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# HISTORY OF MINING IN THE LAKE POOPO REGION AND ENVIRONMENTAL CONSEQUENCES

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## Abstract

Bolivia is a country with many mineral resources, located mainly in the Andean region of this country, where the lake Poopo is located. From thousands of years ago, the mining activity has a large importance; however, the natives used these resources formerly for ceremonial use and taking care with the environment. From the colonial time, the extraction of these resources was indiscriminate and the region of the lake Poopo suffers terrible consequences for the environmental pollution.

*Key words* – Bolivia, environmental effects, gold, history, mining, Poopo Lake, tin.

## Introduction

The Poopo lake is located in the Bolivian Altiplane between 3600 to 3900 masl (Cross et all., 2001); these belong to a greater endorrhoeic system called TDPS encompassing lake Titicaca, Desaguadero river, lake Poopó, and Salars (Fig. 1), located between 14° and 22° South Latitude and 66° and 71° West Longitude (Argollo 2001).

This area, especially the north part of the Poopo Lake, has intensive mining and metallurgic activity, the mining products in the region are primarily exported; among the minerals produced are lead, tin, silver, iron, etc.

## Bolivian mining background

Bolivia has important mineral resources and its mining tradition dates back a long time. Many of the greatest events in the country's history are closely linked to the discovery and development of its mineral resources. The origins of mining date back to the Tiwanaku (2000 BC. –1200 AD.) and Inca (1380–1550 AC.) civilizations,

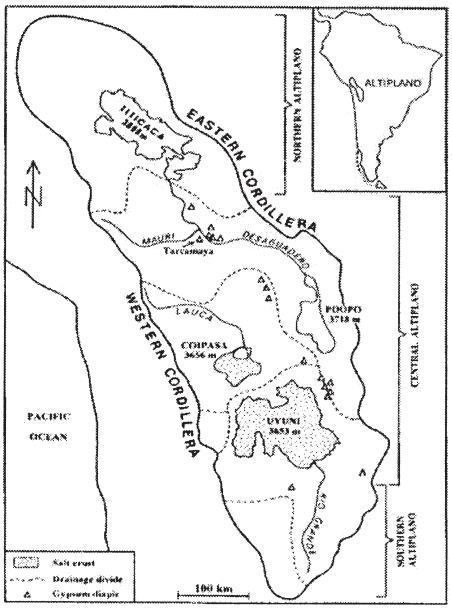


Fig. 1. *Location of the Poopo Lake and the central Altiplano (Risacher, 2000).*

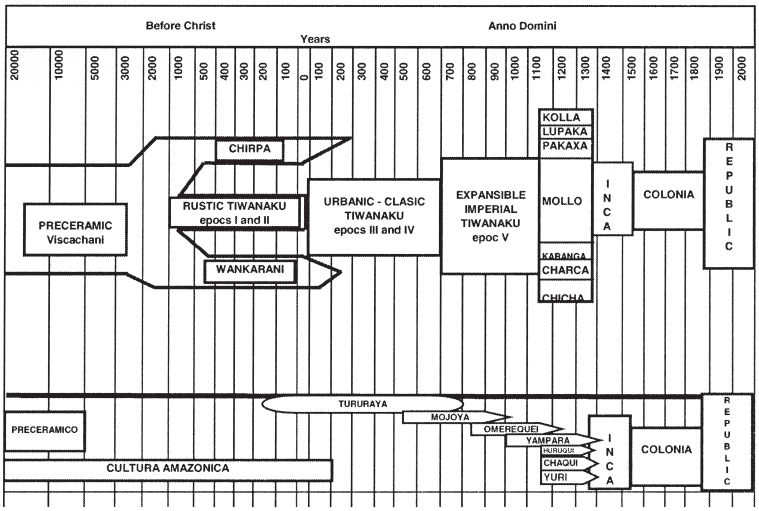


Fig. 2. *Bolivian cultural time history.*

known for their gold and silver wealth – inferred from the archeological items found – and their mining and metallurgic technologies (Fig. 2).

Several researchers and historians have shown that Tiwanaku was the first civilization in the Americas (Ponce, 1995) to mine and use minerals. They displayed a high level of technology in mineral extraction and metal craft, such as copper foundries mainly used for clamp production. They were the first to know about mineral development, value, and proper use.

This showed the level of knowledge they achieved in the course of their civilization, knowledge used for the production of many a great works of art and monument that live through centuries as proof of the quality of those "primitive" inhabitants of the Americas.

Bolivia was a major gold producer in pre-Columbian times, as inferred from the rich gold works left by pre-Columbian cultures, including hammered and laminated objects, repoussé work, burnished articles, casts, and welded and gold-plated items (Humerez, 1996). Other minerals, such as silver, were also used in similar works.

Copper was used to produce objects in different shapes, discs, vases, containers, tools, and weapons. Mercury was used to paint the faces of warriors and noble women. Tin, iron, and lead were byproducts of lead/silver mine foundries. All these minerals were extracted by the Incas in La Paz, Oruro, and Potosi.

Mining, metallurgy, gold work and artisanry used the following materials (Escalante 1993):

- Gold: for hammered and laminated objects, repoussé work, burnished articles, casts, and welded and gold-plated items.
- Silver: same techniques as above
- Copper: for objects of different shapes, discs, vases, containers, tools, and weapons.
- Mercury: used to paint the faces of warriors and noble women.
- Tin: It has not been found as a metal in archeological sites.
- Iron: "Iron Age" (Source: Gold Museum – La Paz)
- Lead: byproduct of lead/silver mine foundries (Source: Gold Museum La Paz)
- Salt: Abundant barter element (Source: Gold Museum – La Paz)

In the third decade of the 16th Century, the Spaniards, attracted by these treasures, arrived and violently conquered the Inca Empire. They discovered gold deposits in Cochabamba and silver deposits in Poopó (Oruro) and Potosi.

The first colonial silver mine was located in Oruro. However, Potosi became famous as a silver production site due to a rich silver vein discovered in 1554. The mining of Cerro Rico, silver refining and mining of the mid 16th Century sustained a population of 150,000 inhabitants, making the City of Potosi the largest in South America (Montes de Oca, 1997) and one of the biggest cities in the world. At a time when Bolivia was the major silver producer of the world (1553–1825), a popular Spanish-language term was coined to mean fabulous wealth: "vale un Potosi" (it is worth one Potosi).

From the mid 18th Century, silver mining in Potosi experienced difficulties due to the decrease in mineral concentrations and the problems making "mita labor" effective after the Cataris' uprisings. (Mita was a forced

labor system whereby all indigenous peoples between 18 and 25 years old had to work for 12 hours a day in the mines.) By the end of the 18th Century, the decline of Potosi was rather quick, and was made faster by the long struggle for independence. At the beginning of the Republic period (1825), Bolivian mining was practically in ruins.

It was not until the second half of the 19th Century that silver mining saw some growth and then dominated the industry. During that time, regional activity was also reactivated with tin mining, extracted first in 1860 (Capriles, 1977) at the Caracoles mine, located in La Paz. By the beginning of the 20th Century, Bolivia became a major tin producer, driven by the high world demand and its high prices.

The discovery of tin in silver concentrates brought about an increase in production from 100 tons in 1861 to 9,739 tons in 1900. In that year, tin relegated silver to a second place in the list of the main export minerals, and Bolivia was positioned as one of the world's major tin producers, reaching a production of 47,000 tons in 1929 (Troeng, 1997).

When the Bolivian "tin fever" started, some of the world's biggest fortunes were amassed and Chilean capitalists bought many mines. Between 1900 and 1913, great consortiums chaired by Patiño, Hoschschild, and Aramayo formed; they controlled Bolivian mining industry until 1952.

In 1924, Patiño became the sole owner of Llallagua, the richest tin deposit in the world, and controlled 10 % of the world's tin production, and 80 % of the foundries through a complex chain of almost 100 companies scattered around the world.

The positive development of tin mining beginning around 1900 became adversely affected after 1930 due to negative internal dynamics, including lack of investments, tax evasion, and capital outflows – exacerbated by trans-nationalization and the international depression, all of which brought tin prices down. The mining industry would never again be able to produce the same quantities of minerals as in 1929. Back then, mining exports accounted for 90 % of all exports and tin made up 74 % of mineral exports (Hermosa, 1979).

Between 1940 and 1946, there was an excruciating need of strategic war minerals for World War II. However, Bolivia, despite the high demand, did not take advantage of it. Bolivia exported and annual average of 40,000 tons of tin a year to the U. S. at the price of $0.41 per pound, at times when the international market prices were up at $4.50 per pound, thus, losing economic resources that could have been invested in much needed socio-economic development. The U.S. accumulated those tin reserves and sold off when they had a surplus, which resulted in a low international price.

In 1952, the state-run Corporacion Minera de Bolivia [Bolivian Mining Corporation], COMIBOL, was created. It gradually declined because of high inflation, little international demand, and low tin prices. Under its regulation, mining operations were classified into three categories:

- Large Mining Sector (state owned)
- Medium-sized Mining Sector
- Small Mining Sector

The small mining sector included many companies with small production. A fourth sector would later appear: the Mining Cooperatives.

One of COMIBOL's first initiatives was to devise massive employment of miners laid off by old private mining companies. Consequently, in 1956, the number of miners employed by COMIBOL reached 36,000 (Troeng, 1997). COMIBOL's production went down over the 50's. High inflation, low international demand and consequent lower tin prices, lower tin concentrations which meant, high extraction costs, reduced the mining industry. Annual production reduced from 26,000 tons in 1953 to 15,000 tons in 1960 (Capriles, 1977).

There was a slight increase in the sector in the 70's thanks to a raise in international prices and a period of political stability in the country. During that period, Bolivian tin production reached 30,000 tons a year and COMIBOL started a recuperation, strengthening, modernization, and diversification phase. The highest international price for tin was recorded in 1980, reaching $7.61/ pound.

A cycle of democratic governments was interrupted in 1964, when a period of military administrations overtook political life. This lasted until the early 80's. The democratic system has prevailed in Bolivia since 1982. Unfortunately, the major source of Bolivian exports faced its most critical times in those first years until the world tin market collapsed in October 1985. The tin economy collapse and steep drops in tin prices forced mining to turn away from the traditional underground mining of vein tin/silver deposits.

The government inaugurated in 1985 decided to implement a new economic policy, which reduced the state's participation in mining. The COMIBOL was the first target, and 75 % of its employees were fired. Many of its mining operations were closed down and efforts concentrated only on operations considered economically sustainable.

Production reduced drastically, hitting bottom at almost zero in 1987. It has been recovering since then. Many laid-off miners got together into mining cooperatives, to run several mines previously operated by the COMIBOL.

In 1987, Bolivian mining went through deep structural changes, average metal prices of interest for Bolivian export increased by 10 % compared to 1986 prices and, thus, production increased. The mining sector started a transformation, from single-metal production (tin) to more diversified mining. Consequently, in 1987, metals traditionally extracted by private miners, such as wolfram, antimony, zinc, and lead, began being produced by cooperatives.

In 1992, the mining cooperative sector was the major gold and tin producer in Bolivia, with significant silver, antimony, lead, and zinc production as well (Redwood, 1993). Since 1993, the medium-sized mining sector has been the biggest gold producer, mostly due to Kori Kollo mine's (open pit mine) gold production.

Governmental organizations that support the mining industry have undergone streamlining processes. Actions taken by Bolivia have been positively recognized by multilateral organizations like the World Bank, the International Development Bank, and the International Monetary Fund. Economic growth through foreign investment is the foundation of the economic policy of the current administration.

## Background on the mines around Lake Poopó

In the Lake Poopó area, mining activities date back to pre-Columbian times. Intensive mineral resource development started at the beginning of the Colonial times with the extraction of surface silver deposits in Poopó and Cuyuma. Mining went into a halt during the independence war, but restarted in the 1860's with the transfer of foreign investments and technologies, including new extraction technologies. Oruro was one of the place with the highest mining activities in the region, and the one with the most important mines, dating back to colonial times, all of which are mentioned next.

### The Huanuni Mine

This is the most important tin mine in Bolivia. It is located approximately 50 km southeast of Oruro. It began silver production in the Colonial times. In the early 1900's, tin production started, with an annual average production of 6,000 tons of tin concentrates (PPO, 1996). The main components of its industrial infrastructure are an underground mine, with a main gallery located next to Pozoconi Mountain, a mineral treatment plant, and utility facilities. Silver, zinc, and lead containing minerals are also extracted there.

### The San Jose-Itos Mining Center

This mine is located in the city of Oruro. It dates back to the Colonial times, to the same year the city was founded, in 1606. In 1865, a Chilean-French company, Compania Minera de Oruro [Oruro Mining Corporation], rehabilitated the old silver mine and started industrial mining. Modern tin, zinc-silver-lead production started in 1948, when this mine was administered by "Banco Minero de Bolivia" [Bolivian Mining Bank]. San Jose was nationalized in 1952, along with several of the largest mines in Bolivia, and it has since then been under the COMIBOL administration.

It is an underground mine, with several levels and a main entrance on Cerro San Felipe, at around 3,800 m.a.s.l. The mineral treatment plant is located on the eastern side of Cerro San Cristobal. San Jose's historical production was of around 5,000 tons a year of minerals with silver and lead and a little gold concentrates (COMIBOL, 1995). This mine was closed down in 1992, and has since been inactive, though its illegal extraction has not stopped.

The operation was inefficient with low productivity, high quantities of antimony and other impurities, high production costs due to lack of investment and a poor management. The mine and its mining infrastructure are now deteriorated and great quantities of waste materials are scattered on the side of the mountain where it is located. There are also large quantities of tailings near the concentration plant.

### The Kori Kollo [rich hill] Mine

This is one of the most important operations in South America. It is located in the La Joya District, 40 km northeast of Oruro. The mine is being developed under a mining concession granted by the state to Empresa Minera Inti Raymi S.A. Since 1988, the U.S. Battle Mountain Gold Company has had equity shares in Inti Raymi, and currently owns 88 % of the shares. A conventional open-cut global operation from 1984 to February 1993 leached the hills of rusted ore.

The Kori Kollo's ore is processed in a carbon in leach gold and silver recovery plant, with capacity to process 17,000 tons of ore a day.

Gold and silver are recovered by electrolysis, and are later melted to obtain doré as final product. In 1994–95, this plant exceeded its original 245,000 gold ounce capacity, and in 1995, Inti Raymi produced almost 36 tons of gold (PPO, 1996).

The mine's operations comply with international environmental standards, and operators frequently monitor the mine to detect any anomaly.

### The Bolivar Mine and the Avicaya-Bolivar District

This ore deposit was discovered in the early 19th Century and was initially developed for oxidized minerals with high silver contents. Tin extraction began around 1880, intensified after 1910. In 1977, an exhaustive mining program started; after positive results it became a joint venture between COMIBOL (50 %) and COMSUR (50 %), with the latter the operator. Its main entrance and its concentration plant, utility facilities, administrative facilities, and the mining camp are west of the Cerro El Salvador. The tailings are confined by clay and geotextile linings (PPO2, 1996), and have monitoring wells installed in order to detect any leak into underground waters.

### The Vinto Tin Foundry

This was built in 1971 to treat Bolivian mineral concentrates locally. Its initial objective was to treat 6,000 tons of concentrates per year. This foundry was later expanded to treat 20,000 tons. However, operations declined gradually until it only treated 2,600 tons in 1987, year when it lost millions of dollars.

The foundry process at this plant is very complex, with 40 steps, including material transfer among some of them. Most of the metallic tin goes through different processes such as toasting, reduction, volatilization, fusion, and refining. The $SO_2$ emissions reach levels of 14,000 tons/year (PPO, 1996) and metallic particle emissions between 400 and 1,000 tons/year. It does not comply with new Bolivian regulations regarding emissions, and to be able to comply with them, it needs major modifications.

The refinery, on the contrary, uses current thermal crystallizers and the tin product resulting from this process has high purity.

## Environmental effects of the mining activity in the Poopo lake

The Poopo region contains degraded water resources resulting mainly, on the one hand, from organic and bacteriological pollution in the sewage waters flowing from the urban centres in the area and heavy metal pollution from mining and metallurgic industries ALT (1999) and on the other hand, from high levels of salinity in certain bodies of water due to the natural conditions in the area.

Around 120 mines of lead, tin, gold and other metals leave their remains directly to the Poopo Lake, giving as result of the constant entrances of mining waste, high heavy metal concentrations in the water and sediments. In some previous studies (PRH, 1989) have been reported high discharge of heavy metals concentrations in the Poopo Lake, that are between 300 and 3500 times values from world-wide lakes. This issue is seen especially for lead, tin and antimony, originating almost in their totality of mines detected in the north of the lake.

Due to the mining activities in the area, mainly on the eastern part of lake Poopó, and the indiscriminate disposal of liquid mine residues, discarded ore, and washings, and substances used for mineral processing, such as highly toxic cyanides and xantates the health of the people living on the region is not the best. There have been reports of diseases throughout the region, like lung silicosis, caused by silica bi-oxide, which, after being inhaled settles in the lungs and favours the development of tuberculosis. Heavy metals, mainly from foundry plants residues, are poisoning. The effects on man are mental alterations, anaemia, nervous and renal problems, blood pressure, reproductive system anomalies, reduction in red blood cells and slower reflexes.

## Environmental consequences

In the Andean Cultures, Tiwanaku, Aymara and Inca, the principal characteristic has been the nature respect, and the rational use of the natural resources. Their Culture was considerate part of nature, in this way the Andeans Cultures lives in complete harmony with all around they.

The Tiwanaku Civilization was one of the most important Andean Cultures. The agriculture has been their principal activity, and the base of their economy, with a impressive agriculture because they invent a cultivation system called Sukakollus, between respect to the nature, they create a true “ecologic harmony”.

The Sukakollus were rectangular platforms with water channels. The water comes from the nearest rivers in the region.

This platforms had a stone base with a fine clay cape, this clay cape control the humidity and salt level in the superior levels ground, then they put it a cape of sand this cape retain the nutritional products value, finally a cape of ground with natural fertilizer.

The cultivation with this procedure to permit the next agriculture solutions:

- To keep a permanent humidity level using little water.
- To get a correct vegetal nutrition because this nutrition don’t produce the erosion.
- The water goes with stop is in this way than the roots don’t decompose.

This technique is making discovery again.

The Tiwanaku Culture made another activity like gold and silver funditions, for make ceremonial objects, and don’t use with monetary forms.

When the Spaniards arrives, the mine works were irrationals and without environmental control, especially with the gold and silver, thousands of people death in the mines, the agriculture weren't the economic base of the culture, with tortures in the agriculture jobs, and in the mines jobs.

A lot of Andean Cultures were destroys, complete Civilizations lost, and the environment pollution, making a ecological problem.

## Conclusions

In Bolivia mining has through history been one of the most important economic activities. This mining activity of gold, silver, tin and copper mainly was attractive for Spanish colonizers, who conquered the Incas Empire. After independence mainly tin was produced. Today, as a result the mining production is diversified towards gold and the polimetalics minerals. Of those many mines have been of environmental protection. The environmental damages are several.

Present and historic activities in the Poopo Area are responsible for acid drainages originating from metals and minerals remainders and inactive mines that contaminate groundwater, lakes and rivers, causing risk to the region people, damaging the flora and fauna and degrading the quality of the water.

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