

Digging Down, Building Up: Chile's Copper Mining Industry

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I. Executive Summary

Chile's remarkable economic ascent in recent years is due in great part to the strength of its mining industry and its copper exports. This research paper explores the business and socioeconomic aspects of the mining industry in Chile. It contains a discussion of the operations and production of mineral ore, as well as an analysis of the impact on Chilean society from the wealth generated by mining, with particular emphasis on the copper trade. We examine the correlation between Chile's overall GDP growth and the mining sector. Recent developments in mining technology are discussed. Safety aspects of mining are covered, as well as the environmental implications of large-scale excavation. The information contained herein is based on the notes taken, observations made, and interviews conducted during the author's visit to Chile in January 2012, plus secondary sources.¹

2. Inspecting the Copper Mine

Surrounded by waves of oppressive heat, with beads of sweat dripping from her furrowed brow, Carolina Millado traipses over to the utility vehicle that will take her back to the main entrance of the Los Bronces Copper Mine. Her utilitarian work boots are designed for safety, not grace. She has just completed her inspection of the Los Bronces mining safety operations as *Auditor de Calidad* (Quality Inspector). Her written report is due tomorrow, immediately before the morning conference call with senior management. She will be briefing her superiors on the mine's compliance with ISO 9001, an international standard on quality management systems. As a relatively junior member of the international engineering firm TechInt, her job requires extensive travel to remote locations throughout Chile, such as Huasco and Vallenar in the arid Atacama region. Finally reaching the exit, Carolina shuffles her feet in a largely futile attempt to remove the dirt and dust from her boots. The mining industry is not a beauty contest. There are no benefits conferred for being "cleaner" than the competition. All that matters is getting results, as efficiently (and safely) as possible. As Señora Millado makes her way back to the trailer that serves as her temporary workspace during her weeklong visit, she reminds herself that is ultimately her reason for being employed: maintaining operational safety at the mine.



Open-pit copper mines such as the Los Bronces site, northeast of Santiago, can be grueling environments for human workers.

Image credit: Anglo American PLC

¹ Authorship of photos & figures is attributable to the author unless otherwise noted.

In the aftermath of the 2010 Copiapó Mining Accident, firms such as TechInt, specializing in mining safety, have grown as various mining operators seek to improve their compliance with government regulatory laws. The Chilean *Ministerio de Minería*, or Ministry of Mines, is responsible for oversight and maintaining a constant vigilant presence, to minimize hazards to human workers, in the wake of significant mining incidents over the past decade.

Meanwhile, about 65 km to the southwest, in the heart of the nation's metropolis, a meeting of financial analysts is underway at Minera Los Pelambres (MLP). Dressed in crisp dark grey business suits, the young professionals pore over Excel spreadsheets projected on the conference room wall, detailing the company's most current financial position. The contrast between the hot and dusty mines and the air conditioned, ultramodern office space interior of the MLP headquarters could not be more stark. Yet, in the juxtaposition of these widely varying working conditions, we can begin to see the outlines of a common theme which inexorably links them: the incessant global demand for copper, the endless churning of conveyor belts and gurgling of floatation tanks, and the constant quest to extract and refine raw mineral ore from the earth's crust. These are the forces that drive the men and women of MLP and similar firms to provide their labor. These intrepid Chileans, like their ancestors, seek to mine copper and to enjoy profits commensurate with this enterprise.

Forecasted increases in copper supply are not expected to meet forecasted growth in demand for copper over the next decade. China's relentless demand, coupled with the overall global economic recovery, has driven market prices for this metal to record highs. Already we can see the signs of strain in the markets, as bizarre stories emerge of copper thieves ready to take advantage of the unusually high commodity prices (Fig 1.).



Copper has a wide variety of industrial uses. Examples of various parts fabricated from the reddish colored metal are shown here.

Image credit: aft-corp.com



This dramatic view from MLP's downtown Santiago offices highlights the geological formations that are the sources of Chile's mineral wealth.

3. Why Copper ?

Let us briefly examine the properties that make copper so desirable. Copper is a highly conductive metal, which means it does not resist the flow of electricity or thermal energy.

It is the second most conductive metal, after silver. This property, combined with its relative ductility, means that copper can be easily shaped and formed into copper wires for use in the transmission of electrical currents.

Other industrial uses of this versatile metal include pipes and fittings for indoor plumbing, roofing, and antimicrobial applications.

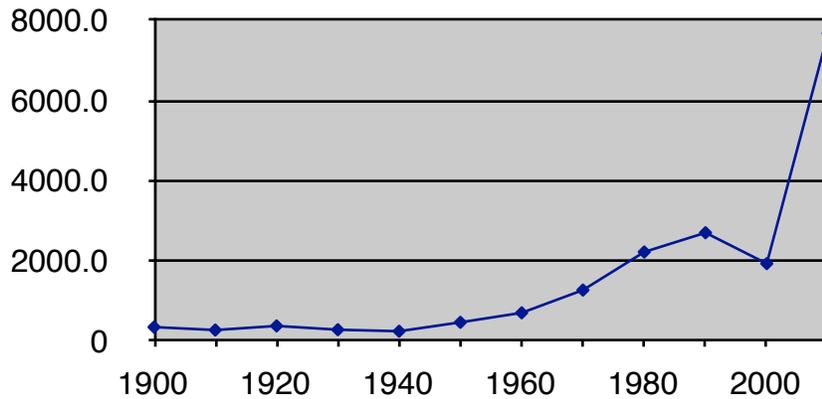


Fig 1. Historical Copper Prices 1900-2010 (in USD\$ per metric ton)

Source: U.S. Geological Survey, historical copper statistics

4. Digging for Ore

Although up to 30 percent of copper is recycled worldwide, the majority of copper is obtained thru the mining of porphyry copper ore. Chile accounts for about one-third of global copper ore production. What is involved in this process? According to MLP's public informational press kit, their process consists of the following steps:

- Mining
 - Rock containing ore is blasted and collected from pit with giant mechanical shovels
 - Transported via truck or conveyor belt to next stage
- Crushing / Grinding
 - Rocks are pulverized into a fine powder
- Concentrating via Froth Flotation tanks / cells
- Roasting & Smelting
 - Mixed with carbon and heated to drive off impurities, leaving only metal
- Electrolysis
 - Electric current is applied and used to form highly purified copper cathodes

5. Copper in the Securities Exchange Markets

Some may consider copper to be less aesthetically attractive than other metals such as gold, silver, or platinum. The difference in value between copper and its metallic cousins may be partly due to its relative abundance when compared to these other, scarcer metals. Despite this perceived lack of luster, copper remains a valuable metal with many industrial and technological applications, and consequently it is only logical for investors to consider it as an investment opportunity, particularly if they wish to diversify commodity holdings within their portfolio.

Holding physical copper metal for appreciation is a fundamentally impractical proposition for the mainstream investor, because managing the volumes and quantities involved is too unwieldy. Nevertheless, some enterprising individuals are hoarding buckets of copper pennies based on the intrinsic value of the underlying metal. These stockpiles may someday be worth much more than they are today, but for most people the logistics, transportation, and transaction costs involved in processing such volumes are simply not feasible.

Many mainstream investors prefer to trade in marketable securities whose underlying performance is somehow connected to the copper industry. The stocks of copper mining companies and other related businesses are sometimes bundled into exchange-traded funds, or ETFs. The following table is not intended to be a comprehensive listing, but rather to give the reader a sense of some of the different products available to an investor who wishes to invest in the copper mining industry.

Investment Product Name	Description
Antofagasta PLC (ANTO.L)	Antofagasta is a Chilean-based copper mining group with interests in transport and water distribution. It is listed on the London Stock Exchange. Antofagasta's activities are mainly concentrated in Chile where it owns and operates three copper mines.
Anglo American PLC (AAL.L)	Anglo American Sur SA, a subsidiary of Anglo American, holds a significant portfolio of copper assets in Chile, including the large open pit Los Bronces mine, the open pit El Soldado mine and the Chagres smelter.
First Trust ISE Global Copper Index Fund (CU)	The index is a modified linear weighted index designed to track public companies that are active in the copper mining industry based on analysis of revenue derived from the sale of copper.
Global X Copper Miners ETF (COPX)	The Solactive Global Copper Miners Index is designed to reflect the performance of the copper mining industry. It is comprised of selected companies globally that are actively engaged in some aspect of the copper mining industry, such as copper mining, refining, or exploration.
iPath Dow Jones-UBS Copper Total Return Sub-Index (JJC)	Reflects the returns that are potentially available through an unleveraged investment in the futures contracts on physical commodities comprising the index (currently the Copper High Grade futures contract traded on the COMEX).

Table 1. Sample Listing of Copper Mining Stocks and Exchange-Traded Funds

Sources: Morningstar, Inc., Yahoo Finance

Of particular interest is the recent emergence of physically backed copper ETFs. These investment vehicles are intended to provide the investor with exposure to the spot price of copper, without having to possess the physical metal.

6. Safety in the Chilean Mining Industry

“Chile is a fishing country - Chile is also a mining country”

- *Cristian Peña, Chief Information Officer, Minera Los Pelambres*

Señor Peña knows all about mine safety. A former crisis manager at ONEMI², the Chilean equivalent of FEMA, he is a naturally risk averse individual. Before every meeting, he routinely gives everybody an earthquake safety briefing, instructing his audience how to react if there is an event. Although our meeting takes place within the relatively safe confines of the company headquarters in downtown Santiago, we take these lessons to heart.



Safety requires constant vigilance in seismically active Chile.

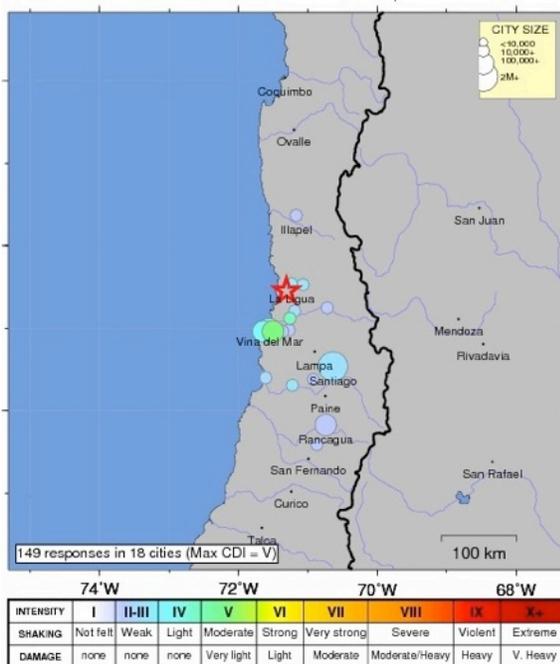


Fig 2. On January 9, 2012, we experienced a seismic event of magnitude 5.1, centered near Valparaiso, as depicted in this U.S. Geological Survey diagram.

The value of the emergency evacuation briefing was quite apparent, given the seismic activity later that day (Fig 2). Safety and avoidance of industrial accidents are an ever-present concern in Chile. The importance of conducting safety conscious operations has never been more urgent.

Tremors and earthquakes are a commonplace occurrence in this region. Indeed, Chile’s rich mineral deposits are due in part to its proximity to natural fault lines in the Earth’s crust. Thus, mining company executives and engineers must constantly perform a delicate balancing act to ensure the safety of their workers, reviewing and improving on-site safety programs, while simultaneously keeping costs associated with safety measures under control. Incurring excessive costs would place them at a competitive disadvantage, relative to others operating in the same sector.

² *Oficina Nacional de Emergencia del Ministerio del Interior y Seguridad Pública* (Interior Ministry, National Office of Emergencies and Public Security)

The financial costs and psychological burdens of hazardous working conditions in mines came to the fore, when Chile turned a near tragedy into an inspiring story of heroic deeds. The Chilean Mining Accident of 2010 and subsequent rescue of 33 miners from the San José mine was a watershed in Chilean history. Few other events have captured international media attention and inspired such solidarity with and among the Chilean people. According to conversations with a sampling of Chileans, the economic and cultural consequences of the 2010 Chilean Mining Rescue continue to reverberate throughout Chilean industry and society. This momentous occasion in Chilean history is a shining example of the capacity of humans to overcome seemingly insurmountable obstacles thru optimism, determination, and teamwork. Although some of the survivors are rumored to have subsequently lapsed into alcoholism and drug abuse, the key take-away message is this: “Whatever you set your mind to, you can accomplish.” Chile is currently reaping the economic benefits of this can-do attitude and collective team spirit.

7. Chile’s New Mining Prosperity

The signs of an abundance of wealth from the mining industry are everywhere in Santiago: from the gleaming skyscrapers, to the fashion-and-style conscious elite of Santiago’s populace. Access to credit is plentiful. Everywhere you turn there is a new bank or other financial institution, bustling with activity. The opulence is not extreme, for at their core Chileans are a practical people. Take for example the Santiago Metro system, which is heavily subsidized by the government. Such a major public works project and similar undertakings are only possible in the context of profits from the mining industry filling the national treasury’s coffers. The economy is robust and the people remain hardworking. Worker productivity is at an all time high, and while Chile’s miners are unionized, there have been few major strikes in this sector in recent years. Labor relations appear to be stable and healthy. Tourists are treated with care.



Chile has prospered in recent years as revenues from mining activities have percolated throughout the economy.



Fig 3. Chile’s Gross Domestic Product
Sources: Google / World Bank

Chile’s government policies, which combine strong free market principles, along with a healthy dose of public subsidies for social support systems and networks, have resulted in tremendous GDP growth (Fig. 3) over the past 2 decades, since

the fall of General Pinochet. Essentially they have served as a repudiation of strictly socialist or purely capitalist economics, in favor of a more flexible, blended model. This hybrid approach allows for the peaceful coexistence of private equity ownership, foreign direct investment, along with traditional state-owned enterprises, whereby mining profits are distributed into the economy by means of publicly owned industries (i.e. CODELCO³).

8. Modernization & Green Mining

What does a modern, mass-produced automobile and the conveyor belts and monster trucks carrying tons of raw copper ore down the mountain from the Los Pelambres mine have in common? They are both machines that have been fully outfitted with sensors that measure ambient temperature, weight, vibrations, tire pressure, atmospheric conditions, and other parameters. These sensors relay information about the entire mining operation back to a centralized command center, where decisions are made in real time, and dozens if not hundreds of adjustments can be made in order to optimize the efficiency with which the ore is collected from the source and delivered to its destination. Just as a modern car computer will fine-tune adjustments to the air-fuel mixture ratio based on sensory input, similar sensors and control logic provide near instantaneous feedback regarding the status of the entire system. As we witnessed during a visit to a sophisticated traffic control center in the outskirts of Santiago, there already exists an indigenous capacity to absorb and process large amounts of data. Chile is already operating as a 21st century, Information Age society.



Our student group visited a modern traffic surveillance center, shown here. CCTV cameras are used to monitor hazardous situations and dispatch police or road crews. Similar remote sensing, command and control tools can be used in a mining context.

There is definitely a growing awareness in Chile of the need to employ environmentally sustainable mining techniques. Whereas previously MLP's overall mission statement bluntly stated the need to maximize only profits and revenues, the most recent iteration of the mission statement takes a more nuanced approach. It speaks of the need to engage with multiple stakeholders, including local community leaders, and environmental watchdog groups, to ensure that the mining operations are being conducted in such a way that will reduce the negative environmental impact. The goal is to minimize the uncontrolled release of toxic chemicals used in the refining process, such as sulfuric acid.

³ *Corporación Nacional del Cobre de Chile* (National Copper Corporation of Chile)



The Gran Torre Santiago, pictured here, is under construction and slated to be completed in 2013.

Already the tallest building in South America, it serves as a testament to Chile's ambitions and wherewithal.

9. Concluding Summary

Chileans seem to have a love-hate relationship with their Mining Industry. On the one hand, it is only logical for Chileans to take full advantage of the natural resources that are available to their country. The entire nation celebrated the successful rescue of their beloved miners. And Chile's citizens reap the benefits of mining profits in the form of public subsidies and entitlements. Yet, the fact that such a large percentage of Chile's GDP is so dependent on exporting natural resources indicates that Chile still has far to travel if it wishes to break away from its colonial history and dependence on raw materials. Several of Chile's government initiatives have been geared towards diversifying the manufacturing base and steering the industrial output away from pure mining. For example, such efforts as Startup Chile (which awards thousands of pesos in seed capital to aspiring young businesspeople) are intended to incubate entrepreneurial activity, sponsor startup formation, and create synergies between companies. Essentially, the Chilean government is using a portion of its mineral profits to invest in speculation that some rather intelligent people will spawn entirely new industries and will ultimately catapult Chile far in front of the competition.

10. Closing Thoughts

While lounging in Santiago's spacious airport, waiting for the departure flight home, you observe several weary travelers taking a break from the frenetic pace of their voyage, pausing for a moment of personal reflection...

Following suit, you decide to close your eyes for just a minute...

Memories of your recent travel experiences surface, and you remember catching a fleeting glimpse of a wide, meandering road during one of the longer tour bus rides...

Driving past the glass skyscrapers, past the vineyards, past the dusty hills and the dry valleys, past the open-pit mines, the road flows forever forward...

You search for meaning in this vision, and when the forms take shape, you begin to see the road winding its way around unforeseen obstacles towards a distant horizon...

The dream becomes more real with each passing moment. Suddenly, a reddish glint appears!

The image before you is clear: the road leading ahead to Chile's bright future is paved with gleaming ingots of copper.



The road ahead...

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Appendix A: Original Notes from Los Pelambres Mining Site Visit

- 1/3 of the world reserves of copper are located in Chile
- Nitrate was also mined, but then Germany replaced this chemical with a substitute
- Michelin, Komatsu, Siemens, Enaex, FFE are all partners (they share risk)
- Ratio of company employees to contractors is 1:21
- Of 5,800 employees, only 800 are MLP employees
- “Federated Operations”
- The Mining Industry is not a beauty contest. There are no benefits conferred for being “Cleaner” than the competition
- It’s a dirty, dusty, sweaty, messy affair
- The primary goal is to extract, transport, and refine the ore as cheaply and efficiently as possible
- Safety and Industrial Accidents are an ever-present concern - this was emphasized during the seismic activity and emergency evacuation briefing during our visit to the (relatively safe) confines of the company headquarters in downtown Santiago
- Mining Safety – long term improvements. Afectamientos (special word for mining inspectors / safety officers). Increased after the accident
- Sensors in the tires. Sensors in the conveyor belts
- To determine how much stuff is transported
- MLP contributes 1% to the overall Chilean GDP
- Paying for trucks by TON of ORE transported. (fixed assets). Profit driven cooperation contracts (like incentive-based contracts). Are the workers contractors, Parts of the core business are run by other companies (paid by ton of ore moved per km)
- Blasting - ore extracted - crushers. Plant located 10 miles from the mine
- 10% of power is generated by Regenerative braking on the conveyor belt
- Floating process to get the copper
- Higher concentration of copper here than elsewhere in the Earth’s crust.
- Cristian Pena, Los Pelambres Mining (CIO of Minera Los Pelambres)
- Pena also worked in crisis mgmt.
- Equivalent of FEMA
- Consortium of Companies (Japanese) to ensure supply chain of copper
- Long term contracts, have to have the buyer side already in place before opening a new mine exploration / speculation
- 5th largest mine in Chile, 10th largest in the world
- Grinding, floatation cells
- Moly plant, water is reused
- 90 mile wide, 6 inch diameter concentrate pipeline (all this falls under Operations)
- Copper concentrate (what is the consistency)
- High pressure pipes
- Chilean Lusik family / only Chilean privately owned
- Economic Value Added, EVA (target function) - graph from Powerpoint presentation

- Former mission: Continually increase the value of MLP above its opportunity cost thru mgmt of excellence of business
- Cost Projection - profit (finite amount of copper to be extracted). \$1.7 B in revenue to give back to the shareholders
- 175 KTPD
- 175,000 tons per day - 2010
- 85,000 tons per day in 2003
- Plan is to 2x double production in a few years
- Archaeological sites “rescue”
- Profit driven cooperation contracts
- Never had a strike, “Chile is a mining country” - also “Chile is also a fishing country”
- Very small company operation, safety issues (the big disaster 33 miners trapped) - cause was small company
- Government regulation, they don’t put a supervisor in every mine
- Supply not sufficient to meet demand (China)
- EAP / ERP Enterprise Asset Planning
- Is Mining a source of pride for the Chilean people...
- Compare with USA aerospace industry / NASA space program
- Maximize the generation of sustainable value for the system formed by all the company stakeholders by means of a premium operation, the feasibility of new mining resources and the development of relations based in trust & mutual benefit
- New strategy: add sustainable value for ALL stakeholders
- Trust & Mutual benefit
- New vision: Be global bench mark in mining business sustainability before the year 2020, becoming the preferred company by stakeholders

Appendix B: Interview notes with Sra. Carolina Millado

- C.M. trabaja desde Vallenar (desde el norte de Chile)
- Copiapo / Region de Atacama / Huasco
- Proyecto Desarrollo Los Bronces
- www.youtube.com/watch?v=A8sIunbaSiQ
- www.youtube.com/watch?v=4fesryDhqZA
- Viaje el martes en la tarde a Santiago
- Mañana tambien trabaja un rato
- El martes vuelve a Vallenar
- Nunca ha estado en las minas subterraneas
- Solo en las minas abiertas
- El ambiente depende ...en los bronces un calor terrible
- El proyecto de Los Bronces de la minera Anglo American
- Trabajar en minas, con puros hombres, no es facil para las mujeres
- Es interesante que una mujer puede estar en las minas
- Su trabajo tiene que ver con la preparacion de reportes ISO 9001