

REVIEWS

Exploration for Platinum-Group Element Deposits.

JAMES E. MUNGALL, EDITOR. 526 Pp. 2005. Mineralogical Association of Canada Short Course Notes Volume 35. ISBN 0-921294-35-2. Price US\$55.

Canada is obviously the place to be for platinum group elements (PGE). Two hefty tomes of Canadian origin on the subject of economic geology of PGE have appeared in the last three years, with the first being the weighty volume edited by Louis Cabri and published by CIM in 2002. The latest, and the subject of this review, is a set of course notes published by the Mineralogical Association of Canada, compiled to accompany a short course on PGE exploration held at the recent PGE Symposium in Oulu, Finland. Editor James Mungall has cast the net wide for experts in the full spectrum of PGE geology and geochemistry, and has produced an extremely impressive volume, which is really more of an advanced textbook than a mere set of notes.

The range of topics is too wide to describe in detail in this review but, in summary, the book covers the magmatic and aqueous geochemistry of the PGE; the geological and geochemical features of the major deposit types including placer and hydrothermal accumulations, as well as the more economically significant magmatic types; genetic models and economic considerations; case histories of discoveries; and discussions of some of the more contentious issues in ore targeting.

The scope includes magmatic Ni-Cu sulfide deposits with significant by-product PGE, such as Sudbury and Noril'sk. The book is thus of as much relevance to nickel explorers as it is to PGE hunters, not the least because PGE have become widely used as important pathfinder elements for these deposits. I would hazard a guess that in the present booming nickel market, nickel explorers will in fact form the bulk of the potential market for this book. They will find that it contains the best available single source of information on the topic of exploration geochemistry for the PGE deposits.

A number of chapters are worth singling out. The opening chapter by Mungall is an excellent and very timely study of the complex and much-misunderstood field of magmatic geochemistry of PGE. The exposition is very clear, and it sets the tone of the book in that it succeeds in clarifying the relevance of academic research to the practicalities of ore deposit targeting. The chapter by Arndt on "Conduits of Magmatic Ore Deposits" is mainly concerned with the immensely important Noril'sk deposits, and does an excellent job of seeing the "forest through the trees" of the large volume of often conflicting research publications on these deposits in recent years. A chapter by Distler and Yudovskaya on the unusual and, to Westerners at least, mainly unknown Sukhoi Log shale-hosted deposits of Siberia is intriguing and opens up a whole new array of exploration opportunities for the more ambitious explorers to consider.

This book goes well beyond being a mere set of course materials and serves both as a comprehensive handbook for explorationists involved in the search for the full spectrum of

PGE deposit types and for Ni-Cu sulfides, and as a handy and up-to-date summary of a complex and fast-moving research field. The chapters are pitched at the level of a recent geology or geochemistry graduate with a sound basic understanding of igneous and aqueous geochemistry, but without assuming any prior knowledge of the PGE field. I highly recommend it as an indispensable resource for the academic and exploration industry communities alike.

STEVE BARNES

CSIRO EXPLORATION AND MINING

AUSTRALIAN RESOURCES RESEARCH CENTRE (ARRC)

26 DICK PERRY AVENUE, TECHNOLOGY PARK,

KENSINGTON, WA, 6151

AUSTRALIA

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Infrared Spectroscopy in Geochemistry, Exploration Geochemistry, and Remote Sensing.

PENELOPE KING, MICHAEL RAMSEY, AND GREGG SWAYZE, EDITORS. Mineralogical Association of Canada, Short Course Series Volume 33. 2004. 284 Pp. ISBN 0-921294-33-6. Price \$40.

This 284-page-long volume, including 20 color plates and an index, is a collection of invited papers that originated from a short course on infrared spectroscopy for geoscientists organized by the Mineralogical Association of Canada. As outlined in the preface of the volume, the main objective of the short course was to update geoscientists on advances in infrared technology being developed in the laboratory through to satellite-based systems, with particular emphasis on measurement and mapping of mineral composition for more effective ore deposit exploration, as well as for environmental monitoring and assessment of natural and anthropogenic processes. Such a volume would, in theory, be of interest to readers of *Economic Geology*, particularly those interested in understanding how a new generation of proximal and remote spectral-sensing technologies can be used to measure and target prospective economic mineralization. The book essentially aims to arm geoscientists with mineral mapping tools to complement existing "frontline" geochemical and geophysical methods currently available to the mineral industry. However, the volume only partly succeeds in reaching this objective.

The volume has 12 chapters. The first five chapters are an excellent account of the fundamental physics of infrared measurement and mineral spectroscopy. They are well illustrated and referenced with generally judicious use of equations that should not be too threatening to most geoscientists. The reader is walked through the principles of the interaction of electromagnetic radiation with matter and its significance for measuring material composition. The range from visible (400–700 nm) to the thermal infrared (7–14 mm), where we feel heat, is examined as many materials have diagnostic spectral information at different wavelengths. By themselves,

these chapters are a useful teaching reference for undergraduate and postgraduate students interested in the application of infrared spectroscopy to geoscience.

The remaining seven chapters branch into a various applications, although only chapter 10 is focused on mineral exploration. Chapter 11 examines the use of infrared spectroscopy for measuring sulfide abundances, which has significant potential in enhanced ore characterization. Chapter 9 examines the use of hyperspectral remote sensing data for mapping hydrothermal alteration mineralogy of an eroded stratacone, and these data are compared with oxygen isotope data to constrain the temperatures of hydrothermal activity. The remaining chapters present interesting environmental applications that include mapping of (1) dust mineralogy immediately after the collapse of the World Trade Center, (2) the composition of roofing materials in urban areas, (3) minerals associated with acid drainage surrounding abandoned mine sites, (4) asbestos-related minerals in natural geological exposures and mineral provenance in sand dunes, (5) active volcanism, and (6) the surface composition of our planetary neighbors.

Chapters 2, 4, 7, 9, and 11 are useful for geoscientists interested in understanding the spectral signatures of mineralogy of geologic systems. However, there is little information presented in the volume that shows how infrared spectroscopy can be used to map different styles of mineralization, apart from the classic epithermal style (chapters 9 and 10). Furthermore, the power of spectral sensing to measure and map mineral chemistry, which has been demonstrated around the world for a range of deposit types, has unfortunately not been covered in this volume. Missed examples of mineral chemistry for mineral exploration include Tschermak substitution effects in white mica and chlorites in volcanic massive sulfide systems, Fe-Al contents of Ca-garnets in copper skarns, and Ca-Na contents of plagioclase in porphyry copper systems. There is also a lack of validation data in many of the remote mineral maps presented, which does not help in convincing the reader of the accuracy of these products.

There is no description on the range of instruments currently available for operational proximal (laboratory, field, mine) and remote (airborne, spaceborne) spectral-mineral mapping. Most of the remote sensing case histories are focused on NASA's research instrument, namely the airborne AVIRIS, which is not readily available operationally to the mineral industry, particularly outside of the United States. Still, AVIRIS does remain the benchmark hyperspectral instrument to which other systems are compared.

For these above reasons, this volume is not ideally suited for geoscientists wanting to learn more about how infrared spectroscopy can be used effectively for mineral exploration. However, it does represent an excellent volume on the theory of infrared mineral spectroscopy and its potential use in a range of geoscience applications.

THOMAS CUDAHY

CSIRO EXPLORATION AND MINING
AUSTRALIAN RESOURCES RESEARCH CENTRE (ARRC)
26 DICK PERRY AVENUE, TECHNOLOGY PARK,
KENSINGTON, WA, 6151
AUSTRALIA
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Altered Volcanic Rocks; A Guide to Description and Interpretation. C. GIFKINS, W. HERRMANN, AND R. LARGE. 2005. 275 Pp. CODES Special Publication. University of Tasmania. ISBN 1862952191. Price AUD\$135.

This volume is a comprehensive guide to alteration, primarily in submarine volcanic successions and in relation to volcanic rock-hosted massive sulfide (VHMS) deposits. The book has two great strengths: its general descriptions of the variations in style and type of alteration observed in submarine volcanic environments and the many case studies with detailed data pages that provide supporting evidence. The latter also serve as an excellent example of a comprehensive methodology for recording diverse data sets that relate to alteration.

The book is divided into chapters, with the first chapter, "Alteration in Submarine Volcanic Successions," providing a background for the book. An overview of the variety of processes that lead to alteration is followed by a summary of the general geology of the major VHMS districts referred to in the book. The majority of examples are based on the authors' extensive knowledge of the Cambrian Mount Read volcanic rock sequence in western Tasmania and the Cambrian-Ordovician Mount Windsor subprovince in Queensland.

The next three chapters provide a framework for describing and understanding alteration. These sections, "Describing Altered Volcanic Rocks," "Common Alteration Textures and Zoning Patterns," and "Geochemistry of Altered Rocks," are based on a broad volume of information that is succinctly summarized. Numerous geochemical, analytical, and descriptive techniques for understanding alteration are presented and will be useful to many economic geologists. The emphasis throughout the book, however, is placed on high-quality field and hand sample descriptions. Tables are used to highlight the important descriptive terms available for the type, intensity, and distribution of the alteration. The importance of using mineral assemblages, as well as the distribution of minerals, to define the alteration type is highlighted, as opposed to the use of geochemical or general terms that are linked to a genetic process.

The bulk of the volume (p. 97–233) is devoted to three chapters that include detailed descriptions of particular environments related to alteration in the submarine environment. Each of these chapters, "Seafloor- and Burial-related Alteration," "Synvolcanic Intrusion-related Alteration," and "Local Hydrothermal Alterations Related to VHMS Deposits," includes a general description of the processes relevant to the environment and is supported by case studies. Detailed data sheets for representative samples within the study areas are also provided. The data sheets provide a variety of information, which is summarized by an "alteration facies" at the top of a brief table. The table includes the sample number, location position in the succession, and details of the alteration mineralogy, textures, timing, and style. In addition, each sheet typically contains a photograph of a hand specimen and a photomicrograph, plus the location of the sample on a cross section. Many sheets also show an "Alteration box plot," stacked short-wave infrared (SWIR) spectra, and a TiO₂-Zr immobile element plot. A table of major element geochemistry is also generally included.

The final chapter highlights one of the major reasons for understanding alteration, i.e., the ability to explore for and discover mineral resources. This chapter, "Finding Ore Deposits in Altered Volcanic Rocks," begins with a concise summary that illustrates the reason for detailed physical descriptions of the rocks and high-quality, field-based datasets. Most important, particularly in relation to VHMS deposits, is the ability to distinguish between diagenetic, metamorphic, and hydrothermal processes. This differentiation then allows better use of broad scale "vector tools," such as the use of alteration indices, mineral chemistry, and isotopic vectors.

Any weaknesses in the volume partly derive from attempts to generalize beyond the authors' substantial experience and understanding of alteration in submarine environments. References to alteration in subaerial volcanic and igneous settings are distracting and, in some cases, inaccurate. For example, "intense" alteration in a high sulfidation system may result in a vuggy quartz rock with textural preservation. Use of "intense" in this volume, however, typically refers to examples of strong alteration combined with the effects of deformation. The authors also clearly state their preference for an extremely loose definition of sericite to include white mica and illite. Unfortunately, this creates some confusion and loss of information that can be obtained (particularly using SWIR spectrometers) regarding the temperature and intensity of the alteration. In fact, illite is not even referenced in the index, although it is included in some descriptions within the volume.

Several frustrating typographic errors were noted throughout the volume, including a table listing albite-dominant alteration as "Na-depletion," some misspellings, and at least two mislabeled SWIR spectra. The book, although it includes several non-Australian examples, is still fundamentally Australian-centric and North American readers will have to adapt to "Cainozoic," as well as outdated mineral names such as "sphene." In addition, specific references to the cost of analyses at named Australian laboratories or by consultants are out of place, and will likely be incorrect by the time anyone reads the book.

These complaints, however, are all relatively trivial, as overall the book is well organized and well written. The wealth of information presented on alteration in the submarine volcanic environment is supported by clearly drawn figures and extensive references. The book requires some effort to digest completely; however, the photographs of volcanic and alteration textures make the volume a "keeper" by themselves. *Altered Volcanic Rocks* will be a valuable resource for exploration geologists, mineralogists, and students for many years.

ANNE J. B. THOMPSON

PETRASCIENCE CONSULTANTS INC.
700-700 WEST PENDER ST.
VANCOUVER, B.C. V6C 1G8
CANADA
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