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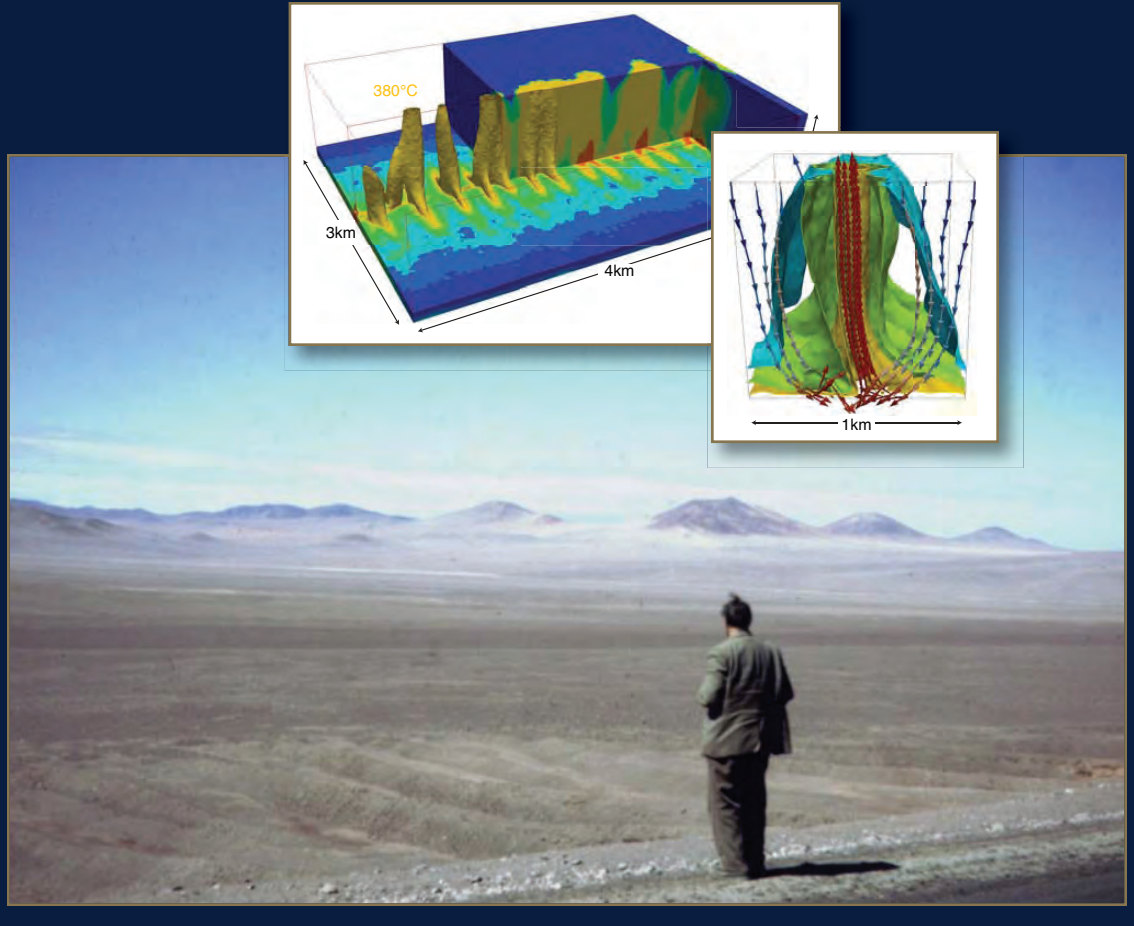
Building Exploration Capability for the 21st Century



Karen D. Kelley and Howard C. Golden, Editors

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On the cover: Photograph showing typical gravel-covered plain potentially concealing copper mineralization in the Andes, northern Chile. Conceptual thinking and application of technology can assist in exploring similar covered terrane (Brown, Fig. 2). *Inset:* A three-dimensional simulation of the hydrology of black smoker vent fields at mid-ocean ridges, showing temperature distribution over time (taken from Weis, Fig. 5).

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Special Publications of the Society of Economic Geologists

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First Edition 2014

Printed by
Colt Print Services, Inc.
2525 Frontier Avenue
Boulder, CO 80301
www.coltprint.com

Additional copies of this publication can be obtained from

Society of Economic Geologists, Inc.
7811 Shaffer Parkway
Littleton, CO 80127

www.segweb.org

ISBN 978-1-629496-37-5

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Innovations in Exploration Technology and Exploration Targeting

Case Studies of 21st Century Exploration Success

Preface

This Society of Economic Geologists Special Publication was initiated as a companion volume to the SEG 2014 Conference, *Keystone 2014: Building Exploration Capability for the 21st Century*, September 27 to 30, 2014, in Keystone, Colorado. The goal of the SEG 2014 Conference, and of this publication, is to bring together studies focused on new capabilities that will be required to address the future of increased demand for raw metals and depletion of near-surface deposits. New tools and methods of applying these capabilities, together with new concepts and technologies from fields not currently considered within the "traditional" realm of economic geology, are explored in the 16 papers in the volume. The papers are divided into four broad themes: Fundamental Advances in Economic Geology, Deposit Footprints and Mineral System Science, Innovations in Exploration Technology and Exploration Management and Targeting, and Case Studies of the 21st Century Exploration Success.

The first five papers in this volume illustrate the need for an integrated approach to understanding Earth history and metallogenesis. In the past decade, it has become clear that the geosphere and biosphere are closely linked, and that their coevolution has affected global metallogeny. The identification of patterns of mineral evolution utilizing novel techniques and research on the role of biology in forming select mineral deposit types demonstrate that minerals have been essential to life's origins and evolution, and that life has played a key role in the origins and evolution of the geosphere. Recognition of such trends and links is only possible through methods development and experimental studies. For example, advances in mineral deposit geochronology have promoted the ability to establish not only the timing of mineralization, which is critical for evaluating secular trends, but also the time scales required to concentrate metals in Earth's crust. Numerical modeling of hydrothermal ore-forming processes and research on the experimental constraints of metal transport and deposition are permitting a better understanding of the physical and chemical properties of hydrothermal fluids, and ultimately to the development of new and improved ore deposit models that assist in mineral exploration and resource assessment.

The second theme includes five papers focused on how ore deposits form and/or how to target them through the integration of geologic field work with modern techniques in geochemistry, mineral chemistry, and geophysics. These papers highlight the fact that ore deposits form by a variety of processes at a variety of scales. Recognition of such processes and their effects at different scales is critical for future mineral exploration. Most explorers agree that the majority of the easily targeted major deposits with a clear surface expression have already been discovered and that future exploration will increasingly rely on (1) identifying deposits at greater depths, or (2) recognizing genetically related features that are distal to the deposits. The mineral system concept encompasses all geologic factors that control the generation and preservation of deposits, including source, transport, deposition, and postmineralization events. Viewing deposits in this integrated way permits a better understanding of the entire system and expands the mappable expression of a deposit. Therefore, exploration should include targeting of the deposits themselves (i.e., footprint), as well as the pathway of hydrothermal fluids (i.e., footpath) that led to formation of the deposit.

Four papers focus on proposed innovations in technology and methodology that hold promise for the future of mineral exploration. Muon geotomography is a novel, field-tested geophysical technique that creates 3-D images of subsurface density distributions and is designed to guide drilling operations to regions of high-density contrast. Future borehole sensors, as yet undeveloped, may provide enhanced capabilities that can yield measurements up to about 1-km depth. As near-surface deposits in well-explored areas become rare, exploration will be focused under cover. It is proposed that the development of 3-D geologic models will allow the evaluation of regional-scale, hard-rock data and will play an integral part of resource identification. Also important as exploration shifts to greater depths is developing a low-cost method of drilling that enables mapping of mineral systems beneath cover. Such a method may be provided by coiled tubing (CT) drilling technology. From a mineral economist perspective, future exploration must also include "conceptual" exploration capabilities, which will further the understanding of resource depletion and help guide the future of mining.

The last two papers in this volume present case studies of recent mineral deposit discoveries. The first is a review of the decade-long (1999–2010) history of discoveries made by a major international company, Anglo American Exploration. This paper highlights factors that played a key role: the discovery environment, methods and techniques used, and traits of the geoscientists involved in the discoveries. The other paper is about the discovery of the Nova-Bollinger Ni-Cu sulfide deposit in Australia by a junior mining company. This deposit was discovered by utilizing diverse methods that were designed specifically for the type of deposit being sought, and also those appropriate to the scale and stage of exploration.

We thank all of the authors for their cooperation in meeting the tight deadline required. The copyediting done by Mabel Peterson and Alice Bouley maintained high-quality standards for this volume. Finally, all papers benefited from reviews by expert referees, who are listed below.

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The Society of Economic Geologists, Inc., thanks our sponsors for their generous financial support of the SEG 2014 Conference held September 27–30, 2014, at Keystone Resort, Colorado

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