METAMORPHOSED AND METAMORPHOGENIC ORE DEPOSITS

CONTENTS

Ores and Metamorphism: Introduction and Historical Perspectives
F.M. Vokes

Regional Metamorphic Remobilization: Upgrading and Formation of Ore Deposits
B. Marshall, F.M. Vokes, and A.C.L. Laroque

Discriminating between Regional Metamorphic Remobilization and Syntectonic Emplacement in the Genesis of Massive Sulfide Ores
B. Marshall and P.G. Spry

Metamorphic Fluids and Their Relationship to the Formation of Metamorphosed and Metamorphogenic Ore Deposits
I. Cartwright and N.H.S. Oliver

Regional Metamorphism and Ore Formation: Evidence from Stable Isotopes and Other Fluid Tracers
C.A. Heinrich, A.S. Andreuc, and M.D. Kuill

Fluid Inclusions in Metamorphosed and Synmetamorphic (Including Metamorphogenic) Base and Precious Metal Deposits: Indicators of Ore-Forming Conditions and/or Ore-Modifying Histories?
R. Marshall, A.D. Giles, and S.G. Hagemann

Sulfidation and Oxidation Haloes as Guides in the Exploration for Metamorphosed Massive Sulfide Ores
P.G. Spry

Meta-Exhalites as Exploration Guides to Ore
P.G. Spry, J.M. Peter, and J.F. Slack

Metamorphism of Komatite-Hosted Nickel Sulfide Deposits
S.J. Barnes and R.E.T. Hill

Metamorphism of Ni-Cu Sulfides in Mafic-Ultramafic Intrusions: The Svecofennian Saaksjarvi Complex, Southern Finland
F. Mancini and H. Papunen

Tungsten Mineralization and Metamorphic Remobilization in the Felbertal Scheelite Deposit, Central Alps, Austria
R. Höll and R. Eichhorn

Gold Deposits in Amphibolite and Granulite Facies Terranes of the Archean Yilgarn Craton, Western Australia: Evidence and Implications of Synmetamorphic Mineralization
J. Ridley, D.I. Groves, and J.T. Knight

Subduction-Related Diamond Deposits? Constraints, Possibilities, and New Data from Eastern Australia
W.L. Griffin, S.Y. O'Reilly, and R.M. Davies

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PREFACE

Many of the world’s largest deposits of base and precious metal ores are located in metamorphic terranes. Deformation, metamorphism, and the accompanying fluid-flow regimes have tremendous capacity to both form and modify such deposits. Nevertheless, ideas regarding the relationships of specific deposits to metamorphic and deformational processes affecting their host rocks have varied over the years; once again, these relationships and associated concepts are being scrutinized and intensely questioned. It is, therefore, an appropriate time to review knowledge and beliefs pertaining to several aspects of these ores. Not only is such a review of academic interest (important and exciting as this may be), but also, a better understanding of the timing of mineralization relative to deformation, metamorphism, and regional and local fluid flow is essential to more effective exploration for, and exploitation of, these types of ore.

It has not been practical to cover all aspects of ores in metamorphic terranes in this volume. The individual papers are authoritative, being based on the original research of well-recognized experts in their respective fields, and in many cases they present new data. While a degree of balance has been sought, it is recognized that some important ore types and related processes lack consideration. This is undoubtedly the case for some nonsulfidic ore types, and with one exception, most nonmetallic mineral deposits in metamorphic terranes. Furthermore, contact metamorphic ores have received no attention because their ore-generating events are predominantly magmatic-hydrothermal (rather than regional metamorphic), and in any case, such ores would warrant a whole volume to do them justice.

The distinction between metamorphosed, metamorphic, and metamorphogenic mineral deposits is addressed, and the terms defined, in an introductory chapter by Vokes that also reviews the historical development of ideas on ores in metamorphic terranes. Aspects of this terminology have also been developed in several other papers (e.g., Marshall, Vokes, and Larocque; Marshall and Spry; and Heinrich, Andrew, and Knill). It is apparent that some see metamorphogenic as a subset of syntectonic-syn-metamorphic, whereas others apply it to any deposit formed during metamorphism, irrespective of the nature of the transporting fluid.

The currently most contentious aspect of ores in metamorphic terranes is the distinction between metamorphosed-remobilized preexisting deposits and those thought to have been formed by metamorphic-deformational events. Marshall, Vokes, and Larocque review the possible roles of metamorphic remobilization in the upgrading of existing deposits and the formation of new ones, while Marshall and Spry thoroughly review the problem of metamorphosed versus metamorphogenic ores, present guidelines to aid in discriminating between these ores, and apply their guidelines to a range of major ore deposits.

The generation of metamorphic fluids, the magnitude and complexity of fluid-flow regimes, and the all-important role of these fluids in modifying existing ores and forming new ones are covered by Cartwright and Oliver. These authors are followed by Heinrich, Andrew, and Knill, who use mass-balance and metal-solubility arguments to constrain metamorphogenesis, before discussing the contributions of stable isotopes and other fluid tracers in studies of metamorphic ore formation. Marshall, Giles, and Hagemann close the section on fluids by focusing on the application of fluid-inclusion studies to determine the genesis and fluid history of metamorphosed-metamorphogenic deposits.

Exploring for and assessing ore deposits in metamorphic terranes are facilitated by the recognition of a range of lithologic-mineralogic guides that result from metamorphism of preexisting ores and their associated host rocks. These ore indicators have district-wide and more local significance for exploration. Spry reviews exploration guides provided by the mineralogical changes produced by sulfidation and oxidation processes in the vicinity of sulfide ores; Spry, Peter, and Slack evaluate the use of characteristic horizons of metamorphosed exhalites as guides to the presence of possible economic, exhalative ores.

The remaining five papers are devoted to aspects of a selected number of ore types found in metamorphic terranes. Two papers deal with the metamorphism of Ni-(Cu) ores of magmatic affiliation found in Precambrian rocks: Barnes and Hill review the metamorphism of komatiitic volcanic-hosted Ni ores in Archean terranes, and Mancini and Papunen consider Ni-Cu ores associated with Proterozoic mafic-ultramafic intrusions in the Fennoscandian shield. Höll and Eichhorn present a reassessment of the metamorphic development of the Felbertal scheelite deposits in the central Alps of Austria. Evidence for the metamorphogenic (symmetamorphic) origin of important Au deposits in high-grade metamorphic terranes in the Archean Yilgarn craton of Australia is discussed by Ridley, Groves, and Knight. The final paper, by Griffin, O’Reilly, and Davies, deals with the possibility of subduction-related diamond deposits, this being the only nonmetallic ore type considered in the volume.

Throughout the volume, the spelling “terrane” has been used, regardless of whether it relates to, for example, a region of high-grade metamorphism or a geotectonic entity. Where the use is not obvious from the context, clarification is provided by way of a footnote.

Reviews in Economic Geology volumes have in the past, with one exception, been produced in connection with a Society of Economic Geologists Short Course devoted to the theme of each volume. This is not the case with the present volume, principally because of the difficulty in bringing together such a widely distributed set of authors. We nevertheless hope that the volume will provide an up-to-date and relatively comprehensive coverage of the relationships between metamorphism-deformation and fluid flow, and the formation and modification of metallic mineral deposits.
ANITA S. ANDREW received her B.Sc. (Hons.) and Ph.D. degrees from the University of Sydney, with thesis study addressing the scale of fluid movement during metamorphism. After holding a postdoctoral position at Virginia Polytechnic Institute and State University, she joined Commonwealth Scientific and Industrial Research Organisation (CSIRO) as a Research Scientist in 1982. There she applied isotopic techniques to problems of ore genesis and mineral exploration. In 1993, she moved to the newly formed Division of Petroleum Resources at CSIRO, researching problems related to petroleum exploration; in particular, she worked on developing new isotopic techniques for inter- and intrabasinal correlations. Currently, Andrew leads the CSIRO Petroleum Exploration and Appraisal research program. She is an author of more than 90 scientific and technical publications.

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IAN CARTWRIGHT is currently Senior Lecturer in crustal fluid flow at the Department of Earth Sciences, Monash University, Australia. He received his B.S. degree from the University College of Wales, U.K., in 1982, and his Ph.D. from the same institution in 1986. Prior to arriving at Monash in 1990, he was a research fellow at the University of Wisconsin, Madison. His research interests encompass fluid flow in a range of geologic environments, including metamorphic, ore-forming, and hydrogeologic systems. Most of his research involves the application of petrology, stable isotopes, and other geochemical tracers to constrain conditions of fluid-rock interaction, pathways of fluid flow, fluid volumes, and the timing and duration of fluid-flow events.

RONDI M. DAVIES is now completing a Ph.D. study on the diamonds of eastern Australia, which has included detailed studies of morphology, internal structure, inclusion chemistry, N aggregation and isotopic composition of diamonds from a number of localities. She also has carried out similar studies of diamonds from Myanmar, Thailand, and the Slave craton of Canada.

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DAVID GROVES is Professor of Economic Geology and Director of the Centre for Strategic Mineral Deposits within the Department of Geology and Geophysics, University of Western Australia. He received his Ph.D. degree from the University of Tasmania, with study focused on cassiterite-sulfide deposits, under the supervision of Mike Solomon, and has since researched tin, nickel, zinc-copper, PGE, and gold deposits. Currently, he leads an integrated research team that is studying the genesis of ore deposits, with special emphasis on orogenic lode gold deposits, and assisting in the development of exploration models based on deposit and genetic models. His recent
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NICHOLAS OLIVER (B.Sc., Hons., University of Queensland, 1981; Ph.D., Monash University, 1988) has a wealth of field and analytical experience in appraisal of alteration systems in metamorphic rocks and ore deposits, mostly in Australia. These include studies of regional albition, veining and related Cu-Au mineralization in the Mount Isa block, greenstone-hosted Au in the Yilgarn and Pilbara cratons, Cu in the Kanmantoo district of South Australia, and iron in the Hamersley province of Western Australia. He has published papers on mechanical constraints on fluid flow in these systems as well as a range of more geochemical-isotopic-petrologic papers. He was appointed as the W.C. Lacy Professor of Economic Geology in the School of Earth Sciences at James Cook University in 1997.

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Chapter 1—Ores and Metamorphism: Introduction and Historical Perspectives

Frank M. Vokes

ABSTRACT ................................................................. 1
INTRODUCTION .............................................................. 1
OVERVIEW OF EARLY LITERATURE .............................. 2
ASPECTS OF PRESENT SITUATION .................................. 7
CONCLUSIONS .............................................................. 13
ACKNOWLEDGMENTS .................................................... 13
REFERENCES ............................................................... 13

Chapter 2—Regional Metamorphic Remobilization: Upgrading and Formation of Ore Deposits

Brian Marshall, Frank M. Vokes, and Adrienne C.L. Larocque

ABSTRACT ................................................................. 19
INTRODUCTION .............................................................. 20
TERMINOLOGY AND CONCEPTS ...................................... 21
TEXTURAL AND MINERALOGICAL UPGRADING ..................... 23
THE COMPOSITION OF SOURCE OR PARENT MINERALIZATION ....... 23
TRANSFER PROCESSES IN METAMORPHIC REMOBLIZATION ..... 24
MAGMATIC AND MAGMA-RELATED REMOBLIZATION .......... 28
EMPLACEMENT-SITE PROCESSES AND RELATIONSHIPS .......... 30
TRANSPORT RATES AND DISTANCES .................................. 32
CONCLUSIONS .............................................................. 34
ACKNOWLEDGMENTS .................................................... 34
REFERENCES ............................................................... 35

Chapter 3—Discriminating between Regional Metamorphic Remobilization and Syntectonic Emplacement in the Genesis of Massive Sulfide Ores

Brian Marshall and Paul G. Spry

ABSTRACT ................................................................. 39
INTRODUCTION .............................................................. 39
SCOPE OF PROBLEM ..................................................... 40
GUIDELINES FOR SUCCESSFUL DISCRIMINATION .............. 49
SOME CONTENTIOUS EXAMPLES ....................................... 53
CONCLUSIONS .............................................................. 72
ACKNOWLEDGMENTS .................................................... 73
REFERENCES ............................................................... 73

Chapter 4—Metamorphic Fluids and Their Relationship to the Formation of Metamorphosed and Metamorphogenic Ore Deposits

I. Cartwright and N. H. S. Oliver

ABSTRACT ................................................................. 81
INTRODUCTION .............................................................. 81
FLUIDS IN METAMORPHIC TERRANES ............................... 82
VARIATIONS IN FLUID PRODUCTION IN TIME AND SPACE ....... 85
FLUID MIGRATION AND CHANNELING ................................ 85
VEINS ................................................................. 88
METAL TRANSPORT AND ORE DEPOSITS ............................ 89
DISCUSSION ............................................................ 89
SUMMARY ............................................................... 92
ACKNOWLEDGMENTS .................................................... 92
REFERENCES ............................................................... 92

Chapter 5—Regional Metamorphism and Ore Formation: Evidence from Stable Isotopes and Other Fluid Tracers

Christoph A. Heinrich, Anita S. Andreu, and Matthias D. Knill

ABSTRACT ................................................................. 97
INTRODUCTION .............................................................. 97
METAMORPHIC ORE FORMATION: SOME BASIC REQUIREMENTS . 98
LENENBACH, A METAMORPHIZED, DOLOMITE-HOSTED, BASE METAL DEPOSIT .................................. 102
METAMORPHIC COPPER ORE FORMATION AT MOUNT ISA .... 104
BASE METAL DEPOSITS IN SILICATE-RICH METAMORPHIC ROCKS ......................................................... 107
MESOTHERMAL GOLD DEPOSITS ...................................... 108
IMPLICATIONS: METAMORPHOGENIC GOLD VS. BASE METAL DEPOSITS ................................................... 112
SUMMARY AND CONCLUSIONS ....................................... 112
ACKNOWLEDGMENTS .................................................... 114
REFERENCES ............................................................... 114

Chapter 6—Fluid Inclusions in Metamorphosed and Synmetamorphic (Including Metamorphogenic) Base and Precious Metal Deposits: Indicators of Ore-Forming Conditions and/or Ore-Modifying Histories

Brian Marshall, Alan D. Giles, and Steffen G. Hagelmann

ABSTRACT ................................................................. 119
INTRODUCTION .............................................................. 120
FLUID INCLUSIONS, REGIONAL METAMORPHISM, AND LATE TECTONICS ..................................................... 122
FLUID INCLUSION CHARACTERISTICS OF MASSIVE SULFIDE DEPOSITS IN THE LOW-TEMPERATURE REGIME .......... 127
FLUID INCLUSION CHARACTERISTICS OF GOLD DEPOSITS IN THE HIGH P-T (INTERMEDIATE-TO HIGH-TEMPERATURE) REGIME .................................................. 132
CONCLUSIONS AND IMPLICATIONS .................................. 143
ACKNOWLEDGMENTS .................................................... 144
REFERENCES ............................................................... 144

Chapter 7—Sulfidation and Oxidation Haloes as Guides in the Exploration for Metamorphosed Massive Sulfide Ores

Paul G. Spry

ABSTRACT ................................................................. 149
INTRODUCTION .............................................................. 149
FERROMAGNESIAN SILICATES .......................................... 150
ZINGIAN SPINEL (GAHNITE) AND ZINGIAN STAURORILITE ... 156
DISCUSSION AND APPLICATION TO EXPLORATION .......... 157
ACKNOWLEDGMENTS .................................................... 159
REFERENCES ............................................................... 159

Chapter 8—Meta-Exhalites as Exploration Guides to Ore

Paul G. Spry, Jan M. Peter, and John F. Slack

ABSTRACT ................................................................. 163
INTRODUCTION .............................................................. 163
SUMMARY ............................................................... 182
ACKNOWLEDGMENTS .................................................... 182
REFERENCES ............................................................... 182