

REVIEWS

Gold in the Yellowstone Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project. C. D. ANGLIN, H. FALCK, D. F. WRIGHT, AND E. J. AMBROSE, Editors. Pp. 448. Geological Association of Canada, Mineral Deposits Division, Special Publication no. 3 (DVD included). 2006. ISBN 1-897095-09-0. Price Can\$76.00, Member Price Can\$57.00.

The Yellowknife greenstone belt in the Archean Slave province is one of Canada's major gold mining districts, and one of the best preserved and exposed Archean volcanic belts worldwide. Declining reserves, following more than 60 years of continuous gold production, stimulated the initiation of the Yellowknife EXploration science and TECHnology project in 1998. The resulting EXTECH III project, the third of a series of projects initiated by the Geological Survey of Canada in collaboration with various university and industry partners, had the objective of defining new exploration targets for gold mineralization in the Yellowknife greenstone belt using new technology and exploration concepts accomplished through multidisciplinary studies and ran from 1999 to 2003. The EXTECH project built on a comprehensive geological and geochronological database developed over 60 years of government and industry mapping programs. Progress on the geological understanding of the Yellowknife greenstone belt had been incremental, with significant contributions from Jolliffe, J.F. Henderson, Brown, J.B. Henderson, and, more recently, Helmstaedt, Bleeker, and coworkers. The recent studies challenged some of the long-held views for the gold-bearing zones throughout the Yellowknife district, which since Boyle (1961) had been viewed as type examples of shear zone-hosted gold deposits. An improved understanding of the structural and metamorphic evolution of the region also warranted a new look at the controls on gold mineralization. Willingness from government, industry, and universities provided the impetus to develop the cooperative and multidisciplinary approach undertaken by the EXTECH program.

The resulting volume contains 25 papers that are organized into five parts: historical background; regional geology; mineral deposits and regional metallogenic studies; exploration technology; and data integration. A mix of new data, integration, and interpretation of the principal deposits in the Yellowknife belt are brought together with chapters on the history and regional geology of the belt. Unfortunately, color figures and photographs from individual papers are relegated to the back of the volume. One of the highlights of the volume is an extensive set of appendices that includes much of geological data obtained by the project in spatially referenced digital format. Of particular note is the 3-D database for the Yellowknife mining camp that contains data from more than 42,000 drill holes from the Con and Giant mines. Additional value is provided in the form of digital copies of two research theses and a field guide on the regional stratigraphy and structure of the Yellowknife area. A 2-D digital

geological compilation of the Yellowknife district is provided in only ArcView format, thereby limiting its reader appeal.

The first part, comprising three papers, focuses on a history of the geological understanding (Helmstaedt) of the Yellowknife greenstone belt, and as well as the effect of gold exploration and mining on the on-going development of the region (Moir et al., Bullen, and Robb). These well-written papers are essential reading that provides thoughtful analysis of the socio-economic impact of exploration and mining on this part of Canada's north.

Part II comprises seven papers that deal with the regional geology of the Yellowknife greenstone belt. Papers on the geology and geochemistry of the volcanic and sedimentary sequences (Jackson and Cousens, Finnigan and Duke, Cousens et al.), structural setting (Martel and Lin), metamorphic history (Thompson), and crustal architecture (Snyder et al., Jones and Garcia) provide detailed accounts on their respective topics. In particular, Martel and Lin recognize the importance of the crustal-scale Yellowknife River fault zone in the localization and preservation of the Jackson Lake Formation, a sedimentary sequence comparable to Timiskaming-type conglomeratic sequences often spatially associated with gold mineralization in Archean greenstone belts worldwide. Four generations of structures are recognized throughout the greenstone belt, with the earliest generation not recognized in the Jackson Lake Formation, indicating that this event probably gave rise to the angular unconformity between this formation and the underlying Kam and Banting groups. Thompson presents results of a comprehensive study of the metamorphic characteristics of the Yellowknife belt and contends that the results can be used to target gold mineralization. For example, metamorphic mapping that revealed an apparent correlation between metamorphic zone boundaries and gold occurrence in greenstone belts in the Superior province of Canada can be used to target prospective zones in the Yellowknife region. In addition, Thompson contends that the volume of alteration surrounding the Giant mine has been underestimated, making the deeper parts of the mine remaining prospective. Although the papers in part II provide a wealth of information and a 2-D map compilation is provided as an appendix, the reviewer would like to have seen a regional synthesis linking features present at the crustal and lithospheric mantle scale (e.g., magnetotelluric electrical resistivity, seismic reflection data) with those at the belt and mine scale (stratigraphic reconstruction, structural and metamorphic history).

Part III, comprising eight papers, deals with descriptions of individual deposits as well as regional metallogenic aspects of the Yellowknife greenstone belt. Hauser et al., Canam, and Hubbard et al. provide detailed geological descriptions of the Con and Giant mines. Siddorn et al. provide an integrated structural model of the Con-Giant gold system. Relative timing constraints indicate that refractory gold-arsenopyrite mineralization is associated with a first generation of structures, whereas free-milling gold-pyrite mineralization is associated

with second generation structures. These authors suggest that the Con and Giant deposits are part of the same gold system offset by the West Bay fault during Proterozoic faulting. Large-scale lithogeochemical alteration haloes at Con and Giant are described by van Hees et al., who contend that the ore fluids responsible for mineralization were derived from metasedimentary rocks to the east of the gold system. In a description of the Crestaurum deposit, located 15 km to the north of Yellowknife, Ootes et al. suggest that it is a northern extension of the Con-Giant gold system. In a separate paper, van Hees et al. examine the possible role of magmatic fluids in the formation of the metasedimentary rock-hosted Ptarmigan deposit. Cousens et al. investigate the lead isotope signatures of more than 20 mineralized localities in the Yellowknife region and indicate that mineralizing fluids at Con, Giant, and Crestaurum are isotopically similar, probably related, and possibly derived their lead from a heterogeneous source such as metasedimentary rocks.

Part IV focuses on “exploration technology” and comprises four papers on topics ranging from surficial geology to laboratory, borehole, and ground geophysical studies. Kerr presents baseline surficial geology information including till geochemistry, ice flow indicators, biogeochemistry, and soil profiles. Geochemical anomalies in till demonstrate the effectiveness of this technique in the Yellowknife region and several anomalies coincide with areas considered favorable based on metamorphic mapping by Thompson. Laboratory electrical and petrophysical measurements on samples from Con and Giant are discussed by Katsube et al., and Keating and Katsube present electromagnetic survey results for the Gold Lake and Crestaurum areas. Both studies demonstrate the importance of petrophysical measurements to better understand the geophysical response of mineralization. Mwenifumbo et al. present results of multisensor borehole geophysical logging at the Giant and Crestaurum deposits that demonstrate the technique can effectively map intervals with hydrothermal alteration. Potassium highs, detected by gamma-ray spectrometry, correlate with sericite-rich alteration and zones of sulfide enrichment, detected by induced polarization, are associated with gold-rich rocks. This study demonstrates that borehole logging is an underutilized technique that is highly applicable to many Archean gold systems worldwide and should be an integral component of future brown fields exploration programs.

The final section, part V, deals with data integration and comprises two papers. The 3-D GIS model (Kirkham et al.) of the Con and Giant mines is a highlight of the volume. This model incorporates exploration and mining drilling data of more than 42,000 drill holes from the two major gold mines, as well as surface features, structural geology, mining areas, and point sample data. The development of the model directly led to three targets for further exploration, a significant achievement itself. Wright et al. deal with weights-of-evidence-type prospectivity mapping of the Yellowknife

greenstone belt. Knowledge-based methods employing neural-networks or self-organizing maps may have provided additional insights into the prospectivity of the belt.

Notwithstanding the significant wealth of information provided in this volume, there are limitations to the value of some of its components. Consistently, there is a lack of detailed geochronology to constrain the temporal links between a geological event and an episode of gold mineralization. Surprisingly, there is limited use of the excellent 3-D model developed for the Con-Giant gold system. What lessons were learned in the development of the 3-D model that may assist others when building such maps? Why is the Con-Giant gold system developed in the Yellowknife greenstone belt and not the belt immediately west or east? Overall, there is a distinct lack of linking observations made at the mine scale to those at the terrane scale. Scale integration is critical to exploration and should form the basis of any future studies in the Yellowknife region. Of particular interest is how an explorer can use the knowledge, maps, and models provided throughout the volume to explore outside the traditional mining environment. Further work in these areas may have helped the EXTECH III project achieve one of its key objectives, to develop an improved exploration model for Archean shear zone-hosted gold deposits.

Is the volume of value to the economic geology community? It will be of great value to students and researchers interested in gaining a detailed understanding of the characteristics and architecture of a well-mineralized Archean greenstone belt. The volume also offers the mineral explorer an ideal starting point from which to launch future exploration programs in the Yellowknife greenstone belt. The volume is very well organized, with each paper providing detailed documentation of numerous aspects of the geology of the Yellowknife greenstone belt as well as appendices with abundant digital data and an excellent 3-D model of the Con-Giant gold deposit. The volume also highlights the importance of multidisciplinary studies and how advances in our understanding of the geology of the Yellowknife belt and its gold mineralizing systems have been necessarily incremental. Ultimately, the measure of the EXTECH III project's success will be its part in the discovery of economically valuable gold deposits in the Yellowknife region and elsewhere.

REFERENCES

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KEVIN F. CASSIDY

ADJUNCT RESEARCH FELLOW
SCHOOL OF EARTH AND GEOGRAPHICAL SCIENCES
THE UNIVERSITY OF WESTERN AUSTRALIA
NEDLANDS, WESTERN AUSTRALIA 6009
AUSTRALIA

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Introduction to Mineral Exploration. Second Edition.

CHARLES MOON, MICHAEL WHATELEY, AND ANTHONY EVANS, Editors. Pp. 498. Blackwell Publishing. 2006. ISBN 1405113170. US\$84.95.

This book has a simple aim, to introduce the reader to the broad spectrum of the exploration world, and it achieves it well. There are many books that cover various aspects of the tremendously broad field of economic geology. Some focus on the ore deposits, some focus on the economic and/or environmental aspects, but this book, as the title implies, focuses on the process of exploration. And in my opinion, it is the best on the market. Not that there won't be critics. The treatment of ore genesis is shallow, at best, and even in the various subfields of exploration—geophysics, geochemistry, remote sensing, geostatistics, and mineral economics—specialists in these disciplines will have things to quibble with. It could, however, be argued that this would be the case in any broad treatment. But to give credit where credit is due, this is a very competent overview of the general process of exploration and no other book does it better.

Appropriately, this is a multi-author exercise with each author contributing in his own area of expertise. The first three chapters, by Moon and Evans, provide a simple introduction to mineral economics, mineralogy, and mineral deposit geology. The next three chapters, by Moon and Whateley, cover the early stages of exploration and details of remote sensing. This is followed by fairly detailed chapters from John Milson on geophysical methods and Moon on geochemical methods. Neither of these will substitute for common texts on these disciplines, but both provide a useful introduction for beginning geologists looking for a place to start. I have already recommended these chapters to undergraduate students about to begin their first season of field work, as a useful overview that will serve them well until they gain more experience and

have an opportunity for specialized coursework in these disciplines.

The next three chapters add Barry Scott to the previous author list and review advanced exploration topics, including database management, property evaluation techniques, and project evaluation. I suspect that the discussion of cash flow and risk assessment will leave many experienced project managers wanting more depth, but to be fair to the aims of the book, this is a welcome introduction to most field geologists who have little knowledge of these subjects.

The second half of the book involves six case studies. This is welcome in bringing geology, maps, and field work to the fore, but will disappoint some in that there are many more detailed assessments of the studied deposits in the published literature. But it is better to include some case studies than to leave the field aspect out altogether.

On the technical front, the book is well edited and remarkably free of grammatical errors. In keeping with the intended low cost of the book, there are no color or high resolution photographs, but illustrations are generally clear and readable.

Overall, the success of this book is that it surveys a broad range of subjects having to do with the general field of mineral exploration. It is more applied and more practical than most textbooks in economic geology. Whereas there may not be many university courses for which this would serve as the main or only textbook, I can think of no better introduction to the day-to-day work of economic geology. I will recommend this book enthusiastically to my own students and state that it should be in every economic geology library.

LARRY MEINERT

DEPARTMENT OF GEOLOGY
CLARK SCIENCE CENTER
SMITH COLLEGE
NORTHAMPTON, MA 01063
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Impact Structures in Canada. RICHARD A.F. GRIEVE. Pp. 210. Geological Association of Canada. 2006. GeoText 5. Hardcover. ISBN 1-897095-11-2. Price Can\$60.00, member, Can\$45.00.

The importance of hypervelocity impact processes in the early development and subsequent history of Earth and other planetary bodies is becoming increasingly accepted into mainstream models of planetary evolution. Although there is a currently flourishing community of impact-focused research scientists, a few pioneering geologists have diligently constructed the knowledge foundation upon which this present research is built. Richard Grieve, now nearing retirement, is one of these masons. In this volume, he provides a snapshot of the current state of knowledge of impact structures on his home territory.

The book starts with a comprehensive introductory chapter on the hypervelocity impact record and process, the physical features that are generated, and the geochemical and geophysical signatures that are left in the geologic record. Although textually and pictorially similar to many other reviews on impacts by the author, it provides a useful preface to the features discussed in subsequent chapters. These chapters deal, individually, with the 29 Canadian impact structures.

Each impact structure is consistently described. An interesting historical account of how the crater was discovered, the resulting early research, and ultimately how each structure was confirmed as having been generated by the impact process, is detailed. Sections on the physical morphology of each crater, the geology of the target, geochemical and geophysical signatures, and geochronologic constraints are also presented. These sections often highlight sources of data that have been accrued by the author, which have not been

previously presented. They are, however, brief, and the accompanying photomicrographs and selected geochemical data are of questionable value in many cases. The presented age constraints detail for the first time some of the weaknesses on which the ages of these impacts are based, which helps provide valuable context for age tabulations that have been published for decades. Because other sections are bolstered by figures and/or tabulations, it is unclear why the best isochrones or step heating profiles are not presented.

Perhaps of particular interest to readers of this journal, the economic deposits located within some craters are only mentioned for a minority of structures that contain exploited deposits. Where presented, detail is limited, perhaps in favor of the aspects presented above. A preferred reference for economic aspects of impact structures is the paper by the same author published in 2005 in *Mineral Deposits and Earth Evolution* Special Publication of the Geological Society of London.

This Geotext volume provides a useful and concise summary of features in Canadian impact structures that will be of primary interest to those in the impact community. Given that there are few opportunities to provide such an amalgam of the history, literature citations, selected data, and geochronologic background for a set of craters, this review is of value. The volume will serve as a good starting reference on Canadian impact craters and is a fitting preretirement compendium of decades of study of these structures.

JAMES WHITEHEAD

SCIENCE AND TECHNOLOGY STUDIES
ST. THOMAS UNIVERSITY
FREDERICTON, NEW BRUNSWICK
CANADA
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