

Introduction to the thematic issue: analysis of exploration geochemical data for mapping of anomalies



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The journal *Geochemistry: Exploration, Environment, Analysis* (GEEA) ‘focuses on mineral exploration using geochemistry...’ (<http://www.geolsoc.org.uk/geea>). GEEA is well-known for geo-analysis, which involves development of techniques and methods for systematic measurements of the chemical properties of a variety of Earth materials (e.g. rocks, soils, sediments, waters, vegetation, etc.). The most common chemical property measured from every geochemical sample is the concentration of one or more elements. The task of analysing geochemical concentration data (or geochemical data in short) from mineral exploration programmes aims basically to identify and separate samples with anomalous chemical concentrations from samples with background chemical concentrations. GEEA has published at least 50 papers on exploration geochemical data analysis (Appendix 1), which represent roughly 10% of all papers published in GEEA since its first issue in 2001. To contribute to the achievement of GEEA’s aim, this thematic issue contains eight papers on the development of methods and techniques for exploration geochemical data analysis.

Traditionally, methods and techniques for analysis of geochemical data for mapping of anomalies to support mineral exploration broadly fall into two categories of statistical analysis (Levinson 1974; Rose *et al.* 1979; Howarth 1983): (1) univariate analysis; and (2) multivariate analysis. In recent years, not only statistical but also spatial analysis is involved in mapping of geochemical anomalies to support mineral exploration (Zuo *et al.* 2016) (see Appendix 1). Moreover, with advancements in geographic information systems, most exploration data are integrated with geochemical data for more effective mapping of significant geochemical anomalies (Bonham-Carter 1994; Pan and Harris 2000; Carranza 2008). The eight papers contained in this thematic issue demonstrate the utility and added value of integrated analysis.

In the first paper, Ghane & Asghari (2017) used minimum/maximum autocorrelation factor analysis, which is a multivariate geostatistical method, and sequential indicator simulation methods on drill core geochemical data to model the Sury Gunay epithermal gold deposit, NW Iran. The results of their study indicate that high values of mineralization factors correlate with volcanogenic breccia and dacite porphyry, which are the known hosts of the deposit, and that high probabilities of silicification correlate with high concentrations of ore elements.

In the second paper, Shahrestani & Mokhtari (2017) incorporated drainage density of catchment areas in correcting stream sediment geochemical residuals for the effect of dilution on element concentrations to recognize significant geochemical anomalies. Using known occurrences of Au mineralization to validate their results, their study showed that drainage density does indeed enhance significant stream sediment geochemical anomalies.

In the third paper, Cracknell & de Caritat (2017) applied self-organizing maps to integrate and analyse catchment-based National Geochemical Survey of Australia (NGSA) geochemical data together with geophysical and geological data across northern Australia to identify areas prospective for gold. The results of their study, validated against known Au mines and mineral occurrences, indicate that catchment-based geochemical data and summaries of geophysical and geological data can be combined to highlight areas that potentially host previously unrecognized Au mineralization.

In the fourth paper, K. Wang *et al.* (2017) demonstrate the application of partial least squares regression (PLSR) to the analysis of multivariate geochemical anomalies. They applied PLSR separately to major oxides and trace elements to extract geochemical anomalies. The results of their analysis, which were validated by known occurrences of mineral deposits, show multivariate anomalies of major oxides and trace elements coinciding with known ore-bearing strata and ore-controlling faults. The associations of major oxides and trace elements extracted by PLSR are similar to those extracted using the traditional cluster method; however, PLSR allows mapping spatial variations that cluster analysis does not. Therefore, PLSR is now a proven technique for mapping of multivariate geochemical anomalies to support mineral exploration.

In the fifth paper, Chen & Wu (2017) applied the one-class support vector machine (OCSVM) to identify multivariate geochemical anomalies from stream sediment survey data of the Lalingzaohuo district, China. They compared the performance of the OCSVM model with that of the previously proposed continuous restricted Boltzmann machine (CRBM). The results show that anomalies identified by the OCSVM model occupy 19% of the study area and contain 82% of the known mineral deposits whereas anomalies identified by the CRBM model occupy 35% of the study area and contain 88% of the known mineral deposits, indicating the advantage of the OCSVM model over the CRBM model.

In the sixth paper, Zhao *et al.* (2017) applied staged factor analysis (SFA) and fractal/multifractal techniques to process litho-geochemical data from the Laochang district, Yunnan province, SE China, to identify geochemical signatures related to the deposit-type sought. The results of their study clearly demonstrate that SFA greatly assisted interpretation of geochemical zonation patterns genetically related to intrusions as well as multi-element associations of the mineral deposit-type sought as validated by known mineral occurrences. The results of their fractal/multifractal analyses further illustrate that element distributions are greatly influenced by fault density and that integrated methods are useful for identifying significant multi-element anomalous signatures and generating reliable target areas for further prospecting.

In the seventh paper, [Li et al. \(2017\)](#) applied local singularity analysis (LSA) to geochemical data from fracture fills to identify and extract geochemical anomalies associated with the Shaxi porphyry Cu-Au mineralization. The results of their study indicate that combining LSA with fracture fill geochemical analysis can effectively delineate geochemical anomalies associated with deep-seated or concealed porphyry-type mineralization as validated by known mineralized areas.

In the eighth paper, [W. Wang et al. \(2017\)](#) applied principal components analysis and the fractal/multifractal analytical techniques to stream sediment geochemical data to reflect the geology, metallogenesis and mineral potential in the Duolong mineral district, Tibet, China, which is an underdeveloped area that has received attention in recent years due to its Cu-Au resources. The results of their study, validated by the few known mineral deposits in the area, show that geochemical anomalies are spatially coincident with structures, suggesting the presence of mineralization but also a genetic relationship between mineralization and regional fault structures. The results of their study further indicate that the spectrum-area multifractal model is more effective for characterizing spatial patterns caused by specific geological processes, and the singularity theory can reveal the geochemical behaviour of elements or element associations from various geological processes.

Acknowledgement We thank Editor-in-Chief Kurt Kyser for agreeing to publish this special collection of papers in a thematic issue of GEEA. We are grateful to all the authors for the contributions, even to those who withdrew their papers after considering the reviewers' comments and those whose manuscript were not acceptable to the reviewers. We deeply appreciate the support of the following individuals for the invaluable time they have given to review the submitted manuscripts, many of who graciously reviewed more than one manuscript indicated by numbers in parenthesis: Peyman Afzal (2), Monica Arias, Guoxiong Chen, Shishi Chen, David Cohen, Yuan Feng (2), Mario Gonçalves (2), Eric Grunsky, Ardesheer Hezarkhani, Karel Hron (2), Yue Liu (2), Jennifer McKinley, Ahmad Reza Mokhtari (2), Charles Moon (2), Martiya Sadeghi, Ricardo Valls, Qingfei Wang, Wenlei Wang (2), Fan Xiao (2), Shuyun Xie, Douglas Yager, and Mahyar Yousefi (3). We also thank Jessica Pollitt, staff editor of GEEA, for assisting the authors, reviewers and ourselves regarding the use of the online manuscript submission and review system.

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Appendix 1

GEEA articles on analysis of exploration geochemical data for mapping of anomalies published since the first issue in 2001 until the present thematic issue.

- Clare, A.P. & Cohen, D.R. 2001. A comparison of unsupervised neural networks and k-means clustering in the analysis of multi-element stream sediment data. *GEEA*, 1(2), 119–134.
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- Xu, Y. & Cheng, Q. 2001. A fractal filtering technique for processing regional geochemical maps for mineral exploration. *GEEA*, 1(2), 147–156.
- Klassen, R.A. 2001. The interpretation of background variation in regional geochemical surveys – an example from Nunavut, Canada. *GEEA*, 1(2), 163–175.
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- Grünfeld, K. 2007. The separation of multi-element spatial patterns in till geochemistry of southeastern Sweden combining GIS, principal component analysis and high-dimensional visualization. *GEEA*, 7(4), 303–318.

- Stanley, C.R. & Noble, R.R.P. 2007. Optimizing geochemical threshold selection while evaluating exploration techniques using a minimum hypergeometric probability method. *GEEA*, **7(4)**, 341–351.
- Stanley, C.R. & Noble, R.R.P. 2008. Quantitative assessment of the success of geochemical exploration techniques using minimum probability methods. *GEEA*, **8(2)**, 115–127.
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