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See table of contents

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decipher the effects of Recent ecological and environmental change coupled with long-term Late Cenozoic environmental change. To this extent, the largest chapter, Part II, provides seven papers on diatoms as indicators of environmental conditions in flowing waters and lakes. These papers, which range from 12 to 43 pages in length, cover the use of diatoms for assessing and indicating environmental conditions in rivers and streams, hydrologic and climatic change in saline lakes, mediation of biogeochemical silica depletion in the Laurentian Great Lakes, surface water acidity, lake eutrophication, long-term environmental change, and water-level change in freshwater lakes.

Part III is devoted to the ominous sounding "extreme environments" to which many Canadians can also readily relate. Papers in this part present reviews on diatoms as environmental indicators near the Arctic and alpine treelines, in freshwater lakes of the High Arctic, in Antarctic freshwater, and in aerial habitats (soils, wet rocks, moss, *etc.*).

Part IV is devoted to marine and estuarine environments, with papers on diatoms as indicators of coastal paleoenvironments and relative sea-level change, environmental change in brackish waters, estuaries, shallow coastal environments, and marine paleoceanography. Coverage dwindles to some extent in Part V with shorter, but interesting, articles dealing with eclectic applications in archeology, oil exploration, forensic studies, toxic effects, atmospheric transport, and commercial diatomite deposits.

The book is written in review style to compile the rapidly accumulating and scattered information on applied diatom studies in a form that is readily accessible to interested readers. Illustrations are generally simple black and white graphs, maps, charts, and tables, all of which are legible and relatively consistent in appearance. By design, the book does not contain aspects of diatom biology, morphology, ecology, taxonomy, or biostratigraphy, which must be gathered from other sources. A useful glossary of terms is included. The index is adequate but many geographical names are not cited, so there is no direct way to search out specific geographic areas of interest. Nor is there an index to specific taxa.

The editors conclude with an epilogue dealing with the all too familiar problem of how to sustain the expertise and institutional infrastructure needed for basic taxonomic studies, biological studies, and full enumerations to document population communities and structures. Sophisticated tools for statistical analysis have overreached our ability to make basic observations and produce raw data. The trend towards directed research and client-oriented service makes it very difficult to obtain long-term goals for developing the fundamental basis needed for taxonomically oriented science. Although true, this may be a digression, for Stoermer and Smol consider this a time of rich opportunities for diatom studies applied to environmental analysis.

ESSAY REVIEW
Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective

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The discovery in 1975 of the giant Olympic Dam deposit on the Stuart Shelf of South Australia and the subsequent realization of its significance have attracted keen interest from the world's exploration industry, as well as research institutions. In the early years, there was little knowledge in the public realm about the deposit. By 1983, with the aid of underground exploration and development of the deposit, it became referred to as an iron oxide-rich "hydrothermal breccia complex" (Smith, 1993), and was thought to represent a unique deposit type (*i.e.*, new style of mineralization not previously recognized or explored for). Consequently, a rush to find a "look-alike" began. However, by the mid- to late 1980s, researchers and exploration geologists began to realize that there were broad metallogenic similarities between Olympic Dam and other deposits around the world. This realization culminated in the seminal paper by Hitzman *et al.* (1992) that distilled information, specifically for those deposits of Proterozoic age. Over the last decade, this class of deposits has become a prime target for exploration, resulting in the discovery of two major deposits which are now in production (*i.e.*, Candelaria in Chile and Ernest Henry in Australia), and several that are currently under development (*e.g.*, Sossego and Salobo in Brazil), from both the Proterozoic and the Phanerozoic. The attraction is obvious: the prize is both large and high grade (*e.g.*, 0.15-1 billion tonnes of around 1% Cu and 0.5 g/t Au), and has not previously been the subject of concerted exploration activity. Despite increased knowledge and level of interest and exploration, however, there is still disagreement on how these deposits formed and even which deposits belong to the class. Nor has it been possible to predict which deposits may be productive, subeconomic, or barren. The aim of this new volume is "to bring together a diversity of knowledge, experience and opinion from around the globe to assist in understanding this important family of deposits and answering some of the questions they pose" (Porter, this volume, p. 3-5).

This 350-page monograph includes the papers presented at the AMF International Conference "Hydrothermal Iron Oxide Copper-Gold & Related Deposits: A Global Perspective" held in Perth, Western Australia on 4-5 December 2000, and was distributed to the delegates as a Proceedings Volume. It contains additional papers, not presented at the conference. All 24 papers, including five of a "general" nature, five from Australasia, eight from the Americas, and six from Eurasia and Africa, were carefully selected and were included by invitation only. They cover most, but not all, of the world's important IOCG provinces. In all, there are 54 authors/co-authors,

representing an excellent cross-section of industry and research-oriented groups. The quality of all aspects of the publication is excellent. The volume includes 132 figures, including three full-page colour pages of rock specimens, 32 tables, and biographies of principal authors. As well, each paper has the appropriate reference notation. It might have been nice to have had lists of the figures and tables in an Appendix.

Authors of "general" papers cover specific topics or aspects relating to iron oxide copper-gold deposits. Authors writing on a province or individual deposit include an overview of the district/deposit's place in the tectonic, geologic, and metallogenic framework of the region as a whole, followed by a more detailed description of the geology, structure, alteration, mineralization, mineralogy, geochemistry, and other characteristics of the district/deposit. In addition, they address many questions relating to low-Ti iron oxides, the common feature/link of the iron-oxide copper-gold family of related deposits. Deposits range from Fe-apatite ores at Kiruna without any significant Cu-Au, to Fe-REE-F at Bayan Obe without significant Cu-Au, to the Fe-Cu-Ag without Au at Mantos Blancos, *etc.* They occur over an extensive depth range, from the ductile field as at Osborne in Australia, to a shallow brittle regime as at Olympic Dam. Many of the Proterozoic deposits are intracratonic; some Paleozoic systems are found on the continental margins above a subduction zone. The association of elements from varying geological environments, from basinal brines, to igneous associations or in metamorphic fluids has led many researchers to seek to identify a common genetic link between all the deposits attributed to the "family"; unfortunately, there does not appear to be a single model.

General Papers

Hitzman provides an update on the overall understanding of this family of deposits by first describing the nine key or important characteristics that 'connect' the end member deposits [*e.g.*, it now appears that although magnetite-apatite ("Kiruna-type") and iron oxide-Cu-Au deposits share many features in common, they may have fundamentally different origins], secondly by examining a number of districts in the context of a new model for this broad deposit family, and finally concluding with a discussion of the sources of ore fluids (*i.e.*, dominantly magmatically derived or wall-rock controlled) and the exploration implications of this new model. Deposits associated with orogenic basin collapse (*e.g.*, Cloncurry District, Australia; Grenville Province, Canada; Lufilian Orogen, Southern Africa), anorogenic magmatism (*e.g.*, Gawler Province, Australia; Southeast Missouri), extensional environments along subduction-related continental margin (*e.g.*, Mesozoic rocks of northern Chile; Pliocene rocks of the High Andes of northern Chile - northern Argentina), as well as other deposits that may be in the IOCG family (*e.g.*, Wernecke Mountains, Yukon; Mount Painter area, Australia; Vergenoeg, South Africa; Bayan Obo, China), are discussed. Hitzman emphasizes that there is probably a spectrum of deposits stretching from classic porphyry copper deposits to examples of both the magmatic-apatite and iron oxide-Cu-Au systems. The critical factor for making an iron oxide-Cu-Au system is the influx of non-magmatic, oxidized, saline, and relatively Cu-rich solutions.

Pollard examines evidence for the nature of the hydrothermal fluids, the source of the fluids, the nature of the associated intrusive rocks, and comparisons with porphyry Cu-Au deposits from worldwide deposits. Barton and Johnson, on the other hand, discuss alternative brine sources for IOCG systems; multiple sources are possible/likely. Yardley *et al.* discuss the chemistry of crustal brines and how recent analytical work is making it possible to characterize a much wider range of brine types. The section concludes with an excellent overview paper by Haynes, which looks at the IOCG deposits' position in the ore deposit spectrum and their modes of origin.

Australasia

Reynolds describes the detailed geology of the ~1590 Ma Olympic Dam Cu-U-Au-Ag-REE deposit. Tectonism, hydrothermal activity, dyke intrusion, brecciation, alteration and mineralization within the system were broadly concurrent and interdependent. The deposit is believed to have formed in a high-level volcanic environment, venting to the surface, and possibly forming a composite phreatomagmatic eruption crater, which has subsequently been completely eroded.

Williams and Skirrow provide an overview of IOCG deposits in the Curnamona Province and the Cloncurry district (Mt. Isa Block), both extensively metasomatized terrains. Data suggest a close temporal association with I-type granitoids, with mineralization being localized by a range of brittle-ductile and brittle structures.

Mark *et al.* describe the evolution of the >1510-1500 Ma Ernest Henry Fe-Oxide-(Cu-Au) hydrothermal system, hosted in an infill-supported, hydrothermal breccia. One page of colour photographs showing various rock types and alteration styles is included. The disseminated character of the sulphides in ore and the related halo suggest that the system is readily detectable using airborne and/or ground geophysical techniques. Teale and Famning describe the ~1605 Ma Portia - North Portia Cu-Au (-Mo) deposit, with particular emphasis on the timing of mineralization, albitization and origin of the ore fluid. Skirrow describes the Tennant Creek Au-Cu-Bi deposits of the Tennant Creek district. These represent some of the highest-grade deposits within the IOCG global family. He offers a reappraisal of diverse high-grade systems.

The Americas

In this section, deposits from Chile, Brazil, Missouri and Canada are included. Marschik *et al.* describe the Early Cretaceous Candelaria deposit and the Punta Del Cobre district in Chile. They suggest that hydrothermal activity, with an important magmatic component in the ore-forming fluids, in the region occurred coeval with the emplacement of the Copiapo Batholith and regional uplift. They suggest that burial at the time of mineralization did not exceed 2-3 km. Hooper and Correa describe the Panulcillo and Teresa de Colmo copper deposits from the Coastal Cordillera of Chile, as two contrasting examples of iron oxide-Cu-Au mineralization. The belt includes the Candelaria, Mantos Blancos, Manto Verde, and El Soldado deposits. Panulcillo is characterized as a pseudo-

stratiform FeOx CuAu/ skarn deposit, Teresa de Colmo as a multistage hydrothermal-tectonic breccia associated with the emplacement of a stock.

From Brazil, the Alemao Cu-Au(U-REE), the Igarape Bahia Au-Cu-(REE-U), and the Salobo iron oxide Cu-Au deposits are included. All are hosted in Archean metamorphic rocks that have undergone intense hydrothermal potash metasomatism. In general, they have a common spatial and temporal relationship between granitic intrusion and ore formation. Similarities in hydrothermal alteration patterns and ore mineralogy and chemistry indicate that these deposits could be part of the IOCG family of deposits.

In southeast Missouri, eight known major and numerous minor magnetite and hematite deposits, hosted in a Mid-Proterozoic granite-rhyolite terrain, are associated with caldera subsidence and sometimes trachyte ring intrusion. Deposits are within or near the margins of these structures, and within a major Proterozoic tectonic zone. Although, to date, only magnetite and hematite have been produced, potential for REEs, copper and gold exists. Characteristics and general chemistry of deposits from this metallogenic province suggest an association with iron oxide mineralization.

The Proterozoic iron oxide-Co-Au-Bi Nico and Cu-Ag Sue-Dianne deposits within the southern Great Bear Magmatic Zone, Northwest Territories, Canada is the only known significant Canadian example of the Proterozoic IOCG class. The deposits occur in a post collisional plutonic terrane, and are related to continental volcanic rocks and the emplacement of A-type rapakivi granite plutons (~1856Ma). Characteristics include both Salobo-type magnetite-rich schists and ironstones to Kiruna-type magnetite-apatite-rich veins and Olympic Dam sulphidized magnetite-hematite breccias. Two colour pages of rock types and alteration patterns are included.

Eurasia, Africa

Smith and Chengyu describe the geology and genesis of the Bayan Obo Fe-REE-Nb deposit in China, the world's largest REE resource, with estimated reserves of up to 1500 million tonnes of iron oxides (35 wt.% Fe), 48-100 million tonnes REE (6 wt.% REE_2O_3), and 1 million tonnes Nb (0.13 wt.% Nb). The deposit was formed by multistage hydrothermal replacement of Proterozoic marble. Although the source of the metals and fluids is uncertain, the deposit has many similarities to IOCG deposits, and also many differences such as the absence of significant base metals and absence of evidence of brines. The mineralization may be related to a carbonatite.

Iron oxide systems and base metal minerlaization in northern Sweden are described by Carlon. Four forms of iron mineralization are recognized, as being either stratigraphic or in brittle-ductile tectonic zones. Regional and local alteration is spatially associated with the mineralization; Cu-Au mineralization, which cuts the iron formations and magnetite-apatite bodies, is associated with the emplacement of granitic suites of 1.88-1.75Ga.

Nisbet *et al.* examine the exploration for iron oxide copper-gold deposits in Zambia and Sweden, and compare them with the Australian experience. The Zambian deposits occur in a Cambrian granitoid suite (A-type), with associated Fe-Cu-Co-U mineralization. They further suggest that the classic Copperbelt mineralization may also be of this age and genesis. In Sweden, the mineralization is associated with alkalic to A-type granitoids (1790-1895Ma).

Fourie describes the Vergenoeg fayalite iron oxide flourite deposit in South Africa. Massive iron oxides and associated breccias, with sulphides and REEs, occur in both the pyroclastics that form the roof of the Bushveld Complex, and the volcanic pipe that triggered the hydrothermal alteration and explosive volcanism.

The Phalaborwa (Palabora) deposit in Africa is the second largest copper mine in the world and the largest in Africa. Mineralization is hosted in a pipe and is interpreted to be the product of interaction of multiple pyroxenitic to carbonatitic magmas and their volatiles, which were ultimately derived from decompression melting of metasomatized mantle during extension. The orebody at Loolekop has many features that are consistent with being a proximal end-member of the IOCG deposit group. It is suggested that studies of carbonatitic complexes might provide useful analogies for understanding the mineralizing processes that have produced the large IOCG deposits.

Closing Comments

The iron oxide-Cu-Au deposits form a spectrum of intrusion-related Cu-Au deposits that also encompasses porphyry Cu-Au deposits. This spectrum reflects changes in oxygen and sulphur fugacities, chemical equilibria, temperature, and tectonic regime due to differing host rocks and levels of emplacement. All of these aspects are well addressed in this volume, thus making it the most comprehensive and up-to-date reference book for explorationists, researchers, and students interested in these large, difficult to find, but highly rewarding, deposit types. The overall production quality is very good, with excellent black and white drawings and some colour photographs, and no typographical errors to be found.

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