 49).

Knowledge About Coal in a Colonial Environment

Knowledge About Coal in Cuba

There were several factors that hindered the development of coal-mining skills in Cuba. In 1844, the inspector of mines, Joaquín Eizaguirre, mentioned earlier, was asked by the Ministry of Overseas Affairs to choose an intelligent young man to whom he could teach his duties. The ministry claimed that this young apprentice would then assist Eizaguirre in his office. At that time, there were only limited op-

portunities for higher education and only a small number of professionals worked in institutions (Altshuler and Baracca 2014).

Félix Varela described this situation in 1814 in his work *Instituciones de filosofía ecléctica para uso de la juventud* (Gran 1945). But in the following decades, some initiatives related to the Economic Society were undertaken. A member of that society and secretary of the Section of Education, Alejandro Ramírez, who before coming to Cuba lived in Guatemala and Puerto Rico, asked for chairs in physics and chemistry to be founded at the University of Havana (Altshuler and Baracca 2014; Puig-Samper and Maldonado 2005). The authors of the memorandum of the 1847 exposition demanded better education opportunities on the island and especially insisted on the need for a chair in chemistry:

> Sciences are like a torch that sheds its light on the workshops of industries in order to illuminate with its clear and brilliant light all its operations, and avoid any doubts, uncertainty and all awkward experiences of a simple routine. (Memoria 1848, 65)

This demand sheds light on the limited degree to which the Spanish authorities were willing to invest in an educational system on the island. It seems they were only willing to provide state-sponsored education to select individuals in the mother country. As the coal mining situation in Cuba became untenable, the Cuban authorities demanded that the Ministry of Ultramar send a second mining engineer to the island to assist the inspector of mines. The ministry, however, was reluctant to help and instead asked the inspector to find and train a new assistant on his own (AHN Ultramar 77, Exp. 4).

The lack of special training institutions was a common problem for colonial mining, and this had been the case in New Spain since the eighteenth-century. The Royal College of Mines in Mexico, founded only in 1792, was initiated, organized and headed by Fausto Elhuyar. He came to New Spain after studying at the Royal College of Mines in Almadén (Spain) and after having worked as an engineer in various royal mines around Spain. In New Spain, he promoted enlightened education and economic politics, and encouraged the institutionalizing process of engineer training. Previously, mining experts had been trained in the early modern style of transmitting knowledge through everyday practice (Sumozas García-Pardo 2007, 28–70). The Economic Society of Havana reported a similar situation in the silver industry on the island. The assayer (*ensayador*) of silver ore was not a trained chemist—as was the case in Europe's silver mines—but a person who had learned his trade through practice (Memoria 1848, 47).

An education in geology, mineralogy or mining techniques was not available in Cuba and the possibilities of intercolonial student exchange, for instance with New Spain, were restricted by the government in Madrid. That possibility was

completely removed after Mexican independence. The last option left for Cubans to attain higher and specialized education was to send young men from the island to Europe to pursue their studies in Spain, England or France. Upon their return to Cuba, they would promote specialized studies, propagate their knowledge in publications printed either in the metropolis or in Havana and use their knowledge to benefit the national economy. There is a long list of men who, in the nineteenth century, upon completion of their studies in Europe returned to Cuba to engage in such activities. Among them are Félix Varela, Tomás Romay or Felipe Poey, who all travelled to Europe to study there. When they returned to Cuba, they became distinguished members of the small scientific community on the island. Alvaro Reynoso, for instance, after receiving his PhD in chemistry in Paris, brought the new agricultural methods of Justus Liebig to Cuba (Baracca 2014). His return to the island was part of a contract he had made with the Cuban government wherein the government awarded him a grant to pay for his education in Europe. In return, Reynoso was expected to become a teacher in the Cuban education system (AHN Ultramar. 20, Exp. 21).

Such contracts and the encouragement given to young men to leave the island for prolonged periods of time were supported by a handful of so-called enlightened Spaniards, who either came to Cuba on special governmental missions, such as Policarpo Cía, or because they held important positions in the colonial administration and government. Cía, who in 1854 published his important account on Cuban geology, had worked beforehand in the mining administration of Camagüey (then called Puerto Príncipe) from 1846 to 1850 (AHN Ultramar 19, Exp. 24), and made an inspection tour in 1851 before returning to Spain. Even some Catholic churchmen, such as Bishop Espada, would become promoters of enlightened education at the end of the eighteenth century (Cuevas 1990).

This Spanish-American exchange of knowledge was part of a broader network of exchange that comprised the European Academies of mining (Whitaker 1951), especially the German institutions (Hausberger 2009). The Spanish mine engineers traveled around Europe. German professors taught in Almadén and German engineers went in large numbers to New Spain and independent Mexico to teach at the Mexican Academy of Mining and to work in the globally renowned silver mines. To have seen the mines of Zacatecas or Taxco, Huancavelica or Potosí and to have had the opportunity to work in them and participate in engineering enterprises gave a great boost to the careers of the academics. The experiences made by European mining engineers in various parts of America could either last a lifetime or be limited to a few years. In the latter case, people such as Elhuyar or Cía became important figures in the European Spanish engineer community on their return to Europe.

The Cuban head of the mining department, Joaquin Eizaguirre, studied at the Spanish Academia de Minas in Almadén. He is clearly of Basque origin and maintained a network with other Basques in Cuba. After his time as inspector of mines in Cuba, which began in 1837 (Zamora y Coronado 1840, 477), he neither immediately returned to Spain nor did he engage in any teaching activities. Instead he worked in a private company, which began to build steam ships in Cuba in 1856, with fellow Basques, Antonio and Claudio Lopez and (his supposed cousin) Patricio Satrústegui (Echenagusía 2001; Rodrigo y Alharilla 2010). Only in 1852 did he become a *Negociado de Minas* in Spain and collaborate with the German mining engineer and geologist Guillermo Schulz (Llaneza and González-Pumariega 2005, 44).

A Common History: Spain, Philippines, Cuba and British India

Even though silver and mercury mines were the foremost areas of interest for these engineers, in Spain some specialists were able to scientifically explore the existing coal mines. In his report on coal mining in Catalonia, Joseph Comes, the director of the Botanical Garden in Barcelona, speaks of different special survey missions to Catalan coal mines between 1768 and 1786. The Catalan Real Conferencia de Física completed the first study. Coal was extracted from one of the mines, Villa de Isona, then analyzed and compared to coal of English and Scottish origin. The health authorities of Barcelona demanded an analysis of coal in 1785. Finally, in 1786, the Catalonian Academy assigned the boards of chemistry and of natural history to examine two patterns extracted from recently discovered sites (Comes 1786, IX–X). In Spain, various economic societies promoted the idea of mining mineral coal and organized demonstrations that showed its utility to a broader public. These associations often demanded further geological and chemical surveys of deposits that had been well known since the end of the eighteenth century (Coll Martín and Sudrià i Triay 1987, 17–25). Some of the geologists surveying coal mines in Spain seem to be of German origin: Guillermo Schulz mostly worked on coal mines in Asturias and Galicia from the 1830s to the 1850s (Schulz 1858b; 1858a). Gabriel Heim published a report in 1861 on mines of the Chavitteau mining company at Quirós in Asturias (Heim 1861). Some of the capital investments made there were also of French origin, such as the Compagnie Minière et Métallurgique des Asturies or the Société Houillère et Métallurgique des Asturies (Rißmann 2003, 41). Other companies investing in Spanish coal mines came from Belgium (Coll Martín and Sudrià i Triay 1987, 198).

From a perspective of transfer and circulation of knowledge, Cuba and Cuban mining were still in a rather good position compared to the Philippines, the other remaining Spanish colonial territory. From the 1850s on, on different

islands of that archipelago and on Guam, an island that forms part of the Mariana Islands, coal deposits were found and declared. Nevertheless, the lack of knowledge was such that the owners and entrepreneurs could barely exploit them. A serious lack of geological and mining knowledge hindered the development of a new branch of colonial industries. The merchants who held licenses for exploitation asked the government in Madrid to send a mining engineer from Spain to help to develop the coal mining industry. In response, the Spanish government offered to lend the mine inspector in Manila, José Centeno y García, to the coal mining company. Although he was not an expert in coal mining, he must have been helpful to the company as they repeatedly asked for a prolongation of the lending-contract (AHN Ultramar, 434, Exp. 17). This episode shows that in the Philippines, even less than in Cuba, well-trained personnel for coal mining were available, but the geological knowledge was underdeveloped.

From the perspective of the mistakes made by de la Sagra, Taylor and Clemson, it can therefore be concluded that the case of la Prosperidad was no exception. The knowledge of experimentation with coal was still under development and the analyses they applied were more or less the standardized method of analyzing coal. The determination of a type of coal was carried out by its visual features, often combined with the analysis of its combustion properties. The knowledge these kinds of analyses relied on had been developed over centuries. The different and competing categories of description, and the designation and identification of types of coal, which the analysts in the colonies relied on, had evolved over a long period of time in different parts of Europe.

More sophisticated analyses were carried out in specialized chemical laboratories in Paris and Berlin. Only around 1830 were new methods for analyzing black coal used. These focused not on the amount of "coal," but on oxygen, nitrogen, hydrogen and carbon, as reported by Carl Karstens in his *Untersuchungen über die kohligen Substanzen des Mineralreichs*:

> The real nature of mineral coal and the reasons for its different behaviors, that is, not only the difference between lignite and black coal but even more among the different types of black coal, can only be shown when the ratio of carbon, hydrogen, oxygen and nitrogen is known. (Karsten 1826, 47)

Karsten, a mining expert and chemist, could refer to works by Antoine Laurent de Lavoisier who had discovered carbon and worked with hydrogen. Furthermore, Karsten combined these works with those of Carl Wilhelm Scheele and Joseph Priestley on oxygen. Thanks to Lavoisier and Henry Cavendish, he also knew about the conversion from water to gas, and vice versa. This knowledge was the

basis on which Karsten in 1826 was able to ascertain that it was not the amount of coal but the ratio of the above-mentioned substances that was crucial for identifying the quality of coal. The evolution of knowledge about the chemical analysis of coal did not end with Karsten's publication. He himself mentioned the difficulties involved in understanding the geological history of the composition of this carboniferous matter; he was also unable to explain why the different mechanical devices needed different kinds of coal (Karsten 1826, 78). Yet, Karsten was also unable to solve the main problem of geological prospecting: the composition of a coal-layer, he wrote, was on no account homogeneous. The results of a chemical analysis of one part of the deposit could produce a result that differed strongly from the analysis of other parts (Karsten 1826, 44–47).

Assuming that de la Sagra, or Taylor and Clemson had known the solutions Karsten proposed and possessed all the instruments needed to undertake these analyses, they may still have produced different results in 1828 and 1839. Karsten's specialized knowledge and the ability to implement it were limited to a small number of chemical laboratories in Europe, and neither Spain nor Cuba had direct access to them. Furthermore, de la Sagra, Taylor and Clemson made the common mistake of analyzing only one extract from the deposit rather than sampling more material, as de la Sagra did before publishing his *Histoire*. This confinement of scientific practice was something British geologists and scientists in the British colonial world experienced as well. News of the findings in Cuba spread almost immediately to British India, where only four years later de la Sagra published his results in the *Anales de ciencia, agricultura, comercio y artes*, the director of the Asiatic Society in Calcutta, James Prinsep, referred to them in a journal he published, *Journal of the Asiatic Society* (Prinsep 1832b, 366). Prinsep was very committed to encouraging the colonial government to exploit coal deposits in the Khasi-Hill region, today the state of Meghalaya (Watson 1834; Grout 1995). Thus, the results of the analyses of Cuban coal were also debated in the Cuban Spanish community and eventually shown to be wrong, the knowledge about this spread around the world in transcolonial form: it did not circulate via Europe or a European publication. Prinsep referred to de la Sagra by citing the Cuban journal as source of his knowledge. Thus, Prinsep was convinced by the data de la Sagra had published. Furthermore, in 1832, Prinsep himself published the results of a proto-chemical analysis of coal extracted from the Khasi-Hills and other Indian regions in the *Edinburgh New Philosophical Journal* (Prinsep 1832a, 347–349). The form of the table is reminiscent of those presented by de la Sagra. The difference between the results was that Prinsep's outcome fortunately depicted the quality of the matter extracted from the mines, whereas de la Sagra's results differed considerably from the rest of the sediment.

Conclusion

The issue of coal in Cuba, though a very short episode in history, has revealed transfer processes between English, Spanish, Catalan, Cuban, Mexican, US American and French actors. It has also revealed an even broader network of knowledge, which is less actor-related but rather constituted of books published from the late eighteenth to the mid-nineteenth centuries. The colonial situation for structuring these networks of knowledge transfer is of immediate importance, as Cuba was still a Spanish colony. Spain's weakened colonial domination would continue until 1898, when it lost the rest of its remaining overseas possessions. England was a colonizing state and communication was structured by this expansive engagement, which reached India. US colonial activities were first comprised of a continental expansion, with increasing overseas expansion taking place at the end of the nineteenth century.

The history of coal mining in Cuba is therefore a case of transcolonial transfer and adaptation processes. British and US American investors acted within the Spanish dominion. Spaniards and criollos, who had fled the war in Santo Domingo/Haiti, came from the former Spanish colonial territories; some had arrived from Spain to work as entrepreneurs or administrators. Cubans studied in Paris, London, Philadelphia and Madrid before applying their knowledge on their home island. The resource "coal," increasingly important in many branches of the industrialized production of goods, became an issue of concern, even in regions of the world where industrialization seemed to differ from the English model. This was the case in some parts of the European continent and in some of the British colonies, for instance, where an alternative method was used to produce goods for mass consumption (Bayly 2004).

The extent to which industrialization can be understood as a product of the transfer of knowledge is still an open question. Area studies have mostly been undertaken that have showed the advancement of the new production method and the changes in social composition and working conditions. This short case study on the history of coal mining in Cuba investigates local and regional differentiations and the interdependencies that occurred. Industrialization depended on factors such as changing patterns of consumption and production. It thus remains pivotal to any study of industrialization to consider the resources that were needed to industrialize processes of production and to produce newly demanded commodities. Furthermore, it is important to define in a certain context the role that knowledge of the resources and technologies played in developing new industries.

The Cuban case shows a process involving the both the experiences already made with coal as a resource and new developments, both intermingling with the idea of a local production of this mineral. In the social and political situation of

Cuba, local, colonial and foreign actors focused on coal for different reasons in different economic sectors, also in public administration. They searched for new possibilities to develop their finances or to create new economic systems; they also had to prospect for new ways of increasing knowledge. Thus, the rather short and limited experiences made with this carboniferous resource initiated processes of social, economic and political adaptation.

The short period of the local coal mining economy represents, for instance, a history of expansion of economic activities into the mining and transportation sectors. Coal in the Cuban economic situation of the first half of the nineteenth century also represented possibilities to substitute locally available organic combustive resources with either rare local timber or imported coal. Timber was a highly coveted resource in Cuba because an important shipbuilding industry existed there that claimed most of the high-quality timber. Converting timber into charcoal was quite ineffective, but some of the transportation facilities, *ingenios*, factories and forges used this organic material. Expectations for yields from the local production of coal were much lower than for imported coal, coming mostly from England. The ignorance of geological circumstances and chemical features encouraged ideas of economic development and this probably led to the different branches of Cuban economic and administration to keep a close watch on this new industry.

In focusing on these local examples, industrialization and the industrious revolution can be analyzed as part of a knowledge transfer processes, and not simply as part of a new developmental step of capitalism.

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