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Identification of geochemical anomalies by number-size (N-S) fractal model in Bardaskan area, NE Iran

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Full Title:	Identification of geochemical anomalies by number-size (N-S) fractal model in Bardaskan area, NE Iran
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Abstract:	Geochemical anomaly separation and identification using the number-size (N-S) model at Bardaskan area, NE Iran, is studied in this paper. Lithogeochemical data were used in this study which was conducted for the exploration for Au and Cu mineralization and enrichments in Bardaskan area. There are two major mineralization phases concluded epithermal gold and a disseminated systems. N-S Log-log plots for Cu, Au, Sb and As illustrated multifractal natures. Several anomalies at local scale were identified for Au (32 ppb), Cu (28 ppm), As (11 ppm) and Sb (0.8 ppm) the obtained results suggests existence of local Au and Cu anomalies whose magnitude generally is above 158 ppb and 354 ppm, respectively. The most important mineralization events are responsible for presence of Au and Cu at grades above 1778 ppb and 8912 ppm. The study reveals threshold values for Au and Cu are being a consequence of the occurrence of anomalous accumulations of phyllic and silicification alteration zones and metamorphic rocks especially in tuffaceous sandstones and sericite schist types. The obtained results were correlated with fault distribution patterns reveals a positive direct correlation between mineralization in anomalous areas and the faults present in the mineralized system. Keywords: Geochemical anomaly, Epithermal system, Number-size (N-S) model, Multifractal, Bardaskan, NE Iran.

Identification of geochemical anomalies by number-size (N-S) fractal model in Bardaskan area, NE Iran

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1. Introduction

Identification and recognition of anomalies from background is an essential issue in geochemical exploration. In the last century, customized statistical methods usually assumed that the concentration of chemical elements in the crust follow a normal or log-normal distribution. A geochemical anomaly as defined is a region where the concentration of a specific element is greater than a certain threshold value by statistical parameters, such as mean, median, mode, and standard deviation (Bolviken et al., 1992; Cheng and Agterberg, 1996; Li et al., 2003). But, statistical methods e.g., by histogram analysis or Q-Q plots assuming normality or lognormality and do not consider the shape, extent and magnitude of anomalous areas and disregarding spatial distribution (Cheng et al., 1994; Agterberg, 1995; Afzal et al., 2010; Deng et al., 2010).

Fractal models and methods can be introduced and established by Mandelbrot (1983), which he has applied to objects that were too irregular to be described by ordinary Euclidean geometry (Agterberg et al., 1993; Cheng et al., 1994; Sim et al., 1999; Davis, 2002). Fractal models have been applied to geosciences studies since late 1980s (For example, Turcotte, 1986; Meng and Zhao, 1991; Sim et al., 1991; Cheng et al., 1994; Agterberg et al., 1996; Cheng, 1999; Gonclaves et al., 2001; Li et al., 2003; Zuo et al., 2009; Afzal et al., 2010; Carranza and Sadeghi, 2010; Deng et al., 2010; Afzal et al., 2011; Afzal et al., 2012). Mandelbrot (1983) proposed number-size (N-S) model based on the elemental geochemical distributions and occupy number of samples relationships. Agterberg (1995) and Deng et al. (2010) depicted that there are various parameters which have a key role in elemental distributions for a given geological-geochemical environments.

In this paper, Cu, Au, As and Sb anomalies are separated and delineated by number-size model in Bardaskan area, NE Iran. Subsequently, a general discussion is argued whereby the anomalous threshold values are correlated to the relevant structural, lithological, and alteration data and this may explain how obtained results were derived.

2. The number-size model

The N–S model, which was introduced and proposed by Mandelbrot (1983), can be used to describe the elemental distribution without pre-treatment and evaluation of data. The model shows that there is a relationship between desired certain attributes (e.g., ore element in this paper) and their cumulative numbers of samples with those characteristics. Based on the model, Agterberg (1995) proposed a multifractal model named size-grade for determination of the spatial distributions of giant and super-giant mineral deposits. Monecke et al. (2005) utiliized the N-S model to describe element enrichments associated with metasomatic processes during the formation of hydrothermal ores in the Waterloo massive sulfide deposit, Australia. The model is expressed by the following equation (Mandelbrot, 1983; Sanderson et al., 1994; Zou et al., 2009; Deng et al. 2010):

$$N(\geq\rho) = F\rho^{-D} \quad (1)$$

where ρ denotes element concentration, N(≥ρ) denotes cumulative number of samples with concentration values greater than or equal to ρ, F is a constant and D is the scaling exponent or fractal dimension of the distribution of element concentrations. Respect to Mandelbrot (1983) and Deng et al. (2010), log-log plots of N(≥ρ) versus ρ show straight line segments with different slopes −D corresponding to certain concentration intervals.

3. Geological setting of the Bardaskan area

The Bardaskan area of about 7.5 km^2 is situated about 16 km North of Bardaskan in NE Iran (Fig. 1). This mineralized area is located in Taknar zone, which is one of the subdivisions of Iranian central structural zone at north Darouneh fault (Alavi, 1994). Bardaskan area includes Au epithermal and Cu disseminated systems (Babakhani et al., 1999). The study area is mainly comprised of Upper Precambrian volcanic, metamorphic and volcano-clastics rocks from Taknar zone. Volcanic rocks are included rhyolite, rhyodacite, diabase and spillite. However, the metamorphic rocks, including meta-sandstone, schist especially sericite schist and chlorite schist, and slates are existed in the mineralized area. Tuffaceous sandstones and schists are extended in this area (Fig. 1).

The main structural features are two faults system trending NE-SW and E-W. Locally, their feather type fractures and joints are intense, as illustrated in Fig. 1. The main alteration zones of phyllic, silicification and chloritization types were accompanied by the quartz-sulfides veins to veinlets fillings of quartz. The ore minerals, specifically chalcopyrite and pyrite and native Au are present and, the latter ones occurred in the zone of quartz-sulfide veins and sericite alteration zone, as depicted in Fig. 1. Precise extension and relationships between alteration zones and mineralization, and economical evaluation of the area are still being investigated and is under study.

4. Litho geochemistry

Total of 483 collected lithogeochemical samples were analyzed by ICP-MS for elements which relate to Au and Cu mineralization and are of interest, and As and Sb concentrations were of no significance. The location map of the samples' position in the area is depicted in Fig. 2. Statistical results show that Au, Cu, As and Sb mean values are 38 ppb, 437, 10.3 and 1.72 ppm, respectively. Their distributions and are not normal and variation between maximum and minimum for these data show a wide range (Fig. 3).

The elemental grades were sorted out based on decreasing grades and their cumulative numbers. Finally, elemental log-log plots were generated for Au, Cu, As and Sb, as illustrated in Fig. 4. Based on this procedure, there are 5 geochemical populations for Au, Cu, As and Sb (Fig. 4). Cu anomalous threshold is 28 ppm and its high intensity anomaly is 8912 ppm. Also, it is obvious that there are four steps of Cu enrichments based on log-log plot, as shown in Fig. 4.

The first event for Cu N-S variations occurred at grades below 28 ppm. The second event shows up between grades 28 ppm and 354 ppm. The third happen is between 354-8912 ppm for Cu concentration. The final event included major Cu mineralization which occurred and interpreted in grades higher than 8912 ppm. Au threshold and high intensity anomalies are 32 ppb, and 1778 ppb, as depicted in Fig. 4. Au log-log plot shows that major Au enrichment occurred at 158 ppb and higher. As anomalous threshold (as pathfinder of Au) is about 1.6 ppm. There are three enrichment steps interpreted as seen in N-S log-log plot of Au and As in Fig. 4. Major As enrichment started from 25.1 ppm, and, 177.8 ppm concentration is beginning of high intensity As anomaly. Threshold value of Sb is 0.8 ppm and high intensive Sb anomalous parts have concentrations higher than 12.6 ppm.

Geochemical maps were constructed with IDS (Inverse Distance Squared) method by RockWorks™ v. 15 software package. The area was gridded by 10 m×10 m cells. Obviously situations of Au anomalies are in northern parts of the area and the high intensive anomalies are situated in NE parts as depicted in Fig. 5. Moreover, Cu anomalies are situated in northern, central and southern parts of the area also high intensive Cu anomalies were situated in central part of the deposit (Fig. 5). Main As and Sb anomalies exist in northern part of the area and correlated with Au anomalies location, as depicted in Fig. 5.

5. Comparison with geological characteristics

Thresholds values of elements obtained from N-S model are compared and correlated to specific geological particulars of the area including considering nature of lithological units, faults and alterations. Au, Cu, As and Sb distributions in the Bardaskan area, and the faults map are shown in Fig. 6. The anomalous parts visibly show the main identified faults especially in northern, NE and central parts of the area. Comparison between faults positions and elemental anomalies shows that faults intersect the anomalies situated near those structures (Fig. 6). Moreover, faults and elemental anomalies have a proportional relationship. High grade elemental anomalies occurred inside and within the fault zones or situated on faults intersection areas (Fig. 6). This is a positive parameter because silicified and quartz-sulfide veins were occurred along these faults and Au particles are existed in these veins and veinlets.

In the area, based on results of the N-S model, the elemental anomalies correlated with different rock types. High amounts of Cu, over 8912 ppm, are highest in sericite and chlorite schists. There are sulfide mineralization especially chalcopyrite. The Au high intensity anomalous parts, higher than 158 ppb, are situated in tuffaceous sandstones. Also there are quartz-sulfide veins and veinlets. An epithermal system is existed in this area and correlated within main Au, As and Sb anomalies. Also, the main step As mineralization, higher than 25 ppm, is correlated within sericite schists as presented in Fig. 7. Alterations have a strong positive relationship with Cu, Au, As and Sb anomalies, especially in northern part of the area. All of the anomalous parts are covered by chloritization, sericitization and silicification alterations. Most chloritization alteration is associated with Cu anomalies (Fig. 7). Cu with concentration at higher than 354 ppm, Au higher than 158 ppb, As higher than 25 ppm, and Sb higher than 12 ppm do have anomalies in northern parts of the area and are covered by chloritization and silicification alterations.

6. Conclusions

The study on Bardaskan area indicates the potential use of the N-S model for geochemical anomaly separation as a useful tool for geochemical exploration, commonly used in lithogeochemistry. The advantages of the model relies fundamentally on its straightforwardness, and easy computational achievement, as well as the possibility to compute the anomalous threshold values for different elements, which is the most useful criteria for cross examination of information with numerical data from different sources.

There exists a proper correlation between the calculated anomalous threshold values and the geological specifics in the Bardaskan area. These results may also be interpreted differently according to their multifractal curves in log-log plots. Cu, Au As and Sb concentrations in the area may be a result of the four steps of enrichment, i.e., mineralization and later dispersions. Au and Cu log-log plots were shown that there are three steps for their mineralization and dispersion. Major Au mineralization occurred in silicified units in NE parts of the area. Au

particles are occurred in quartz-sulfide veins and veinlets. Main anomalies of As and Sb are situated in NE part of the area and correlated with main Au anomalies. It can be interpreted that there is an Au epithermal system.
The occurrence of Cu higher than 8912 ppm in tuffaceous sandstones and chlorite schists in central parts of the area has been actually realized in the samples collected from the field. The studied elements anomalies have proper and direct relationships with faults in Bardaskan area. High intensity elemental anomalies are mostly located at faults intersections or near to fault zones. It is important because quartz-sulfide veins and veinlets are occurred along these faults. There is a good correlation between chloritization and silicification alterations and anomalous concentration, of Au, Cu, As and Sb. Silicification alteration has good relationships with Au high grade anomalous enrichment parts.

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Table

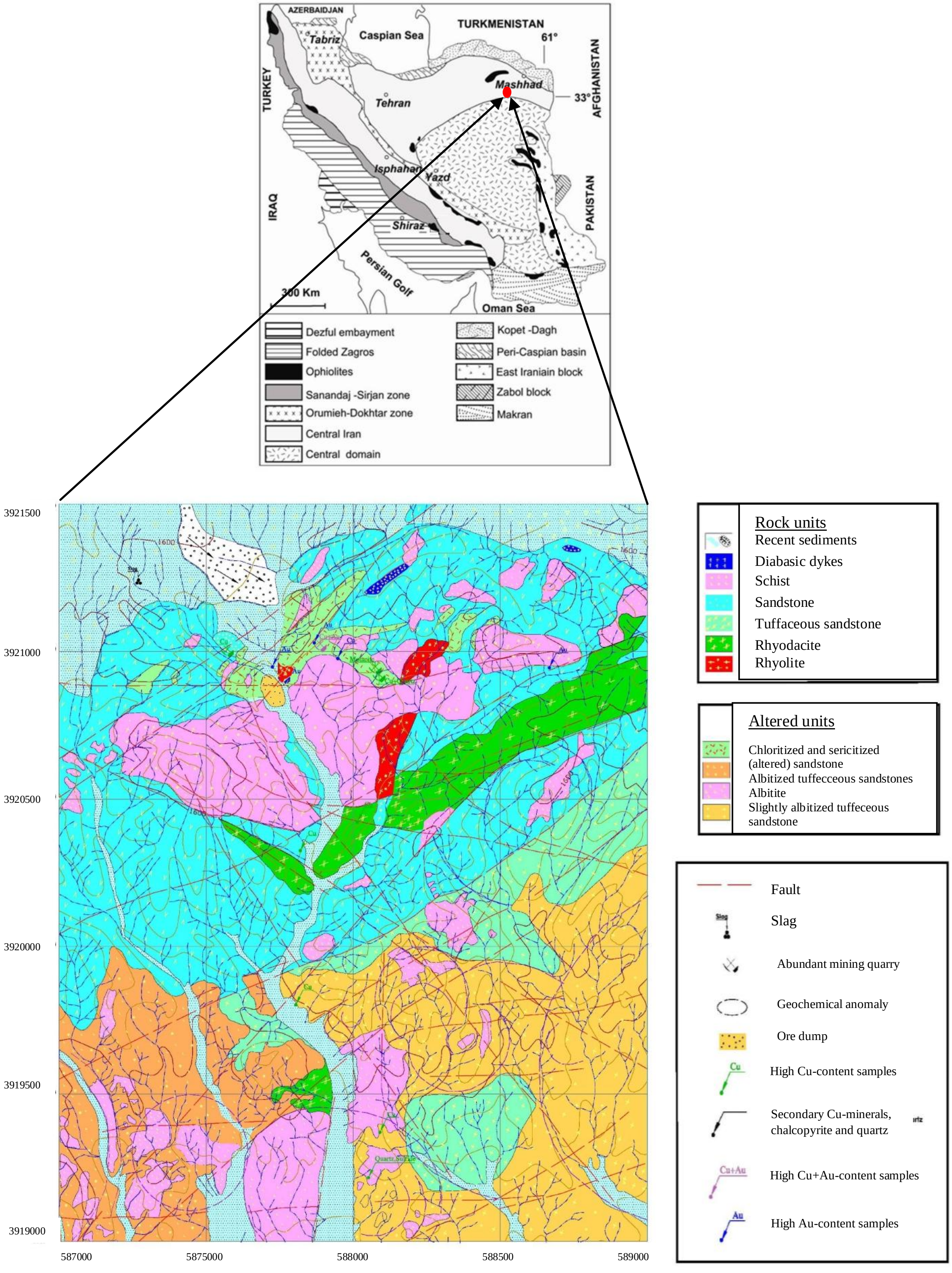

Fig. 1. Location of Bardaskan area in Iranian structural map (Alavi, 1994) and Geological map of the area.

Table

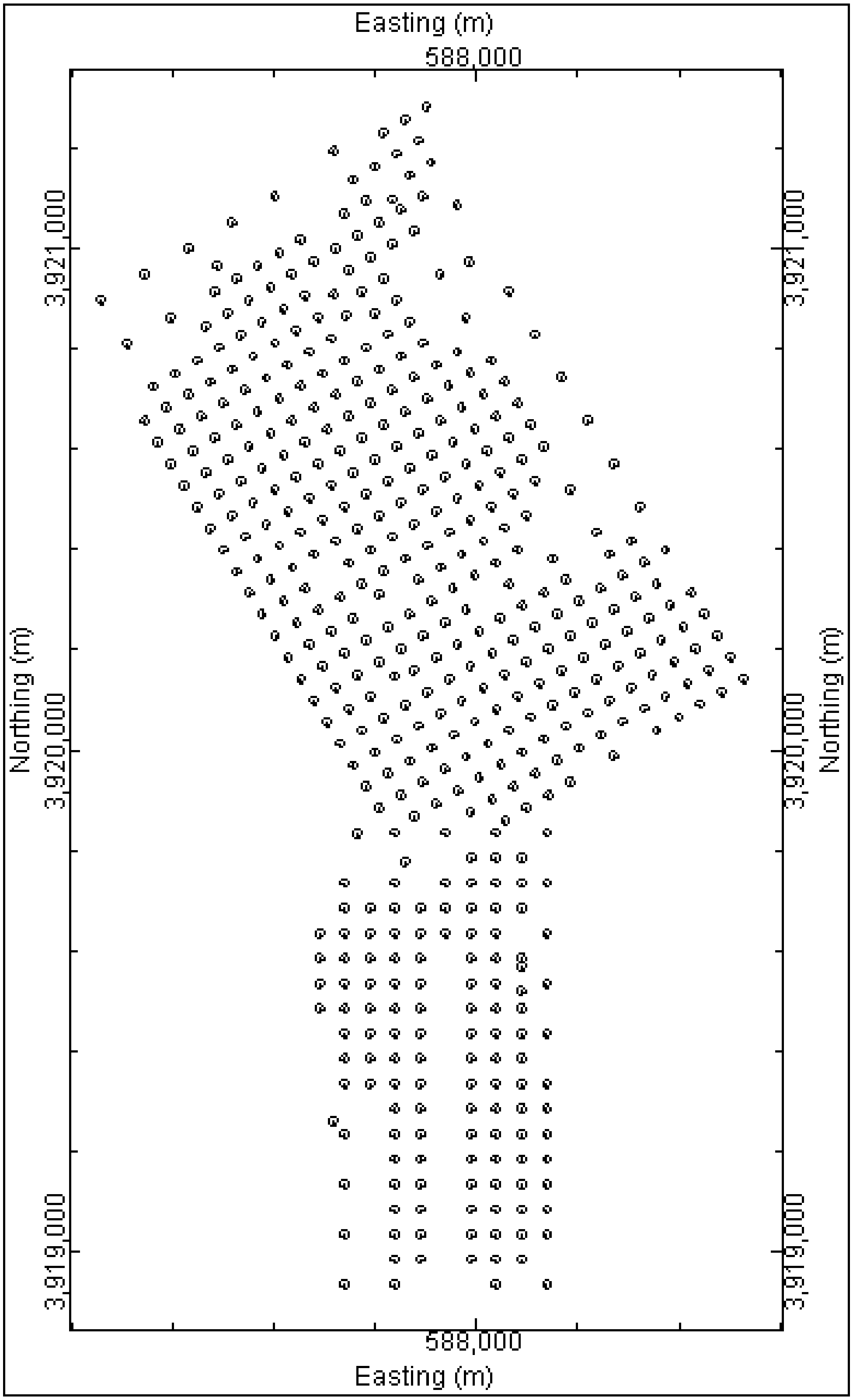

Figure 2. Lithogeochemical samples location map of Bardaskan area

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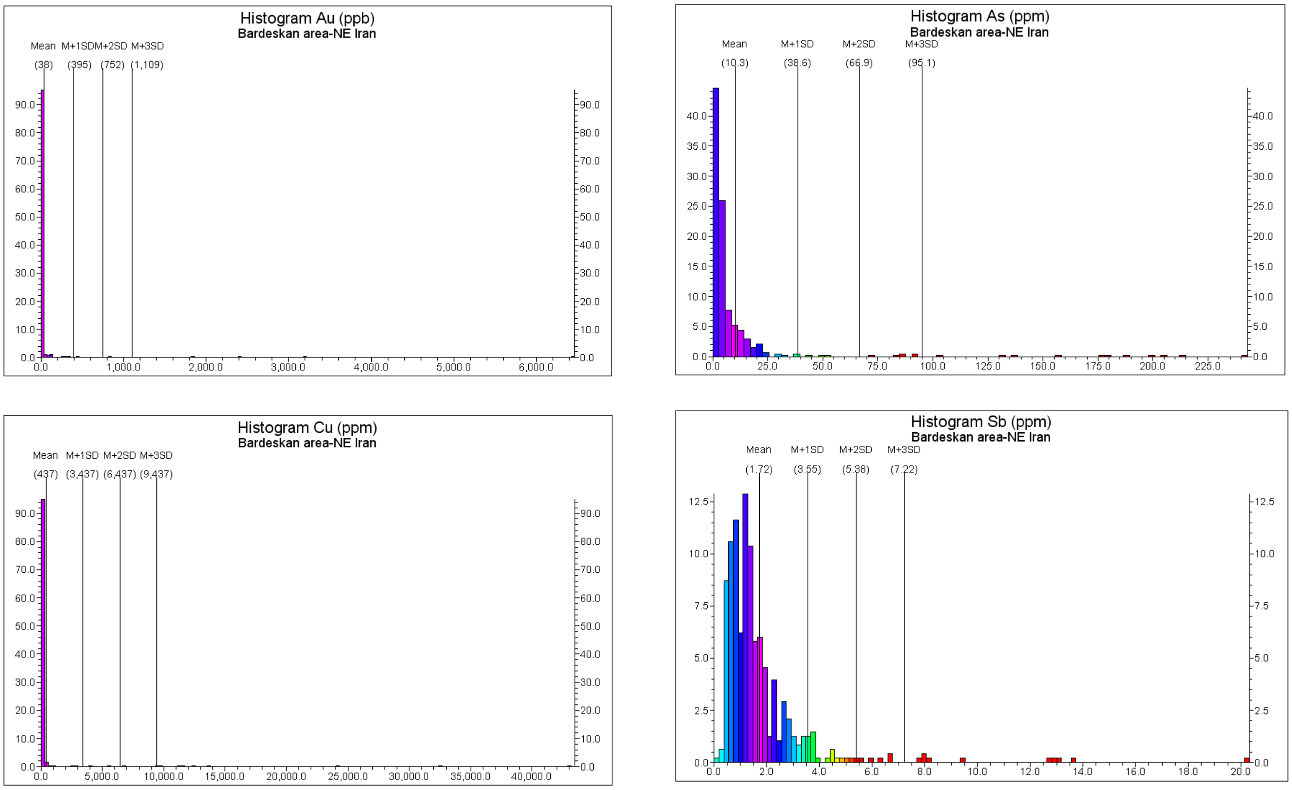

Fig. 3. Au, Cu, As and Sb in Bardaskan area

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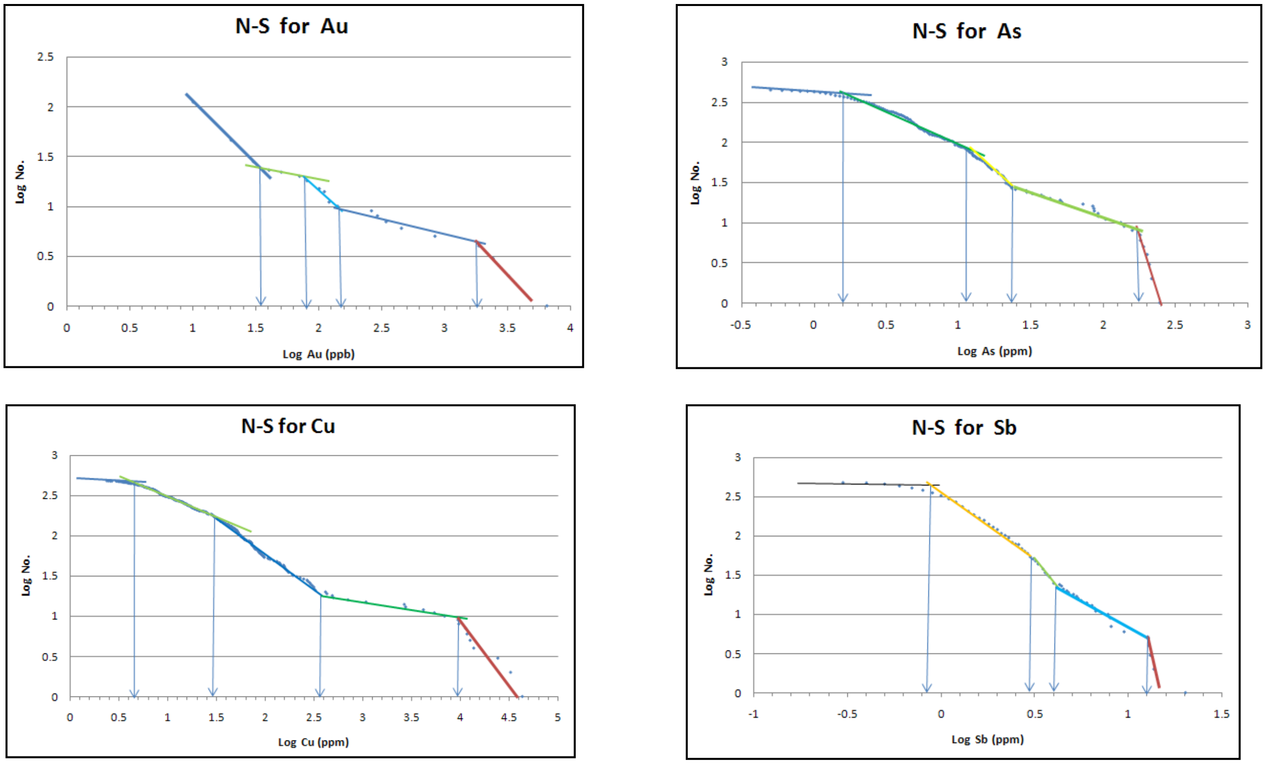

Figure 4. Log-log plots resulted from N-S model for Au, Cu, As and Sb.

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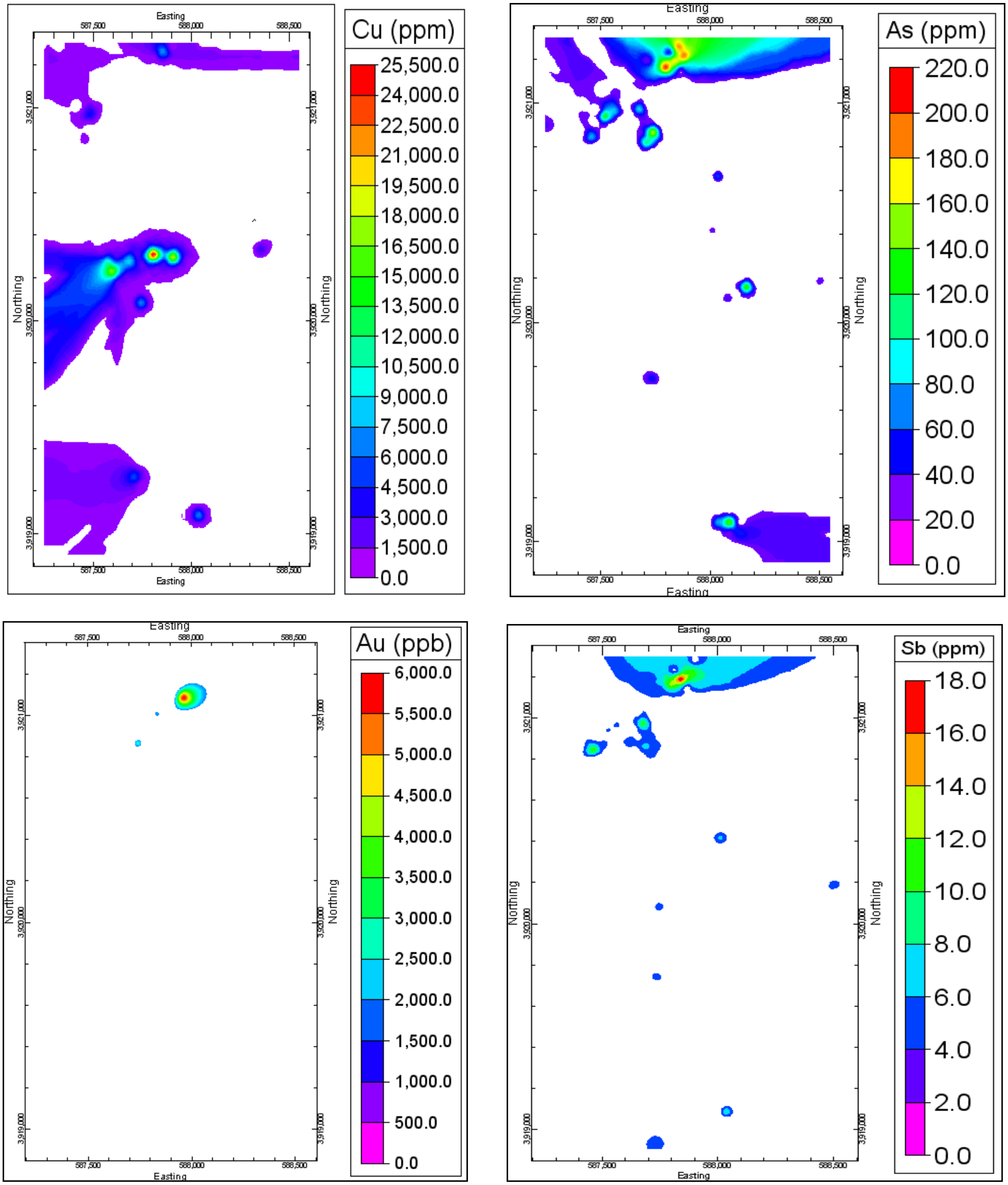

Fig. 5. Au, Cu, As and Sb geochemical population distribution maps based on N-S model

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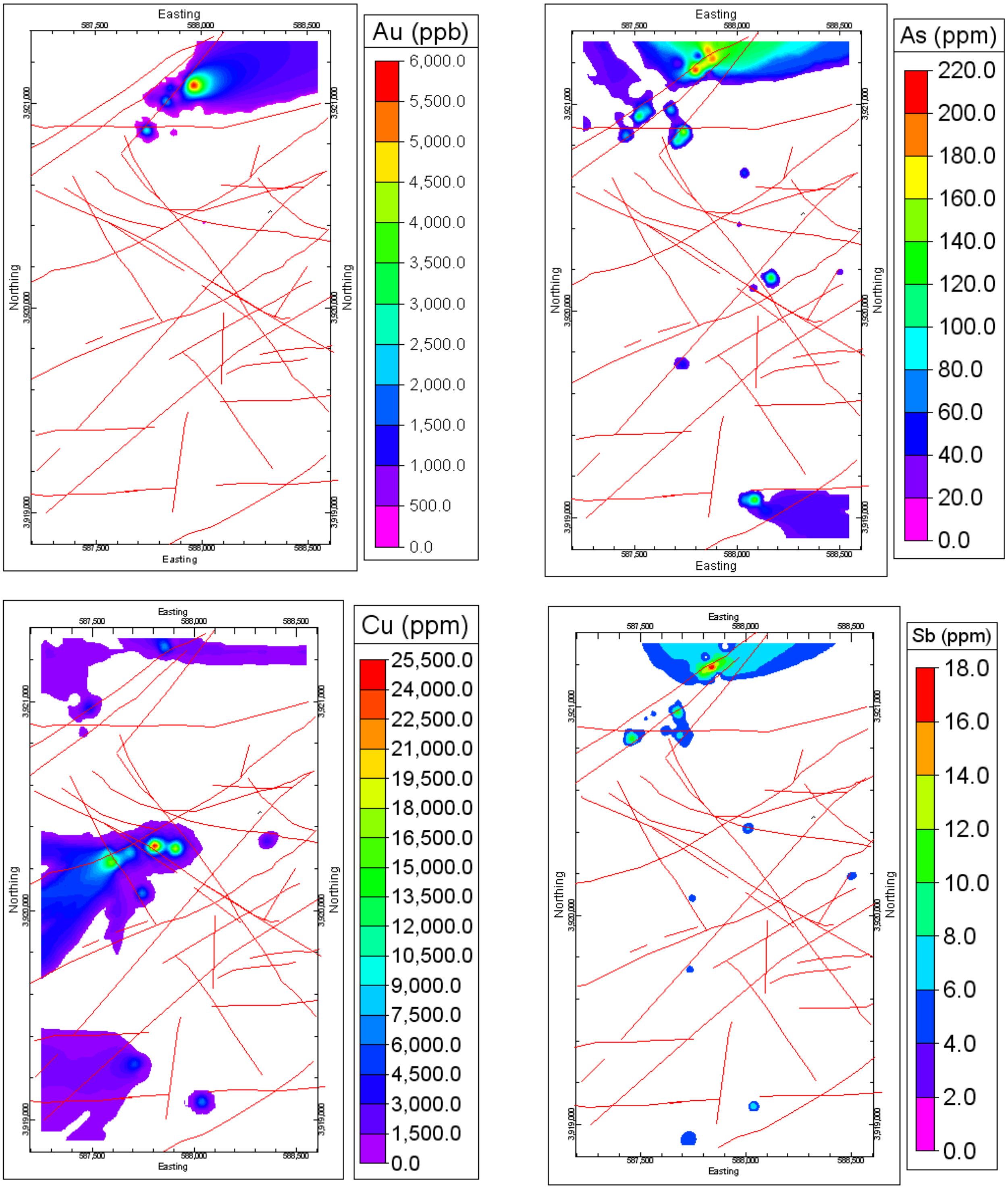

Fig. 6. Elemental geochemical population distribution maps based on N-S model imposed on fault location

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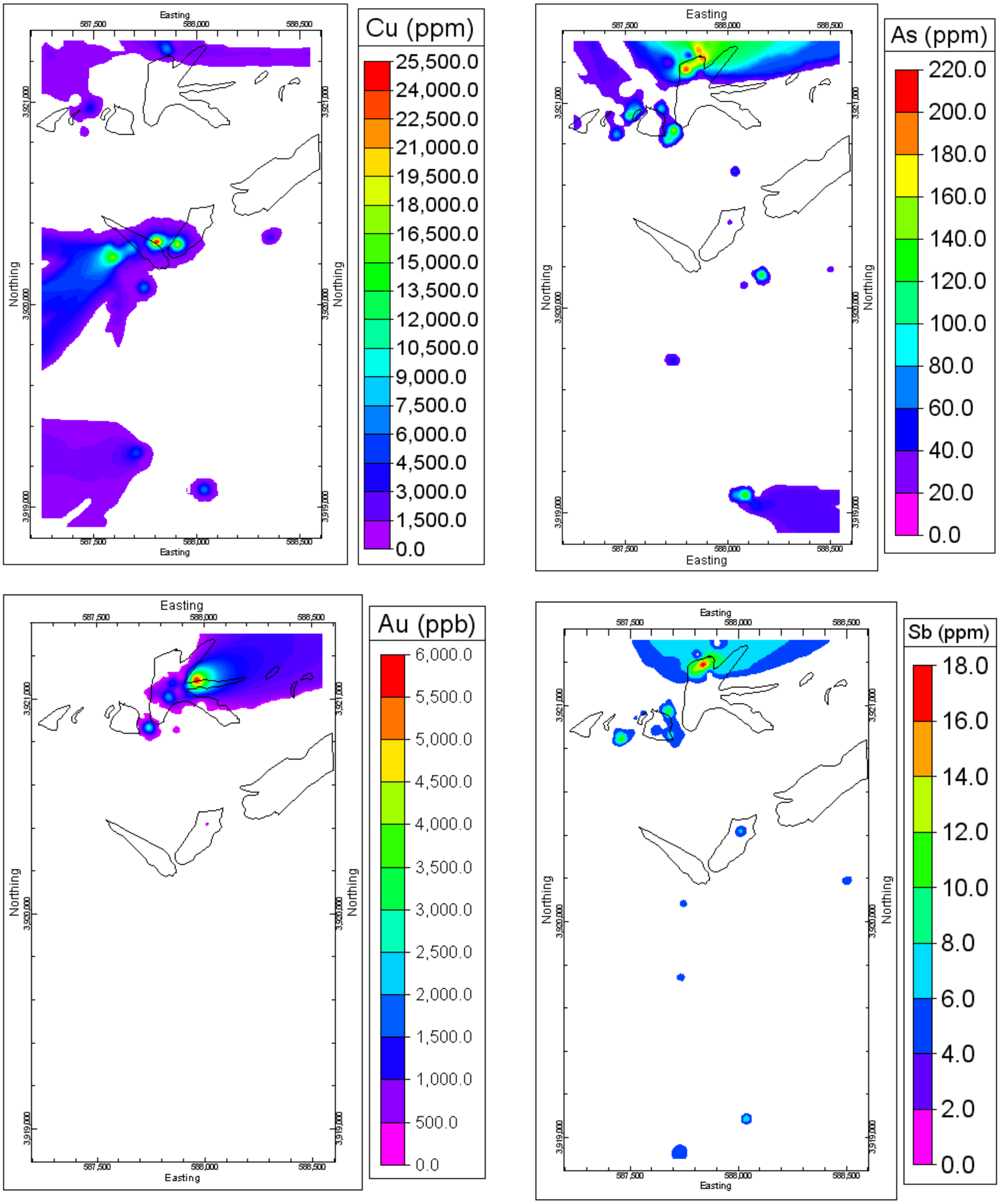

Fig. 7. Relationship between Au, Cu, As and Sb distribution and chloritization, phyllic and silicification alterations and sulfide mineralization (polygons)