THE ORIGIN OF THE SUBSURFACE IGNEOUS CLASTICS ACCUMULATION IN AL-TINIF VICINITY, WEST IRAQ, A NEW CONCEPT

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ABSTRACT

The presence or otherwise of a shallow igneous intrusive body and the origin of the igneous clastics accumulation in Al-Tinif (Al-Waleed) vicinity is a matter of controversy. Many authors conducted different types of geophysical, geochemical and petrographical studies; some of them were associated with drilling. None of the ten drilled boreholes, to maximum depth of 193m, struck an igneous body. The extracted cores from these boreholes indicate inhomogeneous materials including breccia, sand grains and rounded, altered basalt pebbles. Petrographic studies showed cyclic graded bedding sediments with fining upwards nature. Geophysical studies showed major positive anomaly surrounded by negative anomalies. Two scenarios are assumed in this study, the first one (depends on the previous works) is the assumption of presence of an igneous body with arguments, whereas the second scenario deals with the absence of an igneous body. Many indications are given to support the second scenario.

فكرة جديدة حول أصل التجمعات الفتاتية النارية تحت السطحية في منطقة التنف، غرب العراق

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المستخلص

إن وجود جسم ناري وأصل التجمعات الفتاتية النارية تحت السطحية وفي أعماق ضحلة في منطقة التنف (الوليد) هو موضوع نقاش بين العديد من الدراسات التي جرت في المنطقة ومنها دراسات جيوفيزيائية وجيوكيميائية وصخارية والبعض منها كانت مصحوبة بحفر الآبار. إن الآبار العشرة المحفورة في منطقة التنف والى أقصى عمق 193 متر لم تستطع الوصول إلى جسم ناري. وان اللباب المستخرج من هذه الآبار يحتوي على مواد غير متجانسة من قطع صخارية بعضها نارية إضافة إلى الرمال والأطيان وبعض الحصى المدور من البازلت المتحور. أثبتت الدراسات الصخارية وجود دورات ترسيبية جميعها تشير إلى التنعم نحو الأعلى. الدراسات الجيوفيزيائية أثبتت وجود شاذة رئيسية موجبة محاطة بشواذ سالبة. في هذه الدراسة تم افتراض احتمالين، الأول (يعتمد على الدراسات السابقة) و يشير إلى وجود جسم ناري وتم مناقشة هذه الاحتمالية. أما الإحتمالية الثانية أشارت إلى عدم وجود جسم ناري وتم دعم هذه الاحتمالية بالعديد من الأدلة المتنوعة.

INTRODUCTION

In the western part of Iraq no surface exposure of igneous rocks occur (Sissakian et al., 2001), on contrary to neighboring areas in Syria and Jordan, where large parts are covered by lava flows. The most recent flows in Syria was before 4000 years (Bender, 1974), moreover three stages of basaltic flows are recorded during Quaternary in Syria (Ponikarov, 1967). Nevertheless, the topographic maps, of scale 1:100 000 and 1:250 000, (based on aerial photographs) depict the occurrence of igneous rocks, on surface, in the western parts of Iraq. All these areas were checked by Sissakian et al. (2001) and were found to be accumulation of chert and / or limestone fragments, both coated by desert varnish.

Many geophysical studies revealed the presence and/ or the possibility of presence of igneous intrusions in the western part of Iraq. Among these studies are Sallomy et al. (1981 and 1982), Al-Ameri et al.(1981), Al-Kadhimi et al. (1985), Al-Bdaiwi (1982), Al-Atia (2000), Al-Atia et al. (2002), Yakta et al. (2002) and Al-Bdaiwi et al. (2005).

The aim of this study is to discuss the possible presence of an igneous intrusive body and the origin of the subsurface igneous clastics accumulation in Al-Tinif (Al-Waleed) vicinity (Fig.1). However, the study reviewed the majority of the western part of Iraq, along the Iraqi – Jordanian and Iraqi – Syrian borders, for acquiring the results of this study.

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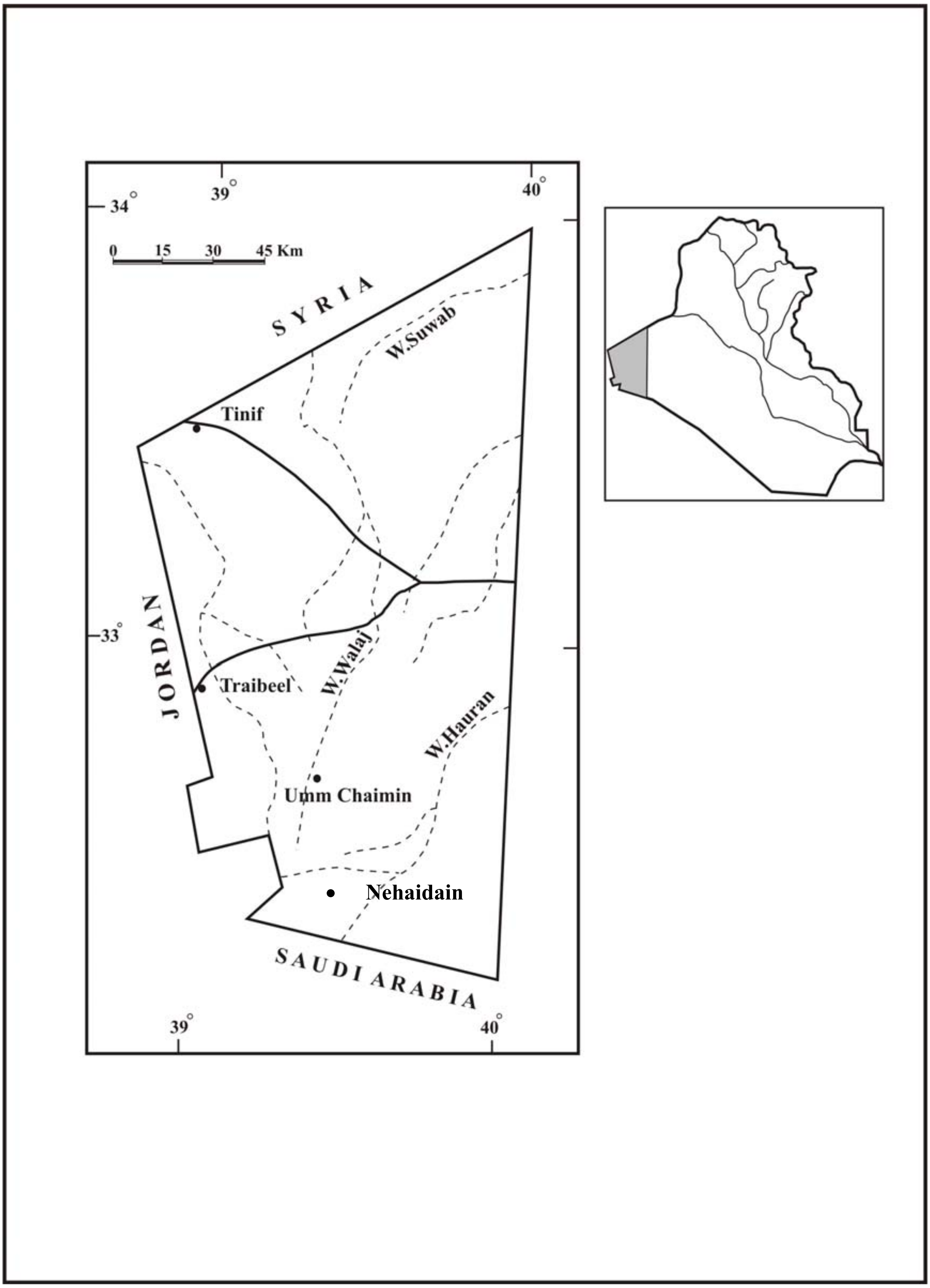

Fig. 1: Location map of the studied area

DATA USED

To achieve the results and discussions of this study the following data was reviewed, analyzed and interpreted:

- Relevant reports and studies, which dealt with the presence and / or description of subsurface igneous rocks in the involved area.
- Landsat images of different scales from different sources, including Google Earth on line, 2006.
- Geological maps of different scales for the studied area and its surroundings.
- Topographical maps of different scales.

GEOLOGICAL SETTING

The study area is covered by the Early – Middle Eocene Ratga Formation (equivalent of Dammam Formation). The main lithology of the Ratga Formation is limestone, dolostone, marly limestone and some marl interlayers, with abundant chert nodules, lenses and layers of phosphorites. The exposed thickness of the Ratga Formation is 16 m, whereas the total thickness is 85 m, in K.H.5 / 8 (Hagopian, 1979).

The study area is characterized by the presence of two main sets of lineaments, as deduced from Landsat images. These are of NW – SE and NE – SW trends; and to less extent of E – W trend, with lengths of few tens of kilometers, many of them extend to Syria and Jordan (Fig.2.). The study area is bounded by two lineaments of NW – SE trend, with length of 42 Km, from which only 19 Km is in Iraq. The distance between the two lineaments ranges from (2.4 – 3.6) Km. The nearest basalt flow, in Syria is 78 Km southwest of the northwestern end of the lineaments (Fig.2). Those of NE – SW trend cut the lineaments of NW – SE trend, most probably indicating a zone of strike-slip faults, which formed a tectonic depression (sag ponds). Since “major strike-slip movements never takes place along a single fault plane, but is distributed through a zone” (Park, 1988). The discontinuous lineaments may indicate a strike-slip fault zones, which are typically belts of braided nearly vertical shears, bound elongated blocks, which are squeezed upwards along those shears to make high-standing source areas for sedimentation (Crowell, 1974, in Sylvister, 1988). Crustal blocks may sag, subside, or tilt between or adjacent to bounding faults, making local sites for deposition. Sylvester (1988) depicted pull-apart basins as deep , rhomb-shaped depressions bounded on their sides by two, sub parallel , overlapping strike-slip faults and their ends by perpendicular or diagonal slip-faults, termed “ transferred faults”, which link the ends of the strike-slip faults.

Moreover, the study area and the near surroundings are also characterized by the presence of ring structures, some of them are suggested by magnetic anomalies (Blisckovsky et al., 1971, C.G.G., 1974, Sallomy et al., 1981 and 1982 and Al-Ameri et al., 1981). These ring structures are either elevated , like the one in Traibeel vicinity (Fig.3), which is (6 – 12) Km wide and (5 – 15) m elevated from the surrounding, or are subsided, forming depressions of different depths, ranging from few meters up to 30 m, like in Um Chaimin (Hagopian,1979) (Fig.4). The shallow depressions are either closed or open. These shallow depressions, especially the former, are filled by fine loam, forming flat areas called playas, locally are called "Faydha" or "Khibrah"(Figs. 2, 3 and 4).

From tectonic point of view, the area is located within the Stable Shelf (Rutbah – Ma`aniyah Zone, Rutbah Subzone) (Al-Kadhimi et al., 1996). From neotectonic point of view, the area is uplifted, with amount of more than 400 m and rate of uplift, which attains more than 0.2 cm / 100 years (Sissakian and Deikran, 1998).

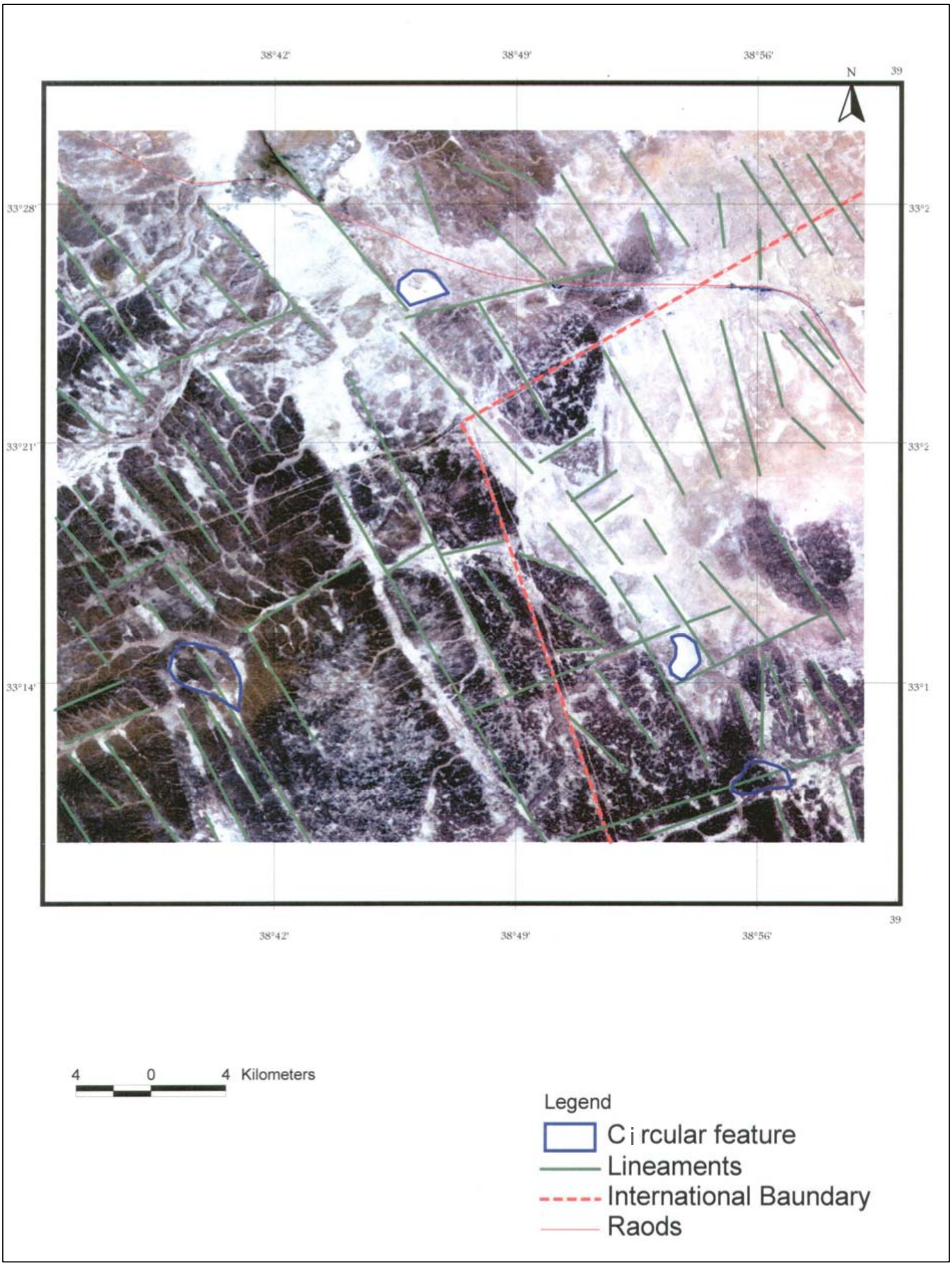

Fig. 2: Landsat image showing lineaments of the study area

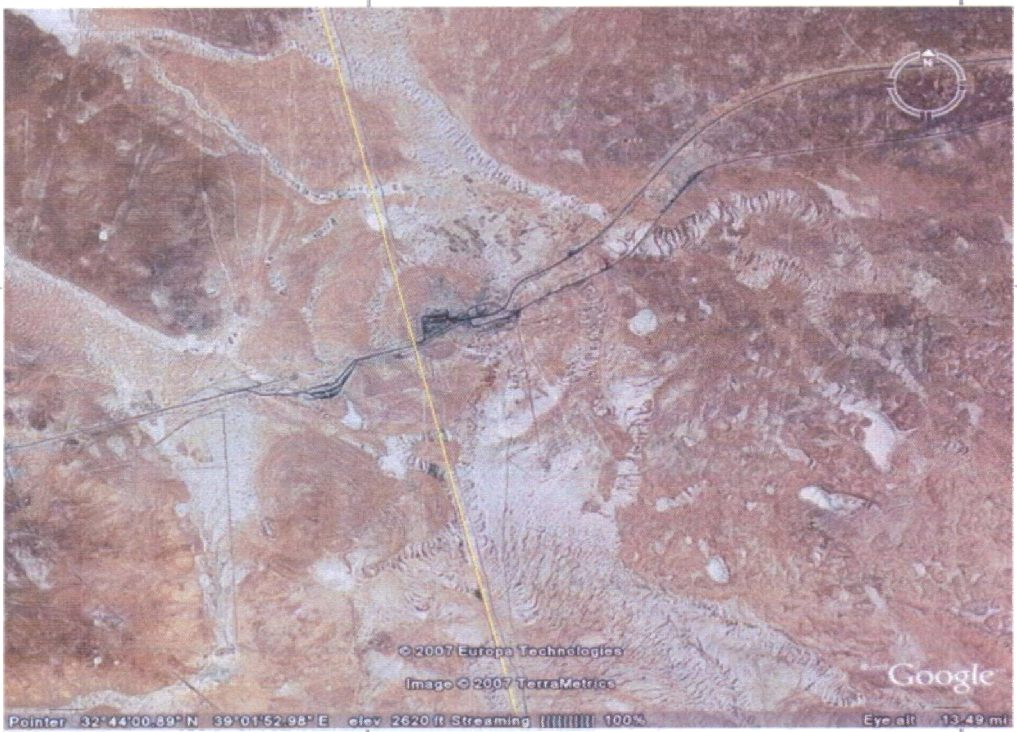

Fig. 3: Landsat image, showing elevated ring structure in Traibeel vicinity

Fig. 4: Landsat image of Um Chaimin depression

PREVIOUS STUDIES

Studies, which dealt with investigating the presence of igneous intrusions, in the study area and the rest of the western part of Iraq, are mainly geophysical works. Some of them are associated with drilling, petrographical and geochemical interpretations.

It is worth to mention that all the executed works are related to magnetic anomalies, which are presented within the aeromagnetic maps (C.G.G., 1974). Some of these anomalies show circular features (Figs.3 and 4) others are longitudinal features (Fig.2), which may represent igneous bodies or high susceptible magnetic sedimentary features (personal communication, Jassim Al-Kadhimi, 2006). These were interpreted as ring structures and were attributed to igneous intrusions (Sallomy, et al., 1981 and 1982, Al-Ameri et al., 1981, Al-Bdaiwi, 1984 and Al-Bdaiwi et al., 2005).

Sallomy et al. (1981 and 1982) studied a circular magnetic anomaly in Al-Nahaidain area (Fig.1) which has a diameter of 30 Km and suggested the presence of an igneous dyke at depth of (150 – 300) m. It may be, however an indication for hydrocarbon bearing structures (personal communication, Jassim Al-Kadhimi, 2006). Moreover, Jassim and Buday in Jassim and Goff (2006) supposed that such circular forms are indication for gas explosion, like the Um Chaimin depression (Fig.4). Al-Amiri et al. (1981) interpreted the ring structures in the Western Desert as "a surface expression of crypto volcanic structures".

Al-Bdaiwi (1984) studied the area of the present work and drilled six boreholes with depths of (15 – 45) m .Non of the boreholes succeeded in striking igneous intrusion or body. The penetrated sequences in the six boreholes consist either of limestones of Ratga Formation or accumulation of coarse sand, with rounded and angular grains, rich in heavy minerals, with predominant zircon, tourmaline and rutile cemented by carbonate materials. The study was based on an aeromagnetic survey anomaly (C.G.G., 1974), which attributed the anomaly to the presence of igneous body at depth of 2.7 Km and a smaller one at depth of 0.7 Km.

Al-Bdaiwi et al. (2005) conducted a drilling program based on the ground magnetic follow-up to the existed airborne magnetic anomalies, his previous study (Al-Bdaiwi, 1984) and the detailed magnetic and gravity surveys in the study area (Table 1), consequently they drilled four boreholes (Fig.5).

They concluded the following possibilities:

1 - Hypabasal igneous activities
2 - Gas explosion and fluidization
3 - Low temperature hydrothermal activity (may have taken place latter on)

Table 1: Depth of the four boreholes with recorded magnetic anomaly and generalized penetrated sequence (in each borehole)

Borehole No.	**Total depth (m)**	**Magnetic Anomaly (γ)**	**Main penetrated sequence**
B.H.1 (T1)	193	70	Alluvium, gravel, decomposed and rounded basalt pebbles, breccia. No bedrock
B.H.2 (Ts)	150	40	Breccia, the bed rock of Ratgah Formation is struck
B.H.3 (Tn)	93	40	Breccia , the bedrock of Ratgah Formation is struck
B.H.4 (Tp)	138	≤10	Loose fine sand. No bedrock

- According to Al-Bdaiwi et al. (2005), the location of the intrusive body is at or near the location of B.H.1. But, the recorded magnetic anomaly near B.H.2 and B.H.3 is the same, whereas the depth and the encountered materials are not so. Therefore, it could be concluded that the recorded anomalies has nothing to do with a shallow intrusive body. Because, B.H.4 is near B.H.1, but the recorded anomaly near the former is less than 10 γ. Moreover, in the location of B.H.3 the recorded magnetic anomaly is 40 γ, which is higher than the recorded magnetic anomaly in the location of B.H.4 (les than 10 γ), but in the former the Ratga Formation was struck at depth of 93 m, whereas in the latter only loose sand was encountered to a depth of 138m, without striking the bedrock of Ratga Formation.

In reviewing the data of Al-Bdaiwi et al. (2005), it could be seen that the penetrated sequences in the four boreholes consist mainly of:

- B.H.1 (T1)
  0 – 35 m, brownish alluvium mixed with gravel and sand, some times with **rounded pebbles of decomposed basalt.**
  35 – 80 m, mixture of gravels and sand, with **decomposed rounded pebbles of pyroclastic rocks.**
  80 – 193 m, breccia (after Yakta et al., 2002) rich in black shale.
- B.H.2 (Ts)
  The core consist of extensively brecciated (so called by the authors) basaltic rock fragments. At depth of 150 m (end of the borehole) limestone of Ratga Formation was struck.
- B.H.3 (Tn)
  The same as B.H.2, but at depth of 93 m the Ratga Formation was struck.
- B.H.4 (Tp)
  The penetrated sequence consists of loose, medium to fine sand, for the total depth of the well, 138 m.
- Palynological studies revealed Early Paleocene (Danian) age for some samples with some flora, which could be reworked, indicating Ordovician, Silurian and Carboniferous ages. Al-Bdaiwi et al. (2005) referred to INOC specialists for the aforementioned dating.
- The magnetic anomalies of the ground survey (Fig.5) were used by Al-Bdaiwi et al. (2005) for locating the four boreholes. The location of each borehole shows the following magnetic anomalies:

B.H.1 (T1)	70 γ
B.H.2 (Ts)	40 γ
B.H.3 (Tn)	40 γ
B.H.4 (Tp)	≤ 10 γ

Based on the samples obtained by Al-Bdaiwi et al. (2005), two comprehensive studies were carried out. The first one dealt with the petrography of the core of B.H.1 (Yakta et al., 2002) and the second one dealt with the geochemistry of the cores of the four boreholes (Al-Atiya et al., 2006)

In reviewing the (first) comprehensive petrographic study carried out by Yakta et al. (2002) for the core of B.H.1 (T1),which is the deepest borehole (193 m), and the best drilled among the others, with the best extracted core, the following interesting results and conclusions were postulated (by the present author):

- At depth of (38 – 88) m, the recognized rock fragments and minerals (in the core) prove that " their source is in Syria and Jordan, as deduced from mineral composition".
- At depth "more than 88m basic and ultrabasic rock fragments rich in pyroxene and poor in feldspar were recognized, moreover olivine altered to serpentine occur too".
- Presence of "fragments of volcanic lava flow, as indicated from the vesicular texture with angular shape of the fragments".
- Six main sedimentary cycles of graded bedding were observed in the extracted core , with clear fining upwards character in the grain size distribution, consisting of sand , dark minerals and igneous rock fragments, breccia, which decrease in amount and size, upwards (Isko, in Yakta et al.,2002) .

In reviewing the (second) comprehensive geochemical study of Al-Atiya et al. (2005) the following interesting data is acquired (by the present author):

- Chemical analysis of 88 collected samples from the core of the four boreholes show the following (as main constituents):

SiO_2	41.7 %
Al_2O_3	8.2 %
Fe_2O_3	5.6 %
CaO	17 %
MgO	6.16 %
MnO	0.059 %
K_2O	0.6 %
Na_2O	0.5 %
L.O.I.	0.81 %

- No significant correlation coefficient was observed between the concentration of oxides and trace elements (Mn, Ni, Co, Zn, Cu, and Pb).
- High percentage of CaO (13.6, 17.3, 25.4 and 15.0 %) and for SiO_2 (43.3, 40.5, 37.7 and 44.8 %) could be observed in all core samples of the four boreholes B.H.1, B.H.2, B.H. 3 and B.H. 4, respectively.
- Increasing of Fe_2O_3 concentrations downwards of B.H.1, especially from depth of 145 m to the end of the borehole. Such increase was recognized in B.H.4 in two zones, the first one is to the depth of 50 m, whereas the second one is from depth of (85 – 135) m (final depth of the well). This zonation supports the observed six sedimentary cycles and changes in sediments supply due to climatic changes.
- In B.H.2, such increase was observed in depth interval of (65 – 115) m.
- No definite increase was observed in B.H.3.
- Table (2) shows a comparison of basalt constituents from different localities. According to Al-Atiya et al. (2005), which shows that there is no mutual relation between the exposed basalts in Syria and Jordan with those fragments, which were observed and studied from the drilled cores.

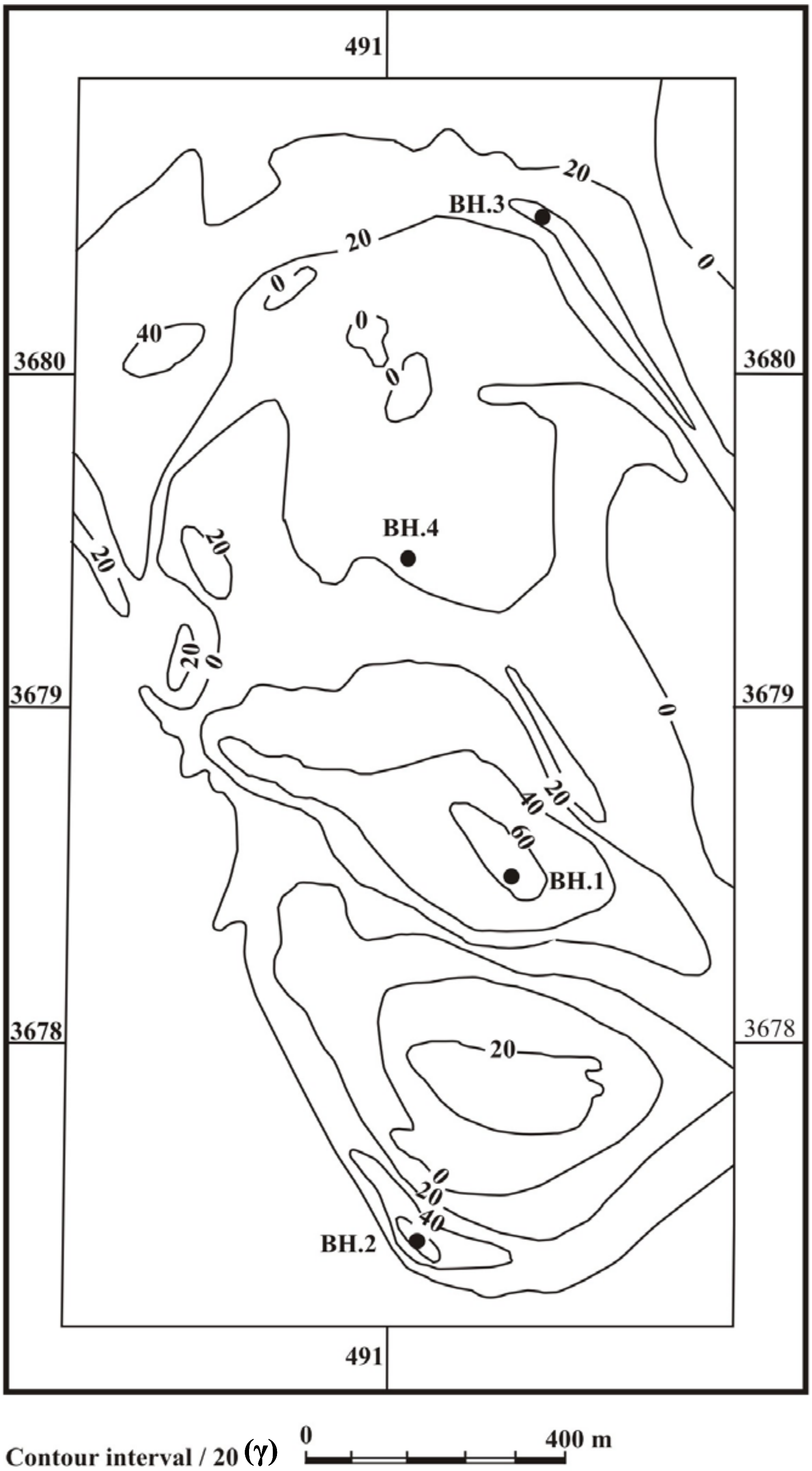

Fig. 5: Magnetic anomaly map and location of the four boreholes
(after Al-Bdaiwi et al., 2005)

Table (2): Comparison between average concentrations of main oxides of the studied rocks and other basalts from Syria and Jordan (after Al-Atia et al., 2005)

Oxides	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
SiO_2	44.01	45.95	49.75	45.03	46.33	45.70	42.71	50.83	41.70	55.00
Al_2O_3	14.68	14.36	14.07	14.94	18.59	14.49	17.66	14.07	8.02	11.00
FeO	8.71	9.21	7.5	9.12	9.56	8.92	6.41	11.94	5.6	7.0
Fe_2O_3	3.38	1.59	3.20	1.27	2.36	3.22	6.17			
MgO	7.28	9.48	7.40	9.46	5.72	9.60	4.90	6.34	6.16	8.00
CaO	11.26	10.75	10.26	10.73	9.73	9.48	9.91	10.42	17.00	-----
Na_2O	3.66	3.88	3.74	3.71	3.20	3.06	4.72	2.23	0.50	0.70
K_2O	1.00	0.78	0.60	1.11	0.94	0.90	1.90	0.82	0.61	0.80
TiO_2	2.49	1.45	1.81	2.18	2.53	2.25	2.73	2.03	0.81	1.10
MnO	0.20	0.21	0.20	0.24	0.17	0.15	0.09	0.13	0.059	0.08

1 – Basalt from Jordan, 35 km ESE of H5 (Late Eocene – Miocene)
2 – Basalt from Jordan, 15 km ESE of H5 (Miocene – Pleistocene)
3 – Basalt from Jordan, 35 km ESE of H5 (Miocene – Pleistocene)
4 – Basalt from Jordan, 10 km NE of H5 (Pleistocene – Holocene)
5 – Basalt from SW of Syria (normal basalt)
6 – Basalt from SW of Syria (sub alkali basalt)
7 – Basalt from SW of Syria (alkali basalt) (Ponikarov, 1967)
8 – Average concentrations of oxides in basalts (Hatch et al., 1979)
9 – Average concentrations of oxides in the studied rocks
10 – Average concentrations of oxides in the studied rocks, after correction to remove the effect of carbonates

- Table (3) shows comparison between the concentrations of some trace elements in the extracted cores and the carbonate rocks of the Ratga Formation. It is clear that the concentrations, of the metallic elements, in the extracted cores are extremely higher than those present in carbonates of Ratga Formation. The Mn, for example is 16 times higher, whereas the Ni is 24 times higher. These mean that the extracted core has nothing to do with the carbonates of the Ratga Formation and they are derived from igneous rocks.

Table (3): Concentration of some trace elements in the extracted cores and rocks (after Al-Atiya et al., 2005)

Location and/ or geological unit		Number of samples	Mn ppm	Ni ppm	Cu ppm	Zn ppm	Co ppm
Umm Chaimin Unit		28	10 – 120 (30)	1 – 40 (7)	1 – 11 (5)	—	—
Al-Tinif Unit		55	20 – 90 (30)	2 – 60 (12)	1 – 20 (2)	—	—
Al-Nahaidan Unit		35	20 – 440 (30)	1 – 8 (3)	1 – 6 (2)	—	—
Study area	B.H.1	38	180 – 1066 (470)	131 – 341 (215)	12 – 58 (44)	10 – 695 (141)	—
	B.H.2	24	23 – 1222 (557)	89 – 286 (81)	20 – 64 (34)	63 – 179 (106)	17 – 37 (28)
	B.H.3	17	22 – 589 (407)	81 – 228 (81)	12 – 57 (32)	53 – 128 (88)	20 – 35 (27)
	Total samples	79	(479)	(172)	(37)	(112)	(26)

Between parentheses indicates the mean
The three mentioned units belong to Ratga Formation (Hagopian, 1979).
– not analyzed

DISCUSSION OF PEVIOUS WORKS (The First Scenario)

The previous works dealt with the assumption of the presence of an igneous intrusion, in Al-Tinif (Al-Waleed) vicinity. The following scenario was assumed (based on the acquired data from the executed works):

- Al-Bdaiwi (1984) (based on C.G.G., 1974); Yakta et al. (2002); Al-Atiya et al. (2005) and Al-Bdaiwi et al. (2005) speculated the presence of an igneous intrusion in a shallow depth of few hundred meters, below the surface.
- The igneous body could not reach the surface.
- During the intrusion, the penetrated rocks destroyed and crushed the surrounding and overlying rocks (a gas explosion could be speculated; Al-Bdaiwi et al., 2005).
- A deep trough was formed or was present and was filled by the weathering products of the intrusive igneous body, which was found in the drilled cores, inform of breccia, loose sand and rock fragments.

In arguing the aforementioned assumed scenario, the following points remain in discordance with the scenario:

* The igneous rocks below the surface are eroded and their weathering products were accumulated in the trough (above the igneous intrusion).
* The presence of rounded and decomposed basalt and pyroxene rock pebbles in the trough.
* The presence of graded bedding of fining upwards nature in the penetrated sequence, with six sedimentary cycles, in B.H.1.

* The high percentage of the cementing materials of the breccia fragments, less than 2 mm, form 75.82 % of the breccia
* The accumulated materials are underlain directly by limestone of Ratga Formation at depths of 150 m and 93 m in B.H.4 and B.H.3, respectively.
* The country rocks show no indication of alteration or fusion by igneous activity.

THE PROPOSED SCENARIO (Second Scenario)

From reviewing the presented data in the aforementioned studies and their arguments, beside the studies and interpretation of the author for the available field data, Landsat images and reviewing the core, in the site, the following scenario is assumed, by the author:

- A large trough of karst and/ or tectonic origin (sag pond) is formed, most probably before the Pleistocene, which is limited by the two mentioned lineaments (Fig.2) and most probably due to strike-slip faults, but not necessarily it is regular and continuous all over the distance of the two lineaments, as it is indicated from the discontinuous lineaments and as it is the case in tectonic depressions (Sylvester, 1988). This is also confirmed by drilling of three boreholes with depth of few meters, in the site (Al-Bdaiwi et al., 2005), where bedrock of Ratga Formation was struck in all of them. The Ratga Formation in B.H.2 is struck at depth of 150 m; it is a good indication for existence of a fault, because the maximum known thickness of the formation is not more than 85 m (in K.H. 5/8). The presence of the trough is also confirmed by the magnetic and gravity surveys conducted by Al-Bdaiwi et al. (2005).
- The trough was filled by weathering products of the exposed lava flows in Jordan and Syria, then gradually the supply of the igneous fragments was decreased due to gradual change in the global climate (Yan and Petite–Maire,1994; Al-Juboori, 1997), which consequently changed the type of the infilling materials due to change in transportation ability, as indicated by:
  1– Presence of rounded pebbles of altered basalt fragments (Al-Bdaiwi et al., 2005).
  2- Presence of surface basaltic flow fragments within the extracted cores (Yakta et al., 2002).
  3- Presence of cyclic and fining upwards graded bedding materials, mainly of clastics, in the extracted cores (Isko in Yakta et al., 2002).
  4- The cementing materials of the breccia, encountered in the B.H.1, for the fragments less than 2 mm, forms 75.82 % of the breccia (Yakta et al., 2002), which means large amount of cementing materials. Such large amount of cementing materials could be only of sedimentary origin.
  5- The increase of Fe_2O_3 concentration downwards in B.H.1 from depth of 145 m to the end of the borehole (193 m) (Al-Atiya et al.., 2005) .This could be explained by decrease in the transportation ability of the fragments from Syria and Jordan (which are rich in Fe_2O_3) and increase of transported materials from near by areas in the site, due to gradual climatic changes from wet to semi arid, which is a well known phenomenon in the area and as indicated by the presence of dense drainage net of large valleys (Fig.2). This holds good for other boreholes, which show accumulation of inhomogeneous materials, very similar to infill sediments of alluvial origin derived from near surroundings.
- The trough has nothing to do with common ring structures, which are common in the Western Desert. Although it shows circular anomaly in the regional geophysical maps of scale 1: 1000 000 (C.G.G.,974), but the detailed magnetic and gravity studies carried out

by Al-Bdaiwi et al.(2005) confirmed the rectangular shape for the anomaly (Fig.5), which coincides with the NW – SE lineaments (Fig.2). This could be another indication for the trough rather than the shallow igneous body, although an igneous body may use the trough, for ascending.

- A subsurface drainage (due to the presence of subsurface cavities), which may have shared in the filling of the trough, can not be ignored.

The following phenomena also could be argued, which need explanations, to be in accordance with the author's assumption (the second scenario):

* The present drainage is towards NW, which means from the studied site towards the existing lava flows in Syria and Jordan. This contradicts the assumption of filling the trough by the weathering products of the lava flows in Syria and Jordan. But, this could be explained by, the drainage before (at least) more than 4000 years was in reverse direction, from NW towards SE and was changed gradually. The dense set of lineaments may be an indication for a tectonic unrest, which shared in reversing the gradient direction.
* The presence of angular shaped fragments within the breccia could be explained by breaking down of the larger fragments, into small, by weathering, during the transportation nearby the accumulation site. Therefore, angular fragments could be seen, in the core. This also could be explained by increase of pyroxene percentage with depth, which means they were subjected to high weathering , in the beginning of the accumulation, due to wet climate, which changed gradually to semi dry , consequently the weathering ability decreased (Al-Mukhtar in Yekta et al., 2002).
* The indicated non-similarity between the constituents of the basalt fragments, in the site, with those present in Syria and Jordan, as deduced by Al-Atiya et al. (2005) (Table 2), could be clearly explained by the indicated non-similarity between the constituents of basalt flows, in the same locality, but within different stages of lava flows (Table 2, columns 1, 2, 3 and 4). So it is more likely to have different constituents for the basalt fragments found in the cores of the studied site, after being transported from different localities and altered.

CONCLUSIONS

From reviewing the most relevant and comprehensive studies, available data and field observation of the site and the extracted cores, the following could be concluded:

- A trough of tectonic origin (most probably) combined with solution origin is more likely filled by weathering products of surface lava flows in Syria and might be in Jordan, too, in its initial stage.
- The presence of the trough is confirmed by geophysical surveys.
- The weathering products are transported as alluvial materials and accumulated in the deep trough, as inhomogeneous materials of graded bedding nature with clear fining upwards character of six sedimentary cycles. The constituents of the infilling materials changed gradually due to the gradual change in climatic conditions, which affected on the weathering of the rocks and the type of the transported materials. Therefore, near the surface no concentration of igneous rocks are present in the accumulated materials, as compared to deeper parts, which is indication for weathering product of the surrounding carbonate rocks.

- The detected magnetic anomalies has rectangular shape, which coincides with the shape of the trough, as deduced from the two lineaments and has nothing to do with common ring structures in the Iraqi Western Desert.
- The presence of a deeper igneous body, shallower than the basement, is possible, but has no relation to the trough and the accumulated igneous clastics.

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