HYDROMETALLURGY 2003

Proceedings of the 5th International Symposium Honoring Professor Ian M. Ritchie

Sponsored by

The Extraction and Processing Division (EPD) of TMS
The Mineral and Metallurgical Processing Division (MPD) of SME
Metallurgical Society (MetSoc) of CIM

2003 TMS/EPD Fall Meeting held in conjunction with
33rd Annual Hydrometallurgy Meeting and
2003 Conference of Metallurgists
Vancouver BC Canada
August 24-27, 2003

TMS

MET SOC
CIM | ICM

SME
SOCIETY FOR MINING METALLURGY AND EXPLORATION

Professor Ian M. Ritchie

HYDROMETALLURGY 2003

Proceedings of the 5th International Symposium Honoring Professor Ian M. Ritchie

Volume 1
Leaching and Solution Purification

Volume 2
Electrometallurgy and Environmental Hydrometallurgy

Edited and Organized by

TMS Representatives

Courtney Young, Chair
Metallurgical and Materials Engineering
Montana Tech
Butte MT USA

Akram Alfantazi
Metals and Materials Engineering
University of British Columbia
Vancouver BC Canada

SME Representatives

Corby Anderson
Center for Advanced Mineral and
Metallurgical Processing (CAMP)
Montana Tech
Butte MT USA

Amy James
The Shaw Group, Inc.
Denver CO USA

CIM Representatives

David Dreisinger
Metals and Materials Engineering
University of British Columbia
Vancouver BC Canada

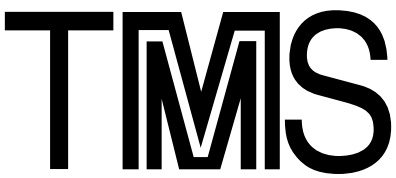
Bryn Harris
Process Research Ortech
Mississauga, Ontario, Canada

A Publication of
TMS

A Publication of **TMS (The Minerals, Metals & Materials Society)**
184 Thorn Hill Road
Warrendale, Pennsylvania 15086-7528
(724) 776-9000

Visit the TMS web site at
http://www.tms.org

Printed in the United States of America
Library of Congress Catalog Number 2003108188
ISBN Number 0-87339-554-9



If you are interested in purchasing a copy of this book, or if you would like to receive the latest TMS publications catalog, please telephone (800) 759-4867 (U.S. only) or (724) 776-9000, EXT. 270.

Foreword

International Hydrometallurgy Symposia have been landmark conferences with worldwide participation by academic, industrial, administrative, and government personnel involved in a variety of hydrometallurgical applications: metal production, recycling, waste treatment and minimization, research and development, water and soils remediation, etc. Always well attended, these symposia have been held every 10 years since 1963 under sponsorship of the American Institute of Mining, Metallurgy and Petroleum Engineers (AIME) with the lead society alternating between The Minerals, Metals and Materials Society (TMS) and the Society of Mining, Metallurgy and Exploration (SME). Proceedings from these symposia are also well referenced and have served the hydrometallurgical community for decades. The four previous symposia and proceedings were organized and edited by M.E. Wadsworth and F.T. Davis (Dallas, TX, 1963), D.J.I. Evans and R.S. Shoemaker (Chicago, IL, 1973), K. Osseo-Asare and J.D. Miller (Atlanta, GA, 1983), and J.B. Hiskey and G.W. Warren (Salt Lake City, UT, 1993).

In order to better satisfy the hydrometallurgical community, the AIME-affiliated societies of TMS and SME approached the Metallurgical Society (MetSoc) of the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) to begin cooperating at a global level by having one large symposium as opposed to several small, competing annual conferences. In this regard, the three societies decided to combine the 5th International Symposium on Hydrometallurgy with the 2003 Hydrometallurgy Meeting of MetSoc in conjunction with the 2003 CIM Conference of Metallurgists in Vancouver, British Columbia between August 24 and 27. The societies also agreed to hold future symposia every five years with organization responsibility rotating to SME in 2008, CIM in 2013, and ultimately back to TMS in 2018. Other global societies would be welcome to get involved as well and, with this in mind, the organizing committee decided to honor Professor Ian M. Ritchie for all his efforts in promoting and advancing hydrometallurgical technologies through his own research and development activities as well as with the A.J. Parker Cooperative Research Centre for Hydrometallurgy in Australia that he developed and began directing in 1992. "Hydro 2003: The Ritchie Symposium" and the ensuing proceedings represent the first effort of this unprecedented and hopefully increasing cooperation among these societies and possibly a host of other international organizations.

The organizing committee anticipated that 4 plenary and 90 invited papers would be submitted to the proceedings. These were expected to cover a variety of topics including, but not limited to, fundamentals, biotechnology, leaching, environmental applications, crystallization and precipitation, adsorption, ion exchange, solvent extraction, cyanide and alternatives for precious metal extraction and recovery, chloride and other lixiviant use in base metal extraction and recovery, process development and modeling, thermodynamic and kinetic evaluations, plant practices and innovations, scale-up, waste treatment and minimization, waste water and resource recovery, cementation and corrosion, process mineralogy and characterization, future role of hydrometallurgy, economic evaluations, and pyrometallurgical comparisons. Plenary presentations were planned for Monday morning followed by 3 concurrent sessions, each with 6 papers beginning Monday afternoon and ending Wednesday afternoon. However, the committee received over 250 abstracts and attributed this as strong support by hydrometallurgical community for the cooperation of the societies as well as for the symposium being named in honor of Professor Ian M. Ritchie. Based on this extremely favorable response, the committee decided to accept 180 abstracts and, of these, 154 papers were eventually submitted for publishing in these proceedings. This forced the committee to expand the number of concurrent sessions to five with some morning sessions having seven papers.

Most of the anticipated topics were covered and the end result was another International Hydrometallurgy Symposium and Proceedings of high value; however, the strengths are in leaching and solution purification as well as electrometallurgy and environmental hydrometallurgy which explains why the proceedings are divided into two volumes with these specific names. Volume 1 includes Ian Ritchie's plenary "Is Extractive Metallurgy Becoming Extinct?" as well as 17 papers on precious metal leaching with cyanide and alternatives particularly thiosulfate, 32 papers on leaching applications and fundamentals using heap, chloride and autoclave techniques, and 24 papers on solvent extraction. On the other hand, Volume 2 includes the three plenary presentations by Bruce Conard on "Challenges," Doug Halbe on "Business Aspects," and Cees Buisman on "Biotechnologies" as well as 25 papers covering acid-rock drainage, arsenic, recycling and other environmental issues, 14 papers dealing with precipitation and crystallization, 9 papers on plant operations, and 18 papers about electrowinning regarding such topics as history, additives and impurities, anode and cell design, acid mist, and fundamentals. Excellent papers also cover adsorption (2), ion exchange (4), and electrochemistry (5), the latter being critical reviews for understanding leaching, precipitation, cementation, and electrowinning.

The organizing and editing committee gratefully acknowledges all the authors and presenters without whom none of this would be possible. Their patience and understanding of the review process for 154 papers was and is appreciated. Many of the authors also helped spread the word about the symposium which the hydrometallurgy community consequently received with great enthusiasm. This, of course, includes the four plenary speakers! Sincere appreciation is also extended to the various entities (universities, institutions, companies, agencies, etc.) that sponsor the research and publication efforts of the authors as well as their expenses to attend and present at the symposium. The committee is also indebted to the session chairs and co-chairs who volunteered their services and expenses to help run this event. Critical to the success of Hydro 2003 has been the support of the three societies involved and their willingness and ability to cooperate, particularly at the division level including TMS/EPD, SME/MPD and MetSoc/Hydrometallurgy Section. Specific people include TMS's Dan Steighner, Director of Member, Marketing, and Meeting Services; Michael Packard, Manager of Meeting Services; Christina Raabe, Manager, Continuing Education and Information Transfer; Marla Boots, Technical Programming Assistant; and Stephen Kendall, Book Publishing Coordinator; MetSoc's Gillian Jazzar, Administration and Meeting Planning; Ronona Saunders, Publications, Web and Marketing; Eric Brosseau, Registration and Dispatcher; and SME's Tara Davis, Publicity and Programming Manager; and Joette Cross, Meetings Manager. Finally, sincere appreciation is extended to the committee's universities and companies for the time, computer, and secretarial resources to help make the editorial changes to most of the 154 papers; this would not have happened without the marvels of e-mail, the worldwide web, and two wonderful administrative assistants who always come through in the clutch: Gail Bergman (Montana Tech) and DaNette Rule (Montana Tech/CAMP).

Courtney Young, Chair
Montana Tech
Butte MT USA

Akram Alfantazi
University of British Columbia
Vancouver BC Canada

Corby Anderson
CAMP/Montana Tech
Butte MT USA

Amy James
The Shaw Group, Inc.
Denver CO USA

David Dreisinger
University of British Columbia
Vancouver BC Canada

Bryn Harris
Process Research Ortech
Mississauga, Ontario, Canada

Ian M. Ritchie – A Biography

Professor Ian Mackay Ritchie was born on March 18, 1936 in Tidworth, Hampshire, England the son of Lieut. Col. W.J. and Mrs L.E.P. Ritchie. In 1959 he married Ann McMahon, the girl who had nursed him when he was in hospital four years earlier. Ian and Ann have three children, Kathy, Andrew and Alec of whom they are extremely and lovingly proud.

Ian received his high school education at Watford Boys Grammar School and then went on to Cambridge University where he obtained a B.A. in Natural Sciences and an M.Eng. in Chemical Engineering. His final year project, from which he published a paper, was on solvent extraction. He also received a "blue" for playing badminton for Cambridge. Upon graduation, he accepted a position with Transitron Electronic Corporation, in Wakefield, Massachusetts, USA as a Research and Development Engineer. His research there was largely in solid state chemistry and resulted in a paper and a patent.

He left Wakefield in February 1962 to take a Ph.D. in Physical Chemistry at the University of Melbourne in Australia. This was also in solid state Chemistry, the topic being the reactions between metals and gases such as oxygen. Despite a substantial teaching load as a tutor, he was able to complete his degree in 1965 and was made a Lecturer in that year. In 1968, he was promoted to Senior Lecturer. During these years at Melbourne University, his focus was on metal oxidation reactions. For his work in this field, he was awarded the Grimwade Prize for Industrial Science from Melbourne University.

Several important changes took place in 1972. He took up a position as Associate Professor at the University of Western Australia in Perth and he started investigating the effect of oxide films on cementation reactions and other corrosion reactions. So began his interest in hydrometallurgy which has increased steadily with the years. He was awarded the Australasian Corrosion Medal in 1979 for his work in this area. In 1984, he made another move, this time as Professor of Chemistry at Murdoch University in Perth, Western Australia, where he remains today, even though he has supposedly retired. During his time there, he was named Pro Vice-Chancellor of Research for three years (1986-1988) and served as Acting Dean of the School of Mathematical and Physical Sciences for eight months (June 1991-January 1992) after which he began finalizing the plans for the A.J. Parker Cooperative Research Centre for Hydrometallurgy. In June of 1992, the Centre was formally established and Dr. Ian Ritchie was appointed as director.

For the past decade, Dr. Ritchie has dedicated his life to the Centre and it is obvious he has succeeded (as addressed later). However, the opportunity did not come by chance; it came from the previous two decades that he also dedicated to furthering hydrometallurgical technology. Since 1970, Ian authored a book, edited another, and published an additional 124 papers with 88 appearing in refereed journals and the other 36 in conference proceedings. He has also been professionally active as a referee reviewing manuscripts for 9 journals including one as a member of the Editorial Board, as a researcher in numerous hydrometallurgical areas particularly gold processing and metal cementation, and a recognized invited-lecturer presenting keynote and plenary addresses at a variety of conferences including twelve in the last six years. He has, on several occasions, given youth lectures in hydrometallurgy for schools. However, perhaps his most daunting task has not been working the ropes to keep the Parker Centre for Hydrometallurgy funded but rather to find students to conduct research and help keep it running. Consequently, Dr. Ritchie has first-hand experience regarding the difficulties associated with recruiting students into hydrometallurgy. This is one reason why he was asked to give a plenary on the status of "Extractive Metallurgy Education" for the Hydro 2003 Symposium. His interesting perspectives on the subject are included in

"Is Extractive Metallurgy Becoming Extinct?" in these proceedings. Dr. Ritchie has also received numerous accolades for his efforts including the 1997 Stokes Medal for Electrochemistry and the 1997 Applied Research (R G Becher) Medal from the Royal Australian Chemical Institute, the 1997 Western Australian Citizen of the Year (Professions), and the 2000 President's Award from the Australasian Institute of Mining and Metallurgy. He has received a Doctor of Science from Cambridge University (1999) and an Honorary Doctorate from Murdoch University (2001). He has been elected a Fellow of the Australian Academy of Technological Sciences and Engineering (1993) and a Fellow of the Australian Academy of Science (2001). In 2003, he was awarded a Centenary Medal by the Australian Commonwealth Government.

On three occasions during his teaching career, Dr. Ritchie went on sabbatical leave. In 1970, he studied with Dr. W. Hayes at the Clarendon Laboratory, Oxford University. In 1982, he returned to Oxford to study with Dr. H.A.O. Hill in Department of Inorganic Chemistry. In 1989, his travels took him to Mintek in South Africa as a consultant and then to Department of Metallurgical Engineering at University of Utah, Salt Lake City, as a Visiting Professor. During these leaves, he would teach courses, particularly on "Electrochemistry in Hydrometallurgy." In this course, Ian covers all aspects of electrochemistry (i.e., Evans' diagrams, redox potential, mixed potential, corrosion, metal dissolution, metal recovery, cementation, surface control, etc.) and includes laboratory exercises (i.e., cyclic voltammetry, intermittent galvanostatic polarization, ring-disk studies, reversibility, etc.) as well as the use of free energy for thermodynamically modeling hydrometallurgical processes. Students have proclaimed that the course rates among the highest they have ever taken and additionally point out that his lectures were eloquently delivered, well organized, and showed concern for the students and their understanding due to his one-on-one approach with them. He truly takes a genuine interest in the student and their success. This insures that science is not only learned but learned to be applied. Due to his research and educational activities, particularly in electrochemistry, oxidation and kinetics, hydrometallurgy and associated technologies have been tremendously advanced via their applications and their understanding. The hydrometallurgical community has him and the one of the world's leading research organizations, the AJ Parker Cooperative Research Centre for Hydrometallurgy, to thank.

A.J. Parker CRC for Hydrometallurgy – At a Glance

In 1992, Dr. Ritchie finished developing and began directing the A.J. Parker Research Centre for Hydrometallurgy via an Australian Government grant for approximately A$10.5 million (Australian). Since then, he has been responsible for its growth and, in the 5th Year Review of the Parker Centre carried out at the end of 1997, the Review Panel said of the Centre's research:

> "The A.J. Parker CRC has achieved a high level of research excellence and has established itself as a world leader in the field of hydrometallurgy and is producing excellent results."
>
> "It is the firm opinion of the Panel that each program area has produced at least one hallmark outcome that makes a significant contribution to the field of hydrometallurgy. To have credit for just one alone would be a tremendous accomplishment."
>
> "The qualities and capabilities displayed by the Director and other members of research management are truly exemplary. The Director devotes 100% of his time to CRC activities. He is clearly the guiding force behind the success of this Centre. He demands a high measure of excellence from himself and has left this imprint on others. The esteem in which he is held is reflected by the prestigious awards that he has recently received."

Currently, the Parker Centre, as it is more commonly referred, is in its second 7-year funding

cycle via an A$18.5 million Commonwealth Grant, has over 85 full time staff and research scientists, and employs about 45 students, mainly doctoral candidates. The staff, scientists and students are from five joint venture research partners comprised of universities (Curtin, Murdoch and Queensland) and government research agencies (CSIRO Minerals and WA Dept of Industry and Resources). With an annual research budget near A$17 million, the Centre is now the largest hydrometallurgical research organization in the world with 12 industrial partners representing most of the leading mining companies in the world. Under Ian's leadership, the Centre has been recognized with three awards: the 1996 Western Australian Industry and Export Award for Research, a 1999 Inaugural Award for Technology Transfer from the Cooperative Research Centres' Association, and the 1999 Business and Higher Education Round Table Awards for Outstanding Achievement in Collaborative Research and Development involving a Cooperative Research Centre.

The Parker Centre has become a focus of world-class efforts to provide technical solutions to the minerals industry. Hydrometallurgy activities encompass both fundamental and applied research in alumina, gold, and base-metal sectors. The Centre is now growing its client base into overseas markets, particularly North America, South Africa and Europe. Quality, strategic R&D by the Centre is seen by the industry as an attractive investment. A recent survey of the industry revealed an estimated ten-fold return based on direct costs of research to the client. In addition, the Centre has a strong commitment to education of postgraduate students wishing to enter the mining industry as well as providing specialist courses for those technical professionals already employed in the industry. The wide range of employment opportunities in the mining industry is reflected in the diversity of the disciplines amongst the Centre's research team: extractive metallurgy, chemistry, biotechnology, physics, engineering, molecular modeling, microscopy, geology and computational fluid dynamics.

Typical examples of Parker Centre research activities include using (1) atomic force microscopy and molecular modeling to control gypsum scaling and improve the understanding of alumina crytallization in a Bayer plant, (2) biology to hasten the leaching kinetics of copper from chalcopyrite, improve the degradation of thiocyanate and cyanide in gold process waters, and modify the (3) computational fluid dynamics and lasers to make thickeners work more efficiently, (4) strain gages and metallography to determine the electrowinning conditions to minimize stressing in cobalt and nickel production, (5) solvent extraction to remove manganese from cobalt/nickel process solutions, separate rare-earth metals such as neodymium from one another, and examine phase separation and organic degradation as well as cross-contamination of solvent extractants, (6) synergists to improve selectivity of given solvent extractants as alternatives to the expensive option of developing new extractants, (7) modern gravity recovery techniques to pre-concentrate gold prior to hydrometallurgical processing, (8) geotechnical parameters to understand and model heap leaching kinetics, predict the leaching behavior of preg-robbing ores as well as the effect of minerals on thiosulfate leaching of gold, and oxidize sulfide minerals to thiosulfate for gold dissolution, (9) traditional research methods to minimize copper-catalyzed oxidation of thiosulfate and to improve upon ferric ion precipitation from nickel-laterite leach solutions as well as the leaching kinetics of base metals by chloride and of gold by ammonium thiosulfate both with and without copper, (10) autoclaves to determine the effect of chloride on pyrite oxidation, and (11) sulfur dioxide to produce ferrous cation which reductively dissolves manganese dioxide. In fact, contributions from these activities to Hydro 2003 Symposium and Proceedings are major and greatly contribute to its success. These contributions come from multi-disciplinary teams which help keep the hydrometallurgical community on top of cutting-edge technology.

Session Chairs and Co-Chairs

Opening Remarks

Dave Dreisinger
Metals and Materials Engineering
U of British Columbia
Vancouver BC Canada

Akram Alfantazi
Metals and Materials Engineering
U of British Columbia
Vancouver BC Canada

Honorary Plenary

Courtney Young
Metallurgical and Materials Engineering
Montana Tech
Butte MT USA

Cyanide

Bill Staunton
A. J. Parker Centre for Hydrometallurgy
Murdoch University
Murdoch WA Australia

John Hollow
Fairbanks Gold Mining, Inc.
PO Box 73726
Fairbanks AK USA

Alternatives and Thiosulfate I

Phil Thompson
Dawson Metallurgical Laboratories, Inc.
2030 N. Redwood Road, Suite 70
Salt Lake City UT USA

Mike Nicol
A. J. Parker Centre for Hydrometallurgy
Murdoch University
Murdoch WA Australia

Thiosulfate II

Mark Aylmore
A.J. Parker Centre for Hydrometallurgy
CSIRO Minerals
Perth WA Australia

Chris Flemming
Lakefield Research Limited
185 Concession
Lakefield Ontario Canada

Heap Leaching I

Larry Todd
Leaching & Environmental
Phelps Dodge Process Technology Center
Safford AZ USA

Pragna Bhakta
Newmont Mining Corporation
PO Box 669
Carlin NV USA

Heap Leaching II and General

Greg Wardell-Johnson
A. J. Parker Centre for Hydrometallurgy
Murdoch University
Murdoch WA Australia

Mark Vancas
Bateman Engineering
350 S. Williams Blvd., Suite 230
Tucson AZ USA

Fundamentals I

Courtney Young
Metallurgical and Materials Engineering
Montana Tech
Butte MT USA

Pat Taylor
Metallurgical & Mining Engineering
Colorado School of Mines
Golden CO USA

Fundamentals II

James Budac
Sherritt International
10101 114th Street
Fort Saskatchewan AB Canada

Corby Anderson
CAMP
Montana Tech
Butte MT USA

Chloride

Gus van Weert
Metals and Materials Engineering
U of British Columbia
Vancouver BC Canada

Dirk Verhulst
Altair Nanomaterials Inc.
204 Edison Way
Reno NV USA

Pressure and Autoclave

Ken Lamb
AMEC E&C Services
111 Dunsmuir Street, Suite 400
Vancouver BC Canada

V. Ramachandran
RAM Consultants
9650 E. Peregrine Place
Scottsdale AZ USA

Ion Exchange

Gerald Sterzik
Teck Cominco Metals
Box 1000
Trail BC Canada

Khosrow Nikkah
AMEC Mining and Metals Consulting
111 Dunsmuir Street, Suite 400
Vancouver BC Canada

Adsorption and Solvent Extraction I

Don Ibana
A.J. Parker Centre for Hydrometallurgy
Curtin University of Technology
Perth WA Australia

Saskia Duyvestyn
Metallurgical Engineering
University of Utah
Salt Lake City UT USA

Solvent Extraction II

Charles Maes
CYTEC
2085 E. Technology Circle, Suite 300
Tempe AZ USA

Juris Harlamovs
Teck Cominco Metals
Box 1000
Trail BC Canada

Solvent Extraction III

Kathy Sole
Anglo American Research
Laboratories (Pty) Ltd
Johannesburg South Africa

Mark Dietz
Chemistry Division
Argonne National Laboratory
Argonne IL USA

Solvent Extraction IV

Jim Lommen
Fluor Daniel Inc
Address 10547 W 69th Pl
Arvada CO USA

David Hughes
Outokumpu Technology Group
Riihitontuntie 7 C
Espoo Finland

Plenaries

Bryn Harris
Process Research Ortech
Mississauga ON Canada

Amy James
The Shaw Group, Inc.
Denver CO USA

Corby Anderson
CAMP/Montana Tech
Butte MT USA

Electrochemistry

Akram Alfantazi
Metals and Materials Engineering
U of British Columbia
Vancouver BC Canada

Kwadwo Osseo-Asare
Pennsylvania State University
Materials Science and Engineering
University Park PA USA

Precipitation I

Dave Dreisinger
Metals and Materials Engineering
U of British Columbia
Vancouver BC Canada

David Muir
A.J. Parker Centre for Hydrometallurgy
CSIRO Minerals
Perth WA Australia

Precipitation II

Larry Twidwell
Metallurgical and Materials Engineering
Montana Tech
Butte MT USA

John Dutrizac
CANMET
555 Booth Street
Ottawa ON Canada

Precipitation III and Electrowinning I

Phil Guerney
JKTech - JKMRC
University of Queensland
Indooroopilly QLD Australia

Tim Robinson
Phelps Dodge Process Technology Center
9780 E. Sanchez Road
Safford AZ USA

Electrowinning II

Tony Bagshaw
AMIRA International Limited Research
PO Box 1368
W. Perth WA Australia

Andreas Siegmund
RSR Technologies, Inc.
2777 Stemmons Freeway, Suite 1800
Dallas TX USA

Electrowinning III

Peter Mason
Falconbridge (Australia) Pty. Ltd.
Suite 701, Level 7, 9 Sherwood Road
Toowong QLD Australia

Doug Robinson
Dremco, Inc.
via Bistolfi 35
Milano Italy

Acid Rock Drainage

Lynn McCloskey
MSE Technology Applications, Inc.
200 Technology Way
Butte MT USA

Phil Sibbrell
US Geological Survey
Leetown Sci. Ctr.
Kearneysville WV USA

Arsenic

Nick Welham
A. J. Parker Centre for Hydrometallurgy
Murdoch University
Murdoch WA Australia

Bryn Harris
3670 Sainte Famille
Montreal Quebec Canada

Environment

Doug Alexander
Anglo American Research
Laboratories (Pty) LtdUniversity of Arizona
Johannesburg South Africa

Brent Hiskey
Materials Science & Engineering
University of Arizona
Tucson AZ USA

Recycling

Rob Stephens
Teck Cominco Metals
Box 1000
Trail BC Canada

Paul Queneau
P.B. Queneau & Associates Inc.
5906 McIntyre St., Bldg. 2
Golden CO USA

Operations

Nick Hazen
Hazen Research
4601 Indiana Street
Golden CO USA

John Marsden
Phelps Dodge Corporation
1 N. Central Avenue
Phoenix AZ USA

TABLE OF CONTENTS

VOLUME 1: LEACHING AND SOLUTION PURIFICATION

Honorary Plenary

Leaching

Cyanide & Alternatives

Thiosulfate

Heap Leaching

Chloride

Pressure & Autoclave

Solution Purification

Adsporption & Ion Exchange

Solvent Extraction

TABLE OF CONTENTS

VOLUME 2: ELECTROMETALLURGY AND ENVIRONMENTAL HYDROMETALLURGY

Plenaries

Electrometallurgy

Electrochemistry & Cementation

Electrowinning

Operations

Environmental Hydrometallurgy

Recycling

Precipitation

Arsenic

General

Author Index

Author Index