Morphotectonic Analysis of Chahnimeh Depressions in Sistan, Iran

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Abstract: Image processing of satellite photographs combined with fieldwork and extensive use of aerial photographs show that the whole Helmand block is a compressional depression produced by the activities of strike slip faults. These faults have generated bending in the East Iranian mountains and formed them to the present sigmoidal appearance. The deepest area is in the Sistan, where the East Iranian mountains have been mostly curved and the Helmand River generates several seasonal lakes. This area has been the base level for the Helmand River, probably since the Upper Cretaceous. Through the extreme pressures the mountains have been broken and partly totally removed by subsequent erosion. There are some natural deeper patches, inside the Sistan depression, called Chahnimeh, where the structural grains are more suitable for the generation of these phenomena. The very strong winds over this area have no significant effect on the origin of the depressions, as some authors believe. The Chahnimeh depressions have not been caused by wind, since they are usually covered by water, which is the only water resource used for drinking and agriculture. The water in the depressions is drained by underlying faults, since it is not salty.

Key word: Aerial photograph, Chahnimeh depressions, Morphotectonic, Satellite photograph, , Sistan

تحلیل مورفوتکتونیکی چاه‌نیمه در سیستان ایران

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چکیده : خشکسالی شدید در شرق ایران از یکطرف، وازدیاد مصرف آب برای کشاورزی و شرب از طرف دیگر، سبب شده است تا آب رود هیرمند در موقع پر آبی و سیل به گودالهایی طبیعی به نام چاه نیمه واقع در دشت سیستان، که از طرف مقامات مسؤل برای ذخیرهٔ آب آماده سازی شده است، هدایت گردد. تا کنون از چاه نیمه‌های یک تا سه بهره برداری شده و گودال طبیعی دیگری به نام چاه نیمه چهار در دست آماده سازی است، به طوریکه در ماه‌های اخیر آبگیری نیز شده است. گودال های طبیعی بیشتری هم در دشت سیستان وجود دارند که آنها هم میتوانند با هزینه بیشتری آماده سازی شوند. در سال 1382 شمسی آبهای چاه‌نیمه‌ها نه فقط به مصرف اهالی زابل رسید، بلکه اهالی زاهدان هم با صرف هزینهٔ سنگین لوله کشی، از این آب استفاده کرده اند. به علت وجود بادهای 120 روزه، که از سهمناکترین بادهای جهان بشمار میروند، تبخیر آب از این چاه نیمه ها فوق العاده زیاد است. گرچه علت پیدایش گودالهای چاه نیمه ها همان بادهای 120 روزه وغیرتکتونیکی ذکر شده اند، نتایج این بررسی، آنها را تکتونیکی و در اثر گسلش میداند، یعنی از این راه هم مقادیری از آبهای چاه نیمه ها فرارمیکنند. از طرف دیگر، کشاورزی روزافزون افغانستان و ایجاد سدهای متعدد در آنجا، امکان استفاده از آب رود هیرمند برای ذخیره سازی را در آینده مورد سؤال قرار میدهد. تلاشهای متعددی که تا کنون برای استفاده از آبهای زیر زمنی از طریق حفر چاه بعمل آمده به نتیجه نرسیده است، معذالک بر رسیهای این تحقیق آبهای زیر زمینی زیادی را در دشت سیستان پیش بینی مینماید، که فقط با حفر چاه در نقاط مناسب قابل بهره برداری میباشند. از اینرو پیشنهاد میشود قبل از سرمایه گذاری کلان برای آماده سازی چاه نیمه های بیشتر، به این مهم نیز توجه شود.

واژه‌های کلیدی: تصاویرماهواره‌ای، تصاویرهوایی، چاه‌نیمه، سیستان، مورفوتکتونیک

Fig.1- Satellite image of the large Iranian plateau. Some geographers think the Iranian plateau comprises a more extensive mountain zone extending from eastern Asia Minor and the Caucasus to the plains of the Punjab without considering the political borders (Fisher, 1968).

1- Introduction

Although some writers believe that the Iranian upland is bordered by the Caucasus, Alborz and Kopet Dagh mountains to the north, the Zagros and Makran ranges to the west and south and the Eastern Iranian mountains to the east, as it is politically, other writers speak of the entire upland comprising a more extensive mountain zone extending from eastern Asia Minor and the Caucasus to the plains of the Punjab (Fig. 1) as the Iranian plateau (Fisher, 1968).

Since in this study more attention will be paid to the catchment area of the Helmand river, which rises from the Hindu Kush mountains, the extensive Iranian plateau, in which this river is the largest (Papoli, 1995), will be considered. The Hamun (lake) is the largest fresh water lake in this plateau (Krinsely, 1970), although through drought in recent years only different parts of it, named Puzak, Saberi, Helmand and Goade-zereh ,exist (Fig.2 & 3). They are in some years even only seasonal lakes. Although the Hamun is mainly fed by the Helmand River, terraces and alluvial fans on the west side of the Hamun are indications that some streams from the East Iranian mountains, e.g. the Shour river, have entered the lake (Fig. 3). The origin of the Sistan depression has not been a matter of extensive research yet. Some geologists believe that it is a remnant of the Neo-Tethyan Ocean (Eftekhar-Nezhad, 1973). The deepest area of an ocean is at its border only when this is a trench of an active subduction zone. But there is no active subduction in this area. On the contrary, we are facing here a collision of the Lut and Helmand blocks, which produce the East Iranian Mountains. Some geologists found it enough to say that the Sistan depression is of tectonic origin, without giving any further explanation.

The first writer of this paper has investigated for the first time the following depressions:

1. Jaz Murian depression (Farhoudi & Karig, 1977).
2. Gav Khuni depression (Farhoudi, 1978).
3. South Caspian block (Farhoudi, 1991, 1996).

Beside, the depressions are similar to the depress-sion near Frankfurt (Main) in Germany, not far from Messel (Messel Depression), in which the Eocene oil shale underlain by the Permian Rotliegende in 60 m depth in an area of 0.7 km^2 (Backhaus & Rahnama-Rad, 1985 and 1991 and Harms et al. 1999).

The origin of the Helmand block and the Chahnimehs, which are the local base level for the Helmand river and of great significance for drinking water and agriculture in eastern Iran, is the matter of investigations in this paper.

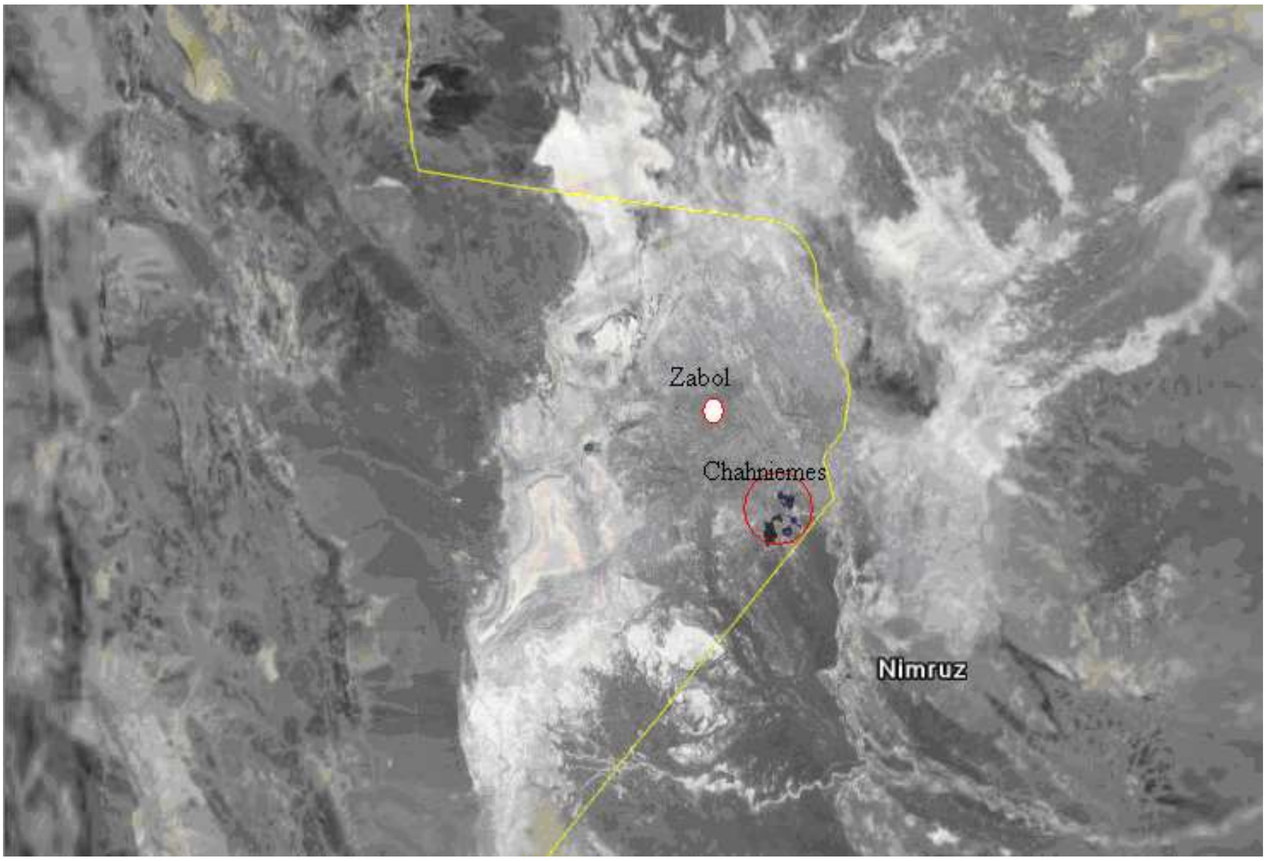

Fig. 2 – Satellite processed image of the Sistan plain. The Chahnimehs I, 2, 3 and 4 appear as small black patches to the SW of Zabol City. Several NW trending lineaments can be revealed. The alluvial fans to the west of Hamuns Saberi and Helmand are indications that there has been some influx in the west side, too.

2- Geographic Setting

The Helmand (Hirmand) river rises from the Hindu Kush mountains and runs about 1000 km through Afghanistan to enter into the Sistan depression in Iran (Fig 3), which slopes gently (1:2500) towards northeast. After such a long distance, the river deposits only fine sediments, not suitable for increasing ground-water resources in the Sistan depression. The lowest and the highest points of this depression have an elevation from the sea level of 450 m and 510 m respectively. The city of Zabol has been built on relatively higher area, the former terraces called Hussein Abad and Ghaleh Nosrat. There are no natural border lines between Iran, Afghanistan and the Helmand block in the Sistan plain. The very high evaporation is due to droughts and strong winds, and reaches up to 4 m / year according to the local Water Organization. At first, the Helmand River has mainly a SW course. Near the Iranian border, the direction changes to NNE through a large meander. The river divides at the Iranian border into 2 branches. The first branch, the Sistan River, with a NW course has to pass 60 km in the Sistan plain to enter the Hamun. There has been built a channel to provide water for the Chahnimehs, a short distance after the division. Several other channels provide water for different purposes. The second branch, the Parian Moshtarak, passes a course to the N along the Iran-Afghanistan border, before turning again towards Afghanistan.

There are strong winds over 120 days from May to September in the Sistan area. The winds are blowing from NE over the Sistan plain and, according to the local Water Organization, maximum velocities reach up to 110 km per hour and an average velocity of 30 km per hour. Some scientists from the mentioned organization believe that the origin of the Chahnimehs is due to wind erosion. The micro climatic differences produced by the strong differences in elevation of the ca. 7000 m high Hindu kush mountains over the only approximately 500 m high vast Sistan plain may help to produce such wind.

3- Geological Setting

The active subduction of the Indian Ocean (Farhoudi & Karig, 1977) under the Iranian plate (Fig. 4) in Makran of Iran and Pakistan is now accepted by nearly all geologists. The geological past of the Eastern Iranian Mountains is still debatable. A branch of the Neotethyan Ocean separated the two Lut and Helmand blocks and produced the Baluch ocean in the Early Cretaceous

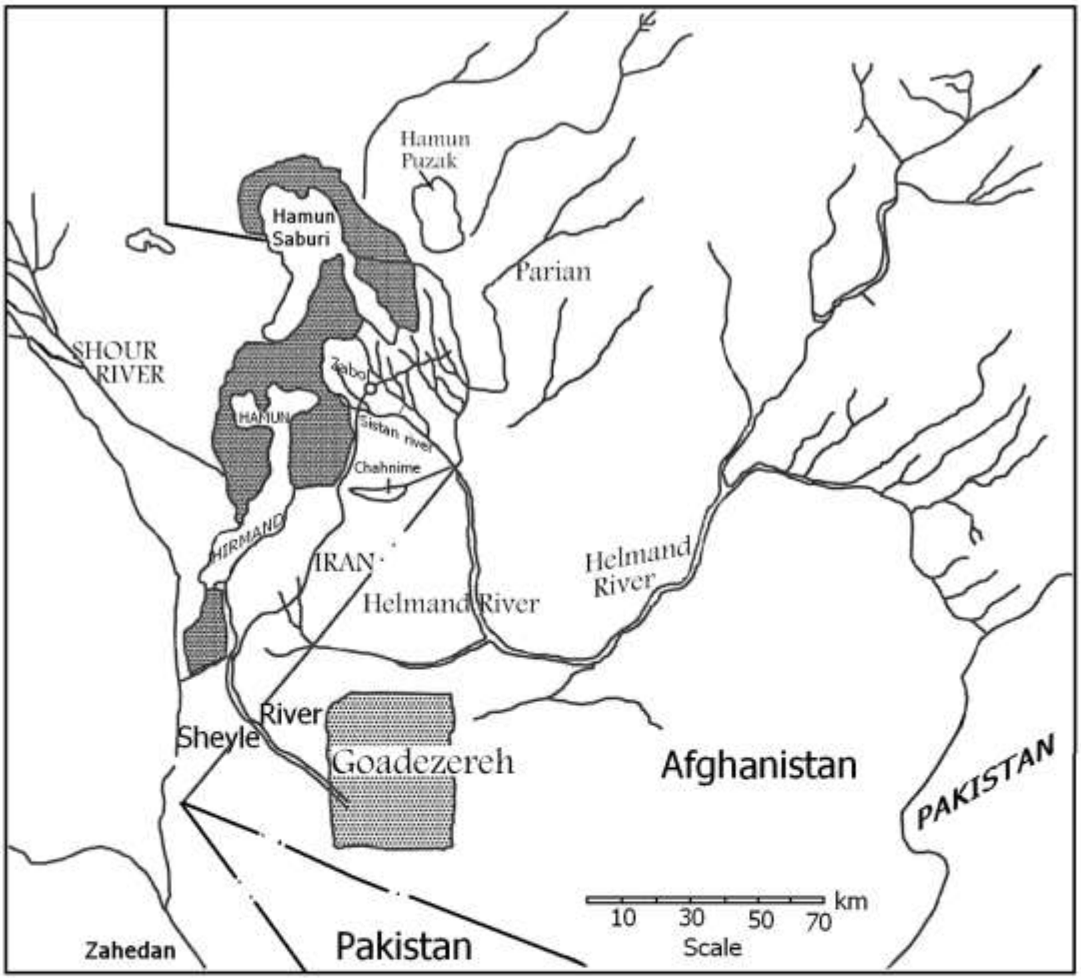

Fig. 3 – The course of the Helmand river and its tributaries inside Iran.

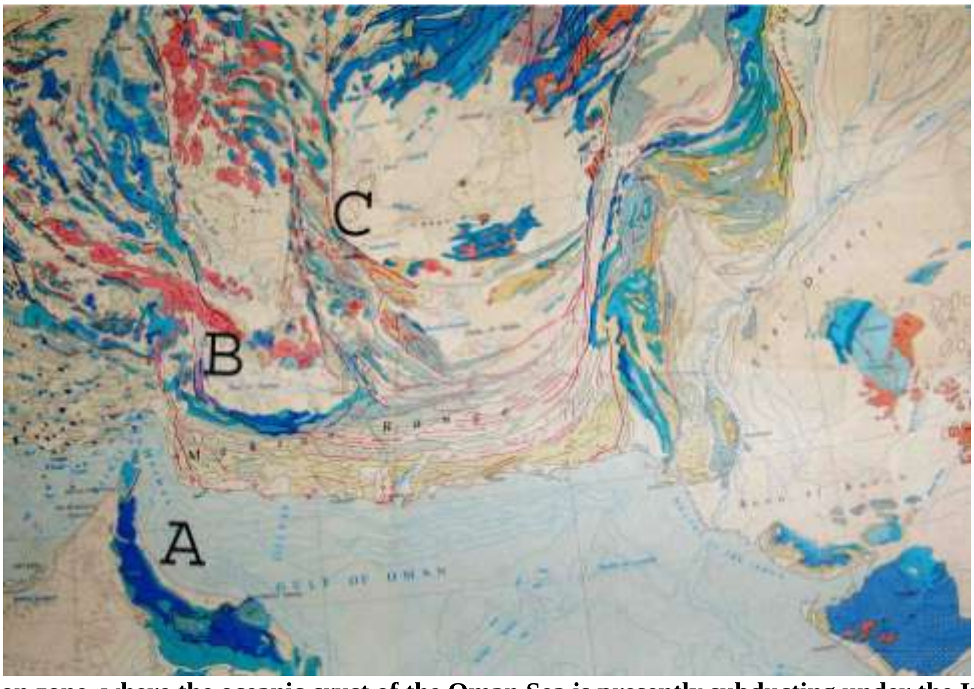

Fig. 4 – Subduction zone, where the oceanic crust of the Oman Sea is presently subducting under the Iranian plate. The similarity of the bending of Oman Mountains (point A), Makran ophiolites (point B), and East Iranian Mountains (point C) is in so far remarkable, as they encircle the Oman Sea, Jaz-Murian depression, and the Helmand block respectively.

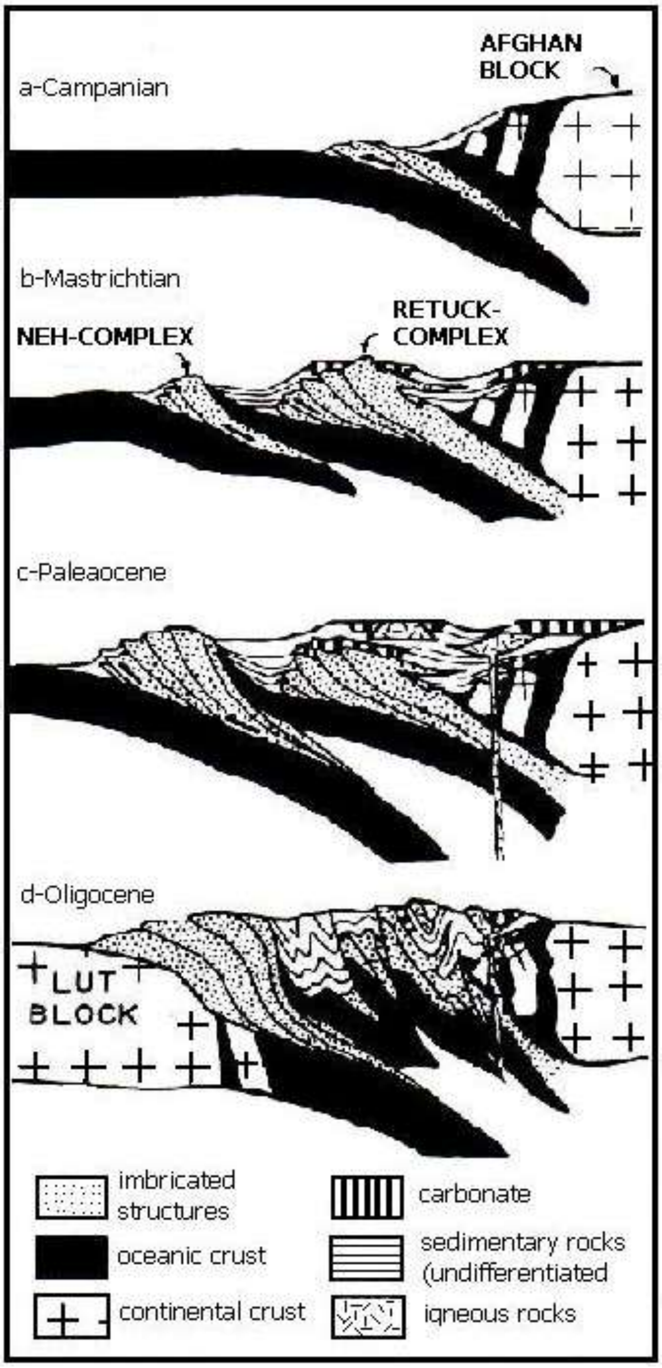

Fig. 5 -The evolution of subduction in the Sistan plain according to Tirrul et al., 1983.

(Stocklin, 1972). This ocean didn't extend very much, probably due to the convergence of India and Tibet in that time. It disappeared through subduction under the Lut block to the west (Fig. 5) at the Upper Cretaceous-Lower Tertiary time (Eftekhar-Nejad, 1973, King & Berberian, 1986). They believe that the presence of calc-alkaline rocks north of the Lut block is an indication of this claim. On the contrary, Tirrul and others, 1983 believe that the presence of igneous rocks on the Helmand block and the fact that both Retuk and Neh ophiolite complexes (Fig. 6) slope to the east and moreover, the deposition of limestone on the Retuk complex (Fig 6), showing uplift due to the collision of the Lut and Helmand blocks, are all indications that the Lut block has been subducted to the east under the Helmand block. This idea has been disputed by other geologists (Samani & Ashtari, 1992). Anyhow, subduction to the west or to the east or both, the extensive presence of flysch, large patches of ophiolites, vast areas covered by intrusive and extrusive rocks to the north of the Lut block and finally the activities of the Nehbandan fault (Fig. 7) are indications that the whole area of Sistan has been subjected to complex structural forces (Shahriari & Khatib, 1997).

From the stratigraphic point of view there are no structures older than the Mesozoic in eastern Iran. In the Helmand block, which is significant in this paper, more than 500 m lake deposits cover the Neogene sedimentation.

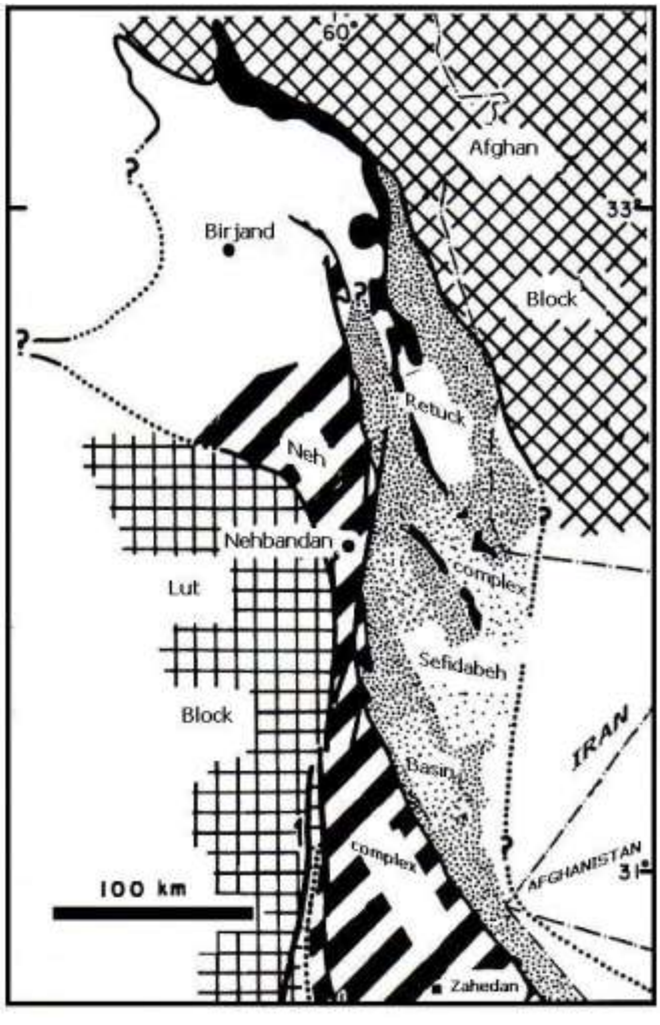

Fig. 6 – The suture zone between the Helmand and the Lut blocks producing Retuk, Neh, and Safidabeh complexes (Tirrul et al., 1983).

4- Discussion

The sigmoidal appearance of the Eastern Iranian mountains, changing trend from NW-SE at the SE part to NS and even to NE-SW to the north (Fig.8), the many segmentations of the Nehbandan fault (Shahriari

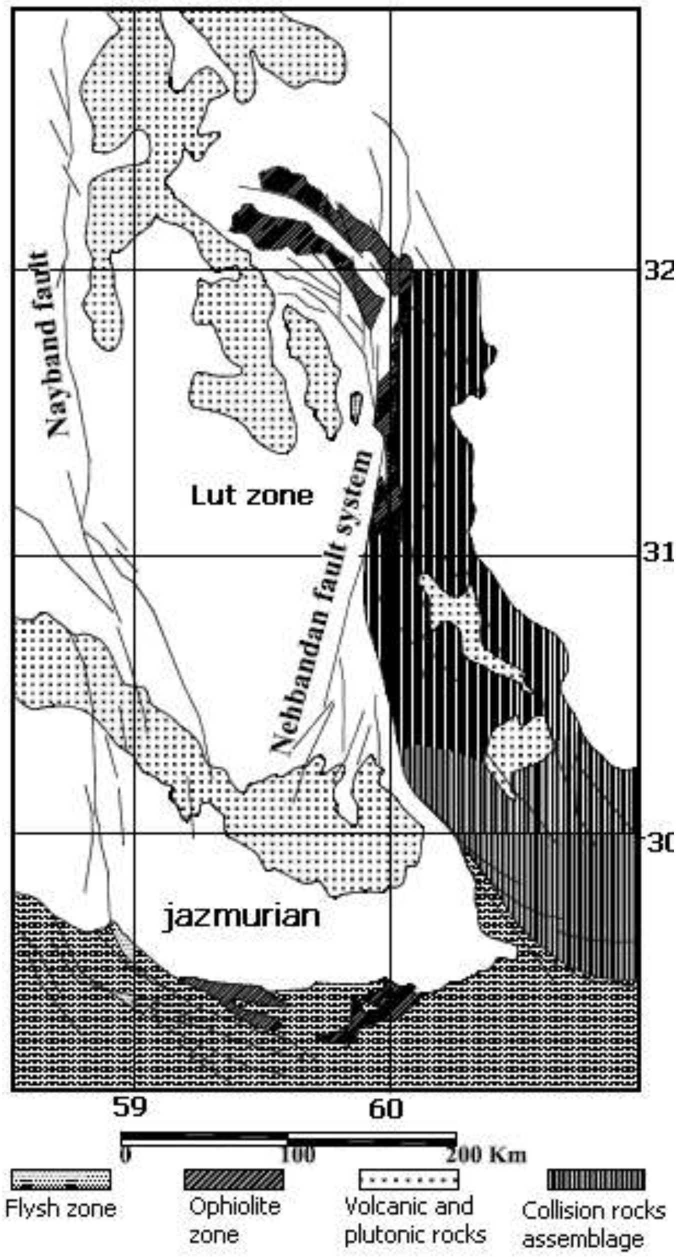

Fig. 7 –The Nehbandan fault system and sigmoidal appearance of the East Iranian mountains (Shahriari and Khatib, 1997).

& Khatib, 1997) and the subsidence of the two Helmand and Lut blocks indicate geologically a very complex area. The rotation of the mountains occurs not only in the Eastern Iranian mountains. The same rotation happens in the Oman Mountains and the ophiolite belt to the east of the Jaz-Murian depression. Although the depressions in front of the two latter structures have been related to subduction, there is a similarity in their appearance with the Eastern Iranian Mountains (compare points A and B with point C in Fig. 9). Probably, both subduction and bending structure cause the strong depressions in points A and B. The bending in the Eastern Iranian Mountains reaches its maximum in front of the Sistan depression (Fig. 8), which is the deepest part of the Helmand block. Although the mountains are strongly dissected in that area, their curvature can be shown through enhancing of satellite photographs. Despite the fact that thick

Fig. 8 -Processed satellite image showing that the bending of the East Iranian mountains has its maximum bending around the western part of the Sistan plain. This is also the deepest part of the Helmand depression.

Alluvium has covered most of the lineaments in the plain (Fig. 2), some of them could be enhanced and, together with field work (Fig.9), analyzed (Fig.10). They confirm the above- mentioned indications that the Sistan plain has resulted from a compressional depression. The deeper Chahnimehs have been produced where the structural grains have allowed this.

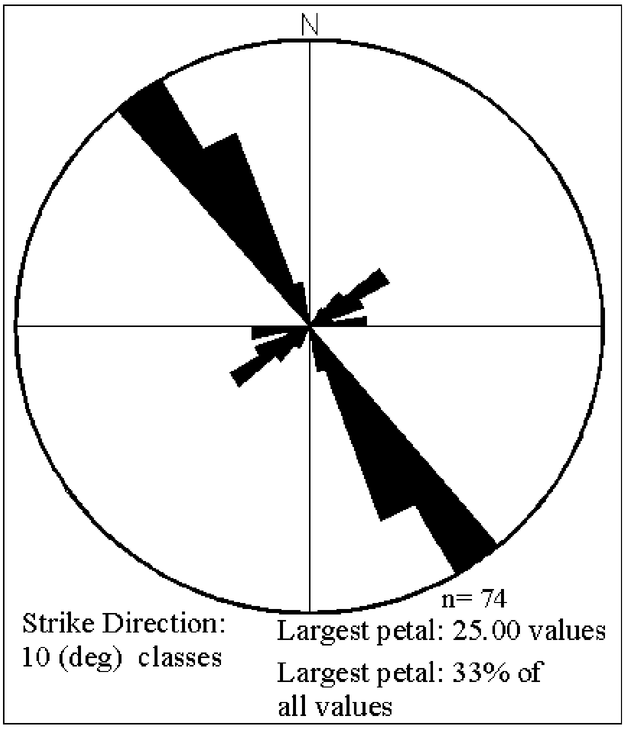

Fig. 9- Most parts of the Sistan plain and sowith the lineaments are covered by alluvium. Analysis of the not covered lineaments show, mainly fractures with a NW irection, which confirms fracturing through bending of the structure.

Due to incompetent deposits, the fault plains around the Chahnimehs are not very remarkable (Fig. 10). Another indication that the Chahnimeh depressions are fault-controlled is the fact that despite of the high evaporation their water is not salty. The salt water is heavier and is drained through the faults.

5- Conclusion and suggestions

The Sistan plain is a compressional depression, which probably has been continuing from the Upper Cretaceous onwards and has been the local base level for the Helmand and some other rivers. The Chahnimeh depressions can only be used temporarily as water resources. Because of the very fine-grained and thick deposits, the water can only be found by drilling in suitable fractures after confirmation by geophysical methods.

6- Acknowledgements

Supported by the Research Councils of Shiraz University (Project Nr. BF-81-25), Zabol University, and the Water Organization of Zahedan city.

Fig. 10 – Field work confirms the fact that the Chahnimehs are fault-controlled, even when the fault plains are not very sharp, due to the incompetence of the overlying materials.

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