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# Investigation of Lineaments Related to Ground Water Occurrence in a Karstic Area: A Case Study in Lar Catchment, Iran

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**Abstract:** The aim of this research was to demonstrate the spatial correlation between hydro geomorphologic features identified as lineament and fracture traces located in a karst geological catchments of the study area and subsurface ground water parameters. In this research emphasis was given to investigate whether structural and topographic factors mapped using remote sensing, aerial photo interpretation and derived from the geologic map, can be correlated with hydrologic phenomena. With this assumption, Land sat TM7 spectral bands were analyzed. Springs geographic locations were surveyed with a high precision GPS unit. Black and white 1/20000 aerial photos, geology and topography maps were used to create different thematic layers. These data sets were later displayed on a GIS environment to investigate their geospatial correlation. Owing to the good correlation between the above mentioned factors and hydrologic phenomena, it was concluded that tectonic elements have a positive influence on the groundwater occurrence and they act as transmission routs in the limestone bodies. The importance of structural geological elements such as lineaments and faults in explaining the patterns of springs was demonstrated.

**Key words:** Structural elements, lineament, spring, Karst, Lar Catchment

## INTRODUCTION

Karst water resources evaluations have been increasingly implemented in recent years as the demand for water has been increased. Information on karst water resources characteristics provides threshold values for different water based activities. Approximately 11% of Iran territories is covered by carbonate rocks (Afrasiabian, 1998) and within the Lar catchments, 33% of the area is occupied by exposed karstified carbonate rocks, in which sinkholes, caves and karstic springs occur locally.

Characterization of the natural and regional extend of lineaments developed on the hard formations and their relationship to water resource discharge points is important for the evaluation of ground water resources. Tectonic elements such as faults, joints, folds and bedding patterns play an important role in the karstification and lineaments derived from remotely sensed data, might have high correlation with vertical or near vertical zones of fractures concentration which may act as conduits for transport and storage of ground water (Lattham and Parizek, 1964; Parizek, 1976; Krishnamurthy *et al*., 2000).

In the last two decades remote sensing and GIS have been widely used for preparation of different types of thematic layers and integration of them for different purposes. Application of remote sensing and GIS in ground water resources management and using structural element and lineament for investigating water resource have been practiced by Krishnamurthy and Srinivas (1995), Solomon and Ghebreab (2008), Sener *et al*. (2005) and Pirasteh *et al*. (2006). Krishnamurthy and Srinivas (1995) discussed the role of geological and geomorphological factors in ground water exploration. Sener *et al*.

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(2005) and Kim *et al*. (2004) investigated ground water potential zone through the analysis of lineament and Pirasteh *et al*. (2006) distinguished groundwater potential zones in karst area using geospatial techniques.

This research was carried out in an area of approximately 740 km$^2$ within Lar river catchment, about 85 km North East of Tehran, capital city of Iran.

The propose of this research was to investigate the spatial correlation of hydro geomorphologic features identified as lineament and fracture traces located in a karst geological catchments of the studied area as they might be possibly related to the subsurface ground water parameters.

## MATERIALS AND METHODS

### Study Area

The research was conducted within the Lar catchment located in upstream of Lar dam, southern part of Alborz Mountains and 85 km far from Tehran city, Iran, from May to December 2007. The study area, about 750 km$^2$, located in the coordinates of between 35, 48 to 36, 04 N and 51.32 to 52.04 E and at the elevations of 2400-5670 m above sea level, as a part of Lar river catchment, has been shown in Fig. 1. Lar river flows from north west to south west and has 6 main tributaries. The area covers the middle sector of the Alborz Mountains. The Alborz Mountains are a continuation of the Alpine Type Mountains, which are a complex asymmetric belt of folded and faulted rocks (Stoklin, 1974). The area is mainly underlain by limestone, volcanic beds and lake deposits. The limestone units consist of medium bedded limestone of upper Jurassic age (Lar formation) and a massive fine grained limestone of Early Cretaceous age (Tiz-koh formation) and marly limestone of Middle Jurassic (Dalichai formation). The volcanic rocks include mainly trachy- andesitses, formed by the activities

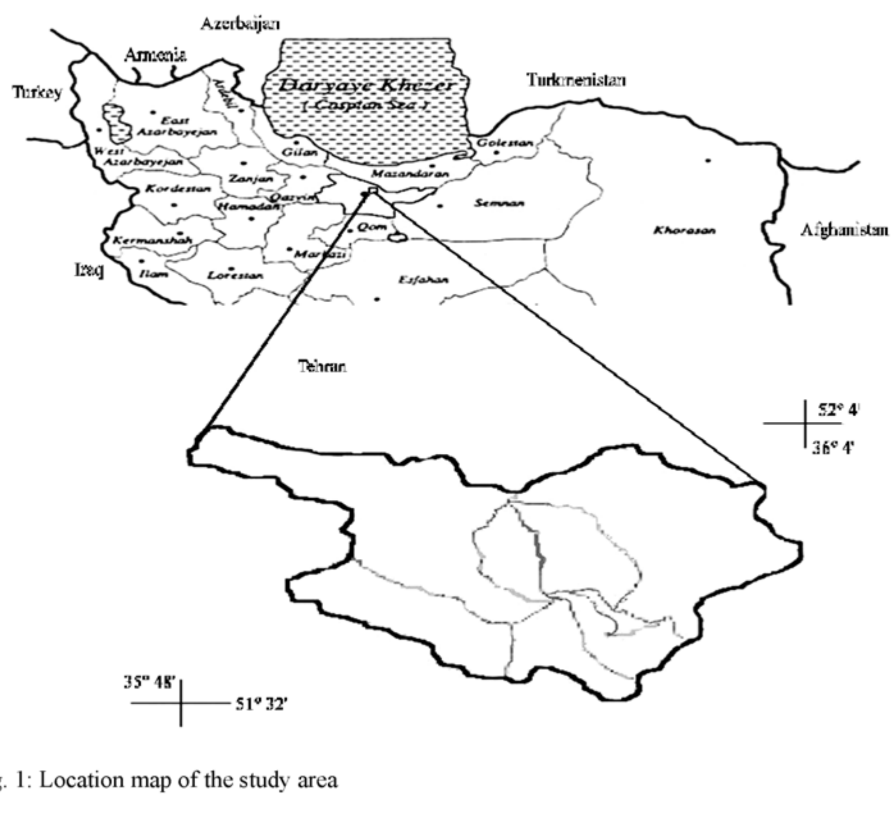


Fig. 1: Location map of the study area

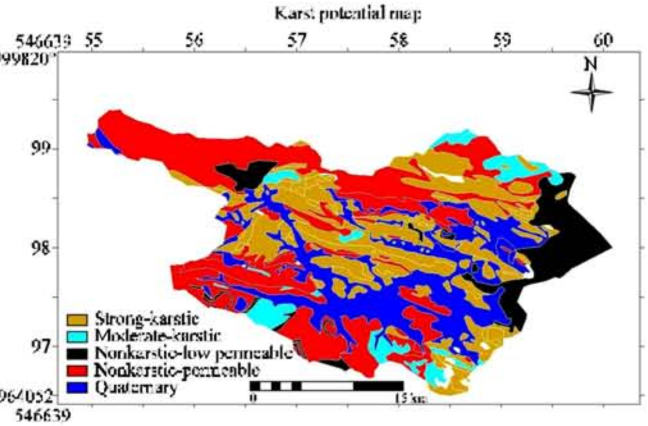


Fig. 2: Karst potential map

of Damavand Mountain which is of Early Pleistocene age and also Tuff of Miocene age (Karaj formation). The lake deposits consist of two units informally named as lower and upper deposits (Stoklin, 1974).

This research was accomplished using ILWIS 3.1 (Integrated Land and Water Information System), PCI EASI/PACE 8.2 and Microsoft Excel software at Soil Conservation and Watershed Management Research Institute of Iran (SCWMRI). Land Sat TM 2002 satellite images and 1/50000 scaled topographical maps, geological maps and black and white 1/20000 aerial photos used in this research were supplied from Geological Survey of Iran and Iran Remote Sensing center. The research had five stages; i.e., data collection, satellite image processing, thematic layer creation, building a database and spatial analysis.

### Thematic Layers

Different thematic layers were prepared and classified to several classes to investigate spatial relationship between geo-structural and hydro geomorphic data. After categorization, all the thematic layers were integrated with one another by GIS technique using the cross, distance and buffer operation.

### Karst Potential Layer

The concept of karst potential was used to provide an indication of where karst might occur and what level of karst development might be anticipated. This was carried out by analyzing geology maps, images and aerial photos (Fig. 2).

Criteria used to evaluate karst potential within a particular polygon created by the researcher are likelihood that karst forms on soluble bed -rock (e.g., massive and thickly bedded limestone, dolomite)' the proportion of soluble bed -rock based on lithology, unit thickness and strati-graphic information and position. There are, of course other important factors that control karst potential (e.g., secondary porosity, mineralogical composition, etc.), but that type of information was not available at this scale of mapping and data collection.

### Topo Springs Layer

The topographic map shows a large number of ground water discharge points such as springs and seeps observed at the time of the topographical survey. They have been classified in the form of discharges with short duration. Data of the fieldwork have been added to what was termed as topo-spring layer (Fig. 3).

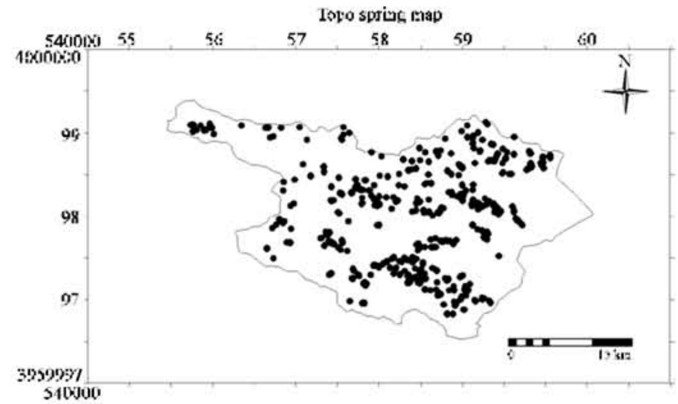


Fig. 3: Topo spring map

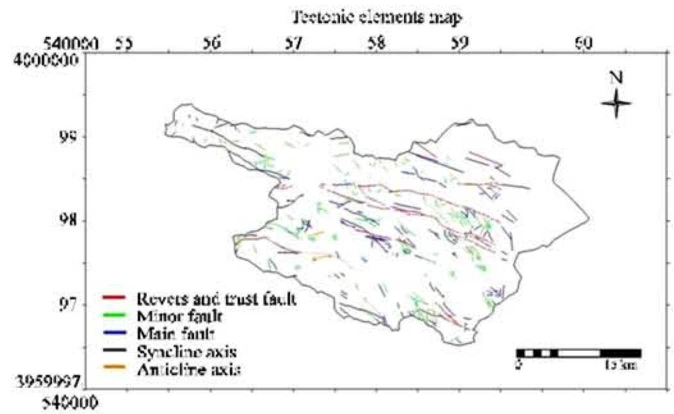


Fig. 4: Tectonics elements layer

## Topography, Elevation and Slop Layer

Topographic data is a vital element in determining the water table. The topographic map was digitized on a 1/50000 scale base map and after generating a Digital Elevation Model (DEM), topographic elevation and slope maps were extracted from the DEM.

## Tectonics Elements Layer

This layer was prepared from tectonic elements shown on the geologic map and compiled by adding some elements which were extracted by visual stereoscopic analysis of 1/20000 scale, black and white aerial photographs (Fig. 4). The lineaments resulting from visual interpretation of enhanced images were in a separate layer although the same features may coincide.

## Drainage Layer

Drainage pattern is one of the most important indicators of hydro geological features and the pattern, texture and density are function of underlying lithology. Drainage map was prepared from the topographical map with 1/50000 scale.

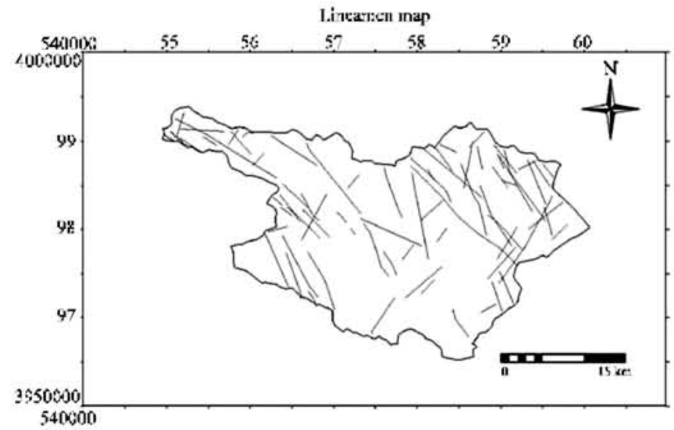


Fig. 5: Lineament layer

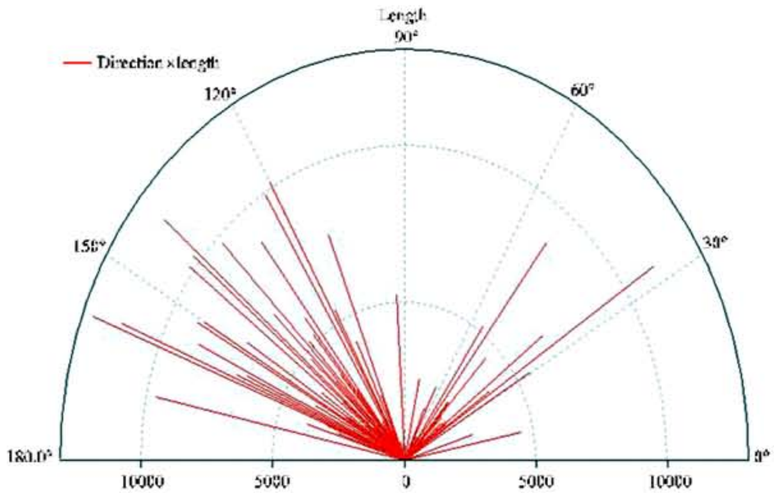


Fig. 6: Rose diagram for the lineaments showing major trends of lineaments occurring in the study area

**Identification of Lineaments on Land Sat TM Image**

The Land Sat Imagery was acquired on 18.7.2002, which was suitable because vegetation was developed after the spring period and in July it could be assumed that vegetation cover possibly responded to the soil moisture in fractures.

For lineament extraction, different techniques have been used, suggested by Suzen and Toprak (1998) and Moore and Waltz (1983) and also automatic lineament extraction by PCI EASI/PACE soft ware was experimented. The most effective method was found to be image enhancement by different filter operations and visual extraction of lineaments, checking and removal of questionable lineament and integration of the lineament extracted from different filter operations in one layer. In addition, the images were integrated with digital elevation model in order to better evaluate the relationships between tonal linear features and topography. The land sat images were also compared with geological map and black and white 1:20000 aerial photos to provide additional information on lineament. Optimum bands used for lineament extraction were the summation of band 4, 5, 7 (Fig. 5). Lineaments were detected and summarized in a Rose diagram (Fig. 6).

## RESULTS AND DISCUSSION

Ground water studies on hard formations often require extraction of data from images and remote sensing and GIS providing support in groundwater studies. Due to insufficient data, maps of Lineament and structural elements are important tools that may reveal points of groundwater recharge and discharge, flow and development. In particular, groundwater occurrence in hard formations are mainly controlled by the lineaments corresponding to fractures, joints and faults. Furthermore, the distribution of lineament is closely related to groundwater discharge points and their concentration. Most ground water resource exploration and evaluation projects consider relationship between lineament and tectonic elements with well data as a tool, on the contrary, this study uses relationship between springs data and lineament to narrow down the study targets. The overall results demonstrate that relationship between lineament, structural elements and groundwater discharge points presented in this study can be used for future groundwater exploration to narrow down exploration targets. In this study, to investigate further relationship between lineament and groundwater occurrence, all data layers were integrated in GIS environment and results were discussed as follow:

The relationship between the percentage of springs and the distance from the main tectonic elements and lineaments. Figure 7 and 8 showed a tendency for springs to occur at short distance from tectonic elements and lineament and it can be concluded that they were conduits of water and signify their role in conveying water.

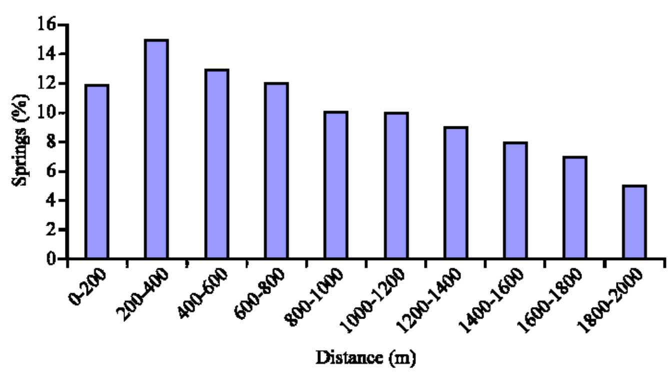


Fig. 7: Relationship between percentages of springs and distance from tectonic elements

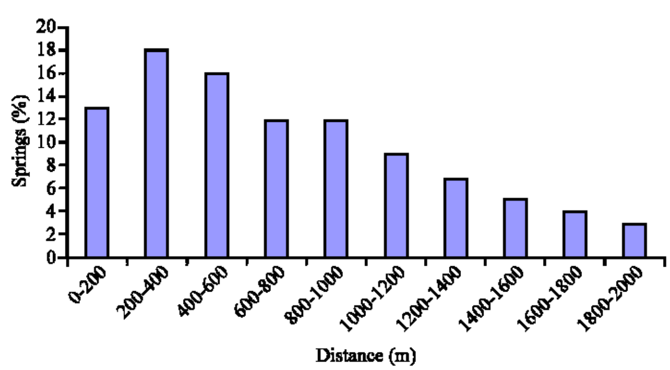


Fig. 8: Relationship between percentages of springs and distances away from lineaments

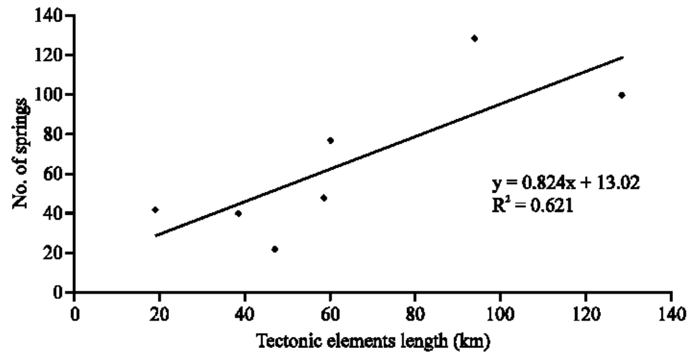


Fig. 9: Relationship between tectonic elements length and number of springs in sub catchments of study area

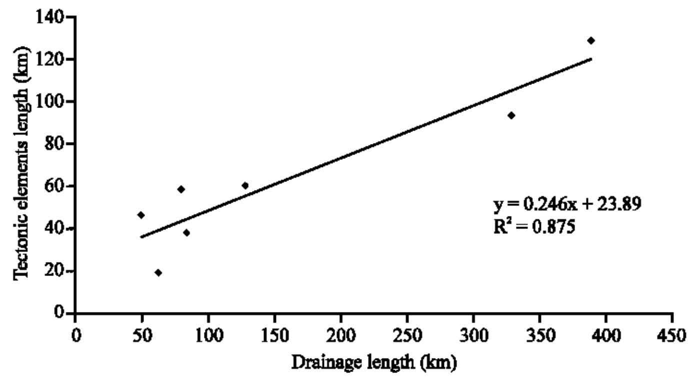


Fig. 10: Relationship between tectonic elements and drainage length

From the good correlation between number of springs and tectonic elements' length and also the concentration of springs close to the lineament and tectonic element, it was concluded that fractures indicate zones of enhanced porosity and conductivity thus they can have a positive influence on the ground water occurrence and they act as transmission routes in the limestone bodies.

Tectonics elements generally correspond to fracture zone and location of springs is a function of fracture zones then it can be expected that there is a good relationship between tectonics elements and number of springs. Figure 9 and 10 showed that this was the case in the Lar catchment.

In geologically active region, drainage is a function of tectonic and generally high drainage is expected in regions of high faults and fold. Figure 11 showed a good correlation between tectonics elements and drainage lengths.

A concentration of springs was found in the lower slope classes. The same was true for the relationship between elevation classes and percentage of springs.

The relationship between number of springs in karstic area and distance from limestone contact, Fig. 12 shows a tendency for springs to occur at short distance from limestone contact. This can be the result of ground water escaping from the karstic area through the shear zone near the contact of competent and in competent rocks.

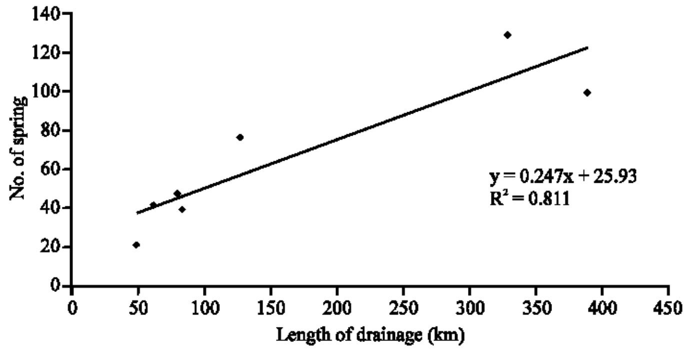


Fig. 11: Relationship between drainage length and number of springs

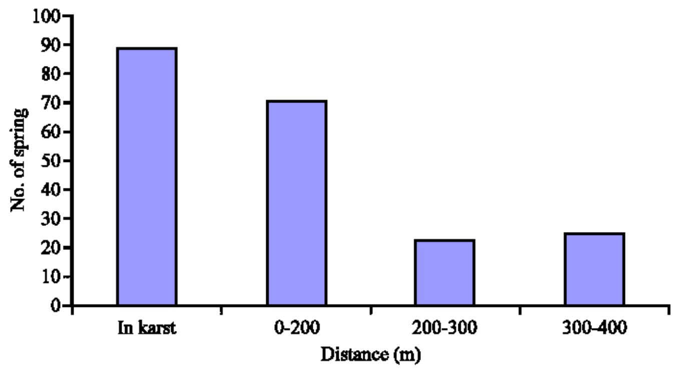


Fig. 12: Relationship between number of springs within karstic area and distance away from limestone contact

A rose diagram generated for lineaments Fig. 6, extracted from the satellite image, suggests that the dominant lineaments orientation is between 140-170 degrees and that it can be related to the main structural direction. The second lineaments trend lied between 140-110 N-W, shows cross folding or shear zones. The third class of lineaments was orthogonal to the first directions and was consistent with the counterclockwise rotation of compressive stress.

In karst potential map generated based on previously described criteria, a continuous body of karst units bounded by non-karstic terrains was distinguished. There was also a small discontinuity in North West, north and south of the study area.

From the dominant trends of lineament extracted from satellite image and the tectonics elements' map and the location of discontinuity, it is likely that underground passage ways and exchange of groundwater occurs between adjacent catchments and sub catchments within Lar catchment. This is also confirmed by the presence of large and active sinkholes in the study area and known under ground water losses to the reservoir.

## ACKNOWLEDGMENT

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