NEOTECTONIC MOVEMENTS IN DARBANDI BAZIAN AREA, SOUTHWEST OF SULAIMANIYAH CITY, NE IRAQ

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ABSTRACT

The northeastern part of Iraq is known to be tectonically an active area due to its position in the northeastern marginal part of the Arabian Plate, which is in collision with the Eurasian (Iranian) Plate. Therefore, the whole area referred to the High Folded Zone is consequently active. The activity, however, is not uniform; locally more active areas do exist causing Neotectonic movements.

Darbandi Bazian Gorge that is located southwest of Sulaimaniyah city, NE Iraq suffers from Neotectonic movement**,** being more active from near surroundings**.** The gorge is located within the Pila Spi Formation that consists of well bedded, hard limestone and dolostone with very rare marl intercalations; its thickness is about 120 m. The Pila Spi Formation forms a continuous ridge, few hundred kilometers in length that represents the boundary between the High Folded and Low Folded Zones, the former being in the north.

The area had suffered from Neotectonic movement, which is indicated by the existence of large alluvial fans, southwards of Darbandi Bazian Gorge, the fans are formed by a single perennial stream that was previously flowing out of the gorge towards south. The older alluvial fan is now inactive, because the stream is divided into two parts; the divide point being on the top of the Pila Spi Formation that forms a high ridge, about 200 m and dips southwestwards. Part of the stream; called Chamai Bawa Fany flows southwards across the alluvial fan, whereas the other part; Tainal Stream flows northeastwards then turns southeastwards; parallel to the ridge of the Pila Spi Formation and continues its direction for about 20 Km, then turns southwestwards and crosses the same ridge in another gorge; called Basara, which is parallel to Darbandi Bazian Gorge.

The abandoned alluvial fan, the presence of old fan near Cham Chamal town, the division of the stream into two opposite parts, the abnormal trend and course of Tainal Stream, and the abnormal shape of the Darbandi Bazian Gorge are good indications for uplifting Neotectonic movement in Darbandi Bazian area, which is estimated to be during the late Holocene.

حركات بنيوية حديثة في منطقة مضيق دربند بازيان، جنوب غرب مدينة السليمانية، شمال شرق العراق

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المستخلص

تتميز المنطقة الشمالية الشرقية من العراق بكونها من المناطق النشطة بنيوياً لوقوعها في الطرف الشمالي الشرقي من الصفيحة العربية والتي هي بحالة اصطدام مع الصفيحة الأوروسية (الإيرانية)، وعليه تعتبر مناطق نطاق الطيات العالية من المناطق النشطة. إلا أن النشاط يتباين من منطقة إلى أخرى مسبباً حركات بنيوية حديثة.

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يقع مضيق دربند بازيان جنوب غرب مدينة السليمانية، شمال شرق العراق ويتميز بنشاطه البنيوي الحديث لكونه أكثر نشاطاً من المناطق المحيطة به. يقطع المضيق تكوين بيلاسبي والذي يتكون من الصخور الكلسية والدولومايت ذات التطبق الجيد والصلابة العالية مع القليل من الطفلن وبسمك حوالي 120 متر. ويشكل تكوين البيلاسبي سلسلة جبلية تمتد لمئات الكيلومترات ويعتبر الحد الفاصل بين نطاقي الطيات العالية والطيات الواطئة.

إن الأدلة على الحركات البنيوية الحديثة هي: وجود مراوح غرينية كبيرة جنوب مضيق دربند بازيان والتي تشكلت بواسطة جدول موسمي، والذي كان سابقاً ينحدر من المضيق باتجاه الجنوب. إن المروحة الغرينية القديمة الموجودة قرب مدينة جمجمال غير نشطة حالياً بسبب انقسام الجدول الى قسمين، ونقطة الانقسام تبدأ من قمة تكوين بيلاسبي والذي يشكل جرفاً عالياً في المنطقة، يرتفع حوالي 200 متر عن المناطق المجاورة لها ويميل باتجاه الجنوب الغربي. وجزء من الجدول والذي يسمى "جمي باوة فامي" يتجه الآن إلى الجنوب، أما الجزء الثاني ويسمى جدول "تينال"، فيتجه نحو الشمال الشرقي ثم الجنوب الشرقي ويستمر بهذا الاتجاه لحوالي 20 كيلومتر، ثم يغير اتجاهه الى الجنوب الغربي ويقطع نفس السلسلة في مضيق يسمى "باسارة"، ويكون هذا المضيق موازياً لمضيق دربند بازيان.

إن المروحة الغرينية القديمة (المهجورة) ووجود مروحة غرينية قديمة قرب مدينة جمجمال وانقسام الجدول إلى جزئين والاتجاه والمسار الغريب لجدول تينال والشكل الغريب لمضيق دربند بازيان، كلها أدلة جيدة لوجود حركة نهوض بنيوية حديثة في منطقة الدراسة، ومن المحتمل حدثت في نهاية الهولوسين.

INTRODUCTION

Darbandi Bazian Gorge is located southwest of Sulaimaniyah city, NE Iraq (Fig.1). The gorge is within Pila Spi Formation that forms a continuous ridge in NW – SE direction that extends off the study area for few hundred kilometers, starting from Iraqi – Iranian borders, in the southeast; crossing Darbandi Bazian Gorge and extends northwestwards until Iraqi – Turkish borders (Sissakian, 2000). Towards south, southeast and southwest, the area is a highly dissected plain (Cham Chamal Plain) with dense drainage patterns forming typical bad land. Whilst towards north and northeast, a gently rolling morphology exists, but changes to a mountainous landform with high peaks that attain 2773 m (a.s.l.) called Pera Magroon Mountain and other mountains and hills.

Darbandi Bazian Gorge is like other hundreds of gorges, in northeastern and northern parts of Iraq, which cross topographic barriers, either a limb or the whole anticline (Sissakian and Abdul Jabbar, 2010); they are usually formed due to:

- Structural effect, like fault, plunge area, lineament that facilitate the evolution of the gorge
- Headward erosion
- Active mass movements

In all aforementioned cases, a stream must contribute in carving of the hard rocks. The size of the gorge depends on many factors; among them is the size of the stream, its gradient and amount of running water.

Darbandi Bazian Gorge separates the ridge into two parts; the northwestern one is called Qashlagh Mountain, with a peak of 1440 m (a.s.l.), whereas the southeastern one is called Hanjira Mountain, with a peak of 1120 m (a.s.l.). The width of the gorge in the outlet (within Pila Spi Formation) is about 100 m and widens northeast wards to about 1 Km. The width of the gorge, in the inlet is 3 Km, with steeper southwestern slope that attains about (35 – 55)°, whereas the northeastern slope attains about (15 – 25)°. This difference, in both slopes is due to exposure of hard rocks of the Pila Spi Formation in the southwestern slope, while soft rocks of the Gercus and Kolosh formations are exposed in the northeastern slope (Sissakian, 1995 and Ma'ala, 2007). The elevation of the surface in the crossing point, where Baghdad – Kirkuk – Sulaimaniyah main road passes through the gorge (Fig. 2) is about 960 m (a.s.l.), and the height of the cliff is about 200 m. The following coordinates define the crossing point, in the outlet: Latitude 35° 38' 20.49" N and Longitude 44° 58' 21.38" E.

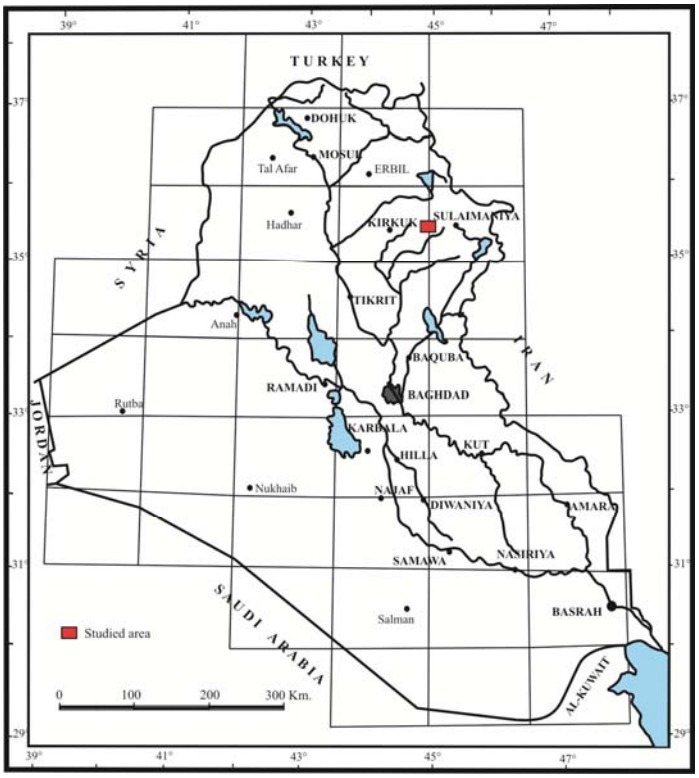

Fig.1: Location map of the study area

Fig.2: Google Earth image showing
1) Qashlagh Mountain, **2)**Darbandi Bazian Gorge, **3)** Hanjira Mountain, **4)** Tainal Stream, **5)** Basara Gorge and **D)** The former divide point of Tainal Stream

The aim of this study is to construct the model of the two streams along both sides of the Darbandi Bazian Gorge and to discuss how and why the gorge was evolved. Moreover, to indicate if there is a Neotectonic movement in the area and if the existing alluvial fans have any indication for the movement.

PREVIOUS WORKS

Darbandi Bazian area is not mapped geologically, therefore very limited data are available, among them are:

- Ibrahim (1984) compiled a geological map, scale 1: 100000 from interpretation of aerial photographs without mentioning the presence of any fault or alluvial fan in Darbandi Bazian area.
- Sissakian (1995) compiled the geological map of Kirkuk Quadrangle, scale 1: 250000 without mentioning the presence of any faults or alluvial fans in Darbandi Bazian area.
- Hamza (1997) compiled the Geomorphological Map of Iraq, scale 1:1000000 without mentioning the presence of alluvial fans in Darbandi Bazian area.
- Sissakian and Deikran (1998) compiled the Neotectonic map of Iraq, scale 1: 1000000; they assumed that the involved area is regionally up warded (more than 1000 m) during Neotectonic movements.
- Ma'ala (2007) compiled the geological map of Sulaimaniyah Quadrangle, scale 1: 250000 without mentioning the presence of any faults or alluvial fans in Darbandi Bazian area.

METHODOLOGY

The available geological maps and data in the area involved were reviewed; Google Earth images were carefully interpreted to delineate the reason how and why the gorge of Darbandi Bazian was formed and what was the original model of the stream that crosses the gorge. Topographic cross sections; from topographic maps scale of 1: 20000 were drawn along the gorge and its both sides to determine the gradient on both sides. The size and gradient of the stream, and the coverage area of the alluvial fan that exists in the crossing, were compared with the size and gradient of other existing valleys, and the coverage areas of the existing alluvial fans along the Pila Spi Formation on both sides of the crossing; in order to reveal the relation between the size of the valleys and accompanied alluvial fans. Field inspection was carried out for the existing alluvial fans and along both sides of the gorge area to collect the required data for confirming the achieved results from interpretation of Google Earth images and aerial photographs.

GEOLOGICAL SETTING

The study area is located within the High Folded and Low Folded Zones within the Unstable Shelf, Outer Plate (Al-Kadhimi *et al*., 1996 and Fouad, 2010, respectively). The top of the Pila Spi Formation represents the boundary between the two mentioned zones. The exposed formations in the area and near surroundings are (Sissakian, 1995 and Ma'ala, 2007):

– Kolosh Formation (Early – Late Paleocene)

The formation is exposed in the northern part of Darbandi Bazian Gorge; it consists of fine clastics, which are characterized by their black color, the thickness is about 150 m.

– Sinjar Formation (Middle – Late Paleocene)

The formation is exposed in the northern part of Darbandi Bazian Gorge; it consists of limestones, the thickness is 50 m.

– Gercus Formation (Early – Middle Eocene)

The formation is exposed in the northern part of Darbandi Bazian Gorge; it consists of claystone alternated with siltstone and sandstone. The red color is distinguishable character, the thickness ranges from (100 – 150) m.

– Pila Spi Formation (Middle – Late Eocene)

The formation is exposed along the southern part of the Darbandi Bazian Gorge and its northwestern and southeastern sides; it consists of limestones and dolostone, the thickness is about 120 m.

– Fatha Formation (Middle Miocene)

The formation is exposed south of Darbandi Bazian Gorge; it consists of claystone, marl and limestone, siltstone and sandstone occur in the upper parts, with very rare gypsum in the lower parts, the thickness is about 100 m.

– Injana Formation (Late Miocene)

The formation is exposed in the south of the Darbandi Bazian Gorge; it consists of reddish brown sandstone, siltstone and claystone, in cyclic nature, the thickness is 150 m.

– Mukdadiya Formation (Late Miocene – Pliocene)

The formation is exposed south of the Darbandi Bazian Gorge; it consists of grey sandstone, siltstone and claystone in cyclic nature. Some of the sandstone beds are pebbly, the thickness is 400 m.

– Bai Hassan Formation (Pliocene – Pleistocene)

The formation is exposed south of the Darbandi Bazian Gorge; it consists of conglomerate, reddish brown sandstone, siltstone and claystone, in cyclic nature, the thickness is about 500 m.

ALLUVIAL FANS

Alluvial fans are apron-like deposits of granular debris that extend from the base of a mountain front to a low land below. Each fan radiates from a single source channel, and has fan-like shape in plan view. Its transverse profile is arched, and the longitudinal profile is slightly concave. Slopes are usually less than 10^{o}. They are best developed in semiarid deserts, where elongate mountain ranges that are tectonically active (basin-and-range topography) and lack protective vegetation cover, are subjected to erosion by episodic heavy rain precipitation (Bull, 1991). In the study area, Qashlagh and Hanjira Mountains are the source area for formation of the alluvial fans; they form elongated mountain chain with maximum height of 1440 m, almost with rare vegetation cover, forming the range topography. Whereas, Cham Chamal Plain is the depositional basin in which the alluvial fans are formed. Therefore, the "basin-and-range topography" is typically formed in the study area.

Alluvial fans are formed due to decrease of gradient of a stream; hence, the coarse grained solid materials carried by the water are dropped down. As this reduces the capacity of the channel, the channel will change direction over time; gradually building up a slightly mounded or shallow fan shape. Therefore, the deposits are usually poorly sorted. The fan shape can also be explained with a thermodynamic justification: the system of the sediment introduced at the apex of the fan will trend to a state, which minimizes the sum of the transport energy involved in moving the sediment and the gravitational potential of material in the cone (American Geological Institute, 1962). Therefore, there will be iso-trnsport energy lines forming concentric arcs about the discharge point at the apex of the fan. Thus, the materials will tend to be deposited equally about these lines, forming the characteristic cone shape (National Aeronautics and Space Administration, 2009).

In Darbandi Bazian area, the cone shape is poorly developed, because the materials of the fans are of fine size. Because the shape of the fans is related to grain size; fans built of boulders and cobbles have a high pronounced arch. Whereas, those built of silt, sand and fine gravels have broad, flattened profiles (Bull, 1991).

In Darbandi Bazian area, the shape of the fans indicates that the size of the fan building materials is fine, indicated by their shapes (Fig.3). However, coarse materials (up to 15 – 40 cm) of limestone of the Pila Spi Formation could be observed in different locations within Cham Chamal Plain, about (20 – 30) Km southwards from Darbandi Bazian Gorge; indicating old stage of fans and the large energy of the stream when it was continuously flowing out of the gorge. On contrary the existing fans, near the gorge, are built by low energy streams and are still active (Fig.4) as indicated from their light tones, because the tone is a function of the activity; those with dark tone are inactive and vise versa (USGS, 2004).

The alluvial fan south of the Darbandi Bazian Gorge has coverage area of about 10 Km^2, whereas the older one, near Cham Chamal town has coverage area of about 36 Km^2 (the remaining part only). The gradient of the concerned alluvial fan is 2.5% (1: 40), whereas the gradient along the northeastern side of the gorge is 1% (1: 100). The latter gradient is good indication for the absence of alluvial fan in the northeastern side of the gorge, because usually the slope of alluvial fans is about 10° (Bull, 1991).

Fig.3: Google Earth image showing Darbandi Bazian Gorge with developed alluvial fans within Cham Chamal Plain.
Note the main fan on top of which Darbandi Bazian town is built **(D.B.T.)** and the absence of fans northeastwards of the gorge

Fig.4: Google Earth image, note the light tone alluvial fans, indicating their activity and dark tone of the main fan, indicating it is inactive

RESULTS

Darbandi Bazian Gorge that crosses a ridge within the Pila Spi Formation shows, nowadays a single stream (Chamai Bawa Fany), which flows just from the outlet of the gorge towards south, and then changes towards southwest. On the other side of the gorge, Tainal Stream flows northeastwards, and then changes its trend towards southeast, and then towards south and crosses the same ridge in Basara Gorge. A large alluvial fan is built southwards from the gorge, another old one, much bigger with coarser materials is present far from the gorge for about (20 – 30) Km. No alluvial fan is built north wards of the gorge and no blocks of the Pila Spi Formation were found there. To carve the present "V" shape gorge within the Pila Spi Formation, about 18 000000 m^3 of limestone has to be eroded and transported, either southwards or northeastwards. Certainly, this needs a stream with large transporting ability, which means a large stream with very high energy and has to be much bigger than the present stream (Chamai Bawa Fany). No faults were observed along the gorge, neither transversal nor parallel. Many faults, however, are present along the slopes of both sides of Darbandi Bazian Gorge.

The response of alluvial fans, either to be activated or abandoned, to Neotectonic movements is very common phenomenon world wide (Backer, 1993; Markovic *et al*., 1996; Mello *et al*., 1999; Kumanan, 2001; Bhattacharya *et al*., 2005; Jones and Arzani, 2005; Philip and Vidri, 2007; Woldai and Dorjsuren, 2008, among others). The author believes that Darbandi Bazian Gorge was formed due to a main stream that was divided latter on into two streams. The main stream was flowing towards south and had built up two stages of fans from the eroded and transported materials from the nowadays gorge area. Latter on, the stream was divided into two parts due to Neotectonic movement. The area due to the north of the ridge was up lifted, as compared to the southern side, consequently dividing of the main stream into

two parts. The divide point being within the ridge of the Pila Spi Formation, consequently the feeding of the alluvial fan was almost terminated, the first stage of alluvial fan (near Cham Chamal town) was abandoned, and the erosion started to decrease its original coverage area. Whilst the younger alluvial fan is still active, but with very slow rate of feeding, because the nowadays valley starts just at the top of the Pila Spi Formation, along the main road in the crossing area (Figs.3, 4 and 5).

DUSCUSSION

The dividing of the main stream that was responsible for building of the fans and evolving of the Darbandi Bazian Gorge into two parts could be explained either due to faulting or Neotectonic movement. Careful inspection of the gorge area, in the field and from interpretation of Google Earth images and aerial photographs indicated the absence of any fault across the stream. Although many faults are very clearly observed along the top and slopes of the Pila Spi and Gercus formations and have caused severe distortion to the beds (Figs.5 and 6). Therefore, the only possibility for dividing of the stream into two parts (flowing into opposite directions) is the presence of a Neotectonic movement in the involved area. The Neotectonic movement is confirmed by the following indications:

– **Size of the Main Fan**: When comparing the size of the present alluvial fan (10 Km^2), in the outlet of the gorge (Fig.5), and the stream that flows out of Darbandi Bazian Gorge, with other nearby fans and their associated valleys, it could be seen clearly that the valleys are almost of the same size. However, the main fan is much bigger than the nearby fans, which have coverage areas that range from (1 – 5) Km^2. This could be only explained by a presence of a much larger stream that was responsible for evolution of the main fan and the other old fan that exists near Cham Chamal town. Therefore, the only possibility for building such big alluvial fan is that the stream, on both sides of Darbandi Bazian Gorge, was originally one stream, otherwise the main fan would be the same size of the surrounding fans, because the streams are of the same size, and the gradient, the rainfall and the source materials are the same. Moreover, if the stream that crosses the Darbandi Bazian Gorge was not originally a continuous stream, then the present valley wouldn't be able to carve within the hard limestone of the Pila Spi Formation and to evolve the present gorge, with typical "**V**" shaped outlet (Figs.3, 4 and 5).

– **Absence of Alluvial Fans**: In the northeastern side of the gorge (Figs.3 and 4) alluvial fans are absent. This indicates that the stream in Darbandi Bazian Gorge was originally one stream, as it is supposed in this study. If not so, then the northern part (Tainal Stream) when leaving the gorge northeastward would build an alluvial fan too, as it is the case in the opposite side; the existing fan. Careful inspection in the field and interpretation of Google Earth images, and aerial photographs showed no any evidence for the presence of alluvial fans northeastwards from the Darbandi Bazian Gorge. Moreover, if the Tainal Stream had carved the limestone of the Pila Spi Formation along the northeastern limb of the anticline, then limestone blocks have to be found northeastwards from the gorge, as it is the case in the opposite side within Cham Chamal Plain. But, no such blocks were found in the field. Finally, if Tainal Stream had formed the gorge, starting from northeastward side, then how the "**V**" shape is formed in the southwestern limb without reaching Tainal Stream to the "**V**" shaped ridge?. Therefore, it is obvious that the gorge was formed by a continuous stream, which was a flowing southwest ward.

Fig.5: Google Earth image showing both sides of Darbandi Bazian Gorge.
Note the size of the main fan as compared to the size of the nearby fans

Fig.6: Google Earth image, the northwestern side of Darbandi Bazian Gorge.
Note the faulted beds of the Pila Spi and Gercus formations
and the absence of alluvial fans in the northeastern side

– **Shape and Trend of Tainal Stream**: The shape and trend of the stream prove the stream was originally one stream and flowing southwestward. The Tainal Stream, in nowadays starts directly from the bottom of the Pila Spi Formation; in Darbandi Bazian Gorge (Figs.2, 6, 7 and 8). It flows northeastwards then changes its direction towards southeast and flows for about 20 Km parallel to the ridge of the Pila Spi Formation, then changes its direction to wards southwest, crosses the same ridge, in Basara Gorge (Fig.2), and flows southwards. It is clear that it was easier to Tainal Stream to cross the same ridge in Darbandi Bazian Gorge instead of Basara Gorge. It is worth mentioning that carving of the limestone beds, by Tainal Stream, of the Pila Spi Formation in Darbandi Bazian Gorge is easier than Basara Gorge, because the formation in the former is thinner and the beds are highly distorted due to faulting, which make them to be easily eroded, consequently carving will be easier. Along the straight part of Tainal Stream course, and after 11 Km from the gorge, near Tainal village (point D in Fig.2), still the divide point of the stream could be observed, where the contour line of height 850 m (a.s.l.) marks the divide point on the topographic map of Sulaimaniyah Quadrangle at scale of 1: 100000. Moreover, the branches also indicate the original direction of the stream (towards NW not SE), before changing its direction (towards SE) (Fig.2) due to Neotectonic movement.

Fig.7: Google Earth image, the southeastern side of Darbandi Bazian Gorge.
Note the faulted beds of the Pila Spi and Gercus formations
Absence of alluvial fans to the left (northeastwards) of the gorge

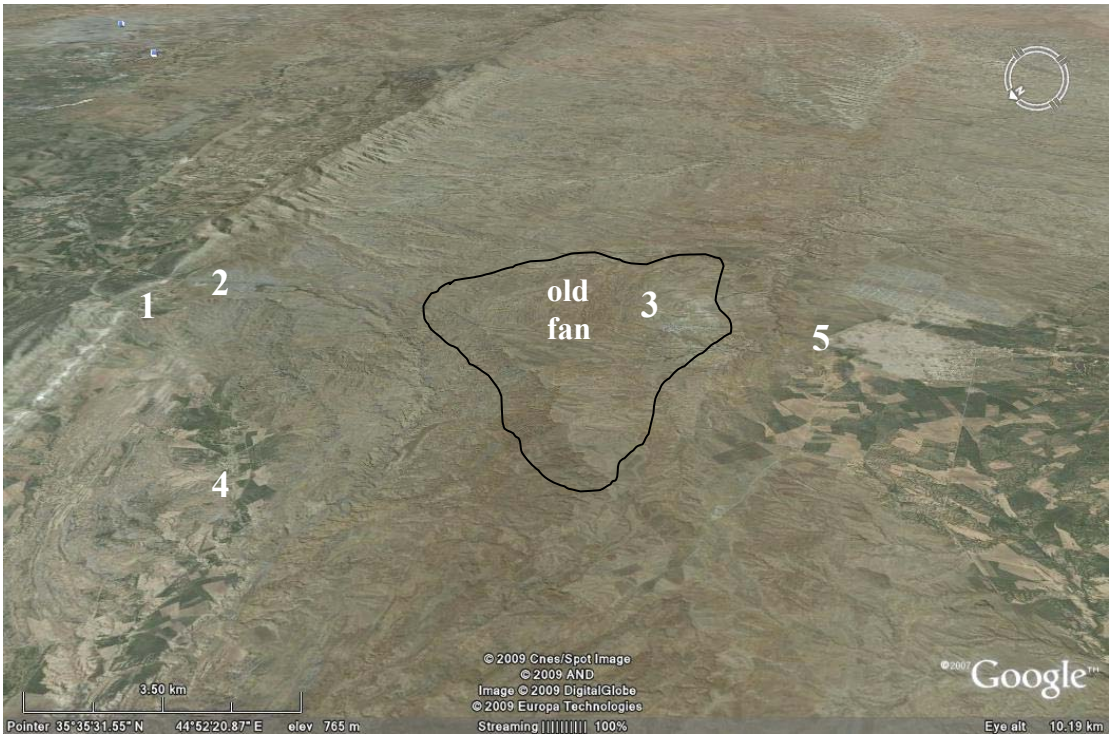

Fig.8: Google Earth image, note the location of Darbandi Bazian Gorge and starting point of Tainal Stream (**1**), the two alluvial fans (**2** and **3**), Chamai Bawa Fany Stream (**4**) and Cham Chamal town (**5**)

– **Presence of Old and Large Alluvial Fan**: This confirms that the stream in Darbandi Bazian Gorge was originally one stream and flowing southwestwards. The size and starting point of the present stream, before merging in Chamai Bawa Fany Stream, was disable to build such a large fan, with coverage area of about 36 Km^2 (the remaining part only) that extends till north of Cham Chamal town (Fig.8) and to transport limestone blocks (15 – 40 cm) to distance of (20 – 30) Km from the apex of the fan. Therefore, the only explanation for the presence of this fan is that the stream was continuously flowing out of Darbandi Bazian Gorge with large transporting energy and had built the alluvial fan system (Figs.3, 4, 5 and 8).

– **'V' Shaped Limestone Ridge:** The ridge of the Pila Spi Formation (Figs.3, 5 and 7) confirms the stream that evolved the Darbandi Bazian Gorge was originally one stream. A stream with the size of the present stream that flows from the southern side of Darbandi Bazian Gorge is disable to carve in limestone of the Pila Spi Formation and forms the present 'V' shape. About 18 000000 m^3 of limestone beds were carved and transported, only from the southwestern limb of the anticline. If the volume of the second limb is added, then in total 36 000000 m^3 of limestone beds, beside the volume of clastics of the Gercus and Kolosh formations, were carved and transported by a stream, which is impossible to be the present one. On contrary, if we assume the Tainal Stream had formed Darbandi Bazian Gorge, then the same volume of limestone, beside triple or more size of clastics were transported northeastwards to form the gorge. No single limestone block of the Pila Spi Formation was found northeastwards of the gorge. On contrary, limestone blocks up to (15 – 40) cm far from the apex of the fan; to a distance of (20 – 30) Km are still present in Cham Chamal Plain.

– Shape of the Darbandi Bazian Gorge: The shape of the gorge confirms the up ward movement of the Darbandi Bazian Gorge and division of the main stream into two parts. The present southern outlet has typical "**V**" shape within the ridge of the Pila Spi Formation, with width of about 100 m (Figs.3, 5 and 7), which is carved by an out flowing stream. Whereas, the northeastern outlet has no uniform shape (Figs.6 and 7), with width of about 3 Km, this is attributed to gentle northeastern limb of the anticline, highly deformed Pila Spi Formation in the northeastern limb, and up ward movement. These factors have accelerated the erosion of the limestone of the Pila Spi Formation, consequently clastics of the Gercus and Kolosh formations were exposed and due to their weak resistance to erosion; they were eroded easily and the present day landscape (Figs.6 and 7) is developed by the originally southwestward flowing stream.

DATING OF THE NEOTECTONIC MOVEMENT

Because no precise dating facilities are available, to the author, therefore, conventional dating is used in estimating the age of the Neotectonic movement. The dividing of the main stream was after the deposition of the old alluvial fan, which is most probably of Late Pleistocene age, because it covers the rocks of the Bai Hassan Formation (Pliocene – Pleistocene). Therefore, the movement must be during or after Late Pleistocene. But, the author believes it is much younger, because the present fan was also built before the stream was divided and because the indications of the divide point along Tainal Stream are still present, therefore the age of the Neotectonic movement was most probably during late Holocene.

CONCLUSIONS

The following could be concluded from this study:

- Darbandi Bazian Gorge is built up by a main stream that was flowing south wards, including the present day two streams; Tainal and Chamai Bawa Fany.
- The main stream was divided into two parts (flowing into opposite directions) due to Neotectonic movement that had occurred along the ridge of the Pila Spi Formation and near surroundings.
- The area of Darbandi Bazian Gorge was up uplifted due to Neotectonic movement.
- Indications for the Neotectonic movement are: the presence of the alluvial fan just near the gorge, the old alluvial fan near Cham Chamal town, the strange trend of Tainal Stream and the 'V' shaped limestone ridge, in the Darbandi Bazian Gorge.
- The age of the Neotectonic movement is most probably during late Holocene.

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