Referring to areas at the heart of the mining process that present the most critical technological challenges for the industry's evolution.
本文旨在探讨采矿流程中的核心问题、提出了迫在眉睫的技术难题，以期进一步推动行业的发展进步。

CORE CHALLENGE TAILINGS
BACKGROUND
The copper mining industry extracts large volumes of material, of which only a small fraction corresponds to the element of economic interest that one seeks to recover. Once this material has been processed and the copper and other elements of value have been extracted, waste known as tailings is produced (comprised of ground material, water and reagents).
尾矿成为主要难题
背景
铜矿开采行业通常会开采出大量原料，但这其中只有一小部分原料真正具有经济价值。人们总是对经济的发展趋之若鹜。一旦开采出的原料经加工处理后得到了铜和其他具有经济价值的元素，废料也随之产生，比如我们熟知的尾矿（包含地面物质、水和一些反应物）。

Tailings are transported via pipelines to places specially conditioned for their deposition, known as reservoirs or dams depending on the method used to build the retaining wall (a reservoir's retaining wall is built with borrow pit material and is waterproofed from the top down the inner bank. Meanwhile, the retaining wall of a tailings dam is built with the coarser part of the tailings).
尾矿经由管道排放至特定地点进行沉积，根据挡土墙构建方式的不同，有些我们称之为水库，有些叫水坝（水库的挡土墙用的是借土坑材料，从顶部到下方的凸岸都是防水的。尾矿坝的挡土墙则是用更粗质的尾矿构建而成）

The fine solids settle in the reservoirs and a clear water lagoon is formed on the surface (National Geological and Mining Service [Sernageomin], 2013.
水库内精细固体沉淀，其上方形成澄清的水池（国家地质和采矿服务【国家地质矿产局】)，2013

The chapter Gravitating Core Challenges of the Mining Road Map was developed based on work by Enrique Molina, Director of Innovation in Mining at Fundacion Chile, who identified the sector's challenges and structured the gravitating core challenges.
章节“采矿路线图的地心引力核心挑战”是以智利矿业创新委员会董事 Enrique Molina 的理论为基础指导而制作的。Enrique Molina 确定了行业内的挑战，提纲挈领地揭示了引力的核心挑战。

The Core Challenge Tailings section was drafted based on work by the technical commission created for the core challenge, which was comprised of the following members: Angela Oblasser, Antonio Videka, Carmen Gloria Dueñas, Carolina Soto, Constantino Suazo, Cristian Cifuentes, Enrique Román, Felipe Mujica, Gerard Van Lookeren, Grecia Pérez de Arce, Gullibert Novoa, Gustavo Tapia, Hernán Cifuentes, Jacques Wiertz, Juan Carlos Alarcón, Juanita Galaz, Julio Echevarría, Luis Felipe Mujica, Juan Rayo, Marcelo Capone, Miguel Herrera, Patricio Renner, Raúl

Espinace, Rodolfo Camacho, Ronald Álvarez, Rosana Brantes, Sebastian Valerio, Sergio Barrera, Timothy Gardner, Ulrike Broschek and Waldo Vivallo.
“尾矿的核心挑战” 基于核心挑战技术委员会的建议起草。技术委员会负责明确和解决采矿业的核心挑战，现有以下成员：Angela Oblasser, Antonio Videka, Carmen, Gloria Dueñas, Carolina Soto, Constantino Suazo, Cristian Cifuentes, Enrique Román, Felipe Mujica, Gerard Van Lookeren, Grecia Pérez de Arce, Gullibert Novoa, Gustavo Tapia, Hernán Cifuentes, Jacques Wiertz, Juan Carlos Alarcón, Juanita Galaz, Julio Echevarría, Luis Felipe Mujica, Juan Rayo, Marcelo Capone, Miguel Herrera, Patricio Renner, Raúl Espinace, Rodolfo Camacho, Ronald Álvarez, Rosana Brantes, Sebastian Valerio, Sergio Barrera, Timothy Gardner, Ulrike Broschek 和 Waldo Vivallo.

The following team from Fundación Chile was in charge of drafting this section: Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito y Hernán Araneda.
以下来自智利基金会的成员负责起草本文内容：Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito y Hernán Araneda.

FIGURE/19
Composition of a tailings dam

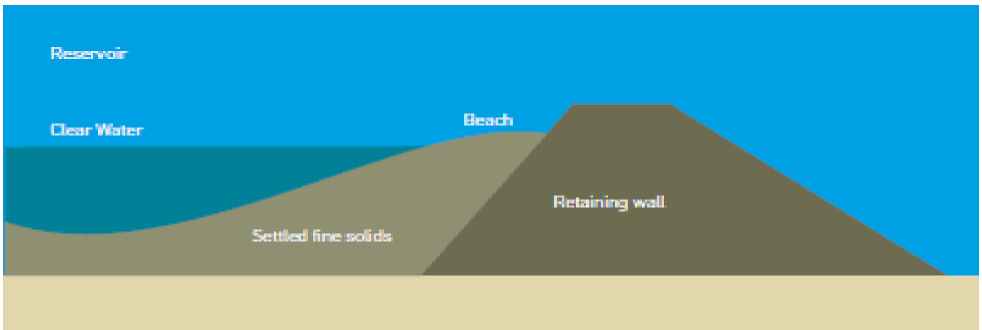


图19

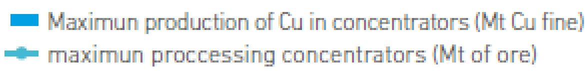
尾矿坝的组成：Reservoir 水库、Clear Water 澄清水、Beach 滩、Settled fine solids 精细固体沉淀池、Retaining wall 挡土墙

Due to declining ore grades in mines that are currently operating, and which are part of the mining firms’ development project portfolio, greater efforts must be made to extract increasing volumes of material to maintain production levels or to grow in line with market demand, which will result in a proportional increase in the amount of waste that must be disposed of, either as sterile material or in the form of tailings.
现如今，矿井中的矿石等级不断降低，而矿业公司欲丰富自己的开发项目组合，矿产业必须加大力度提取更多原料，以维持生产水平、满足市场需求。这无疑会导致废料的增多，废料最后会被处理成无菌材料或以尾矿的形式存在。

It is estimated that there could be an almost twofold increase in the production of tailings by 2035: if today 2.1 million tonnes of tailings are dumped every 36 hours, in 20 years we will do the same in just 21 hours.
据估计，到2035年，废料产量将是现在的两倍，打个比方：假设现在每36个小时倾倒210万吨废料，20年以后，每21个小时就有210万吨废料倾倒。

The following graph presents a projection through 2025 of the relationship between the material treated and the fine copper contained in the concentrate that is produced. The 5.7% annual increase in fine copper contained in concentrates means that treatment of the ore must grow at a rate of 8% annually, increasing from 549 million tons of ore treated in 2013 to 1.389 billion tons in 2025 (Cochilco, 2014d). That is, the Chilean mining industry will have to extract, transport, and process increasing volumes of ore, which will have a direct impact on the production of tailings.
下表中，专家根据过去的趋势预测了从现在到2025年，原料处理量与产出的精矿中纯铜含量之间的关系。若精矿中纯铜含量年要有5.7%的年增长率，则矿石处理量必须有8%的年增长率。2013年矿石处理量是54900万吨，在上述比例下，预计2025年矿石处理量会是13.89亿吨(Cochilco, 2014d)。这就意味着，智利采矿行业必须不断提高提取、运输和处理的矿石量，这势必直接导致尾矿的增多。

GRAPH/30
Relationship between ore treated and the fine copper contained in the concentrate that is produced
图30
原料处理量与产出的精矿中纯铜含量之间的关系



选矿厂最大铜产量（万吨，精铜）
选矿厂最大矿石处理量（万吨，矿石）

This scenario poses a tremendous challenge for the Chilean mining industry. Tailings are currently a major source of conflict between companies and communities: 47% of the tailings produced in the country have complaints against them or some sort of conflict with the population (JRI, 2015), which presents a significant challenge that must be addressed with the participation of all stakeholders (mining companies, communities and public sector) to make progress in materializing the vision presented in this document.
智利矿业面临着巨大挑战。尾矿的问题是矿业公司和社区之间最大的矛盾：47%的尾矿处理的问题收到来自社区的抱怨和投诉，或收到当地居民的投诉(JRI, 2015)。所有利益相关者（包括矿业公司、社会和公共事业部门）都必须共同承担责任、解决这一棘手难题，携手努力推动和实现本文内提到的美好愿景。

Though no major incidents have been reported in our country over recent times, recent international experience has shown that one of the main risks associated with tailings dams has to do with the breaching of containment walls and the consequential flooding of neighboring areas.

尽管目前国内尚未报道过大的冲突事件，但根据近年来国际上发生的情况看来，尾矿坝带来的主要风险是防护外墙溃裂和随之而来的泄洪波及到邻近区域。

These events can happen as a consequence of seismic or extreme climatological events and pose a significant risk to neighboring communities. In addition, 连第五页，第四页是单独的表格）leakage from tailings dumps, active and inactive, has gained importance in environmental impact assessment processes. They pose a long term challenge for mining operations, as they can cause an impact many years after the deposition of tailings. Deficient control and mitigation of leakage can have negative effects on public health and people's quality of life, polluting water bodies and soils, and causing negative impacts on other economic activities such as agriculture and livestock farming.
这些事件可能会由于地震或极端气候引起，从而对周围社区造成巨大的安全隐患。不仅如此，尾矿场有意无意的泄漏对环境亦造成很大的影响。这是采矿操作长期面临的一个问题，因为久而久之总有一天尾矿沉积会因这种泄漏受到影响。对泄漏的控制力度不足和排污力度不足会给公众健康造成伤害，亦影响了人们的生活质量。人们赖以生存的水体和土地会受到污染，连带其他经济活动亦无法有效进行，如农业和畜牧业。

Another important issue to be highlighted has to do with the irregular closure of tailings dams, which poses a risk of pollution to watersheds, rivers, lakes and coastal areas from leakage; a risk that the facilities could collapse; particulate matter emissions, aesthetic and landscape alterations, and acid drainage, among others.
另一值得关注的问题是尾矿坝的非定期关闭，周围的水域、河流、湖泊和沿岸地区受到污染物泄漏的潜在威胁；工厂倒闭的风险；颗粒物排放，美学和景观改造，酸性物质排放，等等。

Lastly, the increasing scarcity of water and space must be considered, critical matters when the projected increase in tailings is considered. In fact, in the future a significant proportion of mining production will take place in the central region, where the population density is higher and where there is more competition over the use of land and water resources.
最后，我们不能忽略一个严峻的问题：水源和空间的稀缺，因为上文中已预测到尾矿的量会逐年提升。事实上，将来矿业生产很大一部分会在中部地区进行，而中部地区人口密度越来越高，土地和水资源日益紧张。

Figure/20
Future mining resources in the Central Region

Over 50% of the country's future copper resources are currently found in Chile's central region, from the Coquimbo Region to the O'Higgins Region.
图20 未来中部地区采矿资源分布图
超过一般的国家未来铜资源已确认在智利的中部地区，从Coquimbo到O'Higgins。

操作

Table/7 表格7
Recent incidents associated with tailings deposits dumps

最近几年尾矿沉积场发生的事故

DATE	LOCATION	COMPANY

日期、地点、公司

21/NOV/2015 Hpakant, Kachin state, Myanmar No information

2015年11月2日，缅甸克钦邦帕坎，无信息

5/NOV/2015	Germano mine, Bento Rodrigues, distrito de Mariana, Região Central, Minas Gerais, Brazil	Samarco MineraÇão S.A.

2015年11月5日，地址和公司名建议保留（*to keep the original address and name, same as below*）

10/SEP/2014	Herculano mine, Itabirito, Região central, Minas Gerais, Brazil	Hercules MineraÇão Ltda.

2014年9月10日，

7/AUG/2014	Buenavista del cobre mine, Cananea, Sonora, Mexico	Southern Copper Corp.

2014年8月7日，

4/AUG/2014	Mount Polley mine, near Likely, British Columbia, Canadá	Imperial Metals Corp

2014年8月4日，

15/NOV/2013	Zageur Copper Molybdenum Combine, Kajaran Synuik Province, Armenia	Cronimet Mining AG

2013年11月15日，

31/OCT/2013	Obed Mountain Coal Mine, northeast of Hinton, Alberta, Canada	Sherrit International

2013年10月31日

17/DIC/2012	Former Gullbridge mine site, Newfoundland, Canada	No information

2012年12月17日

4/NOV/2012	Sotkamo, Kainuu Province, Finland	Talvivara Mining Company PLC

2012年11月4日，

21/JUL/2011	Mianyang City, Songpan Country, Sichuan Province, China	Xichun Minjiang Electrolytic Mangenase Plant

2011年7月21日

4/OCT/2010	Kolontár, Hungría	MAL Magyar Alumínium

2010年10月4日，

25/JUN/2010	Huancavelica, Peru	Unidad Minera Caudalosa Chica

2010年6月25日

29/AUG/2009	Karemken, Magadan región, Russia	Karamken Minerals Processing Plant

2009年8月29日

14/MAY/2009	Huayuan country, Xiangxi Autonomus Prefecture, Hunan province, China	-

2009年5月14日

22/DIC/2008	Kingston fossil plant, Harriman, Tennessee, USA	Tennsesse Valley Authority

2008年12月22日

8/SEP/2008	Taoshi, Linfen City, Xiangfen county, Shanxi province, China	Tashan mining company

2008年9月8日

10/JAN/2007	Miraí, Minas Gerais, Brazil	Mineraçào Rio Pomba Cataguases Ltda

2007年1月10日

6/NOV/2006	Nchanga, Chingola, Zambia	plc (KCM) Konkola Copper Mines

2006年11月6日

30/APR/2006	Miliang Zhen'an county, Shangluo, Shaanxi Province, China	Zhen'an county Gold Mining Co. Ltd

2006年4月30日

14/APR/2005	Bangs Lake, Jackson Country, Mississippi, USA	Mississippi Phosphates Corp

2005年4月14日

In the face of this reality, the state has defined an institutional framework and adopted a series of rules aimed at regulating this activity, especially with regard to the risks associated with the management of tailings. The main regulations governing mine waste dumps are:
为解决这些难题，国家研究了制度框架，实施了一系列规定治理尤以尾矿处理为重点难点的多项问题。治理矿业废物倾倒的主要规则是：

• Supreme Decree (SD) 248, which regulates the design, construction, operation and closure of tailings dumps.
  最高法令248管理尾矿场的设计、建造、作业和关闭
• SD 132, Mine Safety Regulation, which establishes the general regulatory framework that National Mining Extractive Industry operations must comply with.
  最高法令132管理矿业安全问题，设立了总体治理框架，国家矿业开采行业作业流程必须遵守这一框架
• Law 19,300 on General Environmental Regulations. Organic Law of the Environment Superintendence.
  19300法令是关于总体环境治理。环境治理的基本法令。
• Law 20,819, enacted in early 2015 to amend Law 20,551, regulating the closure of mine operations and facilities and introducing other legal changes.
  20819法令颁布于2015年，对20551法令进行修订。该法令对矿井和作业设施的关闭做了规定。该法令亦包含其他的法令修订。
• Law 3,525, Organic Law of the Sernageomin (National Geological and Mining Service).
  3525法令，国家地质矿产局（Sernageomin）基本法令。

Despite the fact that progress has been made with the regulatory framework to protect people and the environment, pending issues remain that must be addressed together with the

authorities, such as leakage, for example.
在有针对性的治理框架的作用下，居民安全和环境保护颇有成效。不过，仍有悬而未决之事需政府干预，如泄漏问题。

The expected growth in production, together with a scarcity of land for deposition and doubts they produce in the community, suggest the need to review current deposition procedures, evaluate the design methodology for new dumps and seek alternatives to mitigate the impact that could be caused by dams currently in operation.
产量的增加、用来进行沉积的土地资源的稀少、社区的质疑，等等一系列问题预示着各方需检视现行的沉积流程以及评估新的尾矿场的设计，另辟蹊径，寻找更佳措施缓解现有的尾矿场已给社会带来的负面影响。

REGISTRY OF TAILINGS DUMPS IN CHILE
Sernageomin regularly updates its registry of the tailings dumps in the country. According to that information, there were 718 tailings dumps throughout the country in 2015, of which 119 are active, 443 are inactive, 124 are abandoned, and 32 are lacking information. The following figure shows the status of the dumps registered and their distribution in the different regions of the country.
智利尾矿场的注册情况
Sernageomin定期更新国内尾矿场的注册情况。根据获得的数据，2015年，智利共有718座尾矿场，其中119座在用，443座闲置，124座废弃，另有32座无登记信息。以下数据揭示了登记过的尾矿场的运营状态和在国内的分布情况。

Figure/21
Status of tailings dumps
in Chile by region
图21 智利尾矿场区域分布状态

active：投入使用

Non active：闲置 abandoned：废弃 N/I：无登记信息

The registry establishes the existence of 124 dumps classified as abandoned, a condition to classify all dumps with no known owner or certificate of origin, or where there is official or reliable information to indicate that no closure measures were taken. This situation forces the state to take responsibility for evaluating the structural risk and leakage of polluted water, in addition to the means for capturing and neutralizing them.
从登记情况我们可以看出，124家尾矿场被划为废弃状态，废弃状态是指没有场主的尾矿场，或无起源证明的尾矿场，亦或者有官方或可靠信息证明该场确未办理过关闭手续。这种情况，必须由国家出面，担起责任，评估其结构风险，检查是否有受污染水源泄漏。仅仅治理表面污染是不够的。

For their part, the Atacama and the Coquimbo Regions concentrate the largest number of active dumps, with 37 and 36, respectively. The Valparaiso and the Antofagasta regions trail far behind, with 20 and 12 dumps, respectively.
在这方面，Atacama和Coquimbo地区集中大量的在用尾矿场，分别有37座和36座。Valparaiso和Antofagasta地区的尾矿场数量最少，分别为20座和12座。

Of the total number of active dumps, 63 are for copper mine tailings. However, when dumps whose source ore includes copper and another mineral are considered, this number increases to 87.
所有在用的尾矿场中，63座是铜矿尾矿场。然而，有87座尾矿场，其源头矿石不仅含有铜，还含有另一种矿石。

The main tailings-producing mine operations are those belonging to the large-scale mining category. The remaining tailings are produced by medium and small scale mines. Codelco is the main producer with 28% of the total tailings produced in the country. It is followed by the company Antofagasta Minerals (AMSA) with 16% and BHP Billiton with 13% (JRI, 2015).
主要的高尾矿产量的矿井作业都属于大型采矿一类。其余尾矿来自中小型矿井。Codelco是尾矿产量大企业，国内28%的尾矿来自Codelco。其后是Antofagasta Minerals (AMSA)，16%，BHP Billiton，13%(JRI, 2015)。

Current production of tailings is concentrated mainly in the northern regions, with 62% of the total. The central region produces 37% of mine tailings, while production of tailings in the southern region is practically nonexistent (1%).
目前尾矿主要聚集在北部地区，占总量的62%。中部产出37%的尾矿，而南部地区几无尾矿踪影。

The main tailings producing mine operations in northern Chile are Escondida, Chuquicamata, Collahuasi, Caserones, Centinela, Candelaria, Ministro Hales and Salvador. Regarding central Chile, the main tailings producing operations are Los Pelambres, El Teniente, Andina, Los Bronces and El Soldado.
智利北部主要的尾矿生产矿井作业是Escondida、Chuquicamata、Collahuasi、Caserones、

Centinela、Candelaria、Ministro Hales 和 Salvado。

The largest operational tailings dumps in Chile are El Mauro, Minera Los Pelambres; Las Tortolas, Los Bronces; Talabre, Chuquicamata and Minstro Hales, Pampa Pabellón, Collahuasi,and Ovejería de Andina; Carén, El Teniente; and Laguna Seca, Escondida.
智利最大的操作型尾矿场是El Mauro、Minera Los Pelambres；Las Tortolas、Los Bronces；Talabre、Chuquicamata 和 Minstro Hales、Pampa Pabellón、Collahuasi，和Ovejería de Andina；Carén、El Teniente；和Laguna Seca、Escondida。

VISION OF CORE CHALLENGE 核心挑战下的愿景
"To attain global technological leadership that, when applied to the design, operation, and environmental closure of tailings dumps, facilitates obtaining the social license to operate and ensures the mining industry's development."
"努力占领全球技术领导力高地，在尾矿场的设计、作业和封闭性方面提高技术含量，加快脚步赢得社会作业许可，确保采矿行业发展。"

GRAPHIC/31 图表31
Tailings dams according to metal produced
根据生产金属种类划分尾矿坝属性
CHALLENGES, SOLUTIONS AND R&D LINES
The group of experts that participated in the technical workshops defined four challenges, based on the background information evaluated and the vision established for the Core Challenge: Tailings. Potential solutions and R&D lines were identified for each of these.
挑战、方案和研发线
参与技术工作的专家基于背景信息的分析和核心挑战（尾矿）的愿景，指出了四种挑战。每一项挑战都配对了可行的方案和研发线。

Challenge No. 1: Dealing with increasing shortages in water and space.
The mining industry has gradually reduced its water consumption, thanks to technologies that have allowed the deposition of thickened tailings, in paste and filtered. However, this has not been implemented in a cross-cutting way throughout the industry, as additional conditions are required for this type of application to be implemented on a larger scale. Furthermore, in addition to the intensive water consumption by the copper concentrate line of production using sulfide ores, the gradual exhaustion of oxide resources and their replacement with sulfides will cause a significant increase in water consumption for this purpose. Currently net freshwater consumption by copper mining is between 0.5 and 0.7 cubic meters per tonne of ore processed, with evaporation and water retention in tailings dams the main reasons behind said consumption.
挑战1：应对日益严峻的水资源和空间资源不足。
如今，矿产业正逐步减少对水资源的消耗，在新型技术的辅助下，我们可以沉积增厚了的尾矿，先处理成膏状，再进行过滤。然而，并不是行业内所有矿业公司都大力推广使用该技术，因为要应用这种技术，对尾矿场的其他软硬件要求很高。使用硫化矿生产铜精矿会消耗大量水资源，除此以外，氧化物资源和其替代物硫化物资源的逐步耗尽亦会大幅增加水消耗量。目前，铜矿开采的淡水净消耗量每吨矿石需0.5到0.7立方米。尾矿坝内有蒸发和保水性等因

素，但水资源日益减少背后的主因是对水的消耗。

In addition, the lack of space and the conflicts it produces means there is a need for new technologies and methods to be developed that could in the future allow the mining industry to do without tailings.
另外，空间的缺乏和后续的矛盾意味着我们确有需要开发新技术和新方法，在将来某一天，可以实现无尾矿产生的采矿流程。

table /8 表格8
Solutions and R&D Lines. Challenge: 方案和研发线。挑战：
dealing with the increasing scarcity of water and space
应对日益严峻的水资源和空间资源不足

SOLUTION	R&D & i LINE	方案 研发和i线

Efficient and high-capacity separation of solids from liquids
有效的、大容量固体液体分离装置
Minimize evaporation.
液体蒸发最小化
Water recirculation 水的再循环
Optimal operational management.最佳操作管理
Use of seawater or lower quality water for flotation process and its impact on transportation, both of water as well as tailings, and for the management of dumps.
使用海水或低质水进行浮选流程及其对交通的影响，两种水质对尾矿及垃圾场的管理带来的不同影响。

Improving and developing cost-efficient methods for separating solids from liquids on a large scale: filtering, HD thickeners.
提高和开发高性价比的方式进行大范围的固液分离：过滤、HD增稠剂。

Development of different compacting methods to increase dump capacity: electro-separation, agitation, parcellation, others.
开发不同的压缩方法提高尾矿场容量：电镀分离、搅拌、分割等。

Tailings transportation: rheology modifiers, others.
尾矿的运输：流变改性剂等。

Improvement/conversion of conventional deposition methods into new deposition methods for existing dams.
对现有尾矿坝的传统沉积方式做调整

Improvement and development of operational, physical, chemical or biological methods to reduce evaporation from dump.
改进和发展操作上、物理上、化学上和生物上的方法来减少尾矿场的蒸发。

Development of new pumping systems. 开发新的抽运系统

Development of technologies to facilitate parcellation of central lagoon, among others.
开发新技术促进中央泻湖的分割等。

Effects of seawater on dump's operation and stability in short-, medium- and long terms.
提高场内使用海水的有效性，维持短期、中期和长期有效性。

Dry processes for mineral recovery.
用干燥法进行选矿回收
Prediction and monitoring of the socioenvironmental footprint of tailings dumps (Mining Footprint type).
预测和监测尾矿场对社会环境的影响（采矿影响类）
Management of water resources based on their availability and use on a watershed level.
根据水资源是否充足和流域规模情况管理水资源
Comparison of sands and crushed ores.
对比沙和岁矿石
Mining without tailings dumps.
无尾矿产生的采矿
Development and improvement of new methods or dry processes for mineral recovery.
开发新方法或调整干燥法以进行选矿回收

Development and improvement of new methods for predicting and monitoring of the socioenvironmental footprint of a tailings dump.
开发和提升新方法，预测和监测尾矿场对社会环境的影响。

Development and improvement of methods for managing water resources based on their availability and use on a watershed level.
开发和提升新方法根据水资源是否充足和流域规模情况管理水资源

Improvement and development of compacting technologies like electro-separation, agitation, parcellation, vibration and others to increase the amount of water recovered from the dump and to expand its capacity.
提升与开发压缩技术如电镀分离、搅拌、分割、振动和其他技术来提高尾矿场的水的回收利用率，扩展尾矿处理量。

Development of new methods that do without tailings dumps.
开发新方法，实现无尾矿采矿技术。

Challenge No. 2: Minimizing the impact of
leakage and ensuring the stability of dumps.
挑战2：最大程度降低尾矿泄漏的危害，保证尾矿场的稳定性
Leakage, and its impact on the environment and people, represents an ongoing challenge for

operating tailings dumps and the future sustainability of the mining business. In this sense, developing and improving technologies that can neutralize the tailings before their deposition is indispensable, as is characterizing deposition sites and sealing them to prevent any contact with surface waters. As a complement, existing legislation needs to be strengthened to ensure that future tailings dumps are designed and operated under the “zero effective discharge” concept.
泄漏和后续对环境和生命的危害不言而喻。尾矿的泄漏是尾矿场长期面临的一个挑战，亦是采矿事业今后可持续发展道路上的一道坎儿。从这个角度考虑，尾矿场很有必要开发提升新技术，可以在尾矿沉积之前就被中和，再选取特殊的沉积位置密封，避免一切与地表水接触的机会。作为辅助措施，现有法律必须进一步加强力度来管控和确保未来的尾矿场的设计和运作都要以“有害物质零排放”为理念。

The physical stability of dumps is a critical issue. A recent review of catastrophic failings at major tailings dumps internationally reveals that the flaws correspond to overtopping (erosion), instability in walls and the impact of a major earthquake. These flaws are normally caused by a combination of things, among which defective design and construction, lax control in operation and mistaken calculation of natural events, among others, stand out.
尾矿场的物理稳定性是一个重要课题。对国际上大型尾矿场的灾难性事件进行回顾后不难发现，通常是越堤（腐蚀）、墙体不稳和地震原因造成最后的灾难。这些原因又涉及诸多环节，其中，设计和建造缺陷、作业的控制不严和自然事件的错误计算等成主要因素。

Lastly, the geochemical stability of dumps is normally associated with the potential production of acid through a chemical reaction in the tailings with water and atmospheric oxygen. In this context, a distinction must be made between dumps that are abandoned, in operation, and those which are to be built in the future, so strategies can be created to adequately control and/or neutralize each of the aforementioned situations.
最后，我们不能忽视尾矿场的地化稳定性。地化稳定性通常决定着尾矿内的物质会不会和水还有大气氧反应生成酸性物质。因此，废弃尾矿场、在用尾矿场和未来将要建造的尾矿场必须区别对待，尾矿场要构建合适的战略对以上情况进行充分的管控和/或中和。

TABLE/9 表格9
Solutions and R&D Lines. Challenge: 方案和研发线。挑战：
Minimizing the impact of leakage and ensuring the stability of dumps.
最大程度降低尾矿泄漏的危害，保证尾矿场的稳定性

Zero discharge through capture and treatment of leakage and contact waters.
通过对泄漏和被污染的水源的治理，实现有害物质0排放
Treatment and neutralization of tailings for deposition.
待沉积的尾矿的预处理和中和
Waterproofing of future dumps.
未来尾矿坝的防水性
Localization and monitoring of leakage.
泄漏的定位和监测
New techniques for characterizing deposition sites.
开发新技术选取沉积位置

Control of particulate matter.
管控颗粒物
Sealing of tailings dump
尾矿场的密封
Improvement and development of passive, active and combined methods. Technologies to avoid the occurrence of post-closure leakage, including the management of surface waters and their interaction with the dump, in addition to the waterproofing (coating or sealing) of dumps.
提升和发展被动、主动和综合方法。要开发技术以避免尾矿场的关闭后泄漏，包括管理地表水与场内物质的相互作用，只做好尾矿场防水工作（涂层和密封）是不够的。
Improvement and development of low-cost, simple, efficient and scalable technologies for the treatment (neutralization) of tailings prior to deposition (pyrite, arsenic, others).
提升和开发低成本、操作简易有效、具有可扩展性的技术在沉积前处理（中和）尾矿（黄铁矿、三氧化二砷，等）
Development of technologies for waterproofing the base of future deposits, such as bio-sealing, polymers, among others.
开发新技术为未来的沉淀物地基做好防水工作，如生物密封、高分子聚合物等。
Improvement and development of low-cost technologies for the localization and monitoring of leakage.
提升和开发低成本高回报的技术进行泄漏的定位和监测。
Improvement and development of low-cost technologies for characterizing sites.
提升和开发低成本高回报的技术选取地址。
Improvement of existing technologies, such as phytostabilizers, suppressors, soil bio-feeders, granular covers, bio-sealing, among others. Improvement and development of predictive models. Development of plotters. Development of new control technologies.
提升现有技术，如光稳定剂、抑制剂、土壤生物支路、颗粒覆盖、生物密封等。提升和开发预测模型。开发绘图机。开发新的控制技术。
Improvement and development of new technologies for sealing tailings dumps
提升和开发新的技术密封尾矿坝。

Challenge No. 3: Promote conversion of a liability into an asset
挑战3：把债务转换为资产
The concept of an Environmental Liability (EL) can be interpreted as abandoned or paralyzed mine operations, including their wastes, posing a significant risk to life, public health or the environment (Sernageomin, 2008). Abandoned or paralyzed tailings dumps fit with this definition.
环境债务（EL）这一概念可以指废弃或瘫痪状态的矿井作业，包括废料在内，都会对人们的生活、公共健康和环境产生巨大的危害(Sernageomin, 2008)。废弃或瘫痪状态的尾矿场在其之列。

The conversion of tailings dumps into assets is aimed at using the tailings, or part of them, as a source of value. While the recovery of elements of commercial value constitutes a contribution, it does not fully resolve the problem. Alternative uses need to be found that involve a significant proportion of tailings produced and to just those elements like copper, gold, molybdenum, iron or others that might be present and subjected to reprocessing. The adequate management of

environmental liabilities would directly benefit communities and contribute to the future sustainability of the mining industry.
把尾矿场转换为资产，即让尾矿发挥出其价值。对有商业价值的元素进行回收利用是一种措施，不过这远未能解决问题。我们必须从尾矿中寻找大量的替代物质，或者从现有金属中找一些元素如铜、金、钼、铁等，把它们二次加工。充分管理好环境债务会直接造福社区安全，亦巩固了采矿行业长期可持续发展。

TABLE/10 表格10
Solutions and R&D Lines: 方案和研发线：
promoting conversion from a liability to an asset.
把债务转化为资产

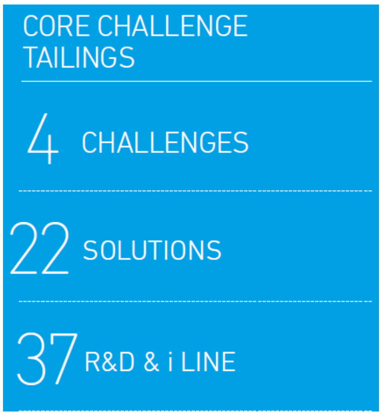
Investigate industrial uses for tailings
调查行业对于尾矿的使用
Recovery of valuable elements
回收有价值的元素
Use of dump surface for other purposes.
有效利用尾矿场地面
Develop industrial uses for tailings
开发尾矿的其他使用方式
Waterproofing and filling of mine excavations
矿井挖掘的防水工作和填充工作
Improvement and development of low-cost technologies for characterizing tailings for the recovery of valuable elements.
提升和开发低成本高回报的技术分析尾矿，以获得可回收的有价值元素
Improvement and development of sampling techniques to achieve high recovery level.
提升和开发取样技术，以获得高回收率
Analytical progression: rare earths, other elements of interest.
分析进阶：稀有土地和其他有价值元素
Development and improvement of technologies for recovering elements of interest.
开发和提升技术，以回收有价值元素
Industrial, recreational purposes.
行业目的和其他目的

Challenge No. 4: Fostering community inclusion and acceptance
As has already been noted, a significant proportion of currently operating tailings dumps have difficulties with neighboring communities, which is translated into complaints addressed to the anchorites and legal action taken by the population.
挑战4：促进社区的融入和接纳
我们之前就提到过，很大一部分现有在用的尾矿场和周围社区的关系紧张，导致很多的匿名投诉，社区居民走法律途径声讨尾矿场。

Resolving this challenge requires fulfilling the basic condition of giving communities access to clear and understandable information on neighboring tailings dumps, a matter that can be

addressed by developing special technologies for this purpose. As a complement, the creation of spaces for participation must be fostered to involve communities and effectively communicate the progress made in the handling and treatment of tailings.
着手解决这个问题的基础条件是明确告知社区居民，他们周围有哪些尾矿场，这可以通过特殊的技术手段实现。为此，我们必须开辟一条路径让社区参与进来，促进尾矿场和社区之间的有效沟通，让社区居民知晓尾矿的处理情况。

TABLE/11 表格11
Solutions and R&D Lines. Challenge: 方案和研发线。挑战：
fostering community inclusion and acceptance. 促进社区的融入和接纳
Real-time registration and communication of variables critical to the dump and its vicinity.
实时登记尾矿场信息，尾矿场和周边地区社区应随时保持重要信息的沟通
Development of shared-value products.开发符合共同价值观的产品
Definition of safe standards for implementing local/operational networks
定义安全标准，依照标准执行当地/操作流程
Development of operator-community-process communications interface.
简历沟通桥梁，连接尾矿场和社区
Improvement and development of phenomenological models.
提升和开发现象主义模式
Development of sensors for online monitoring of critical variables.
开发感应器，建立在线监测技术，监测尾矿场重要变化
Energy generation from tailings transportation.
尾矿运输带动能源产生
Waters for different uses as a function of their quality.
不同水质的水的用途不同



核心挑战：尾矿
4大挑战、22种方案、37条研发和i线
RESOURCES 资源
INFRASTRUCTURE 基础设施
- Fiber optic networks for telecommunications 电信光纤网络

LEGAL INSTITUTIONAL 法律机制
- Promote R&D&i ecosystem 促进研发和i生态系统
- Personnel Development Policy 人力资源开发政策
- Regulation to take responsibility for leakages泄露的管理工作

(non-circumstantial sources) and contact waters.（非环境水源）和接触水

- Decisions on existing liabilities. 现有的负债的处理决定
- Promoting reprocessing of tailings in operation. 加快现有的尾矿的再处理

CAPACITIES 能力建设

- Specialized human resources for inspecting dumps.建立检查尾矿场的特殊人力资源人群
- Specialized human resources for operating dumps.建立操作尾矿场的特殊人力资源人群
- Specialized human resources for R&D 建立研发小组

SUPPLIERS 供应商

- Strengthen local suppliers in instrumentation/representation. 强化当地供应商在检测/表述方面加强能力

ALLIANCES 联盟

- Alliances Projects FIE Codelco, AMSA and Enami 联盟项目FIE Codelco, AMSA 和 Enami
- Alliances between industries and Technical Training Centers, training of operators

行业、技术培训中心、操作员培训中心形成联盟

- Alliances between research centers, Universities, Industries, State, Suppliers.

研究中心、高等学府、行业、政府、供应商形成联盟

INFOGRAPHIC/1 信息图表1

Technology Watch: Tailings (Patents)

技术简报：尾矿（专利）

2010年至2015年间获得70份专利

主要技术趋势

-固体废料的销毁或转化

-液体混合器

-工业淤泥处理

-以上环节所需工具

-水处理

-污染物性质

拥有专利最多的国家

PATENT YEAR CITATIONS

Patent	Year	Citations
US8137566B2 *Recovery of tailings ponds*	2012	22
US8859090B2 *Micro-structured surface having tailored wetting properties*	2014	4
US7682582B2 *Simultaneous removal of H2S and SO2 from tail gases*	2010	4
KR101315807B1 *Production of Refuse Derived Fuel and Treatment of Biomass with zero discharge system Using Microbial Materials*	2013	3
CA2750934C *Parafinic froth treatment with tailings solvent recovery having internal flowrate inhibiting asphaltene mats*	2012	3
US8197676B2 *Method for tailings solvent recovery*	2012	3
FR2937257A1 *Methode of construction applicable aux adsorbeurs radiaux de grosse taille*	2010	2
US9068245B2 *Process for the recovery of gold from anode slimes*	2015	1
CN102267751B *Rapid precipitation and concentration tank for tailing sewage*	2013	1
EP1676478B1 *Slime remover and slime preventing/removing agent*	2011	1

专利年份引用
尾矿池回收；
微结构表面，其具有特定的潮湿属性；
即时清除尾矿中的H2S和SO2；
生产废弃物衍生燃料，利用微生物材料处理大量废弃物，仍实现零排放；
用尾矿溶剂回收物处理石蜡泡沫，内部流量抑制沥青烯隔垫；
尾矿溶剂回收方法；
适合大型径向吸附器的构造方式；
从阳极泥回收提取金元素的流程；
建立尾矿污水快速沉降和浓缩池；
泥的清除工作，泥的预防/清除溶剂

COUNTRIES WITH MOST PATENTS

Canada 19
USA 18
Germany 13
Japan 7
France 7
China 7
Denmark 3
Holland 2
Switzerland 1
Greece 1

拥有专利最多的国家

（国家名从上至下）加拿大、美国、德国、日本、法国、中国、丹麦、荷兰、瑞士、希腊

MAIN UNIVERSITIES

University of Freiberg
University of Nankín

主要大学：德国弗莱堡大学、中国南京大学

MAIN COMPANIES AND/OR R&D CENTERS

- Basf AG
- Suncor Energy INC
- Kurita Water IND LTD
- Smith & Co AS F L
- Changchun Gold Res INST
- Du Pont
- Fort Hills Energy LP
- Nippon Sodaco
- Total E&P Canada LTD.
- Chinanat Gold Group Corp Technology CT

主要公司和/或研发中心

INFOGRAPHIC/2

Technology Watch: Tailings(Publications)

信息图表2：技术简报：尾矿（出版物）

SCIENTIFIC PUBLICATIONS 2010-2015

科学出版物 2010-2015

MAIN RESEARCH TRENDS	N°
Ecology and Environmental Science	22
Engineering	14
Geology	9
Ore processing	9
Agriculture	8
Geochemistry and Geophysics	6
Materials Sciences	6
Water Resources	6
Applied Biotechnology and Microbiology	5
Chemistry	5

主要研究趋势

生态学和环境科学；工程学；地质学；矿石处理；农业；地球化学和地球物理学；材料科学；水资源；应用生物技术和微生物学；化学

SCIENTIFIC PUBLICATIONS

69

科学出版物 69

MOST-CITED PUBLICATION

Hydraulic conductivity of geosynthetic clay liners to tailings impoundment solutions

援引最多的出版物

Authors
Shackelford, Charles D
Sevick, Gerald W
Eykholt, Gerald R.

作者

MAIN RESEARCH INSTITUTIONS	Nº
University of Vigo	8
Chinese Academy of Science	7
University of Arizona	7
University of Chongqing	6
University of Anhui	5
Sun Yat-sen University	4
Canadian Department of Agriculture and Agri-food	3
Universidad Técnica Federico Santa Maria	3
University of Belgrade	3
AGH Science and Technology University	2

主要研究机构

维戈大学、中国科学院、亚利桑那大学、重庆大学、安徽大学、中山大学、加拿大农业和农业食品部、费德里科圣玛丽亚科技大学、贝尔格莱德大学、克拉科夫 AGH 科技大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有出版物最多的国家：中国、西班牙、美国、智利、波兰、加拿大、伊朗、塞尔维亚、孟加拉国、沙特阿拉伯

CORE CHALLENGE: SMELTING AND REFINING

BACKGROUND

Smelting is the pyrometallurgical treatment of copper concentrate. The purpose is to separate the mineral from other substances contained in the concentrates, of which iron and sulfur are the most abundant. This is achieved in successive stages through which blister copper, copper anodes or FR (Fire-refined) copper can be produced. These products differ from copper cathodes because they contain a higher proportion of impurities, which can be eliminated in a subsequent stage, known as electrolytic refining.

核心挑战：冶炼

背景

熔炼是指火法处理铜精矿。目的是为了把矿物分离出来，铜精矿中亦含有其他物质，其中铁和硫的比例最大。这个环节涉及多项工序，粗铜、阳极铜或火法精炼铜（FR）都是这个环节的生成物。这些产品与电解铜不同，这些产品杂质含量较高。随后我们会使用电解精炼法去除这些杂质。

Electrolytic Refining is an electrochemical process aimed at “refining” the anodic copper obtained from smelting to produce high-purity copper cathodes, which are then sold.

电解精炼法是一种电化法，用来“提纯”阳极铜。阳极铜是熔炼出来用来生产高纯度电解铜。电解铜可作为商品出售。

Smelting and refining is considered a business with tight margins, in which revenues mainly come from treatment and refining charges, TC/RC, the sale of sulfuric acid, location factors (freight savings, or Freight Allowance), penalizations for the quality of concentrate and anodes and bonuses from the recovery of valuable metals, the majority of these being variable.

冶炼被认为是一种低利润商业模式。冶炼的收入主要来自材料处理费用和提纯费用，TC/RC、硫酸销售费用、位置因素（理想的位置可以节省运输费用）、精矿质量和阳极质量不过关的话，会有罚款收入、还有贵重金属回收利用后的分红。其中大部分收入并不稳定。

For their part, the most significant costs are associated with energy (mainly electricity), labor, maintenance and supplies, all of these with a high fixed cost component. Smelters “charge” the companies that produce concentrate according to the following mechanisms (Parra, 2011):

另一方面，最显著的支出是能源（主要是电能消耗）、劳动力、维护和供给。这些所有因素都固定在一个比较高的数字。冶炼厂根据以下标准向生产精矿的公司“收取”费用(Parra, 2011)：

Treatment Charges (TC): Corresponds to the cost of smelting the concentrate, which is charged based on the tonnage of concentrate to be treated.

粗炼费（TC）：与熔炼精矿的成本挂钩，根据精矿的量收费

- Refining Charges (RC): Charged based on pounds of copper “refined.”

精炼费（RC）：根据“提纯”后的铜的重量收费

- Price Sharing (PS): Used in replacement of TC and RC, it corresponds to a percentage of the sales price.

价格共享（PS）：替代TC和RC的方式，与销售价格占比有关

- Price Participation (PP): Corresponds to the commercial cost paid/charged complementary to TC and RC, equivalent to a percentage of the sales price of fine copper when it surpasses a base value (normally 10%).

价格参与（PP）：与收取的商业成本有关，作为TC和RC的补充，相当于超过基值后（一般来

说是10%），精铜的售价的其中一部分。

TCs are mainly defined in two ways:
粗炼费主要有两种方式：

1. Setting the price in long-term contracts between smelters and the companies that produce concentrate, which allows the former to ensure the supplies needed to operate. This has prompted smelters to invest in the development and operation of mining projects, thus gaining greater control over the fate of the concentrate produced.

冶炼厂和精矿公司签订一个长期合同，合同中设定价格，保证冶炼厂有稳定的精矿来源。冶炼厂有动力下成本下功夫投资开发采矿项目的运作，亦有更好的技术和设备处理精矿。

2. Through spot loads, where charges for treatment and refining are defined “load by load.”

通过现场工作量，粗炼和精炼费以“每单”计算

The section Core Challenge 这一部分的核心挑战
Smelting and Refining was drafted based on work by the technical commission created for the core challenge, which was comprised of the following members:
“冶炼和精炼”章节基于核心挑战技术委员会的建议起草。技术委员会负责明确和解决采矿业的核心挑战，现有以下成员：
Alejandro Dagnino, Andrés Secco, Antonio Luraschi, Benjamin Martinich, Carolina Águila, Cristián Martínez, Daniel Smith, Domingo Fuenzalida, Emilio Castillo, Enrique Roman, Fernando Hernández, Francisca Domínguez, Froilán Vergara, Gabriel Riveros, Gerardo Cifuentes, German Richter, Ignacio Moreno, Igor Wilkomirsky, Jonathan Castillo, Jorge Cantallopts, Jorge Zuñiga Aguirre, José Urrutia, Juan Carlos Torres, Leandro Voisin, Leonel Contreras, Luis Felipe Mujica, Manuel Cabrera, Marco Rosales, Orlando Rojas, Pedro Reyes, Rene Bustamante, Ricardo Bonifaz, Ricardo Parada, Roberto Parra, Rodrigo Abel, Victor Garay Lucero, Victor Paredes, Yanko Gonzalez.

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China has currently become the leading actor in copper smelter production, with over 5 million tonnes of fine copper per year, followed very far behind by Chile and Japan with approximately 1.5 million each (Cochilco, 20153), thus gaining a predominant position in the determination of treatment charges (TC).
中国目前已成为铜冶炼能力领先的国家，每年纯铜提取量为500万吨，远远领先于排名其后的智利和日本，后两者每年分别约150万吨(Cochilco, 20153)。中国是处理费（TC）计算方式的决定性大国。

This is of particular relevance when one considers that China is the main destination for copper concentrate produced in Chile.
因此，中国是智利产铜精矿的主要目的大国。

Close to one third of exports are sent to that country, for a total of 887,000 tonnes of fine copper (content)14 in 2014 (Cochilco 2015f).
几近1/3的出口量是运往中国的，2014年精铜总量达88.7万吨（铜含量）(Cochilco 2015f)

China is expected to attain a share of close to 60% of the global concentrates market, which would translate into even greater power to determine prices (TC/RC, penalizations, PP, others), exposing the Chilean mining industry to a high-risk scenario.
中国有望获得全球精矿将近60%的份额，这更强化了中国对价格（TC/RC, 罚金, PP等）决定权，这对智利采矿行业是一种威胁。

In addition to this, it must be noted that the future trend Chilean copper production is increasingly inclined toward a majority production of concentrates, thanks to the gradual exhaustion of copper oxide deposits. This will impose major challenges in terms of the infrastructure for transporting this product, a significant portion of which consists in gangue or material without commercial value (Cochilco, 2015d). On top of the scenario described, where significant concentration in the smelting and refining business can be observed, the sale of copper could face difficulties due to the impurities it contains, which could be catalogued as hazardous or even cancerous materials.
除此以外，我们必须注意到未来的一个趋势，即智利铜的生产越发依赖于大量的精矿，原因是氧化铜矿床的日益耗尽。这给运输的基础设施带来很大压力，而运送的货物含有脉石或没有商业价值的原料(Cochilco, 2015d)。最最重要的是，据我们观察的冶炼提取行业内对大部分精矿的处理情况，由于杂质较高，铜的销售情况面临很多难题，所含杂质有些甚至是有毒有害致癌物质。

This would be translated into discounts in the sales price associated with the cleaning of ships, in addition to treatment costs.
这会导致销售价格降低，不仅与处理成本有关，亦与清理船只相关。
Eventually, smelters could even reject “complex” concentrates like those with high arsenic contents, which account for a significant proportion of Chilean production, in that way reducing the possibilities for selling them.
最后，冶炼厂甚至会拒绝“多金属”精矿，如含有大量砷的精矿。而大部分智利产精矿都含有砷。所以智利的精矿的销售情况便不容乐观。
For our country, which currently exports 2.5 million tons of copper as cathodes (both refined as well as electrowon) and 2.7 million tons in concentrates (Cochilco 2015g), it is fundamental to anticipate the risks associated with concentrate markets and, based on that, strengthen its position in the cathodes market.
智利目前输出250万吨阴极铜（提纯法和电解法）和270万吨精矿（Cochilco 2015g)。我们必须审视精矿市场的风险，从而巩固我们在阴极铜市场的地位。
However, the current situation in Chilean smelters and refineries poses significant challenges that must be overcome to foster the development of the national mining industry.
然而，智利冶炼厂和精炼厂的现况对整个国内行业是个极大的挑战，我们必须想办法解决问题，促进智利矿产业的发展。

14 Corresponds to fine copper content in bulk, of which copper concentrates are almost

100% of Chilean exports.
14 指的是大量的来自（几乎全部）智利出口的铜精矿的精铜。

CURRENT SITUATION IN CHILEAN SMELTERS AND REFINERIES
智利冶炼厂和精炼厂的现况
There are currently seven copper smelters in Chile: five are state-owned (Caletones, Potrerillos, Hernán Videla Lira, Chuquicamata and Ventanas) and two are private (Chagres and Altonorte). They use the technologies Flash (flame fusion), Teniente Converter (TC) and Noranda Converter (NC) (bath fusion) for the fusion of concentrates, in both cases with Pierce Smith converters, a situation that has remained unchanged for almost three decades. Fusion capacity using Flash Furnace technology for fusion of concentrates accounts for 25% of total national capacity (Chuquicamata Flash Furnace and Chagres smelter). The remaining 75% of national smelting capacity, including the TC in Chuquicamata, operate with TC or Noranda technology.
智利现有7家铜冶炼厂：5家是国企（Caletones, Potrerillos, Hernán Videla Lira, Chuquicamata和Ventanas），2家是私企（Chagres 和 Altonorte）。他们使用Flash（焰熔）、Teniente 转炉（TC）和Noranda转炉（NC）（熔池熔炼）技术熔融精矿。还有三十来年一成不变的Pierce Smith转炉。使用flash熔炉技术熔融精矿的比例占全智利的25%（Chuquicamata Flash 熔炉和 Chagres冶炼厂）。其余75%是用TC技术或Noranda技术，包括Chuquicamata的TC。
This is detailed in the following graph. Smelters' performance can be evaluated as a function of direct operating costs, revenues and the level of capture and sequestering of metallurgical gases. Chilean smelters are in an unfavorable position with regard to other global actors in all of these categories, which is explained by low revenues and high labor and energy costs. Low levels of metallurgical recovery also have an impact, as they reduce Bonus Metal revenues. In addition to this is the obsolescence and small scale of the operations (in the case of Potrerillos, Chagres, Paipote and Ventanas, with fusion levels of between 340,000 and 720,000 KTPA of concentrate).
下表中有详细描述。冶炼厂的业绩可以通过直接运营成本、收入、收集和隔离冶金气体的表现来综合评价。智利冶炼厂与其他国家同类冶金厂相比，缺乏诸多优势，低收入、高人力成本和高能源成本。冶金回收率低下亦会减少额外金属收入。另外的劣势是操作技术的陈旧和规模的狭小（Potrerillos, Chagres, Paipote 和 Ventanas，精矿熔融水平在340000和720000KTPA之间）
When the gross margin is analyzed15, the numbers indicate that of the seven smelters, four are in the last decile in terms of global competitiveness in the business and register negative margins. In the case of refineries the situation is even worse, as all of them (3) have negative margins.
我们来分析一下毛利15，通过毛利我们可以看到，7家冶炼厂里有4家的业绩排在全球同业最后，呈现负值。精炼厂的情况更是糟糕，毛利都是负值。

15 Gross Margin is an economic parameter that to a great degree reflects a business's competitiveness and is defined as Total Revenues minus Net Cash Cost. (Excludes localization factor, as it does not come from efficiency factors, but rather from the specific location)
毛利作为一项经济参数，很大程度上反映了企业的竞争力。毛利的计算是总收入减去净现金成本（不包括地理位置因素，因为它不属于有效因数，属于特定位置）

GRAPH/32
Capacities and technologies of Chilean smelters

Total capacity of 7 national smelters: 6,470 KTPA concentrate.
Fusion technology of national smelters: 75% Teniente-Converter Noranda, 25% Flash Furnace.

图表32

智利冶炼厂的能力和技术

7家冶炼厂总处理量：6470KTPA精矿。智利冶炼厂的熔融技术：75%是Teniente转炉和Noranda转炉，25%是焰熔。

TABLE/12
Smelter Gross Margin

图表12 冶炼厂毛利

SMELTERS	DIRECT COST	TOTAL REVENUES	CASH MARGIN

冶炼厂---直接成本---总收入---现金利润

China
World
Chile

中国—世界—智利

Average (c/lb Cu)

平均值（c/lb Cu）

Source: Study "State of the Art and Vision of Future in Smelting-Refining," Alta Ley Program, August 2015.

信息来源：“冶炼-精练工艺现状和未来愿景”研究

TABLE/13
Gross Margin Refineries

图表13 精炼厂毛利

On top of the low level of competitiveness that Chilean smelters show, there is also the determination of new limits for sulfur emissions (sulfur dioxide, SO2, and arsenic, As)16, a standard that was implemented on OECD recommendations that regulations be drafted to reduce SO2 and toxic pollutants.

除了智利冶炼厂竞争力低下，新的硫排放限制亦给冶炼厂带来压力（二氧化硫和砷）16.这个标准是由经合组织建议制定及起草，以降低二氧化硫和有毒有害物质的排放。

In the case of existing smelters, the regulation establishes a freeze on SO2 emissions and imposes maximum SO2 emissions (in tons per year) and 95% capture and sequestration, setting a five-year deadline for compliance. A more demanding emissions limit is established for new smelters, equivalent to the capture of 98% of SO2 and 99.976% of As emissions. In addition, they must capture and sequester 95% or more of sulfur and arsenic.

现有的冶炼厂都收到了二氧化硫减排的通知，规定了二氧化硫排放上限（每年减排的二氧化硫以吨计量），要收集和隔离95%的二氧化硫，5年内需合规。新建冶炼厂的排放上限更加收

紧，相当于收集98%的二氧化硫和99.976%的砷。另外，新的冶炼厂必须收集和隔离超过95%的硫和砷。

Chilean refineries (Chuquicamata, Potrerillos and Ventanas) contribute 6.8% of global installed capacity and 6.6% of global production of electro-refined copper cathodes (Amec Foster Wheeler, 2015). With 1.3 billion tons of anodes produced per year, Chile could use 100% of its refineries' capacity, which totals 1.12 billion tons of cathodes.

智利精炼厂（Chuquicamata, Potrerillos 和 Ventanas）装机容量占全球的6.8%，电解阴极铜占全球6.6%（Amec Foster Wheeler, 2015）。智利年产阳极铜13亿吨，所有精炼厂全部投产，可生产11.2亿吨阴极铜。

The electrodeposition technologies currently in use are:现用的电沉积技术是：

- Permanent cathode永久阴极
- Starter sheets始极片

On average, permanent cathode technology uses denser current than starter sheets (278 and 260 A/m2, respectively). Efficiency of electrical current is an important operational parameter and, as can be seen in graphs 33 and 34, no correlation can be observed between the current density used and the current efficiency. That is, there are no major differences in the average current efficiency values for each of the technologies.

通常来说，永久阴极技术比始极片使用更密集的电流（分别是278和260 A/m2）。电流效率是一项重要的操作参数，如图表33和34所示，电流密度和电流效率之间并无联系。即，两种技术的平均电流效率几乎差别。

16 S.D. No. 28, published in the Official Gazette on 12 December 2013.

S.D. No. 28, 2013年12月，官方Gazette发表

GRAPH/33

Electrodeposition technology (permanent cathodes)

Avg. current density: 278 A/m^2

Avg. current efficiency: 95%

图表33

电沉积技术（永久阴极）

平均电流密度：

平均电流效率：

GRAPH/34

Electrodeposition technology (starter sheets)

Avg. current density: 260 A/m^2

Avg. current efficiency: 95.3%

图表34

电沉积技术（始极片）

平均电流密度：

平均电流效率：

However, when productivity is analyzed one can see that permanent cathode technology is far superior when compared to starter sheets (see graphs 35 and 36), though, it is important to highlight that there is a significant number of modern starter sheet refineries with very strong productivity (mechanization and automation).
然而，分析一下生产率我们可以发现，永久阴极技术远胜于始极片（图表35和36）。不过仍不容忽视的是很多现代化始极片精炼厂拥有很强的生产率（机械化和自动化）。

GRAPH/35 图表35
Refining technology versus productivity (Man Hours per ton of cathode, MH/t cath) (permanent cathode)
精炼技术与生产率（每吨阴极铜所需工时，MH/t cath）（永久阴极）
Avg. productivity: 1.4 MH/t cath
平均生产率：

GRAPH/36
Refining technology versus productivity (HH/t cath) (starter sheets)
精炼技术与生产率(HH/t cath) (始极片)

Chilean refineries in an uncompetitive position: in 2013 they were in the last decile of the industry in terms of gross margin, which registered negative numbers. This is because their costs are higher than those of the rest of the industry (Amec Foster Wheeler, 2015). The year 2013 was particularly negative for Chilean smelters and refineries due to very high mining activity, a low dollar exchange rate and high electricity costs.
智利精炼厂缺乏竞争优势：2013年，智利精炼厂的毛利出于国际同行业落后水平，毛利为负值。因为智利精炼厂所需成本比其他地区精炼厂要高（Amec Foster Wheeler, 2015）。2013年对智利冶炼厂和精炼厂来说是悲惨的一年，因为那一年的采矿活动频繁、美元汇率走低、电力成本增加。

As the world's biggest copper producer, Chile must defend its position in the global market by selling cathodes. This has its advantages compared to the sale of concentrate, due to:
作为全球最大的铜生产大国，智利必须守卫自己在全球范围内的地位，所以智利考虑销售阴极铜。比起销售精矿，销售阴极铜好处多多，原因在于：

- Possible restrictions on concentrate exports (maritime transport).

精矿的出口有潜在受限因素（海运）

- Possible increases in treatment and refining charges due to Asian smelters' negotiation power.

亚洲的谈判权增加，可能会导致处理和提炼精矿的费用增加

- Possible reward from the quality of cathodes, rather than penalizations and additional costs from shipping concentrates.

相比从运输精矿的罚金和其他成本而言，高质量的阴极铜可能带来回报

- Additional revenues from the recovery and sale of valuable metals contained in the concentrates.

精矿中的贵重金属的回收和销售带来额外收入

To make progress in the aforementioned direction requires lifting existing operations out of the

state of technological obsolescence they are in, upgrading and/or replacing facilities to make them world-class operations with low operating costs and high levels of sequestration that comply with current and future environmental regulations.
为了在上述几方面获得进展，我们必须摆脱现行操作技术的陈旧、提升和/或取消陈旧设施，使之成为世界一流的操作设施，实现经营成本低和分离率高的目标，早日与现行和未来的环保条例接轨。

In particular, we must aspire to all smelters possessing an electrolytic refinery, something normal and desirable worldwide, which would allow the operational synergies (treatment of anode scrap and byproducts) to be taken advantage of in a better way and for savings to be made on shipping.
尤其，我们必须要求所有冶炼厂拥有相应的电解精炼厂，这是全球普遍的情况，也广受欢迎。经营性协同效应（阳极废料和副产品）可被充分利用起来，运输费用也大大节省。

In addition, treatment of anode sludge would be more efficient with just a single noble metals plant in the country (for economy of scale and because it is a highly specialized technology), something that Codelco has already considered in the Noble Metals Plant Project in Mejillones.
另外，为了更有效率地处理阳极泥，应由且只由一家智利更高端的金属厂（出于经济规模的考虑，并且这种技术非常专业）处理阳极泥。Codelco已着手考虑在Mejillones建立这种高端的金属厂。

Inspired in technologies developed in Chile for the Teniente Converter, China has been promoting an explosive development of efficient smelting technologies that are currently setting global standards because of their cost advantages.
受智利Teniente转炉的技术启发，中国已突破性地开发出高效的冶炼技术，由于中国成本较低，这种技术在国际上已被视为国际标准。

The northern part of the country (especially the Antofagasta Region) has a need to deal with complex concentrates that face restrictions or which cannot be exported, especially if one considers the tremendous volume that will come from Underground Chuquicamata. This scenario opens up the opportunity to transform smelters into specialized centers for the treatment of this type of concentrate.
智利北部（尤其是Antofagasta地区）需要处理多金属精矿，这种精矿有很多限制，或甚至无法出口，特别是如果考虑到大量的这种精矿会来自Underground Chuquicamata。这种情况催生了把冶炼厂转型为处理多金属精矿的特殊中心。

VISION OF CORE CHALLENGE 核心挑战愿景
“To attain global technological leadership that, when applied to the industrial design and operation, facilitates obtaining the community’s acceptance to operate to high performance standards that guarantee an economic margin in the second quartile at a bare minimum.”
“努力占领全球技术领导力高地，在尾矿场的工业设计、作业方面提高技术含量，加快脚步赢得社会作业许可，确保绝对最小值为中位数的经济利润

CHALLENGES, SOLUTIONS AND R&D LINES 挑战、方案和研发线
The group of experts that participated in the technical workshops defined four challenges, based

on the background information evaluated and the vision established for the Core Challenge: Smelting and Refining. . All of the solutions identified, with their respective R&D lines, apply to more than one challenge. There are cases in which R&D lines are added in consideration of the challenge at hand. For example: the solution "High level of capture and treatment of complex concentrates" is pertinent to Challenges 1, 2 and 3. This solution contains three R&D lines for Challenge No. 1, which a line of R&D is added when the solution is proposed in the context of Challenge No. 2 and two lines of R&D when the solution is proposed in the context of Challenge No. 3.
参与技术工作的专家基于背景信息的分析和核心挑战（尾矿）的愿景，指出了四种挑战：冶炼和精炼。。所有方案已确认，并配有专门的研发线，对每种挑战执行方案。在一些案例中加入研发线是为了解决眼前棘手的难题。如：方案“多金属精矿的高水平收集和处理”与挑战1、2和3都有关。整个方案针对挑战1提供三条研发线：在解决挑战2时，增加一条研发线，在解决挑战3时，又增加一条研发线。

The solutions and R&D lines identified for each of the challenges presented are detailed below:
Challenge No. 1: Increasing efficiency of smelting and refining processes Chilean smelters show important deficiencies that can be explained by a low fusion capacity, low copper recovery rates and nonexistent recovery of byproducts and energy. This, together with the process's high unit cost, creates a scenario in which one of the main challenges is to make smelters more efficient. The table below compares the parameters of Chilean smelters with those of other countries to identify the productivity gaps.
以下是每种挑战的方案和研发线的细节描述：
方案1：智利冶炼厂由于熔融能力低、铜回收率低和副产品和能源回收技术差，在冶炼和精炼流程方面存在巨大缺陷，如何提高冶炼和精炼效率？再加上流程的单位成本高，冶炼厂如何提高效率是主要挑战之一。以下表格比较了智利冶炼厂和其他国家冶炼厂的参数区别，来看下生产率的差距到底在哪儿。

TABLE/14 表格14
Productivity gaps of Chilean smelters
智利冶炼厂生产差距

PARAMETER	UNIT	SMELTERS CHINESE	SMELTERS JAPANESE	SMELTERS GERMAN	SMELTERS CHILEAN

参数---单位---中国冶炼厂---日本冶炼厂---德国冶炼厂---智利冶炼厂

Fusion capacity
Sulfur sequestered
Unit costs
Copper Recovery
Energy Recovery
other metals

熔融能力---硫的分离---单位成本---铜回收---能源回收---其他金属

TABLE/15 表格15

Solutions and R&D Lines. Challenge: 方案和研发线。挑战：

increasing the efficiency of smelting and refining processes

提高冶炼和精炼流程效率

Minimal loss of copper and other metals of value.

High-capacity processing equipment and long campaigns.

Minimum processes and unit operations.

High level of capture and treatment of complex concentrates.

把铜和其他贵重金属的损失降到最小；大容量流程设备和长期能力；简化流程和单位操作；多金属精矿的高水平收集和处理

Continuous conversion with solid white metal.

Instrumentation and expert control system for BS furnaces.

Slag cleaning.

Automation, mechanization and robotization of refineries.

Valuable metals recovery (Mo, Re, U, Ge).

Recovery from smelting dust and anode sludge.

Use of High Pressure Nozzles in bath smelting furnaces.

Molten layer technology

持续用固体白色金属转化---仪器和专家共组控制系统控制BS熔炉---熔渣清洗---精炼厂的自动化、机械化和机器化---贵重金属回收（Mo, Re, U, Ge）---冶炼尘土和阳极泥的回收---在熔池冶炼熔炉使用高压喷嘴---融化层技术

Continuous conversion with solid white metal.

Continuous conversion with solid white metal.

Use of High Pressure Nozzles in bath smelting furnaces.

New continual electro-refining process.

Direct-to-blister smelting.

Instrumentation and expert control system for BS furnaces.

Use of High Pressure Nozzles in bath smelting furnaces.

Packed-bed technology

持续用固体白色金属转化---持续用固体白色金属转化---在熔池冶炼熔炉使用高压喷嘴---新

的持续电解提纯流程---直产粗铜冶炼---仪器和专家共组控制系统控制BS熔炉---在熔池冶炼熔炉使用高压喷嘴---填充床技术

Intensive mechanization, automation, robotization.

Continuous processes.

Minimum waste produced and other byproducts gained.

Good labor conditions and Advanced Human Capital

密集型机械化、自动化和机器化---持续流程---废料和副产品最少化---良好的工作环境和先进的人力资本

Continuous conversion with solid white metal.

Instrumentation and expert control system for BS furnaces.

Automation, mechanization and robotization of refineries.

Continuous conversion with solid white metal.

Automation, mechanization and robotization of refineries.

Use of High Pressure Nozzles in bath smelting furnaces.

Direct-to-blister smelting.

New continual electro-refining process.

持续用固体白色金属转化---仪器和专家共组控制系统控制BS熔炉---精炼厂的自动化、机械化和机器化---持续用固体白色金属转化---冶炼厂的自动化、机械化和机器化---在熔池冶炼熔炉使用高压喷嘴---直产粗铜冶炼---新的持续电解提纯流程

Challenge No. 2: Reducing the environmental impact.

There are significant gaps in terms of sulfur and arsenic sequestration, which constitutes a major environmental challenge for Chilean smelters. The need to raise the standards of these parameters to equal those implemented in other countries has resulted in a new regulation (Decree No. 28 of 2013) establishing a new sequestration level of 98% (SO_2 and As) for future facilities.

挑战2：减少对环境的负面影响

我们的硫和砷的隔离工作远不如其他国家做的好，这对智利的环境影响很大。智利政府亟需提高环境参数标准，与其他国家的执行标准处于同一水平，所以一项新的法规诞生（Decree

No. 28 of 2013），未来的工厂必须做到98%的隔离率（二氧化硫和砷）

TABLE /16 表格16
Solutions and R&D Lines. Challenge: reducing the environmental impact.
方案和研发线。挑战：减少会环境的负面影响

Minimal loss of copper and other metals of value.

High-capacity processing equipment and long campaigns.

High level of capture and treatment of complex concentrates.

Minimum waste produced and other byproducts gained.

Good labor conditions and Advanced Human Capital

把铜和其他贵重金属的损失降到最小---大容量流程设备和长期能力---多金属精矿的高水平收集和处理---废料和副产品最少化---良好的劳动力供给和先进的人力资本

Continuous conversion with solid white metal.
Instrumentation and expert control system for BS furnaces. Recovery of valuable metals (Mo, Re, U, Ge).
Recovery from smelting dust and anode sludge.
Slag cleaning.
Automation, mechanization and robotization of refineries.
Molten layer technology
Use of High Pressure Nozzles in bath smelting furnaces.

持续用固体白色金属转化；仪器和专家共组控制系统控制BS熔炉；贵重金属回收（Mo, Re, U, Ge）；冶炼尘土和阳极泥的回收；熔渣清洗；精炼厂的自动化、机械化和机器化；融化层技术；在熔池冶炼熔炉使用高压喷嘴

Continuous conversion with solid white metal. 持续用固体白色金属转化

Instrumentation and expert control system for BS furnaces.
Automation, mechanization and robotization of refineries.
Packed-bed technology
Use of High Pressure Nozzles in bath smelting furnaces.
Treatment of high As concentrates in BBF.

仪器和专家共组控制系统控制BS熔炉；精炼厂的自动化、机械化和机器化；填充床技术；在熔池冶炼熔炉使用高压喷嘴；BBF高砷含量精矿的处理

Recovery of valuable metals (Mo, Re, U, Ge).
Recovery from smelting dust and anode sludge.
Slag cleaning.
Control of impurities
Control of Sb and Bi in refineries.

贵重金属回收（Mo, Re, U, Ge）；冶炼尘土和阳极泥的回收；熔渣清洗；杂质控制；精炼厂的Sb和Bi的控制

Challenge No. 3: Improving labor conditions.挑战3：改善工人工作环境
The incorporation of new technologies in smelting and refining processes will not just have an

impact on the aforementioned challenges, but will also contribute to improving the labor conditions for people working at operations.
冶炼和精炼流程中结合新技术不仅能改善上述挑战，亦能造福工厂员工，改善作业工人工作环境

Manipulation of molten material poses a risk to the workers involved in the process, meaning that eliminating the current gap in the accident rate, mainly explained by the existence of multiple non-continuous processes in operations, constitutes a major challenge to be addressed.
处理融化材料对工人工作环境带来安全隐患。提升安全性、降低事故发生率，亦是我们亟待改进之处。目前，多种间歇式生产流程是我们面临的一大难题。

TABLE/17 表格17
Solutions and R&D Lines. Challenge: 方案和研发线。挑战：
improving labor conditions 改善工人工作环境

Minimum processes and unit operations.
Intensive mechanization, automation, robotization.
High level of capture and treatment of complex concentrates.
Good labor conditions and Advanced Human Capital
Minimal loss of copper and other metals of value.
High-capacity processing equipment and long campaigns.

简化流程和单位操作；密集型机械化、自动化和机器化；多金属精矿的高水平收集和处理；良好的工作环境和先进的人力资本；把铜和其他贵重金属的损失降到最小；容量流程设备和长期能力

Recovery of valuable metals (Mo, Re, U, Ge).
Recovery from smelting dust and anode sludges.
Slag cleaning.
Control of impurities
Control of Sb and Bi in refineries.

贵重金属回收（Mo, Re, U, Ge）；冶炼尘土和阳极泥的回收；熔渣清洗；杂质控制；精炼厂Sb和Bi的控制

Continuous conversion with solid white metal.
Instrumentation and expert control system for BS furnaces.
Automation, mechanization and robotization of refineries.

持续用固体白色金属转化；仪器和专家共组控制系统控制BS熔炉；精炼厂的自动化、机械化和机器化

Instrumentation and expert control system for BS furnaces.
Automation, mechanization and robotization of refineries.
Packed-bed technology
Use of High Pressure Nozzles in bath smelting furnaces.
Treatment of high As concentrates in BBF.

仪器和专家共组控制系统控制BS熔炉；精炼厂的自动化、机械化和机器化；填充床技术；在熔池冶炼熔炉使用高压喷嘴；BBF高砷含量精矿的处理

Automation, mechanization and robotization of refineries.
Control of impurities
Control of Sb and Bi in refineries.

精炼厂的自动化、机械化和机器化；杂质控制；精炼厂Sb和Bi的控制

Continuous conversion with solid white metal.
Instrumentation and expert control system for BS furnaces. Recovery of valuable metals (Mo, Re, U, Ge).
Recovery from smelting dust and anode sludges. Slag cleaning.
Automation, mechanization and robotization of refineries.
Molten layer technology
Use of High Pressure Nozzles in bath smelting furnaces.

持续用固体白色金属转化；仪器和专家共组控制系统控制BS熔炉；贵重金属回收（Mo, Re, U, Ge）；冶炼尘土和阳极泥的回收；熔渣清洗；精炼厂的自动化、机械化和机器化；熔化层技术；在熔池冶炼熔炉使用高压喷嘴

Continuous conversion with solid white metal. 持续用固体白色金属转化

CORE CHALLENGE: SMELTING AND REFINING

3 CHALLENGES

19 SOLUTIONS

79 R&D & I LINES

核心挑战：冶炼和精炼

3大挑战；19种方案；79条研发i线

INFRASTRUCTURE 基础设施

- Pilot tests (China/Chile) 初步试验（中国/智利）
- Laboratory tests. 实验室试验

CAPACITIES 能力

- Research in basic sciences. 基础科学研究
- Universities contribute to research, instrumentation and control.

获得诸多大学的研发、仪器和管理支持

- Advanced human capital with specialty: fluid dynamics, transport phenomena, reaction kinetics, thermodynamics, electrochemistry, materials science, process modeling, optoelectronics, mineral chemistry, digital technology and mechatronics.

先进的特殊行业人力资本：流体动力学、运送现象、反应动力学、热力学、电化学、材料科学、程序模型、光电学、矿物化学、数字技术和机电一体化

- Training of technical workers in operation and maintenance skills at Technical Training Centers

在技术培训中心对技术工人操作和维护培训

- Center specialized in arsenic. 砷的研究中心
- Organization and transparency. 组织架构和透明度
- Technology think tank for mining. 矿业的技术智囊团

SUPPLIERS供应商

- Strengthen the development of local suppliers of instrumentation, expert control, mechanization, automation, robotization, information management, optimization software, data transmission, engineering design and specialized support services.

加强开发当地供应商，如仪器、专家控制、机械化、自动化、机器化、信息管理、软件优化、数据传输、工程设计和其他专业领域的支持。

- System structured to accompany local companies with technological capacities.

构建支持系统以支持当地公司的技术能力提升

ALLIANCES 联盟

- China - Chile cooperation agreement.

中国-智利合作协议

- Alliances with national and international universities and centers of excellence.

与智利国内和国际大学和优秀研究中心形成联盟

INFOGRAPHIC/3 信息图表3

Technological surveillance smelting (Patents)

技术监测冶炼（专利）

2010-2015 共有119项专利

MOST-CITED PATENTS 引用最多的专利

EP1148295B1

Gasification melting furnace for wastes and gasification melting method

废料的气化熔炉和气化融化方法

US7771666B2

Method of producing nanoparticles using an evaporation-condensation process with a reaction chamber plasma reactor system

利用蒸发-凝聚流程，用分馏塔等离子体反应器系统生产纳米颗粒

US8052774B2

Method for concentration of gold in copper sulfide minerals

硫化铜矿的金元素的富集方法
EP1811821B1
Method of recycling waste printed circuit boards
回收利用废弃印刷电路板方法
EP1964936B1
Process for recovering noble metals from electric and electronic wastes
从电气和电子废料中回收贵金属的流程
US8173086B2
Process of recovery of base metals from oxide ores
从氧化矿中回收基体金属的流程
US2010275730A1
Method for recycling precious metal from used printed circuit boards
从旧的印刷电路板中回收贵金属的方法
US7776135B2
Method for the recovery of gold
回收金元素的方法
US8800775B2
Method for recovering metals from electronic waste containing plastics materials
从含有塑料材质的电子废料中回收金属的方法
US7815706B2
Method and apparatus for recovering platinum group elements
回收铂系元素的方法和装置

MAIN
TECHNOLOGICAL
TRENDS

· Mitigation of climate change from production.

主要技术趋势

生产造成的气候变化减小

COUNTRIES WITH MOST PATENTS

拥有专利最多的国家
日本、美国、中国、芬兰、德国、台湾、法国、加拿大、澳大利亚、意大利

MAIN UNIVERSITIES

- Central South University, China
- National Technology Institute of Japan
- Beijing University of Science and Technology
- Espirito Santo Federal University
- Jiangxi University of Science and Technology
- Northeastern University of China
- University of Tokyo
- University of Utah Research Foundation

主要大学

中国中南大学、日本国家技术研究所、北京科技大学、圣埃斯皮里图联邦大学、江西理工大学、中国东北大学、东京大学、犹他州立大学研究基金会

MAIN COMPANIES AND/OR R&D CENTERS

- Outotec OYJ
- Tanaka Precious Metal IND
- Dowa Metals & Mining CO LTD
- JX Nippon Mining & Metals Corp
- Precious Metals Recovery PTY LTD
- Mitsubishi Materials Corp
- Kosaka Smelting & Refining CO
- Nippon PGM CO LTD
- Outokumpu OY
- Umicore AG & CO KG

主要公司和/或研发中心

INFOGRAPHIC/4 信息图表4

Technology Watch: Smelting (Publications)技术简报：冶炼（出版物）

SCIENTIFIC PUBLICATIONS 2010-2015

科学出版物2010-2015

MAIN RESEARCH TRENDS	N°
Metallurgy /Metallurgic engineering	63
Engineering	51
Ecology and environmental sciences	49
Materials sciences	29
Ore processing	29
Mineralogy	24
Chemistry	18
Geology	15
Water resources	10

主要研究趋势：

冶金/冶金工程、工程、生态和环境科学、材料科学、选矿、矿物学、化学、地质学、水资源

MOST-CITED PUBLICATION

Low grades ores - Smelt, leach or concentrate?

Authors:
Norgate, T
Jahanshahi, S

引用最多的刊物

低等级矿石—冶炼。过滤还是精选？

作者：

PRINCIPALES INSTITUCIONES DE INVESTIGACIÓN
Russian Academy of Science
University of Belgrade
Central South University, China
University of Prague
Chinese Academy of Science
Czech Geological Service
Shahid Bahonar University of Kerman
Minnig and Metallurgy Institute Bor
Polytechnic University of Silesia
University de Tohoku

主要研究机构：

俄罗斯科学院、贝尔格莱德大学、中国中南大学、布拉格大学、中国科学院、捷克地质服务机构、Shahid Bahonar University of Kerman、Mining and Metallurgy Institute Bor、西里西亚理工大学、日本东北大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有科学出版物的国家

Czech Rep	33
Russia	22
Serbia	15
USA	15
Japan	10
Poland	10
Australia	9
Irán	9
Canada	8
Czech Rep	8

捷克共和国、俄罗斯、塞尔维亚、美国、日本、波兰、澳大利亚、伊朗、加拿大、捷克共和国

INFOGRAPHIC/5 信息图表5

Technology Watch: Refining (Patents) 技术简报：精炼（专利）

TOTAL PATENTS
2010-2015
77
PATENTS

2010-2015 共有77项专利

MAIN
TECHNOLOGICAL
TRENDS

- Obtaining copper
- Technologies related to metals processing
- Solid waste management technologies
- Electrolytic production
- Recovery and refining of metals via solutions electrolysis

主要技术趋势

获得铜元素、与金属加工有关的技术、固体废物管理技术、电解法生产、以电解方案回收和提炼金属

US8052774B2

Method for concentration of gold in copper sulfide minerals

硫化铜矿的金元素的富集方法

US7700343B2

Sulfur-oxidizing bacteria and their use in bioleaching processes for sulfured copper minerals

硫氧化细菌在硫铜矿石的生物浸出过程的运用

US8834715B2

Copper recovery apparatus and copper recovery method

铜回收装置和铜回收方法

US2010065433A1

System and apparatus for enhancing convection in electrolytes to achieve improved electrodeposition of copper and other non ferrous metals in industrial electrolytic cells

建立系统和装置以加强电解质传导，从而提升铜和其他有色金属的电解槽电沉积

EP1903119B1

A method of manufacturing high purity copper

制作高纯度铜的方法

US7811534B2

Method for the treatment of copper-bearing materials

含铜材料的处理方法

US8192596B2

Ultrahigh-purity copper and process for producing the same

超高纯度铜及其制作流程

US7736487B2

Process for recovery of copper from copperbearing material using pressure leaching, direct electrowinning and solution extraction

使用加压浸出、直接电解冶金法和溶液提取的方式从含铜材料中回收铜元素

US7722756B2

Process for multiple stage direct electrowinning of copper

多段直接电解冶金铜的流程

US7736488B2

Process for recovery of copper from copperbearing material using pressure leaching, direct electrowinning and solvent/solution extraction

使用加压浸出、直接电解冶金法和溶液提取的方式从含铜材料中回收铜元素

COUNTRIES WITH MOST PATENTS

拥有专利最多的国家

Japan	22
USA	11
Chile	9
China	7
Austria	4
Finland	4
Poland	4
Canada	3
Australia	2
Switzerland	2

日本、美国、智利、中国、奥地利、芬兰、波兰、加拿大、澳大利亚、瑞士

MAIN UNIVERSITIES

- University of Chile
- Free University of Brussels
- University of Osaka
- University of San Luis
- University of Santiago de Chile
- University of British Colombia

主要大学

智利大学、布鲁塞尔自由大学、日本大阪大学、圣路易大学、智利圣地亚哥大学、英属哥伦比亚大学

MAIN COMPANIES AND/ OR R&D CENTERS

- JX Nippon Mining & Metals Corp
- Pan Pacific Copper CO LTDA
- Nippon Mining CO
- Phelps Dodge Corp
- Freeport McMoran Corp
- Outotec OYJ
- Xiangguang Copper CO LTDA.
- Sumitomo Metal Mining CO

主要公司和/或研发中心

INFOGRAPHIC/5信息图表5

Technology Watch: Refining (Publications)技术简报：精炼（出版物）

SCIENTIFIC PUBLICATIONS

科学出版物

PRINCIPALES TENDENCIAS DE INVESTIGACIÓN	N°
Materials sciences	62
Metallurgy / Metallurgic engineering	44
Other technology-science topics	15
Physics	11
Engineering	8
Chemistry	7
Crystallography	4
Mineralogy	3
Ore processing	3
Microsocopy	2

主要研究趋势

材料科学、冶金工程、其他技术科学课题、物理学、工程学、化学、结晶学、矿物学、矿石加工、显微镜学

SCIENTIFIC PUBLICATIONS

98

科学出版物98

MOST-CITED PUBLICATION

The role of stacking faults and twin boundaries in grain refinement of a Cu-Zn alloy processed by high-pressure torsion 引用最多的出版物

堆积层错和孪晶界对高压扭转下铜锌合金晶粒细化的作用

Authors
Wang, Y.B.
Liao, C.Z.
Zhao, Y.H 作者：

MAIN RESEARCH INSTITUTIONS	N°
University de Tohoku	6
University of Brunei	4
University of Kyushu	4
Russian Academy of Science	4
French National Center for Scientific Research	3
Academy of Sicences of the Czech Republic	3
University of Monash	3
Northwestern Polytechnical University, USA	3
University of Lorraine	3

主要研究机构
日本东北大学、文莱大学、九州大学、俄罗斯科学院、法国国家科研中心、捷克科学院、莫纳什大学、美国西北工业大学、洛林大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS拥有科学出版物的国家

China	28
Japan	12
Australia	9
USA	9
UK	8
Russia	8
South Korea	7
France	6
Canada	5
Czech Rep.	5

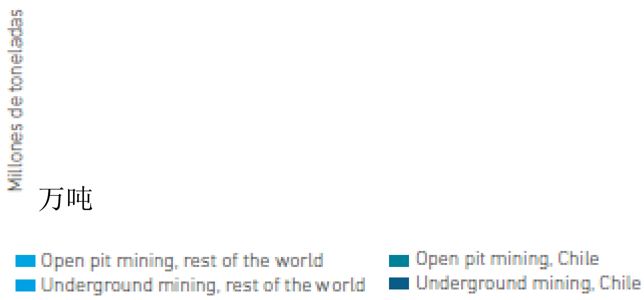
中国、日本、澳大利亚、美国、英国、俄罗斯、韩国、法国、加拿大、捷克共和国

CORE CHALLENGE; MINEOPERATIONS AND PLANNING核心挑战；矿井作业和规划
BACKGROUND背景
The majority of ore currently extracted in Chile and around the world comes from openpit mines.

Over 3 billion tonnes of ore were extracted worldwide in 2014, of which 87% came from open-pit mines. Chile concentrated approximately 30% of that production.
目前在智利和世界其他地区的矿石都来自露天矿井。2014年全球有超过30亿吨矿石被提取出来，87%来自露天矿。智利对其中约30%矿石进行选矿。
The Core Challenge Mine Operations and Planning section was drafted based on work by the technical commission created for the core challenge, which was comprised of the following members: Agustín Sepulveda, Andrés Pérez, Brian Baird, Carlos Urenda, Christian Schnettler, Claudio Rojas, Cleve Lightfoot, Francisco Abbott, Hugo Toro, Jorge Soto, Murray Canfield, Nury Briceño, Pablo Asiain, Pierre Perrier.
“核心挑战：矿井操作和规划”的起草工作是基于核心挑战技术委员会的建议起草。技术委员会负责明确和解决采矿业的核心挑战，现有以下成员：Agustín Sepulveda, Andrés Pérez, Brian Baird, Carlos Urenda, Christian Schnettler, Claudio Rojas, Cleve Lightfoot, Francisco Abbott, Hugo Toro, Jorge Soto, Murray Canfield, Nury Briceño, Pablo Asiain, Pierre Perrier.

The following team from Fundación Chile was in charge of drafting this section: Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito, Hernán Araneda.
以下成员负责此部分的起草：Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito, Hernán Araneda.

GRAPH/ 37 图表37
Ore extracted in Chile and the world, 2000-2030
2000年至2030年，智利和全球矿石提取量



万吨

（从上至下从左至右）

世界其他地方露天矿、世界其他地方地下矿、智利露天矿、智利地下矿

While it has been estimated that there will be a significant increase in production from underground mines by 2025, open-pit mines continue to contribute the largest share of total production, at close to 5 billion tonnes.
业内人士预估到2025年，地下矿井的出矿量会有大幅增加。但现下露天矿仍是总产量的功臣，近50亿吨。
The surface exploitation method, known as open-pit or strip mining, is the first option evaluated in the development of a mining project, as it is usually cheaper if the ore body is close to the surface and is regular in shape. Depending on the concentration of the elements that are of economic interest, the potential contaminants and in general the geometry of the ore bodies, open-pit mines can far exceed 500 meters in depth.
地面开采，又称露天开采，是采矿项目发展前景的首选。矿体接近地表，形状规则，处理成

本较低。根据具有经济价值的元素的浓度情况、潜在污染情况和矿体的总体几何结构，地下500米深度以下亦可成为露天矿。

However, when the ore body is located at a greater depth or else has surpassed the economical limit of strip mining, then the underground method will be chosen.
然而，如果矿体的所在位置深度过深，一般的露天矿的开采模式已无法满足经济要求，则会采取地下采矿方式。
In this case the underground method will be defined by a series of factors related to the body shape, other characteristics of the ore as well as the rock that surrounds it, environmental and technological factors, and economic considerations related to the ore reserves available, the required production rate, mine lifespan, productivity, and lastly the cost per ton of ore using every possible method.
这时，地下采矿方式由一系列多种因素决定，如矿体形状、矿的其他特性和周围岩石性质、环境和技术因素、矿石储量等经济因素、需要的生产率、矿井生命周期、生产率，最后是每种可行方式下采矿每吨的成本。
Over 50% of Chile’s fine copper production, in any of the forms it is sold in, comes from the six operations detailed in the table below:
超过50%的智利精细铜产量，无论以何形式售出，均来自于以下6处矿井：
TABLE/18 表格18
Largest operations in Chile (mainly open-pit) and their contribution of fine copper
智利最大的矿井作业（主要是露天矿），其贡献的精细铜产量

KT FINE Cu 千吨 精铜 % of total % Acum. 占总量百分比 占累积百分比

All of the above operations (Except for Anglo American Sur, which includes underground production from El Soldado) are open-pit mines. In the case of Chuquicamata, the transition to an underground mine is already under way and production could begin at the end of this decade. Eventually all operations could go through this transition.
以上所有作业（除了Anglo American Sur以外，Anglo American Sur包含来自El Soldado的地下生产）都是露天矿井。Chuquicamata已开始转型为地下矿，近十年就可开始生产。最后所有的作业都可以经历这种转型。

The main underground operations in Chile belong to Codelco (El Teniente and Andina Divisions) The El Teniente Division contributed 8% of the fine copper produced nationally in 2014, while the Andina Division accounted for 4% of the total., Both divisions also have open-pit mines whose production is also included in the aforementioned numbers.
智利主要的地下矿操作来自Codelco（El Teniente和Andina矿区）。El Teniente矿区在2014年为智利精细铜总量贡献了8%产量，Andina矿区是4%。两个矿区都有露天矿，之前提到的两个数字是包含露天矿的产量的。

It is estimated that an average of 20 years pass between the discovery of a deposit and when operation starts. The exploration phase lasts an average of 10 years, while the study, financing, permits and construction phase takes another 10 years (Fuentes, 2010).
专家估计，平均来看，发现矿床之后20年才可能开始采矿。探究阶段平均长达10年，之后各

种研究、融资、许可和建造又要花费差不过10年(Fuentes, 2010).

The majority of large porphyritic copper deposits discovered in Chile have been the result of a detailed geological analysis in promising areas, after applying metallogenic criteria indicating the areas that are favorable to exploration, followed by the execution of geological prospecting programs guided by geochemical and geophysical research. In the case of exploration in areas covered in pre-ore rocks, exploration must be guided by the extrapolation of favorable geological patterns present in the pre-ore rocks or by the existence of geophysical and geochemical anomalies (Zauschquevich & Sutulov, 1975).

大部分智利的大型斑岩型铜矿床是通过专家对潜在地区地质的细致分析后发现的。专家们先应用成矿学标准找出适合勘探的地区，再运用地质化学和地质物理学的知识进行地质勘探。当对有矿前期岩石的地区进行勘探时，必须使用外推法。这里的外推法是根据可见的矿前期岩石或是根据地质物理和地质化学异常现象推测出的地质模式(Zauschquevich & Sutulov, 1975)

Estimating the size or tonnage of ore and the ore grades has habitually been based on a geological interpretation or 3-D model of the deposit and geostatistical processing of the data collected. This is used to quantify the Mineral Resources, which after successive phases can become Mineral Reserves.

矿石的大小、总吨数和矿石等级的预估一般是根据地质判读或矿床的3D模型和数据的地质统计学处理。专家通过以上方式可以确定矿物资源数量，经过一系列处理后可以预测矿物储备量。

According to the Mining Commitee17, conversion of Resources into Reserves includes the following phases: exploration prospect that gives rise to the idea; technical-economic analysis on an order of magnitude to produce a study of the scope; a pre-feasibility study, and a feasibility study, which offers a database that is used by a backer or financial institution to decide on a project's development.

根据矿业委员会（17）所做的定义，资源到储备的转化会经历以下几种阶段：有指导意义的勘探前景；技术-经济分析，从量级到范围分析；预可行性研究和可行性研究，背后的支持团队和金融团队可应用可行性数据库分析项目的发展前景。

In the early stages information is fragmentary or insufficient and a high risk is involved, a factor that diminishes as the information is improved and strengthened.

项目前期，由于信息琐碎和不足，存在较高风险，但随着信息的丰富，危险因素大大减少。

17 Qualification Commission for Skills Related to Mining Resources and Reserves, created by Law No. 20,235. 资格审查委员会要求的采矿资源和储备技能，No.20235条款规定。

资源到储备的转化

矿物资源，碎片信息

Mineral Reserves

Functional Models

矿物资源，功能模型

High Risk

高风险，

Low Risk

低风险

Progressive transition toward reduced uncertainty and risks

进一步减小未知风险

Exploration	Profile	Pre-feasibility	Feasibility

勘探---建档---预可行性---可行性

The successive mining studies must reflect the growing level of certainty in the relevant exploration parameters and, in the event that favorable economic results are available, lead to the mine’s construction, commissioning and operation.
一系列的采矿研究必须反映出相关勘探参数不断提升的确定性，并且，在可获得良好的经济效益时，采矿研究必须对矿井的建造、试运行和操作发挥指导性作用。

Operating a mine is a multidisciplinary task that must be coordinated to be undertaken in a safe and effective way. The work teams that participate include, among others: geology, geotechnics, planning, topography, mine operations, maintenance, administration, services, and support in health, safety, the environment and quality, among consultants from diverse areas. The geology team’s mission includes providing information on the physical, chemical and mineralogical characteristics of the material to be extracted, which is the starting point of the extractive process. This information is taken by the engineering or planning group, which integrates it with other variables related to operation, geotechnics, metallurgy, maintenance and costs, so as to draft a production plan or “mine plan.” This plan describes the materials that will be moved in the operation and the resources required to do so.
采矿作业是一项多学科任务，各部门必须协同发挥特长，确保作业的安全和有效性。参与工作的团队来自于各行各业，如：地质学、地质技术学、规划部门、测绘学、矿井作业部门、维护部门、行政部门、服务部门，还有来自卫生、安全、环境和质检部门的团队，技术顾问都来自不同领域。地质学的团队研究提取的材料的物理、化学和矿物学特性，这是整个提取流程的首要环节。工程部门和规划部门根据上述特性分析和总结关于作业、地质技术、冶金学、维护工作和成本方面的变量，最后起草一份生产计划或“矿井计划”。这份计划介绍了矿井作业过程中要移动的材料，和所需资源。

Movement of materials in the operation includes extraction and transportation of materials comprised of different qualities and concentrations of the element of interest. That is, material lacking in valuable content (“sterile”), material whose valuable content does not justify processing it and materials with different proportions (“ore grades”) of elements of interest. This material, generically referred to as “ore,” will be destined to one of the process lines or the

respective dump.
作业中材料的移动包括所有材料的提取和运输(不同材质的材料和不同价值的元素的精矿)。即缺乏贵重金属的材料（“无菌材料”）、不足以继续加工的含有少量贵重金属的材料和矿石等级不同的材料。我们所说的材料，一般指的就是矿石本身，它们会被运到特定的加工线或者各自的尾矿场。
Mine planning is under continual development during mine operation, in a way that is similar to what is done in the preliminary stages of the mine project or the engineering phase, but with different information inputs.
矿井规划在矿井作业期间是不断变更的。好比在矿井项目或工程阶段初期已拟定一份计划，随着信息更新，计划也实时更新着。

A team traditionally known as “mine operations” is in charge of extracting the materials from the mine. In metals mining this is done in the following unit operations sequence: drilling, blasting, loading, transportation.
传统上我们称作“矿井作业”的团队专门负责从矿石中提取物质的。金属矿床开采中，作业团队是按照以下单位作业工序工作的：钻孔、爆破、装载、运输。

Together the unit operations and the equipment and/or technology used to undertake each one make up a “mining system,” which is closely related to the “exploitation method” in question. For example, currently the majority of large mines operating under the open pit method use a mine system in which the stripping or extraction of the material is done with drilling (mainly rotary) and blasting with explosives, while loading and transportation is carried out using a shovel-dump truck system.
单位操作和所用设备和/或技术共同组成“采矿系统”，这与正在讨论中的“开采方法”有紧密联系。如，现在大部分大型矿井作业用的是露天矿的开采方式，采矿团队使用的矿井系统是用钻井（旋转式）和爆破方式剥离或提取物质，装载和运输用的是轮式自卸卡车系统。

As already mentioned in previous chapters, the Chilean mining industry has been affected by a gradual decline in the quality of its mineral reserves. Copper ore grades are ever lower, mainly due to the greater depths that mines have reached, where the rock is harder. In addition, in the case of open-pit mines, expansion of operations habitually entails removing a larger proportion of sterile material or waste for every tonne of ore to be recovered.
之前的章节已提到过，智利采矿行业已受到矿产储备质量下降的影响。铜矿等级越来越低，这是由于矿井深度越来越深，岩石越来越坚硬。此外，对于露天矿的开采，作业范围的扩大意味着回收每吨矿石必须清除更多的无菌材料或者废料。

This scenario has a direct impact on higher energy consumption per pound of fine copper produced and it has a negative effect on the mine business’s productivity. Furthermore, the need to move larger volumes of waste and grind more ore is added to the increasing hardness of the ore found, which also has an impact on energy consumption (see chapter 4, Section: “Current Scenario and Short Term Challenges”)
这种情况直接导致制作磅精细铜必须依靠更高能耗，进一步降低矿业行业的生产率。不仅如此，采矿作业团队需要移除更多废料、打磨更多矿石，矿石的开采难度更大，更加重能耗（请见章节4：现况和短期挑战）

Another reason behind the growing need for energy in mining has to do with the essentially nonexistent continental waters available to supply the consumption of new operations, with an increasing need to transport water from the sea and the energy expenditure associated with it.
采矿业能耗加重的另一个原因是陆地水的减少，陆地水是新矿井作业的重要水资源。没有了陆地水，我们只能靠运输海水维持采矿作业，增加了能源支出。
While the price of copper has a direct effect on the industry’s productivity (periods of high prices foster the exploitation of mines with lower ore grades and productivity, but with economically reasonable results), it is a fact that declining ore grades and increasing hardness and impurity, in addition to the larger transportation distances, have made productivity a priority focus for Chilean copper mining.
铜的价格直接影响到行业生产率（铜价走高期间，尽管矿石等级偏低，但经济效益不错）。摆在眼前的是，越来越低的矿石等级、越来越高的采矿难度、越来越多的矿石杂质，加上越来越长的运输距离，把生产率推高至智利铜开采业的第一焦点。

CHALLENGES, SOLUTIONS AND R&D LINES 挑战、方案和研发线
Based on the information analyzed, the group of experts who participated in the technical workshops identified four challenges: i) Increasing productivity; ii) Increasing mineral resources and reserves; iii) Environmental protection and social responsibility; iv) Greater workplace safety and quality.
根据以上信息，参与技术工作的专家小组明确了四个挑战：1. 提高生产率；2. 提高矿产资源和储备；3. 注重环保和社会责任；4. 提高工作场所安全意识和质量

As described in the Background part of this section, mine planning and operation includes four phases. These are: i) Exploration; ii) Mine project, engineering and mine control and planning (MC&P); iii) Open-pit mining; iv) Underground Mining. The table below indicates which of the challenges identified applies to each of the phases.
本节背景部分介绍了矿井规划和操作包括4个阶段。分别是：1. 勘探；2. 矿井项目、工程和矿井控制与规划(MC&P)；3. 露天矿开采；4. 地下矿开采。以下表格列明了各个阶段的各项挑战。

TABLE/19 表格19
Challenges and phases of the core challenge: mine operations and planning
挑战和核心挑战各个阶段：矿井作业和规划

CHALLENGES/ PHASES	EXPLORATION	MINE PROJECT, ENGINEERING AND MINE CONTROL AND PLANNING (MC&P)	OPEN-PIT MINING	UNDERGROUND MINING

挑战/阶段；勘探；矿井项目、工程和矿井控制和规划(MC&P)、露天矿开采、地下矿开采

提高生产率；增加矿物资源和储备；注重环保和社会责任；增加工作地安全意识，提高质量。

Challenge No. 1: Increase productivity

挑战1：提高生产率

As mentioned throughout this book, productivity is a central issue that the mining industry must address in the short- and long term. This is a challenge that cuts across all of the phases defined in the context of this core challenge. However, due to the reasons presented above, it gains particular importance in the open pit and underground mining stages.

本文通篇都提高过，生产率是采矿行业短期和长期必须解决的核心问题。它渗透于我们面临的核心挑战涉及的所有阶段。然而，出于以上提及的缘由，生产率在露天矿和地下矿开采方面尤显重要。

In open-pit mining the solutions associated with the movement of large volumes of earth long distances and the management of assets, understood as applying to the universe of equipment for engaging in the required activities, are identified as the mine lines of development to improve productivity.

露天矿面临着长距离运输和资产管理的问题，后者指的是在工作中如何有效联动所有设备。有效解决以上问题被认为是生产率提升的重中之重。

Meanwhile, the solutions associated with increased productivity from underground mining is related to the development of large-scale deep mining, which among other things entails making progress with technologies that allow operation under high levels of geomechanical stress and the development and integration of autonomous operations.

而另一方面，我们再来看一下地下矿的开采。地下矿的主要问题是如何提高大型深层开采生产率，即努力研发地质力学高压下的作业流程和推进自主作业的发展和整合。

TABLE/20表格20

Solutions And R&D Lines. Challenges: Increased productivity

方案和研发线。挑战：提高生产率

Reduce direct intervention by operators, thus improving both safety as well as accountability.

Optimal selection of equipment and calculation of main fleets.

Estimating costs, economic and financial assessment of projects.

Moving large volumes of material large distances

Management of assets

减少作业人员直接干预，提高安全性和问责制；选择最佳设备和计算模型；预估项目成本、经济效益和金融评估；长距离运送大量货物；资产管理

Exploration

Mine Project, Engineering, (MC&P)

Open-Pit Mining

勘探；矿井项目和工程（MC&P）；露天矿开采

- Improvement and development of techniques for automation of sampling and sampling preparation.

- Improvement, development and standardization of methodologies and tools for selecting equipment and calculating fleets.

- Improvement, development and standardization of methodologies and tools for calculating costs and evaluation of mining plans.

取样和样品处理自动化技术的提升和发展；设备和计算模型的选择方法和工具的提升、发展和标准化；计算成本和采矿计划评估的方法和工具的提升、发展和标准化

- Fragmentation/blasting 分裂/爆破
- High-tonnage conveyor belts 高吨位传送带
- Constructability of terraces 平台的施工能力

- Integration of operations (mine-plant). 作业一体化（矿井-工厂）
- Online measurement of ore grades in pits, shovels, conveyor belts.

矿井、铲车、传送带的矿石等级的在线测量

- Integration of remote-controlled unit operations

远程控制单位作业一体化

- Automation and autonomous operations 自动化和自主化作业
- Ease of maintenance: characterization of main equipment, others.

维护简易化：主要设备等的特性描述

- Development of systems for the continuous feeding of crushers to reduce trucks' waiting time.

发展碎石机持续出货系统，减少卡车等待时间

SOLUCIÓN

Development of large-scale deep mining

Management of assets.

方案：开发大型深层开采；资产管理

ETAPA

Underground Mining

阶段：地下矿开采

LÍNEAS I+D

- Continuous mining
- Characterization.
- Gravitational flow.
- Online measurement of ore grades.
- Support and fortification.
- Fragmentation/blasting
- Automation and autonomous operation.
- Operation under high levels of geomechanical stress

研发线

持续开采；特征描述；重力自流；在线矿石等级测量；支持和安全强化；分裂/爆破

自动化和自主化作业；地质力学高压下作业

Challenge No. 2: Increased mineral resources and reserves

挑战2：增加矿物资源和储备

The second challenge identified in this core challenge has to do with the first two phases: Mine Exploration and Project Engineering and Mine Control and Planning. In the case of exploration, a possible solution identified is to improve and develop technologies that allow an increase in the rate at which new discoveries are made. Meanwhile, increasing mineral resources and reserves in the engineering and planning stage entails improving tools that allow, among other things, the investment cycle for projects to be reduced, thus closing the gap in the projected and real parameters and developing optimal strategies for the consumption of reserves.
和新挑战中明确的第二个挑战涉及前两个阶段：矿井勘探和项目工程、矿井控制和规划。勘探阶段，一种可能的方案是提升和发展技术，以加快新发现问世速度。同时，在工程和规划阶段增加矿物资源和储备即提升工具力度，缩短项目投资周期，从而减小预测数据和实时参数的差距，开发最佳战略，合理利用储备。

TABLE/21表格21

Solutions and R&D Lines. Challenges: Increased mineral resources and reserves

方案和研发线。挑战：增加矿物资源和储备

Increasing success rate of campaigns.
Reducing the duration of the investment cycle
Closing the gap in the projected and real parameters.
Optimal strategies for the consumption of reserves.

提高工作成功率；缩短投资周期；减小预测数据和实时参数的差距；开发最佳战略，合理利用储备

Exploration
Mine Project, Engineering, (MC&P)

勘探；矿井项目、工程（MC&P）

- Improvement and development of prospecting techniques.

勘探技术的提升和开发

- Improvement and development of drilling technologies.

钻井技术的提升和开发

- Improvement and development of characterization technologies.

特性描述技术的提升和开发

- Integrating knowledge from operations and projects.

作业和项目的知识一体化

- Characterization and modeling of variables (geosciences).

变量（地质科学）的特性描述和模型制作

- New sequencing tools (based on blocs, others) that integrate operational restrictions.

开发新的分离工具（基于块区等）整合所有作业规限

- Improvement of tools for defining the transition from pit to underground mine.

开发工具识别露天矿到地下矿的转变

- Improvement of tools for integrated medium term mine planning in a mining district.

开发工具制定一体化的矿区的中期矿井规划

- Holistic planning that integrates relevant variables on geo-metallurgy, geomechanics, then environment (acid, wind, others), commercialization, etc.

制定整体规划，整合地质冶金学、地质力学、环境学（酸性物质、风等）和商业化的相关变量

Challenge No. 3: Environmental protection and social responsibility

挑战3：注重环保意识和社会责任

As mentioned in previous chapters, socioenvironmental aspects have gained particular relevance in the mining industry's development and future sustainability. In this context, the R&D lines identified in the context of this challenge are associated with the management of waste and its potential impacts.

之前章节中提到过，社会环境已成为采矿行业未来可持续发展密不可分的一部分。所以，研发线明确如何管理好废料和及其潜在威胁是主要挑战

Table /22表格22

Solutions and R&D Lines. Challenge: Environmental protection and social responsibility

方案和研发线。挑战：注重环境保护意识和社会责任

Management of waste and its potential impact.	Open-pit mining	- Control of dust/emissions - Techniques that allow the future use of land and to control erosion. - Potential for acid production. - Tires. - Lubricants.

管理好废料及其潜在威胁；露天矿；尘土/排放控制、开发未来使用土地，控制腐蚀、产酸作用的潜力、轮胎、润滑剂

Challenge No. 4: Greater workplace safety and quality挑战4：提高工作地安全意识和质量

A constant concern for workplace safety is a continual focus of the mining industry's attention. The accident rate in mining is less when compared to other economic activities undertaken in the country, while the mortality rate has gradually declined. This Roadmap identifies this aspect as an important challenge for the exploration phase, in which the idea is to make progress in the development of techniques to reduce direct intervention on the part of operators.

工作场所的安全问题一直是采矿行业的关注焦点。智利采矿业的事故率与其他经济活动相比相对较小，事故死亡率持续下降。本路线图明确了勘探阶段安全的重要性。勘探的目的是进一步推进技术的发展，减少作业人员直接干预。

Table /23表格23

Solutions and R&D Lines. Challenge: Greater workplace safety and quality

方案和研发线。挑战：提高工作场所安全意识和质量

Reduce direct intervention by operators, thus improving both safety as well as accountability.	Exploration	· Improvement and development of techniques for automation of sampling and sampling preparation.

减少作业人员直接干预，增强安全性和问责制；勘探；取样和样品处理自动化技术的提升和

发展

CORE CHALLENGE; MINE OPERATIONS AND PLANNING
核心挑战；矿井作业和规划

4种挑战；13种方案；35条研发线

- Research in basic sciences. 基础科学研究
- Universities contribute to research, instrumentation and control.

获得诸多大学的研发、仪器和管理支持

- Advanced human capital with specialty: process modeling, management of assets, mechatronics, robotics, characterization and modeling of variables, geo-metallurgy, geochemistry, geophysics and the environment.

先进的特殊行业人力资本：流程建模、资产管理、机电一体化、机器人技术、变量的描述和建模、地质冶金学、地质化学、地质物理学和环境学。

- Training of operators and maintenance workers in Technical Training Centers who are experts in automation and robotics.

在技术培训中心安排自动化和机器人技术专家为作业人员和维护人员培训

- Technology think tank for mining. 矿业的技术智囊团
- Organizations for the transfer of knowledge.知识转让机构

SUPPLIERS供应商

- Strengthen the development of local suppliers of instrumentation, expert control, mechanization, automation, robotization, information management, optimization software, data transmission, engineering design and specialized support services.

加强开发当地供应商，如仪器、专家控制、机械化、自动化、机器化、信息管理、软件优化、数据传输、工程设计和其他专业领域的支持。

- System structured to accompany local companies with technological capacities.

构建支持系统以支持当地公司的技术能力提升

ALLIANCES 联盟

- Alliances with national and international universities and centers of excellence.

与智利国内和国际大学和优秀研究中心形成联盟

- Alliances between industries and Technical Training Centers to train operators

行业和技术培训中心形成联盟为作业人员提供培训

- Alliances between research centers / Universities / Industry / State/ Suppliers

研究中心/大学/行业/国家/供应商形成联盟

INFOGRAPHIC/7信息图表7

Technology Watch: Planning (Patents)技术简报：规划（专利）

TOTAL PATENTS
2010-2015
43
PATENTS 2010-2015 共有43项专利

MAIN TECHNOLOGICAL TRENDS主要技术趋势

- Procedures for underground or surface mine operation.

地下矿或露天矿的开采流程

- Diverse details related to the equipment that creates the fractures or completely frees the ore material from the vein.

从矿脉中分离矿石的设备的细节

US8144245B2

Method of determining a machine operation using virtual imaging

使用虚拟成像模拟机器操作以决定它是否合适

US8567871B2

Method for automatically creating a defined face opening in longwall mining operations

长壁开采作业中，自动生成被定义的端面开启

US7925474B2

System and methods(s) of blended mine planning, design and processing

混合矿井规划、设计和加工的系统和方法

US8070394B2

Versatile grout bag type of underground support

地下支持，多用途水泥袋

US7853439B2

Mining optimisation 采矿最优化

US2010104376A1

Grout bag type of underground support 地下支持，水泥袋

US8376467B2

Method for automatically producing a defined face opening in plow operations in coal mining

煤矿开采中自动生成犁操作的被定义的端面开启

US7681660B2

Arrangement for positioning drilling unit

定位钻井单元

US8886382B2

Method and system for regulating movement of an entity between zones

管理矿区之间实体运输的方法和系统

US7883298B2

Supporting device for an advance working or mining machine

先进的工作或采矿机械的支持维护设备

COUNTRIES WITH MOST PATENTS拥有专利最多的国家

USA	9
Australia	9
Finland	8
Germany	6
Sweden	5
France	3
S. Africa	2
Japan	2
Belgium	1
Italy	1

美国、澳大利亚、芬兰、德国、瑞典、法国、南非、日本、比利时、意大利

MAIN UNIVERSITIES

- University of Sydney 主要大学 悉尼大学

MAIN COMPANIES AND/OR R&D CENTERS 主要公司和/或研发中心

INFOGRAPHIC/9 信息图表9

Technology Watch: Exploration (Patents)技术简报：勘探（专利）

TOTAL PATENTS
2010-2015
315
PATENTS

2010-2015 共有315项专利

MAIN TECHNOLOGICAL TRENDS 主要技术趋势

- Work with lasers 激光技术
- Seismology, Prospecting and seismic or acoustic detection.

地震学、勘探学和地震或声学检测

- Tunnels or galleries.隧道或平巷
- Methods or guidelines for reading or recognizing printed or written character, or to recognize patterns.

阅读或识别打印或书写字符，或识别图形

- Systems that use reflection or re-irradiation of the electromagnetic waves that are not radio waves.

使用非无线电波电磁波的反射或二次辐射

MOST-CITED PATENTS 引用最多的专利

US7860301B2

3D imaging system 3D影响系统

US7756615B2

Traffic management system for a passageway environment

利用交通管理系统管理通道环境

US7725253B2
Tracking, auto-calibration, and map-building system
跟踪、自动标定和绘图系统
US7832126B2
Systems, devices, and/or methods regarding excavating
挖掘系统、设备、和/或方法
US8325030B2
Heat stress, plant stress and plant health monitor system
热应力、植物抗性和植物健康监测系统
US8050206B2
Wireless network camera systems
无线网络照相系统
US8235110B2
Preconditioning an oilfield reservoir
预处理油田储层
US2011030586A1
Carbonate products for carbon capture and storage
使用碳酸酯产品收集和储存碳
US8585786B2
Methods and systems for briquetting solid fuel
把固体燃料制成煤球
US2011096168A1
Video delivery systems using wireless cameras
使用无线相机传送视频
COUNTRIES WITH MOST PATENTS拥有专利的国家

USa	162
Australia	39
Canada	34
China	17
Germany	16
Sweden	15
Switzerland	14
Finland	8
UK	7
S. Africa	5

美国、澳大利亚、加拿大、中国、德国、瑞典、瑞士、芬兰、英国、南非

MAIN UNIVERSITIES 主要大学

- University of Sydney 悉尼大学
- California Technology Institute 加州理工学院
- Chinese University of Mining and Technology 中国矿业大学
- University of Jianghan 江汉大学
- Catholic University of Chile 智利天主教大学
- University of Akron阿克伦大学
- University of Nevada内华达大学
- Southeastern University诺瓦东南大学
- University of Utah Research Foundation犹他大学研究基金会
- University of Western Ontario西安大略大学

MAIN COMPANIES AND/ OR R&D CENTERS

- Caterpillar INC.
- Shell Oil CO.
- Exxonmobil Upstream res CO.
- Foro energy INC.
- Tech resources PTY LTD.
- Sandvik Mining & Constr OY.
- Halliburton Energy Serv INC.
- Safemine AG.

主要公司和/或研发中心

INFOGRAPHIC/10 信息图表10

Technology Watch: Exploration (Publications) 技术简报：勘探（出版物）

SCIENTIFIC PUBLICATIONS 2010-2015

科学出版物2010-2015

MAIN RESEARCH TRENDS 主要研究趋势

Geochemistry and Geophysics 地质化学和地质物理

Geology 地质学

Ore processing 矿石加工

Minerola Mineralogy ogía 矿物学

Ecology and environmental sciences 生态学和环境科学

Remote Sensors 远程感应

Physical Geography 自然地理学

Computer Sciences 计算机科学

Engineering 工程学

Other Technology and Science topics 其他技术和科学课题

SCIENTIFIC PUBLICATIONS

449

MOST-CITED PUBLICATION

The "chessboard" classification scheme of mineral deposits: Mineralogy and geology from aluminum to zirconium

Authors
Dill, Harald G.

科学出版物 449

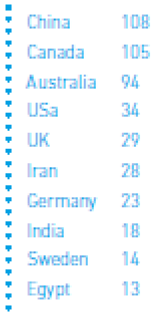
引用最多的出版物

矿床“棋局”分类表：铝和锆的矿物学和地质学

作者：

Principales Instituciones de Investigaci ón 主要研究机构
Chinese University of Geosciences 中国地质大学
Chinese University of Geosciences, Beijing campus中国地质大学北京分校
Commonwealth Scientific and Industrial Research Organization (CSIRO)
联邦科学与工业研究组织
Canadian Geological Service加拿大地质调查局
Chinese University of Geosciences, Wuhan campus中国地质大学武汉分校
University of Western Australia 西澳大学（澳大利亚）
Chinese Academy of Geological Sciences中国地质科学院
Chinese Academy of Science 中国科学院
Islamic Azad University in Damavand 伊斯兰自由大学
Queen’s University 皇后大学

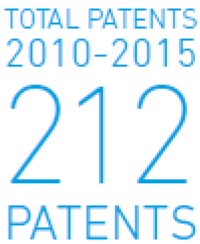
COUNTRIES WITH SCIENTIFIC PUBLICATIONS拥有出版物的国家



China	108
Canada	105
Australia	94
USa	34
UK	29
Iran	28
Germany	23
India	18
Sweden	14
Egypt	13

中国、加拿大、澳大利亚、美国、英国、伊朗、德国、印度、瑞典、埃及

INFOGRAPHIC/11 信息图表11
Technology Watch: Operation (Patents)技术简报：作业（专利）



2010-2015 共有212项专利

MAIN TECHNOLOGICAL TRENDS主要技术趋势

- Drills especially adapted to change drilling direction, with means for collecting substances.

钻井转向钻头，同时可收集物质

- Manufacture of composite layers, parts or objects based on metallic dusts, sintered with or without compacting.

用金属粉尘，压缩或非压缩制造复合材料层、零件等

MOST-CITED PATENTS ON OPERATION引用最多的作业专利
US7776256B2
Earth-boring rotary drill bits and methods of manufacturing earthboring rotary drill bits having particle-matrix composite bit bodies
钻地旋转钻头，制造具有粒子基体复合体的地旋转钻头的方法

US7802495B2

Methods of forming earth-boring rotary drill bits 钻地旋转钻头的制法

US7954569B2

Earth-boring bits 钻地钻头

US8517125B2

Impregnated material with variable erosion properties for rock drilling

可作为钻头的不同侵蚀特征的浸渍材料

US7913779B2

Earth-boring rotary drill bits including bit bodies having boron carbide particles in aluminum or aluminum-based alloy matrix materials, and methods for forming such bits

钻地旋转钻头，包括钻头体碳化硼颗粒，颗粒是铝或铝合金基体材料。还有制造这种钻头的方法

US8156871B2

Liner for shaped charges 锥形装药内衬

US7784567B2

Earth-boring rotary drill bits including bit bodies comprising reinforced titanium or titanium-based alloy matrix materials, and methods for forming such bits

钻地旋转钻头，包括含有增强钛和钛合金集体材料的钻头体，还有制造这种钻头的方法

US7807099B2

Method for forming earth-boring tools comprising silicon carbide composite materials

制造含有碳化硅复合材料的钻地工具的方法

US8322466B2

Drill bits and other downhole tools with hardfacing having tungsten carbide pellets and other hard materials and methods of making thereof

有表面堆焊硬合金的钻头和其他钻井工具，该硬合金含有碳化钨颗粒和其他坚硬材质。还有制造上述工具的方法

US7977420B2

Reactive material compositions, shot shells including reactive materials, and a method of producing same

反应物质复合物、散弹枪弹，包括反应物质 ，和制造方法

COUNTRIES WITH MOST PATENTS IN PLANNING拥有规划专利最多的国家

USA	136
Germany	32
Holand	13
Canada	7
Australia	7
UK	5
France	5
Sweden	5
China	4
Chile	3

美国、德国、荷兰、加拿大、澳大利亚、英国、法国、瑞典、中国、智利

MAIN UNIVERSITIES主要大学

- Chinese University of Mining and Technology中国矿业大学

MAIN COMPANIES
AND/OR R&D
CENTERS

- Baker Hughes INC.
- Halliburton Energy Serv INC.
- Kennametal INC.
- Longyear TM INC.
- Potter Drilling INC.
- Schlumberger technology BV
- Smith International
- TDY IND INC.

主要公司和/或研发中心

INFOGRAPHIC/12

Technology Watch: Operation (Publications) 技术简报：作业（出版物）

SCIENTIFIC PUBLICATIONS科学出版物

2010-2015

MAIN RESEARCH TRENDS 主要技术趋势

Engineering 工程学

Geology 地质学

Ore processing 矿石加工

Ecology and environmental sciences 生态学和环境科学

Water resources 水资源

Geochemistry and Geophysics 地质化学和地址物理

Metallurgy / Metallurgic engineering 冶金/冶金工程

Meteorology and Atmospheric Sciences 气象学和大气科学

Computer Sciences 计算机科学

SCIENTIFIC

PUBLICATIONS 科学出版物

MOST-CITED

PUBLICATION 引用最多的出版物

TOUGHREACT Version 2.0: A simulator for subsurface reactive transport under non-isothermal multiphase flow conditions

TOUGHREACT 版本 2.0：非热能多相流条件的地下反应传递模拟器

Authors 作者

Xu, Tianfu;

Spycher, Nicolas;

Sonnenthal, Eric; et al.

MAIN RESEARCH INSTITUTIONS 主要研究机构

Tarbiat Modares University 塔比阿特莫达勒斯大学

Shahrood University of Technology沙赫鲁德技术大学

Islamic Azad University in Damavand伊斯兰自由大学

Beijing Institute of Technology 北京理工大学

Chinese University of Mining and Technology 中国矿业大学

Chinese Academy of Science 中国科学院

Indian Institute of Technology 印度理工学院

Russian Academy of Science 俄罗斯科学院

Commonwealth Scientific and Industrial Research Organization (CSIRO)

联邦科学与工业研究组织

Pratap University of Agriculture and Technology Pratap农业技术大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS拥有技术出版物的国家

USa	64
China	63
Iran	52
Canada	27
India	22
Turkey	22
Australia	21
Spain	15
Russia	13
France	11

美国、中国、伊朗、加拿大、印度、土耳其、澳大利亚、西班牙、俄罗斯、法国

CORE CHALLENGE: ORE CONCENTRATION 核心挑战：选矿

BACKGROUND背景

As has been previously noted in this book, productivity in mining has declined due to factors that exceed the decline in the quality of the geological resource (measured by sterile material ratio and ore grades). In addition, the national mining industry’s overall demand for energy has increased, to a great degree due to the increased processing of ore concentrate.

本文之前已提到过，采矿生产率有所下降，这是由于不断减少的地质资源（通过测量无菌材料比例和矿石等级）。除此以外，智利采矿行业总体能量需要不断上升，这是由于不断增加的选矿活动和矿石加工

This means that concentration, the productive process that follows the extraction of sulfide ores, is a priority aspect to be addressed if transformations are to be implemented to resolve the productivity challenges that the industry faces.

这意味着，选矿这一生产流程已成为继硫化矿的提取之后，行业转型任务的重中之重。我们已知，行业转型是解决当前行业面临的生产挑战的重要途径。

The concentration process starts with reducing the size of particles, or “comminution,” which consists in two consecutive stages: crushing and wet grinding. They account for a significant proportion of the cost associated with the concentration process due to the high energy consumption that grinding entails.

选矿流程首先是减小颗粒尺寸，或称“粉碎”，有两个环节：粉碎和湿法粉碎。这两个环节与成本控制问题息息相关，会涉及到很多能耗问题。

The Core Challenge Ore Concentration section was drafted based on work by the technical commission created for the core challenge, which was comprised of the following members: Agustín Sepulveda, Andrés Pérez, Brian Baird, Carlos Urenda, Christian Schnettler, Claudio
Rojas, Cleve Lightfoot, Francisco Abbott, Hugo Toro, Jorge Soto, Murray Canfield, Nury Briceño, Pablo Asiain, Pierre Perrier.

矿石挑战：选矿的起草工作是基于核心挑战技术委员会的建议起草。技术委员会负责明确和解决采矿业的核心挑战，现有以下成员：Agustín Sepulveda, Andrés Pérez, Brian Baird, Carlos Urenda, Christian Schnettler, Claudio

Rojas, Cleve Lightfoot, Francisco Abbott, Hugo Toro, Jorge Soto, Murray Canfield, Nury Briceño, Pablo Asiain, Pierre Perrier.
The following team from Fundación Chile was in charge of drafting this section: Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito, Hernán Araneda.
智利委员会负责起草工作，成员有: Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito, Hernán Araneda.

The copper sulfide ores that one seeks to recover through flotation-concentration are normally accompanied by other minerals of lesser or no relative economic benefit (“gangue”), with their separation being the objective of the concentration process.
整个浮选选矿流程中，我们的目标回收物就是硫化铜矿。矿石里除了含有硫化铜矿，通常参有其他无经济价值的元素（“脉石”），选矿的过程和目的就是为了分离这些物质。
Thus a copper concentrate is obtained that is comprised mainly of copper sulfides like bornite and chalcopyrite.
如此，便得到了铜精矿，主要含有如斑铜矿、黄铜矿的硫化铜。
The gangue is the “tail” of the flotation process and is dumped as tailings.
脉石是浮选选矿的“收尾”产物，作为尾矿处理。
Electricity, steel (in the form of coatings and grinding equipment) and water are inputs that are critical to determining costs throughout this process, especially due to the initial process of reducing particle sizes, or “comminution.”
电力、钢材（以涂料和研磨设备形式）和水资源是加工流程成本的决定性输入因素，尤其初始阶段，如减小颗粒大小，或“粉碎”
The grinding process accounts for the largest proportion of the cost associated with concentration due to its high energy consumption. In fact, over one third of the electricity consumed in metal mining is used in the grinding process. This stage shows low levels of energy efficiency (around 1%).
研磨是选矿过程中花费最大的一个流程，它的能耗最高。其实，金属矿开采中，超1/3的电能是消耗在研磨过程中。这个阶段的能源效率很低（差不多是1%）
In the case of crushing, efficiency is 50%, while energy consumption corresponds to approximately 1% of the total required to produce copper.
在粉碎阶段，效率是50%，但能耗相当于制铜总能耗的约1%
This can be observed in the following graph.
以下图表有详细说明。
GRAPH/38 图表38
Detail of spending stages in operation of concentration process
选矿环节各操作环节的花费情况

Crushing
Grinding
Collective flotation
Thickening of Concentrate
Selective flotation
Tailings
Management of concentrate
Fresh water (desalinated)
Reclaimed water
General concentrator

粉碎、研磨、混合浮选、浓缩、优先浮选、尾矿、选矿管理、淡水（脱水）、再生水、一般选矿机

With regard to the consumption of steel goods, it has been calculated that it will reach 1.077 million tonnes by 2025, equivalent to a 127% increase over 2014 (Cochilco 2014e) currently grinding costs account for 22% of this stage's operating costs.
到2025年，钢材产品的消耗据计算将达到107.7万吨，在2014年基础上增加了127%(Cochilco 2014e)。目前，研磨占这个阶段操作成本的22%。

Graph/39 图表39
Operating cost of grinding stage. 研磨阶段操作成本
Electric power for grinding 研磨所耗功率
M&R Services (Mech-Elec) M&R 服务 (Mech-Elec)
Grinding balls 3 and 5 研磨机3和5
Rest of grinding process 研磨流程中其他环节
Water is also in high demand in concentration processes, from grinding to flotation, and to facilitate the transportation of process tailings. Continental water sources have traditionally been used but over recent years increased volumes of seawater have been incorporated, with the consequential impact on energy consumption.
从研磨到浮选，再到尾矿的运输，整个选矿过程中，水尤为重要。陆地水资源一直是主要来源，不过近几年由于能耗越来越高，采矿行业也频繁地使用海水来工作。
The below graph shows that the national supply of grinding balls is expected to surpass demand between 2017 and 2018, but after 2019 national supplies will only suffice to supply those projects classified as probable and a portion of the ones considered possible.
下表中，可以看到，智利国家供给的研磨机有望在2017年和2018年都保持供货充足，而到2019年，研磨机的供应就没有那么多了，只供应给具有较高回报潜力的项目或其中一部分。

GRAPH/40图表40
Supply-demand balance of steel balls (2014-2015)钢珠的供需平衡情况

Base
Probable
Possible
Potential
National supply

（从上到下，从左到右）

基线、极大可能、可能、有潜力、国家供给

Other problems affecting the grinding and flotation process have to do with the accumulation of large particles that reach the rougher flotation cells and can have a negative impact on the flow of slurry, creating dead zones and reducing the recovery rate of valuable minerals, in addition to increasing maintenance costs. The flotation process also needs to efficiently deal with fine particles to make efficient use of the kinetic energy that the process demands.

影响到研磨和浮选流程的另一些问题是进到粗浮选槽的大颗粒的残积会导致泥浆流动不畅，形成死区，这样会减少贵重金属回收率，当然这也会在造成维护成本的增加。浮选流程也需要有效利用颗粒，有效动能。

In addition to the aforementioned operating costs, the capital cost (investment) required to concentrate minerals is very high and can become a “bottleneck.” This makes management of assets particularly important in concentration plants.

除了上述操作费用，资产成本（投资）也是选矿过程中一项很高的指标，可称之为“瓶颈”。选矿厂的资产管理其实非常重要。

Smart technologies18 have emerged as a means for optimizing the use of assets and improving process efficiency. In addition to improving people’s safety, these technologies help to stabilize processes (lower variability), cut costs, increase productivity and improve the quality of intermediate and end products.

智能科技的诞生，优化了资产的利用，提升了流程效率。除了要提高人员的安全性，这些科技促进了流程的稳定性（较低的变量）、减少成本、提升生产率、提高了中间环节产品和最终产品的质量。

They are currently widely used in developments involving control of multiple variables in the crushing, grinding, flotation and thickening processes. For their part, the providers of maintenance services have also been adapting their models and practices to these new trends, in particular proactive maintenance:

智能科技广泛应用于粉碎、研磨、浮选和浓缩环节的变量控制。维护商亦在模型建设中使用到智能科技，以适应新形势，尤其是主动维护：

Monitoring and registering the key performance parameters of a given piece of equipment to analyze patterns or signals to determine its conditions and in this way plan specific maintenance activities and program the right moment for intervening in a given asset.

监测和录入特定设备的主要性能参数、分析使用模式和信号，以决定其使用环境。再规划具体的维护方式，在特定的资产条件下，选择合适的时间进行维护。

While the use of predictive models for failures to undertake programmed maintenance is an accepted practice, there is an opportunity to increase productivity if the modeling of fatigue and corrosion in critical parts is improved so maintenance can be carried out in consideration of the cost and likelihood of failure. Among the trends in maintenance services is organizing maintenance around the reliability of assets, according to their operational context and expected maintenance costs.

尽管运用失败预测模型进行既定的维护是惯例，但关键时刻对疲劳和侵蚀情况建模可能对提高生产率有不可磨灭的帮助，如此一来，维护工作可以辅助监控成本和失败概率。 维护服务众多趋势之一是根据作业环境和预期的维护成本，围绕资产可靠性开展维护工作。

[18] See Chapter 6, Smart Mining Section.

章节6，智能采矿

CHALLENGES, SOLUTIONS AND R&D LINES

Based on the information analyzed, the group of experts who participated in the technical workshops defined the following challenges and identified solutions and R&D LINES for them, which are presented below.

挑战、方案和/或研发线

根据以上信息，参与技术工作的专家小组定义了以下挑战，并明确了方案和研发线，请见以下内容。

Challenge No. 1: Increased productivity 挑战1 提高生产率

In the current context this considered essential for making progress in the management of assets, to reduce energy and steel consumption and also to more efficiently use and transport water to increase the productivity of the ore concentration stage.

现有情况下，提高生产率被认为是提升资产管理能力、降低能耗和钢材消耗、更有效利用和运输水资源的推动力，从而提高矿石选矿环节生产率。

In particular, it must be noted that there are currently concentration plants in operation with froth flotation cell banks that have an extraordinarily high power installed and their operation needs to be subjected to a critical cost effectiveness analysis.

特别值得注意的是，有些选矿厂用的是泡沫浮选槽库，安装了超高功率，有必要对这种操作进行严谨的成本-效果分析。

TABLE/24 表格24

Solutions and R&D Lines. 方案和研发线

Challenge: increased productivity 挑战：提高生产率

SOLUTION

Management of assets

Reducing energy and steel consumption

Efficient water use and transportation 方案-资产管理-降低能耗和钢材消耗-有效的水资源利用和运输

Monitoring of key equipment 主要设备的监测

Handling of Uncrushable Material 耐压材料的处理

Instrumentation's ease of maintenance 设备维护简易性

Robotization and autonomous operation 操作机器化和自主化

Impact of the use of seawater使用海水的影响

Fragmentation/blasting 分裂/爆破

Pre-classification 预分类

Pre-concentration 预选矿

Development of new equipment and adaptation of existing technologies.

新设备的开发和现有技术的应用

Classification efficiency 分级效率

Development of automatic sensors and controls / process optimizers

自动感应器的开发、控制/处理优化器

Impact of the use of seawater 使用海水的影响

Grinding and coating means 研磨和涂层方法

Use of seawater or desalinated water 海水和淡水的使用

Reducing the water make-up 降低补水量

More efficient pumping 更有效泵送

Challenge No. 2: Increased mineral resources and reserves挑战2，增加矿物资源和储备

To increase the resource base and mineral reserves, there is a need to increase copper recovery, control for impurities and develop new technologies.

提高资源基础和矿物资源，就必须提高铜回收率、控制杂质和开发新技术。

TABLE/25 表格25

Solutions and R&D Lines. 方案和研发线

Challenge: increasing mineral resources and reserves

挑战：增加矿物资源和储备

Increasing ore grades in concentrates and the recovery of element of interest

Control of impurities

Development of new technologies 提高精矿的矿石等级，提高贵重金属回收率；控制杂质；开发新技术

Selective flotation of byproducts 副产品的优先浮选

Development of automatic sensors and controls / process optimizers

自动感应器和开发，控制/处理优化器

Pyrite depression 黄铁矿的抑制

Flotation of fines, roughers and sands 精浮选、粗浮选和砂浮选

Explore use of nanoparticles in flotation 探究浮选流程里纳米颗粒的应用

Impact of the use of seawater 使用海水的影响

Development of technology to guarantee the quality of concentrate

发展技术，保证选矿质量

Development of concentration methods 选矿方法的发展

核心挑战：选矿

2种挑战 6种方案 24条研发i线

CAPACITIES 能力

- Research in basic sciences. 基础科学研究
- Universities contribute to research, instrumentation and control.

获得诸多大学的研发、仪器和管理支持

- Advanced human capital specialized in: fluid mechanics, materials sciences, nanoscience, process modeling, robotics, automation and control, geochemistry and environment.

先进的特殊行业人力资本：流体力学、材料科学、纳米科学、流程建模、机器人技术、自动化控制、地质化学和环境学

- Training of operators and maintenance workers in Technical Training Centers who are experts in automation and robotics.

在技术培训中心安排自动化和机器人技术专家为作业人员和维护人员培训

- Technology think tank for mining. 矿业的技术智囊团
- Organizations for the transfer of knowledge.知识转让机构

SUPPLIERS供应商

- Strengthen the development of local suppliers of instrumentation, expert control, mechanization, automation, robotization, information management, optimization software, data transmission, engineering design and specialized support services.

加强开发当地供应商，如仪器、专家控制、机械化、自动化、机器化、信息管理、软件优化、数据传输、工程设计和其他专业领域的支持。

ALLIANCES 联盟

- Alliances between national and international universities and centers of excellence.

与智利国内和国际大学和优秀研究中心形成联盟

- Alliances between industries and Technical Training Centers, training of operators

行业、技术培训中心、操作员培训中心形成联盟

- Alliances between research centers, Universities, Industries, State, Suppliers.

研究中心、高等学府、行业、政府、供应商形成联盟

INFOGRAPHIC/13 信息图表13

Technology Watch: Crushing (Patents) 技术简报：粉碎（专利）

TOTAL PATENTS 2010-2015

77

PATENTS

2010-2015，共有77项专利

MAIN TECHNOLOGICAL TRENDS

- Preliminary treatment of ore or scrap
- Methods or ancillary devices or accessories especially adapted to to crushing and disintegration
- Means of transport specially adapted to underground conditions.

主要技术趋势

矿石和碎片的初步处理；粉碎和分解的方法或辅助装置或附件；地下运输方法

MOST-CITED PATENTS

引用最多的专利

US7861955B2

Wet-grinding gypsum with polycarboxylates

聚羧酸盐湿磨法石膏；

US8960337B2

High impact resistant tool with an apex width between a first and second transition

最高幅宽在第一和第二转换间的高抗冲工具

US8302890B2

Modular ore processor

矿石模块处理器

US8022019B2

Method of making proppant used in gas or oil extraction

在气体或石油萃取的支撑剂的制造方法

US8434706B2

Overburden removal system with triple track mobile sizer

覆岩清除系统，拥有三重移动筛选器

WO2010037215A1

Method and apparatus for processing a sized ore feed

处理一定的给矿量的方法和装置

EP2319624A1

Method for fine crushing of lump material

块料的精细粉碎方法

US2010044276A1

Method and apparatus to create an oil sand slurry

制造油砂泥浆的方法和装置

DE102009018236A1

Mobile crusher for use in open-cast mining for crushing broken rock, has loading belt connected with hopper, suspended by hydraulic cylinder on upper ring support at raised and lowered position and partially compensated by counterweight

露天采矿中用到的移动粉碎机，用来粉碎碎石。配有连接料斗的装载带，悬吊在上方环状支撑物的液压缸下，上下各有一个支撑物，维持平衡。

US8182601B2

Powder formed from mineral or rock material with controlled particle size distribution for thermal films

由矿物或岩石材料制成粉末，具有可控热膜粒度分布

COUNTRIES WITH MOST PATENTS

拥有最多专利的国家

英国、德国、澳大利亚、加拿大、英国、俄罗斯、智利、瑞士、中国、法国

MAIN UNIVERSITIES

- Chinese University of Mining and Technology
- University of Houston
- University of Melboune

主要大学

中国矿业大学、休斯顿大学、墨尔本大学

MAIN COMPANIES AND/OR R&D CENTERS

- Tech Resourses PTY LTD
- Takraf GMBH
- Unimin Corp
- Joy MM Delaware INC
- Thyssenkrupp Foerdertechnik
- Suncor Energy INC
- Arter Teknolodzhi LTD
- Harnischfeger Tech INC
- Corporación Nacional del Cobre - Codelco

主要公司和/或研发中心

INFOGRAPHIC/14
Technology Watch:
Crushing (Publications)

SCIENTIFIC PUBLICATIONS 2010-2015

SCIENTIFIC PUBLICATIONS

信息图表14
技术简报：粉碎（出版物）
科学出版物2010-2015；科学出版物

- Ore processing
- Mineralogy
- Engineering
- Metallurgy / Metallurgic engineering
- Chemistry
- Materials sciences
- Nuclear Science and Technology
- Fossil fuels

矿石加工；矿物学；工程学；冶金/冶金工程；化学；材料科学；核科学与技术；矿物燃料

MOST-CITED PUBLICATION

Large particle effect in chemical/biochemical heap leach processes - A review

Authors
Ghorbani, Y.
Becker, M.
Mainza, A.

引用最多的出版物：大颗粒对化学/生物化学堆浸流程的影响

—回顾
作者：

MAIN RESEARCH INSTITUTIONS
University of British Colombia
Chalmers Technical University
Chinese University of Mining and Technology
University of Cape Town
ADP Group of Companies
AGH Science and Technology University
Amec Americas Limited
Aminpro Chile
Caspeo
Chinese University of Geosciences

主要研究机构
哥伦比亚大学；歌德堡大学；中国矿业大学；开普敦大学；ADP公司集团；AGH科学技术大学、Amec Americas Limited、Aminpro Chile、Caspeo、中国地质大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有科学出版物的国家
南非、澳大利亚、智利、美国、加拿大、中国、瑞典、芬兰、印度、伊朗

INFOGRAPHIC/15
Technology Watch:
Grinding (Patents)

TOTAL PATENTS
2010-2015
113
PATENTS

信息图表15 技术简报：研磨（专利）

2010-2015，共有113份专利

MAIN TECHNOLOGICAL
TRENDS

- Presses specially adapted to specific ends
- General layout of separation in the plant
- Control systems especially adapted to crushing and disintegration
- Metalworking

主要技术趋势

用于特定目的的压力
工厂的总体分离安排
粉碎和分解的控制系统
金属加工

MOST-CITED PATENTS ON GRINDING引用最多的研磨专利

US8147980B2

Wear-resistant metal matrix ceramic composite parts and methods of manufacturing thereof

抗磨损金属基金属陶瓷构件和制作方法

US7757976B2

Method of processing nepheline syenite powder to produce an ultra-fine grain size product

加工霞石正厂岩粉生产超细粒径产品

US7954734B2

Disruptor system for dry cellulosic materials

用于干纤维素材料的粉碎机系统

WO2012016286A1

Sorting mined material

开采出材料的分类

US7677079B2

Method and device for sensing wear

检测耐磨材料的方法和装置

US7861955B2

Wet-grinding gypsum with polycarboxylates

聚羧酸盐湿磨法石膏

US8960337B2

High impact resistant tool with an apex width between a first and second transitions

在第一和第二转换间有最大幅宽的高抗冲工具

US7690589B2

Method, system and apparatus for the deagglomeration and/or disaggregation of clustered materials

解聚集群材料的方法、系统和装置

US8302890B2

Modular ore processor

矿石模块处理器

US8157193B2

Waterless separation methods and systems for coal and minerals

煤油和矿物的污水分离方法和系统

COUNTRIES WITH MOST PATENTS IN GRINDING

拥有研磨专利最多的国家

美国 澳大利亚 德国 智利 丹麦 印度 芬兰 英国 日本 法国

MAIN UNIVERSITIES

- McGill University
- University of KwaZulu-Natal
- University of Queensland
- University of Santiago de Chile
- University of Melboune

主要大学

加拿大麦吉尔大学、南非夸祖鲁纳塔尔大学、澳大利亚昆士兰大学、智利圣地亚哥大学、墨尔本大学

MAIN COMPANIES AND/OR R&D CENTERS

- Smidth & CO AS F L
- Unimin Corp
- Outotec OYJ
- Metso Minerals France SA
- Schlumberher Technology BV
- Tech Resources PTY LTD
- Arter Technology BV
- KDH Humboldt Wedag GMBH

主要公司和/或研发中心

INFOGRAPHIC/16
Technology Watch: Grinding
(Publications)

SCIENTIFIC PUBLICATIONS
2010-2015

SCIENTIFIC
PUBLICATIONS

296

信息图表16

技术简报：研磨（出版物）

2010-2015 科学出版物

- Engineering
- Geology
- Ore processing
- Ecology and environmental sciences
- Water resources
- Geochemistry and Geophysics
- Metallurgy / Metallurgic engineering
- Meteorology and Atmospheric Sciences
- Remote Sensors
- Computer Sciences

工程学、地质学、矿石处理、生态学和环境科学、水资源、地质化学和地质物理学、冶金工程学气象学和大气科学、远程感应、计算机科学

MOST-CITED
PUBLICATION

Large particle effect in
chemical/biochemical heap
leach processes - A review

Authors
Ghorbani, Y.
Becker, M.
Mainza, A.

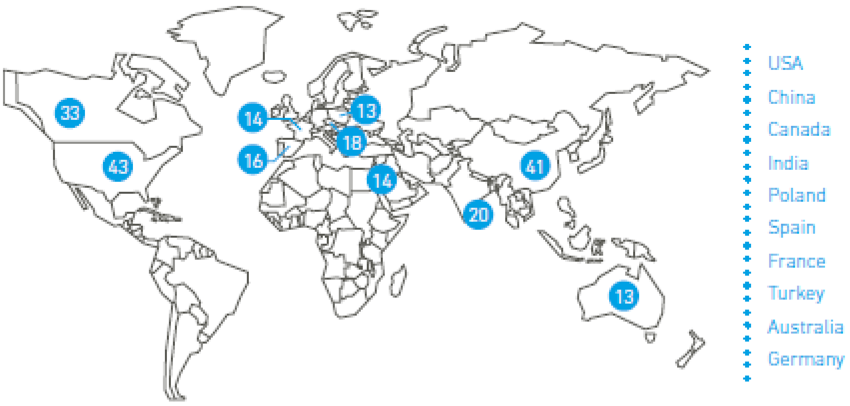
引用最多的出版物：大颗粒对化学/生物化学堆浸流程的影响

作者：

Chinese University of Mining and Technology
University of Saskatchewan
Korea Institute of Geoscience and Mineral Resources
University of Pretoria
Chinese Academy of Science
United States Department of Energy
University of British Colombia
French National Center for Scientific Research
Spanish High Council for Scientific Research

中国矿业技学
萨斯喀彻温大学、韩国地质科学和矿物资源研究所、比勒陀利亚大学、中国科学院、美国能源部、哥伦比亚大学、法国科学研究中心、西班牙高级科学研究委员会

COUNTRIES WITH SCIENTIFIC PUBLICATIONS



拥有科学出版物的国家
美国 中国 加拿大 印度 波兰 西班牙 法国 土耳其 澳大利亚 德国

INFOGRAPHIC / 17
Technology Watch: Flotation (Patents)

信息图表17

技术简报：浮选（专利）

TOTAL PATENTS
2010-2015

88

PATENTS

2010-2015 共有得88项专利

MAIN TECHNOLOGICAL TRENDS

- Expected effects of flotation agents
- Specified materials treated by flotation agents, specific applications

主要技术趋势：

浮选剂的预期效果；浮选剂处理的特殊材料，特殊应用

US7763166B2

Relocatable countercurrent decantation system

可重新定位的逆流倾析系统

US8011514B2

Modified amine-aldehyde resins and uses thereof in separation processes

改良后的胺醛树脂和其在分离过程中的应用

US8424601B2

System and method for minimizing the negative enviromental impact of the oilsands industry

减小油砂行业对环境的负面影响，研究解决方案和系统

US8757389B2

Amine-aldehyde resins and uses thereof in separation processes

胺醛树脂和其在分离过程中的应用

US8133970B2

Oxidized and maleated derivative compositions

氧化的和马来酸盐衍生化合物

US9114406B2

Steam driven direct contact steam generation

蒸汽动力直接接触气化

US7922788B2

Process for recovering gold and silver from refractory ores

耐火矿石中回收金和银的过程

US8025341B2

Mobile oil sands mining system

移动油砂采矿系统

CN102085526B

Recycling method of blast furnace dust generated in steel making industry

制钢行业高炉灰回收方法

US2011155651A1

Separation of copper minerals from pyriteusing air-metabisulfite treatment

使用空气偏亚硫酸氢盐从黄铁矿中分离铜矿

COUNTRIES WITH MOST PATENTS

拥有专利最多的国家

美国 加拿大 澳大利亚 德国 巴西 日本 俄罗斯 法国 新西兰 智利

MAIN UNIVERSITIES主要大学

· Technical University of Aquisgran

Aquisgran技术大学

· University of Manchester曼彻斯特大学

· McMaster University 麦克马斯特大学

· University of Osaka 大阪大学

· University of Utah Research Foundation犹他研究基金会大学

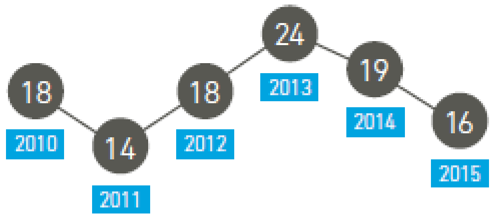
MAIN COMPANIES AND/OR R&D CENTERS

- Barrick Gold Corp
- Basf AG
- BHP Billiton SSM Dev PTY LTD
- Cytec Tech Corp
- Evonik Industries AG
- Ex Tar Technologies INC
- Geordia Pacific Chemicals LLC
- Sumimoto Metal Mining CO

主要公司和/或研发中心

INFOGRAPHIC/18
Technology Watch: Flotation
(Publications)

SCIENTIFIC PUBLICATIONS
2010-2015



SCIENTIFIC
PUBLICATIONS

109

信息图表18

技术简报：浮选（出版物）

科学出版物2010-2015

MAIN RESEARCH TRENDS
Ore processing
Engineering
Mineralogy
Metallurgy / Metallurgic engineering
Ecology and environmental sciences
Chemistry
Materials sciences
Fossil fuels
Biochemistry and Molecular Biology
Biotechnology and Applied Microbiology

主要研究趋势

矿石加工、工程学、矿物学、冶金工程学、生态学和环境科学、化学、材料科学、矿物燃料、生物化学和分子生物、生物技术和应用微生物

MOST-CITED
PUBLICATION

Large particle effect in
chemical/biochemical heap
leach processes - A review

Authors
Ghorbani, Y.
Becker, M.
Mainza, A.

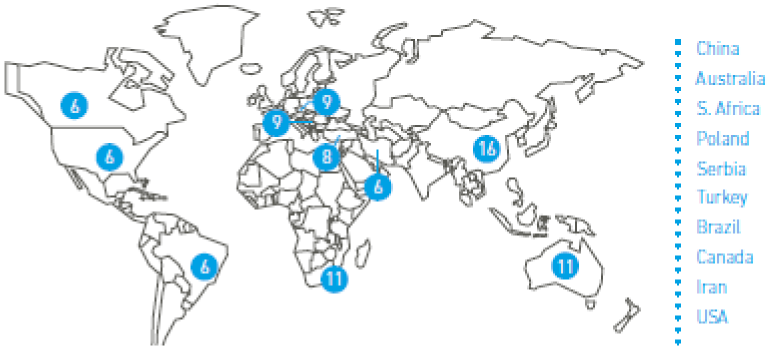
*引用最多的出版物：*大颗粒对化学/生物化学堆浸流程的影响

MAIN RESEARCH INSTITUTIONS
University of Belgrade
University of Queensland
University of Cape Town
Chinese University of Mining and Technology
AGH Science and Technology University
Amirkabir University of Technology
Chinese Academy of Science
Chinese National Engineering Research Center of Clean Coal Combustion
Krakow Agricultural University
Al-Hussein Bin Talan University

主要研究机构：

贝尔格莱德大学、昆士兰大学、开普敦大学、中国矿业大学、AGH科学技术大学、阿米尔卡比尔理工大学、中国科学院、中国洁净煤燃烧国家工程研究中心、克拉科夫农业大学、Al-Hussein Bin Talan大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS



拥有科学出版物的国家

中国、澳大利亚、南非、波兰、塞尔维亚、土耳其、巴西、加拿大、伊朗、美国

CORE CHALLENGE: HYDROMETALLURGY 核心挑战：湿法冶金术

BACKGROUND背景

Copper Hydrometallurgy is the method used to process copper oxide ores and some types of sulfides. It prompts diverse physical and chemical reactions19 to extract the copper from the rest of the crushed material, dissolving it in an acid solution (leaching stage) before then continuing with a solvent extraction stage followed by electrowinning to produce high-purity copper cathodes.

湿法提铜是加工氧化铜矿和一些硫化物的方法。这种方法是通过产生的各式物理和化学反应，从粉碎后材料中提取铜。溶剂萃取步骤后，再用电解冶金法生产高纯度电解铜，把电解铜溶解进酸性溶剂（浸出）。

Oxides are formed near the surface because they are ores produced by a deposit’s oxidation process as it is attacked by the oxygen in the air and in the form of oxidizing fluids (water, air) (Codelco, 2008)

表面附近会形成氧化物。这些是矿床氧化过程中形成的矿石。空气中的氧气以及以氧化液形式存在的氧气（水、空气）会渐渐侵蚀表面，这个过程称为矿床氧化过程。

The industry has been going to increasingly greater depths to extract minerals (open pit mines are ever deeper and/or are becoming underground mines, while underground mines are also going deeper).

采矿行业为了提取矿物，正不断向更深的深度开挖矿井（露天矿的深度更深，或者露已然成为了地下矿，同时地下矿也不断走深）

19 The main processes involved are: agglomeration, ROM leaching, Heap leaching, solvent extraction and electrowinning.

主要流程有：凝聚、ROM萃取、堆浸、溶剂萃取和电解冶金法

Thus, the industry has not incorporated any new leachable deposits to its resource base. While an average of 2 million tonnes of electrowon cathodes were produced from 2009 to 2012, in 2013 and 2014 it fell to around 1.9 million and 1.8 million tonnes, respectively.

采矿行业目前尚未将新的可萃取矿床纳入资源基础。电解冶金阴极铜2009年至2012年的平均年产量是200万吨，2013年和2014年分别降至190万吨和180万吨。

In the same way, mining companies' project portfolios and future development plans are heavily based on maximizing mines that are currently operating (brownfield projects), where the increasing depth of deposits will lead to the depletion of oxide ores. This, together with declining ore qualities, both in terms of ore grades as well as the leachable quality, has led to recent estimates that just 12% of projected copper production in 2026 will be cathodes produced through electrowinning, thus resulting in significant idle capacity at electrowinning plants.

同理，采矿公司的项目组合和未来发展计划力着于最大化开采现正在作业中的矿井（棕地项目），而这些矿井的深度开发将耗尽氧化矿储量。再加上不断降低的矿石质量，这里指的是矿石等级和可萃取物治疗，行业预测2026年，铜产量中只有约12%可用电解冶金法制造为阴极铜，电解冶金厂将出现大量闲置产能。

GRAPH/41 Projected Chilean copper production through 2026

图标41 智利2026年铜产量预测

The Core Challenge Hydrometallurgy section was drafted based on work by the technical commission created for the core challenge, which was comprised of the following members: Agustin Sepulveda, Andrés Pérez, Brian Baird, Carlos Urenda, Christian Schnettler, Claudio Rojas, Cleve Lightfoot, Francisco Abbott, Hugo Toro, Jorge Soto, Murray Canfield, Nury Briceño, Pablo Asiain, Pierre Perrier.

The following team from Fundación Chile was in charge of drafting this section: Francisco Klima, Tomás González, Enrique Molina, Philip Wood, Cristóbal Arteaga, Manuel Arre, Nicole Valdebenito, Hernán Araneda.

核心挑战：湿法提铜基于基于核心挑战技术委员会的建议起草。技术委员会负责明确和解决采矿业的核心挑战，现有以下成员：（Name as below）

智利基金会负责起草工作，成员有：（Name as below）

Copper production (Kton)

铜产量（千吨）

Concentrates Cathodes Sx-Ew 精矿；阴极 Sx-Ew

In the coming years development of the national mining industry will be based on the exploitation of sulfide ore reserves (mostly chalcopyritic), for which mineral concentration processes are currently used. However, in this future scenario, hydrometallurgy must also address treatment of sulfide ores.
未来几年，智利采矿行业的发展将依赖于硫化矿储备的开发（主要是黄铜矿），硫化矿是目前矿物精矿加工过程的产物。然而，一旦这种成为趋势，湿法冶金必须解决硫化矿的处理问题。

Hydrometallurgy is uncompetitive compared to concentration, as the latter allows over 90% to be recovered in a matter of hours while the former obtains between 35% and 60% in periods of over 300 days. Along these lines, there is a clearly crucial need to endow hydrometallurgy with technologies that allow it to increase its efficiency in terms of recovery times.
湿法冶金相比浓缩技术没有什么竞争力，后者在几小时内就有90%回收率而前者在300天内也就35%到60%。出于这种巨大差别，湿法冶金术亟需加入新技术提高效率和回收率。

In addition to this, it must be kept in mind that energy is the most significant cost item in the hydrometallurgical process. Depending on the purchase price, it represents between 25 and 30% of the total (with between 80% and 90% of this expense generated by the electrowinning process)
不仅如此，我们必须意识到，湿法冶金过程中，能耗是最大的开支。根据能耗价格的不同，能耗可以占总成本的25%-30%（能耗的80%-90%使用在电解环节）
In the case of water, while its consumption is relatively low (0.1 to 0.2 m3 per ton of ore), potential future usage restrictions associated with the challenges mentioned earlier in this book and the implications this might have for the leaching of low-grade sulfide ores could halt the implementation of this process.
水资源方面，尽管消耗较低（每吨矿石0.1到0.2立方米）但未来可能有各种使用限制，结合上文所提到的挑战和其对低等级硫化矿的萃取的影响，这种限制可能会制约这个流程的执行。

Lastly, it is worth mentioning that significant improvements in productivity could make the extraction of marginal resources that are currently not considered part of reserves profitable. In other words, technological step changes could turn these liabilities into assets, as has happened before.
最后值得一提的是，生产率的大幅提升可增加边际资源的价值，有些标记资源尚不被认为是储备的一部分。换言之，技术的提高可以化负债为资产，这不是不可能，曾经我们见证过这种良性循环。
Very significant new processes and technologies in the field of hydrometallurgy have been developed over recent decades. In late 1980, the Lo Aguirre Mine in the Metropolitan Region implemented a cathode production plant based on technologies that were new at the time, combining a novel Thin Layer (TL) heap leaching process with solvent extraction and electrowinning operations.
最近几十年，行业出现了全新的湿法冶金加工过程和技术。八十年代，大城市里的Lo Aguirre

矿井在一家阴极生产厂，使用了当时最新技术，结合新颖的Thin Layer (TL)堆浸流程和溶剂提取和电解法。

It was the first plant in the world to apply the TL heap leaching process on a commercial scale, in addition to being the first commercial application in Chile of the copper solvent extraction and electrowinning process.

它是世上第一家商业化使用TL堆浸流程的工厂，同时亦是智利第一家把铜溶剂提取和电解法推广为商业模式的工厂。

This new process made it profitable to extract copper from ores with grades below 0.5%, as is currently the case in mines like El Abra, Radomiro Tomic and Lomas Bayas. TL heap leaching integrated with solvent extraction and electrowinning became one of the most important innovations in copper mining in metallurgy in the 1980s and 1990s, both in Chile as well as in the rest of the world.

从等级为0.5%以下的矿石中提取矿的流程因为这样的新流程而更有经济效益，现下许多矿井的等级都为0.5%以下， 如El Abra, Radomiro Tomic 和 Lomas Bayas。TL 堆浸技术结合了溶剂提取，电解冶金法成为八十年代和九十年代冶金术铜矿业中最重要的创新，这在智利和其他国家都是一大进步。

CHALLENGES, SOLUTIONS AND R&D LINES 挑战、方案和研发线

Based on the information analyzed, the group of experts who participated in the technical workshops defined the following challenges and identified solutions and R&D lines.

根据以上信息，参与技术工作的专家小组明确了以下挑战并确定了方案和研发线

Challenge No. 1: Environmental protection and social responsibility

挑战1：注重环境保护意识和社会责任

A very important issue is related to the need for a "social license" to operate, to obtain communities' acceptance of operations, conditioned, among other things, on full compliance with environmental regulations. Because of this, adequate handling of hydrometallurgical wastes is a fundamental activity for the industry.

必须重视"社会作业许可"，赢得社区对我们的作业的理解和适应，使作业合规于环境保护条例。在此之前，湿法冶金废料的合理处理是行业的基础。

TABLE/26
Solutions and R&D Lines. Challenge: environmental protection and social responsibility

SOLUTION	R&D LINES
Management of solid, liquid and gaseous wastes	Waste management

表格26 方案和研发线。挑战：注重环境保护意识和社会责任

固体、液体和气体废料的管理；废料管理

Challenge No. 2: Increased productivity 挑战2：提高生产率

Improving the efficiency of processes, both in terms of the kinetics of copper extraction as well as the consumption of acid and energy, is and will continue to be a very important matter for dealing with declining ore grades, the soluble content of the ores and the presence of acid

consuming varieties.
提高加工过程效率，包括提取铜的动力学和酸和能量的消耗方面。效率的提高对于处理低等级矿石、矿石可溶物质和耗酸种类问题极为重要。

TABLE/27
Solutions and R&D Lines.
Challenge: increased productivity

SOLUTION	R&D LINES
Reducing energy and water consumption	Energy consumption in EW
Development of new technologies	New leaching, solvent extraction and electrowinning process.

表格27 方案和研发线
挑战：提高生产率
（从上到下，从左到右）降低能耗和水资源消耗；开发新技术；EW的能耗；新的浸出、溶剂萃取和电解流程

Challenge No. 3: Increased mineral resources and reserves
挑战3：增加矿物资源和储备
The existence of altered materials with a low presence of soluble copper, the appearance of clays that affect the percolation of leaching pads and refractory copper ores (primary sulfides of the chalcopyritic type), which are aspects that must be dealt with more and more.
替代材料可溶性铜含量较少、黏土影响浸出垫的渗漏度和铜矿的耐火性（黄铜矿类的主要硫化物）都是我们必须不断应对的难题。
In this context, the base of mineral resources and reserves will continue to heavily determine productivity and the business outlook, which is why it is of the utmost importance that more efficient and versatile treatment methods become available that are capable of responding to ore variability
在这样的情况下，矿物资源和储备的基体会不断深刻影响到生产率和行业前景，所以我们必须重视它们，必须开发更高效更多样的处理方法以应对不断变化的矿石参数。
TABLE/28 表格28
Solutions and R&D Lines. Challenge: increasing mineral resources and reserves
方案和研发线。挑战：增加矿物资源和储备

Use of future idle capacity
Recovery of copper and precious metals
Development of new technologies

未来闲置产能的使用；铜和贵重金属的回收；开发新技术

Leaching of low ore grade ores (ROM, oxides, sulfides) and gravels.

Concentrate leaching.

Leaching of white metal, dusts.

Leaching of altered ores, clay soils, producers of fines.

On-site leaching.

低等级矿石和碎石的浸出（ROM、氧化物、硫化物）；精矿浸出；白色金属、尘土浸出；替代矿石、黏土的浸出，精细金属的生产者；现场浸出

Precious metals recovery

New leaching, solvent extraction and electrowinning process.

贵重金属回收；新的浸出、溶剂萃取和电解冶金流程

CORE CHALLENGE: HYDROMETALLURGY

3 CHALLENGES

6 SOLUTIONS

10 R&D & i LINES

核心挑战：湿法冶金

3种挑战、6种方案、10条研发i线

CAPACITIES

- Research in basic sciences 基础科学研究
- Universities contribute to research, instrumentation and control. 获得诸多大学的研发、仪器和管理支持
- Advanced human capital specialized in: surface physicochemistry, nanoscience, mineral chemistry, electrochemistry, process modeling, management of assets, geochemistry and environment.

先进的特殊行业人力资本：表面物理化学、纳米科学、矿物化学、电化学、流程建模、资产管理、地质化学和环境

- Training of technical workers in expert operation and maintenance skills at Technical Training Centers

在技术培训中心对技术工人进行专家作业和维护技能的培训

- Technology think tank for mining. 矿业的技术智囊团

SUPPLIERS

- Strengthen the development of local suppliers of instrumentation, expert control, mechanization, automation, robotization, information management, optimization software, data

transmission, engineering design and specialized support services.
加强开发当地供应商，如仪器、专家控制、机械化、自动化、机器化、信息管理、软件优化、数据传输、工程设计和其他专业领域的支持。

- System structured to accompany local companies with technological capacities.

构建支持系统以支持当地公司的技术能力提升

ALLIANCES

- Alliance between national and international universities and centers of excellence.

与智利国内和国际大学和优秀研究中心形成联盟

- Alliance between industries and Technical Training Centers to train operators and maintenance workers.

行业、技术培训中心、操作员培训中心形成联盟

- Alliance between research centers / Universities / Industry / State/ Suppliers

研究中心、高等学府、行业、政府、供应商形成联盟

INFOGRAPHIC/19 信息图表 19

Technology Watch:技术简报

Electrowinning (Patents)电解冶金（专利）

TOTAL PATENTS
2010-2015
61
PATENTS

2010-2015 共有61项专利

MAIN
TECHNOLOGICAL
TRENDS
Not identified

主要技术趋势 未明确

05

MOST-CITED PATENTS 引用最多专利

US7901561B2
Method for electrolytic production and refining of metals

US7846233B2
Leaching process for copper concentrates

US8658007B2
Oxygen-producing inert anodes for SOM process

US7846309B2
Metal electrowinning cell with electrolyte purifier

US7740745B2
Non-carbon anodes with active coatings

CN101717969A
Alloy material suitable for inert anode of metal fused-salt electrolysis cell

US8784639B2
Electrochemical process for the recovery of metallic iron and chlorine values from iron-rich metal chloride wastes

US8598473B2
Bus bar electrical feedthrough for electrorefiner system

US2011000782A1
Aluminum recovery process

US8070851B2
Chloride heap leaching

金属的电解生产法和精练；铜精矿的浸出；SOM流程的制造氧气的惰性阳极；带有电解净化器的金属电解冶金槽；带有活性涂层的无碳阳极；适合金属熔盐电解槽的惰性阳极的合金材料；回收金属铁和回收富含铁的金属氯废料中的氯的电化学方法；电精炼系统的汇流条电引入；铝回收流程；氯的堆浸

COUNTRIES WITH MOST PATENTS

Canada	16
USA	11
Bahamas	7
Switzerland	6
South Korea	6
Norway	5
Luxembourg	4
France	4
China	4
UK	3

有用专利最多的国家

加拿大、美国、巴哈马、瑞士、韩国、挪威、卢森堡、法国、中国、英国

MAIN UNIVERSITIES 主要大学

- University of Seoul Research and Development Foundation

首尔研究和发展基金会大学

- University of Alabama

阿拉巴马大学

- Boston University

波士顿大学

- University of British Colombia 哥伦比亚大学

· Free University of Brussels 布鲁塞尔自由大学

MAIN COMPANIES AND/ OR R&D CENTERS

- Alcan INT LTD
- Aluminum Of America
- Aluminum Corp of China LTD
- BHP Billiton SALTD
- Elkem AS
- Green Metals LTD
- Moltech Invent SA
- Pechiney Aluminium

主要公司和/或研发中心

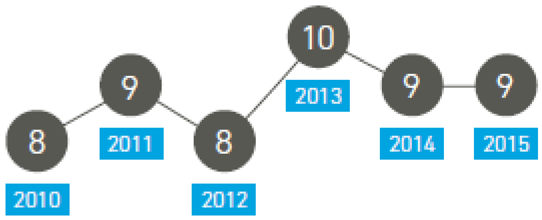
INFOGRAPHIC/20 信息图表20

Technology Watch:技术简报

Electrowinning (Publications)

电解冶金（出版物）

SCIENTIFIC PUBLICATIONS 2010-2015



SCIENTIFIC PUBLICATIONS

53

2010-2015 科学出版物

MAIN RESEARCH TRENDS	N°
Metallurgy / Metallurgic engineering	30
Engineering	11
Chemistry	8
Materials sciences	7
Electrochemistry	3
Instrumentation and instruments	2
Ore processing	2
Optics	2
Physics	2
Mineralogy	1

主要研究趋势

冶金工程学、工程学、化学、材料科学、电化学、仪器和工具、矿石加工、光学、物理学、矿物学

MOST-CITED PUBLICATION

The influence of alloying elements on the electrochemistry of lead anodes for electrowinning of metals: A review

Authors
Clancy, M
Bettles, C.J.
Stuart, A.

引用最多的出版物

合金元素对金属电解冶金术的铅阳极的电化学特性有何影响—回顾

作者：

MAIN RESEARCH INSTITUTIONS
University of Concepción
Commonwealth Scientific and Industrial Research Organization (CSIRO)
Glencore Xstrata
James Cook University
San Carlos Federal University
University of Alexandria
University of Laval
University of Monash
Amirkabir University of Technology
Australian Synchroton

主要研究机构

康塞普西翁大学、联邦科学与工业研究组织（CSIRO）、嘉能可-斯特拉塔、詹姆斯库克大学、圣卡洛斯联邦大学、亚历山大大学、拉瓦尔大学、澳大利亚莫那什大学、阿米尔卡比尔理工大学、澳大利亚Synchroton

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有科学出版物的国家

澳大利亚、智利、伊朗、中国、巴西、加拿大、埃及、南非、美国、阿尔及利亚

INFOGRAPHIC / 21 Technology

Watch: Solvent Extraction (Patents)

信息图表21

技术简报：溶剂萃取

TOTAL PATENTS
2010-2015

141

PATENTS

2010-2015 共有141项专利

MAIN TECHNOLOGICAL TRENDS

- Solid waste management technologies
- Obtaining metals from rare earths
- Obtaining noble metals
- Metal composites from rare earths

主要技术趋势

固体废料管理技术；稀土元素中提取金属；提取贵重金属；稀土元素中提取金属复合物

MOST-CITED PATENTS ON FLOTATION

引用最多的浮选专利

US8177881B2

Method for extracting and separating rare earth elements

提取和分离稀土元素的方法

US7829044B2

Phosphonamides, process for producing the same, and use thereof

磷酰胺和制作方法和应用方法

EP1752550B1

Method of recovering nickel and cobalt

回收镍和钴的方法

US7686865B2

Method and system for recovering metal from metal-containing materials

从含金属物质中提取金属元素的方法和系统

US7935322B2

Method and system for recovering metal from metal-containing materials

从含金属物质中提取金属元素的方法和系统

WO2012149642A1

Processes for recovering rare earth elements from various ores

从不同的矿石中回收稀土元素的方法

US8916116B2

Separation of iron from value metals in leaching of laterite ores

红土镍矿浸出贵重金属，从中分离出铁

US8147782B2

Producing nickel hydroxide suitable for pelletization with iron-containing ore and for stainless steel manufacture

生产氢氧化镍，用于含铁矿石的粒化和不锈钢制造

US7750066B2

Treatment of aqueous compositions containing contaminants

含有污染物的水化合物的处理

JP4524394B2

Extraction Method Of Am, Cm And Ln Existing In Acidic Solution

酸性物质中提取Am、Cm和Ln

COUNTRIES WITH MOST PATENTS IN FLOTATION

- Japan
- USA
- Australia
- Germany
- Canada
- Finland
- UK
- China
- France
- Spain

拥有浮选专利最多的国家

日本 美国 澳大利亚 德国 加拿大 芬兰 英国 中国 法国 西班牙

MAIN UNIVERSITIES

- University of Nevada
- University of British Colombia
- Central South University, China
- Chung Yuan Christian University
- University of KwaZulu-Natal
- Catholic University of Lovain
- Complutense University of Madrid
- University of Nantes
- Northwestern University
- University of Osaka

主要大学

内华达大学、哥伦比亚大学、中国中南大学、台湾中原大学、南非夸祖鲁纳塔尔大学、Lovain 天主教大学、马德里康普顿斯大学、法国南特大学、美国西北大学、日本大阪大学

MAIN COMPANIES AND/ OR R&D CENTERS

- Cognis Ip Man GMBH
- Commw Scient IND RES ORG
- Cytec Tech Corp
- Freeport McMoran Corp
- JX Nippon Mining & Metals Corp
- Nippon Mining CO
- Outotec OYJ
- Porcess Res Ortech INC

主要公司和/或研发中心

INFOGRAPHIC/22
Technology Watch: Solvent Extraction (Publications)

SCIENTIFIC PUBLICATIONS 2010-2015

SCIENTIFIC PUBLICATIONS

信息图表22

技术简报：溶剂萃取（出版物）

2010-2015 *科学出版物*

MAIN RESEARCH TRENDS

- Engineering
- Chemistry
- Metallurgy / Metallurgic engineering
- Ore processing
- Ecology and environmental sciences
- Mineralogy
- Food science and technology
- Water resources
- Biochemistry and Molecular Biology
- Electroscopy

主要研究趋势

工程学、化学、冶金工程学、矿石加工、生态学和环境科学、矿物学、食品科学与技术、水资源、生物化学和分子生物、气体电离检定法

MOST-CITED PUBLICATION

Removal of transition metals from rare earths by solvent extraction with an undiluted phosphonium ionic liquid: separations relevant to rare-earth magnet recycling

Authors
Vander Hoogerstraete, T
Wellens, S.
Verachtert, K

引用最多的出版物

溶剂萃取法清除稀土元素过渡金属，用的是未稀释的磷离子液体：关于稀土元素磁铁分离回收法

作者：

MAIN RESEARCH INSTITUTIONS

- University of British Colombia
- Commonwealth Scientific and Industrial Research Organization (CSIRO)
- Central South University, China
- Council for Scientific and Industrial Research
- Poznan University of Technology
- Korea Institute of Geoscience and Mineral Resources
- National Metallurgical Laboratory of India
- University of Tehran
- University of Damascus
- Wroclaw University of Technology

主要研究机构

哥伦比亚大学；联邦科学与工业研究组织（CSIRO）；中国中南大学；澳大利亚科学与工业研究理事会；波兰波兹南工业大学；韩国地质科学和矿物资源研究所；印度国家冶金实验室；德黑兰大学；大马士革大学；弗罗茨瓦夫理工大学

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有科学出版物的国家

伊朗、澳大利亚、印度、中国、波兰、加拿大、土耳其、日本、韩国、瑞典

INFOGRAPHIC/23
Technology Watch:
Leaching (Patents)

TOTAL PATENTS 2010-2015

291

PATENTS

信息图表23

技术简报：浸出（专利） 2010-2015 共有291项专利

MAIN TECHNOLOGICAL TRENDS

- Ion exchange in which a complex or a chelate is formed; Use of a substance as an ion exchanger that forms complexes or chelates.
- Treatment of a substance to improve its exchange or iron properties forming complexes or chelates

主要技术趋势

复合物或螯合物形成的离子交换过程；生成复合物或螯合物的离子交换剂。

加工离子交换剂提升交换效率，或提升铁的属性，生成复合物和螯合物

MOST-CITED PATENTS引用最多的专利

US8852777B2

Methods for the preparation and purification of electrolytes for redox flow batteries

电解质的准备和净化方法，制作氧化还原液流电池

US7892505B2

Hydrometallurgical process for the treatment of metal-bearing sulfide mineral concentrates

湿法处理含金属的硫化矿精矿的流程

US7858056B2

Recovering metals from sulfidic materials

从硫化物里回收金属

US7846233B2

Leaching process for copper concentrates

铜精矿的浸出流程

US2010155330A1

Target material removal using rare earth metals

使用稀土元素清除目标物质

US7771700B2

Target material removal using rare earth metals

使用稀土元素清除目标物质

US7686866B2

Recovery of copper from chalcopyrite

从黄铜矿中回收铜

WO2011128061A1

Functionalised materials and uses thereof

功能化物质及其利用

US8329124B2

Metal Extractant Reagents Having Increased Resistance To Degradation

金属萃取剂试剂，含有较高抗降解性

US7993613B2

More efficient ether modifiers for copper extractant formulations

更高效的铜萃取剂配方的醚改性剂

COUNTRIES WITH MOST PATENTS IN LEACHING

拥有浸出专利最多的国家

美国 加拿大 日本 澳大利亚 芬兰 德国 智利 中国 南非 巴西

MAIN UNIVERSITIES

- University of British Colombia
- University of Alberta
- Universidad Autónoma Metropolitana de México
- University of Cape Town
- Central South University, China
- Donghua University
- James Cook University
- University of Kingston

主要大学

哥伦比亚大学 加拿大阿尔伯塔大学 Universidad Autónoma Metropolitana de México 开普敦大学 中国中南大学 东华大学 詹姆斯库克大学 金斯顿大学

MAIN COMPANIES AND/ OR R&D CENTERS

- Freeport McMoran Corp
- JX Nippon Mining & Metals Corp
- Outotec OYJ
- Nippon Mining Corp
- Cognis IP Man GMBH
- Basf AG
- Cytec Tech Corp
- Outotec Finland OY

主要公司和/或研究中心

INFOGRAPHIC/24
Technology Watch: Leaching (Publications)

SCIENTIFIC PUBLICATIONS 2010-2015

SCIENTIFIC PUBLICATIONS

信息图表24

技术简报：浸出（出版物）

科学出版物

- Metallurgy / Metallurgic engineering
- Engineering
- Ecology and environmental sciences
- Ore processing
- Chemistry
- Mineralogy
- Materials sciences
- Biotechnology and Applied Microbiology
- Water resource
- Toxicology

冶金工程学；工程学；生态学和环境科学；矿石加工；化学；矿物学；材料科学；生物技术和应用微生物学；水资源；毒理学

MOST-CITED PUBLICATION

Low grade ores - Smelt, leach or concentrate?

Authors
Norgate, T
Jahanshani, S

引用最多的出版物：低等级矿石—冶炼、浸出还是选矿？

作者：

MAIN RESEARCH INSTITUTIONS
Central South University, China
South African Council for Scientific and Industrial Research
Commonwealth Scientific and Industrial Research Organization (CSIRO)
Kunming University of Science and Technology
University of British Colombia
Chinese Academy of Science
University of Concepción
University of Quebec
University of Ultah
Utah System of Higher Education

主要研究机构

中国中南大学；南非科学工业研究理事会；澳大利亚联邦科学与工业研究组织（CSIRO）；昆明科技大学；哥伦比亚大学；中国科学院；康塞普西翁大学；魁北克大学；犹他大学；犹他高等教育系统

COUNTRIES WITH SCIENTIFIC PUBLICATIONS

拥有科学出版物的国家

中国 澳大利亚 美国 土耳其 印度 加拿大 韩国 伊朗 南非 智利