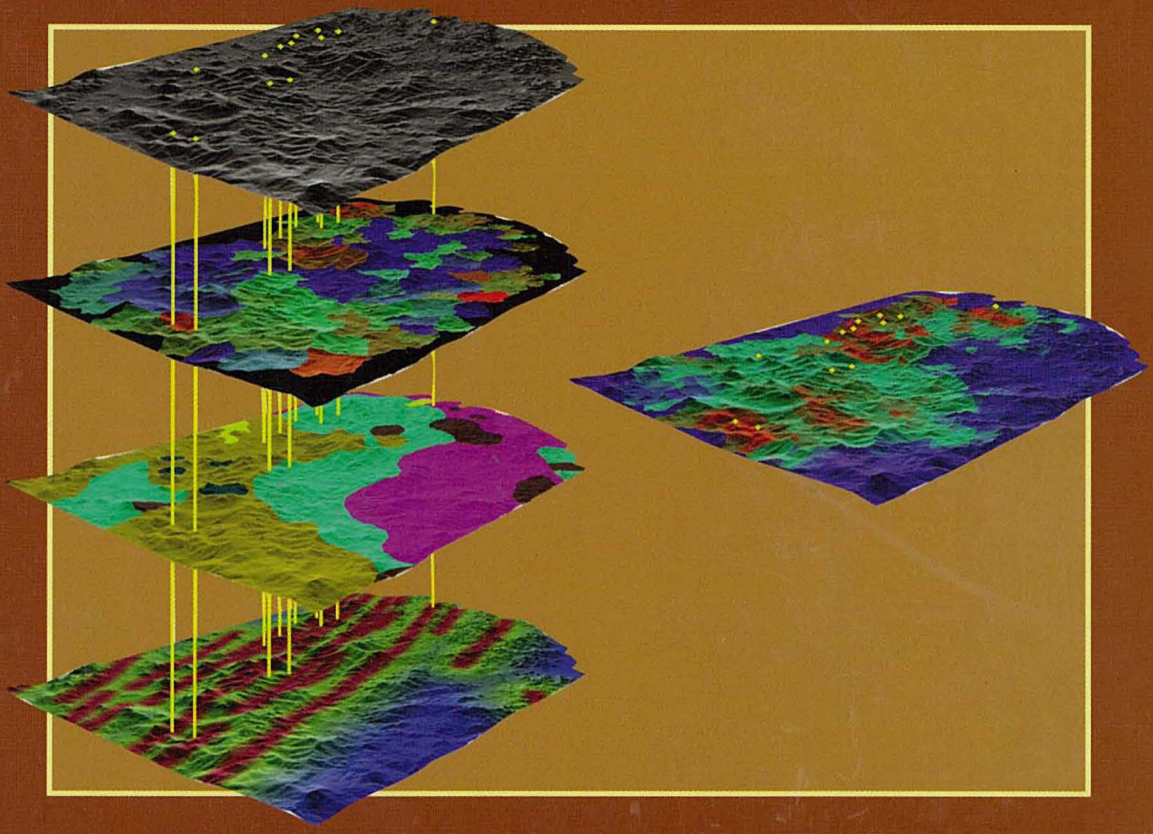
HANDBOOK OF EXPLORATION AND ENVIRONMENTAL GEOCHEMISTRY 11
M. HALE (SERIES EDITOR)

GEOCHEMICAL ANOMALY AND MINERAL PROSPECTIVITY MAPPING IN GIS

EMMANUEL JOHN M. CARRANZA



Handbook of Exploration and Environmental Geochemistry

VOLUME 11

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EDITOR'S FOREWORD

In this volume John Carranza not only offers a comprehensive review of the current state-of-the-art of processing geochemical data, their integration with complementary geodata sets and multivariate data analysis using spatial statistics to create maps enhanced for mineral exploration, but also brings the Handbook series to something of a milestone. This marks the first volume in which the topic of an earlier volume (Vol. 2) is in effect revisited and updated; though the approach and format are – appropriately – entirely fresh.

Part I of the volume (chapters 1-2) introduces the concepts and methods of handling spatial data in a geographical information system for the purpose of predictive modeling for mineral exploration. Part II (chapters 3-5) looks in detail at geochemical data and how they are analyzed, classified, synthesized and attributed to catchment basins prior to their application in predictive modeling. Part III (chapters 6-8) begins by emphasising the importance of additional relevant spatial information and culminates in predictive modeling of mineral prospectivity by means of a range of knowledge-driven and data-driven methods. Throughout the volume there is a wealth of well-illustrated real-world examples. The author admirably demonstrates modern approaches to data analysis and interpretation in mineral exploration in ways which exploration professionals can appreciate and adapt to their exploration programmes.

This volume is the first in the series to go to press after the death in 2007 of John S Webb, whose achievements and influence in exploration and environmental geochemistry did much to lay the foundations for the series. In the 1950s he established the Geochemical Prospecting Research Centre at Imperial College, London, where his pioneering work in exploration geochemistry was soon extended to regional geochemical mapping and environmental geochemistry (leading to the centre being renamed the Applied Geochemistry Research Group). Many destined later to be closely associated with the Handbook series were Webb's PhD students or colleagues at Imperial College: K Fletcher (Vol. 1); Richard Howarth (Vol. 2); Gerry Govett (Vol. 3, series founder and series editor Vols. 1-7); Charles Butt (Vol. 4); Martin Hale (Vols. 6-7 and series editor Vols. 8-11); and Colin Dunn (Vol. 9). In authoring Volume 11, John Carranza, being a former PhD student (and now professional colleague) of Martin Hale, has extended this tradition into the third generation.

Having in some ways brought the series full circle, Volume 11 also shows that geochemical data now constitute just one of several types of data brought together and analyzed together using geographical information systems to yield information to guide mineral exploration. The Handbook series has amply fulfilled Gerry Govett's original vision of thoroughly documenting the value of exploration and environmental

geochemistry. Whilst the value of geochemical data remain undiminished in mineral exploration, John Carranza most eloquently shows here that the time has come when this value is best realized when geochemical data are part of wider armoury of complementary geodata sets and modeling techniques.

MARTIN HALE
The Netherlands
May 2008

PREFACE

Twenty-five years ago, when the second volume of the Handbook of Exploration Geochemistry was published (Howarth, 1983), computers were just becoming useful tools in the analysis of mineral exploration data sets but mapping of geochemical anomalies and prospective areas still usually involved overlaying transparent geochemical map(s) and a geological map on a light table. The late 1980s through the 1990s saw rapid and far-reaching developments in quantitative techniques for mapping geochemical anomalies and mineral prospectivity due to the substantial improvements in the efficiency and availability of computer hardware and software (Agterberg, 1989) including geographic information system (GIS) technology (Burrough, 1987; Bonham-Carter and Agterberg, 1990; Maguire et al., 1991). Two textbooks and several papers published in exploration-related literature have explained and documented various GIS-aided and/or GIS-based methods for analysis of multiple geoscience spatial data sets in order to derive and synthesise pieces of geo-information that are pertinent to the decision-making process at every scale of target generation in mineral exploration. In "*Geographic Information Systems for Geoscientists: Modelling with GIS*", Bonham-Carter (1994) introduced ideas and methods of spatial analysis and modeling in GIS, especially those that are useful for characterising spatial associations between a set of geo-objects of interest (e.g., deposit-type locations) and individual sets of (indicative) spatial features (e.g., geochemical anomalies) in order to develop predictive models of the former set. In "*Information Synthesis for Mineral Exploration*", Pan and Harris (2000) introduced various methods for optimal assimilation of specific pieces of geo-information extracted from various spatial data sets in order to derive optimised geo-information for decision-making in mineral exploration. Nowadays, mapping of geochemical anomalies and/or prospective areas involves stacking digital geochemical and geological maps on top of each other on an electronic light table (i.e., in a GIS).

The objective of this book is to document, survey and demonstrate various GIS-aided and/or GIS-based techniques for mapping of geochemical anomalies and prospective areas during the target generation phase of mineral exploration. This volume consists of three parts, all centred on the theme *predictive modeling* or *mapping* and built upon particular notions and/or methods presented in the aforementioned textbooks and in various papers in exploration-related literature. Built upon the natural link between mapping of exploration targets and GIS, the chapters in Part I review and couple the concepts of (1) mapping geochemical anomalies and mineral prospectivity and (2) spatial data models, management and operations in a GIS. Built upon the remarks of Reimann (2005, pp. 369) that "*Although GIS techniques appear to have simplified geochemical mapping tremendously, most systems do not allow for fast and correct class*

selection for mapping...", the chapters in Part II demonstrate GIS-aided and GIS-based methods for analysis of robust thresholds in mapping of geochemical anomalies. Built upon the notion that locations of mineral deposits of the type sought are intrinsic samples of mineralised landscapes, which are results of interactions of geological processes, the chapters in Part III explain GIS-aided and GIS-based techniques for spatial data analysis and geo-information synthesis for conceptual modeling and predictive modeling of mineral prospectivity. The essence of this book is, therefore, the prudent (thus, not black box) utilisation of GIS in mapping of geochemical anomalies and prospective areas through the application of understanding of relevant earth systems or processes that led to the formation (and/or alteration) of these geo-objects.

Each chapter in this volume is meant to be self-contained. The chapters in Parts II and III are, however, coherently linked by a common case study. The concepts and methods described here are demonstrated with real exploration data sets. Although the geochemical data used here represent Earth materials most commonly sampled in reconnaissance exploration surveys (i.e., stream sediments) and the geological data sets used here represent 'data-poor' situations of mapping exploration targets for epithermal Au deposits, the concepts and methods described here apply equally to geochemical data from different sampling media and to 'data-rich' situations of mapping exploration targets for various types of mineral deposits. In addition, whilst there is neither reference to nor endorsement of any GIS software throughout this volume, the concepts and methods described in every chapter are generic such that they are readily implemented with or in any GIS software. This volume is thus intended to be an instructional textbook and general reference manual for exploration geochemists and/or exploration geologists, who are enthusiastic and already possess skills in applying GIS or who are interested in applying GIS. It is also hoped that geoscience academics and graduate students not only in the knowledge fields of geo-resource exploration but also in the knowledge fields of geo-hazard mapping and/or geo-environmental characterisation would find the concepts and methods described in this volume useful in their work.

I thank the International Institute for Geo-Information Science and Earth Observation (ITC) for resources and a pleasant environment for working (both teaching and doing research in geological predictive modeling) that allowed me to write this book. I thank also my graduate (PhD/MSc) students, from 2002 to the present, with whom I have developed some of the ideas presented in this volume. Most of all, I thank Professor Martin Hale, for coaching me during the years I was a graduate (MSc to PhD) student of mineral exploration at ITC and TU Delft, for continuing to work with me thereafter, for inviting me to write a volume for the series of Handbook of Exploration and Environmental Geochemistry and for editing this volume. The errors in this volume remain mine.

E.J.M. CARRANZA
Enschede, The Netherlands
May 2008

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PART II. GEOCHEMICAL ANOMALY MAPPING