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Geomorphology of Karst Features of Shiraz City and Arjan Plain and Development Limitations

Meysam Jamali, Ebrahim Moghimi, Zean Alabden Jafarpour

***Abstract*—**Karst term is the determiner of a variety of areas or landforms and unique perspectives that have been formed in result of the of the ingredients dissolution of rocks constituter by natural waters. Shiraz area with an area of 5322km^2 is located in the simple folded belt in the southern part of Zagros Mountain of Fars, and is surrounded with Limestone Mountains (Asmari formation). Shiraz area is located in Calcareous areas. The infrastructure of this city is lime and absorbing wells that the city can influence the Limestone dissolution and those accelerate its rate and increase the cavitation below the surface. Dasht-e Arjan is a graben, which has been created as the result of activity of two normal faults in its east and west sides. It is a complete sample of Karst plains (Polje) which has been created with the help of tectonic forces (fault) and dissolution process of water in Asmari limestone formation. It is located 60km. off south west of Shiraz (on Kazeroon-Shiraz road). In 1971, UNESCO has recognized this plain as a reserve of biosphere. It is considered as one of the world's most beautiful geological phenomena, so that most of the world's geologists are interested in visiting this place. The purpose of this paper is to identify and introduce landscapes of Karst features shiraz city and Dasht-e Arjan including Karst dissolution features (Lapiez, Karst springs, dolines, caves, underground caves, ponors, and Karst valleys), anticlines and synclines, and Arjan Lake.

***Keywords*—**Dasht-eArjan, Fault, Karst features, Shiraz City, Zagros.

I. Introduction

YEARS before dealing with the word "Karst", human has been familiar with the phenomena, especially through expansion of caves [17]. Now, 25% of the world's population uses Karst water for drinking [9]. Karst areas provide suitable locations to form settlements and towns in terms of the presence of suitable agricultural lands and landscapes beauty. Karst formations comprise about 33% of the earth [28], and more than 11% of the area of Iran has been covered with Karst formations, the major part of it is in Zagros Mountains chain, Asmari limestone formation, which has more advantages as regards to creating Karst formations [21]. The age of these Karst formations is related to Cenozoic era. Karst in Zagros zone has differences as compared to such formations in other regions of Iran, owing to the regularity of folding in Zagros and being comprised of carbonate and non-volcanic rocks, so that carbonate rocks makes 95% of the mountains[1].

M.Jamali is PhD candidate in Geomorphology, Department of Natural Geography, Science and Research Branch, Islamic Azad University, Tehran, Iran (e-mail: jamali_mir93@yahoo.com).

E. Moghimi is Professor with the Geomorphology, University of Tehran, Iran (e-mail: emoghimi@ut.ac.ir).

Z. Jafarpour is Assistant Professor with the Department of Natural Geography, Kharazmi University, Tehran, Iran.

Carbonate rocks in Zagros are affected by tectonic insertion factors and cold climate with long rainfalls which have caused the maturation and evolution of Karst in Zagros, and have made so many caves such as "Ali Sadr" and "Shapour" [17]. Factures made in carbonate rocks due to tectonic factors is a sequential phenomenon in Zagros Mountains Chain and substantially it is the first stage of karst [1].

Geomorphic studies have shown that by initial dissolution causes the formation of shallow grooves and sinkholes. The typical karstifications are abundantly seen in Zagros, Dasht-e Arjan of Fars, almost all stages of karsification could be seen in this area [2]. The main purpose of this research is to identify and introduce geomorphology of Karst features in Shiraz city and Dasht-e Arjan, Iran. The research was conducted based on field study from the area as well as document review as the data collection method.

II. Research Background

Considering Karst and its features dates back to ancient time when primitive humans were living in caves. The first Greek theories about springs and underground waters has been based on the observations in Greek limestones and having identified Karst in these areas, the first assemblies and cities have been formed [30]. Most attractions of Karst are in Mediterranean region, especially in Dinaric Mountains. Ford, Williams & Millanovic have conducted some research on *Karst* hydrogeology and geomorphology [8]. The expansion of scientific thought on Karst is indebted to three scholars, Grund, Kartzer, and Ballif and the well-known Yugoslavian geomorphologist, Cvijic [28].

The first study on Karst in Iran was begun in Zagros Karst basin in 1971. However, the comprehensive studies have been started in 1990 by establishing Karst Research & Studies Center in Shiraz. This center has first commenced its studies in Maharloo Karst basin, with an area of 4200sq/km, and then expanded its studies to other Zagros Karst basins [3]. On the other hand, studies have been conducted in this area by people like Ahmadipour in Alashtar Basin, Raeisi and Karami in the Karst springs of Gar, BarmFirooz, and Moor mountains in the west of Shiraz, Rezaei and Zamani in the north of Ardekan, Fars province, and some others.

III. Significance & Benefits of Identifying Karst

The dispersion of Karst masses in our country, specially, Karst of arid and semiarid regions, have caused the development of various geomorphologic features in them; on the other hand, the existence of Karst springs with high a rate of flow is so significant in supplying water resources for

villages and cities at the margin of Karst masses. At the present, also, more than 85% of the southern cities of Iran preprints. Supply their drinking water from these formations [3]. Among other important features of Karst, we could mention the ability of tourist attraction. There are beautiful waterfalls, basins and caves such as Alisadr cave in Hamedan and KatalaKhor cave in the south of Abhar which are the factors for tourist attraction [17]. Also, another significance of Karst resources is the low cost of their water, because, if they are carefully studied, using Karst water would be cheaper than making a dam.

IV. Research Method

The present research has been conducted through deductive and analytical-descriptive method. First, Karst features of the studied zone were investigated and identified, and then the method of their formation with regard to the region tectonics and creation of water potentials has been considered. The research method applied in this section is deductive. Data collection is in two field and document review methods. In document review method, the statistics of the required letters in the area of climate and hydrology have been used, and field method includes surveying, and taking position of Karst feature points by GPS, then the data were entered into Arc GIS software, and geomorphology map of the Dasht-e Arjan was prepared [14]-[19].

A. Geographic Location

The studied zone is located between geographical latitude of 29° 29′ to 29°, 47′, and geographical longitude of 52°, 31′ to 52°, 44′. This range is one of the sub-basins of Hele basin, and has an area of about 5322sq/km. The maximum height is 2800m (see Fig. 1).

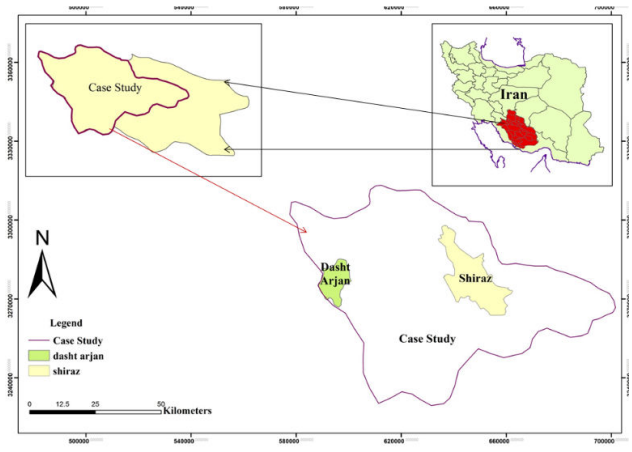

Fig. 1 Study Area location [14]-[26]

The minimum height of Dasht-e Arjan Mountain (Shahneshin Anticline) is 1989m above sea level in Karst pits, and the average height is 1990m above sea level [14]-[18].

B. Climate

The average annual rainfall of Dasht-e Arjan is about 800mm [12]. According to Demartini method, the climate of Dasht-e Arjan is semi-humid and based on Emberger climate index, and it is cold-wet [5]. The climatic conditions of the region, temperature and environment are effective in cave structure. The degree of limestone dissolution has inverse ratio with water temperature, the more the water is cold, the more CO_2 could be solved in it, therefore, and dissolution of lime stones could be done better in colder environments [16].

C. Geology

The outcrops of the region are the sequence of Zagros Mountain Chain, and have an age equal to Alpine folding. The outcrop layers in the studied zone are comprised of geosynclines sediments of Zagros zone, the age of which is from the late Cretaceous to the present era [31]. The outcrops are the result of Alpine orogeny, started from the late Triassic and continued to the end of Pliocene [4]. The geological formations of the region outcrops from old to new as Sarvak, Gurpi, Pabdeh, Jahrom asmari, Gachsaran, and Quaternary sediments, and lacustrine deposits [18] (see Fig. 2).

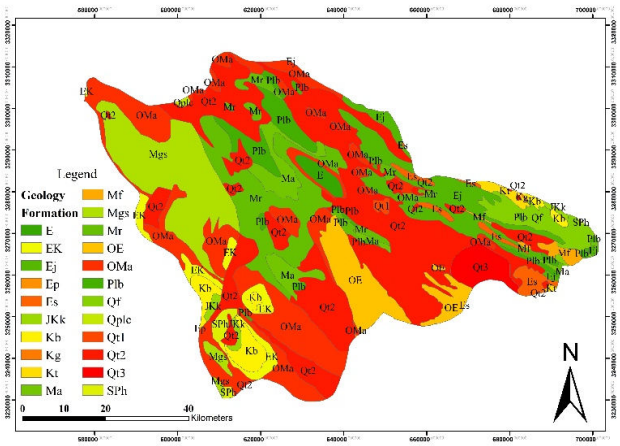

Fig. 2 Geological map of Case Study [26], [27]

D. Tectonics & Structural Geology

The studied zone is considered as a part of Zagros folded region which has a simple and gentle geological structure, including sequences of close anticlines with usually vertical axial plane. Dasht-e Arjan fault is one of the important faults which has caused polje and graben structure in Dasht-e Arjan. Also, the presence of Dasht-e Arjan Karst spring and the formation of about 60 Karst sinkholes in the region is the result of the fault function. Dasht-e Arjan with the height of 2000m above sea level and a graben structure is one of the karst phenomena of the region [26]. There are two major faults in both eastern and western walls of the plain and other Minor faults which have shaped the graben structure of Dasht-E Arjan. The activity of the western fault of Dasht-e Arjan has caused fracture and vertical displacement in Asmari formation of Jahrom, where Dasht-e Arjan springs have been appeared with high rate of flow and appropriate quality; and the eastern fault are responsible for discharging plain and lake to the neighboring zones. Different topographic, tectonic and

geological evidences of the region indicate the same fact (see Fig. 3).

E. Karst Feature

The basis for the formation of Karst morphology depends on carbonate rocks, chemical properties, structural properties, climatic conditions and time [17]. Susceptibility of some sedimentary rocks to dissolution and its significance in relief property, have caused the occurrence of special features which are so-called Karst [6] (see Fig. 4)

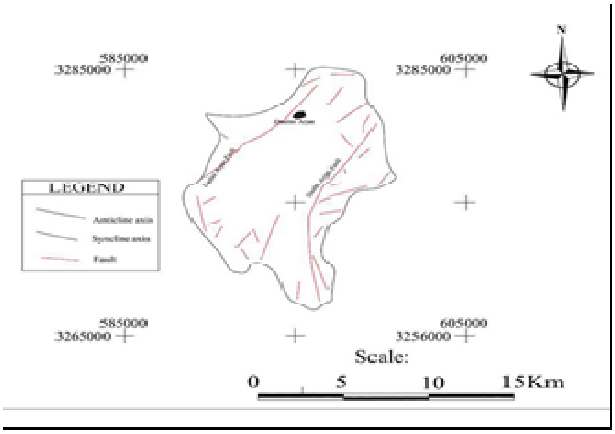

Fig. 3 Structural map of Dasht-eArjan basin, [7]

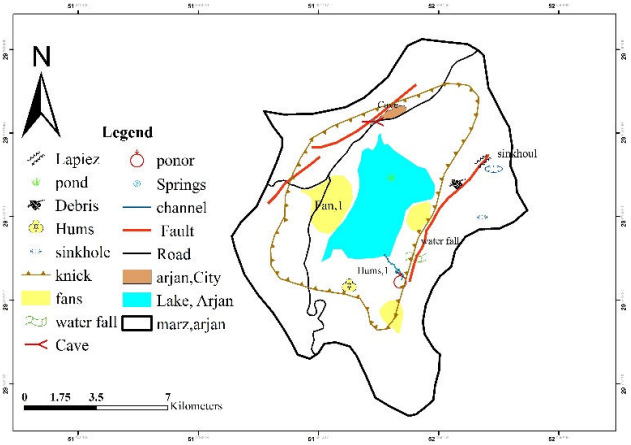

Fig. 4 Geomorphologic map of Dasht-eArjan [26]

This term has been adapted from the name of one of the Yugoslavian states where relatively complete processes of Calcareous forms have been made. Although such forms are typical for dense and massive limestones, some species of these might be developed within evaporite rocks (gypsum and rock salt) [10]. (A sample of karsification is salt domes which are abundantly seen in Zagros of Fars, but it is a rare case in the world) .Even the last stage of karsification that is polje has been occurred in Zagros. Dasht-e Arjan (in Shiraz-Kazeroon road) is a classic sample of karst polje, which has been occurred due to dissolution erosion in Asmari and the fault function [25]. In folded Zagros, first Asmarilimestones and then limestones of Bangestan group have greater role with regard to creating karst facies [25]. Based on the field observations, Karst features of the region are divided into two groups of superficial and deep. Superficial features are: karen, canyon valley, dissolution cavities, polje, hum, ponor, and the present deep Karst features in the region are Karst springs and caves.

F. Polje

Polje is an almost flat-floored depression within limestones. Poljes, which are the most important geomorphologic phenomenon of Karst, are developed parallel with internal motion of earth. Dasht-e Arjan large polje has been changed into a graben due to the function of two long faults with north-south extent [26]. Scraps around polje, which have been composed of Asmarilimestones, have been created due to the function of the mentioned faults. Arjanpolje has steep walls (see Fig. 5)

Fig. 5 Polje Dasht-eArjan [14]

Polje floor has a mild slope from west to east and the water flow is also from west to east. Springs to the west of the region along with runoffs, supply the water for the plain, and at times of profuse rainfall, a seasonal lake is being created. Because of the existence of ponors to the east of the plain, the water currents areto be exited through subterranean canals: at times of any reduction in input flows, the plain dries up.

The formations on the bedding-plain consist of impenetrable strata of Gachsaran which have been covered by alluvium with some thickness of around 30m [16]. Among other sub-constructions in this polje would be the creation of many cascades on Asmari limes of which the majority are just seasonal.

G. Hums

They are individually dispersed hills on Karst level plains as remainders of the dissolution action to be witnessing hills where the primary stratum is a limestone formation. As to the southern margin of Arjan polje, a number of limestone outcrops have still maintained their existence [10], the height of which would come up to several meters (see Fig. 6).

H. Doline (Ouvala)

Doline structures are among the most indicating, fundamental forms of Karst level morphological strata (Fig. 7). Most of the time, dolines are the result of the chemical effect of water on limestones. This is the most significant Parameter, though it is certainly not the only effective one in their formation. All along the faults to the southeast of the Plain, there are a number of oval dolines, and through a canal water of the lake is drained, causing its seasonality [26]. The sub-constructs in the area under study could be observed by a limited number of locations where the vegetation is extremely lush.

Fig. 6 Hums in the southern Dasht-eArjan, Field trip, 2012 [26]

Fig. 7 Doline covered by vegetation, Field visit, 2012 [26]

I. Lapiez (Karen)

Lapiez is defined as the effect of water corrosion on limestone formations. Because of the fact that the limestone formations in the area under study are so widespread, a variety of different types of Lapiez have been created (see Fig. 8).

The most common ones are groove Lapiez in northern Arjan plain where the Lapiez would come out denser and deeper than those of the other parts which might possibly the result of moisture in this section, producing more suitable conditions while the Lapiezs to the south are hollows considerable on Fig. 9.

In the zone of Iran Asmari limestone, corrosion takes place as dissolution causing Lapiezs to take on round shapes [22]. Hollow Lapiezs could also be observed in a limited Segment on Gachsaran formation. Gachsaran formation because of its specific chemical combination of gypsum and salt – has the property of direct dissolution.

Fig. 8 Lapiez on northern slopes of plain, Field trip, 2012 [26]

Fig. 9 Waterfall on the eastern slopes of Dasht-e Arjan Field visit, 2012 [26]

Fig. 10 Karst Valley, Field visit, South East Shiraz, (on Shiraz-Jahrom road) 2011 [26]

J. Karst Valley

They are one of the most primary morphological features in Karst zones. Also, the combination of lithology and tectonic activities play a considerable role in forming dry valleys.

Gorges are the prevalent form of valleys in the region. These valleys with a cross section of the shape V can guide deep within themselves water currents. They do not possess continuous water flows: just having temporary runoffs at times of flooding [16]. The walls to the valleys are made of lime stones which have been ground down to large and small pieces with the expansion of crevices and cracks (see Fig. 10).

The brim to the valleys is overlapping onto very high erosional precipices. The valleys are located on the shoulders of the anticline of the same Rooz gorges [26].

K. Arjan Lake

Water resources of Dasht-e Arjan runoff are resulting from rainfall, raining over the plain, temporary and permanent springs (Dasht-e Arjan waterfall and spring in 1971, UNESCO has recognized this lake as a reserve of biosphere. The maximum height from water level is 2003 m. based on tide mark. In this condition, the maximum area and the basin volume is 21 square kilometers and 43 million cubic meters respectively [23].

The lake's water is drained through a canal and then entered to a large ponor. The depth of the lake is 11 m. in the lowest point of ponor [23]. In view of the fact that the area, the canal volume and the ponor are all lower than those of the lake, the maximum depth of the lake is practically 3.9m. The water sinks into the ground through the canal bed (with the length of 2.5 km.) (see Fig. 11).

Fig. 11 Arjan Lake water channel to ponor, Field visit, 2012 [26]

The ponor limited area at the end of southeast of the plain, Karst sinkholes discharge the water of Arjan Lake into the nearby limestone formations. Using the tectonic studies, the geology and hydrogeologic condition have shown that the water of Dasht-e Arjan has probably discharge to the springs near the Parishan Lake [11]-[13] (see Fig. 12).

However, the latest study in this region has been conducted by Mahdavikia in 2012 in order to detect the water exit route from Arjan Lake. In this study, it has been determined through using tracking test with Uranine pigment that the outflow water from Arjan basin discharges into Dom-e Asb spring [23].

Fig. 12 Ponor in the South East Dasht-eArjan, Field visit, 2012 [26]

L. Dasht-e Arjan Spring

Rainfalls and surface streams were entered into the limestone mass through fractures, splits and holes and usually have discharged by spring [16]. Since this region is located in the highest part of the region within the basin, the height of the spring head is 2038m. Along with the western margin fault, due to the relative low temperature, the dissolution nature of CO_2 has increased, which would result in the expansion of Karst nature. The maximum and minimum outflow levels from Dasht-e Arjan Lake are respectively over 750 and less than 100 liters per second [16]. Having investigated into the spring's hydrography, it becomes clear that any rainfall could affect it after two months (see Fig. 13).

Fig. 13 Karst Springs Dasht-eArjan, Field visit, 2012 [26]

This expresses the reality that Dasht-e Arjan Lake is actually fed by water tables farther away.

M. The Cave & Under Ground Cavities

The most significant, the most evident, karst phenomena within Asmarilime stones are the creation of cavities, small

caves, and caves (see Fig. 14).

Cracks, crevices, and fractures among various strata cause the dissolution and the caving-in of those very strata resulting in caves with cross sections in the shape of oblongs and trapeziums, mostly having the expansion of caves along the breakage on the crevices [16]. There are a large number of small caves in the region to the western brink of the west Arjan precipice fault, whose smallness of dimensions are negligible [22] (see Fig. 15).

Fig. 14 The small caves on the western edge of the West Fault [26]

Fig. 15 Expansion of the city on the slopes of limestone, baba Kohei North of Shiraz, 2012 [26]

Fig. 16 Expansion of city of Shiraz on a limestone area, Drack Mount, Field visit, 2011 [26]

N. Threats of Caves and Karst Areas

Activities such as underground and surface mining, engineering works, urban planning, artificial water storage in the basement, filling the holes with waste and demolition materials and pollution are the major threatening factors of karst areas and often with increasing of the activity volume, these factors cause major difficulties for lands use [29] (Fig. 16).

Among the environmental issues of Karst areas, there are problems related to the subsidence of karst lands and the frequent Flooded of roads and urban areas [29].

V. Conclusion

Karst is generally a hybrid system; the dynamic is the range of landscapes, animals, energy, water, gas, soil and bedrock that the change of any of above cases shall be effective on the entire system [29].

Among the environmental issues of Karst areas, there are problems related to the subsidence of Karst lands and the high frequency of floods inundating roads and urban areas [29].

This city is majorly made of lime, and absorbing wells in the city can affect limestone dissolution, accelerating its rate while increasing the cavitation below the surface. Various factors work to shape Karst formation, including lithology, tectonic structures, weathering, water, and pores being extent within stones [5]-[30]. The Arjan region is located in the folded structure of Zagros zone. The zone possesses mild folding and flouncing with the directionality of northwest to the southeast. Dasht-e Arjan region – which is morphologically considered to be a polje – is among the Karst regions within the semi-arid realm which dates back to Cenozoic Era, and have come into existence as the result of the action of parallel coupled faults. All along the southeastern fault in the plain, there are a number of dolines of which the water drainage within the mentioned region and making it seasonal would be the causing factor.

The existence of ponor, Hums, spring and closing, cave, sinkholes, clint, polje, and Karst formations, having been created as a result of the dissolution of tectonic and Asmarilime stones, covering the whole visible remit of karsification in Dasht-e Arjan could have brought about one of the attractive tourist areas in western Greater Shiraz. Generally speaking, while introducing Dasht-e Arjan attractions, it becomes clear that formations and beautiful Karst and geomorphologic vistas of Arjan polje – more than any other views – are prominent in view so much so that the majority of geologists in the world are interested in visiting this polje.

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