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Research Article

Geomorphology of Badland in Golbaf Playa, SE Iran

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Abstract

This paper deals with piping and badland geomorphology in the presently eroding playa of south Golbaf depression. The playa surface which displays badlands features slopes gently towards the north and is about 105 km in length and its average width is about 2km. Piping badland have progressively been evolved from the north towards the south. To study morphological variations, three sites were selected. In every site the diameters and depths of 61 depressions and their ratio.

If the studied playa is divided into almost five equal parts from south to north, the southernmost part (part1) is almost flat with negligible roughness. Towards the north, on the second part, the playa surface is very gently sloping with ~ 0.5 m relief and is eroded by some gullies up to ~2m. The third part which contains small funnel-shaped depressions shows a relief of ~1m on playa surfaces and is eroded by ~5m deeping gullies. The relief increases on the fourth part up to ~2m and gullies are up to 10m in depth. In the northernmost part, surface relief is about 5 m and gullies are up to 20m in depth. The calculated ratios of average depths to average diameters for sites A, B and C are 1.36, 1.45 and 1.78 respectively, indicating gradual increasing, as well as increasing relationship between diameter and depth of depression by increasing in their size from site A toward site C.

Keywords: Badland; Piping; Geomorphology; Golbaf

Introduction

Badlands are miniature erosional landscapes comprised of several types of landforms formed by a complex combination of processes and customarily associated with arid and semi-arid environments (Warren, 1984). The dramatic character of badlands, exhibiting clear morphological relationships which result from the interaction of geomorphic processes with highly erodible materials, has long stimulated geomorphic speculation and investigation [1]. Vegetation cover on badlands is sparse. Slopes are dissected by a dense drainage network within v-shaped valleys [2]. Badlands exemplify structural and lithological control at all scales and because the buffering effects of vegetation cover are absent, lithological differences in them are often minutely defined by weathering and erosion [1]. However, the requirements of badland occurrence include erodible rock and available relief. The main factor controlling badland formation is the character of the bedrock. Usually, a protective caprock has been removed and a softer rock less resistant to erosion surfaces. Tectonics and uplift are sometimes involved in this process but also land use changes may trigger the formation of badlands [3]. A working session of the 1997 12th International Congress of Speleology concluded that "pseudokarsts are landscapes with morphologies resembling karst, and/or may have a predominance of subsurface drainage through conduit-type voids, but lack the element of long-term evolution by solution and physical erosion" [4]. Pseudokarst is considered to mean karst-like landforms that have formed through processes that are not dominated by solutional weathering or solution-included subsidence and collapse [5]. They are similar to ordinary karsts in terms of shape and general configuration and their characteristic features are closed depressions and integrated underground drainage comprised of pipes and tunnels [6]. Thus, they resemble doline karsts, but in miniature scales [1].

There are several types of pseudokarsts which are introduced by Grimes [5,7]. One type of them is formed in soil and unconsolidated sediments and two main features of it include pipes and surficial depressions [8]. This type is entitled as "badland pseudokarst", also known as surficial pseudokarst [6]. They are erosion landforms characterized by gullying and piping as the major mechanisms of development [1]. Other types have been identified in glaciers [9] in permafrost areas [8], in volcanic terrains Halliday [7], and in avalanche deposits and talus [7]. Crevices may be accompanied with caves. Hence, some authors consider them as crevice pseudokarst. However, the key process in the majority of pseudokarsts is piping, this explains why Parker [10] believe that pseudokarst term is applied to the piped landscape. Badland pseudokarsts not only have been rarely investigated, but also their conditions of occurrence and evolution have not been well defined. Also, most badland research has concentrated on geomorphic processes and few attempts have been made to study longer term badland evolution [1].

In south Golbaf playa (Figure 1), badland pseudokarsts have progressively been evolved from the north towards the south, so that all gradations from initial features to well-developed and large collapse depressions and gullies are present. That is, this area provides an ideal opportunity to study creation and evolution of these badlands. The goal of the present study is, therefore, to introduce these badlands and investigate their development.

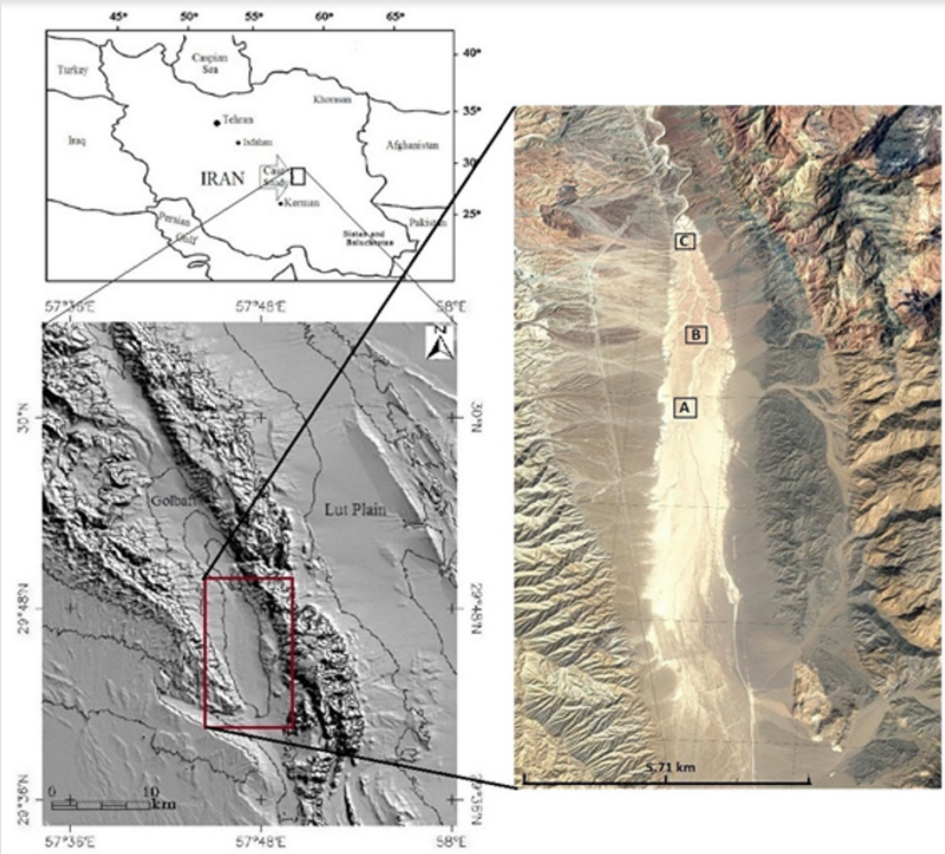

Figure 1: Geographic Location playa and Study Sites.of Golbaf.

Materials and methods

Field measurements

To study morphological variations, three sites were selected, (sites A, B and C). In every site the diameters and depths of 61 depressions. Depressions are not usually quite circular in plan. To tackle this problem, firstly, the maximum diameter of each depression was measured. Afterwards, the diameter at right angle to maximum diameter was determined. Finally, the average of these two measurements was considered as the diameter of each depression. This is the usual practice in morphometrical studies of dolines in true karsts [11].

Data analysis

Using SPSS software, morphometric parameters of depressions were statistically analyzed, and the resulted parameters were compared. Additionally, the relationships among morphometric variables were investigated.

Results

Study area

The south Golbaf playa lies at 57°, 46' to 57°, 47' eastern longitude and 29°, 43' to 29°, 48' northern latitude in SE Iran. It, s elevation ranges from 1752m at south to 1730m at north. Having a length of 9.1 km and an average width of 1.7 km, it is considered as a small elongate playa (Fig 1). This playa is situated at the southern part of Golbaf tectonic valley which trends NNW-SSE. This valley is bounded from the west by Sekonj Mountain with a height of up to 4200 m and from the east, by Abbarik Mountain which reaches 2700 m in height. The elevation of Golbaf valley varies from about 1700 m to about 2000m. The average annual precipitation and temperature in south Golbaf playa are about 110 mm and 17 °C respectively, indicating a dry climate. Precipitation mainly occurs in winter and the driest season is summer with negligible amounts of rainfall.

The mainstream course which drains the area towards the north lies amid the playa. It is 20-100m in width. Its depth varies from negligible amounts at south to about 25m at north, indicating the amounts of incision. In the northern part of playa, all branches joining the main course from eastern and western bahadas have carved gullies in playa deposits. The mainstream leaves the playa at an overflowing point which is located about 2 km at northward limit of playa. The sekonj mountain consists of Jurassic siltstones and sandstones and the Abbarik mountain is mainly comprised of Cretaceous sedimentary rocks which trust over Eocene volcanic and Paleogene pyroclastics [12]. The Golbaf valley is covered with Quaternary alluvial deposits (alluvial fan gravels and playa muds).

The south Golbaf playa lies on the Gowk section of Nayband fault system. This right- lateral system accommodates the shear between central Iran in the west and Lut block in the east. Geomorphic features, as well as, the occurrence of three Ms >6 earthquakes in the last 35 years indicate that it is a very active fault system [13]. The Gowk fault, with a strike of about 155°, lies in a compressive bend amid the Nayband fault system which has a general strike of about 175°. The Golbaf valley exists as a topographic low because of the small up-to-east normal component of Gowk fault [12]. However, Berbarian, [14] suggest that the overall cross-sectional structure of Gowk fault system is a ramp- and- flat trust with superimposed strike-slip motion. This component of motion largely determines the longitudinal evolution of this valley and the structure at depth is reflected mainly in the vertical motions at the surface [12].

Golbaf tectonic valley is 2-4 km in width and there are a series of depressions along it which are commonly separated by alluvial fans. The south Golbaf playa in which badland pseudokarsts have formed is one of these depressions that has received sands, silts and clays from the arriving ephemeral streams. This playa occupies a pull-apart position in a right- step between two major segments of Gowk fault, and is filled with playa deposits that are incised by a through- going longitudinal stream and its tributaries [15].

The studied area is part of a bahada- playa- mountain unit which is a characteristic feature of arid zones. The mountain-bahada border is rather straight and is comprised of active faults. On average, bahadas bordering this playa are about 1.7 km in width and consist of many alluvial fans. Due to high topographic gradients, the mountains contain sharp crests and high drainage densities [16]. There is a 1-3m erosional scarp between playa surface and the bordering bahada which faces towards the bahada. This scarp is created by erosion of sandy skirt encircling the playa, i.e., the playa surface is higher than the surrounding bahada. Thus, it is considered as an inverted relief. Also, there is a north-south trending young normal fault at the western part of playa near its border with bahada with an escarpment facing east. Its influence on badlands is only limited to its scarp surface. The rather straight western border of this playa is mainly controlled by this active fault (Figure 2).

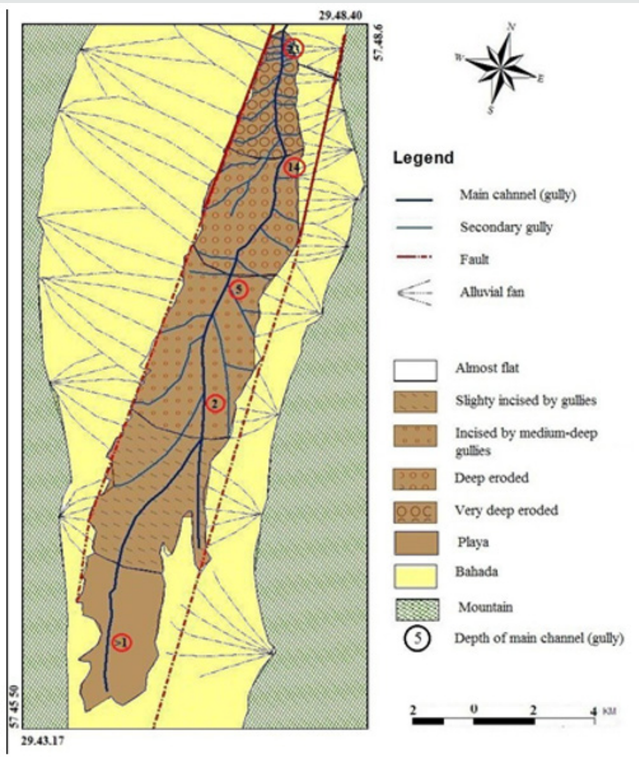

Figure 2: Geomorphology map of Golbaf Playa.

Geomorphology

Depression: There are two types of depressions in the studied area. Depressions of the first type which consist the majority are funnel-shaped and circular to subcircular in plan. They usually contain a swallow hole at the bottom which carries the surface runoff into a vertical pipe. The diameter and depth of these types which increase northwards [17]. These depressions commonly occur in rows, following the original dehydration cracks. Surfaces containing these depressions show pitted topography reminiscent of doline karst. The other type of depressions is only observed in the northernmost part of the playa where badlands are more developed. These depressions have formed by collapse of enlarged horizontal pipes and are circular to elongate in plan, with vertical walls.

Gullies: Gullies are commonly an integral part and one of the most common features in the majority of badlands. Although gullies are less frequent in the studied area, they play an important role in its evolution. Originally, there are two types of gullies in the studied area. Gullies of the first type are both large and long and originate from the erosion of playa surface as a result of Knick point recession and incision by streams flowing from bahada [18]. These are box-shaped in section and have played a major role in the creation of these badlands by forming dehydration fissures through draining the mudrocks and generating hydraulic head for the action of pipe system. The second type gullies are only observed at the northern limit of the studied area and have shaped by roof collapse of enlarged horizontal pipes. These gullies are commonly irregular in shape and may contain bridges and collapse debris along their courses.

Relief: If the studied playa is divided into almost five equal parts from south to north (Figure 1), the southernmost part (part1) is almost flat with negligible roughness. Towards the north, on the second part, the playa surface is very gently sloping with ~ 0.5 m relief and is eroded by some gullies up to ~2m. The third part which contains small funnel-shaped depressions shows a relief of ~1m on playa surfaces and is eroded by ~5m deeping gullies. The relief increases on the fourth part up to ~2m and gullies are up to 10m in depth (Figure 3). In the northernmost part, surface relief is about 5 m and gullies are up to 20 m in depth (Figure 4). Consequently, both inter-gully surface relief and gully depths gradually increase towards the north.

Figure 3: Site A with moderate piping and Site C with big depression.

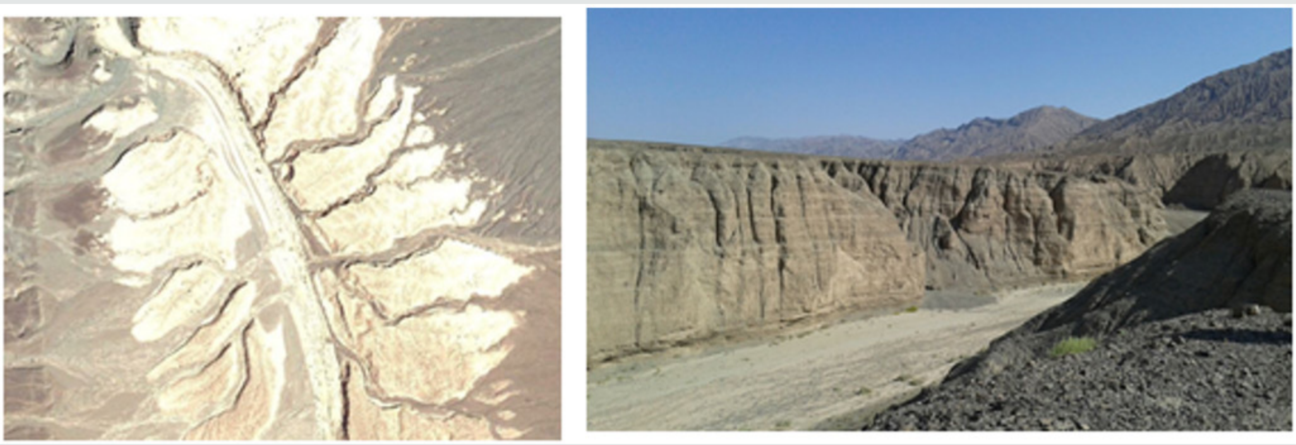

Figure 4: Fifth part with deeping gullies.

Morphometry

The statistics of diameters and depths of 61 depressions on each of measurement sites are presented in Table 1. The Relationship between morphometric parameters for diameter and depth values and ratios of average depths to average diameters are also given in Figure 5. Morphometric analysis indicates that funnel-shaped depression grows in diameter, depth and surface area with the passage of time. Their surface slope angle with the passage of time, the diameter of horizontal and vertical pipes increases. As observed, the average diameters and depths of depressions increase northwards [19]. The calculated ratios of average depths to average diameters for sites A, B and C are 1.36, 1.45 and 1.78 respectively, indicating gradual increasing, as well as scatter diagram that shows increasing relationship between diameter and depth of depression by increasing in their size from site A toward site C (Figure 5).

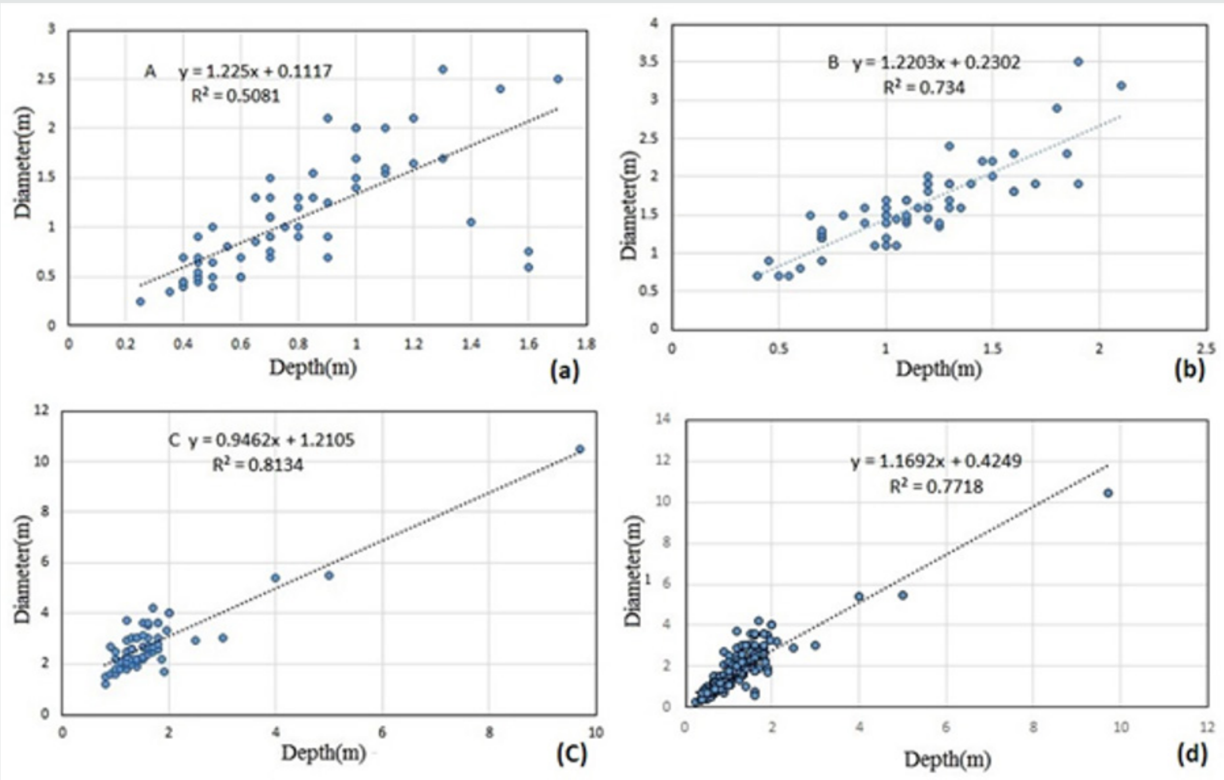

Figure 5: Relationship between morphometric parameters.

Table 1: Morphometric statistics of depressions.

Depth(m), Diameter(m)									
Diameter/Depth ratio									
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
N	Valid	61	61	61	61	61	61	61	61
Mean	0.79	1.14	1.68	1.07	1.62	2.82	1.36	1.45	1.78
Median	0.7	1.1	1.5	0.9	1.6	2.6	1.33	1.4	1.69
Mode	0.7	1.00a	1.20a	0.5	1.6	2.6	1	1.33	2
Std. Deviation	0.34	0.38	1.23	0.59	0.53	1.3	0.42	0.26	0.43
Variance	0.12	0.14	1.51	0.35	0.28	1.69	0.18	0.06	0.18
Skewness	0.87	0.32	5.27	0.83	1.1	3.73	0.09	0.68	0.61
Minimum	0.25	0.4	0.8	0.25	0.7	1.2	0.38	1	0.89
Maximum	1.7	2.1	9.7	2.6	3.5	10.5	2.33	2.31	3.08

Conclusion

Playa deposits are potentially conductive for development of badland because they usually are soft unconsolidated and porous, rich in silt fraction and contain expansive clays. However, at normal conditions, playa surfaces are flat and in depositional regime. Hence, their conditions must be changed into erosional regime by such agents as tectonic activity or, as in the case of studied area, by overflowing and creation of a Knick point downstream of overflowing point. Knick point retreat towards playa surface creates an erosional regime which in retrospect generates hydraulic gradient, gullies and, eventually, dehydration fissures. It seems that the occurrence of dehydration fissures in playa deposits sets the stage for the development of badland pseudokarsts. These badlands form by the appearance of pipes and erosion depressions. As a result of horizontal pipe roof collapse, they transform into a set of gullies and residual hills. Gradual erosion of hills by rain splash, surface erosion, rills and mass wasting will give rise to disappearance of badlands.

Both dry climate and lack of vegetation have influenced badland development in this area. Dry climate has enhanced the dehydration process and creation of fissures. Severe but slight rains which are rather prevalent in this climate have not ample time to soak the soil, but the resulting surficial flows enhance the creation of mudflows which are a main agent of pipe erosion. In contrast, slight but prolonged rains have ample time to soak the soil. Hence, they are effective in triggering mass wasting and widening the gullies.

Lack of vegetation has given rise to decreases in surface permeability and infiltration due to the absence of surface litter and organic matter. The lack of protection by vegetation has intensified rain splash and other types of surface erosion.

It is worth to note that complexity of climate change and its influences, and the effects of tectonics may be so important in landform evolution. However, with respect to the studied area, the relatively rapid evolution of the badlands means limited influence of climate change on their development. Also, considering mudrocks in the studied area are level and undisturbed by tectonic activity (except in the western limit of playa), evidently the influences of climate change and tectonic activity on evolution of these badlands are limited.

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