American Mineralogist, Volume 96, pages 1190–1191, 2011

BOOK REVIEW

QUANTITATIVE MINERAL RESOURCE ASSESSMENTS: AN INTEGRATED APPROACH by Donald A. Singer and W. David Menzie. (2010) Oxford University Press, 232 pages. $74.00. ISBN: 978-0-19-539959-2.

This book is a record of the life work of a recently retired and decorated U.S. Geological Survey geologist, Donald A. Singer, who addresses a topic that is of primary interest and importance to mining and exploration companies, but also to many other decision makers, many of whom may not be directly connected to Earth sciences, e.g., land-use planners, investment bankers, and politicians.

The title is a little misleading as one may think that the book may be about a numerical approach to estimating the contained value of specific, already identified, and proven mineral resources, but it is rather about predicting what mineral resources are out there waiting to be discovered, in so-called "permissive tracts" of land. The title would have been more complete if it had included the phrase "undiscovered mineral resources."

The core idea presented is that there is a predictable distribution of mineral deposits in terms of type, location, size (tonnage), grade (contained metal content), and number. Compilations of minerals deposits by type (or model, e.g. porphyry copper or Kuroko-type) are used define distributions (in a statistical sense) of deposits in terms of grade and tonnage. This forms the first part of the "Three-part Mineral Assessment" methodology developed by the senior author for the USGS. The other two are the mineral resource map and the estimated number of undiscovered deposits.

The authors state in the preface that this book was written mostly for users or practitioners of assessments. As a non-user and non-practitioner I found the style and flow of the book and methodology somewhat confusing and irritating, and that I had to resort frequently to other published sources to find the reasoning and logic about statements made in the text, and in many cases the data used to formulate the distributions. Fortunately, most of these other sources were readily accessible through the excellent USGS open file system. By reading the original sources one realizes two things, first that much of the text has been copied verbatim from original papers and reports, and second that the methodology has been seriously questioned in the past, and that many of the questions that arose in my own mind while reading the book, had already been addressed. The former observation possibly explains my frustration with the book, in that it has not been well thought out as a logical sequence of topics, but rather a miscellany of extracts from previous papers and reports, some of which appear out of context where they are placed in the book.

The authors should be lauded for revealing previous misgivings about their methodology, but then they did receive an endorsement of their methodology from the comprehensive study conducted by the University of Arizona (see Harris and Reiber 1993, USGS Open File Report 93-258-A). This review also listed several suggestions for improvement, including one for clarification of the methodology, one that seemingly has not been met, and persists in this book. The University of Arizona review team do provide a strong endorsement for the statistical approach used in the method, and importantly conclude that it is unbiased and systematic, something clearly absent for comparative estimates made by so-called "expert" geologists, many of whom have clearly not impressed the senior author.

There is considerable reliance placed upon porphyry type mineral deposits (of copper, gold, silver, and molybdenum) in this book, with some liberal reference to others such as Kuroko-type massive sulfide deposits. Other mineral deposits are given very light or scant treatment, leaving the reader to wonder how well the method actually works with other types of deposits. One is also left wondering about deposit models and the generalizations made in such models and considerable real-life variations from such models, and the human desire to classify natural phenomena. The recent review paper by Sillitoe (2010, *Economic Geology*, vol. 105, p. 3–41), highlights the variability of porphyry type deposits, and the fact that some mineralization is associated with incidental sedimentary rocks that may or may not have been eroded subsequent to the mineralizing events. This hints at complex situations that may challenge simplistic classification and complicate the deposit models on which the method is so reliant. Which of these mineralized portions are included or excluded from deposits models, especially when some elements may not always be present in a specific permissive terrain that is under review? It is not always clear that factors such as the amount of post-mineralization erosion are factored into the deposit models that are applied to new areas under review.

The authors make a strong case for economic filtering to be applied to assessments, a recommendation with which I strongly concur. It is an area where significant variability is prevalent, both in the value of the commodity being recovered and in the cost of extraction. It has become patently clear that recent increased demand on commodities from emerging markets (and hence increases in commodity prices) have affected the viability of many mineral deposits and established mines. Given this knowledge then, how applicable are the grade-tonnage models that were formulated a decade ago? The recently announced expansion of one of the world's largest copper mines (Bingham) is a case in point. The new area to be mined adds significantly to the tonnage, but lowers the overall grade because lower grade ore

0003-004X/11/0007–1190$05.00/DOI: 10.2138/am.2011.575

has become economically viable as a consequence of the rise in the copper price. This means that Bingham's position on the grade-tonnage curve has changed. It could be argued that the grade-tonnage model changes every time a new mine plan is constructed as these mine plans are based on current-day economic cut-offs, and therefore that the models used are transient at best, and would require regular updating to be meaningful. It also raises the question whether a land-use decision made a decade ago are relevant to the economic realities and priorities of today or tomorrow.

The second last chapter of the book considers exploration risk. A topic of considerable interest to mining companies, but also to investors many of whom are lured by the potential of very high returns, but seldom appreciate the dangers of the highly skewed probability distributions and extreme rarity of world class mineral deposits. Several risk reduction strategies are proposed including increasing the number of projects examined, applying economic filters of size and grade, exploring around known deposits, and exploring favorable tracts of previously unexplored or covered areas in the hope of finding the first (and often largest) deposit in a region. While this chapter presents a common sense approach to ways of reducing mineral exploration risk, I find the last line of the chapter most appropriate and telling, and I quote: "Perhaps the most important way to reduce exploration risk is to employ personnel with the appropriate experience and yet who are still learning," because it underlines the fact that all the most sophisticated statistical analysis in the world does not replace critical human judgment from assessing mineral resource potential, and in particular the experienced practitioner's ability to deal with variations from the defined norm. An explorer's worst nightmare would be to walk away from a deposit they have discovered, only for someone else to turn it to good because of some oversight based on preconceived dogma.

In the final chapter, the future of this type of mineral resource assessment techniques are considered. Here several limitations of the methodology are highlighted, and in particular some focus is placed on grade-tonnage models that lie at the very heart of the process. While more sophisticated technologies such as probabilistic neural networks are suggested, it is the input data, the geological models, and the volatile economic factors that are required as filters, which are most important and require a system that is both robust and updatable. The authors also highlight the recognition of permissive tracts under cover and methods for assessing such areas as important areas of development, and they call for improved geophysical methods and structural geological interpretations. Again, the quality of geological work conducted by "expert economic geologists" is probably the most important component of advancing the methodologies.

In conclusion, this book is a useful guide to those "users or practitioners" who wish to find a golden thread through the development of techniques with which they are probably very familiar. To those who are new to the subject, like me, perseverance is advised, and reading much of the quoted literature is essential. The techniques applied appear to be very sound, but questions around the grade-tonnage models and the identification of permissive tracts will remain debatable. I found that applying the technique to my area of interest gave me greater insight into the technique.

MATTHEW FIELD
Mayfield, Wells Road
Wookey Hole
Wells, Somerset
BA5 1DN, U.K.