

# پردازش تصویر رقومی جهت نقشه برداری از دگرسانی وسنگ شناسی، با استفاده از داده های ماهواره

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## Digital image processing for lithological and alteration mapping, using spot multispectral data. A case study of Pariz area, Kerman Province

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### چکیده

منطقه پاریز به عنوان یک منطقه آزمایشی انتخاب شده تا داده های دورسنجی در چنین منطقه ای جهت اکتشاف ارزیابی گردد. حدود هشت نقطه کانی سازی شده در منطقه انتخاب شدند که بطور عمده دارای کانی سازی از نوع پورفیری هستند. از تصاویر چند طیفی ماهواره Spot جهت مطالعه زمین شناسی و دگرسانی گرمایی در منطقه استفاده شده است. این منطقه دارای پوشش خاک و رستی کمی است. روشهای پردازش تصویر مختلفی مانند نسبت باندها، آنالیز مولفه های اصلی (Principal Components Analysis)، تبدیل I-S-H (Intensity, Saturation, Hue)، فیلترهای رقمی و ترکیب های هیبریدی نسبت باندها، استفاده شده تا سیماهای تشخیصی که با سنگ شناسی و دگرسانی گرمایی همراه می باشد را واضح تر کنند. ترکیب های رنگی مولفه های اصلی، تبدیل I-S-H و نسبت باندهای ۲ به ۱ روشهای پردازش تصویر بسیار خوبی جهت مطالعات زمین شناسی در چنین مناطقی می باشند. آنالیز خط وارهای نشان داده است که مناطق دارای کانی سازی و مناطق دگرسان شده با مقادیر زیاد خط واره های عکس در ارتباط نزدیک هستند و همچنین همبستگی خوبی بین داده های دورسنجی و ژئوفیزیک هوایی در منطقه وجود دارد.

واژه های کلیدی: داده های دورسنجی، پورفیری، اسپات، دگرسانی گرمایی، مولفه های اصلی، تبدیل I-S-H، ترکیب های هیبریدی نسبت باندها

### Abstract

Pariz area is chosen as a test area to evaluate remote sensing data and application of these data in exploration. Eight known mineralization sites were chosen in the area, which have mainly porphyry type mineralization. SPOT images in XS mode are used to study geology as well as hydrothermal alteration in the Pariz area. Here, soil and vegetation cover is substantially poor. Different approaches such as band ratioing, principal component analysis, I-S-H, decorrelation processing, digital filtering and hybrid composite were used to enhance the diagnostic features associated with the lithologies as well as the hydrothermal alteration. Color combinations of the principal components, I-S-H transformation and 2/1 ratio have proved to be the best image enhancement techniques for geological studies in such areas. Lineament analysis has shown that the areas with known ore occurrences and also the hydrothermally altered areas, are closely associated with the higher photolineament factor values. There is also a good correlation between the geophysical and remote sensing data in the area.

**KeyWords:** Remot sensing data, Porphyry, Spot, Hydrothermal alteration, Principal components analysis, I-S-H, decorrelation Processing

## 1-Introduction:

Tertiary porphyry deposits in Iran are important source of Cu, Mo and locally Au. Most of known porphyry Cu deposits are located in the Central Iranian Volcanic Belt (Urumich-Dokhtar magmatic assemblage of Alavi, 1994), and are aligned parallel to the Zagros Thrust Zone and to the prevalent for axes in the area (Bazin and Hubner, 1969; Jankovic, 1977 and Forster, 1978, Fig. 1). The magmatic processes and associated mineralization in this belt are thought to be related either to subduction along the Zagros Thrust Zone (Forster, 1978; Alavi, 1980, 1994; Berberian et al., 1982; Shahabpour, 1982; Shahabpour and Kramers, 1987), or to a rift setting (Amidi et al., 1984).



شکل ۱- جایگاه کمر بند آتشفشانی گستره ایران مرکزی و کانی سازی های مربوط به آن.

Most of the porphyry deposits exhibit a well-developed zonal pattern of mineralization and wallrock alteration that can be defined by broad variations in major oxides and trace element concentrations (Govett, 1983; Jones, 1992). These elemental compositions in turn reflect variations in mineralogical composition of the altered zones. Most of the hydrothermal alteration processes produce clay and other silicate minerals (e.g., argillic and phyllic zones). Supergene alteration results in the formation of extensive iron oxide minerals, giving characteristic yellowish or reddish color to the altered rocks. These alteration minerals can be detected by remote sensing techniques (Abrams et al., 1977; Abrams et al., 1984; Buvkinham and Sommer, 1983; Elvidge and Lyon, 1984; Amos and Greenbaum, 1989; Drury and Hunt, 1989).

Although SPOT bands are highly correlated, principal component analysis and I-H-S decorrelation processing give excellent results (Gillespie et al., 1986; Jaskolla and Henkel, 1988). SPOT data has been widely used for geological studies (e.g. Lyberis et al., 1990; Huger et al., 1991; Mekamia and Chrowicz, 1992; Yesou et., 1993; Trefois et al., 1996; Alizai, 1997; Ganas et al., 1997; and Deroin et al., 1998).

A SPOT subscene is chosen which covers the Pariz area, situated southeast of Kerman City, to evaluate its potential for lithological mapping and mineral exploration in the semi-arid areas of Central Iranian Volcanic Belt. The area has a mountainous topography and the climate is typical of continental and semiarid, with vegetation cover consisting of low shrubs and bushes with occasional trees in the mountains, along the streams and near settlements. Given the relatively poor soil development but abundant outcrop in this semi-arid area is suitable for applying remote sensing techniques for geological studies. There are eight porphyries and vein type base metal mineralization in the area which are chosen as ground control sites for the present work.

## 2-Geological setting:

The detailed geology of the Pariz area is given by Dimitrijevic

et al. (1971) and GSI (1973). The area is also studied by Navai and Mehdizadeh - Tehrani (1994), Pitcher et al., (1994), Ranjbar (1996), Ranjbar and Roonwal (1997) and Shahabpour (1996).

The volcanic- sedimentary rocks of Eocene age are the oldest rocks in the area represented by pyroclastics, pyroxene trachyandesites, pyroxene andesite, trachybasalts and and-csites. The sedimentary rocks in the volcanic- sedimentary complex are mainly sandstone and less frequently limestone that has very subordinate development in the area. The Eocene volcanic sedimentary rocks are intruded by Oligocene- Miocene plutonic rocks that consist of mainly granodiorite, quartz- diorite, monzonite, tonalite and granite (Fig. 10). The volcanic rocks in the immediate vicinity of these intrusive are widely metamorphosed and altered. Most of the plutonic and volcanic rocks are hydrothermally altered and at places they are mineralized. Argillization, sericitization and propylitization are the most common type of hydrothermal alteration in the area. The Neogene sediments consist of mainly loosely consolidated, unsorted and poorly stratified conglomerate and sandstone overlying the Eocene volcanic- sedimentary rocks. Calcareous terraces, dacitic rocks and recent alluvium are the main Quaternary features in the area.

### 3-Data and methodology

A SPOT subscene in XS mode (path 162, Row 290 on 18 June 1986 at 10:38:26 local time) is used for the present work. Image processing was aimed at enhancing the contrasts related with lithologies and hydrothermal alteration. VIPS-32 image processing software has been used for the present work.

### 4-Discussion

The three SPOT bands are highly correlated (Table 1C). Therefore not much of information can be extracted from either the individual bands or their false color composite. Several band ratios have been tried out, aiming at enhancing the spectral differences between different ground features. The color ratio composite of 1/3, 2/3 and 2/1 showed the best color combination

Table 1A: General statistics for Pariz subscene

Spectral band	Minimum	Maximum	mean	Standard deviation
XS1	31	254	72.68	12.22
XS2	33	254	78.77	12.72
XS3	42	254	75.42	10.33

B: Variance- covariance matrix for the input multispectral bands

	XS1	XS2	XS3
XS1	149.35		
XS2	129.64	162.15	
XS3	101.40	128.01	106.62

C: Correlation matrix for the input spectral bands

	XS1	XS2	XS3
XS1	1.00		
XS2	0.83	1.00	
XS3	0.80	0.97	1.00

B: Variance- covariance matrix for the input multispectral bands

for the input multispectral bands

Spectral bands	PC1	PC2	PC3
XS1	-0.51	0.41	0.75
XS2	-0.64	0.40	-0.65
XS3	-0.58	-0.81	0.07
eigenvalues	381.86	33.01	3.25
Percentage of variance	91.33	7.89	0.78

for discrimination between different lithologies as well as discrimination between altered and unaltered rocks. Band ratio 2/1 enhances the intensely altered rocks. This is due to the higher reflectance of altered rocks in band 2.

Intensity- Saturation - Hue transformation is one of the best image enhancement techniques for this area. The Intensity image that shows the total albedo is enhancing the altered rocks. However the FCC of I-S-H in red, green and blue respectively enhances the lithological boundaries and also the altered rocks can be differentiated from the unaltered ones. The intensely altered rocks appear in shades of yellow and the area corresponding to the propylitic zone, appear in shades of red in the volcanic-

sedimentary complex. The alteration halos around Darrehzar and Sar Cheshmeh deposits are quite clear (Fig.2)

Principal components analysis of SPOT multispectral data has a good potential for enhancing the spectral variation associated with the altered and the relatively unaltered rocks. The first PC image contains 91.33% of the total variance in the original data respectively (Table 1D). Principal component images are generated, using the eigenvector loadings of Table 1 and the procedure given by Dwivedi and Ravi Shankar (1992). Every picture element has been transformed by :

$$I_{pc1} = -0.51 \times I_1 - 0.64 \times I_2 - 0.58 \times I_3 \quad \text{Table 1}$$

Where  $I_{pc1}$  is the new brightness value and  $I_1, I_2, I_3$  corres-

pond to the three spectral bands of SPOT. Essentially, it is a point-wise weighted summation of the three SPOT spectral bands. Similarly, the second and third PCs were computed using the following projection:

$$I_{pc2} = 0.41 \times I_1 + 0.40 \times I_2 - 0.81 \times I_3$$

$$I_{pc3} = 0.75 \times I_1 - 0.65 \times I_2 + 0.07 \times I_3$$

In order to explore the potential of PC transformations for delineating alteration zones, false color composite of the three PC images is generated. Fig. 3 shows the FCC of principal components 1 (red), 2 (green) and 3 (blue) of Pariz subscene. The highly altered zones associated with argillic and phyllic zones appear in shades of green (c.g., Areas around Now Chun, Sar

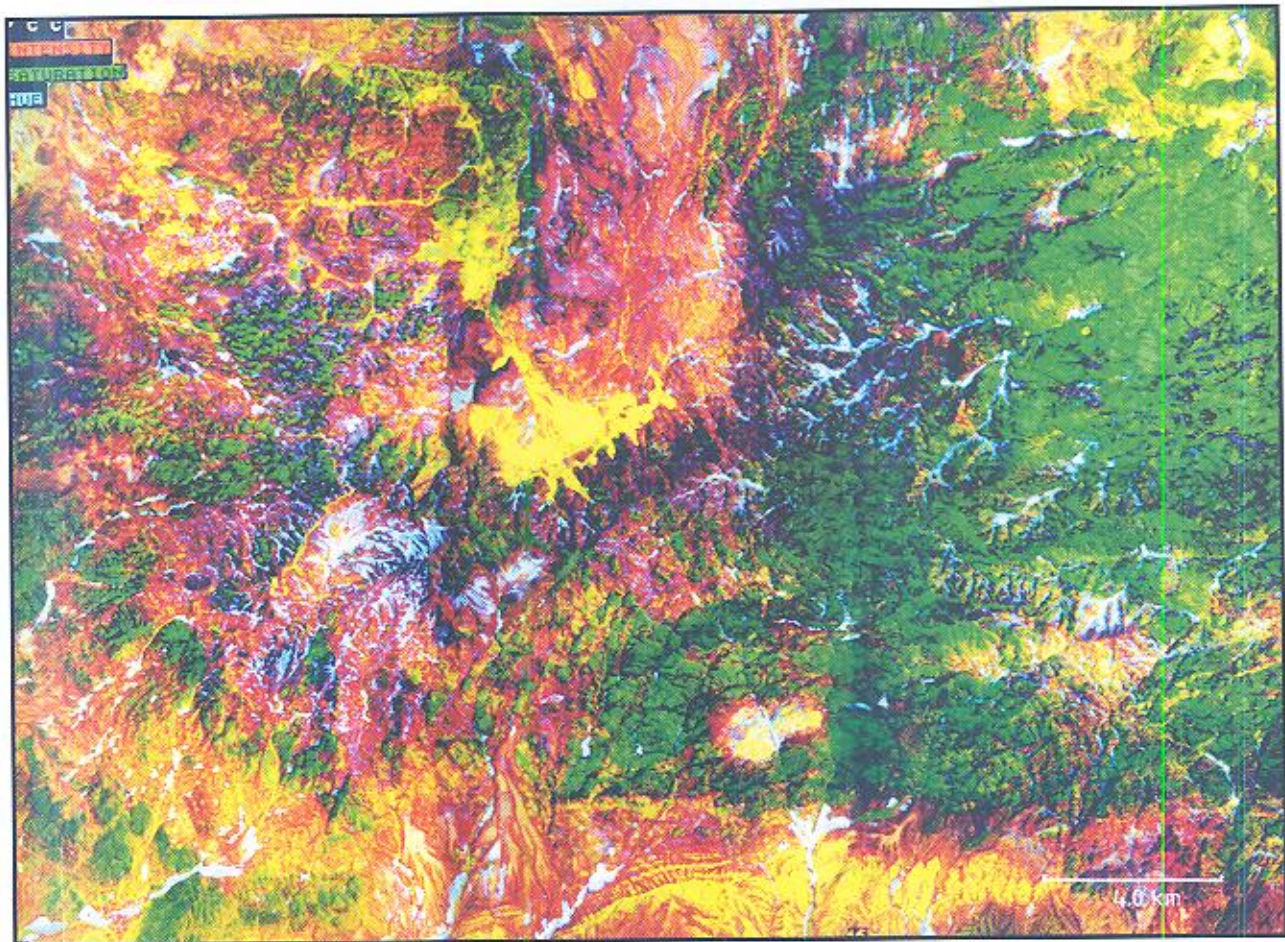


Fig.2 False color composite of Pariz area, prepared by combination of intensity, saturation and hue images.

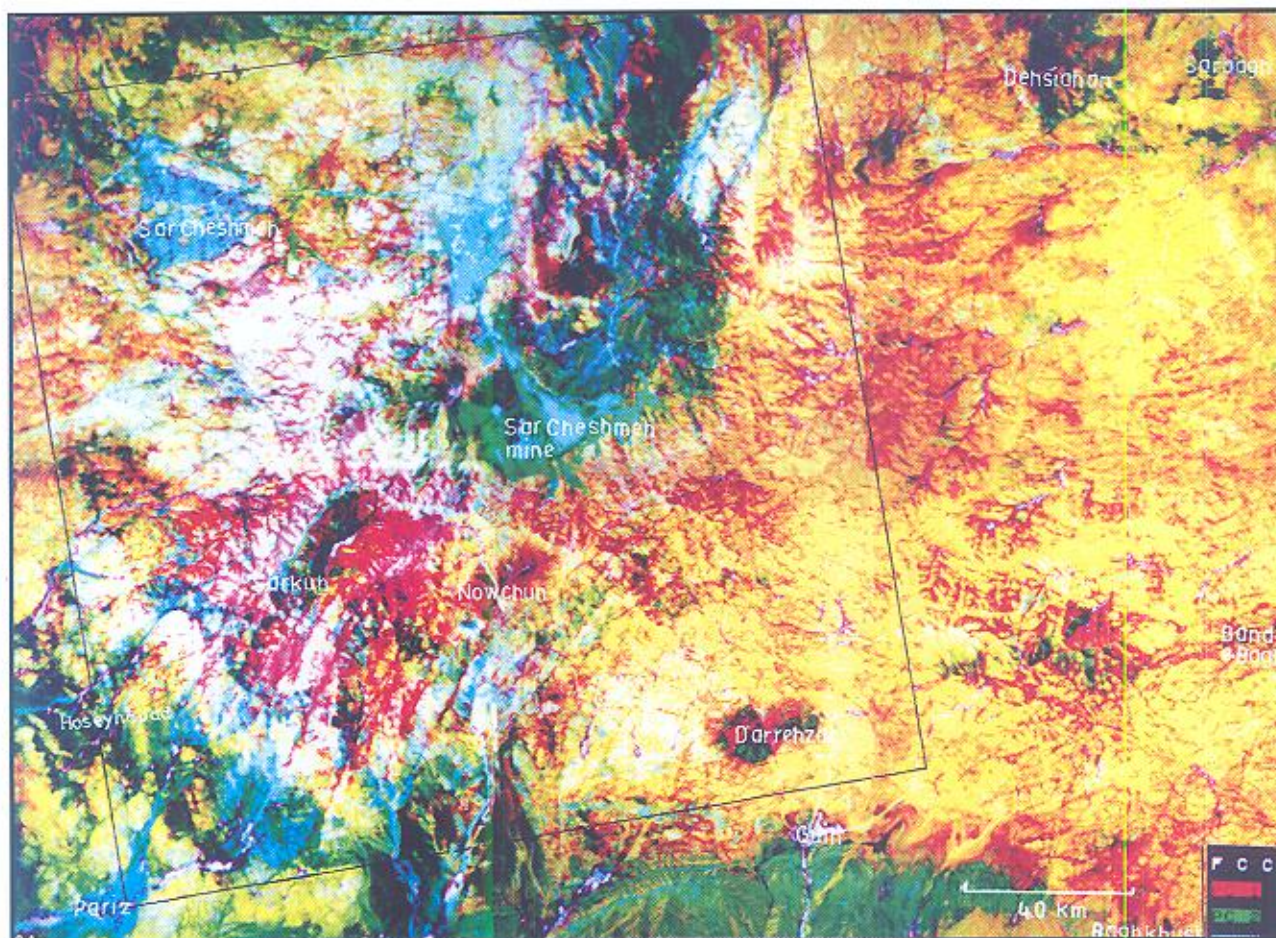


Fig. 3 False color composite of principal components-1, -2 and -3 images. The PC images are generated based on the eigenvector loadings of Table 1D. The rectangle outlines the area of Fig. 8.

Kuh, Hoseynabad, Sar Cheshmeh and Sarbagh). The sedimentary rocks in the south of the area also appear in shades of green, owing to the fact that, the major materials for these rocks are derived from the intrusive and dacitic rocks which have signature

of surfacial weathering. The white color and fine surface texture of calc-tuffa in the northern part of the area impart highest percentage of albedo due to which they appear dark green in principal component FCC images.

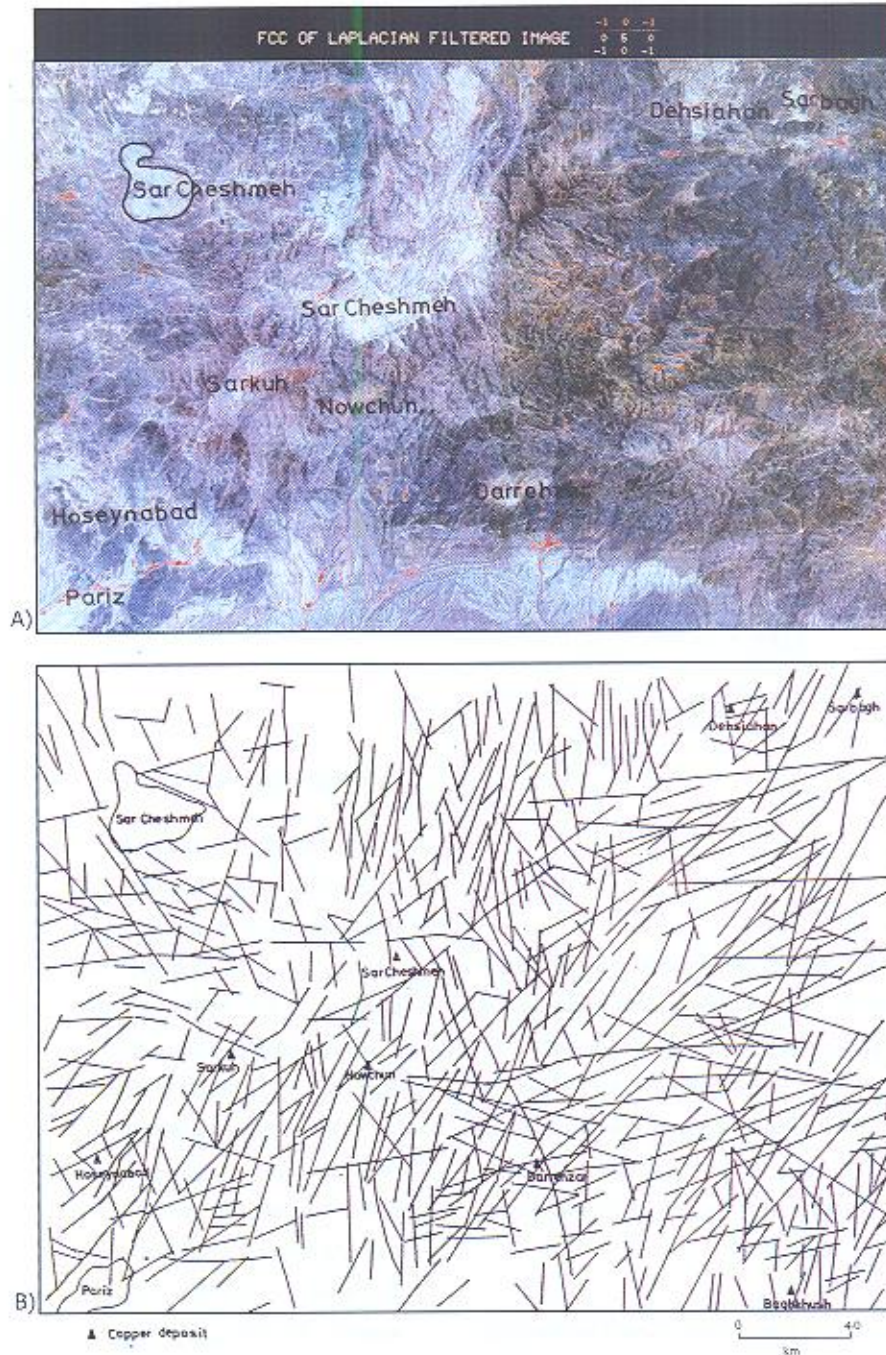


Fig. 4 A: False color composite of Laplacian filtered image of Pariz subscene. The linear features are enhanced in all directions. B: Raw photolineament data for Pariz area as interpreted from the filtered SPOT data.



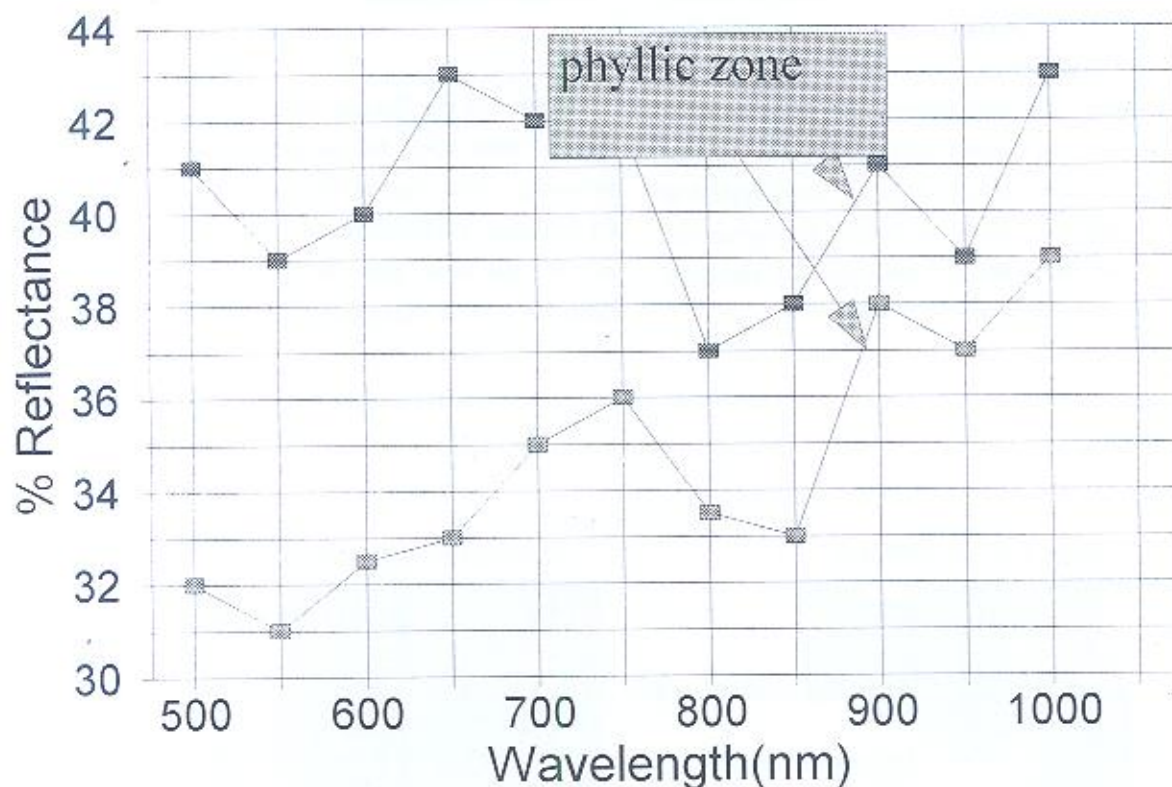


Fig. 7 Reflectance Spectra of the altered rocks from the Darrehzar deposit.

samples collected from the Darrehzar area shows that the altered samples from the phyllitic zone have absorption band around 0.5 and around 0.8  $\mu\text{m}$  (Fig.7). Considering the earlier published data (e.g., Hunt et al., 1978) the shape of the curve indicates the presence of iron oxide in the samples.

The altered areas in the image are verified, using the available geophysical data. Pitcher et al. (1994) have developed a model called "porphyry picker" based on analysis of geophysical data. The method includes a series of mathematical calculations which involves: (1) removing base value from each data set, (2) normalization of each data set, (3) multiplication of magnetics and apparent resistivity values by -1 and addition of +1, (4) addition of data set together and then normalization of the resulted values. The processed data for the Sar Cheshmeh and vicinity is given in Fig. 8. Comparison of Fig. 8 with Fig. 3 reveals that the altered areas such as Darrehzar, Sar Cheshmeh, Sar Kuh and Now Chun are closely related to the lower magnetic and resistivity and higher

$\gamma$ -ray data. They have a good correlation with higher porphyry picker values too. Alteration and geological map of Pariz area-prepared based on the available literature, interpreted satellite data and few ground checks (Figs. 9 and 10).

## 6-Summary and conclusions

In the present study SPOT multipectral data has been used for obtaining geological data as well as recognition and discrimination of different alteration types, in the Pariz area (with several known porphyry copper deposits) and to evaluate its potential for minerals exploration in semi-arid region of Central Iranian Volcanic Belt.

The combination of image interpretation, field and laboratory investigations of selected samples collected from the altered zones and the results of the previous geological investigations, have greatly enhanced the reliability of SPOT data as a potential tool

for exploration of the porphyry copper deposits and geological studies in the Pariz area. The digitally enhanced data of SPOT in XS mode shows that I-S-H decorrelation transformation, principal component analysis and band ratioing (2/1) are best image enhancing techniques for geological mapping. Due to a good spatial resolution, various directional filters can be applied on SPOT data for enhancing the linear features as short as 100 meters. Higher photolineament factor value is roughly associated with mineralization in the Pariz area.

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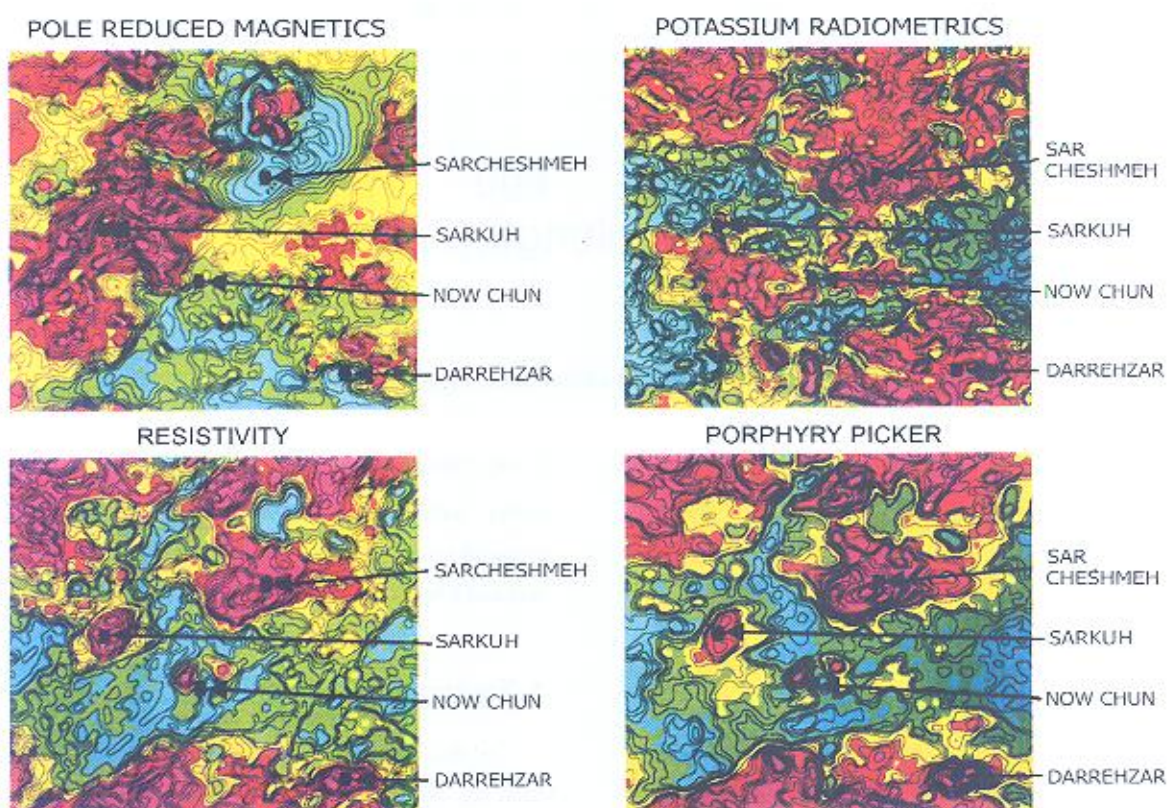


Fig. 8 Pole reduced magnetics, resistivity and potassium radiometric data for the Pariz area (see Fig. 3). The interpreted map (porphyry picker) is showing the areas with potential porphyry Cu deposits. In all maps red represents the higher value and blue represents the lower value, except for resistivity map (after Pitcher et al., 1994).

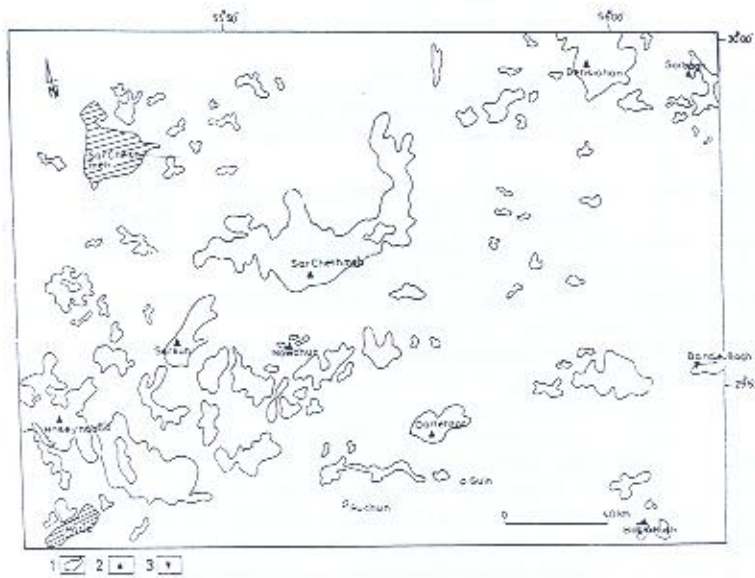


Fig. 9 Alteration map of Pariz area, prepared based on interpretation of SPOT multispectral data. 1 areas with intense hydrothermal alteration (mainly phyllic and argillic), 2 copper mineralization and 3 Pb- Zn mineralization.

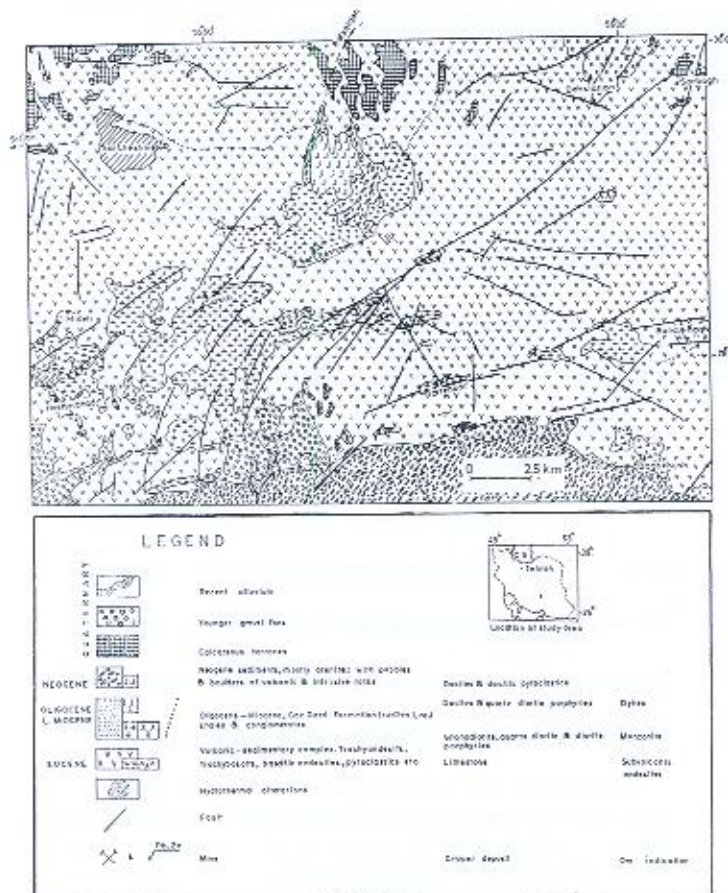


Fig. 10 Geological map of Pariz area, interpreted from SPOT multispectral data (modified after Dimitrijevic et al., 1971).

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