

HYDROTHERMAL IRON-OXIDE COPPER-GOLD & RELATED ORE DEPOSITS

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Abstract: Following the discovery of the giant Olympic Dam ore deposit in 1975, a realisation developed that there was an important class of mineral deposits not previously appreciated. It became apparent that this class, the Iron Oxide Copper-Gold deposits, included not only Olympic Dam, but also a number of other known deposits. It also became apparent that this was a class that could produce large, high grade prizes, of the order of 0.25 to 1 billion tonnes of around +1% Cu and 0.5 g/t Au. As a consequence this class has been one of the major targets of the exploration industry over the last decade, resulting in the discovery of further giant orebodies in Australia such as Ernest Henry, and Candelaria, Salobo, Sossego and others in South America.

This class of deposit however, does not represent a single style or a common genetic model, but rather a family of loosely related ores that share a pool of common characteristics. The principal feature they have in common is the abundance of iron oxides that accompany the ore and the intensity of the associated alteration, particularly albitisation and Fe metasomatism. The iron oxides are present as either magnetite or hematite and almost invariably precede the emplacement of the other economic minerals. These deposits are found throughout geologic time, around the globe and in settings from intra-cratonic, to continental margins above subduction zones.

There is a differences of opinion both on the processes involved in their formation, matched by the diversity in styles of mineralisation within the class, as well as which deposits should be included within the family.

The aim of this volume is to bring together a wide range of knowledge, experience and opinion from around the globe to assist in understanding this economically and geologically important family of deposits.

Introduction

The discovery in 1975 of the giant Olympic Dam ore deposit on the Stuart Shelf of South Australia, and the subsequent realisation of its significance, attracted keen interest from the world's exploration industry. In the early years however, there was little knowledge of what the deposit represented, and it was not until 1983 when underground test openings were developed into the orebody that the realisation dawned it was an iron oxide rich "hydrothermal breccia complex" (Smith, 1993).

At that stage Olympic Dam was believed to represent a unique deposit, an example of a new style of mineralisation not previously recognised or sought. Consequently it sparked a rush to find a direct "look-alike". However, by the mid 1980's researchers and exploration geologists from industry had begun to realise that there were broad metallogenic similarities between Olympic Dam and other deposits around the world and that it was part of a class of deposits that included many orebodies that were already

known. This realisation culminated in the seminal paper of Hitzman, et. al. (1992) that distilled this understanding in the public domain and drew together the common threads - specifically for those deposits of Proterozoic age.

Hitzman, et. al., (1992) focussed attention on the common mineralogy of these deposits, specifically that the ores are dominated by iron oxides, usually with low Ti, present as either magnetite or hematite, with magnetite tending to prevail at depth and hematite towards the surface. In addition there is commonly an association of carbonate, Ba, P and F, with significant accompanying concentrations of light REEs. The hosts and surrounding rocks are also generally intensely altered, ranging from extensive sodic zones at depth and regionally, to potassic at shallow to intermediate levels, and sericite and silica near surface, while the hosts and surrounding rocks are intensely to variably Fe-metasomatised.

Deposits Hitzman, et. al., (1992), incorporated in this class included, in addition to Olympic Dam, Kiruna in Sweden,

the Great Bear Magmatic zone in Canada, the Wernecke Breccias in Canada, the SE Missouri Iron Province in the US, Bayan Obo in China and the Redbank Breccias in Australia. Since then the list of orebodies that different authors assign to the family has been significantly expanded (see Haynes this volume and Pollard, this volume for lists of deposits, size, mineralogy, etc.).

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 (Candelaria in Chile and Ernest Henry in Australia) and several that are currently under development (eg. Sossego and Salobo in Brazil), from both the Proterozoic and the Phanerozoic. The attraction is obvious - the prize is both large and high grade and has not previously been the subject of concerted exploration activity, and as such is "still out there to be found".

However, despite the level of interest and exploration over the decade, and the increase in our knowledge of these deposits, there is still disagreement on how they are formed and even which deposits belong to the class. Nor has it been possible to predict barren ironstones from those that contain economic mineralisation. The aim of this 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.

A Family of Related Deposits

The iron oxide copper-gold (IOCG or FeOx-Cu-Au) class represents a family of loosely related deposits each of which shares some characteristics from a larger pool. Deposit A may overlap with B, B with C, and so on, although A and G might display significant differences.

By definition their common link is the association of low Ti iron oxides with the ore. They range from Fe-apatite ores as at Kiruna without any significant Cu-Au, to Fe-REE-F at Bayan Obo, again without any Cu or Au of economic value, to the Fe-Cu-U-Au-REE of Olympic Dam, and the Fe-Cu-Ag without Au at Mantos Blancos, etc. They also occur over an extensive depth range, from the ductile field as at Osborne in Australia to a shallow brittle regime as at Olympic Dam (Pollard, 2000). Many of the Proterozoic deposits are intracratonic, while some of the key Palaeozoic systems are found on the continental margin above a subduction zone (Hitzman, 2000). Indeed there are also deposits, such as Palabora that some say are key members the family (Vielreicher, et. al., this volume), but which others believe are un-related.

While some researchers seek to identify a common genetic link between all of the deposits attributed to the family there does not appear to be a single model that all obey, although specific models may be invoked with great success for particular groups of deposits or regions (Pollard, 2000, Dostal, 2000, etc.).

apply well to particular deposits, while hybrids could as readily apply in other cases.

Others believe that the family represents a number of different styles of deposit that share particular characteristics (Groves, pers. comm.). The association of elements may be no more than a compatibility of chemistry related to solubility, the common modes of both hydrothermal transport and of precipitation encountered in the Earth's crust, in much the same way that lead and zinc are associated in a wide variety of geological environments, from basinal brines, to igneous associations or in metamorphic fluids. In fact both iron oxides, copper and gold may be transported in, and deposited from all of these media under the right conditions (Yardley, et. al., 2000)

As detailed above, these deposits are characterised by an abundance of iron oxide and a relative deficiency of iron sulphides. Almost invariably gold, and copper occurring as a sulphide and often accompanied locally by substantial pyrite and/or pyrrhotite, overprints or sulphidises/replaces earlier emplaced iron oxides. The iron oxides may be an early evolutionary phase of a continuing hydrothermal event, possibly as at Olympic Dam, or alternatively be a little related pre-existing ironstone emplaced in or along structures that continue to act as fluid conduits through geological time. Examples of the latter are in the Tennant Creek field in northern Australia (Skirrow, submitted) where only a small percentage of the 600 known early stage ironstones of the district are mineralised, or in the iron belt of Chile where there are a significant number of ironstones, many of which are barren (eg. El Romeral) and some (eg Mantos Blancos) which are mineralised.

Haynes (this volume) points out that the deposits of this class are part of a broader spectrum of ores whose mineralogy and form are the result of the surrounding country rock, its composition, oxidation state, chemistry, metal endowment, fluid and heat engine availability and structure. Similarly the iron oxide copper-gold deposits have characteristics in common with the ironstone gold deposits of the Archaean and Proterozoic.

This Volume

This volume brings together a collection of new contributions from some of the world's top experts on iron oxide copper-gold and related deposits, and on the behaviour of fluids in the Earth's crust, to discuss these deposits and their development from differing viewpoints. It also incorporates papers covering most of the world's important "iron oxide copper-gold" provinces, as well as practical descriptive papers on the best examples of these orebodies from right around the globe, written by industry geologists and other renowned experts.

All papers have been by invitation only, with the most appropriate available authors being selected or accepted.

ensure consistency and that the main theme was followed. While the general papers of the first section were requested to cover specific topics or aspects, those writing on a province or individual deposit were asked to 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, mineralisation, mineralogy, geochemistry and other characteristics of the district/deposit. In addition they were requested to address the common feature of the iron-oxide copper-gold family of deposits, namely the iron oxides, including questions such as - how were the iron oxides formed and/or emplaced, and what do they imply about the ore forming conditions? What are the spatial, temporal and chemical relationships between the iron and (other) economic mineralisation, and what part did the iron oxide play in the development and localisation of ore? What are the critical chemical and structural controls on ore? What new ideas have arisen from the author's research and investigations relevant to the understanding of this class of deposit?

Acknowledgments

The author wishes to thank the Management of the Australian Mineral Foundation for entrusting to him the content, design, organisation and editing of the both this volume and the technical program of the associated conference, "Hydrothermal Iron-oxide Copper-gold & Related Deposits: A Global Perspective. The theme of the volume and the conference arose from a discussion with and a suggestion from Kerry O'Sullivan, now Manager Professional Development with the AMF. Kerry was also involved in securing some of the keynote speakers. The cooperation received from Donna Biddick, Professional Development Coordinator and her staff who have so efficiently organised and managed the conference is deeply appreciated. Thanks are due to Lyn Porter of Porter GeoConsultancy who has with diligence and persistence prepared the master electronic file from the many and varied data files received from the authors. Thanks also to all of those throughout the industry, both in Australia and internationally who were consulted and offered advice on the content and program, but particularly to the authors of the 24 papers who are to be congratulated for the high quality of their contributions and for so readily agreeing to participate.

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