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The Impact of the Industrial Revolution on Mining Technology in Mexico in the 19th Century

Juan Carlos Jauregui-Correa

School of Engineering Department, Autonomous University of Queretaro, Queretaro, Mexico
Email: jc.jauregui@uaq.mx

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Abstract

This paper describes the transformation of the mining technology in Mexico from the Spanish colonial time to the Industrial Revolution. The comparison includes the machinery employed between the 16th century and the beginning of the 19th century. In a few years, mining and metallurgical processes drastically changed from wood and animal power to steel and steam engines. Changes implied not only the introduction of new technologies, such as steam engines, rails, dynamite, water pumps, and many other tools, but also new organizations, skills, and techniques. During the colonial period, machines and metallurgical processes were locally developed, and the working organization depended on intense labor activities and animal power. From the 19th century, production increased due to better machines, the use of explosives, and improvements in transportation systems. This paper contributes to disseminating the evolution of technology, comparing the technological transformation of machines and mechanisms.

Keywords

Mining Technology, Technology Transformation, Antique Machinery

1. Introduction

Ibero-American countries became independent from Spain, while the Industrial Revolution transformed many production processes in other parts of the world. New machines were substituting artisans' work, the quality of products improved, and productivity increased considerably. During that period, Mexico became independent from Spain, and the Mexican society was adapting to the 19th century's modern concepts; thus, the new ruling classes had to accept different conditions

from abroad. One condition was the foreign debt, signed with England, France, and Spain. Mexico accepted that foreign companies would exploit the silver mines to overcome international pressure. Therefore, the new companies brought new technology and modern equipment, eliminating the original processes that were developed in Mexico. The impact of the Industrial Revolution on Mexican mining machinery, not only technologically but socially and economically, remains today. The technology transformation impacted every original process, from extraction to refining and casting. Since mining played a crucial role in the economic development of Mexico during this period, particularly in regions rich in silver, gold, and other valuable minerals, this transformation marked the production structure and companies' organization. This paper describes the technological change and how traditional wooden machines were replaced by steel-made equipment.

This paper is part of a series of publications by the author, focusing on the unique aspects of pre-Industrial Revolution mining in Mexico (Jauregui-Correa & Rodriguez-Zahar, 2016; Jauregui-Correa & Escamilla-Gonzalez, 2019; Jauregui-Correa, 2023). During this period, the economic significance of the mining industry in Mexico was paramount. Local miners developed their own machines, and the silver extraction process was distinct. The production organization was well-established, with the mines relying on locally produced supplies such as mules, mercury, salt, and food. The silver and gold extracted were primarily exported to Spain, further highlighting the economic importance of the mining industry at the time (Jauregui-Correa, 2024).

2. General Overview of the Historical Transformation

This paper undertakes a significant comparison between silver production in Mexico before and after the Industrial Revolution. It draws a parallel with the political and economic transformation from a Spanish colony to an independent nation, shedding light on the profound changes that shaped Mexico's history and economy.

During the colonial period, Mexico was a significant silver supplier for the Spanish King, who imposed royal ownership over land and subsoil, granted individuals and indigenous communities the right to extract the minerals, and imposed a production tax. This royal mandate set the production organization entirely under private Haciendas' control. The production of Silver and gold was exchanged for European manufactured goods and supplies, unstimulating local artisan shops. The Mexican economy was based on agricultural production and gold and silver mining; large "latifundium" was devoted only to raising mules and food for the mines. At the beginning of the 17th century, about 370 silver mines were operating along the country. During the Spanish domination, these mines exported around 56,150 tons. Productivity was limited by the wooden machinery, mule power, and extensive labor (Nogues-Marco, 2011; Irigoin, 2018; Backwell, 1971).

At the end of the 18th century, the Spanish fleet was less effective than other European fleets. Spanish ships had less mobility and were slower than their competitors because their intention was to carry more goods. Besides the moving

capacity, France, England, and Holland wanted to introduce their products into the Spaniard colonies, and local business organizations were eager to trade with other countries and not only with Spain. These businessmen mainly supported the independence war in most Spanish territories.

Most Spanish American colonies became independent at the beginning of the 19th century. In Mexico, the new Government accepted a tremendous debt (Bazant, 1995) and allowed foreign companies to operate the mines. These companies brought modern machines such as steam engines, explosive techniques, hammer mills, steel cranks, rail carts, and other engineering procedures. The new manufacturing equipment triplicated the silver extraction during the 19th century. These new companies and the import of modern machinery set the technology dependency of Latin America up to now. These changes contributed to the growth of Mexico's mining industry and its role in the country's economic development (Robles & Foladori, 2019).

3. The Mining Technology during the Spaniard Period

The development of the silver industry during the Spaniard period was marked by the ingenious use of local technology that proved remarkably productive. This unique process, created by Bartolomé de Medina in 1557 (Austin, 1913; Tylecote, 1992), was a European concept that had never been applied before. It was ideally suited for America's type of minerals. The core technology involved the amalgamation of silver ore and mercury. The silver ore was combined with mercury and brine and set to mix in an ample open space known as "patio de beneficio" in Spanish (**Figure 1**).

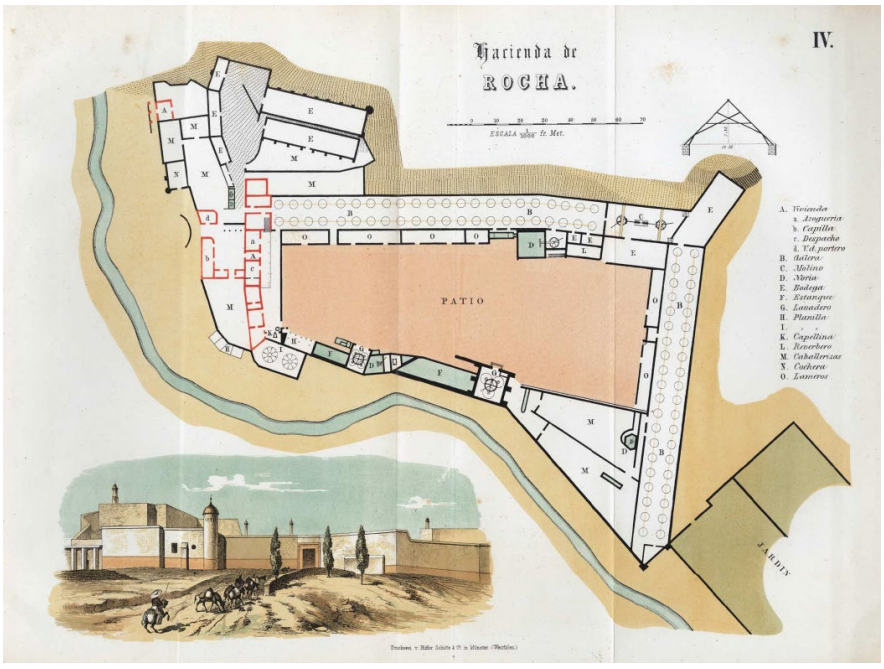

Figure 1. Layout of the "Hacienda de Rocha" (Leon & Lara, 2018), a typical "Hacienda de Beneficio".

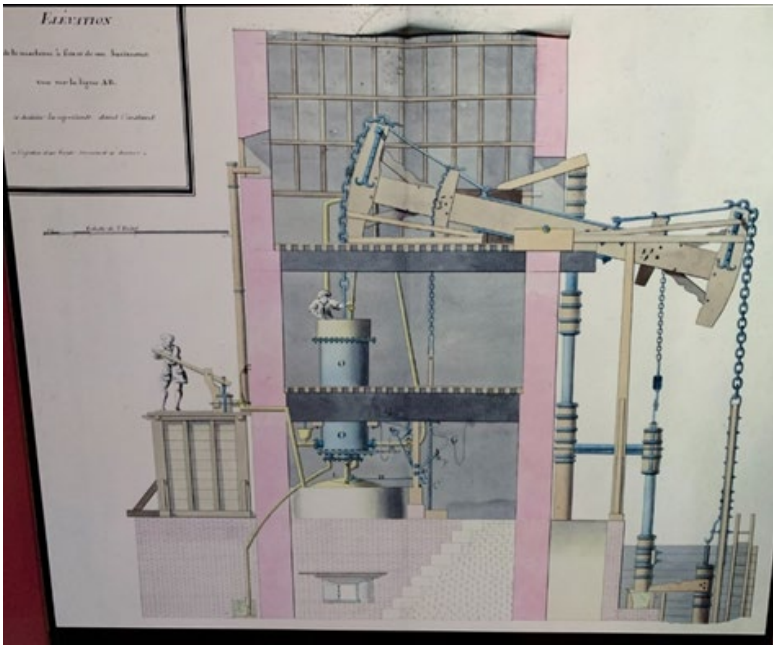

Figure 2. Layout of an elevation system. Picture taken by the author at "Museo de los Metales https://sic.gob.mx/ficha.php?table=museo&table_id=1156".

The process began at the mines, with the "haciendas" strategically built near the extracting areas. Mineral extraction was a laborious task, carried out with hand tools (pickaxes, shovels, and hammers) and transported to the surface on the backs of workers or with wooden carts pulled by mules. In some areas, the mineral was lifted with wooden pulleys and cables. Water was lifted with buckets and winches to combat the constant threat of floods (**Figure 2**). Water management was always a significant challenge in the mine's tunnels, which were supported by wooden timbers to prevent collapses.

Cranks or windlasses lifted the minerals from the tunnels to the surface. These simple machines, powered by hand or mules, pulled buckets filled with minerals to the surface. Ventilation was a big challenge. They generally used natural airflow, and some mines had hand-operated bellows.

Once the mineral was deposited outside the tunnels and moved to the "hacienda" with a mule-powered cart, it was classified by type and size. The ore was washed by hand or in washer machines powered by mules, by hand or with a sluice box, a long, narrow channel with riffles to trap minerals while water runs over the ore to wash it. In this step, soluble minerals were separated. There is scattered information about these machines. Then, the ore was broken with hammer mills (**Figure 3**). Hammer mills were made of wood but were efficient enough to evolve during the Industrial Revolution (Jauregui-Correa, 2023). It was one of those machines with a clever mechanism formed by a vertical pole that rotated a sizeable wooden gear. This gear resembles the design of modern face gears; it rotates a smaller gear that operates the cam mechanism. The camshaft lifted several cams that felt and hit the ore stones. The cams were set out of phase to produce a continuous hammering effect. These machines were transformed from wood to steel,

incrementing their accuracy and speed.

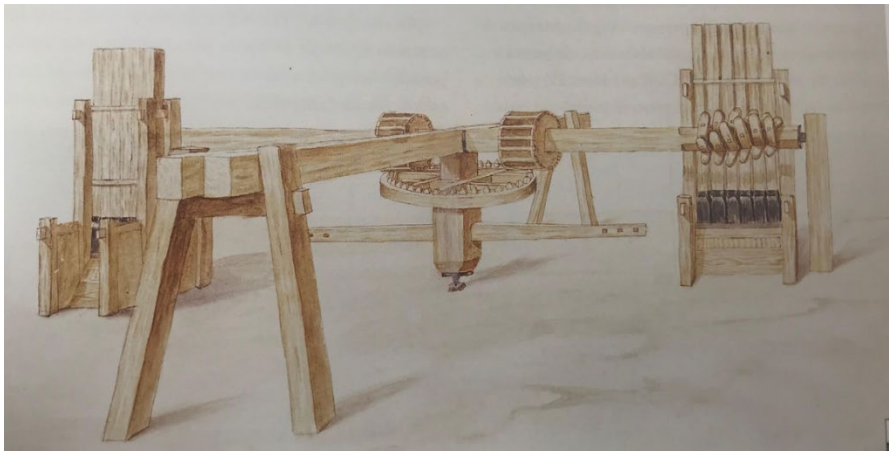

Figure 3. Schematic lithography of a hammer mill (Leon & Lara, 2018).

The broken ore was ground with the unique machine developed locally that was known as the "arrastre" or "Tahoma" (Jauregui-Correa & Escamilla-Gonzalez, 2019). This machine was much more efficient than the traditional stone mills used in other processes, such as wheat milling. It consisted of a wooden tank filled with a stone basalt (**Figure 4**) bed and a flying stone that pressed the ore against the stone bed. The stone bed had no cavities to ensure a continuous surface. A couple of mules made the flying stone rotate and kept the grinding process until the ore became soft dust. The flying stone was attached to a horizontal beam connected to a vertical post that made the rotating mechanism. The vertical post rested on the stone bed and worked as a vertical journal. The originality of this mill was the stone bed and the flying stones (**Figure 5**).

Figure 4. Balast stone similar.

The sludge was mixed with mercury and brine and deposited in a large back-yard, known as "patio de beneficio" in Spanish. The mixture was padded to ensure a good blend. The mixture was let to form the amalgam and then washed with water in a mechanical washer. Once the brine was dissolved, the silver was

extracted by melting the mercury (Figure 6), and the silver was melted in a larger furnace and cast as ingots (Figure 7).

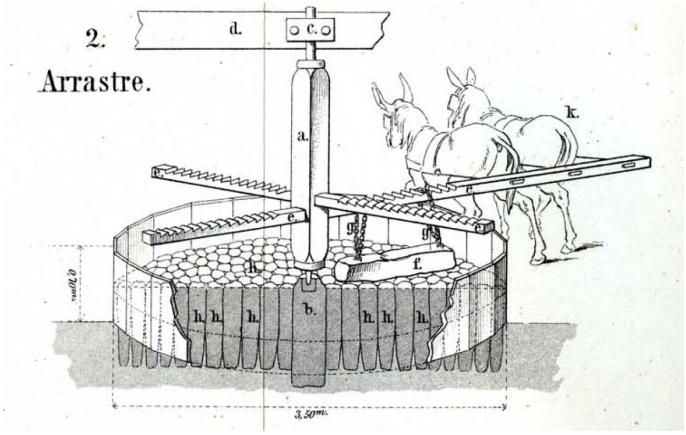

Figure 5. Layout of the "tahona" (Tilmann, 1886).

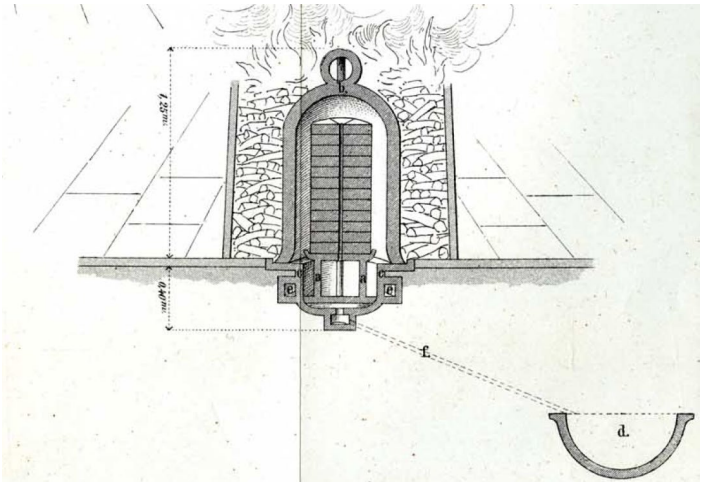

Figure 6. Sketch of the mercury melting furnace (Tilmann, 1886).

Figure 7. Silver furnace, colonial period (https://editorialrestauro.com.mx/los-hornos-en-el-beneficio-de-los-metales-en-la-nueva-espana-siglo-xvi-xviii/).

During this period, the power supply limited production, and it was labor-intensive. The engineering processes were obsolete and not fully reported; with new equipment, newer production processes, better documentation, and production organization, mining productivity significantly improved once industrialization took over the traditional working schemes.

The following section describes some new machinery introduced during the Industrial Revolution.

4. Mining Transformation during the Industrial Revolution

After Spain's independence, the new government allowed foreign companies to operate the mines. These companies brought modern machines such as steam engines, explosive techniques, hammer mills, steel cranks, rail carts, and other engineering procedures. Introducing the new technologies and production processes increased productivity and efficiency in silver mines. This section presents an overview of the new equipment for silver production during the 19th century. The technical description of the new equipment does not need to be included since there is enough engineering information and technical references.

The steam engine had the most significant impact on the manufacturing process. The basic reason was its steady operation, the amount of power, and the cost of energy, compared with traditional animal power. Steam engines moved different equipment, such as pumps, crushers, hammer mills, and hoists. The introduction of the steam engine allowed the extraction of minerals at deeper ore deposits.

Besides machinery, the Industrial Revolution brought new laboratory techniques that improved metallurgical analysis and the adequation of the metal-extracting processes. This new technology also improved the milling process using heavier rams in the new stamp mills. These mills had a similar operation as those in the wooden period but were built with steel and powered by steam engines. They had the same lifting and dropping principle for breaking the ore.

Figure 8. Lifting pulley with steel cables (http://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A485386).

The introduction of new technology brought changes to the mine's layout. Steel headframe structures substituted the wooden structures at the surface to support the hoist (Figure 8). New buildings were required to allocate offices, workshops, and storage facilities. Mines had blacksmith shops to repair and maintain tools, equipment, and machinery. No records of similar facilities exist for the previous period. The mine shaft was also modified to give access to larger equipment, and the tunnels gave access to the rail carts, ventilation, and electric lighting. Techniques for providing adequate ventilation in mines and ensuring the safety of miners were enhanced during this period. As mines went deeper into the earth, ventilation became a critical concern. Ventilation systems, often using manual fans or animals, circulated air within the mines. Lighting in the mines was crucial, and initially, candles were used. Later in the century, oil lamps became more common until electricity became available. The first electric plant was installed in Mexico and operated in the mines near Guanajuato City. Mines often encounter water seepage or flooding. Water pumps were initially operated manually and later by steam engines; with them, they drained water from the mines.

The extraction process also changed. New smelting furnaces were introduced, and flotation cells replaced the antique "patio de beneficio".

Inside the tunnels, miners applied hand drills to create holes in the rock for placing explosives. These drills were manually operated and required significant physical effort. Dynamite and other explosives became more widely used to break up large volumes of rock, increasing the efficiency of ore extraction. Ore, rock, and other materials were transported within the mines using mine carts on rail systems. This method made it easier to move large quantities of material.

Outside the mines, ore transportation and other materials relied on horse and mule-drawn wagons (Figure 9). Railways facilitated the movement of large

Figure 9. Steel carts and tracks for moving minerals outside the mine (https://cienciauanl.uanl.mx/?p=4176).

quantities of oil from mines to processing plants and ports, enabling the mining industry to expand. The new washing machines were powered with steam engines and, at the end of the 19th century, with electric motors (Figure 10).

The metallurgy knowledge and the improvement in process equipment made possible the construction of sophisticated foundries that increased productivity. (Figure 11).

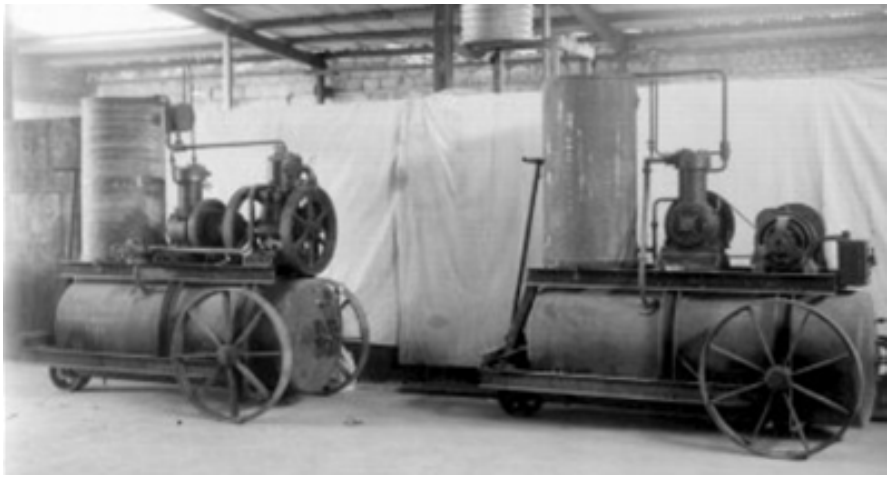

Figure 10. Layout of the washing machine (http://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A104492).

Figure 11. Foundry oven and moving machines. http://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A485418.

The Industrial Revolution had a determinant impact on mining production. It transformed every process and modified the machinery. By the end of the 19th century, the introduction of the electric motor made another significant transformation. Electric motors substituted steam engines, and mines were the first factories in Mexico to have power plants. According to (Robles & Foladori, 2019), silver production in the XVI century was around 2000 tons/year (the equivalent to

modern measurements); by the XVII century, it increased to 4000 tons/year. Mainly because new mining areas were found and new mines started operations. The impact of the new machinery is evident in silver production; in the middle of the XIX century, silver production increased to 8000 tons/year, and production almost doubled in 50 years. The production increment had a minimal impact on economic development during the XIX century, but this topic is outside the scope of this paper.

5. Conclusion

Analyzing antique machines and processes requires gathering old information to be interpreted using current engineering methods. It is clear how the Industrial Revolution modified production processes and social organization and determined the need for engineering management, standardization, and the development of engineering documents. Although this chapter includes only a sample of the information recorded during the Spanish colonial period, it is well known that the engineering drawings and technical data started during the Industrial Revolution.

This paper describes the sudden changes after Latin America became independent from Spain. In particular, the evolution of the mining machinery was significant. Before independence, namely the wooden period, machines were constructed with wood and stones, and they were powered by mules (commonly known as blood engine), which had a limited power capacity in comparison with the steam engine. The introduction of steel pulleys, cables, rails, carts, and many other tools significantly increased the productivity of mines. Despite introducing foreign machinery, local technology played a crucial role in shaping the current economic model.

This paper contributes to disseminating the evolution of technology, comparing the technological transformation of machines and mechanisms.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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