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REVIEWS

Orebody Modelling and Strategic Mine Planning. R. Dimitrakopoulos, Editor. Pp 402. The Australasian Institute of Mining and Metallurgy Spectrum Series 14. Second edition. 2007. ISBN 978-1-920806-76-7. Price (outside Australia) hardcopy A$80.00, CD-ROM A$60.00.

This volume follows the eponymous conference held in Perth, Western Australia, in November 2004. This second edition "includes new developments." One-half of the case studies named in the title apply to Western Australia, with the remainder being scattered over other continents. The majority of articles discuss principles, so the value of the book is not impaired by a parochial focus. Authors are similarly distributed, and all regions have their champions. Authors include academics, senior managers, consultants, but few at operational level.

The printed text is very crisp and eminently legible. There is abundant illustration, all in black and white. The quality of figures and photos is variable, generally fair, but some line work is quite pixelated. Some diagrams are formerly color slides from the conference and so have unintelligible black-and-white scales. Some are too small. References are listed for each paper and appear to be adequately modern. There is no subject index.

The volume contains 8 chapters and 50 articles. The chapters are summarized as follows:

Risk Management: Mine optimization incorporates the certainty that variables are uncertain. A secondary product represented as primary-product equivalent is treated by a risk valuation method from the finance industry. The inherently limited and uncertain data on which management decisions are based leads to an understanding of the scale (time, space, number of samples) needed to comprehend variables. Conditional simulation methods on the dichotomy of local accuracy-global representation and other variable conditions are examined. Methods for evaluating variables not accommodated by commercial software are presented.

New Conditional Simulation: Techniques, principles, and practice of conditional simulation of orebodies and their inherent uncertainties are discussed, including multiple-point geostatistics; computational efficiency and data management in large models using sequential Gaussian, direct block simulation; and model updating by conditional simulation by successive residuals. Stochastic modelling of the probability of occurrence of geological boundaries and of faults is introduced. Conditional simulation of an ilmenite deposit demonstrates risk management in the resource model.

Conventional Mine Optimisation: New developments of the Lechs-Grossmann pit design optimization algorithm aim at increased computational efficiency, by aggregating mining blocks. The complexity of mine scheduling and sharing of infrastructure between several mines is discussed. New software tools, some in-house, used in mine optimization (pit planning, blending, in-pit dumping, mineral processing) are introduced. The benefit of optimization to Chuquicamata open pit is demonstrated. Underground mining is also served by new software for development optimization.

Large-Scale Applications: Grade interpolation is compared with conditional simulation for estimating unknown short-scale variability in grade. Examples from a laterite mine discuss optimization using Net Value cutoffs in waste in place of individual cutoffs for grades of Ni, Co, and penalty elements, and in a gold mine of multi-pit scheduling. In underground operations, stope designing and exploration drilling can be optimized for grade uncertainty and variability. Other approaches to geologic-grade uncertainty and pit design are treated in terms of minimum requirements of the mine and decision-making criteria.

Uncertainty and Reserves: The regulatory situation surrounding reserves and resources requires rigorous presentation to investors. A Competent Person coordinates resource and reserves estimates, incorporating her evaluation of risks and uncertainty in sampling, models, sale, and revenue estimates, and tenure. For the Koniambo Ni-Co laterite-hosted deposit, feasibility study and resource classification are described in terms of sampling protocol, reconciling low-density data with local close-spaced data, 3-D geologic models, and risks in ore continuity. The balance is evaluated between greater confidence in block models and the costs of drilling. Stochastic modelling of risk is introduced to coal mining by case studies.

Geotechnical Risk: Hazard and likelihood in mine design include geomechanical factors such as rock fall, dilution, rock burst, and slope failure. This 'data limited' work is a key feature of geotechnical risk management. Failures of mine design within WA's regulatory framework are illustrated by examples. Prototype economic optimization enhances strategic planning in South Africa.

Blending Optimisation: Ore blending can enhance performance and lower costs through managing contaminants, by pit designs that avoid contaminants, and managing ore supply to different mills. Increasing net present value (NPV) and satisfying various corporate goals by optimization to higher cutoffs carry the possibility of increasing downside risks. Commercial Optimal Mine Exploitation Technology (COMET) optimizer software, which analyzes cutoff, mine schedules, mill throughput, and recovery, is presented. The effect on financial return of grade uncertainty, dilution, and ore model block size is discussed. Hybrid or nested pits derived from conditionally simulated models can manage risk by taking advantage of the increase in knowledge and decrease in uncertainty as mining advances.

New Technologies: Integrated optimization techniques apply to different parts of the mining process and identify the main drivers in increasing NPV. Advances in schedule optimization and open-pit mining rates are discussed. A computationally efficient method is presented on joint conditional simulation of several variables (minerals-metals). New 3-D models of geologic structures that incorporate uncertainty in interpretation utilize the potential-field method.

Geostatistical simulation is applied to blasting, ore loss-dilution, excavating, and loading. Other new models of simulation and optimization apply to extraction sequence and cutoff grades. Multiple simulated ore models may improve production scheduling. Finally, a call is made to sustain research and development in the mining industry.

The book focuses on the modelling and statistics of ore grade and, to a lesser extent, financial modelling in mine planning. Other aspects—milling, metallurgy, and dewatering—are not discussed. The former are the aspects of mining closest to the concerns of explorers. One value of this volume to the exploration geologist or researcher is that it can remedy the ignorance of what constitutes a mineable resource. Understanding how a resource modeller thinks can aid in the way advanced exploration prospects are brought to the productions stage. Its value is, therefore, substantial to SEG members concerned with exploration as a prospect approaches production, but much less for those concerned with geology and genesis alone.

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Palladiferous Gold Mineralisation (*ouro preto*) in Brazil: Gongo Soco, Itabira and Serra Pelada. Alexandre Raphael Cabral. Softcover. Pp. 115. E. Schweizerbart'sche Verlagsbuchhandlung Science Publishers. 2006. ISBN 3-510-95954-X/9783510959549. Price $29.99 GBP.

This book gives a descriptive insight into the weathered nature and oxide mineralogy and petrology of three epigenetic Au-Pd-(Pt) orebodies within two distinct geologic terranes of Brazil. A thorough and descriptive petrological review of the Gongo Soco and Itabira *jacutinga*-type palladiferous gold orebodies, within the Quadrilátero Ferrífero, is used to compare these systems with the bonanza grade Au-Pd-Pt mineralization of the infamous Serra Pelada deposit in the Carajás mineral province. The volume also briefly describes deposit geology and possible fluid sources and characteristics for the various Au-Pd-(Pt) orebodies. However, it is the detailed petrological descriptions of the oxidized orebodies that adds significantly to the limited literature covering these epigenetic Au-Pd-(Pt) deposits. These descriptions greatly advance our understanding of these unique epigenetic Au-Pd-(Pt) deposits, which are broadly spaced in different parts of Brazil.

The book is composed of three main bodies of work that cover individually the banded iron formation-hosted Gongo Soco and Itabira *jacutinga*-style Au-Pd-(Pt) deposits and the carbonaceous rock-hosted Serra Pelada Au-Pd-Pt orebody. Descriptions of the three individual deposits each include brief geologic overviews of the deposit host rocks, deposit histories, and, in the case of the Quadrilátero Ferrífero deposits, descriptions of the more typical palladiferous gold mineralization, or *ouro preto* (black gold). The ouro preto is located within numerous *jacutinga*-style (specular hematite-rich veins) within the Paleoproterozoic banded iron formations of the Quadrilátero Ferrífero, central Minas Gerais state. The strength of the individual deposit descriptions is the thorough and detailed petrographical studies of the secondary Au-Pd-(Pt) mineral characteristics that is eloquently displayed with scanning electron microscope imagery from each deposit. The petrological studies are accompanied by electron-microprobe data, fluid inclusion microthermometry, and bulk-rock geochemistry for each deposit to further characterize their individual natures. In conclusion, the author discusses the Au-Pd-(Pt) composition of each deposit, gold-related mineral assemblages and the formation of secondary auriferous and palladiferrous gold mineralization within the Quadrilátero Ferrífero, and possible sources of ore fluids. The regional aspects of palladiferous gold mineralization within the Quadrilátero Ferrífero and Carajás mineral province are also briefly presented.

The author is to be congratulated on his descriptive work that has focused on the secondary nature and petrology of these unique epigenetic Au-Pd-(Pt) deposits that have, to date, only been marginally described in the scientific literature. This work will add greatly to the geologic understanding of these unique deposits within Brazil and globally.

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The Archaeometallurgy of Copper. Evidence from Faynan, Jordan. Andreas Hauptmann. Pp 388. Springer, Berlin-Heidelberg-New York, 2007. ISBN 978-3-540-72237-3. 106.95 euros.

The Faynan copper district in Jordan is one of the most important historic and long-lived mining sites in the Old World with a 9,000-year-history of copper ore (pigment) production, and 5,000 years of copper smelting from the Chalcolithic and Early Bronze Ages to the Roman and Early Islamic periods. It is located in the Wadi Arabah, the Dead Sea rift-valley system that extends from the Dead Sea to the Red Sea. Ongoing Cenozoic strike-slip movement has displaced the Faynan copper district 100 km northward, from the geologically identical and equally famous ancient Timna copper district along the Gulf of Aqaba in Israel. The copper deposits in the Faynan and Timna districts belong to the family of stratiform, sedimentary rock-hosted copper deposits. Host rocks are part of a transgressive Early Cambrian lagoonal sequence (conglomerate, sandstone, and dolomite) that overlies undeformed Late Proterozoic volcanic-arc rocks and Proterozoic crystalline basement, which are products of incipient rifting within the Arabian-Nubian craton at the western margin of Gondwanaland. The copper mineralization (mostly chrysocolla, with malachite, paratacamite, cuprite, and minor chalcocite) is strata bound and occurs over a few meters width in flat-lying arkosic sandstone, dolostone, and shale. Most of the copper mineralization is in a 1- to 1.5-m-thick shale unit, which also hosts phosphorite nodules, as well as barite and manganese oxides, and is locally enriched in uranium. The

Faynan copper district still contains an attractive resource of about 20 Mt @ 1.35 percent Cu over a 30 km^2 area at the Faynan deposit, as well as 25 Mt @ 2.3 percent Cu over a surface area of 60 km^2 in the Um El Amad/Wadi Malaqa region a few kilometers north of the Faynan deposit (see www.nra.gov.jo). However, both areas are inside the Dana Nature Reserve, where mining is not allowed. It is interesting to note that the neighboring and geologically similar, although smaller, Timna copper district in Israel is currently developed by the Mexican company AHMSA, which will invest 160 million USD for a 45,000 t Cu/year project to start production in 2009.

This book treats a much wider range of subjects than what one would expect from the title. It is written by a mineralogist, now professor of archeometallurgy at the Ruhr University in Bochum, Germany, and head of the Deutsches Bergbau-Museum. The text is easy and pleasantly written, with a surprisingly wide multidisciplinary background of knowledge and modern analytical techniques. Although the Faynan district is the focus of this study, based on a decade of field work by the author, the book provides an excellent overview on geology and metallurgy of ancient ore deposits in the broader eastern Mediterranean region and Near East, including an abundance of data (particularly lead isotope data) on copper and lead ores, slags, and metal artefacts. In a very detailed and systematic way, the ancient mining and smelting activity in the Faynan district is perfectly documented and reconstructed in space and time.

The chronological pattern of ^{14}C dates of charcoal demonstrates that the deposits have been exploited for approximately 9,000 years. The early mining period (Pre-Pottery Neolithic period; oldest ^{14}C age: 7680 ± 120 BP) was for the spectacularly green copper minerals which were used as pigments and beads. Copper metal production via smelting, which requires the production of lime plaster by firing limestone at 800° to 900°C, is first documented at about 3,500 BC, and marks the transition to the Early Bronze Age. Numerous mining sites and settlements at Faynan provide the most extensive and best-preserved evidence of Early Bronze Age copper mining and production in the Old World. The earliest extractive metallurgy was relatively ineffective, and the slags contain 10 to 60 wt percent Cu, mostly as cuprite. This high metal grade testifies to the very high grade of the ore mined at that time. In the Middle Bronze Age, the extraction of copper in Faynan (and parallel in Timna) diminished sharply, probably due to increased copper mining in Cyprus. Cypriot copper production and export reached its peak between 1800 and 1200 BC, but then dwindled. Faynan copper production reached industrial proportions at 1000 BC, with the use of steel tools and the first recycling of Early Bronze Age slags. The overall tonnage of Iron Age slag heaps has been estimated at more than 100,000 tonnes. Mining continued under Roman control until about 500 AD, when the role of Faynan as one of the large copper production centers in the Southern Levant was generally finished, although there was sporadic minor activity during the Islamic period. The ore was mined both in open pits and underground. The famous Umm el-Amad mine, with horizontally striking stratabound copper mineralization, dates back to Chalcolithic mining activity, was exploited in Roman times by room and pillar methods, and is one of the best preserved mines of the entire Roman empire.

About one-third of the book is dedicated to the archeometallurgy of copper, sensu stricto, i.e., the mineralogical and chemical composition of the historic slags and copper metal from the Faynan district, and early copper smelting technology in general. These chapters include detailed field observations of the ancient smelting process, and they also provide in-depth explanations that even include thermodynamic interpretations. The last chapter is on metal trade in prehistoric Palestine, and metallurgical development in the 4th and 3rd millennium BC between Egypt in the west, the Sinai Peninsula in the south, Syria and Anatolia in the north, and Mesopotamia in the east. It appears that green color pigment, the main product of the Faynan mining district in the early stage, is an exclusive trademark of the late Pre-Pottery Neolithic period, after the previous black-red pattern made from iron and manganese (hydro-) oxides, well known from Paleolithic cave paintings. This use of "greenstone" (as various green materials are called, collectively, in archeology) accompanies the fundamental cultural change from food gathering to food production.

The book is superbly produced, with high-quality illustrations, some in color, and has an enormous amount of data over the broad spectrum of geology-mineralogy-metallurgy-archeology. It is very stimulating reading beyond the usual feed of economic geologists, and recalls the deep roots of our business.

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The Archaeometallurgy of Copper. Evidence from Faynan, Jordan. Andreas Hauptmann. Pp 388. Springer, Berlin-Heidelberg-New York. 2007. ISBN 978-3-540-72237-3. EUR106.95.

Granite Genesis: In-Situ Melting and Crustal Evolution. Guo-Neg Chen and Rodney Grapes. 278 p. 218 illustrations. Hardcover. ISBN: 978-1-4020-5890-5. Price USD$129.00.

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