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Geotourism potential of Akre area, Duhok Governorate, Iraqi Kurdistan Region

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Abstract: Geotourism potential of Akre district in Duhok Governorate, Kurdistan region, northern Iraq is studied in detail. Sixteen geotourism sites were investigated, which are divided into three sub-areas according to their geographical positions. All the tourism sites are located in the northern mountainous part of the High Folded Zone due to their variations from the southern part (Low Folded Zone) in geology, geomorphology, hydrology and tectonic settings. Based on comparison with the Potential Touristic Use (P.T.U) characters, most of the studied geosites have medium correspondence with the P.T.U characters, except three sites i.e. Sipa Akre waterfall, Kani Zark spring and Sipa Bjeel waterfall that have good correspondence. This is because they are reachable by pavement roads and can be easily managed and developed by the local people, in addition to their magical landscapes. The Gali Zenta and Guske resorts have very clear geological elements, particularly the famous massive bitumen seeps within the Zenta valley, and this make their correspondence to the P.T.U characters acceptable despite having bad roads and not progressing very well. The Dinarta sub-area geosite, in spite of its specular view and adaptation for tourism vacancy, has low to medium correspondence to the P.T.U characters due to having the worst roads, and are not developed by any local investors and governments in addition to property problems and remoteness from environmental and cultural sites. H_2S rich springs are neglected in the whole Kurdistan region although they have a high economic value by way of balneotherapy. Therefore, the Bekhma and Heshtka hot springs has obtained a very low ratio. The mountainous and caves sites also obtained a low ratio, as the mountain landscapes are neglected particularly for winter tourism, and lack of investment for cave tourism, respectively.

Keywords: Geotourism, Iraq, Kurdistan, Akre, P.T.U

INTRODUCTION

Geotourism is one of the new tourism evolution tools (Dowling, 2013). It is rapidly being recognized as an exciting new direction for tourism surrounding geological and geomorphology attractions and destinations, that is concerned with sustaining or enhancing a destination's geographic character (Wartiti *et al.,* 2007). Geotourism interests is in inanimate nature and earth sciences, particularly geology, geomorphology and landscape (Hose, 1995, 2000; Joyce, 2006; Dowling & Newsome, 2006, 2010). It encompasses many geodiversity elements such as geomorphology (landforms), petrology (rocks), mineralogy (minerals), palaeontology (fossils), stratigraphy (sedimentary sequences), structural geology (folds, faults, and others), hydrogeology (water), or pedology (soils). If the mentioned element owns a scientific value, it is termed geoheritage (Brilha, 2016).

The northern and north-eastern Kurdistan region of Iraq and particularly Akre area is characterized by natural landscapes and tourism geosites. There are very few studies concerning this aspect of earth science of which may aid to increase the value of these areas and consequently lead to increased economic value of the Kurdistan region.

Sissakian *et al*. (2016) is the first group to study geotourism in northern Iraq and they focused on tourism geology in the north and northeastern parts of Iraq. The main aim of the current paper is to introduce the famous sites for geotourism of the studied areas with their evaluations according to the Potential Touristic Use (P.T.U) characters introduced by Brilha (2016).

LOCATION

Akre area is a mountainous region with a rugged topography, located in the High Folded Zone in the northeastern part of the Iraqi Kurdistan region, at approximately Lat. 36° 31 54.0 N to 36° 43 59.6 N and Long. 43° 55 55.6 E to 44°18 12.7 E in the east and Lat. 36° 43 52 N to 36° 53 15.9 N and Long. 43° 37 35.7 E to 43° 53 15.9 E in the west. The total area of the district is estimated to be around 1,600 km^2. The center of the Akre district is located 108 km east of Duhok City, 118 km north-west of Erbil City and 82 km north of Mosul City. The Greater Zab and Khazir rivers create natural boundaries at the eastern and western parts of the area respectively (Figure 1).

MATERIAL AND METHODS

The study was conducted by collecting data through observation i.e. taking attractive photographs of the geosites during the field visits and interviewing the local people and officials for evaluation of the P.T.U characters. The desk

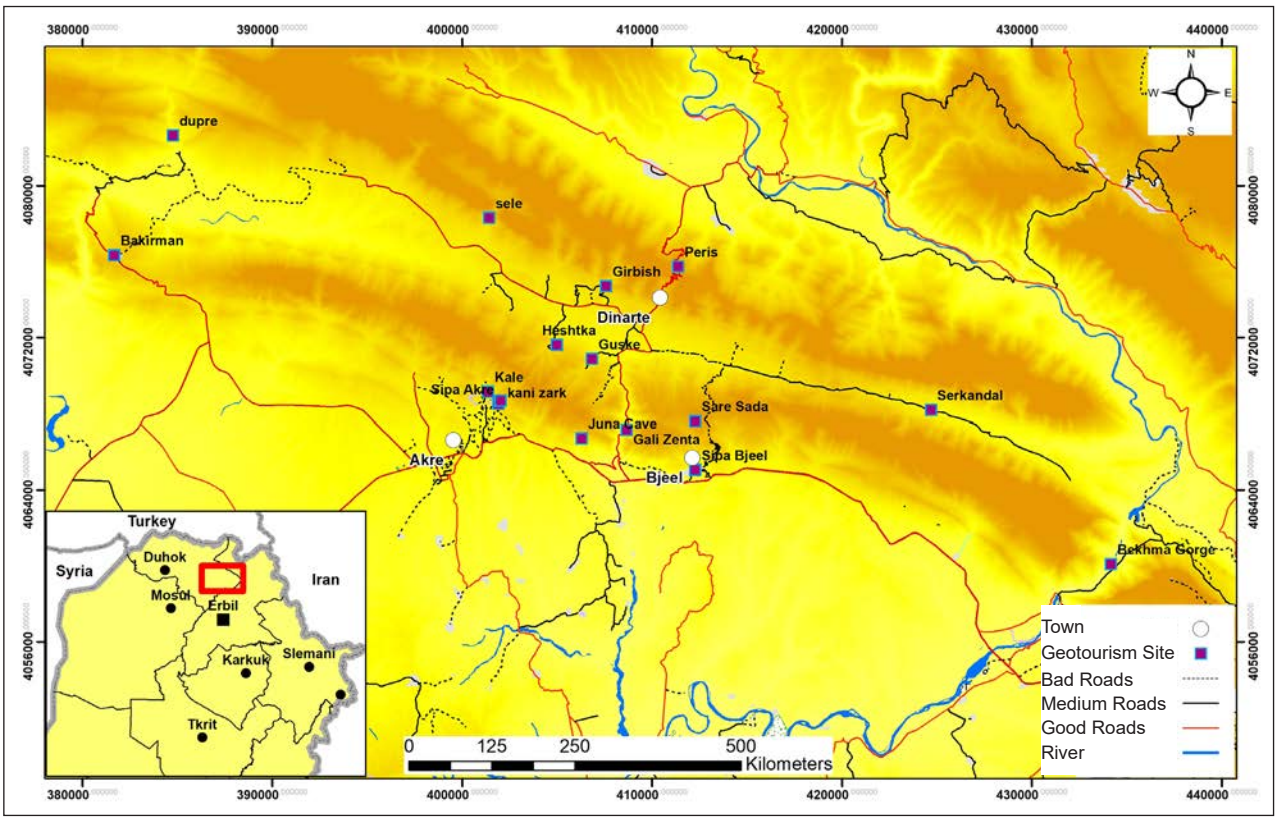

Figure 1: Location map of the study area with distribution of geotourism sites and roads.

work consisted of preparing location maps and satellite images of the sites. The GPS coordination of each site was determined during the field work. The sites were evaluated according to the quantitative assessment of Potential Touristic Use (P.T.U) of Brilha (2016), to discriminate the tourism evaluation of each site. 72 forms for the evaluation were filled by geologists, official and the local people in the studied area.

GEOLOGICAL SETTING

The study area is part of the unstable shelf zone affected by Alpine Orogeny in the Mesozoic Era (Jassim & Goff, 2006). Fouad (2014) however considered it within the outer platform. The northern part which is equipped with the most geosites in the present study is located in the High Folded Zone, while the southern part is located in the northern part of the Low Folded Zone. The High Folded Zone is an integral part of the Western Zagros Fold – Thrust Belt (Fouad, 2012a & b). This is due to the differences in geomorphology, elevation and water abundance in addition to wells which exposed outcrops of the geologic formation, as compared to the Low Folded Zone. The main factors that controlled the geomorphologic phenomena and the geodynamic processes of High Folded Zone are tectonic and structural effects as well as the type of exposed rocks and climatic conditions (Sissakian *et al*., 2014).

Structurally, there are several anticlines noted within the study area, they are Perat in the east, Aqra in the west, Peris in the north and Gara anticline in the north-west, where its southern limb is a part of the studied work. The exposed rocks at the core of the anticlines are mostly of the Cretaceous period, while Cenozoic rocks form the core of the synclines. These synclines are sometimes covered by Quaternary sediments (Zebari, 2013). The base beds that represent the core of the anticline are sub-horizontal, while the beds at the top are inclined to vertical and, overturned at the southern limb. Faults and joints are present in various parts, and several minor folds occur too within the less competent strata (Zebari, 2010). From a topographic standpoint, the study area is a bi-partite: in the northern part, there is a mountain range with roughly E-W orientation and with heights reaching 1500 m, while the southern half is a gentle hilly, plateau-like area, with an average height of 500 m (Csontos *et al*., 2011).

Stratigraphically, the Akre area includes a stratigraphic succession starting from Chia Gara, Sarmord, Qamchuqa, Aqrah, Bekhma and Shiranish formations of the Cretaceous period, which mainly formed the core of anticlines. The latter is overlain by Kolosh, Khurmala, Gurcus, Pilaspi, Fatha, Injana, Miqdadya and Bai Hasan formations of the Tertiary period (Figure 2). The core of Gara anticline is composed of Jurassic formation rocks. However, the current study is focused on the southern limb, that is mainly composed of Cretaceous, Paleogene and Neogene rocks.

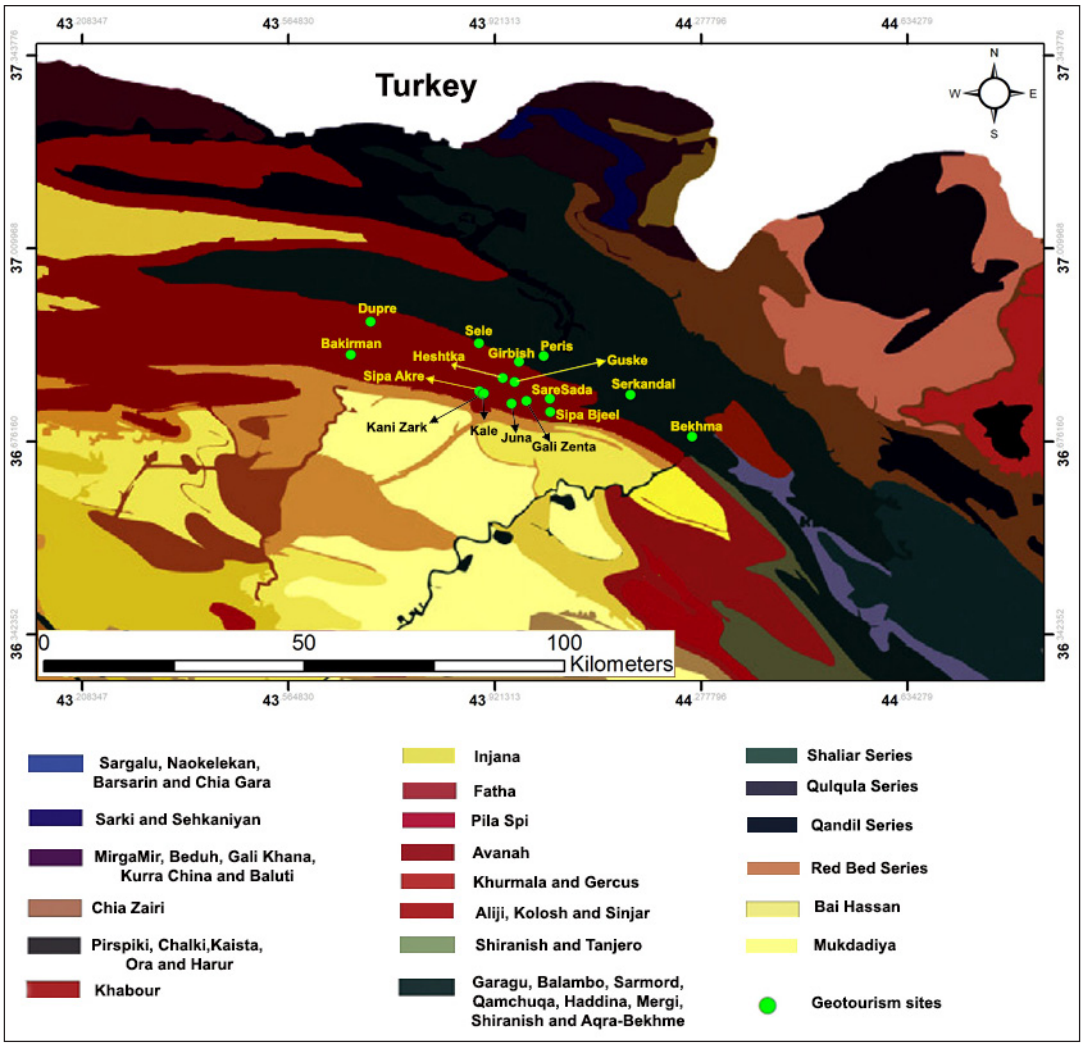

Figure 2: Geological map of the study area showing geotourism sites (modified after Sissakian, 1997).

RESULTS AND DISCUSSION

Geosites of the study area

The Akre district of Duhok governorate in the Iraqi Kurdistan region is famous for geological landscapes which are very attractive and has high tourism potential. Geographically, the area is situated at a very strategic location between Erbil, Duhok and Mosul governorates that enables tourists to reach the tourism sites easily. The study area has great archeological and cultural history with many heritage and religious sites and these give additional advantages to the tourism sector of the area (Malaika & Raswol, 2014). All geosites are located in the northern mountainous part of the district (High Folded Zone) due to the differences from the southern part (Low Folded Zone) in terms of geology, geomorphology, hydrology and tectonism. The northern mountains are characterized by beautiful Mediterranean forests, or bushes, with barren rock surfaces, while the southern lowland is almost totally bare of trees and is covered by grass. The northern mountain area is abounding in water especially gorges and also in the form of karstic wells. The southern lowlands on the other hand have mostly dry wadis with very limited water flow (Csontos *et al*., 2011).

The current work studies geosites of the area (Table 1) which include waterfalls, natural attractive springs, caves, hot springs (H_2S rich), metrological sites and tourism gorges.

Geographically, the study area is divided into three sub-areas with each of them having a number of geosites, as discussed in the following:

1 - Akre center subarea

This sub-area is located in the middle and western part of the Akre district that includes Akre city and extends to Bakirman village from the west. This area consists of the following natural sites (Figure 3):

1.1 Sipa Waterfall

It is located at the center of Akre city and is formed within bedded limestone of Khurmala Formation. The fall

Table 1: Sites of geotourism of the studied area with their coordination, elevation and geological locations.

No.	Geotourism Site	Area	GPS Location	Elev. A.S.L.	Geological Location
1	Sipa Akre waterfall	Akre	36°45'24.6"N 43°54'03.7"E	772 m	On the Khurmala Formation (Paleocene-Lower Eocene) = More than 56 million years.
2	Kani-Zark spring	Akre	36°45'31.7"N 43°54'08.7"E	773 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
3	Kale cave	Akre	36°45'46.6"N 43°53'41.7"E	902 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
4	Bakirman	Akre	36°49'32.2"N 43°40'23.2"E	931 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
5	Juna Cave	Akre	36°44'29.7"N 43°57'01.2"E	792 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
6	Sipa Bjeel Waterfall	Bjeel	36°43'38.1"N 44°01'03.1"'E	605 m	On the Fatha Formation (Miocene) = More than 5 million years.
7	Saresada Mountain	Bjeel	36°45'00.8"N 44°01'02.0"E	1175 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
8	Gali Zenta gorge	Bjeel	36°44'45.0"N 43°58'36.8"E	545 m	On the Cretaceous Formations = More than 130 million years.
9	Bekhma gorge	Bjeel	36°41'03.3"N 44°15'46.6"E	384 m	On the Cretaceous Formations = More than 145 million years.
10	Grbish	Dinarta	36°48'49.7"N 43°57'49.8"E	828 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
11	Heshtka Hotspring	Dinarta	36°47"08.2'N 43°56"06.4'E	837 m	On the Khurmala Formation (Paleocene-Lower Eocene) = More than 56 Million years.
12	Sele spring	Dinarta	36°50'33.1"N 43°53'37.4"E	799 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
13	Guske	Dinarta	36°46'44.7"N 43°57'21.4"E	767 m	On the Aqra Formation (Upper Cretaceous) = More than 65 million years.
14	Serkandal Valley	Dinarta	36°45'23.3"N 44°09'22.6"E	688 m	Upper Cretaceous and Tertiary Formations = More than 65 million years.
15	Pers Mountain	Dinarta	36°49'24.7"N 44°00'22.6"E	1200 m	Cretaceous formations =More than 145 million years.
16	Dupre	Dinarta	36°52'57.4"N 43°42'26.0"E	592 m	Aqra Formation more than 65 million years.

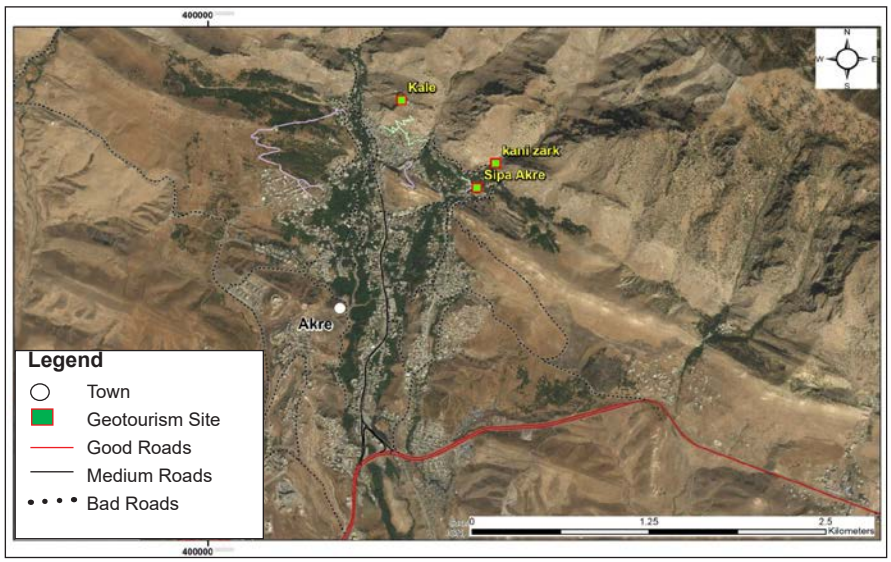

Figure 3: Satellite image of the area around Akre City showing Sipa, Kani-Zark and Kale sites.

is 30 meters high with an elevation of 772 m above sea level (Figure 4a). It is an attractive site for tourists from most parts of Iraq due to it's the low temperature in summer which does not exceed 32°C degrees.

1.2 Kani-Zark spring

The spring flows out from the reefal limestone of Aqra Formation (Upper Cretaceous Age), characterized by presence of rudists and loftusia fossils within Akre city. It has a very specular view, but it needs more conservation and development (Figure 4b). It is famous for treatment of Yolk disease and its name refers to that disease (zark means yellow). It is an attractive spring that attracts thousands of tourists every year for both treatment and vacationing.

1.3 Kale Cave

Kale Cave is located at the top of the Akre Mountain, at elevation nearly 902 m above sea level. It is a natural cave which was progressed by human and is considered as one of the important archeological sites in the area because it has been inhabited since 700 years B.C. (Sarky, 2016), and it was also the base of Mir-Zand princedom (Malaika & Raswol, 2014). It formed on the massive rudist reefal limestone of Aqra Formation. The high solubility of limestone has aided in the creation of large caves (Figure 4c).

1.4 Bakirman Mountain

The site is located 19 km northwest of Akre city on the reefal limestone of Aqra, the bedded limestone of Khurmala and red mudstone of Gercus formations. Bakirman village which lay at the top of the Bakirman Mountain can be one of the important vacation sites in summer due to its lower temperature compared to other places in the area, and also in winter due to the fantastic view of snow covered landscapes (Figure 4d). The Bakirman Stream (Khazir River) is situated 700 m north of Bakirman village below the Bakirman Mountain and flows southwards with a deeply incised channel in the bedrock (Sissakian & Abdul Jabbar, 2010) (Figure 9).

1.5 Juna Cave

This cave is located about 5 km east of Akre city. It has a magical landscape formed by the reefal limestone of Aqra Formation (Upper Cretaceous), located on the southern limb of Akre anticline in Juna village. It offers an attractive view of houses built by local people inside the cave (Figure 4e). The cave can be transformed into a tourism hotel in the future.

2 - Bjeel subarea

Bjeel is located in the eastern part of the studied area that includes Bjeel town. It consists of several attractive geosites (Figure 5):

2.1 Sipa-Bjeel waterfall

The fall is located in a valley at the center of Bjeel town among fruitful trees (Figure 4f). It is one of the most beautiful and famous tourism sites in the whole of Kurdistan region. It has a nice weather and its temperature does not exceed 25 degrees during summer. Geologically, it is located on the limestone beds of Fatha Formation (Middle Miocene), where its water source is from Bjeel spring (locally known as Aqd Spring), that it has the highest discharge spring in Akre area, at 20 liters/sec (Authors of Gara bureau, 2002).

2.2 Sare-Sada Mountain

This mountain is a strategic tourism site in the area due to its location between Bjeel and Dinarta tourism sites, located above Bjeel town at an elevation of 1175 m a.s.l. The temperature is always moderate in summer with very comfortable weather and is covered by snow in winter which creates a charming landscape (Figure 7a). The geosite is located on the reefal limestones of Aqra Formation (Upper Cretaceous) and is characterized by many geological elements such as rudist fossils, quartz geodes and bituminous limestone.

2.3 Gali-Zenta gorge

This gorge is located 3 km west of Bjeel town, near the Akre-Dinarta pavement road (Figure 5). The gorge is very narrow (canyon-like), composed of well thickly bedded, jointed and very hard limestone of Cretaceous Sarmord, Qamchuqa and Aqra formations of Aqra Anticline with very steep walls. The uppermost part is vertical, forming Hoodoos. Zenta stream is flowing southwards with a deeply incised channel in the bedrock (Sissakian & Abdul Jabbar, 2010). The area has a very comfortable weather in summer as it is particularly protected from direct sunlight with a high ratio of water in Gbeer (Brisho) stream which runs inside the gorge. It was confirmed by Jirjees (2015) that the water is suitable for drinking and this makes the Zenta gorge a very attractive site for tourism. Each summer, it attracts ten thousands of tourists from all over Iraq (Figure 7b). The macrofossils rudist and *Loftusia* in addition to bitumen seeps are common in the dolomitized massive limestone of Aqra Formation in Zenta gorge (Malak & Al-Banna, 2014).

2.4 Bekhma gorge

Bekhma gorge is located about 20 km east of Bjeel town and 31 km east of Akre city. It is 4.5 km in length, starting from Bekhma village in the south to Dam engineers' village in the north (Figure 6). Morphologically, it is a narrow gorge with steep eastern walls (canyon-like). The uppermost part is vertical, forming Hoodoos; the Greater Zab River is flowing southwestwards and makes a deeply incised channel in the bedrock (Sissakian & Abduljabbar, 2010). The gorge has a very nice weather with a good amount of water from Greater Zab (Figure 7c), which is the largest surface water in the Kurdistan region of Iraq and form about 1/5 of all surface water of the region (Jirjees, 2015). There are many water pools formed by the Zab river in the Bekhma gorge, in addition to two hot H_2S rich springs, which are located

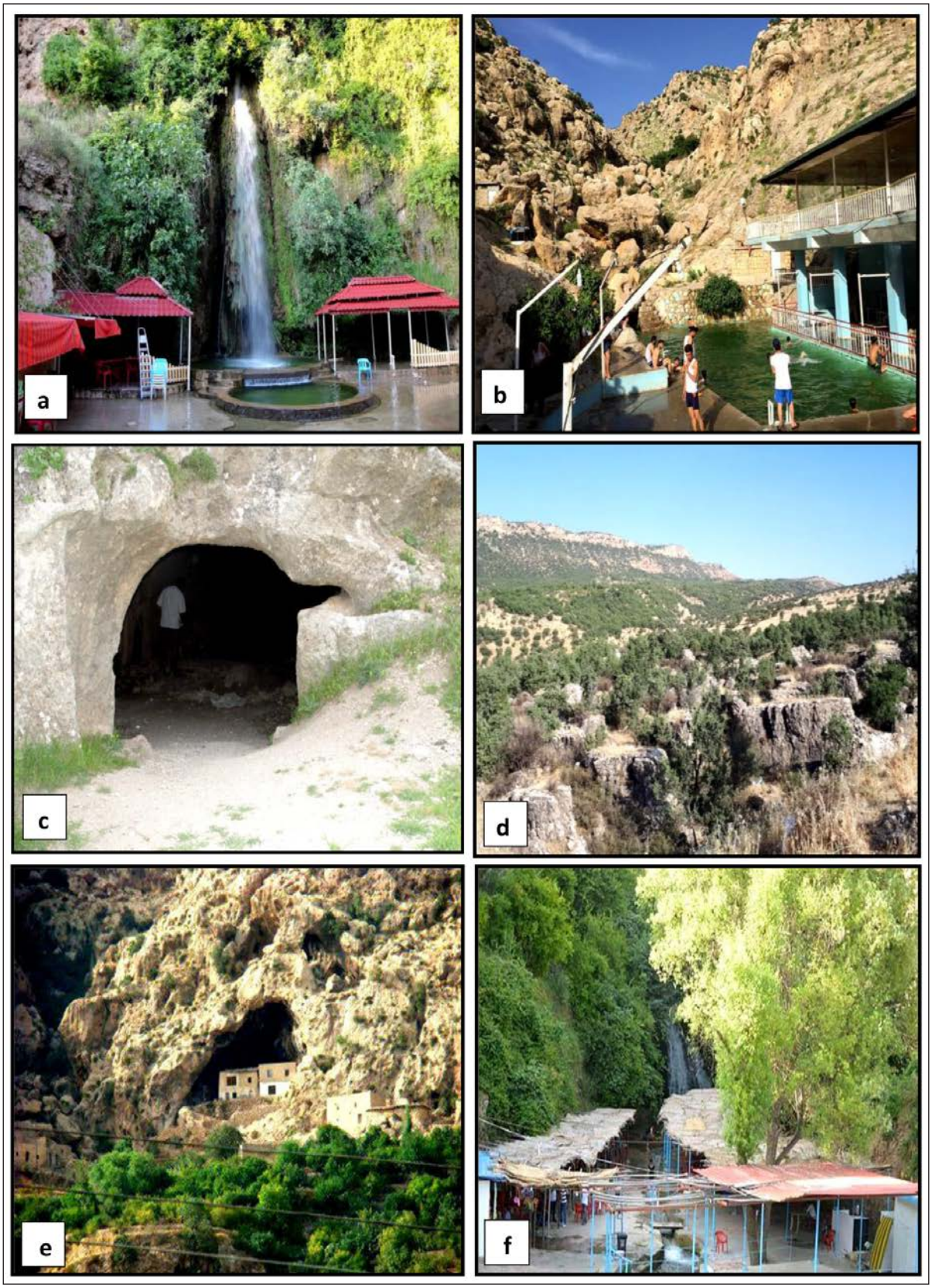

Figure 4: Photographs of geotourism sites (a) Sipa water fall in Akre. b) Kani-Zark pool in Akre. c) Kale Cave in Akre. d) Bakirman Mountain. e) Juna Cave. f) Sipa Bjeel waterfall.

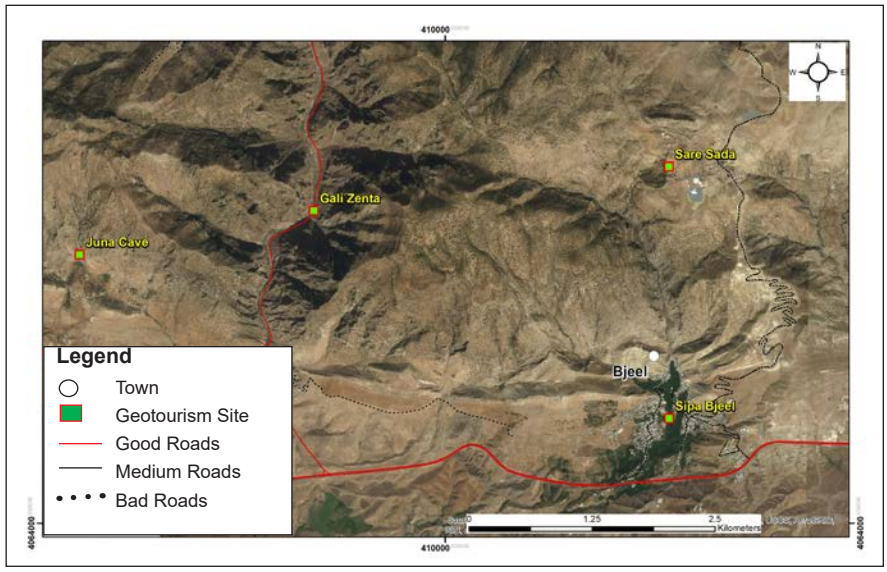

Figure 5: Satellite image of area around Bjeel town showing geotourism sites (Sipa Bjeel, Sare Sada, Gali Zenta and Juna cave).

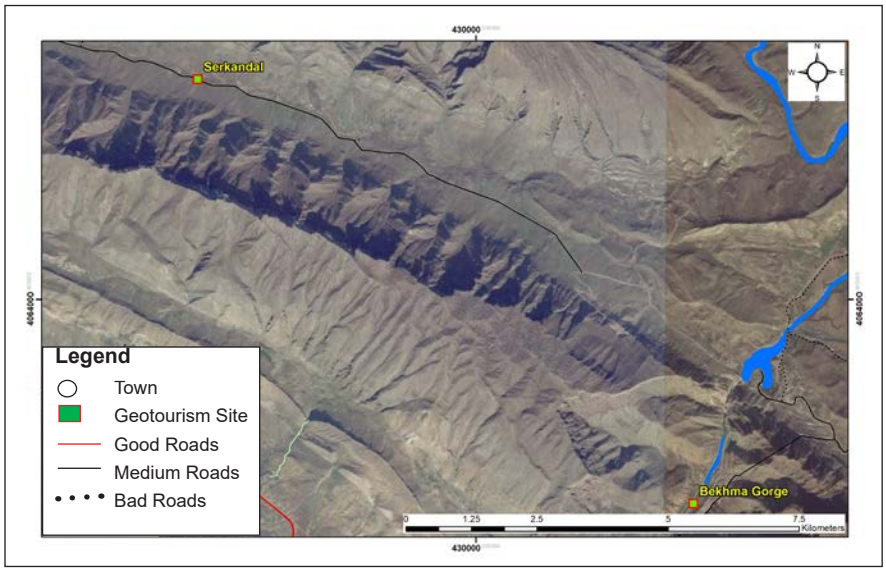

Figure 6: Satellite image of the area around Bekhma gorge showing Sarkandal geotourism site in the northwest.

at the coordinates 36° 41' 03.3" N, 44° 15' 46.6" E. The water pools seeped out from the Chia Gara shale Formation (Late Jurrassic) and their origin may be sought only in the deeper part of the formation (Csontos *et al.*, 2008). Besides its tourism value, Greater Zab which forms the natural boundary of Akre district has a very important value as it is a source for drinking water, irrigation and fishing in the area. The largest hydropower dam project was planned and its establishment was intiated in the Bekhma gorge in two different periods but the geopolitical and economic factors had obstructed the project completion. Despite its strategic location and wonderful landscape, it is unfortunately not exploited for tourism and there is no tourism project in the gorge. Stratigraphically, the gorge is composed of interbeddings of shale, marl and marly limestone of Sarmord Formation and, well thickly bedded, jointed and very hard limestone of Qamchuqa and Bekhme formations (Sissakian & Abdul Jabbar, 2010). In addition, the Chia Gara Formation (Cretaceous) may be present at the site of the river.

3 - Dinarta subarea

This area is located in the northern part of the studied area that includes Dinarta town which is famous in Nahla area. The area contain a lot of wonderful geosites (Figure 8), the most interesting sites are the following:

3.1 Serkandal Valley

It is located 13 km west of Dinarta town, between Perat and Peris mountains (Figure 6). It is a wide area covered by trees and has a lot of streams and springs which gave it the landscape of a small natural park. Serkandal resort is the mainspring of Akre area due to its stunning view and

comfortable weather, in spite of its bad roads (Figure 7d). Unfortunately, the area is not exploited for summer tourism and it needs more developments by the government and investors.

3.2 Girbish resort

Girbish is an amazing village located 3 km west of Dinarta town. The village is famous for its various types of fruitful trees particularly walnut trees which are irrigated by Girbish springs (Figure 7e). It is located at the foot of Peris Mountain on the southern limb of Peris anticline with the springs flowing through the reefal limestone of Aqra Formation (Upper Cretaceous), characterized by bituminous geodes. The Girbish resort is a very suitable place for tourism and vacation particularly because of its very nice weather with moderate temperatures. The springs of the area are cold and fresh. Unfortunately, this resort has not progressed very well and needs more construction of tourism infrastructures to attract more visitors and to raise the economical tourism value of the site.

3.3 Heshtka-Hot spring

It is a H_2S rich spring, located at the east of the Hashtka village in the limestone beds of Khurmala Formation (Upper-Paleocene-Lower Eocene) (Figure 7f). It has a very bad smell and is not used for drinking and irrigation. The spring has bubbles of gas spot in the water. The origin of sulfide in the spring is believed to be from pyrites of the Khurmala Formation which has a significant pyritization in the area (Asaad & Balaky, 2018), in addition to evaporites. The site is neglected and not visited by tourists due to the bad roads in the area, with no exploitation of the H_2S rich springs for skin treatment. However, there is a very high-quality freshwater spring located to the west of the village which is famous among the local people for kidney treatment. Unfortunately, there is no proven article or research on this claim and is also not progressed yet.

3.4 Sele spring

The spring and waterfall are located 8 km west of Dinarta town on the southern limb of Peris anticline on the reefal limestone of Aqra Formation (Upper cretaceous). From a mountain gorge, water flows down over 50-meter in an area covered by willow trees (Figure 10a). It has very suitable weather in the summer for tourists, but the disadvantage of this site is the bad quality of road which decreases the tourist ratio compared to its amazing scenery.

3.5 Guske resort

This tourism site is located 2 km southwest of Dinarta town and 500 m west of the outlet of Zenta Gorge (Figure 8). It is located on the limestone beds of Khurmala Formation (Paleocene-Lower Eocene) and has a very nice landscape with comfortable temperatures due to its location at more than 767 m a.s.l. Its springs are cold, and the resort area is covered by walnut trees which protects the area from the sun rays, thus providing comfortable shades to the resort (Figure 10b). The massive bituminous flow (lava-like) occurred at 850 m southeast of the Guske and has a significant scientific and tourism value in geotourism (Figure 10c). The disadvantage of this resort for tourism is the bad road quality and random tourism services compared to the amazing tourism site.

3.6 Peris Mountain

The top of the mountain which is nearly 1500 m a.s.l. is situated 3 km north of Dinarta town (Figure 8). The mountain is composed of beds of limestone of the Cretaceous Formation, which formed the core of the Peris anticline. Beds of Jurassic formations may crop out from the core of the anticlines away from the geosite. It is accounted as receiving the most snow in winter, exceeding more than 2 meters at some periods of snowfall, presenting a very beautiful landscape of snow caped peaks (Figure 10d). Unfortunately, it is not exploited for winter tourism and there is no tourism related development at present in the area. The weather is comfortable in summer due to its elevation, however, it is also neglected for summer tourism. The site therefore would be one of the most attractive and beneficial sites for tourism in the whole region if it is well developed.

3.7 Dupre resort

Dupre area is located at the foot of Gara Mountain on the southern limb of Gara anticline (Figure 9). It is the most amazing and specular resort in the whole study area. The Khazir river which flows out from springs of Gara Mountain runs through Dupre valley over the limestone beds of Aqra-Bekhma (Cretaceous) (Figure 10e), Khurmala, Gercus (Paleogene) and Pila Spi (Neogene) formations (Figure 10f). The river water is fresh and cold with a high discharge and forms many waterfalls and pools in the site which are tourism sites and visited for vacations (Figure 10e).

Despite the bad road quality and few tourists accommodations, the area received thousands of tourists every year. The tourism value of the site however is decreased due to its geopolitical location; it is located near the Kurdistan Workers Party (PKK) base. The southern sites of Dupre i.e. Kashkava and Hizanke which are located on the Khazir river are also used for tourism.

EVALUATION OF SITES OF GEOTOURISM ACCORDING TO THE QUANTITATIVE ASSESSMENT OF POTENTIAL TOURISTIC USE (P.T.U)

The quantitative assessment of potential touristic use (P.T.U) evaluates 13 criteria of each geosites which affect the potential of tourism value (TV). They are : A-Vulnerability: The deterioration ratio of geosite due to anthropic activity decreases the TV of the site. B-Accessibility: the possibility to access the site via good

Figure 7: Photographs of geotourism sites: a) Sare Sada mountain in winter. b) Geli Zenta gorge with a cafe for tourists. c) Bekhma gorge with Greater Zab river in spring season. d) Serkandal valley in spring season with Perat Mountain in the background. e) Girbish spring in Dinarta area. f) A H_2S rich spring in Heshka.

roads increases the TV. C- Use limitations: the presence of obstacles that affect the development of a geosite for tourism will lower its TV. D- Safety: the high risks that may be faced by visitors to the geosite decreases its TV potential. E- Logistics: available facilities for tourists at the geosite such as accommodation and restaurants will increase its TV. F- Density of population: a high population near the geosite will increase the potential source of visitors to

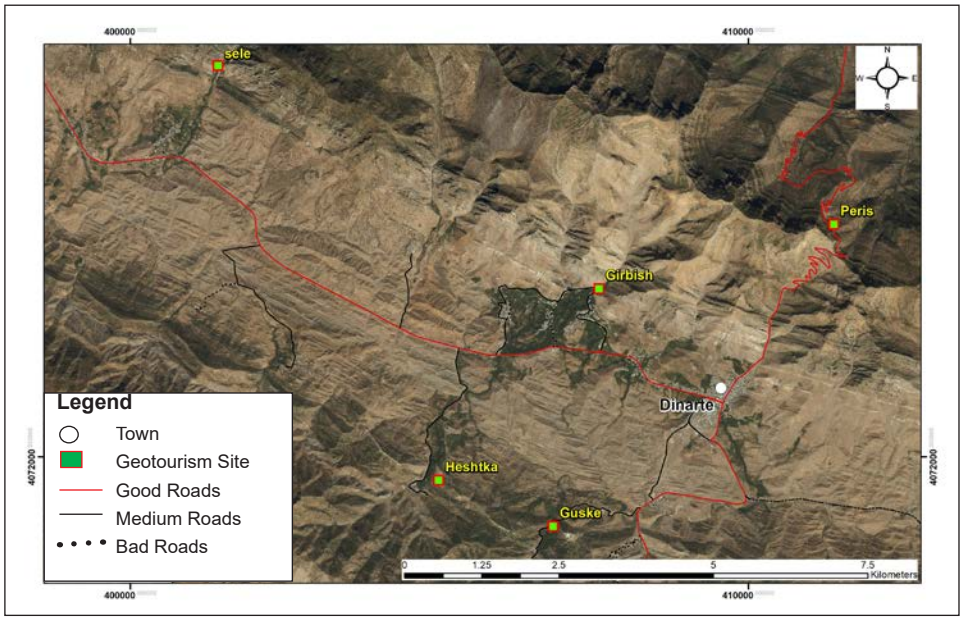

Figure 8: Satellite image of the area around Dinarta town showing geotourism sites (Guske, Girbish, Heshtka and Peris Mountain).

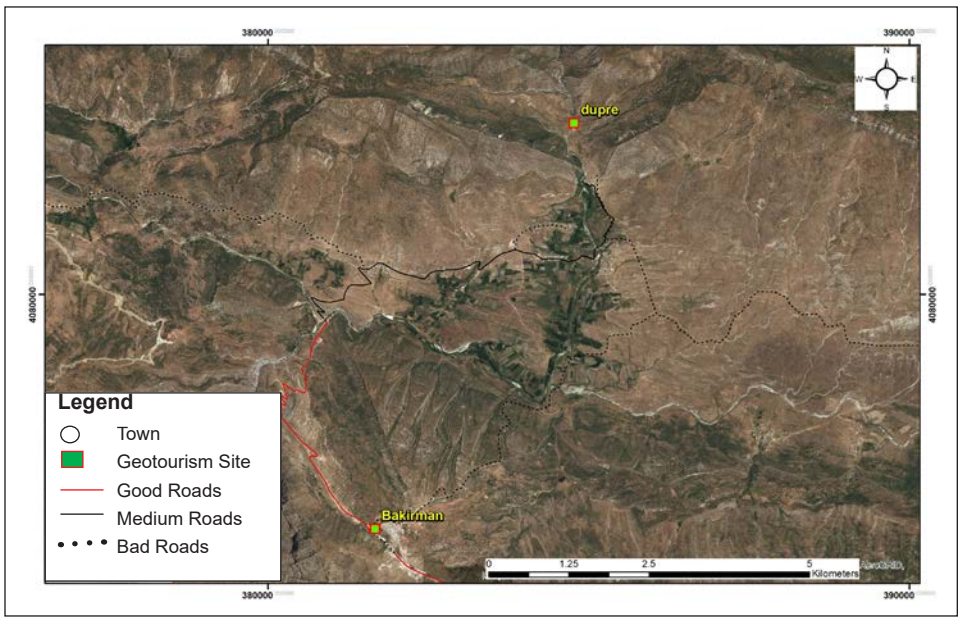

Figure 9: Satellite image of Dupre and Bakirman geotourism sites.

it. G- Association with other values: the existence of other natural or cultural sites near the geosite will increase its TV. H- Scenery: reflect the stunning view of the geosite that attract visitors and thus increases its TV. I- Uniqueness: represents the uncommon element of the geosite which differs it from other areas, this will increase its TV. J- Observation condition: the clearness of geological element will lead to an increased TV. K- Interpretative potential: if the geological feature is understood by the people, a better understanding will increase the TV. L- Economic level: The income due to the geosite compared to the normal income of the local people in the area, a higher ratio of income means an increase of TV. M- Proximity to other recreational areas or the distance of a geosite from other recreational areas or tourist attractions. A short distance reflects higher TV.

Each geosite was evaluated according to the 13 P.T.U characters using the ratio of each character leading to increase TV (Table 2). Each criterion for every character is given a score of 1 to 4 points (4 for very well correspondence leading to increased TV, 3 for good, 2 for moderate correspondence and 1 for low correspondence, while 0 if there is no correspondence between the geosite and characters). The weightage of each character is calculated by multiplying the score with the weight of that character (Brilha, 2016) and, the total weightage of P.T.U is calculated by summing the weights of each geosite (Table 2). All evaluations are based on direct visit to the geosites and information collected from formal offices and local people in addition to geologists in those areas.

Figure 10: Photographs of geotourism sites of the study area: a) Sele waterfall in Dinarta area. b) Guske resort in Dinarta area. c) Massive bitumen flow (lava-like) on the northern limb of Aqra anticline, northern outlet of Zenta Valley near Guske resort. d) Top of Peris Mountain, covered by snow during winter season. e) Waterfalls and pools formed within Aqra Formation at Dupre resort at the foot of Gara Mountain. f) Bedded limestone of Pila Spi Formation at the Dupre resort.

According to Table 2, most sites in the studied area has medium correspondence to P.T.U characters, except three sites which are Sipa-Akre waterfall and Kani-Zark spring in Akre town and, Sipa-Bjeel waterfall, which have a good correspondence. This is because the three mentioned geosites are reachable by pavement roads, easily accessed by tourists and, are easy to manage and progressed by the local people in addition to their magical landscape. The Gali Zenta and Guske resorts which are located within the Zenta Valley both present geological elements in a very clear and

Table 2: Sites of geotourism and their correspondence to P.T.U characters.
A = Vulnerability, **B** = Accessibility, **C** = Use limitations, **D** = Safety, **E** = Logistics, **F** = Density of population, **G** = Association with other values, **H** = Scenery, **I** = Uniqueness, **J** = Observation conditions, K = Interpretative potential, **L** = Economic level, **M** = Proximity of recreational areas.

No.	Geosites	A	B	C	D	E	F	G	H	I	J	K	L	M	Total
	Geosites weights	10	10	5	10	5	5	5	15	10	5	10	5	5	100%
1	Sipa Akre	2.5	10	5	10	1.25	3.75	5	7.5	7.5	2.5	5	5	5	73.75
2	Kani-Zark	2.5	10	5	10	1.25	3.75	5	7.5	5	3.75	5	3.75	5	70.75
3	Kale	7.5	2.5	3.75	10	1.25	3.75	5	0	7.5	5	5	0	5	55.95
4	Bakirman	5	5	3.75	7.5	1.25	1.25	1.25	3.75	5	3.75	5	1.25	5	48.75
5	Juna	7.5	5	2.5	7.5	1.25	1.25	2.5	0	7.5	3.75	5	0	5	48.75
6	Sipa Bjeel	5	10	5	10	1.25	2.5	2.5	7.5	7.5	2.5	5	5	5	70
7	Saresada	7.5	7.5	3.75	10	1.25	2.5	2.5	3.75	5	3.75	5	0	5	57.5
8	Gali Zenta	5	10	5	7.5	1.25	1.25	2.5	7.5	5	5	5	5	5	66.25
9	Bekhma	7.5	7.5	5	7.5	1.25	1.25	1.25	0	2.5	5	7.5	0	3.75	50
10	Grbish	5	7.5	5	10	1.25	2.5	1.25	7.5	5	3.75	5	3.75	5	62
11	Heshtka	10	2.5	3.75	7.5	1.25	1.25	1.25	0	2.5	2.5	7.5	2.5	3.75	53.75
12	Sele Spring	7.5	0	3.75	7.5	1.25	1.25	1.25	3.75	7.5	2.5	5	3.75	5	50
13	Guske	7.5	2.5	5	7.5	1.25	1.25	2.5	7.5	5	3.75	10	3.75	5	62.5
14	Serkandal	7.5	2.5	5	7.5	1.25	1.25	1.25	3.75	5	3.75	5	1.25	5	50
15	Peris	7.5	5	5	7.5	1.25	2.5	1.25	3.75	5	3.75	5	0	5	52.5
16	Dupre	5	0	2.5	0	1.25	1.25	1.25	3.75	7.5	2.5	5	1.25	5	35.25

expressive vision, particularly the famous massive bitumen seeps within the valley, and thus the correspondence to P.T.U characters is acceptable despite having bad roads and not progressing very well. The Dinarta subarea gosite in spite of its specular view and adaptation for tourism, has low to medium correspondence to P.T.U characters due to having the worst roads, not developed by local investors or government, in addition to property problems and remoteness from environmental and cultural sites.

Some of the geosites are only recently used for tourism in spite of their tourism values, such as Dupre which has security problems due to Turkish air strikes on PKK that is at the top of Gara Mountain. Dupre therefore has a negative corresponding to the P.T.U. H_2S springs for tourism are neglected in the whole Kurdistan region despite their economic potential from balneotherapy, such as the Heshtka and Bekhma hot springs. Both sites have a low ratio compared to other sites due to not being used for tourism. The Bekhma hotspring is located within the Bekhma gorge where there is no investment due to geopolitical and property factors, and there had also been problems associated with the establishing a dam in the gorge. The mountain sites which have amazing landscapes, comfortable temperatures in summer and high amount of snow in winter unfortunately are also not developed for winter and summer tourism, but only for spring picnics. These sites therefore have an unacceptable TV. The studied caves have unbelievable TV regardless having abundant geological elements, due to lack of investments in cave tourism in the whole Kurdistan region, and the bad condition of roads leading to the sites.

As mentioned by Newsome & Dowling (2010), rocks, landforms and processes that receive the least attention in tourism will consequently lead to it being the least known and understood. Kurdistan region generally and Akre area particularly need more investigation and attention on the sites of geotourism and good plans so that the investment of the whole sites will bring a positive impact on Kurdistan region revenues. This is especially so as the Kurdistan Regional Government KRG has announced that tourism will be the most recognised sector for raising the economy in the future.

CONCLUSIONS

1-Sixteen sites of geotourism were investigated in the studied area which is divided into three subreas according to its geographical position. These are Sipa Akre, Kani-Zark, Kale, Juna and Bakirman in Akre subarea; Sipa Bjeel, Gali-Zenta, Sare Sada, Bekhma gorge in Bjeel subarea and, Girbish, Heshtka, Sele, Guske, Serkandal, Peris and Dupre in Dinarta subarea. Geographically, the studied areas are situated at a very strategic location between Erbil, Duhok and Mousl cities that enable tourists to reach the tourism sites easily.

2- All geosites are located in the northern mountainous part of the district (High Folded Zone) due to its deference from the southern part (Low Folded Zone) in geology, geomorphology, hydrology and tectonism.

3-Compared to the Potential Touristic Use (P.T.U) characters of Brilha (2016), most of the studied sites have medium correspondence to P.T.U. characters, except for three sites, they are Sipa Akre waterfall, Kani Zark spring and Sipa Bjeel waterfall. These three sites have good correspondence because they are reachable by pavement roads, easy to manage and develop by the local people, and in addition, have magical landscapes.

4-The Gali Zenta and Guske resorts have very clear geological elements particularly the famous massive bitumen seeps within the Zenta valley. thus their correspondence to the P.T.U characters is acceptable, despite having bad roads and not very well developed.

5- As for the Dinarta subarea gosites, in spite of having specular views and adaptation for tourism, have low to medium correspondence to P.T.U characters due to having the worst roads and undeveloped by local investors and governments, in addition to property issues.

5- Tourism at H_2S rich springs is neglected in the Kurdistan region in spite of their high economic value from balneotherapy. The Bekhma hot spring and Heshtka hot spring therefore obtain a very low ratio. The mountain and cave sites also obtain a low ratio due to being neglected particularly for winter tourism and lack of investments for caves tourism.

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REFERENCES

Asaad, I.S. & Balaky, S.M., 2018. Microfacies Analysis and Depositional Environment of Khurmala Formation (Paleocene-Lower Eocene), in the Zenta Village, Aqra District, Kurdistan Region, Iraq. Iraqi Bulletin of Geology and Mining, 14(2), 1-15.

Authors of Gara Bureau, 2002. Hydrological Assessment of Northern Iraq. Investigation of Aqra Basin in Duhok Governorate. Documentation fund of FAO, Erbil.

Brilha, J., 2016. Inventory and quantitative assessment of geosites and geodiversity sites: a review. Geoheritage, 8(2), 119-134.

Chroback, A., 2015. Geotourism potential in the Podhale, Orava, Liptov and Spiš regions (Southern Poland/Northern Slovakia). Acta Geoturistica, 6(2), 1-10.

Csontos, L., Pocsai, T., Sasvari, A. & Kosa, L., 2008. Report on the geology and hydrocarbon perspective of Block Akri-Bijeel, Kurdistan, Iraq. Unpublished, Kalegran LTD. 98 p.

Csontos, L., Pocsai, T., Sasvari, A. & Knocz, I., 2011. Geology and petroleum systems of Akri-Bijeel block, Kurdistan Region of Iraq. Focus, 16-23.

Dowling, R.K., 2013. Global geotourism–an emerging form of sustainable tourism. Czech Journal of Tourism, 2(2), 59-79.

Dowling, R. & Newsome, D., 2006. Geotourism, Elsevier/ Heineman, Oxford, UK. 260 p.

Dowling, R. & Newsome, D.. 2010. Global geotourism perspectives. Goodfellow Publishers Limited, UK. 250 p.

Fouad, S. F., 2012a. Tectonic Map of Iraq scale 1:1000,000, 3rd edit., GEOSURV, Baghdad, Iraq.

Fouad, S.F., 2012b. Structural zonation of Western Zagros Fold – Thrust Belt of Iraq. In: The Evolution of the Zagros –Makran Fold Belt from Turkey to SE Iran. Institute of Earth Science "JaumeAlmera", Barcelona, Spain.

Fouad, S. F., 2014.Western Zagros Fold – Thrust Bekt, Part II: The High Folded Zone. Iraqi Bull. Geol. Min. Special Issue, 6, 57 – 75.

Hose, T. A., 1995. Selling the story of Britain's Stone. Environmental Interpretation,10(2), 16-17.

Hose, T. A., 2000. European geotourism—geological interpretation and geoconservation promotion for tourists. In: Barretino, D., Wimbledon, W.A.P. & Gallego, E. (Eds.), Geological heritage: its conservation and management. InstitutoTecnologico Geo Minero de Espana, Madrid, 127–146.

Jassim, S.Z. & Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, Czech Republic. 341 p.

Jirjees, Sh. J., 2015. Hydrology, Morphometry and Hydrochemistry study of Gibbel Stream in Dinarta - Akre area, Iraqi-KurdistanRegion**.** MSc thesis, Salahaddin University-Erbil (unpublished). 134 p.

Joyce, B., 2006. Geomorphological sites and the new geotourism in Australia. Retrieved from http://web.earthsci.unimelb.edu.au/Joyce/heritage/geotourosmReviewebj.html.

Malaika, M. & Raswol, L., 2014. Activating Heritage Tourism in Akre City by applying sustainable Ecotourism Approaches. European Scientific Journal February special edition, 2, 9-100.

Malak, Z. A. & Al-Banna, N. Y., 2014. Sequence stratigraphy of Aqra Formation (Late Upper Campanian–Maastrichtian) in Geli Zanta corge, Northern Iraq. Arabian Journal of Geosciences, 7(3), 971-985.

National Geographic Society, 2015. Geotourism Charter. Wikipedia, https://en. wikipedia.org/wiki/Geotourism.

Newsome, D. & Dowling, R. K., 2010. Geotourism: The Tourism of Geology and Landsape. Goodfellow Publishers, Oxford. 246 p.

Sarky, S., 2016. An evaluation of participatory ecotourism planning approaches in the Kurdistan region of Iraq. PhD. dissertation, University of Southampton. 268 p.

Sissakian, V.K., 1997. Geological map of Erbil and Mahabad Quadrangle, sheet no. NJ-38-14 and NJ-38-15 (1:250,000). GEOSURV Library.

Sissakian, V. K., Abdul Ahad, A. D., Alansari, N. & Knutsson, S., 2016. Tourism in North and Northeastern Parts of Iraq. Journal of Earth Sciences and Geotechnical Engineering, 6 (3), 90-107.

Sissakian, V. K. & Abdul Jabbar, M. F., 2010. Morphometry and Genesis of the Main Transversal Gorges in north and northeast Iraq. Iraqi Bulletin of Geology and Mining, 6(1), 95 – 120.

Sissakian, V.K., Kadhim, T.H. & Jab'bar, M.F.A., 2014. Geomorphology of the high folded zone. Iraqi Bulletin of Geology and Mining, (6), 7-51.

Wartiti, M., Malaki, A., Zahraoui, M., Ghannouchi, A. & Gregorio, F., 2007. Geosites inventory of the northwestern Tabular Middle

Atlas of Morocco. Environment. Geology, 55(2), 425-422.

Zebari, B.G.A., 2010. Sedimentology of Aqra Formation (Upper Cretaceous) in selected sections in the Kurdistan Region-Iraqi. M.Sc theses, Salahaddin University-Erbil, (unpublished). 135 p.

Zebari, M., 2013. Geometry and evolution of fold structures within the high folded zone: Zagros fold-thrust belt, Kurdistan Region-Iraq. M.Sc theses, University of Nebraska-Lincoln, (unpublished). 80 p.

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