

MININ 2010

Proceedings of the 4th International
Conference on Mining Innovation

23–25 June 2010, Santiago, Chile ■ EDITORS

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The MININ 2010 Conference was organised by the Mining Engineering Department of the Universidad de Chile, the Mining Center of the Pontificia Universidad Católica de Chile and Gecamin.

Mining Engineering Department, Universidad de Chile

The Mining Engineering Department was founded on 7 December 1853. Since the graduation of the first four engineers in 1856, the Department has trained over 1300 professionals for one of the most important Chilean industries. Leadership of the Universidad de Chile graduates in such projects as block caving, heap leaching and El Teniente converter, have brought the university a worldwide recognition. The Department currently has 11 fulltime faculty and conducts research in such areas as mining technology, mineral resources evaluation, hydro-electrometallurgy and environment, pyrometallurgy, mineral processing and mineral economics. The Department offers Master programmes in Mining Engineering and in Extractive Metallurgy and will start in 2010 a Ph.D. program in Mining Engineering.

Mining Center, Pontificia Universidad Católica de Chile

The Mining Engineering Programme was created in 1994 in response to the growing demand for highly skilled engineers capable of combining conceptual design and mine and/or processing plant management. Originally acting as a coordinating body and sharing academic and research resources with the other Departments and Engineering Schools, now the Center offers full fledged degree programmes in Mining Engineering, both Civil and Industrial. In addition, the Center offers a range of postgraduate programmes including the Ph.D. programme in Mining Engineering and in Mineral Engineering. The main focus of the Center's research is mineral economics, with additional strong interests in mine management and control, mining methods and equipment. The Center has six full-time faculty supported by several part-time professors and a number of technical and other staff.

Gecamin

Gecamin is a private, Chilean company created in 1998 that annually organises international technical events with the aim of informing and inspiring mining industry professionals, fostering the exchange of information, and sharing best practices and new technologies applied in mining. The goal of each conference is to bring together engineers, scientists, researchers, managers and

operators to enable a focused discussion on the latest developments and innovations with the ultimate purpose of establishing interdisciplinary networks of research and knowledge exchange. Through these conferences and training programmes Gecamin seeks to help the industry to openly address its most pressing concerns and find more sustainable solutions.

Gecamin organises seminars in partnership with institutions of strong technical excellence in mining such as the Universidad de Chile, the Pontificia Universidad Católica de Chile, the Universidad de Concepción, Chile, the Universidad Técnica Federico Santa María, Chile, The University of Western Australia and The University of Queensland, Australia, among others.

In 12 years of operation, more than 12,000 professionals have attended our events and have been trained in areas of paramount importance to the mining industry. These areas include the following: Geology, Mining Unit Operations, Mine Planning, Mineral Processing, Hydrometallurgy, Paste and Thickened Tailings, Mine and Plant Maintenance, Automation and Control, Water and Energy Management in Mining, Mine Closure, Environmental and Social Impacts Assessment.

Each event organised by Gecamin features a great diversity of technical papers presenting case studies, applications as well as theoretical research and scientific findings. Every conference is documented by the proceedings containing carefully selected peer-reviewed papers. Prominent industry experts and academics bring their knowledge and experience to our events ensuring high standards of the proceedings and the technical programmes.

The next few years are expected to bring a much more positive economic outlook, allowing mining companies worldwide to activate or reconsider alternatives for greenfield and brownfield projects. Sustainability, water in mining and efficient energy use will remain the key focus areas throughout the major part of the industry. For this reason, Gecamin believes it is of great importance to share experiences and discuss alternatives and opportunities for improving operational processes and best practices with colleagues from around the world.

Learn more about our events by visiting www.gecamin.cl

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FOREWORD

Diego **HERNÁNDEZ**
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MININ 2010
4th International
Conference on Mining
Innovation

The 4th International Conference on Mining Innovation, MININ 2010, finds us in the midst of a deep and interesting analysis of the industry, as we are at a historically unprecedented moment. During the coming decades —and only for the case of copper— consumption is estimated to exceed the accumulated consumption in the whole history of humanity so far.

The considerable challenge of expanding production capacity to satisfy the estimated demand for minerals is critically demanding a more active technological development that will allow the industry to respond to market needs in a sustainable manner and in a context of greater social and environmental considerations.

In effect, it is envisioned that the complexity of challenges in the mining sector will increase in such a way that technological capacities in management and innovation will have to be significantly higher. Only through this, will we be able to approach projects in a competitive manner.

For example, in Chile, a country accountable for a third of copper production, a considerable figure of 35% of its mines have been in operation for over half a century and 70% of its productive capacity is already mature. Among other aspects, this means decreasing ore grades, longer hauling distances, lower availability of secondary enrichment and leaching material, and a greater focus on primary minerals of lower grade. In summary, increasing costs and declining competitiveness.

In this context, the mining industry requires —among other things— to improve the predictability of mining plan models; to face the growing complexities and uncertainties of ore bodies; to improve maintenance of fleet and equipment; to optimise training in maintenance and of operators; to improve knowledge of rock fragmentation to move towards more intelligent blasting; to develop new paradigms in mineral transportation that lead us to think of better conveyor and truck fleet configurations; and —why not— to look out to other industries for the transfer of practices and knowledge.

Thus, we live in a time that is characterised by important innovation and growth opportunities. And to make the maximum use of this potential we must also keep in mind how innovation processes are currently organised in mining. Since several decades, these processes are developed in complex networks articulated by large mining companies that have organised innovation and knowledge systems at local and international level, which potentiate and complement each other. Similarly, part of the innovation processes that in the past were developed within mining companies, are carried out today by technology and knowledge-intensive service suppliers, which interact with

the mining companies and play a key role in the competitiveness of the industry.

We know of many examples in the history of mining of successful technological development processes that have been articulated around the needs of the industry. Today, once again and with a real sense of urgency, we must get to trigger a new innovation wave that will allow us to increase mineral production and in this way contribute to the wellbeing of millions of people, whose countries are well into the process of development.

PREFACE

Romke KUYVENHOVEN

Executive Editor

MININ 2010

4th International
Conference on Mining
Innovation

MININ 2010, held on 23–25 June in Santiago, is the fourth of a series of international conferences on mining innovation initiated in 2004 by Gecamin, the Mining Engineering Department of the Universidad de Chile and the Mining Center of the Pontificia Universidad Católica de Chile.

The objectives of MININ conferences are twofold:

1. To exchange the knowledge and experience on mining innovation as applied to or derived from Sampling, Ore Deposit Evaluation, Geomechanics and Geotechnics, Mine Planning, Mine Unit Operations, Maintenance Planning, Information and Automation Technologies and Integrated Mine Management.
2. To promote the international collaboration and technical exchange among professionals dedicated to develop, operate and maintain production systems for the mining industry.

A total of 53 technical papers written by authors from 12 countries and published in this conference proceedings, discuss the emerging concepts, models, developments, technologies and successful innovation practices in the mining industry.

ACKNOWLEDGEMENTS

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MININ 2010
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Innovation

The organisation of the MININ 2010 Conference and these Conference Proceedings are the combined effort of many individuals who have put in long hours of hard work, dedication and talent. We would like to extend profound thanks to all those involved in the Conference organisation for their contributions of time, advice and expertise to this project. We are particularly grateful to:

- The authors for their invaluable contributions, monumental efforts of meeting deadlines, and willingness to share their knowledge and experience.
- The technical reviewers for willingness to invest their personal time in articles corrections, the critical process to ensure the quality of this publication.
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- The Gecamin team for their hard work, professionalism and continuous commitment to making this conference a success.
- Technical and Advisory Committees for their helpful advice and assistance in promoting the conference.

And last but not least, we would like to thank you, readers and participants, whose interest and enthusiasm made this event so versatile and the whole experience so rewarding and enriching.