www.czasopisma.pan.pl PAN www.journals.pan.pl

DE GRUYTER OPEN

Arch. Min. Sci., Vol. 61 (2016), No 2, p. 397–414

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.1515/amsc-2016-0029

EDRIS MANSOURI*, FARANAK FEIZI**,[1]

INTRODUCING Au POTENTIAL AREAS, USING REMOTE SENSING AND GEOCHEMICAL DATA PROCESSING USING FRACTAL METHODS IN CHARTAGH, WESTERN AZERBIJAN – IRAN

ROZPOZNAWANIE POTENCJALNYCH ZŁÓŻ ZŁOTA (Au) W OPARCIU O METODY ZDALNEGO WYKRYWANIA Z WYKORZYSTANIEM PRZETWARZANIA DANYCH GEOCHEMICZNYCH PRZY UŻYCIU FRAKTALI W REJONIE CHARTAGH, NA TERENIE ZACHODNIEGO AZERBEJDŻANU I IRANU

The studied area – Chartagh – is located in the East of Azerbaijan gharbi Province, Iran. In this paper, geology map, ASTER satellite images were used and after processing these images with ENVI softwares, geochemical data analysis consisting of lithogeochemical samples, within geological field observations. On ASTER data; using a number of selected methods including band ratio, Minimum Noise Fraction (MNF) and Spectral Angle Maper (SAM) distinguished alternation zones. Geochemical anomalies were separated by number – size (N-S) fractal method. (N-S) fractal method was utilized for High intensive Au, As and Ag anomalies.

Keywords: Alteration zones, ASTER, Geochemical data, Chartagh, Iran

Badany obszar – Chrtagh, leży w prowincji Gharbi. we wschodniej części Azerbejdżanu i Iranie. W pracy tej wykorzystano dane geologiczne oraz zdjęcia satelitarne z satelity ASTER, przetworzone przy użyciu oprogramowania ENVI oraz dane geochemiczne: wyniki analiz geochemicznych skał z badanego terenu. Na podstawie danych uzyskanych ze zdjęć satelitarnych wyodrębniono wyraźne strefy przeobrażenia skał, z wykorzystaniem analizy pasm, transformacji MNF (*Minimum Noise Factor*) oraz z użyciem transformacji SAM (*Spectral Angle Mapper*). Anomalie geochemiczne wykryte zostały w oparciu o metodę fraktalną N-S (liczba-wymiar), przy pomocy tej metody stwierdzone zostały wysokie poziomy anomalii Ag i Au.

Słowa kluczowe: strefy przeobrażeń skał, ASTER, dane geochemiczne, Chartagh, Iran

* YOUNG RESEARCHERS AND ELITE CLUB, SOUTH TEHRAN BRANCH, ISLAMIC AZAD UNIVERSITY, TEHRAN, IRAN.
** DEPARTMENT OF MINING ENGINEERING, SOUTH TEHRAN BRANCH, ISLAMIC AZAD UNIVERSITY, TEHRAN, IRAN.
[1] E-mail: feizi.faranak@yahoo.com

1. Introduction

In this paper used to apply spectral angle mapper (SAM), Minimum Noise Fraction (MNF) and band ratio to map the iron zones on the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data. Separation of anomalies and background is the most important aim of geochemical exploration operations especially for metallic deposits. Stream sediment and lithogeochemical studies are essential for prospecting of different ore deposits (Hawkes & Webb, 1979). Several methods are used for geochemical data interpretation and modelling such as classical statistics (e.g.,Tukey, 1977; Hawkes & Webb, 1979; Reimann et al., 2005), fractal and multifractal modelling (Cheng et al., 1994; Agterberg et al., 1996; Cheng, 1999; Li et al., 2003; Zuo et al., 2009; Afzal et al., 2010a; Afzal et al., 2010b) and singularity modeling (Cheng, 2007). Fractal theory has been established by Mandelbrot (1983) as an important non-Euclidean branch in geometry. Several methods have been proposed and developed based on fractal geometry for application in geosciences since the 1980s (Agterberg et al., 1993; Sanderson et al., 1994; Cheng, 1999; Turcotte, 1997, 2002; Goncalves et al., 2001; Monecke et al., 2005; Gumiel et al., 2010; Afzal et al., 2010b; Zuo, 2011; Sadeghi et al., 2012). The present study is based on the integration of remote sensing techniques and geochemical data analysis (stream sediment and litho geochemical samples) and as well as geological field verification studies to identify Au, Ag and As prospects in the Chartagh, north-west iran.

2. Geological setting

Chartagh area is located between longitudes 709040 – 710450 and latitudes 4041811 – 4039924 (UTM, WGS 84, zone 38 N) in the east of Azerbaijan gharbi Province, West Iran (Fig. 1). The studied area is a small north part of 1:100000 Takab geological map (Fig. 2). Based on this map, there are lots of silica and silicified units in the studied area, also there are some Schists, altered Schists, Serpentines and Asbestos in the area under research. As it is shown in this map, there is a thrust fault with north west – south east trend from north to south in the east margin of the area. Also there is a fault with the same trend in the south west of the area.

3. Materials and methods

The aims of the paper are to perform spectral angle mapper (SAM), Minimum Noise Fraction (MNF) and band ratio to map zones of hydrothermal alteration on the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite imagery data and delineation of high intensive Au, As and Ag anomalies using Number-Size (N-S) fractal method based on litho geochemical data for finding new prospects in Au mineralization in studied area. ENVI and ArcGIS software packages were used for multi-spectral image interpretation and fractal modeling of geochemical data, respectively.

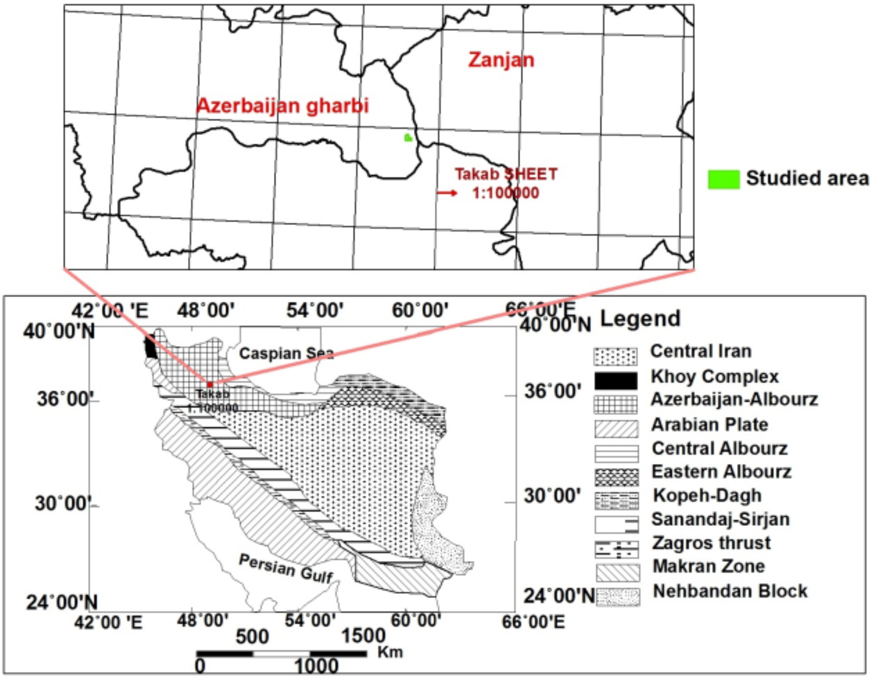


Fig. 1. The studied area in the map of Iran

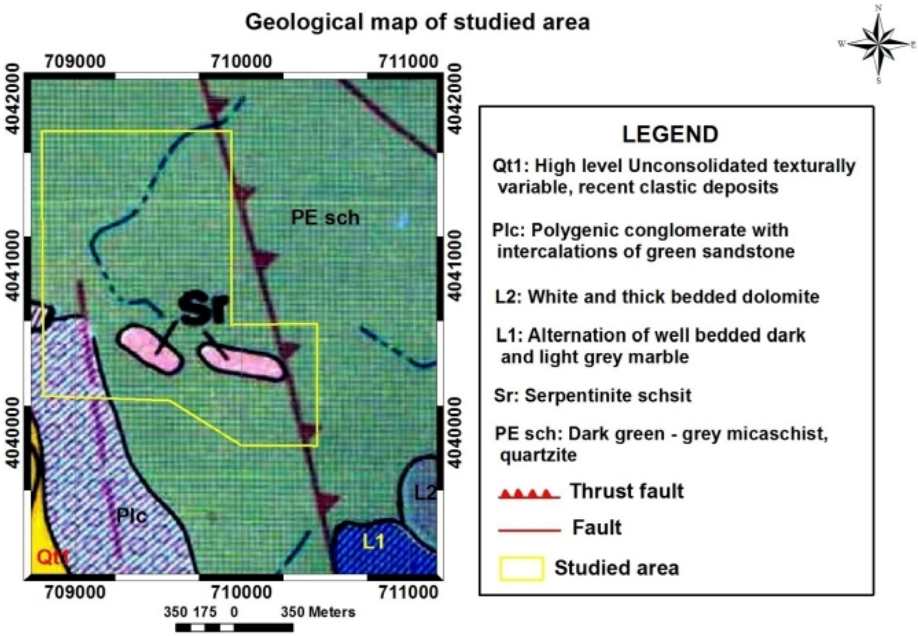


Fig. 2. The geological map of studied area (1:100000 Takab geology map)

4. Result and discussion

4.1. Remote sensing interpretation

The ASTER is an advanced optical sensor comprised of 14 spectral channels that will provide scientific and also practical data regarding various field related to the study of the earth (Rowan & Mars, 2003; Moghtaderi et al., 2007; Yousefifar et al., 2011). Numerous factors affect the signal measured at the sensor, such as drift of the sensor radiometric calibration, atmospheric and topographical effects. Therefore, Aster data set was used and radiance correlation such as wavelength, dark subtract and log residual by ENVI4.4 software which is essential for multi-spectral images, were employed.

4.1.1. Alteration zones investigation

Many image analysis and processing techniques can be used to interpret the remote sensing spectral data (Mars & Rowan, 2006; Azizi et al., 2010; Poormirzaee & Mohammady Oskouei, 2010; Beiranvnd Pour & Hashim, 2012; Oskouei & Busch, 2012). In this research, band ratio, spectral angle mapper (SAM) and Minimum Noise Fraction (MNF) methods were used on ASTER data for discrimination of alteration zones.

Band ratio

Band ratio is a technique where the digital number (DN) value of one band is divided by the DN value of another band. BRs can be useful for highlighting certain features or materials that cannot be seen in the raw bands. Similarly, the choice of bands depends on their spectral reflectance and positions of the absorption bands of the mineral being mapped (Inzana et al., 2003; Kujjo, 2010; Rajendran et al., 2012). For instance, to enhance a specific alteration mineral that hosts a distinct absorption feature, the most unique spectral ratio for that mineral is employed. In order to discrimination of iron oxide, phyllic, propylitic, silica and serpentinization (2/1), (5+7/6), (6+9/7+8), (14/12) and RGB: (4/7,3/4,2/1) were used (Fig. 5).

Minimum Noise Fraction

The Minimum Noise Fraction (MNF) analysis can identify the locations of spectral signature anomalies. This process is of interest to exploration geologist because spectral anomalies are often indicative of alterations due to hydrothermal mineralization. MNF involves two steps; in first step a calculated output value. This predicted band is what that band should be according to the linear equation. The minerals which are sensitive to a specific band are then differentiated from the features which are reflective to the other bands as well; just by taking the difference between the predicted values and the original values (Yetkin et al., 2004). Distribution of iron oxide was created by using MNF method, band 1. Also, phyllic, propylitic and silica alterations were mapped by using residual band 4, residual band 3 and residual band 10 (Fig. 6).

Spectral Angle Mapper (SAM) method

Spectral Angle Mapper (SAM) is a physically-based spectral classification that uses an n-D angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands. This technique, when used on calibrated reflectance data, is relatively insensitive to illumination and albedo effects. End member spectra used by SAM

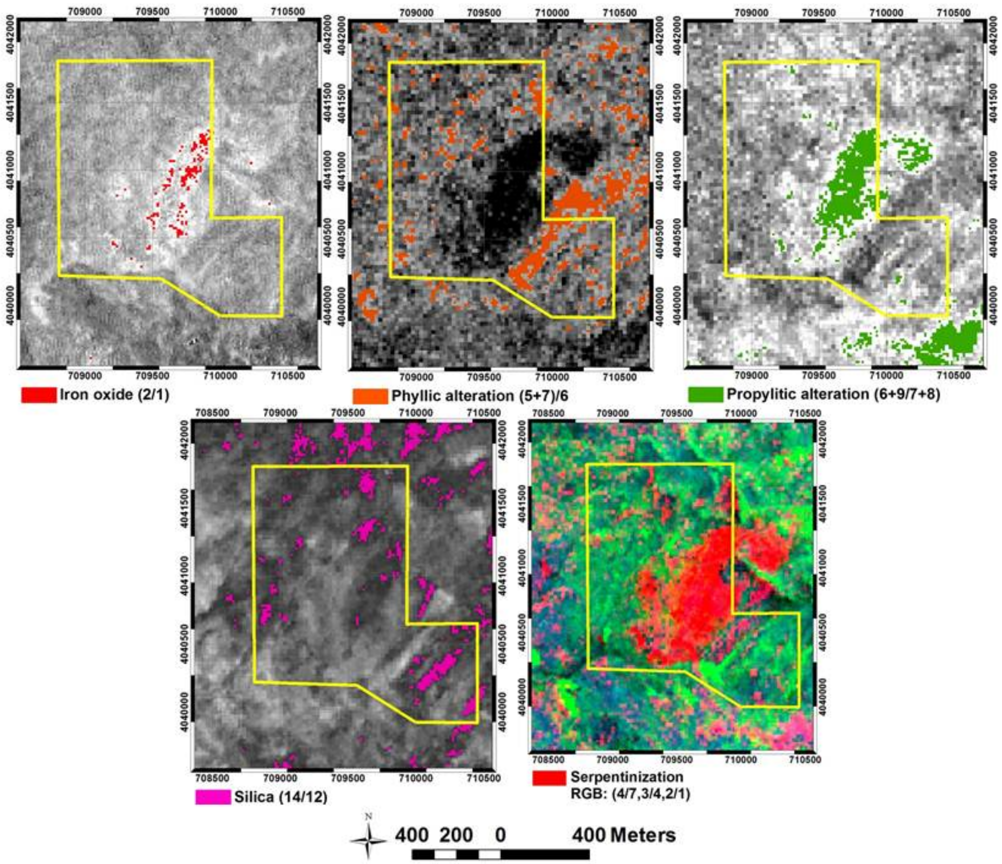


Fig. 3. The iron oxide, phyllic, propylitic, silica and serprntinization images prepared based on band ratio method

can come from ASCII files, spectral libraries, or you can extract them directly from an image (as ROI average spectra). SAM compares the angle between the end member spectrum vector and each pixel vector in n-D space. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified.

SAM classification assumes reflectance data. However, if you use radiance data, the error is generally not significant because the origin is still near zero.

Iron oxide zones were determined on VNIR bands. Mineral spectral such as Hematite, Geothite, Jarosite and limonite by aid of USGS were investigated (Fig. 7).

Propylitic and Phyllic alterations were determined by aid of SWIR bands. Minerals spectral such as Chlorite and Epidote were used for Propylitic alteration (Fig. 9) and minerals spectral such as Illite and Moscovite were used for phyllic alteration by aid of USGS library and alteration were determined (Fig. 8). These minerals are important in identification of hydrothermal alterations related to porphyry systems.

At last with Integration of the Silica, phyllic, propylitic and iron oxide maps, the Final alteration map of studied area was prepared (Fig. 9).

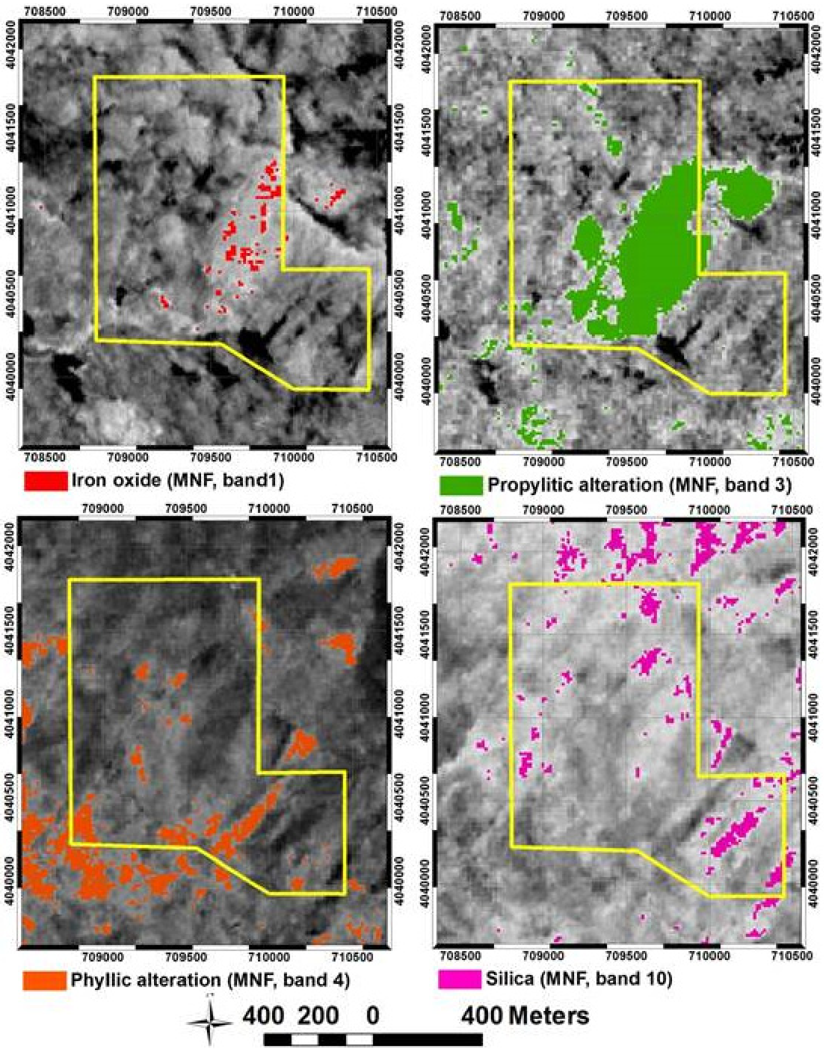


Fig. 4. The iron oxide, propylitic, phyllic and silica images prepared based on MNF method

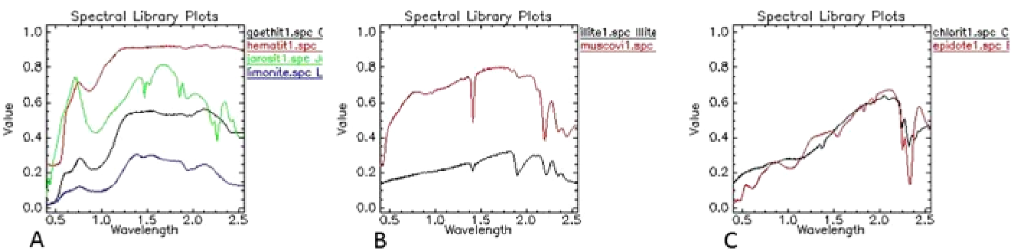


Fig. 5. The remarkable mineral reflection for: A – iron oxide, B – phyllic and C – Propylitic zones

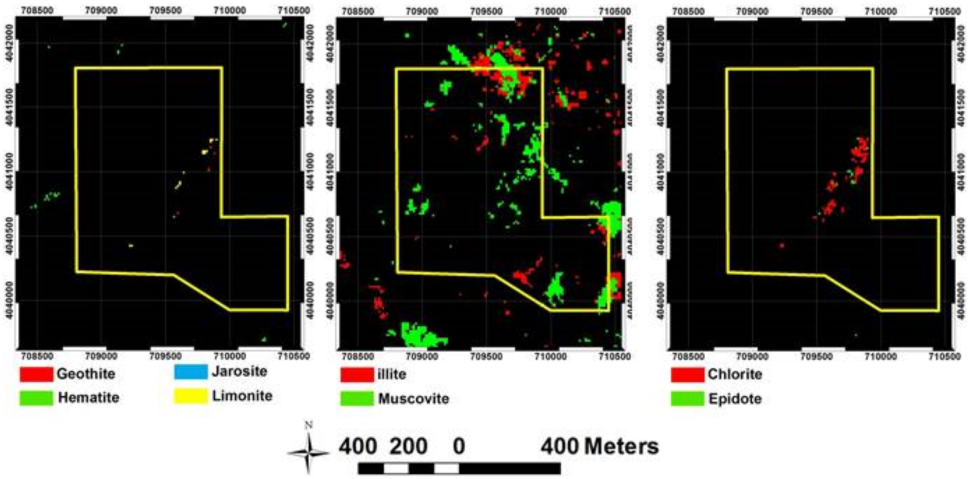


Fig. 6. The iron oxide, phyllic and propylitic images prepared based on SAM method

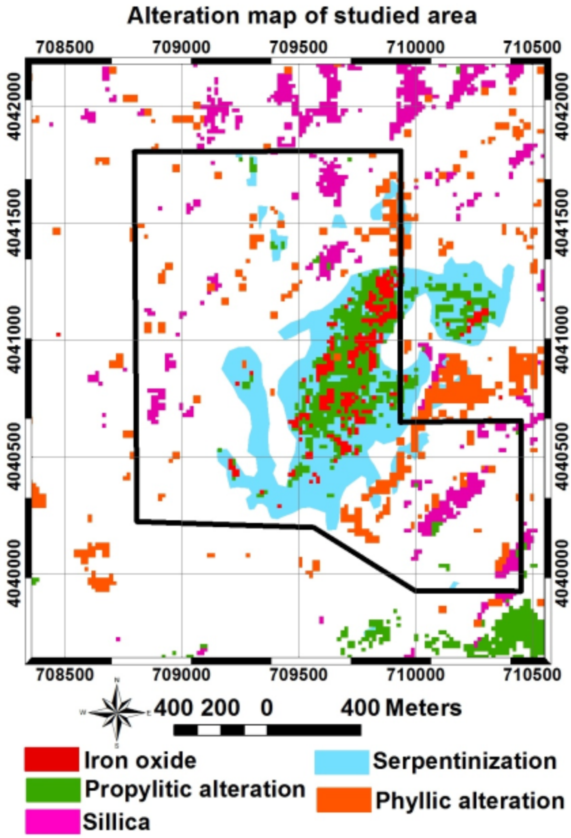


Fig. 7. Final map, prepared by GIS

4.1.2. Field observations and check fields

Finally field studies were done for confirming the results (Figs 8-11). As it were shown in figures all the remote sensing results were confirmed by field studies. As it is shown in Figure 8 Serpentinization zones were extracted with (RGB:4/7,3/4,2/1) which were all confirmed by filed investigations.

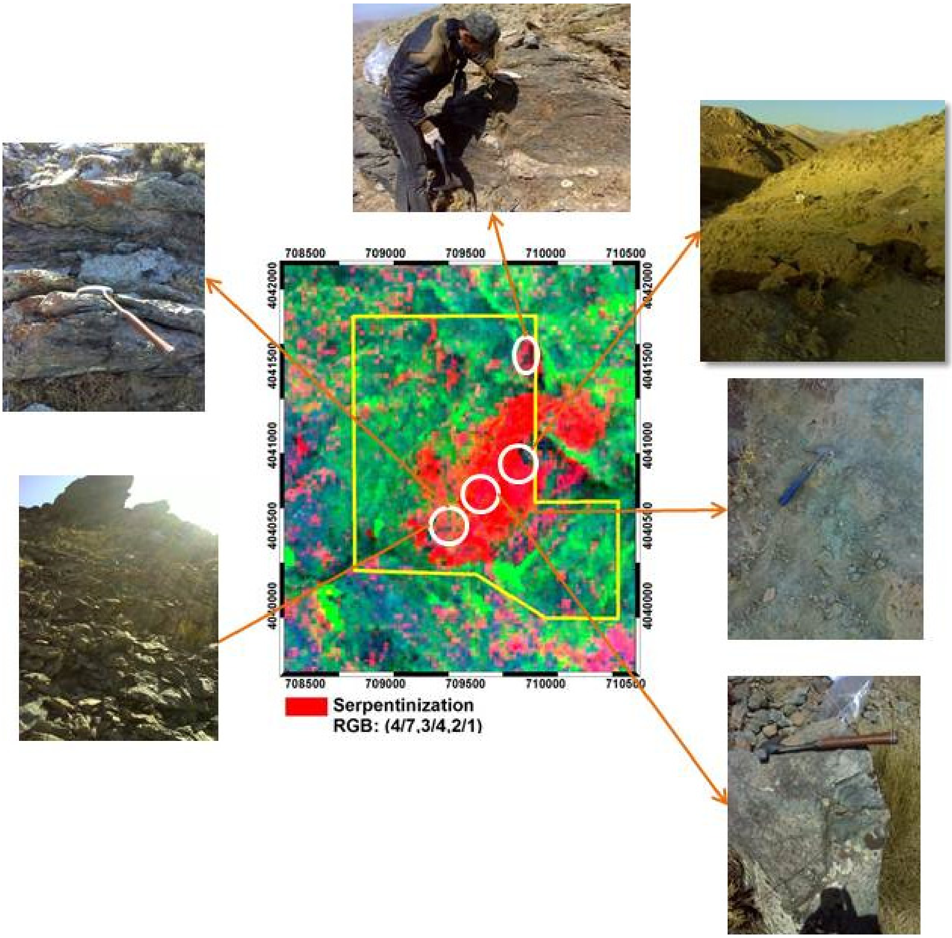


Fig. 8. satellite image processing and check fields for Serpentinization zones

With notification to the presence of Fe minerals as Amphibols in PE sch, SR unites (Amphibol Talc Serpentin Schist) and the Oxidation of these minerals, these unites were extracted as Iron oxide zones by satellite image processing. Filed investigations were confirmed the results (Fig. 9).

Based on 1:100000 geological map, PE sch unite was introduced as Mica schist and Quartzite.The index alteration for this unite is Phyillic which were extracted by image processing as Phyillic unite (Fig. 10).

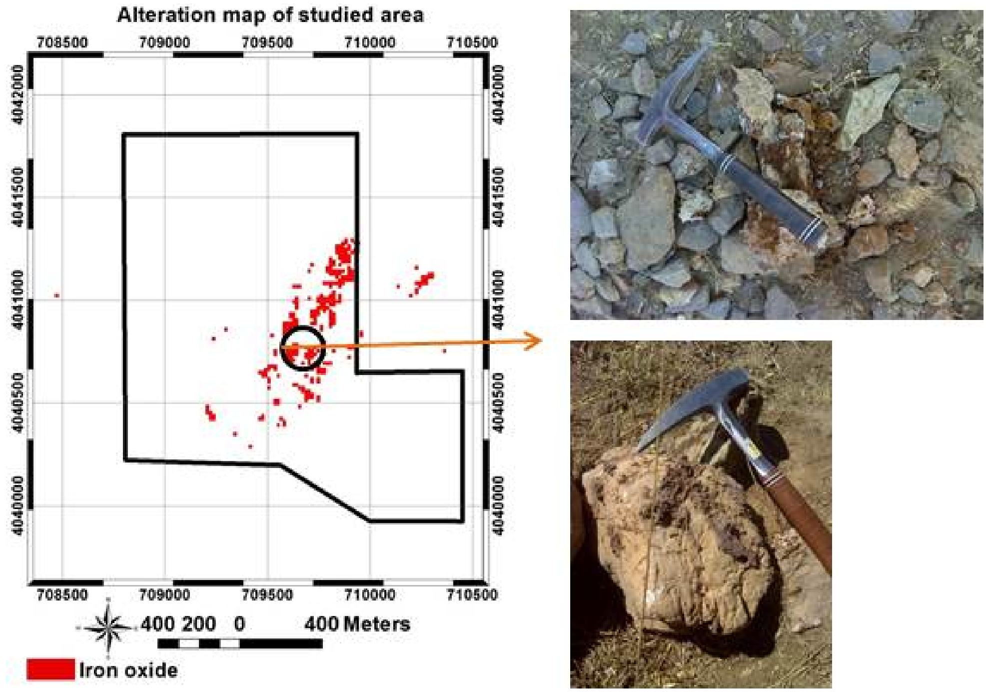


Fig. 9. satellite image processing and check fields for Iron oxide zones

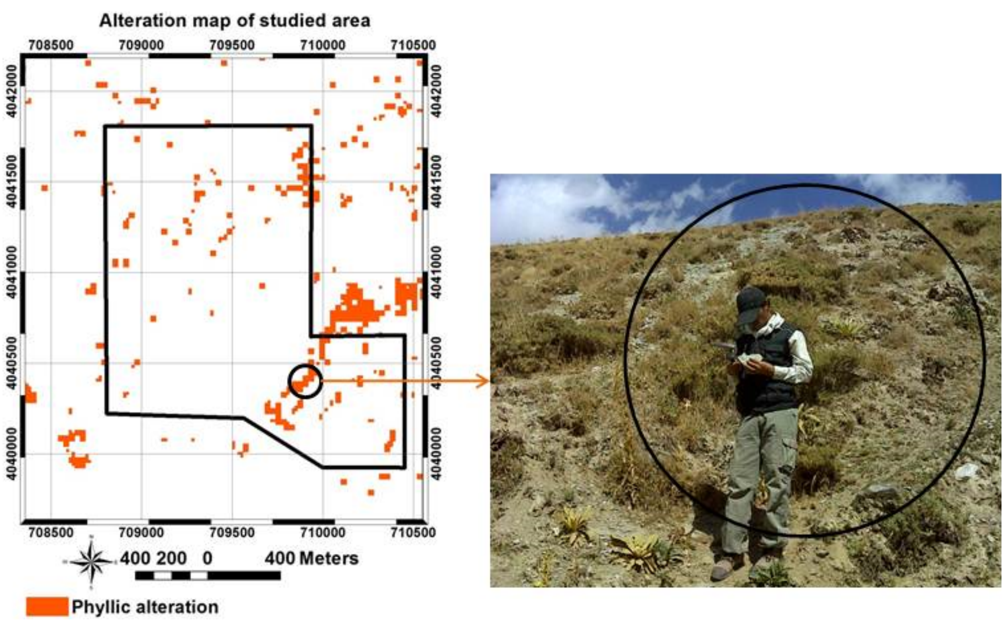


Fig. 10. satellite image processing and check field for Phyillic zones

Because the vine type Quartz mineralization were seen widespread in the area and it was confirmed by remote sensing methods,It seems this unite could be a suitable host rock for poly metal hydrothermal mineralization. So filed investigation and sampling were suggested.The results were indicated, this silica is related to last phase of magmatic differentiation without any mineralization but it could be a suitable pathfinder for exploration (Fig. 11).

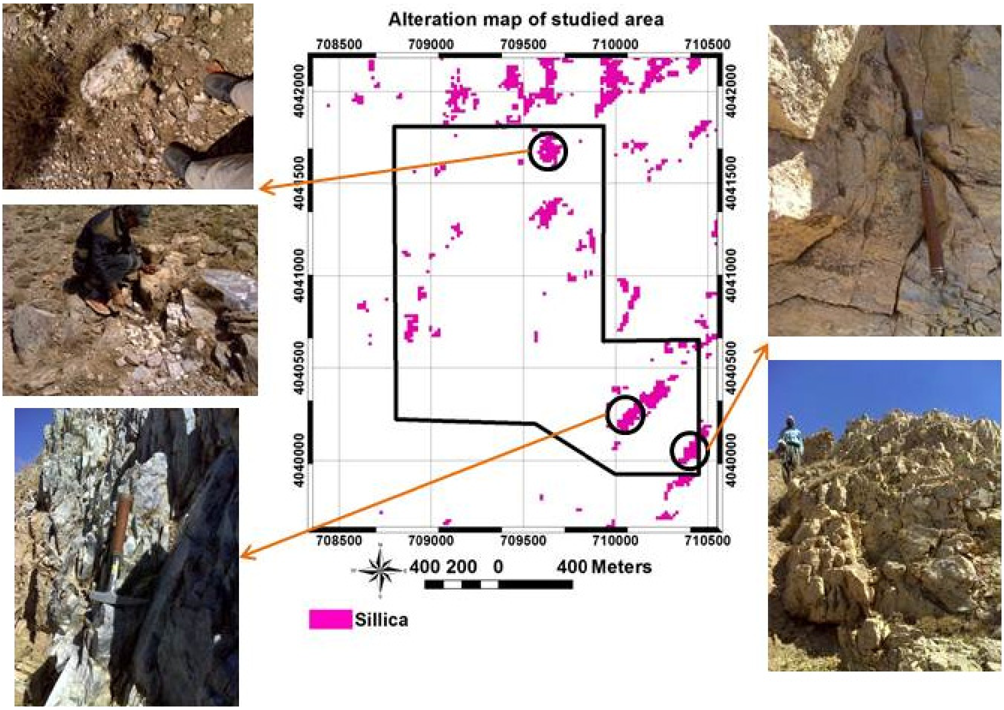


Fig. 11. satellite image processing and check fields for Silica zones

Figure 12 is shown the silica vine which came upward with schist unite in the west of area was mineralized. The result of analyzes were shown the Au assay was variated between 300 to 800 PPb in surface.

5. Geochemical data analysis

Cause of special importance of sampling models, several factors has to considered during the sampling. The most important of them are: Litho logical units, Faults, Alteration zones, Mineralization zones, Topography, Dikes and Intrusive bodies.

In this project, sampling distances were chosen based on the above factors. These factors can change based on experience of researches and filed evidences.

In this project the 147 lithogeochemical samples were chemical analyzed by ICP-MS method for elements especially for copper and gold. In this study, Number-Size (N-S) fractal method was

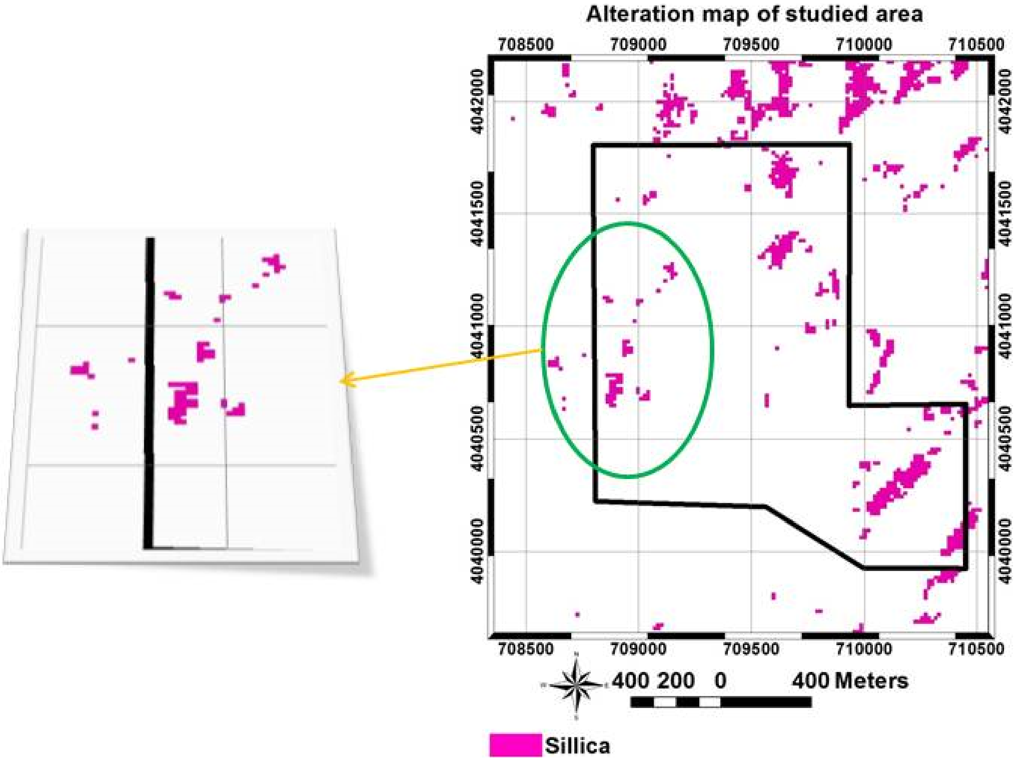


Fig. 12. The hopeful area for Au mineralization.Satellite image processing (up) and checkfiled (down)

utilized for High intensive Au, Ag and As anomalies in the studied area. Some of the samples were chosen on the silica vine in west of the studied area (Fig. 13).

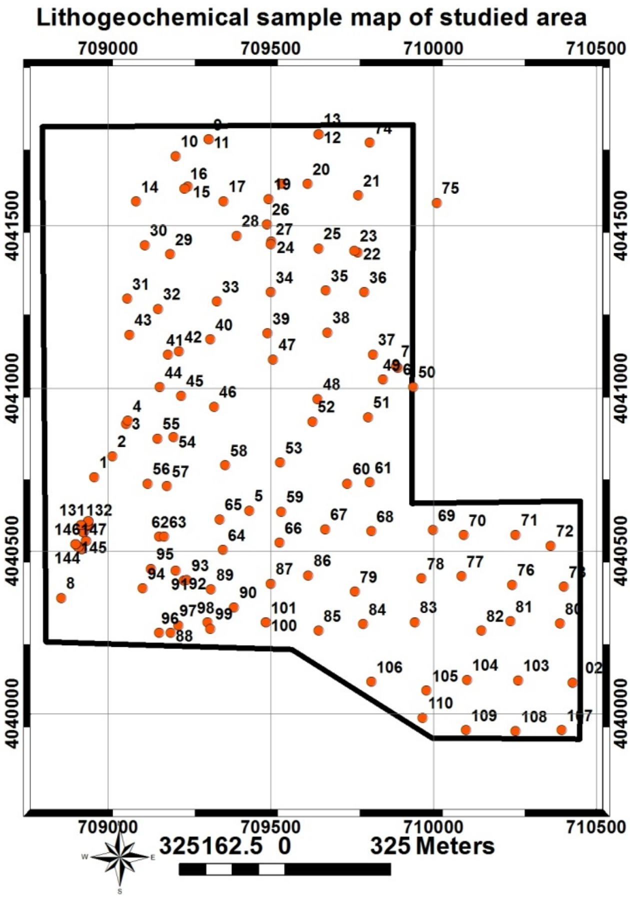


Fig. 13. Lithogeochemical samples location map of the studied area

5.1. Number-Size fractal method

The Number-Size (N-S) method, which was originally proposed by Mandelbrot (1983), can be used to describe the distribution of geochemical populations without pre-processing of data. The method indicates that there is a relationship between desirable attributes (e.g., ore elements) and their cumulative numbers of samples. Based on the model, Agterberg (1995) proposed a multifractal model named size-grade for determination of the spatial distributions of giant and super-giant ore deposits. Monecke et al., (2005) used the N-S fractal model to characterize element enrichments associated with metasomatic processes during the formation of hydrothermal ores in the Waterloo massive sulfide deposit, Australia. A power-law frequency model has been proposed to describe the N-S relationship according to the frequency distribution of element concentrations and cumulative number of samples with those attributes (Li et al., 1994; Sanderson et al., 1994; Shi & Wang, 1998; Turcotte, 1996; Zuo et al., 2009). The model is expressed by the following equation (Mandelbrot, 1983; Deng et al,. 2010):

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

where ρ denotes element concentration, $N(\geq\rho)$ 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. According to Mandelbrot (1983) and Deng et al., (2010), log-log plots of $N(\geq\rho)$ versus ρ show straight line segments with different slopes $-D$ corresponding to different concentration intervals.

5.2. Lithogeochemistry data analysis

A total of 147 lithogeochemical samples were collected from the area and analyzed using the inductively coupled plasma-mass spectrometry (ICP-MS) method for elements which are related to Au, As and Ag mineralization. (N-S) fractal method was utilized for High intensive Au, As and Ag anomalies. These anomalies are related to silica vines which are recognized in west of the area. These anomalies are related together too. As it is shown in Figure 14, Au anomalies were distinguished in west of the area where the silica vines are presents. Figure 15 is shown the anomaly of Ag, which is adapted on Au anomaly in the same place. As it is shown in Figure 16 the As anomalies are adapted with Au anomalies exactly in the same two places, one in the south west corner and another in west of the area.

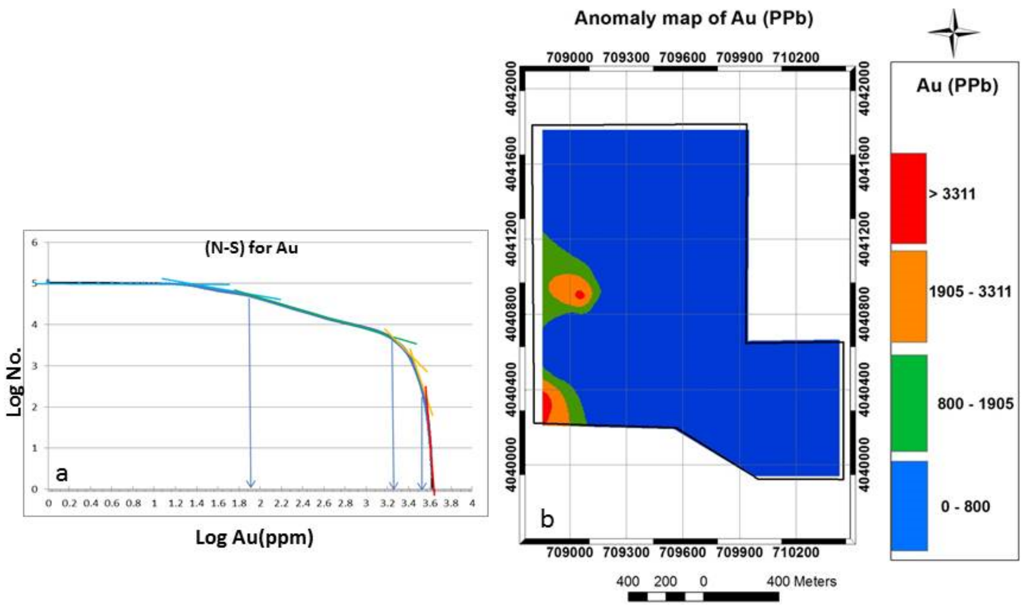


Fig. 14. a – Log-log plots from C-N method for Au. b – Au lithogeochemical population distribution map based on the C-N method

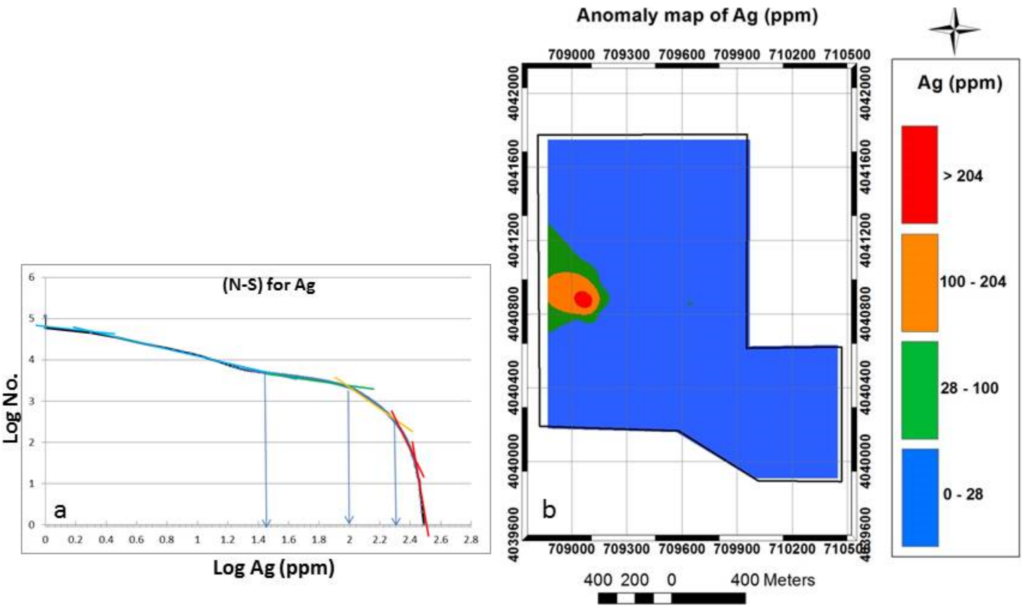


Fig. 15. a – Log–log plots from C–N method for Ag. b – Ag lithogeochemical population distribution map based on the C–N method

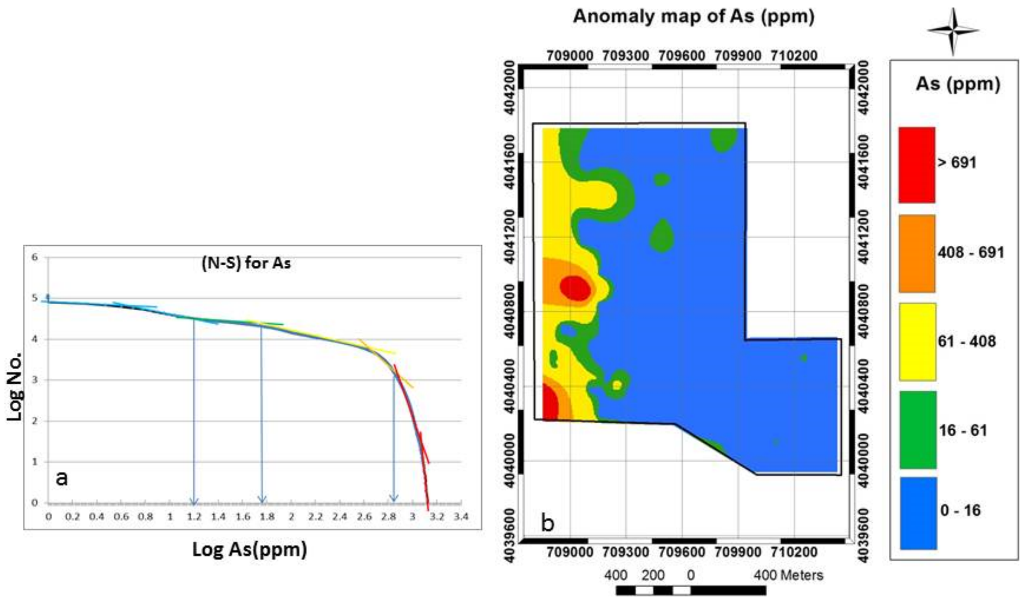


Fig. 16. a – Log-log plots from C-N method for As. b – As lithogeochemical population distribution map based on the C-N method

6. Conclusion

The vine type Quartz mineralization were seen widespread in the area and it was confirmed by remote sensing methods, It seems this unite could be a suitable host rock for poly metal hydrothermal mineralization. The results of filed investigation were indicated, this silica is related to last phase of magmatic differentiation without any mineralization but it could be a suitable pathfinder for exploration. There are just a few silica vines in the west and south west corner of the area which are included Au, Ag and As anomalies. Although there are many outcrops of mineralization such as Galena in this area but they are not confirmed by geochemistry analyses as high potential anomalies.

Finally the Geological map of the area, the results of the geo chemistry analyses and silica vines were integrated in GIS environment with ARC GIS software (Fig. 17). At last two final

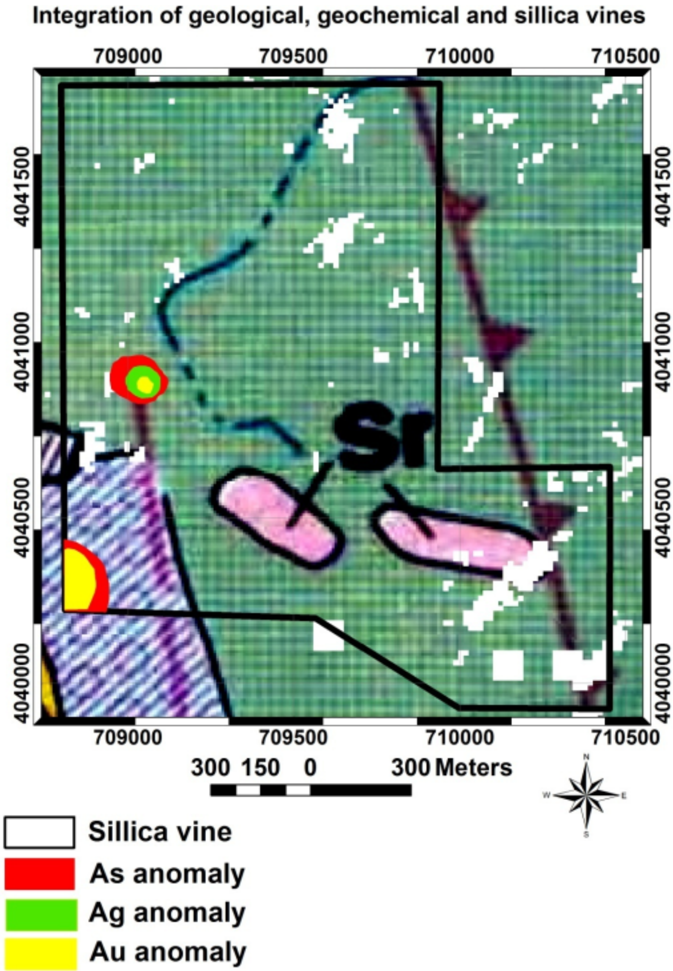
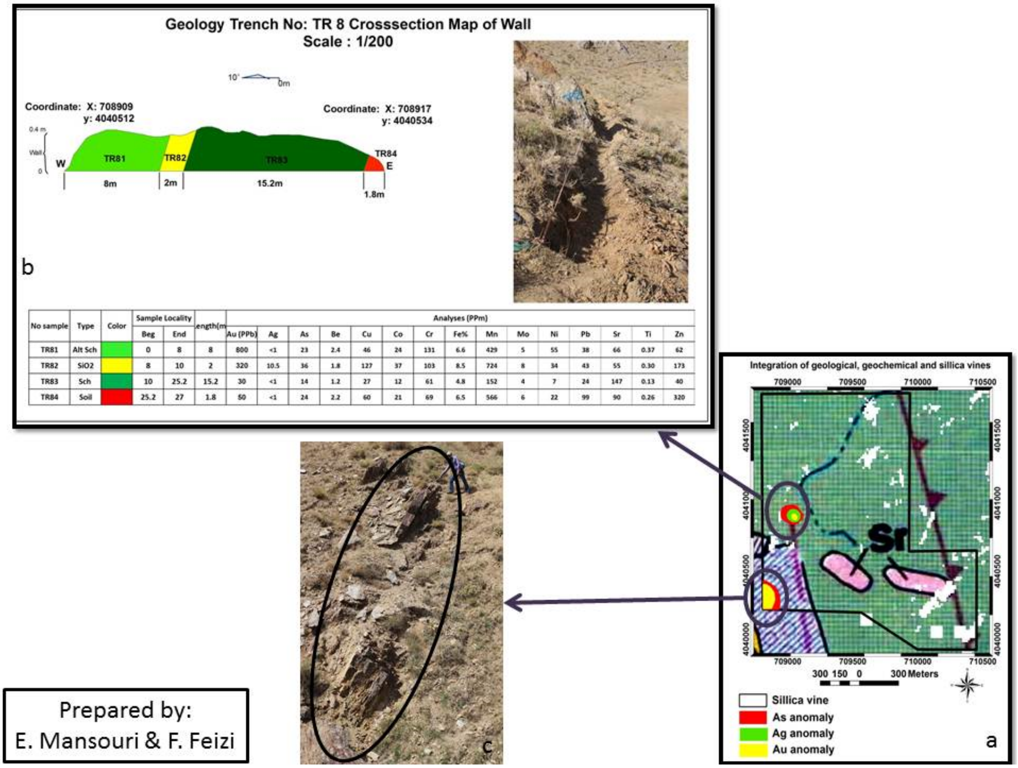


Fig. 17. Integration of geological, geochemical and silica vines

hopeful areas are suggested which are shown in Figure 18(a) by black circles. The check field results of these 2 areas are shown in Figure 18(b) as a trench and sample analyses and Figure 18(c) as a silica vines with Au anomalies.



No sample	Type	Color	Sample Locality		Length(m	Analyses (PPm)														
			Beg	End		Au (PPb)	Ag	As	Be	Cu	Co	Cr	Fe%	Mn	Mo	Ni	Pb	Sr	Ti	Zn
TR81	Alt Sch		0	8	8	800	<1	23	2.4	46	24	131	6.6	429	5	55	38	66	0.37	62
TR82	SiO2		8	10	2	320	10.5	36	1.8	127	37	103	8.5	724	8	34	43	55	0.30	173
TR83	Sch		10	25.2	15.2	30	<1	14	1.2	27	12	61	4.8	152	4	7	24	147	0.13	40
TR84	Soil		25.2	27	1.8	50	<1	24	2.2	60	21	69	6.5	566	6	22	99	90	0.26	320

Fig. 18. The hopeful areas(a) with field investigations (b) & (c)

Reference

Afzal P., Fadakar Alighalandis Y., Khakzad A., Moarefvand P., Rashidnejad Omran N., 2010a. *Application of power spectrum-area fractal model to separate anomalies from background in Kahang Cu-Mo porphyry deposit, Central Iran*. Arch. Min. Sci., Vol. 56, No 3, p. 389-401.

Afzal P., Khakzad A., Moarefvand P., Rashidnejad Omran N., Esfandiari B., Fadakar Alghalandis Y., 2010b. *Geochemical anomaly separation by multifractal modeling in Kahang (Gor Gor) porphyry system, Central Iran*. J. Geochem. Explor. 104, 34-46.

Agterberg F.P., Cheng Q., Wright D.F., 1993. *Fractal modeling of mineral deposits*. [In:] Elbrond, J., Tang, X. (Eds.), 24th APCOM symposium proceeding, Montreal, Canada, 43-53 p.

Agterberg F.P., 1995. *Multifractal modeling of the sizes and grades of giant and supergiant deposits*. International Geology Review, 37, 1-8.

Agterberg FP., Cheng Q. Brown A., Good D., 1996. *Multifractal modeling of fractures in the Lac du Bonnet Batholith, Manitoba*. Comput. Geosci., 22(5), 497-507.

Azizi H., Tarverdi M.A., Akbarpour A., 2010. *Extraction of hydrothermal alterations from ASTER SWIR data from east Zanjan, northern Iran*. Advances in Space Research, 46, 99-109.

Beiranvand Pour A., Hashim M., 2012. *The application of ASTER remote sensing data to porphyry copper and epithermal gold deposits*. Ore Geology Reviews, 44, 1-9.

Cheng Q., Agterberg F.P., Ballantyne S.B., 1994. *The separation of geochemical anomalies from background by fractalmethods*. Journal of Geochemical Exploration, 51, 109-130.

Cheng Q., 1999. *Spatial and scaling modelling for geochemical anomaly separation*. J. Geochem. Explor., 65(3), 175-194.

Cheng Q., 2007. *Mapping singularities with stream sediment geochemical data for prediction of undiscovered mineral deposits in Gejiu, Yunnan Province, China*. Ore Geology Reviews, 32, 314-324.

Goncalves M.A., Mateus A., Oliveira V., 2001. *Geochemical anomaly separation by multifractal modeling*. J. Geochem. Explor., 72, 91-114.

Deng J., Wang Q., Yang L., Wang Y., Gong Q., Liu H., 2010. *Delineation and explanation of geochemical anomalies using fractal models in the Heqing area, Yunnan Province, China*. Journal of Geochemical Exploration, 105, 95-105.

Gumiel P., Sanderson D.J., Arias M., Roberts S., Martín-Izard A., 2010. *Analysis of the fractal clustering of ore deposits in the Spanish Iberian Pyrite Belt*. Ore Geology Reviews, 38, 307-318.

Hawkes R.A.W., Webb H.E., 1979. *Geochemistry in mineral exploration, 2nd edn*. Academic Press, New York, 657 p.

Inzana J., Kusky T., Higgs G., Tucker R., 2003. *Supervised classifications of Landsat TM band ratio images and Landsat TM band ratio image with radar for geological interpretations of central Madagascar*. Journal of African Earth Sciences, 37, 59-72.

Kujjo C.P., 2010. *Application of remote sensing for gold exploration in the Nuba Montains, Sudan*. Bowling Green State University, Master of Science Thesis, 99 p.

Li C., Xu Y., Jiang X., 1994. *The fractal model of mineral deposits*. Geology of Zhejiang, 10, 25-32 (In Chinese with English Abstract).

Li C., Ma T., Shi J., 2003. *Application of a fractal method relating concentrations and distances for separation of geochemical anomalies from background*. J. Geochem. Explor., 77, 167-175.

Mandelbrot B.B., 1983. *The fractal geometry of nature*. Freeman, San Fransisco, 1-468 p.

Mars J.C., Rowan L.C., 2006. *Radiometer (ASTER) data and logical operator algorithms arc, Iran, using Advanced Spaceborne Thermal Emission and Reflection Regional mapping of phyllic and argillic altered rocks in the Zagros magmatic*. Geosphere, 2, 161-186.

Moghtaderi A., Moore F., Mohammadzadeh A., 2007. *The application of advanced space-borne thermal emission and reflection (ASTER) radiometer data in the detection of alteration in the Chadormalu paleocrater, Bafq region, Central Iran*. Journal of Asian Earth Sciences, 30, 238-252.

Monecke T., Monecke J., Herzig P.M., Gemmell J.B., Monch W., 2005. *Truncated fractal frequency distribution of element abundance data: a dynamic model for the metasomatic enrichment of base and precious metals*. Earth and Planetary Science Letters, 232, 363-378.

Oskouei M., Busch W., 2012. *A selective combined classification algorithm for mapping alterations on ASTER data*. Appl. Geomat., 4, 47-54.

Poormirzaee R., Mohammady Oskouei M., 2010. *Use of spectral analysis for detection of alterations in ETM data, Yazd, Iran*. Applied Geomatics, 2, 147-154.

Rajendran S., Khirbash S.A., Pracejus B., Nasir S., Al-Abri A.H., Kusky T.M., Ghulam A., 2012. *ASTER detection of chromite bearing mineralized zones in Semail Ophiolite Massifs of the northern Oman Mountains: Exploration strateg*. Ore Geology Reviews, 44, 121-135.

Reimann C., Filzmoser P., Garrett R.G., 2005. *Background and threshold: critical comparison of methods of determination*. Science of the Total Environment, 346, 1-16.

Rowan L.C., Mars J.C., 2003. *Lithologic mapping in the Mountain Pass*. California area using 341.

Sadeghi B., Moarefvand P., Afzal P., Yasrebi A.B., Daneshvar Saein L., 2012. *Application of fractal models to outline mineralized zones in the Zaghia iron ore deposit, Central Iran*. Journal of Geochemical Exploration, 122, 9-19.

Sanderson D.J., Roberts S., Gumiel P., 1994. *A fractal relationship between vein thickness and gold grade in drill core from La Codosera, Spain*. Econ. Geol., 89, 168-173.

Shi J., Wang C., 1998. *Fractal analysis of gold deposits in China: implication for giant deposit exploration*. Earth Sci. J. China Univ. Geosci., 23, 616-618 (In Chinese with English Abstract).

Tukey J.W., 1977. *Exploratory Data Analysis*. First ed. Pearson, p. 1-688.

Turcotte D.L., 1996. *Fractals and Chaos in Geophysics, second ed*. Cambridge University Press, Cambridge UK, 81-99 p.

Turcotte D.L., 1997. *Fractals and chaos in geology and geophysics*. Cambridge Univ, Press, Cambridge.

Turcotte D.L., 2002. *Fractals in petrology*. Lithos., 65, 261-271.

Yetkin E., Toprak V., Suezen M.L., 2004. *Alteration Mapping By Remote Sensing: Application To Hasandağ-Melendiz Volcanic, Complex*. Geo-Imagery Bridging Continents XXth ISPRS Congress, Istanbul.

Yousefifar S., Khakzad A., Asadi Harooni H., Karami J., Jafari M.R., Vosoughi Abedin M., 2011. *Prospection of Au and Cu bearing targets by exploration data combination in southern part of Dalli Cu-Au porphyry deposit, Central Iran*. Arch. Min. Sci., Vol. 56, No 1, p. 21-34.

Zuo R., Cheng Q., Xia Q., 2009. *Application of fractal models to characterization of vertical distribution of geochemical element concentration*. J. Geochem. Explor., 102(1), 37-43.

Zuo R., 2011. *Identifying geochemical anomalies associated with Cu and Pb-Zn skarn mineralization using principal component analysis and spectrum-area fractal modeling in the Gangdese Belt, Tibet (China)*. Journal of Geochemical Exploration, 111, 13-22.