Journal of Geochemical Exploration 140 (2014) 96–103

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

Catchment basin analysis of stream sediment geochemical data: Incorporation of slope effect

Mehdi Abdolmaleki [a], Ahmad Reza Mokhtari [a], Somaieh Akbar [a,*], Masood Alipour-Asll [b], Emmanuel John M. Carranza [c]

[a] Department of Mining Engineering, Isfahan University of Technology, Isfahan 8415683111, Iran
[b] Geology Department, Faculty of Earth Sciences, Shahrood University, Shahrood 3619995161, Iran
[c] School of Earth and Environmental Sciences, James Cook University, Townsville, Queensland 4811, Australia

A R T I C L E I N F O

Article history:
Received 23 December 2013
Accepted 20 February 2014
Available online 1 March 2014

Keywords:
Stream sediment sample
Catchment basin approach
Slope effect
Iran

A B S T R A C T

This study examines catchment basin analysis of stream sediment samples considering slope effect by incorporating 3D surfaces of catchments and lithologic units within the Rudbar 1:100,000 scale geological map (1:50,000 scale Mahin topographic sheet) in Northern Iran. In this region, 174 stream sediment samples were collected in 625 km^2 of survey area and were analyzed by ICP-OES for trace elements. Background values due to upstream lithologic and dilution effects were calculated using 2D and 3D modeling. In each case, background concentration for every element due to lithology was estimated by weighted average method, and then geochemical residuals were determined and used for dilution effect correction. To identify the areas with possible mineralization, dilution-corrected values in both 2D and 3D models were processed further separately using principal component analysis. Then appropriate principal components (PCs) were integrated by fuzzy OR operator to obtain a mineral favorability map per model. Rock samples, collected over the area, were used to validate the results. Both 2D and 3D models have good agreement with the validation samples, but the 3D model was better. In other words, the use of 3D surfaces allows better representation of anomalies in the study regions. In addition, validation against rock sample analyses demonstrated that using 3D surfaces improves the delineation of promising catchment basins. The effectiveness of incorporating slope effect in catchment basin modeling of promising areas was observed in dilution correction of background and in multivariate analysis of dilution-corrected residuals. Non-parametric significance test also confirmed that results using 2D and 3D surfaces are different.

1. Introduction

Stream sediment sampling remains an effective method in regional geochemical exploration. The results of such activity provide efficient guides for identifying regional geochemical patterns and locating areas of high potential for further mineral exploration. Various techniques have been developed and used for analysis and interpretation of regional geochemical exploration data in order to extract the underlying patterns.

The sample catchment basin approach is a widely employed technique for processing and analysis of regional stream sediment geochemical exploration data. The catchment basin of each stream sediment sampling point includes a region that hydrologically and, in turn, geochemically affects the chemical composition of stream sediments at the sampling point. In other words, in this method, catchment basins are limited by the spill points, which are the stream sediment sample locations. The chemical composition of stream sediments that migrate along drainage system resulted from weathering and erosion of upstream sources. A significant proportion of variations in element concentration in stream sediments are due to upstream lithology; therefore, catchment basin lithology can be used to evaluate geochemical background (Rose et al., 1970). Other properties of catchment basin can be applied in modeling of geochemical variations to predict anomalous basins (Carranza and Hale, 1997; Sanford et al., 1993).

Based on definition of a model, predictive modeling involves describing, representing and predicting an indirectly observable and complex real-world system by analyzing relevant data quantitatively (Carranza, 2009). For modeling of geochemical anomalies in sample catchment basins, factors that influence variations in chemical composition of geochemical samples should be recognized and taken into account for processing and analysis of the data. Because lithology has great influence on element content in stream sediment samples, background concentrations of every element can be estimated as weighted average element content due to lithology using areal proportions of lithologic units in every sample catchment basin (Bonham-Carter et al.,

* Corresponding author. Tel.: +98 9132527392.
E-mail address: somaieh.akbar@mi.iut.ac.ir (S. Akbar).

http://dx.doi.org/10.1016/j.gexplo.2014.02.029
0375-6742/

1987; Carranza and Hale, 1997). In general, certain chemical contents of stream sediments have positive relationships with areas of lithologic units in a catchment basin and have negative relationships with total area of a catchment basin, and these relationships have been used to model background concentrations and dilution effect, respectively (Carranza, 2009).

The following equation shows the relationship between sample element concentration in a catchment and assumed anomaly and background values (Hawkes, 1976):

$$Y_i A_i = Y_a A_a + Y_i^{'}(A_i - A_a) \quad (1)$$

where Y_i and A_i are element concentration of sample i and corresponding catchment basin area, respectively. Y_a represents element concentration due to anomalous sources occupying an area A_a, $Y^{'}_i$ represents element concentration due to background sources occupying an $A_i - A_a$ (Jones, 2002). Eq. (1) can be re-arranged as:

$$Y_a A_a = A_i\left(Y_i - Y_i^{'}\right) + Y_i^{'} A_a \quad (2)$$

Local background content due to lithology in every sample catchment basin can be estimated in two steps. Firstly, a weighted average element concentration M_j ($j = 1, 2\ldots$ m) for the jth lithologic units can be calculated as:

$$M_j = \sum\nolimits_{i=1}^{n} Y_i X_{ij} / \sum\nolimits_{i=1}^{n} X_{ij} \quad (3)$$

where X_{ij} is area of the jth ($j = 1, 2\ldots m$) lithologic unit in sample catchment basin i ($i = 1, 2\ldots n$), and the sum term in the denominator is total area of lithology j (Carranza, 2009). Then, the local background concentration of element ($Y^{'}_i$) due to lithology can be estimated as (4):

$$Y_i^{'} = \sum\nolimits_{j=1}^{m} M_j X_{ij} / \sum\nolimits_{j=1}^{m} X_{ij} \quad (4)$$

where the sum term in the denominator is total area of sample catchment basin i.

Aside from considering effects of lithology, it is important to consider dilution of concentrations along drainages within catchment basins. The term $Y^{'}_i A_a$ in Eq. (2) can be disregarded if A_i is much larger than A_a (Rose et al., 1979; Spadoni, 2006). It is assumed that exposed anomalous sources occupy a small unit area, e.g. $A_a = 0.01$ km^2. Then, Eq. (5) is adapted for dilution correction of element concentrations in stream sediments (Carranza and Hale, 1997):

$$Y_a = 100 * A_i\left(Y_i - Y_i^{'}\right) \quad (5)$$

Positive or negative geochemical residuals ($Y_i - Y^{'}_i$) can be interpreted as enrichment or depletion, respectively, of element concentration in stream sediments. But only positive values are processed further for dilution effect correction because they are of interest in mineral exploration. In summary, measured concentrations at each stream sediment sample location were corrected for background concentration due to upstream lithology and for the effect of downstream dilution.

1.1. Problem definition

It should be noted that the area factor applied in Eq. (5) is a horizontal (2D) projection of the area whereas in reality chemical composition of stream sediments is influenced by surfaces of lithologic units, which vary in three-dimensional (3D) space, as do the surfaces of sample catchment basins. If topographic slope is 0, the projected 2D area is

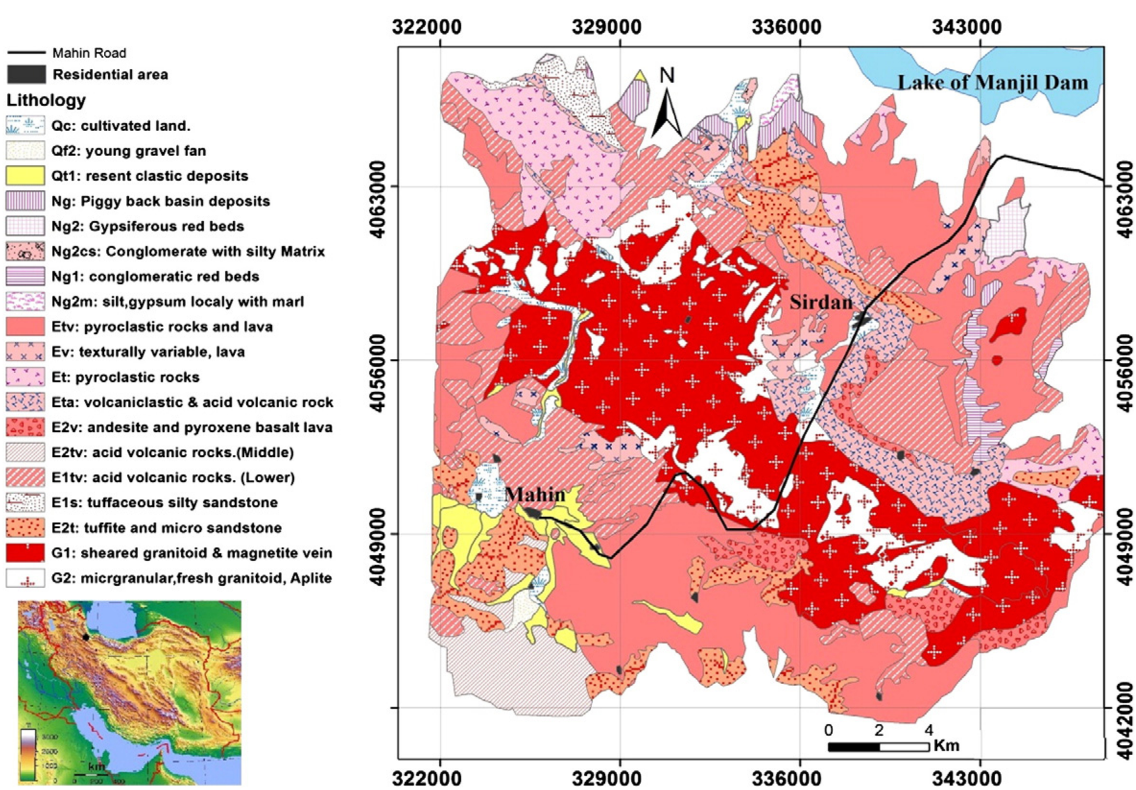

Fig. 1. Lithologic map of the study area.
Adapted from Rudbar 1:100,000 scale geological map, Geological Survey of Iran.