.... Iraqi Journal of Earth Sciences, Vol. 9, No. 2, pp. 27-38, 2009.......

The Impact of Some Geologic Structural Elements on Fuse Plug Southeastern Alignment of Mosul Dam

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(Received 1/9/2008 , Accepted 11/6/2009)

ABSTRACT

This work includes the preparation of aerial photogeological map and the study of many geological profiles. It also involves the study of stratigraphical division and correlations of the exposed bedrocks at Butmah-East and Raven anticlines, particularly the Fat'ha Formation near Mosul Dam northern Iraq.

It is evident that the sinkholes persisting through the area in question were initiated primarily within the upper part of the upper member of Fat'ha Formation. These were produced from the dissolution of thick gypsum beds in addition to the structural interplay and intersections of lineaments and faults. It can be concluded that the recent sinkhole in the tourist city is a product of faults crossing and the study could predict a new sinkhole development about 200m to the southeast of the present one.

تأثير بعض العناصر التركيبية على الامتداد الجنوبي الشرقي لصمام الأمان في سد الموصل

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الملخص

تضمن العمل تحضير خارطة فوتوجيولوجية ودراسة عدة مقاطع جيولوجية إلى جانب التقسيمات الطباقية ومقارنة الصخور المنكشفة في تركيبي بطمة الشرقية ورافان المحدبين، إذ تم التركيز على تكوين الفتحة قرب سد الموصل شمال العراق.

تبين أن الحفر البالوعية الموجودة بالمنطقة قيد الدراسة نشأت بصورة أولية ضمن الجزء العلوي من العضو العلوي لتكوين الفتحة. إن هذه الحفر البالوعية تكونت عن طريق عمليات الإذابة لطبقات الجبسوم

السميكة بالإضافة إلى التداخل و تقاطع التراكيب الخطية والصدوع. إن الحفرة البالوعية الحديثة التي ظهرت في منطقة المدينة السياحية في سد الموصل هي نتيجة تقاطع الصدوع، ويمكن توقع نشوء خسفه بالوعية جديدة على بعد ٢٠٠ متر من الأولى باتجاه الجنوب الشرقي منها.

INTRODUCTION

Little works have been carried out on the geology of the investigated area, and many stratigraphical, sedimentational, structural and geomorphological problems have not yet been investigated. No one has yet done detailed geological work for the area except Al-Haddithi (1990). In addition the previous and recent works dealing with regional geological and geomorphological mapping, like Taufiq and Domas (1977) Al-saigh (1991), Al-Ezzi (1991), AL-Daghastani, and AL-Daghastani (1992) respectively, or dealing with specific problem with small area particularly at dam site such as AL-Ansari *et al*., (1985), Al-Ansari and Gayra (1986), and AL-Juraisy (1992).

The main purpose of the present work is to throw light on the geology, and to show the impact of some geologic structural and geomorphological elements on the fuse plug at southeastern part of Mosul dam.

The method of present work depends on geomorphological interpretation of base map on scale 1:40000. The fieldwork comprises geological map checking, and detailed description of lithological sections of the exposed geological formations.

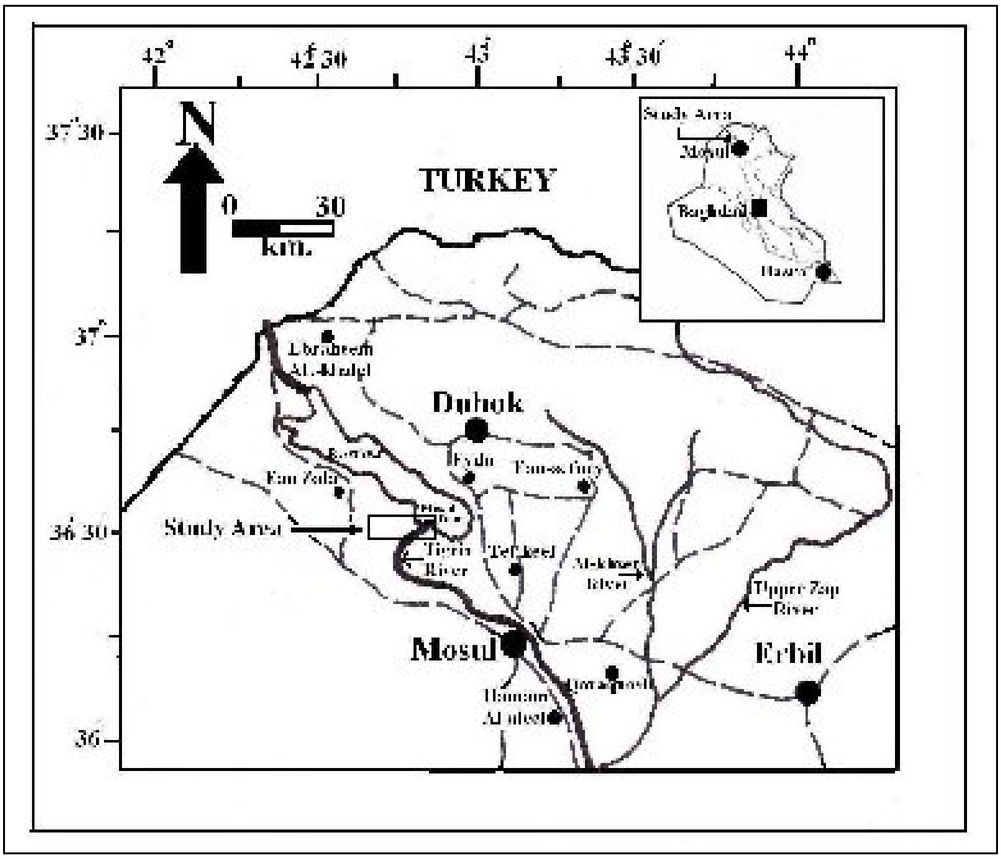

Fig.1: Location map.

LOCATION AND GENERAL GEOLOGY

The studied area is located at a distance of about (40km.) north of Mosul city(Fig.1). It occupies an area more than120 km^2 of mountainous and rugged terrain landforms. The area displays two distinctive anticlines; Butmah-East and Raven, which are trending in approximately E-W direction.

The Euphrates and Fat'ha Formations cover most of the study area, in addition to the remnants of Tigris river terraces. The terraces are unconformably overlain the Fat'ha Formation in continuous and patchy form. The other younger geological formations like Injanah and Bakhtiari (Muqdadiya and Bi-Hassan) are totally eroded (Fig.2).

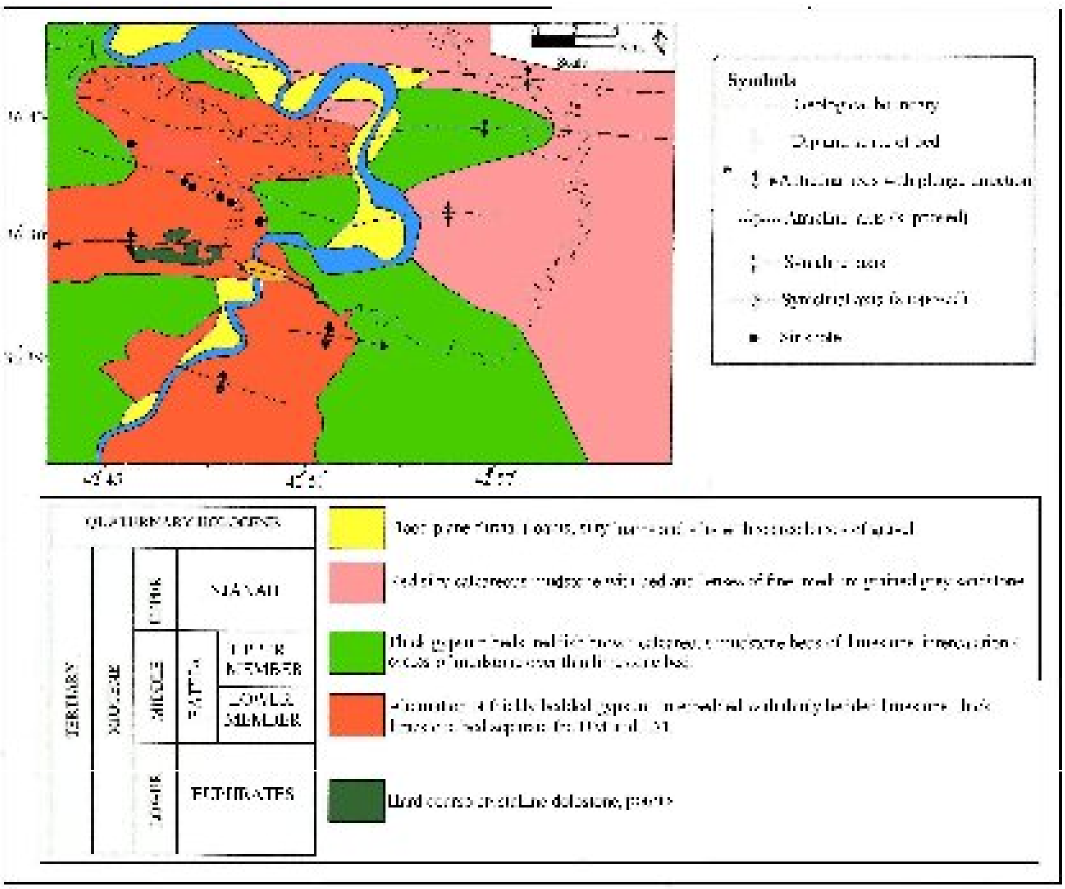

Fig. 2: Regional geological map of the dam and surrounding area.
(After Taufiq and Domas، 1977), modified by the authors.

STRTIGRAPHY AND SEDIMENTATION

The oldest exposure in the study area is the Euphrates Formation (Lower Miocene). It is only exposed in the core of Butmah Anticline. The rocks consists of dolostone, dolomitic limestone, limestone and marl with subordinate sandstones, siltstone and mudstones beds in the upper parts (Fig.3). The Fat'ha Formation is divided into Lower and Upper Members (Taufiq and Damas, 1977) separated by two marked limestone beds which are sandwiched between thick gypsum beds, with a maximum individual thickness of about (40m) (Fig.4)

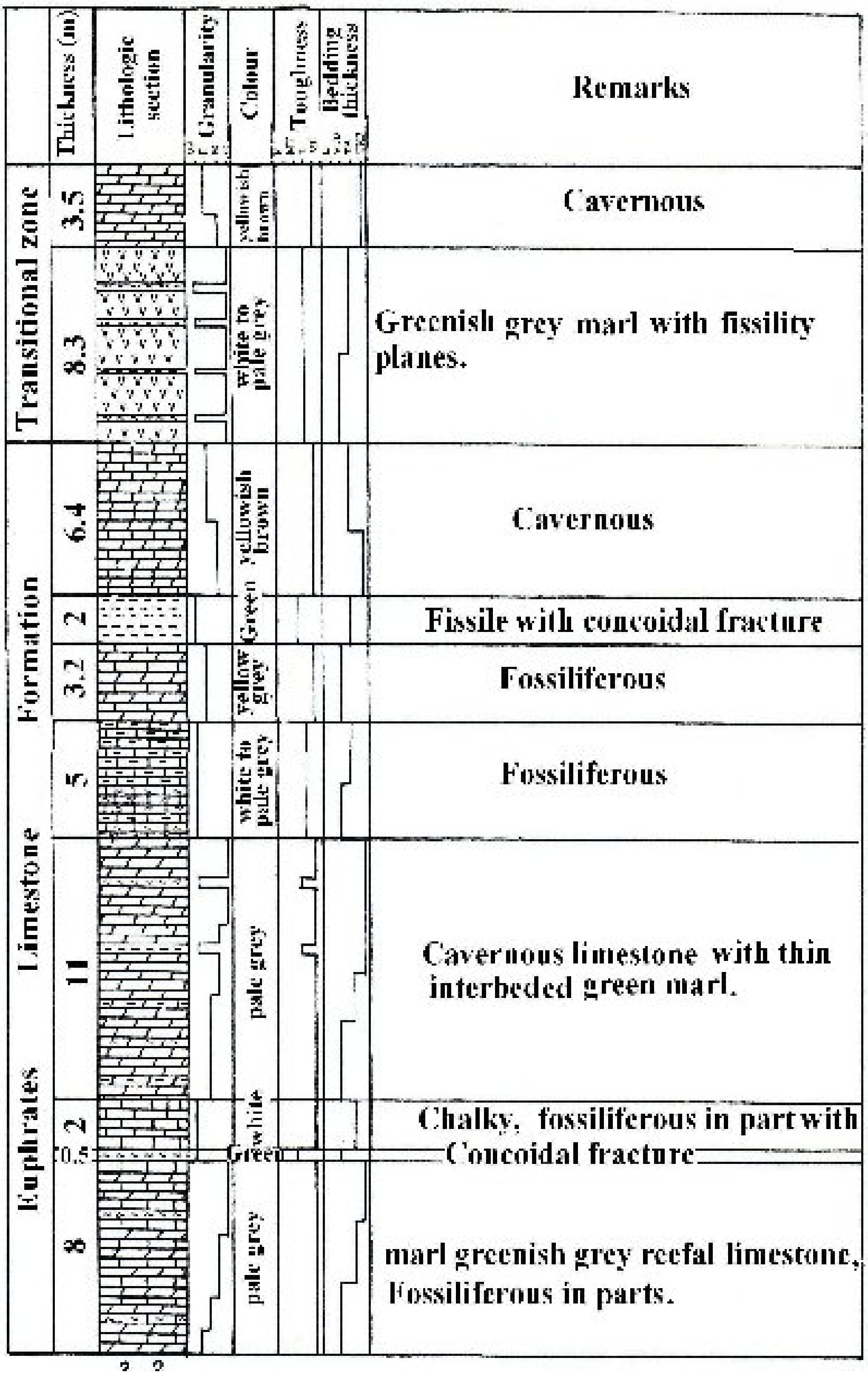

Fig 3: Lithological Section of the Euphraties limestone Formation and the Upper Transitional Zone; After (Taufig and Damas,1977) modified by the authars.

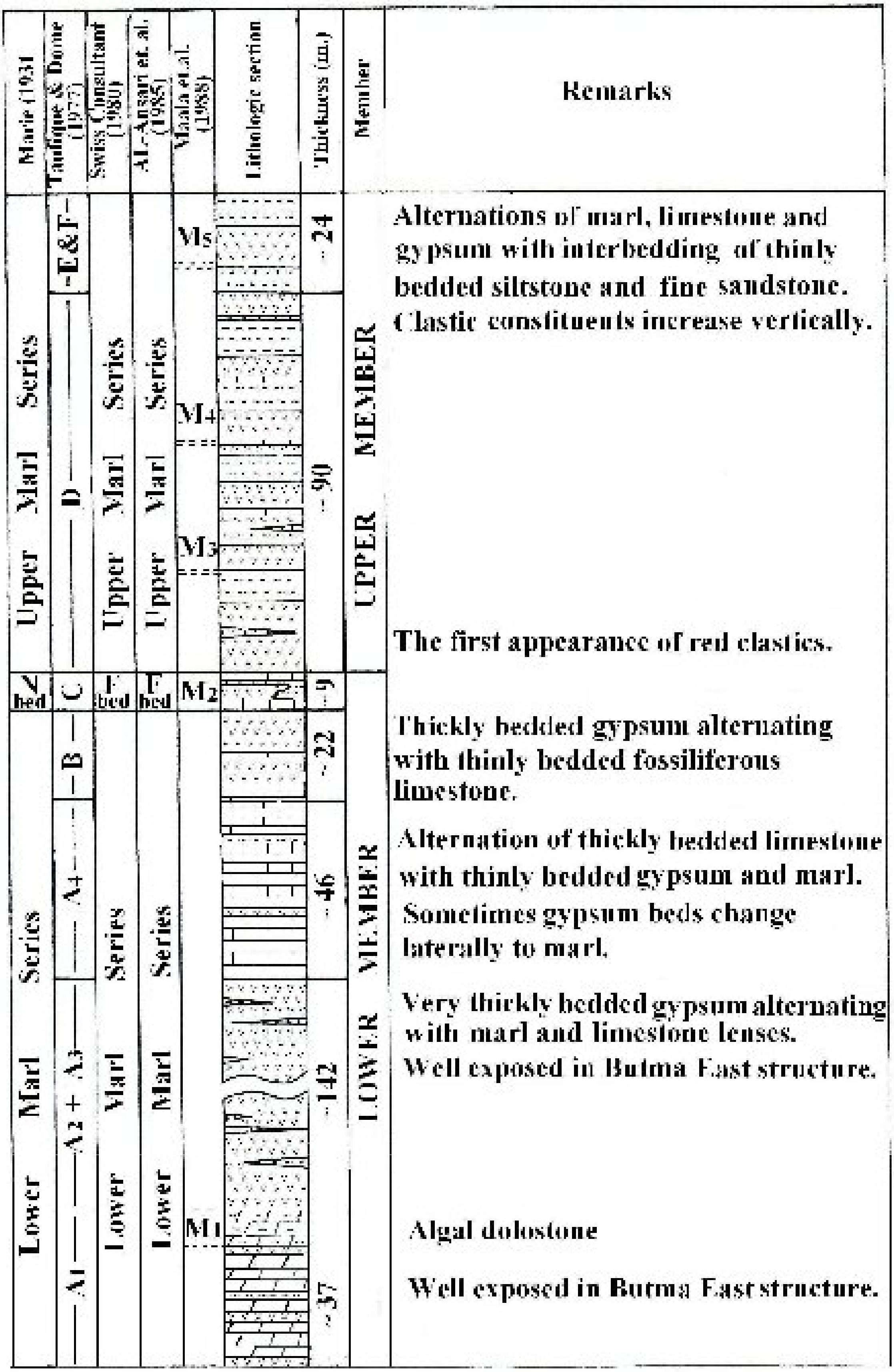

Fig.4: Composite lithologic Section of Fat'ha Formation in Butmah East and Ravan Anticline, After (Taufig and Damas,1977) modified by the authars.

Marie (1931) regards two recognizable limestone beds sandwiched between thick gypsum beds. These two beds are called " marker horizon unit (C) by Taufiq and Domas (1977), N and F- bed by Swiss consultant (1980), and finally as a marker bed no. (2) in correlation with Hammam AL-Alil area by Maala et al., (1988). The top part of the lower member is marked by the first appearance of red clastics throughout the sequence. The Lower Member is different lithologically from the upper member (Al-Naqib and AL-Dabbagh 1992). The clastic / non-clastic ratio increases radically in the upper member (AL-Naqib and Aghwan, 1993) in accordance with the red clastic appearance. On the other hand, the gypsum and limestone beds decrease vertically in both frequency and thickness of individual bed. Consequently, the clastic sediments like marl, mudstone, siltstone and sandstone transitionally increase.

The river terraces in the area are distributed in a narrow elongated belt trending in NW-SE direction. Four stages of terraces have mapped in details by (AL-Dabbagh and AL-Naqib 1991). These terraces are dissected by valleys resulting in relatively small isolated outcrops forming isolated hillcaps.

STRUCTURE

A photogeological map (Fig.5) of Butmah-East and Raven anticlines was prepared. These anticlines run approximately in East-West trending direction following the major trend of Taurus Range. The main characteristics of these anticlines are as follows:

Butmah East Anticline

It is a double plunging asymmetrical anticline. It has about 8km. length and about 3.5km. width. It is characterizied by relatively high dip amount of its southern limb. It becomes nearly vertical, in some places and overturned with about 15º near the reverse fault (F2) in (Fig.5), (AL-Hadithy, 1990).

The relatively high dip amount in the southern limb of Butmah-East anticline is indicating in (Fig.5) by very sharp straight lines of strata. The dip amount is decreasing as far as the southern syncline. The syncline south of Butmah-East anticline comprises the relatively younger beds of the Fat'ha Formation.

The Tigris river terraces are tilted for about 3-5º in some places. This indicats that the latest stage of Alpine Orogenic Movement continued to the Pliestocene and Recent times.

Some places within the northern limb with gentle dip are anomalous where the dip amount reaches 85º. These may represent places of tectonic disturbances.

The faults F1, F3, F4, F5, and F6 in (Fig.5) could be regarded as normal faults and have approximately NW-SE trend. The lengths of these faults range between 0.5-1.2km. The crushed zone of the fault F1 is about 100m width and the dip of the disturbed strata ranges from 15-85º towards the northeast.

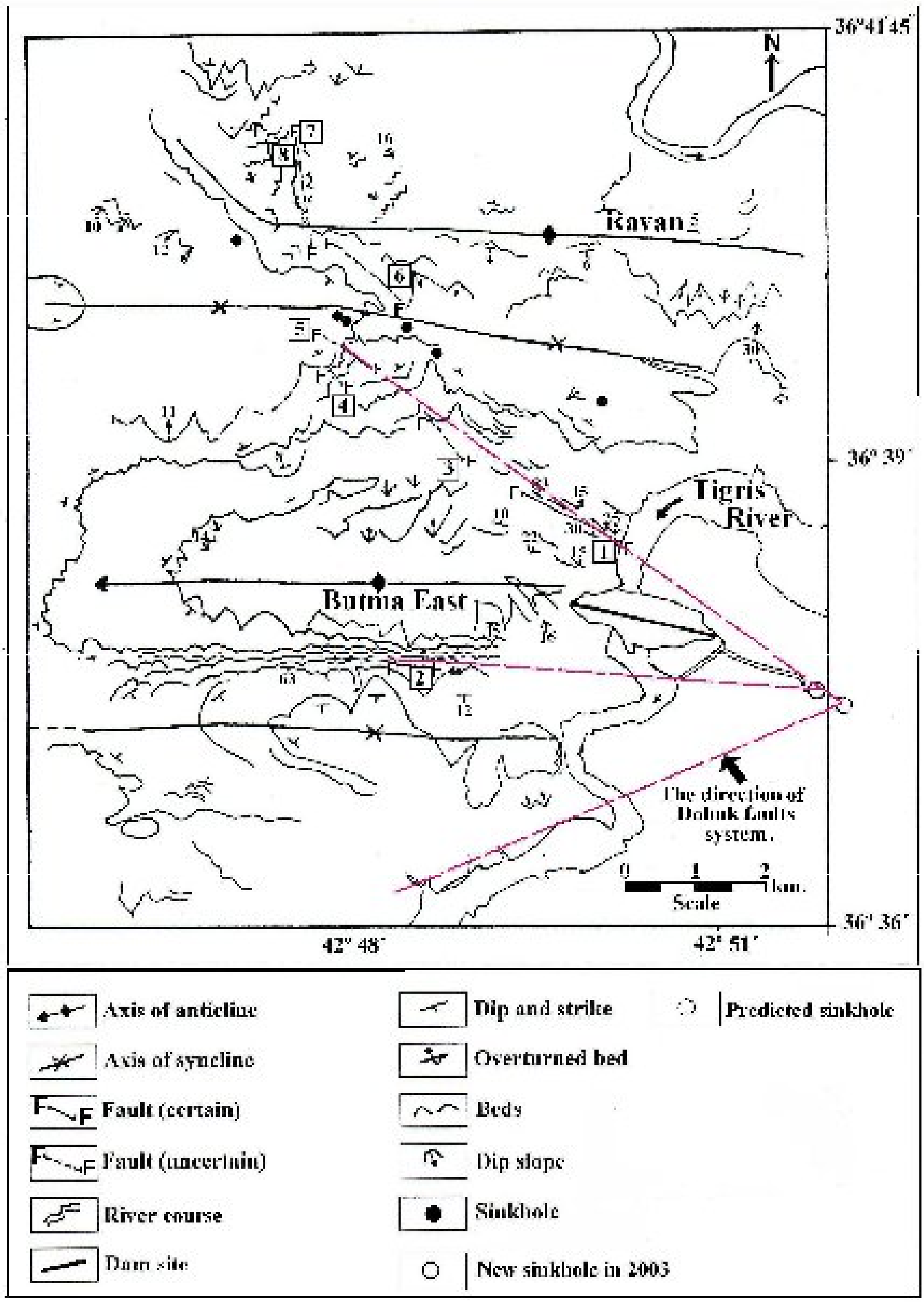

Fig.5: Photogeological map of Butmah East and Ravan Anticlines showing the location of sinkholes.

Ravan Anticline

It is assymmetrical anticline. It has about 9 km length and about 4 km width. The northern limb of Ravan Anticline is gentler than the southern limb. The varied dip amount is related generally to local undulations, or minor folding which goes concordant with the major trend of the anticline. The minor folds (parasitic fold) may be formed later on by forces have the same trend of the original forces which formed the anticline. The extreme western part of Raven Anticline (Fig.5) swings towards the northwestern direction indicated by the major swing of the anticlinal axis. The axial swing runs parallel to the major direction of the faults F1, F3 and F5.

There is a probable fault F7 trending N170S at the swing point and the other small fault F8 is running parallel to the new axial swing direction. Finally Raven Anticline is a low folding in comparison with Butmah-East anticline indicated by its core exposure (Fat'ha Formation).

SINKHOLES

The main orientations of the major valleys in the southern and northern parts are NW-SE, however in northern part, few small valleys have NE-SW direction (Fig.6). This trend may be controlled by the structural position of anticlines.

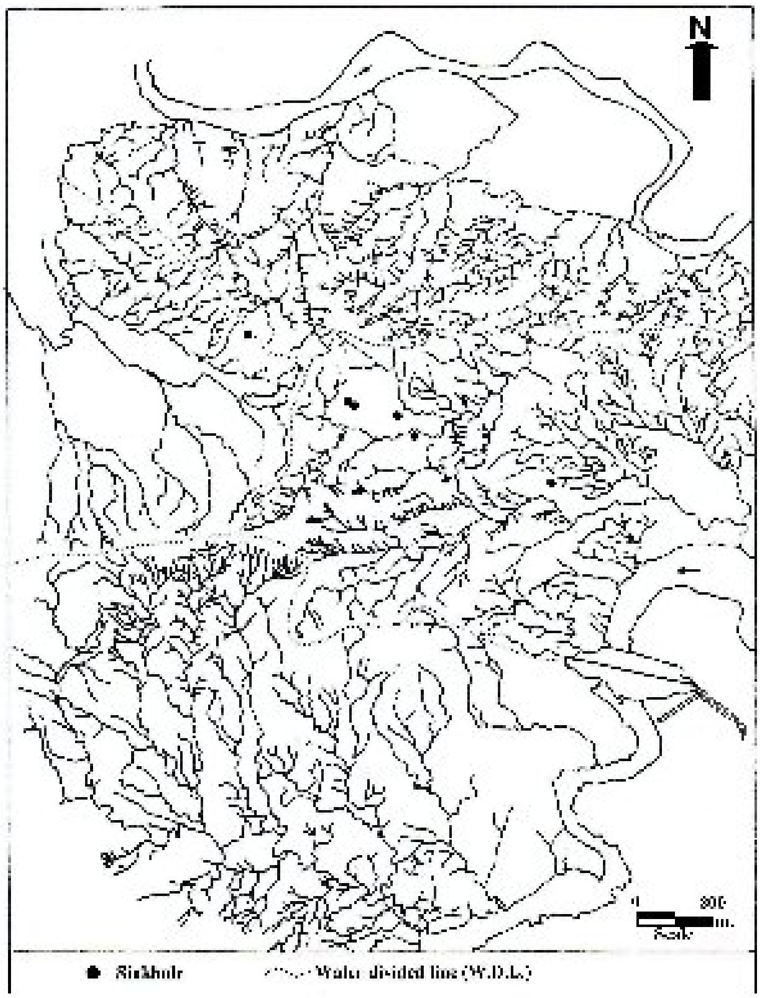

Fig.6: Drainage patterns in the studied area.

The sinkholes are always arranged in NW-SE alignment; they are of various diameters and depths and, occurr usually in areas furnished by thick gypsum beds covered by thin limestone. Andriani and Walsh (2005) classified the sinkholes into six types and the present sinkholes are related to dissolution type. The newly developed sinkhole in the tourist city during the year 2003 can be classified as buried type according to Andriani and Walsh (2005) classification. Kelley *et al*., (2007) studied sinkhole occurrences through their study of geological setting of Mosul dam. The sinkhole in the tourist city, (plate 1) was initiated due to ground water sediment washing. The present work observed that this sinkhole is a dry one.

Plate 1: Sinkhole at tourist city of Mosul Dam, april (2003) after Kelley (2007).

RESULTS AND DISCUSSION

Figure 5 shows sinkhole distributions within the syncline between Butmah East and Ravan anticlines. It is quite obvious that these sinkholes persist within the upper part of the lower member of Fat'ha Formation i.e., within the top part of M_2 (Fig. 4). The newly developed sinkhole in the tourist city is located stratigraphically on the same position. Of the other sinkholes in general the structure within the area consists of two major perpendicular sets of fractures which determined the course of Tigris River direction. They have NE-SW and NW-SE direction and give the river its meandering architecture .

The main structures of the folded zone in Iraq are the reflection of the Zagrus and Taurus interplay, where the structures run in E-W direction and follow the Taurus E-W direction. However when the structures run in NW-SE direction they follow the Zagrus NW-SE direction. Consequently, in the studied area, a set of faults follows Taurus and the other one follows Zagros and these set of faults have buried extensions and definite crossing point that can project on the map. Hence it can be regarded that are point of weakness involving high intensity of fracturing. This can be seen clearly from the crossing of the two main sets of faults, the south western limb of Ravan Anticline. The extensions of faults numbers 8, 6,5,4,3 and 1, cross with the extension of the reverse fault number 2. Eventually the two sets of faults cross at the end of the fuse plug (Fig.5), and could be resulted from a rejuvenation of fault movement. The movement may not be due to tectonic effect but due to the pore water pressure release in the lake or the long term lake draw down.These produced the sinkhole developed at tourist city of Mosul dam in February 2003. It has about 15m. diameter and 15m. depth. The position of this sinkhole shows alternation of thinly bedded white to yellowish white marly limestone with green marl in the bottom. The sinkhole is dry and refilled by about 1200 m^3 of sub-base. The sinking was repeated again during May 2003, October 2004 and it was sinking on March 2005 by about 0.5 m.. Finally, more than 3000m^3 of sub-base filled the sinkhole. Few meters away from the sinkhole, a deep borehole was dugged and, it was dry which, assured that the cause of sinkhole formation was its faults crossing points and not ground water sediments washing, like the case of land subsidence beside the spillway.

In this regard, the present study could predict another sinkhole development on the same alignment of the NW-SE fault extension, but crossing with another set of faults or alignment of NE-SW direction,(i.e., Duhok fault system, Fig.7) about 200m. to the southeast of the first sinkhole (Fig.5). (AL-Saigh, 2008).

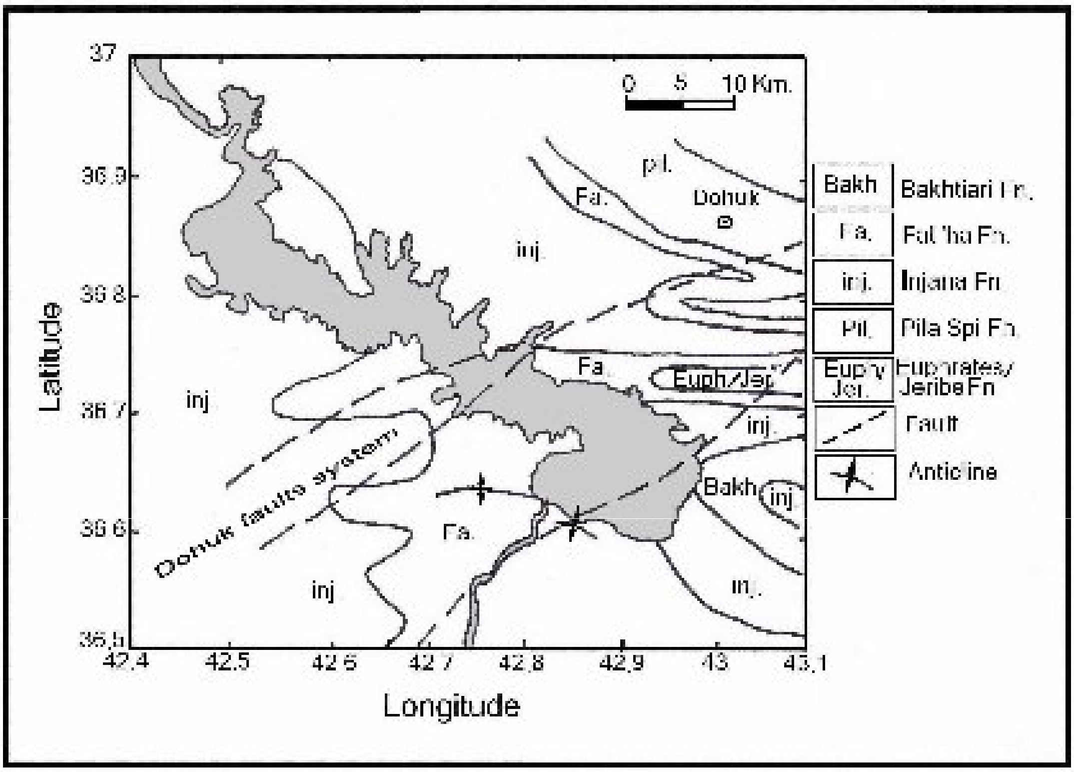

Fig. **7:** Geological map of Mosul Dam showing the Dohuk Fault System, after Al-Saigh (2008).

The alignment of the sinkhole shown on map (Fig.5) is parallel with the alignment of faults. This alignment is a reflection of buried faults. The predicted sinkhole could appear at the surface in the same manner of development of the new sinkhole at tourist city, and it could happen in the near future.

CONCLUSIONS

From the forth mentioned discussion, it can be, concluded that, the crossing of fault alignment extensions could produce buried sinkholes and these could appear on the surface due to repeated operation of lake water pore pressure release, or may be due to local earthquakes. The sinkhole alignments and formations are controlled by fault trends and situated on the same stratigraphical position.

The study recommend the investigation of joints and faults systems around the area to predict the hidden and unexpected sinkhole developments, or other hazards which could threaten the dam structure.

ACKNOWLEDGMENT

The authors are grateful to Dr. Hekmat AL-Daghastani for his valuable notices on geomorphological part of the paper.

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