



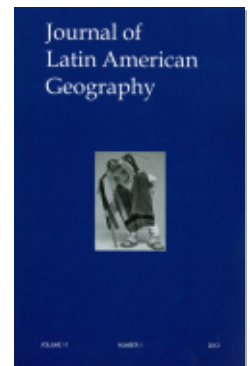
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Sulphur Mining on Mexico's Popocatepetl Volcano (1820-1920): Origins, Development, and Human- Environmental Challenges

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Abstract

This paper traces the origins and development of a little-known extractive industry in nineteenth-century Mexico: volcanic sulphur mining. Unpublished documents from Mexican archives, nineteenth-century travel literature, reports from early scientific expeditions, and historical newspapers provide the bulk of data. Documents show how both Mexican and United States interests – indigenous sulphur miners (*azufreros*) and venture capitalists – confronted the challenges of mining sulphur from the crater of Mexico's Popocatepetl volcano, at 5,426 meters (17,802 feet) elevation.

Keywords: *mining, Popocatepetl, positivism, sulphur*

Resumen

Este artículo traza los orígenes y el desarrollo de una industria extractiva mexicana del siglo diecinueve poco conocida: la minería del azufre volcánico. Documentos de archivos mexicanos no publicados, la literatura de viajes del siglo diecinueve, los informes de expediciones científicas, y los periódicos históricos proveen la mayoría de los datos. Los documentos muestran como los intereses mexicanos y estadounidenses –los mineros indígenas de azufre (*azufreros*) y los capitalistas de riesgo– enfrentaron los retos de extraer el azufre del cráter del volcán Popocatepetl, a una altitud de 5,426 metros sobre el mar.

Palabras clave: *minería, Popocatepetl, positivismo, azufre*

Introduction

Natural resource management has received far less historical attention in newly independent Mexico (1821-1910) than it has in the colonial or post-1910 Revolution eras. For most of the nineteenth century, resource management lacked the administrative clarity imposed by the former Spanish monopoly system or the detailed record keeping of the eighteenth-century Bourbon Reforms (LaFevor 2012). In addition, the foreign invasions and political turmoil of this time hindered resource development and organizational continuity, and new forms of proto-industrial growth struggled to develop in the newly independent Mexican state. That is, until Mexican dictator Porfirio Díaz solidified control over the country's vast natural wealth and implemented a developmental strategy based on the philosophy of *positivismo* (positivism) during the late nineteenth century.

This paper investigates the origins and development of a little-known extractive industry during this time – volcanic sulphur mining – and how its unlikely development is a prime example of Díaz's positivist ideology. It presents a case study of sulphur mining on the volcano Popocatepetl, which contained, at the time, the world's largest known, and perhaps most inaccessible, deposits of the mineral. As a critical ingredient in industrial manufacturing, sulphur was in high demand, yet the western hemisphere lacked a significant supply, instead importing the mineral across the Atlantic Ocean from Sicily. To remedy this geographical imbalance, Mexican and United States interests attempted to develop Mexico's Popocatepetl volcano into the western hemisphere's first industrial sulphur supply, creating, in the process, the world's largest sulphur mine. The elaborate plan, which documents reveal has roots in the mid-nineteenth century, culminated in 1904 with the selling of the volcano and surrounding lands to a New York based company for US \$300,000 (*El País* 1904, *Los Angeles Times* 1904). The volcano and surrounding lands comprise one of Mexico's most recognizable landscapes as well as a critical environmental resource and center of ecological diversity (Heil *et al.* 2003). The little-known sale and attempted development of Popocatepetl is a prime example of an aggressive Porfirian developmental strategy that was willing to sacrifice Mexican territorial integrity in the name of order and progress.¹

President Benito Juárez was the first to introduce positivism as the official philosophy of Mexico in the 1860s. Positivism, and positivistic science, was defined at that time by an elite group of qualified experts tasked with pointing the way towards order and progress (Zea 1997). The philosophy presupposed a conception of reality that was ordered and certain, with fixed patterns of truth discoverable only by science. Scientific truths were evident in the natural manifestations of phenomena, and, in turn, positivist knowledge of these truths was considered not only philosophically, but was actively applied by various institutions to the human condition and all of its problems (Raas 1977, 1984). Science, as conceived by positivist ideology, was the key to solving Mexico's social problems, and its introduction into the public sphere necessitated centralized planning and effective strategies of economic and social development (Rocco 1984). Under Juárez the initial emphasis of positivism was on establishing advanced educational programs to train groups of highly educated technocrats who would, in turn, reinforce positivist thinking in the reconstruction of Mexican society. But during the rule of Porfirio Díaz (1876-1911), positivist thinking became increasingly focused on the mechanics of economic growth and development. Díaz's cadre of technocratic advisors, appropriately named the *científicos*, designed and implemented economic policy, seeking, above all, tangible achievement and material progress (Krause 1976). Studies of Porfirian Mexico are replete with descriptions of how the philosophy, or ideology, manifested in the dictator's decision-making (Flower 1949; Raas 1973; Towner 1977). In short, his official development agenda emphasized export-based economic growth and the importation of science and technology from abroad. Economic growth, the *científicos* posited, depended on industrializing Mexico's precious metals, minerals, and other raw materials for export to foreign markets (Munch 1973). As a result, during Díaz's 35-year rule Mexico witnessed the selling of its natural resources, territory, and infrastructure to foreign interests – most notably oil, railroads, and mining concessions (Brown 1987).

Perhaps there is no clearer example of the logic and spirit of Porfirian positivism than the case of sulphur mining on Popocatepetl. Not only were the rights to the volcano and surrounding lands sold to a New York-based syndicate of venture capitalists, but Mexico also imported advanced mining and engineering technologies from the United States for the purpose of developing the volcano's sulphur resources, both with Díaz's personal approval. These actions demonstrate the extreme lengths to which

Mexico was willing to implement its positivist development strategy. The roots of these transactions can be traced to the years immediately following Mexican Independence. This history also shows how one man, the charismatic Mexican General Gaspar Sánchez Ochoa, became owner and entrepreneur of the volcano, eventually selling the promise of the volcano's immense natural wealth to the United States-based Popocatepetl Company in 1904. However, progress is never so ordered as its ideologues might imagine; the conclusions highlight the conflicts inherent between positivist pressures to develop the sulphur mines and the human-environmental challenges of mining sulphur from the volcanic crater.

Early Scientific Expeditions to the Crater and the First Mining Operations

Independence from Spain in 1821 brought many fundamental changes to Mexico's relationship with the outside world. During the colonial period few outsiders had access to the Spanish colony, but shortly after Independence, the rest of the world began the process of "discovering" Mexico as well as its people, history, and natural resources.² During this time, international groups of scientific explorers often investigated the geophysical characteristics of Mexico's volcanic environments.³ The ascent of Popocatepetl and exploration of its crater were favorite objects of inquiry for these groups, who published accounts of their scientific journeys and findings both in Mexico and in journals back home. The first-hand accounts of these expeditions provide original sources of information on diverse aspects of both the remnants of colonial extractive industries and the nascent, proto-industrial operations of the newly independent Mexican state. These accounts include the early stages of sulphur mining development in Popocatepetl. Although volcanic sulphur mining was a vital colonial industry Popocatepetl had yet to be exploited in a systematic way until after Independence.

The British Glennie brothers completed the first successful scientific expedition to the summit of the volcano in 1827 (Thornton 1851, SMGE 1851).⁴ This well-publicized event was followed shortly thereafter by another international scientific expedition that included Federico Gerolt, Baron von Gros, and Edgerton in 1834 (SMGE 1858). Although both of the early expeditions emphasized the measuring of barometric pressures and other biophysical attributes of the volcanic environment, the latter also was the first to describe what appeared to be vast quantities of yellow sulphur at the bottom of the crater. These were the first observations confirming Humboldt's suspicion several decades earlier that sulphur abounded within the volcanic crater (Humboldt 1822: 471).

Then, in 1836, two years after the Gerolt and von Gros expedition, a resident of nearby Amecameca, Ignacio Reyes, first conceived of commercializing the volcano's sulphur. But it was not until 1849 when Antonio García, a miner from Chihuahua, installed a windlass near the crater's rim that the first exploration of the interior of the crater took place (Figure 1). Using the windlass, miners lowered García to the bottom where he collected sulphur samples for testing in nearby Puebla. The test results were encouraging – plentiful layers of pure elemental sulphur lay at the bottom of the crater (SMGE 1858: 242-243).

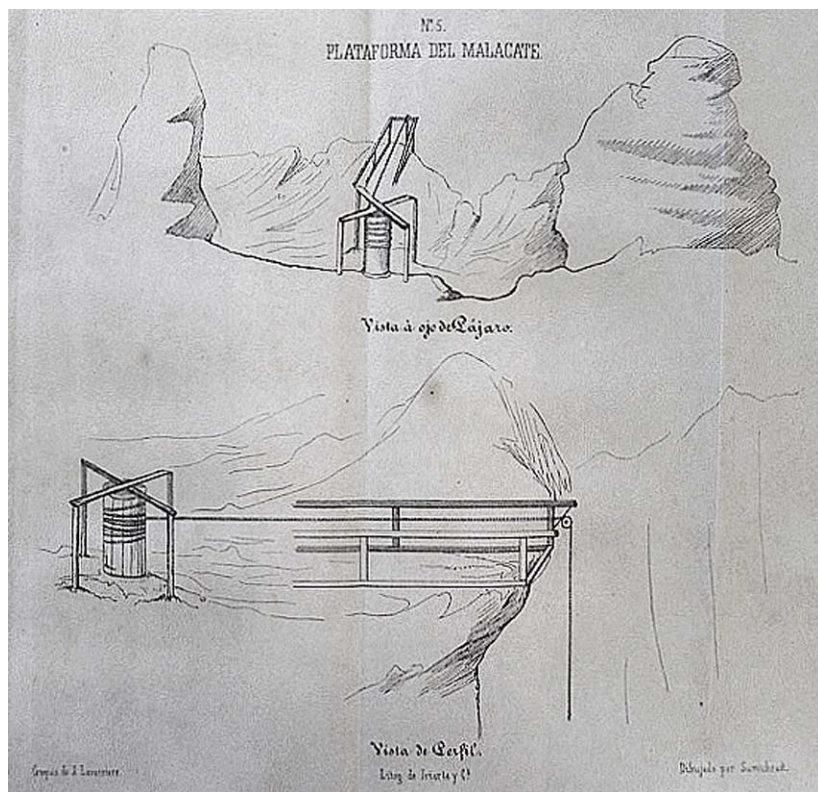


Figure 1. Early drawing of the mining *malacate*, or windlass.
(Source SMGE 1858. Reproduced with permission from the Rare Books Room of the Benson Latin American Collection at the University of Texas at Austin).

As a result of these findings, Reyes and Martín Corchado, a resident of nearby Atlixco, formed a business partnership during the 1850s for the purpose of mining the sulphur. Corchado owned a small ranch on Popocatepetl's northern slopes just below the tree line named *Tlamacas*, which would later serve as a rudimentary sulphur refinery. But the men dissolved their partnership over long forgotten differences, and the rights to sulphur mining in the volcano somehow passed to Juan Música of Puebla (SMGE 1858: 234). The presumably embittered Corchado later appeared in nineteenth-century travel accounts, portrayed as a wild, longhaired Castilian mountaineer who lived in the volcanic crater for months at a time (Cowles 1879). A favorite personality of the indigenous sulphur miners with whom he associated, Corchado often boasted that he was the first to conceive of sulphur mining in the volcano after installing the windlass (Brocklehurst 1883: 111). He also proclaimed to tourists that the volcano's sulphur was his, even though the usufruct rights to the mines continued to change hands throughout the century (Wilson 1856, Landesio 1868, Cowles 1879).

After the initial expeditions of the 1820s and 1830s, another international team of explorers conducted in 1857, what was perhaps the most fruitful scientific exploration of the crater. The mission was led by the astronomer August Sonntag (a recent German émigré to the U.S.), under the tutelage of Baron Johann Wilhelm von Müller (Germany)

and accompanied by two Mexican graduate students. This group published two accounts of their findings, which included observations on the nascent sulphur mining operations in the crater. The first publication (SMGE 1858: 191-264) provided a brief history of the mining operations, including a sensational description of the interior of the crater, which was, at the time, "*terra incognita*" to most. The second publication focused on the volcano's geology and terrestrial magnetism, but also included detailed diagrams of the volcano's interior, topographic maps of the external slopes, and a description of the fledgling sulphur mining operations at that time (Sonntag 1859).

Sonntag's accounts reveal many of the hazards the *azufreros* confronted while working in the volcano. From the bottom of the crater, up to ten indigenous miners at a time extracted sulphur with picks and shovels. Miners then carried the bright yellow rocks in baskets to a point directly beneath the windlass hoisting device, called the *malacate* by the *azufreros*.⁵ Two men positioned above cranked the malacate and hoisted the baskets of sulphur to a flat, basalt outcropping about one hundred twenty-five meters (410 feet) above the crater floor. The malacate operators earned a fixed sum of five *reales* per day, a pittance for the time. The miners in the crater below received one real per basket of sulphur they mined, which each weighed about twenty-five pounds. No *azufrero* could mine and transport more than twenty baskets of sulphur per day, however, because of the extreme altitude, hazardous rock avalanches, and stifling sulphur dioxide fumes that emanated from large volcanic vents (*fumarolas* or *respiraderos*) in the crater. The average daily wage for these workers was only between ten and twelve *reales* per day. A final group of *azufreros* took the baskets of sulphur from the platform of the malacate and climbed outside the crater (SMGE 1858: 191-264; Sonntag 1859) (Figure 2).



Figure 2. Azufreros and guests on the rim of the crater.
(Source: Popocatepetl Company 1904)

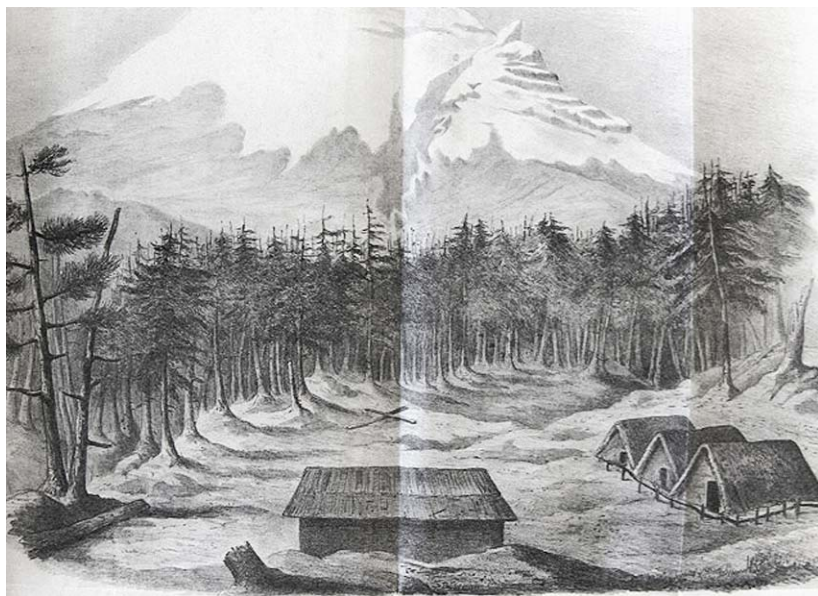


Figure 3. Early drawing of Tlamacas, the sulphur refinery.

(Source: SMGE 1858. Reproduced with permission from the Rare Books Room of the Benson Latin American Collection at the University of Texas at Austin).

Once outside the crater at the mountain summit, *azufreros* slid down the external ice fields on woven mats (*petates*) using metal rods as a type of rudder or steering device. After several hours, these workers finally reached Tlamacas, the sulphur refinery just below the tree line, which consisted of a few wooden shacks (Figure 3). At Tlamacas, workers refined the sulphur by boiling it in cauldrons and distilling it through a series of pipes and containers and eventually into brick molds. Workers then transported the refined sulphur by mule lines to the valley floor below. Ferryman finally transported it across Lake Chalco in canoes and then through the old canal system to Mexico City. Here, the Mexican gunpowder industry used it to manufacture explosives for its army. Following these procedures, the Popocatepetl sulphur industry produced about 7,000 baskets of sulphur annually – about 4,000 being pure, or elemental sulphur (*azufré flor*), and another 3,000 baskets being impure sulphur in need of refinement (*azufré común*). The mining industry functioned only during the dry season, which began in January and lasted until the start of the rains in late March or early April. (SMGE 1858: 243-4; Sonntag 1859; von Gagem 1885; Cadell 1907).

Working conditions in the volcano were difficult, and labor strikes were frequent. The *azufreros* often lived for months at a time in caves or under rock outcroppings at the bottom of the crater where acrid sulphur fumes rotted the workers' clothing and wore down their teeth (Brocklehurst 1883: 110; Ober 1887: 393). Casualties often resulted from missteps on the ice fields of the volcanic slopes (Wilson 1856: 106). Mining sulphur from Popocatepetl during this time was dangerous, inefficient, and relatively unprofitable – at least for the *azufreros*.

Gaspar Sánchez Ochoa and His United States Connections

Of the two Mexican students who accompanied Dr. Sonntag on the 1857 expedition, one took special interest in the sulphur of Popocatepetl – twenty-year-old Gaspar Sánchez Ochoa, a student at the Mexico City Mining College and an Army Lieutenant of Engineers. Six months after his participation in the expedition he petitioned a judge in nearby Atlixco, Puebla, to assume ownership of the volcano. The judge's ruling mentions some previous legal difficulties between owners, possibly referring to the Reyes and Corchado incident, but explains that these had been settled by the time of the request.⁶ Circumstances of the transfer are uncertain, but the young student's petition for ownership of the volcano ultimately succeeded and Sánchez Ochoa became the formal owner of Popocatepetl in 1857 (AGN, 1857, Justicia, vol. 600, exp.3, fols. 10-12)⁷. After Sánchez Ochoa's acquisition of the volcano and surrounding mountain slopes, the young mining student and military engineer began an almost fifty-year struggle to create the world's largest sulphur mine in the volcanic crater.

The young Sánchez Ochoa's plans to develop his volcano had to wait, however, as he next engaged in a secret mission to sell war bonds, purchase ships, rifles, and artillery in the United States to support Mexico's campaigns against the occupying French forces (Miller 1961). Although his four-year stay in the United States on this mission resulted in many misfortunes, the experience would later prove critical during his future business dealings with United States investors over the development of his fledgling sulphur mining industry. But first, Sánchez Ochoa's operation was largely a failure. Although arms shipments from the United States did arrive in Mexico (Miller 1973), he failed in his primary duty, which was to procure a ten million-dollar loan for the republican Mexican government (Miller 1961). He also exceeded his authority and helped indebt the Mexican government for over US \$40 million in worthless junk bonds he sold in San Francisco and New York. American investors became irate, and if not for the calm political stewardship of Mexican Foreign Minister to the United States, Matías Romero (Miller 1965), Sánchez Ochoa might not have returned to Mexico and his large estate on the volcano.

Sánchez Ochoa had supported the renegade Ortega faction for Mexican President while in the United States, disobeying many direct orders from Benito Juárez. When Juárez imprisoned Ortega, Sánchez Ochoa was effectively stranded in New York without support. After having Matías Romero pay his New York hotel bill (the General was penniless), he sneaked across the border under the pseudonym Pablo Aguirre, but officials soon recognized Sánchez Ochoa and imprisoned him in San Luis Potosí (Miller 1961).

Despite these problems, Sánchez Ochoa's experience in the United States came to fruition as he settled back in Mexico and attempted to profit from his volcano. Although details are elusive, Sánchez Ochoa somehow managed to rehabilitate himself to Mexican high-society.⁸ Having apparently been forgiven for past transgressions against the Mexican state and given a federal judgeship on Mexico's Supreme Court (Beezley 2005: 170), Sánchez Ochoa settled into the Hotel Iturbide in Mexico City where he lived off of his sulphur mining profits. In 1867 he appeared during a dinner party in Mexico City with William Seward, Abraham Lincoln's former Secretary of State; Mathías Romero; and United States Colonel Albert Evans. Evans recalled the evening as follows:

The great volcano of Popocatapetl [sic] is the grandest and most striking feature of the glorious panorama of Mexico. As seen from the Castle of Chapultepec...it is so far beyond the power of language to describe...I have met men, in years gone by who professed to have stood upon the edge of the crater of Popocatapetl [sic]; but since I have seen the mountain,

and conversed with General Gasper [sic] Sanchez Ochoa – a thoroughly competent engineer, who owns the vast estate on which it is situated, and made the only actual survey of this stupendous work of the Almighty hand, which has ever been accomplished – I know that some were only liars and vain boasters. Mr. Seward was extremely anxious to ascend the mountain, but General Ochoa, though offering to place every facility at his disposal, frankly told him that the effort was one which a man of his years and infirmities had no right to make, and he could not anticipate fortunate results... On this, the proposed expedition was abandoned. (Evans 1870: 263-4)

As this passage suggests, recreational mountain climbing on Popocatepetl was beginning to be a popular nineteenth-century tourist attraction (Beezley 2004: 40). Realizing the potential value of promoting his volcano and surrounding lands as a tourist destination, Sánchez Ochoa made every effort to encourage travelers to climb the mountain and visit the crater.⁹ Nineteenth-century travel literature is replete with accounts of tourists and foreign adventurers arriving in Mexico City; obtaining a written letter of introduction from Sánchez Ochoa at the Hotel Iturbide where he resided; traveling by canoe, train, and horseback across Lake Chalco and adjoining lands; and presenting the letter to officials in the town of Amecameca. In this small town at the western foot of the volcano, climbers contracted guides (usually *azufreros*); purchased provisions and rented horses; and after riding for several hours up the mountain, spent the night at Tlamacas to prepare for the morning ascent, which usually began around three o'clock in order to reach the best vantage point to see the sunrise over the eastern Gulf (Figure 4).¹⁰



Figure 4: *Azufreros* and travelers gathering at Tlamacas.
(Source: Popocatepetl Company 1904)

Despite the fact that most of the tour guides worked for him, it is unclear if Sánchez Ochoa profited from the many trips he arranged for foreign tourists. But as a result of this tourism, public exposure in United States newspapers provided an effective means of advertising the volcano's immense sulphur deposits. From 1880 until 1910, at least twenty-three articles in major United States newspapers published accounts of climbing trips on Popocatepetl and the immeasurable riches the volcano contained.¹¹ All the while, Sánchez Ochoa was improving his leverage while he negotiated with United States interests over the sale of the volcano and its now well-known sulphur deposits.

Sánchez Ochoa also began to publish his own promotional materials on the riches of the volcano and detailed plans to develop more feasible ways to extract the volcano's sulphur. By making mining in Popocatepetl more productive, he could lower his overall costs, especially labor costs. Lowered costs, he speculated, would allow him to more effectively compete with the cheap Sicilian imports (Sánchez Ochoa 1891, 1902a&b). To accomplish these goals, and also perhaps to make the mines more appealing to potential foreign investors, he outlined several ambitious business plans. The first of these plans, which he implemented during the 1870s, was to increase his work force of *azufreros*. By the 1880s over 100 miners were employed, including a core of 30 workers who lived in the crater for up to 28 days at a time (Brocklehurst 1883: 109).

Yet paying the additional miners proved expensive and the work remained difficult. Worker strikes continued. So to avoid these problems and increase profit margins, Sánchez Ochoa devised two engineering plans to make sulphur production within the volcano less dependent on human labor. First, he conceived of installing a turbine wheel at the bottom of the crater powered by the force of escaping sulphur fumes, a force reportedly equal to about twenty horsepower. The turbine wheel would transport baskets of sulphur from the bottom of the crater to the top on a tramway, thus lessening the hazards of using the *malacate*. The decreased labor costs, Sánchez Ochoa speculated, would allow him to sell the sulphur of Popocatepetl at a price more competitive with the cheap Sicilian sulphur sold on the main plaza in Mexico City and in foreign markets (*Ibid.*). Although there is no evidence the turbine wheel was ever built, the impetus for his plan demonstrates the basic dilemma he faced – that although the sulphur of Popocatepetl was plentiful and high quality, accessing amounts large enough to compete with the cheap Sicilian sulphur was prohibitively expensive.

A second engineering idea, which Sánchez Ochoa considered more seriously, appears to have had its origins in the 1850s (SMGE 1858: 244). The plan involved digging a horizontal tunnel from the bottom of the crater, through the volcano, out to its external slope. Through this access tunnel, *azufreros* would transport sulphur using mining rail carts, alleviating the need to traverse the glacial ice fields on the outside slope, or again, to use the risky and inefficient *malacate* windlass. At the external mouth of the tunnel, a steel wire would run to the Tlamacas refinery just below the tree line. The wire would serve as an aerial tramway for the sulphur baskets, alleviating the dangerous and time-consuming descent from the summit. This idea was under serious consideration during the 1880s and 1890s, when Sánchez Ochoa and United States mining interests began to hammer out the details of a merger.

The Popocatepetl Company

The contractual origins of the Popocatepetl Company appear to have roots in the 1860s, during Sánchez Ochoa's extended stay in the United States as a covert operative, where he had developed many business relationships. During the 1880s, he and wealthy United States interests from California and New York continuously negotiated

The *Report on the Popocatepetl Company and its Development* (1904) refers to the railway depot as located in the small town of Cedar, at the western base of the mountain. Although absent from both historical and modern maps, fieldwork during 2008 identified a small hamlet named *Los Cedros* just outside of Amecameca, which mirrors a sketching in the report (Figure 6). Interviews with older residents confirm the ex-hacienda of Guadeloupe at Los Cedros as the storage house and depot for sulphur shipments.



Figure 6: Sketching of Interoceanic Railway from Cedar to Veracruz.
(Source: Popocatepetl Company 1904)

Remnants of the first Inter-Oceanic Railway are located about forty meters west of the property, mostly buried under suburban development and emerging only occasionally as it runs north and south along the mountain range. Additional fieldwork at construction sites specified in the report and interviews with older residents has found no evidence that the aerial tramway was ever constructed, but older residents did point out the paths where mule lines brought mass quantities of sulphur down from the mountain top and stored it at Cedar. Efforts to confirm the ownership of the hacienda in 2008 were unsuccessful, as the current owner, purportedly the sole descendent of Sánchez Ochoa, was incapacitated due to an extended illness.

United States investor Charles Holt directed the Popocatepetl Company, and its board of directors consisted of prominent financial and political leaders from both Mexico and the United States. In addition to developing the sulphur mines, the board envisioned a vast mountain resort complete with hot springs, fountains, cabins, tennis courts, modern hotels, and a health resort – all to “appeal to the highest class of wealthy residents and tourists” (Popocatepetl Company 1904: 16). The well-known French architect M. Emile Bernard agreed to landscape the area, promising to turn the park into a new Versailles. His Popocatepetl Park was to occupy 2,500 acres of land, benefiting from another “40,000 acres of virgin woods” and “inexhaustible” quantities of high-quality ice from the mountain glaciers (Popocatepetl Company 1904: 19-20).

Mexican governmental support for the project proved essential. President Porfirio Díaz awarded railroad concessions to the Popocatepetl Company in exchange for continued access to mountain streams for waterpower. Díaz also gave his authorization,

in part, because his second wife, Carmelita Romero Rubio Díaz, was an enthusiastic supporter of the planned developments (Iturriaga 1997: 9). Porfirio Díaz wrote, in reference to the plans, "The convenience of the improvements is indisputable" (Popocatepetl Company 1904: 17). Other prominent figures also offered their support. For example, C. J. Williams, Director of the English College in Mexico wrote in reference to the planned sanitariums of the park, "You will have thousands of patients that surely will find great and speedy recovery" (*Ibid.*, 17). Roberto Boker, Vice-President of the Deutsches Haus in Mexico enthusiastically claimed, "The most beneficial results will accrue from the exploitation of the fruitful riches lying idle on this mountain" (*Ibid.*, 18).

There appears to have been little documented opposition to the development plans.¹² Of 63 Latin American newspaper accounts that mention sulphur mining on Popocatepetl or the development of the Park, only one expresses obvious regret over the sale of the volcano to United States interests:

"With great sadness I reveal to our readers, that on the 27th of September, 1904...everything has ended well for all those with legitimate interests in the sulphur of Popocatepetl, the transaction that has been announced so many times in newspapers of this capital [Mexico City] between General Gaspar Sánchez Ochoa and an American syndicate represented by Captain Charles Holt. The total price of the transaction was 300,000 pesos in American gold, of which 96,000 pesos is going to pay creditors...We greatly lament that the greatest orographic beauty of Mexico has become part of the history of the western conquest" (El País, September 30, 1904; vol. 5; Issue 2054; page 1).¹³

Discussion: Successes, Failures, and the Mother of Invention

For two years, rights to the volcano and surrounding lands transferred to the Popocatepetl Company, and some of the volcano's sulphur was, in fact, traded on the international market (LAT 1907). But after this brief period, a combination of human and environmental factors halted the company's progress. First, the manager of the company, Captain Charles Holt, was unable to secure all of the promised financing after one prominent investor died (WP 1904) and the manager of his estate later came under investigation for fraud (NYT 1905). The sales contract for the volcano held that if Holt were unable to secure all of the promised financing by a specified time period (unknown), the volcano would revert back to Sánchez Ochoa. This appears to have occurred (WP 1907; LAT 1924). It is unclear how much investors lost, or how much Sánchez Ochoa was able to keep, but it is probable the General was able to keep at least the initial payment of US \$100,000 from 1903. Although his covert financial operations of the 1860s met with failure as a general result of his "bungling and errors of judgment" (Frazer 1942: 414), Sánchez Ochoa appears to have finally put together a semi-profitable deal – and he was able to keep his volcano.

A second reason for the failure of the Popocatepetl Company is that Mexican political turmoil during the early twentieth century, in part, prevented the company from reforming. Sánchez Ochoa died on the eve of the Mexican Revolution in 1909 (Wakild 2007: 180), and it is unclear if the rights to the volcano remained in his family or if the state assumed control.¹⁴ In 1935, President Cardenas declared the volcano and surrounding lands Mexico's first national Park (*Ibid.*, 182), but ownership of the volcano is uncertain between these dates. As a result of the Revolution, Porfirio Díaz was forced from office and the newly-formed Mexican state redistributed many of the haciendas

and foreign landholdings. In any case, the political climate during the Revolution would have been highly averse to continued ownership of the volcano by United States interests.¹⁵ Although foreign travel accounts during the Revolution reveal that several former *azufreros* still led trips to the crater for tourists, it appears that sulphur-mining operations had mostly ceased by this time.¹⁶

A final reason for the failure of the Popocatepetl Company is that volcanic sulphur mining was quickly becoming obsolete about the same time Sánchez Ochoa sold the volcano. In 1903, a German immigrant to the United States named Herman Frasch invented a method of extracting sulphur from underneath the swamps of Texas and Louisiana (Haynes 1959). The Frasch Process involved injecting superheated steam hundreds to thousands of feet underground to melt previously inaccessible deposits of sulphur found impregnated in porous limestone. Machines pumped the solution to the surface in molten and gaseous form where condensers cooled the sulphur into a solid (McIver *et al.* 1938). Similarities between the condensed gasses from volcanoes like Popocatepetl and those produced by the Frasch process were apparent, and one source even referred to Frasch as having created “a little volcano of his own” (NYT 1910).

By employing this method of extraction, Louisiana sulphur companies soon undersold the imported Sicilian variety on the international market, since “Frasch Sulphur,” as it was named, was both plentiful and more than 99.5 percent pure (Haynes 1959: 28). Within only a few years the world center of sulphur production moved from the Italian regions, where it had remained throughout recorded history, to the swamps of Texas and Louisiana (Kutney 2007). The United States soon produced enough domestic sulphur to become independent from the Sicilian sulphur trade. The United States surplus in sulphur production, in turn, enabled the gunpowder and sulphuric acid production essential for World War I manufacturing of munitions and rubber products, which otherwise would have been largely dependent on the Italian sulphur trade. Frasch's invention was to play a critical, though underappreciated role in shaping world history and economic geography.

After the patent on Frasch's invention expired in 1908 (Mason 1938: 744), Mexico began to develop its own underground sulphur resources. By using the Frasch process, especially along the Gulf Coast and the Isthmus of Tehuantepec (Acevedo Escobedo 1956), Mexico became a world leader in sulphur production by the 1950s (Haynes 1959). The volcano Popocatepetl, however, would never again play a firm role in Mexico's sulphur industry.

Conclusions: Positivism and the Problem of Scale

The sale and attempted development of the Popocatepetl volcano is a prime, though understudied example of Porfirian positivism – the political-economic philosophy that dominated decision-making over natural resource management. Díaz gave explicit approval of the sale of Popocatepetl to the United States and the importation of foreign engineering technology in the form of the aerial tramway from California Wire Works. He allowed United States investors to gain ownership of one of Mexico's most revered landscapes. In effect, Díaz and Sánchez Ochoa sacrificed an indispensable piece of Mexican landscape patrimony and a critical environmental resource in the name of order and progress. Fortunately, the transfer of the lands did not last long enough for the company to seriously affect the landscape.

In addition to the overarching theme of Porfirian developmental positivism in creating favorable economic conditions, domestic politics also played a critical role in the development of the Popocatepetl Company. Research on historical economy often

focuses on the success of foreign investors in the economic periphery in terms of the host country's beneficial economic policies and the foreign investor's comparative advantage in technology and capital. But in Mexico, Brown (1987) has demonstrated that the process also depended on the influence of the host country's wealthy elites and individual politicians who followed their own ambitions, and not simply the balances and flows of international economy. The current study shows that both Mexico's favorable economic policies during the Porfiriato and Sánchez Ochoa's individual ambitions to profit from Popocatepetl's sulphur deposits facilitated and drove the sale of the volcano to United States interests. The sale was not simply a product of economic disequilibrium; rather, internal, domestic political influence and Sánchez Ochoa's personal relationships with United States investors factored heavily as well.

Despite the intense economic and political pressure to develop Popocatepetl, the basic problem faced by the industry was one of scale. Environmental conditions in the volcano were dangerous and the sulphur was difficult to access, although not impossible. Indigenous miners successfully harvested the mineral from the crater throughout the second half of the nineteenth century. Yet despite their collective successes, the skyrocketing demand for sulphur from international markets drove venture capitalists to attempt to expand mining operations by using mechanized labor and elaborate engineering schemes. Although investors never doubted the amount of sulphur in Popocatepetl, mining sufficient quantities of the mineral from the active volcano using available technology ultimately proved unrealistic, especially given the physical difficulties of working in the active crater. In terms of scale, and with microeconomics being critically important, international demand (Popocatepetl Company 1904) required greater amounts than the feasible, local supply afforded.

Notes

¹ For additional information on the lengthy history and cultural significance of Popocatepetl, see Iturriaga, 1997.

² Alexander von Humboldt was one of the few foreign scientists admitted to New Spain, which is, in part, why his publications are so valuable, and continue to leave a lasting impression on twenty-first century scholarship (Mathewson and Sluyter 2006). In his *Political Essay on the Kingdom of New Spain* (1822: 471), Humboldt speculated that sulphur abounded within Popocatepetl, although he believed that no one had successfully climbed the mountain since the time of Conquest. Decades after Humboldt's two-year journey through New Spain (1803-04), Mexican and foreign travelers became the first to conduct scientific expeditions to the crater and confirm Humboldt's suspicions that the volcano indeed held immeasurable quantities of the sulphur.

³ Although the French scientific expeditions of the 1860s are probably the best studied of their kind in nineteenth-century Mexico (Dunbar 1988, Edison 2003, Puyo 2010), many other European, Mexican, and United States travelers also engaged in early scientific expeditions.

⁴ Religious practice near the crater, for which there is archaeological and ethnographic evidence (Glockner 2000; Cook 2004), and snow/ice harvesting from glaciers near the crater (AGN, 1788, Archivo Histórico de la Hacienda, Leg. 408, exps.78-84), suggest that climbing activity was commonplace during the colonial period.

⁵ The Nahuatl word *malacate* means “spindle” (McMeekin 1992), an apt description for the mechanics of the windlass.

⁶ The reference made by the judge to an earlier disagreement also might refer to a heated rhetorical battle between Corchado and Sánchez Ochoa six years before the formal petition in Atlixco (Wilson 1856: 112). Corchado indeed appears to have been at the center of several controversies. From February through April of 1851, Sánchez Ochoa and his lawyers, F. M. Ologuibel and Eduardo Guilac, published newspaper columns on fourteen occasions disputing Corchado's unsubstantiated claim to the volcano. The public dispute appears to have ended in 1851, and by 1857 the Atlixco judge formally declared Sánchez Ochoa the owner of the volcano (AGN, Justicia, vol. 600, exp. 3, fols. 10-12).

⁷ At least two sources claim Benito Juárez gifted the volcano to Sánchez Ochoa for his years of devoted service (LAT 1904; Beezley 2004). I could not verify this in the archives, and I find this unlikely, especially given the chronology of Sánchez Ochoa's ownership of the volcano (AGN, 1857, Justicia, vol. 600, exp. 3, fols. 10-12) and subsequent military accolades of the 1860s.

⁸ Forgiving the liberal war heroes of the Cinco de Mayo generation for transgressions against the Mexican state almost seems to have been an institutionalized practice (Beezley 2005).

⁹ Sánchez Ochoa's advice to Mr. Seward not to climb the volcano is the only exception to this I have found.

¹⁰ See, for example, (Wells 1865; Landesio 1868; Evans 1870; Arriaga 1871; Bishop 1883; Brocklehurst 1883; Conkling 1883; von Gagem 1885; Packard 1886; Ober 1887; Baker 1895; Douglas 1897; Farrington 1897; Janvier 1898)

¹¹ See, for example, NYT (1880; 1883; 1892; 1894a; 1894b; 1903; 1904); WP (1880; 1883; 1895; 1901; 1904a; 1904b; 1907; 1908); LAT (1894; 1903a; 1903b; 1904a; 1904b; 1904c; 1904d; 1907)

¹² Although Díaz assumed control of media outlets to consolidate his rule (Krause 1976), newspapers frequently shifted between political philosophies –conservative and radical, positivist and liberal viewpoints during this time (Flower 1949; Raat 1977). It is therefore simplistic to assume that lack of opposition to the development plans was a general symptom of Porfirian control of the media.

¹³ All translations are mine.

¹⁴ One reference claims the volcano was sold to another New York syndicate with plans to continue the Popocatepetl Company's development (LAT 1912), but I cannot find substantive additional evidence of this possibility.

¹⁵ One reference suggests that Emiliano Zapata's armies may have been utilizing sulphur mined from Popocatepetl to manufacture gunpowder during the Mexican Revolution (AGN, 1915, Emiliano Zapata, caja 9, exp. 3, fol. 13). This again supports the notion that ownership of the volcano was uncertain during this chaotic time period.

¹⁶ According to documents from the municipal archives of Amecameca, however, there appears to have been one last concerted effort to mine sulphur from the volcano. It is unclear who owned the business, or whether it had a role in providing munitions to the Revolution, but in 1919 a small sulphur mining company that employed twenty azufreros still mined sulphur from the crater. In an attempt to blast-open access to greater deposits, management decided to plant cases of dynamite in the fissures and sulphuric vents. The subsequent explosions, at 6 pm on 13 January, caused a mass avalanche that resulted in the prolonged death of thirteen of the twenty azufreros. Only days later did tardy authorities rescue survivors, frostbite having infected many of their limbs. Documents from the official government investigation list the names of the deceased, the families they left behind, and other details of the perilous working environment (AHMA 1919).

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