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TECTONICS OF QUATERNARY TRAVERTINE ACCUMULATION AT AL-FATHA AREA IN MIDDLE IRAQ

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ABSTRACT.- Travertine deposits accumulation at Al-Fatha area occupy a narrow belt of about 200 m width, within the en-echelon overlap of Makhul and Hemrine North anticlines plunge noses, in the central area of Iraq. The aim of this work is to elucidate the local structural and tectonic control on the development of these deposits in the area. Mesofracture analyses in the vicinity of these deposits revealed the effect of two orthogonal tensional joint sets and two extensional shear fracture systems, as well as a system of strike slip shear fractures in development of these deposits. The stress tensors deduced from these fractures ought to stem from the extensional regime that accompanied and postulated folding process in the area. Meanwhile, travertine precipitation in the area seems to be a substantial outcome of these extensional stresses. Alternatively, the step over zone between two segments of a northwest-southeast trending subsurface left lateral fault also, might be the preferred location for these deposits in this area. However, the existence of this fault was approved previously by geophysical investigation. The alignment of separated warm water springs along side with the Dicle River bank in the area seems to be the surface expression of this fault.

Keywords: Travertine, tectonic emplacement

INTRODUCTION

The investigated area is situated at the western bank of the Dicle River where it crosses Makhul and Hemrine North mountains (Figure 1). According to the tectonic subdivision of Iraq, these mountains constitute the southwestern limit of the foreland fold belt of the Zagross collision zone between Arabia and Eurasia (Jassim and Goff, 2006). Makhul and Hemrine North mountains are structurally NW-SE trending double plunging and SW verging elongated anticlines. They are arranged with en-echelon manner at their adjoining plunge noses where the Dicle River penetrates through (Figure 2).

Cyclic alternations of carbonates, evaporites and marls of Al-Fatha Formation (M. Miocene) form the carapace of the hitherto mentioned structures. At their SW and NE flanks, sandstones, siltstones and mudstones of Injana Formation (U. Miocene) crop out within transversal valleys dissecting the opposite limbs of these anticlines. Piedmont and recent gravel deposits cover Injana Formation at the intervening areas between successive transverse valleys.

The term travitonics was firstly introduced by Ford (Ford and Pedley, 1992; from Hancock et al., 1999) to envisage all tectonic and structural aspects that contemporize Quaternary travertine deposits. Travertine is a variety of calcareous rocks that precipitates from either hot or cold springs by somewhat percolating water. The travertine accompanying hot springs exists in several worldwide terranes and it is the subject of many research works mainly for deciphering the hydrological and petrographical aspects of these deposits, besides the active role of microorganisms and paleoclimate in their development (Chafetz and Folk, 1984; Pedley, 1990; Ford and Pedley, 1992; Altunel and Hancock, 1993; Abdulla et al., 1991). However, the structural and tectonic implications of these deposits have attracted the interest of fewer authors (Altunel and Hancock, 1996; Çakır, 1999).

Tufa is another variety of limestone deposited from fresh water. Despite the gradation between these two rock varieties, it is possible to differentiate them by texture which reflects variation in their formation. The pale or white compacted hydrothermal precipitation that is deposi-

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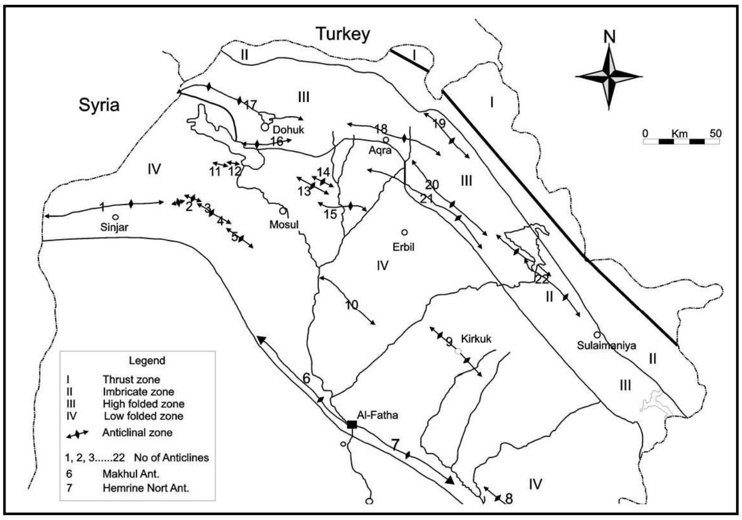

Figure 1- Tectonic subdivisions of northern Iraq (Numan, 1997). The investigated area indicated by a solid square insert.

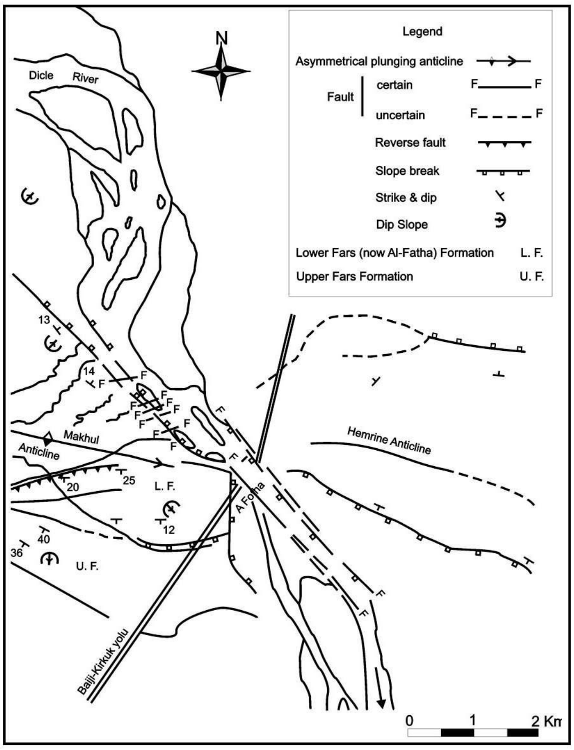

Figure 2- Simplified structural map of Al-Fatha area (Salih et. al., 1996)

ted from hot springs is called travertine. While the term tufa is usually used to describe the porous and bedded sediments that were formed either by cold springs or are accumulated through veins or in lakes (Muir-Wood, 1993; Ford and Pedley, 1996).

The association of travertine and tufa deposits with world wide tectonically active zones had been documented very well. So it is reliable to use the sites of these deposits to map the trace of an active fault approximately (Hancock et al., 1999).

Several springs that are considered to be sources of fracture ridge travertine are localized at step over zones separating adjoined fault segments. The possible cause behind of considering fracture ridge travertine as indicators for step over zones of normal faults is the possible subjection of relay ramps of such faults for complex stress regime (Larsen, 1988). The development of open mode (I) fractures in those sites assists in subsurface flow of fluids.

Other forms of travertine deposits such as terraced mound are emplaced at the lateral ends of main fault sectors where complex network of mesofractures could be present (McGrath and Davison, 1995).

QUATERNARY TRAVERTINE ACCUMULATION AT AL-FATHA AREA

The presence of travertine deposits at Al-Fatha area on the west bank of Dicle river near SE plunge nose of Makhul anticline (Figure 2), was documented firstly by Abdulla et al., (1991). They studied these deposits from the sedimento logical and petrographical aspects of these deposits. They proposed a physicochemical and biochemical role, particularly bacteria and algae in the development of such deposits and their subsequent diagenetic modification. Further, they invocated that the variation of H_2S content in water percolating in the region might have caused the light and dark alternated layering of these deposits.

Travertine accumulation at Al-Fatha area occupies a narrow band with about 200 m width along SE plunge nose of Makhul anticline. The site constitutes a part of overlap zone between the plunge nose of this anticline and the NE plunge nose of Hemrine North anticline. This setting adds a role for structural and tectonic factors contributing to the development of these deposits. This is beside the effect of a subsurface fault inferred by geophysical investigations in the area (Al-Sheikh, 1975; Naqash et al., 1975). The alignment of several separated springs (26°-33°C) in a belt along the west bank of Dicle might be the surface expression of this fault.

Travertine deposits in the area overly the strata of Al-Fatha Formation (M. Miocene) and the recent alluvial sediments as well. The majority of travertine deposits in the area are inactive now except the subordinate accumulation that is precipitating presently at the toe of the large piece.

From a morphological aspect, travertine deposits at Al-Fatha area represent residual part after erosion of a large complex of terraced mound deposits, but they lack pools and elevated edges characterizing such complexes. The vertical thickness of these deposits in the area may reach 20 m.

Lithologically, Al-Fatha travertine is characterized as porous rocks with intermediate density and consists of alternating light and dark bands parallel to the bed rock surface on which it was deposited.

People in the region around the present travertine site use these rocks as building stone especially in facing and for decoration purposes.

STRUCTURAL AND TECTONIC CONSIDERATIONS OF TRAVERTINE ACCUMULATION AT AL-FATHA AREA

The analysis of brittle failure structures at Makhul anticline depicted the prevalence of two sets of extensional fractures and outcrop scale minor faults, one being parallel whereas the other is normal to the general trend of the anticline (Figures 3, 4, 5). The existence of these fractures and faults are concentrated at the hinge zone of the anticline, on its NE limb and near its SE plunge.

The tensional stresses parallel and perpendicular to the fold axes during and subsequent to the bending of strata throughout the folding pro-

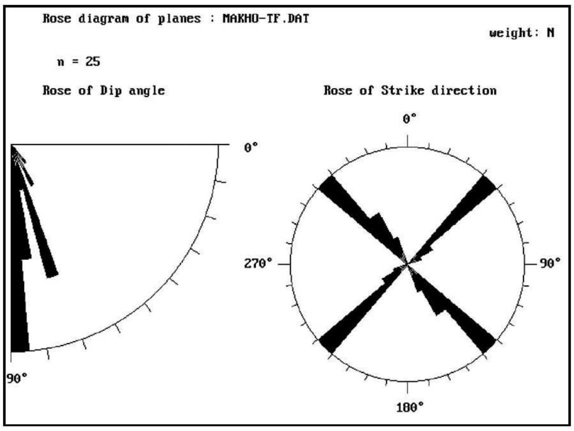

Figure 3- Rose diagram of two orthogonal tension fracture sets at Makhul anticline, the NW-SE trending set is parallel with the fold axis whereas the NE-SW trending set is normal to the fold axis.

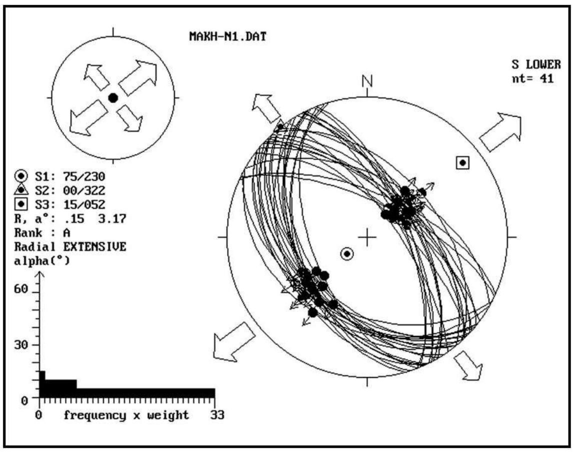

Figure 4- NE-SW extensional stress state interpreted by analysis of normal slip faults and associated extensional shear fractures trending NW-SE at Makhul anticline.

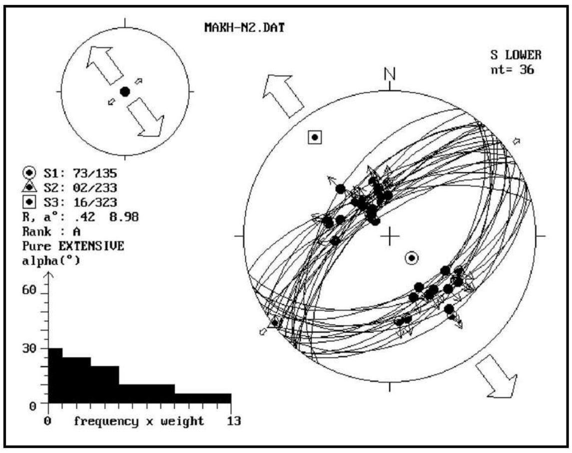

Figure 5- NW-SE extensional stress state interpreted by analysis of normal slip faults and associated extensional shear fractures trending NE-SW at Makhul anticline.

cesses, were responsible for the development of the fracture net in the area (Figures 4, 5).

Such fracture net acted as routes for subsurface flow of carbonate saturated water and ultimately precipitated it as travertine through springs emerging through these fractures.

The effect of the subsurface fault (Al-Sheikh, 1975; Naqash et al., 1975) along the Dicle River should not be excluded in the precipitation of travertine throughout the springs aligned along the trace of such fault. The later interpretation is based on step and flat pattern of travertines deposited on the downthrown hanging wall of the inferred normal fault and the springs might be connected with this subsurface fault through vertical fractures that usually splay within the hanging wall of the normal fault (McGrath and Davison, 1995). The NE-SW directed extensional stress which is inferred from this presumsion is conformable also with the orientation of expected extension that followed the subsequent uplift after folding in Zagros trend (NW-SE).

However, the paroxysmal stage of folding in this area as well as in other regions of northern Iraq developed during Pliocene (Numan, 2001a). Therefore, the precipitation of present travertine deposits in the area might have occurred later on after the cessation of folding. This is inferred from the unconformable setting of these deposits upon outcrops of Al-Fatha Formation (M. Miocene) which was involved in folding.

The alternative interpretation is that the zone of travertine springs in the area could represent the left lateral step over separating the ends of the subsurface sinistrally strike slip fault along western edge of Dicle River (Figure 6).

Accordingly, secondary tensional stresses (Figures 4, 5) might have been developed normal

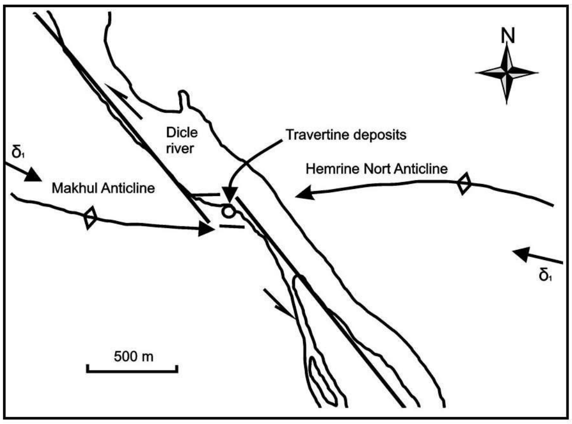

Figure 6- The suggested tectonic model for travertine accumulation at Al- Fatha area, location map after Abdullah et al. (1991).

to the transition zone leading to the formation of a fracture net. The developed fracture net assists in upwelling of the subsurface mineral water which caused the precipitation of travertine at the surface. The primitive compression stress responsible for the left lateral slip on the probable strike slip fault is in ESE-WSW direction. This is conformable with the inferred compressional direction parallel to the Zagros fold trends (Figure 7), which in turn is conformable with the sinistral transpression in the foreland fold belt of Iraq, as a consequence of oblique collision of Arabian plate against Eurasia (Aswad, 1999). Such an oblique collision had also rotated Arabia a counterclockwise (Numan, 2001*a,b*; Hancock and Atiya, 1979).

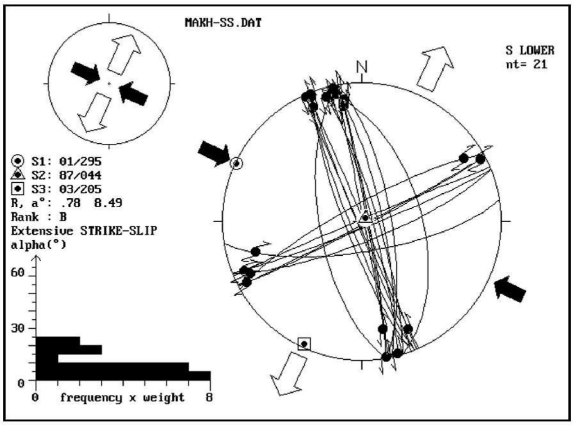

Figure 7- NW-SE strike-slip stress state interpreted by analysis of strike-slip faults and associated shear fractures trending NW-SE and NE-SW at Makhul anticline.

DISCUSSION AND CONCLUSION

The new tectonic travertine accumulation at Al-Fatha area near the SE plunge of Makhul anticline on its northeastern side is caused by NE-SW oriented extensional stresses (Figure 4). Such stresses are developed substantially from the second compression that acted along with Makhul fold trend (Figure 7). The presence of these deposits in the area is also linked with the longitudinal and transverse normal faults with respect to fold axis, and their associated tensional and shear joints that were originated by extensional normal and parallel to the fold axis (Figures 4, 5). On the other hand these deposits that are precipitated by upwelling hot water might be related to the existence of a left jog between two segments of a deep subsurface sinistral strike-slip fault in the region (Figure 6). This presumed ault might have rejuvenated in a recent period subsequent to folding process in the area. However the presence of such a fault along side Dicle River was cited by Al-Sheikh, (1975) as a result of a geophysical investigation in the area. Furthermore, Al-Azzawi (2003) inferred this subsurface fault through mathematical modeling of fold style at either side of such fault.

Therefore, it is reasonable to conclude that the tectonic setting of Quaternary travertine deposits in Al-Fatha area is conformable with the NE-SW extensional stress that exerted substandntially from a second compression phase acted in NW-SE direction along with Zagros fold trends. Meanwhile, such a compression had renewed a subsurface strike slip fault sinistrally along with Dicle River in the region. Indeed, the presence of travertine deposits in the area refers to the step over or jogs between two segments of a fore mentioned fault.

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