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**"Research Note"**

# DETERMINATION OF THE ELEMENTAL ASSOCIATIONS IN THE STREAM-SEDIMENT GEOCHEMICAL EXPLORATION USING FACTOR ANALYSIS IN SHAHKOUH AREA, EAST IRAN*

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**Abstract –** The association of elements in a regional stream-sediment geochemical exploration was investigated by using R-mode factor analysis on 233 samples in the arid environment of the Shahkouh area, east of Iran. A five-factor model with a cumulative variance of 70.60% clearly indicated the group associations of the elements, which coincide precisely with the lithology and the mineralization present in the study area. Factor scores were calculated and mapped in order to delineate the anomalous locations of the relevant association across the whole area. This multivariate statistical method can be used in arid environments, despite the occurrence of some drawbacks in such climate condition.

**Keywords –** Stream sediment, geochemical exploration, factor analysis

## 1. INTRODUCTION

This part of the research is mainly concerned with the use of factor analysis, a multivariate statistical method, on the stream-sediment geochemistry of the Shahkuh area using the results of total analysis of 233 samples for 34 major and trace elements, $SiO_2$, $Al_2O_3$, $TiO_2$, $Fe_2O_3$, MgO, CaO, $Na_2O$, $K_2O$, MnO, $P_2O_5$, As, Ba, Ce, Co, Cu, La, Mo, Nb, Ni, Pb, Rb, S, Sb, Se, Sn, Sr, Th, U, V, W, Y, Zn, and Zr. The minus 150 µm fractions of the stream sediments were subjected to total analysis by X-ray fluorescence spectrometry (XRFS). 30 replicate samples were also analyzed to assess the reproducibility and the precision of the analysis. For most of the elements, the precision was better than ±20%.

## 2. ASSOCIATION OF THE ELEMENTS IN THE STUDY AREA

During geochemical prospecting, several elements are usually studied and their distribution maps are then prepared with the ultimate aim of delineating the significant anomalies. As geochemistry of ore deposits indicates, the ore body is seldomly composed of one single element alone. Therefore it may be more effective to consider the distribution of more than one element at a time rather than one by one [1].

In the present study, in order to achieve a better conception of the interpretation of the elemental distributions in the study area, R-mode factor analysis was applied to the results of the total analysis of 233 stream sediment samples using Unistat statistical software.

R-mode factor analysis provides a means of distinguishing between element associations related to the lithology and those related to possible mineralization. This is done by grouping the elements into associations influenced by the same factor [2, 3]. In the present study all data were transformed logarithmicaly to normalize the positively (or negative) skewed distribution which are present in the data set [4, 5].

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## 3. FACTOR SELECTION

A five-factor model was chosen and subsequently adopted with a cumulative variance of 70.50%. Selecting the number of factors is an important stage in the utilization of factor analysis. There is not a precise mathematical procedure indicating the way of selecting the number of factors in factor analysis. Thus the number of factors extracted was subjective [6] and in this study the factor model was chosen on the basis of the geological interpretation of the structure of the factors. Prior to the selection of the five-factor model, a four-factor model and a six-factor model were also examined; the former resulted a total variance of 65.4% (less than five-factor model) in which the factors were not as meaningful as the selected factor model (five-factor model) and the latter resulted 75.2% of the total variance (more than the five-factor model), but its factor loadings and communalities were small for the elements of interest and with less indication of elemental associations than the five-factor model. Therefore the most suitable model, the five-factor model, was ultimately chosen. The highest loadings of the five factors are indicated in Table 1.

***a) Factor 1 (Ca, Cu, Pb, Zn, S, Sr)***

Factor 1 explains 29% of total variabilities of the data. It has strong positive loadings for the elements Ca, Cu, Pb, Zn, S, and Sr, and clearly delineated the known mineralization which is present in the study area; consequently it may be called a mineralization factor. The association of Ca and sulfide mineralization within the calc-silicate hornfels and the schist intermingled with thin beds of marble are well reflected in this factor. The relatively high negative loading of $SiO_2$ (-0.63) in this factor reveals the decrease of Si content in the stream sediments of the southern part of the study area, which is fairly consistent with the rock characteristics of this part of the area. The map of factor scores for this factor is shown in Fig. 1.

Table 1. The highest factor loadings and the corresponding elements

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Communality |
|---|---|---|---|---|---|---|
| Ca | 0.77 | | | | | 0.6457 |
| Cu | 0.79 | | | | | 0.8513 |
| Pb | 0.87 | | | | | 0.9374 |
| S | 0.84 | | | | | 0.7422 |
| Sr | 0.86 | | | | | 0.7987 |
| Zn | 0.86 | | | | | 0.9588 |
| Ti | | 0.80 | | | | 0.8745 |
| Fe | | 0.90 | | | | 0.8709 |
| Mg | | 0.68 | | | | 0.7450 |
| Mn | | 0.78 | | | | 0.7429 |
| Co | | 0.84 | | | | 0.8014 |
| Ce | | | 0.81 | | | 0.7861 |
| La | | | 0.76 | | | 0.6414 |
| Th | | | 0.85 | | | 0.7791 |
| Y | | | 0.85 | | | 0.8311 |
| Zr | | | 0.61 | | | 0.6710 |
| K | | | | 0.91 | | 0.8707 |
| Ba | | | | 0.68 | | 0.7759 |
| Rb | | | | 0.80 | | 0.8204 |
| Si | | | | | 0.66 | 0.9051 |

***b) Factor 2 (Ti, Fe, Mg, Mn, Co)***

Factor 2 explains 16.8% of total variance. This factor is related to the different environments and mainly explains the presence of Mn-and Fe-oxides in the fine fraction of the stream sediments across the whole area. As is shown in its factor scores map, Fig. 2, the high scores are dominant over the whole area, suggesting the presence of clay minerals of the fine fraction with a reflection of absorption properties.

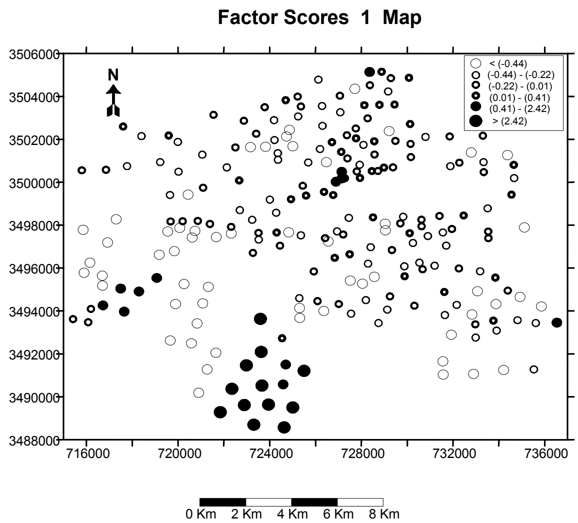


Fig. 1. Spatial distribution of factor 1 scores across the whole area

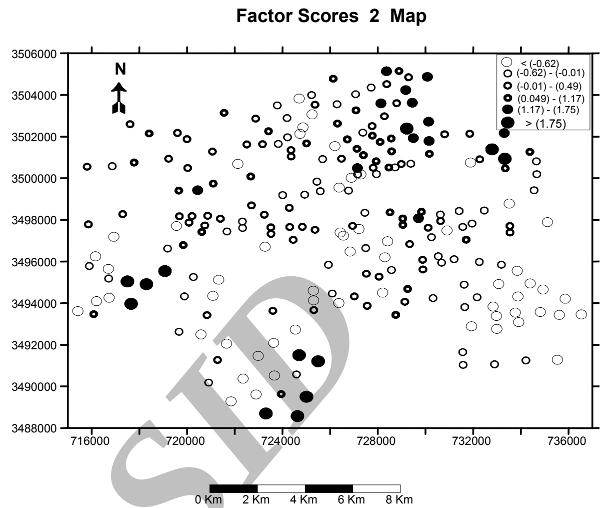


Fig. 2. Spatial distribution of factor 2 scores in the study area

***c) Factor 3 (Ce, La, Th, Y, Zr)***

Factor 3 explains 11.7% of the total information. Its spatial distribution map is indicated in Fig. 3. The strong positive loadings of this factor belong to Ce, La, Th, Y and Zr, which reflect the clastic fractions of minerals such as xenotime, monazite, zircon and thorite. These minerals have been observed by SEM in the stream sediments of the area. This factor may be called "granite factor" in this study. The occurrence of the highest scores in the northeast part of the granite, Fig. 3, may indicate that the granite intrusion has different mineral characteristics from the western and eastern part. This partitioning demands more investigation across the granite body itself, which will be discussed further later.

***d) Factor 4 (K, Ba, Rb)***

Factor 4 accounts for 7.9% of the total variance of the five-factor model. The highest scores of this factor are scanty and their association in the stream sediments can be considered as being lithologically controlled. For brevity the relevant map is not shown.

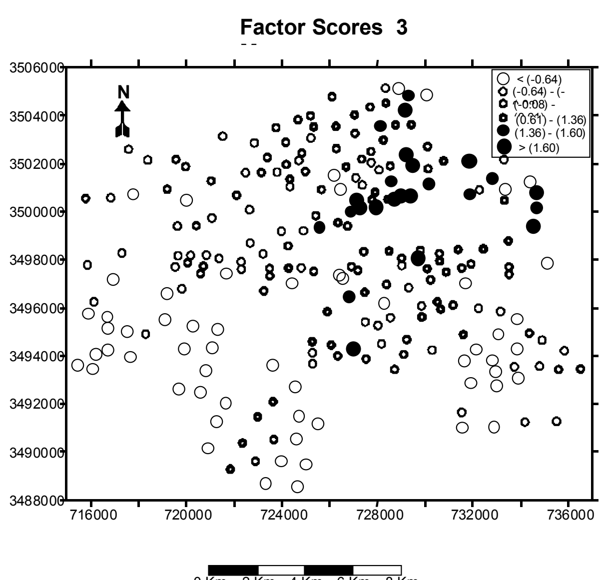


Fig. 3. Spatial distribution of factor 3 scores in the study area

### *e) Factor 5 (Si)*

Factor 5 explains 5.2% of the total variance. The only variable which contributes on this factor is $SiO_2$. This factor may reflect two particular features of the study area. The first feature is that the highest scores mainly dominate over the granite rocks and have divided the area into two distinctive locations of granite and non-granite areas. The second feature is the occurrence of the highest scores in the north part of the granite itself. This may indicate a different degree of alteration of this location from the other parts of the granite, particularly the eastern and southern parts. For brevity the map is not shown.

## 4. DISCUSSION AND CONCLUSION

Lead, zinc and copper mineralization were very well reflected by the geochemical signature of these elements in the stream sediments of the area. The clastic dispestion of some minerals such as ilmenite, xenotime and monazite, which are the results of mechanical weathering of the granite intrusion in the study area were also well reflected in the stream sediments. The carbonate rocks of the southwestern part and to a lesser extent, the mica schist intermingled by the thin beds of marble, were delineated by the stream sediment geochemistry. The carbonate rocks, which are located in the western part of the area due to the particular morphology in this location, were not well reflected in the stream sediments of the area.

The use of a multivariate statistical method such as the R-mode factor analysis, greatly helped the interpretation of the data set in this study when more than 70% of the total variance in the study area was delineated by reducing the data to a 5-factor model. Although the use of the multivariate technique in arid environments is uncommon [7-9], and despite the presence of drawbacks in such an environment, this technique can be successfully used. The application of this technique gave rise to a significant conception of the geochemistry of the stream sediments in the arid environment of the Shahkuh area.



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