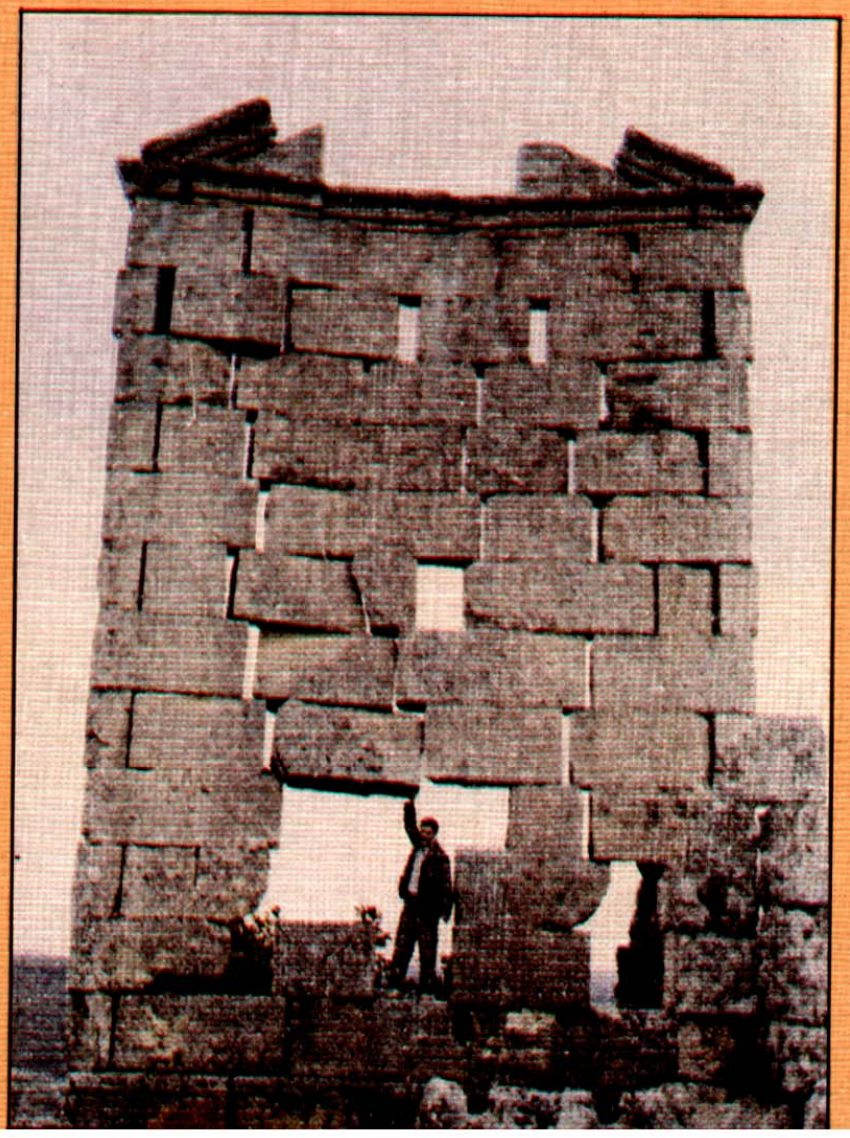
SYRIAN ARAB REPUBLIC
ATOMIC ENERGY COMMISSION (AECS)
Damascus

PROCEEDINGS OF THE REGIONAL WORKSHOP *ON* ARCHAEOSEISMICITY IN THE MEDITERRANEAN REGION

November 4-7, 1992

Damascus



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Indications of Neotectonics along the Syrian Lebanese Fault (Al-Ghab Depression)

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Abstract

Many structures in the Jurassic and Cretaceous dolomitic Limestone, in the pliocene marl and clastic sediments and in the Pleistocene alluvium and lacustrine sediments exposed along the Syrian Lebanese Fault (SLF) have been mapped. They include fresh striated fault planes, folding and faulting of pleistocene alluvium, very steep fault scarps, coseismic rock falls and accumulation of debris at the scarps feet.

These structures have been carefully evaluated. They have been found to be indicative for neotectonics took place during Pliocene and Pleistocene.

Castles and fortresses scattered along the SLF damaged by large historical earthquakes point to neotectonics occurred in the last few centuries.

Stalactites and stalagmites with their growth axes 30° off plumb give strong support to current tectonics still in progress.

1- Introduction

The studies on the historical and instrumental seismicity of Syria and the neighboring countries reveal that most of the devastating and disastrous earthguakes east of the Mediterranean are related to the Syrian Lebanese Fault (SLF) and its northward and southward extensions in the neighboring countries. (Ambraseys and Barazangi, 1989, Sbeinati and Darawcheh, 1990). The SLF is a sinistral leaky transform fault along which the Arabian plate and the Sinai Levantine plate are brought into juxtaposition. (Fig.1).

The amount of the sinistral displacement along the southern extension of the SLF i.e Wadi Araba Fault and Jordan Valley Fault is estimated by Garfunkel et.al 1981 at 7-10 mm/y during Pliocene and Pleistocene, and at 1.5-3.5 mm/y during the last 1000-1500 years.

Chaimov and Barazangi (1990) suggested a 20-25 km sinistral displacement of the Arabian plate along the SLF and AL Yammuneh Fault during the Pliocene and Pleistocene with an annual slip rate of 3.3-4 mm/y.

The geomorpholoqical analysis of some features exposed along the SLF and some other faults of the Palmyridean Fault Belt and the modification affected some of these structures, indicated that frequent tectonics occurred during Neogene and Quaternary (Radwan et al., 1991). They estimated a 3000 m sinistral displacement of the upper Pleistocene alluvium accumulated in Sahl AL Buqeah pull apart near AL Mzieneh with an average slip rate of +5 mm/y. They gave also a 10.3 mm/y and 20 mm/y average slip rates during the time intervals 1203-1306 and 1203-1408 AD. respectivelly, depending on the analysis of the damage caused by historical earthquakes in the southern wall of the Castle of the Knights, located very close to the conjuction of the SLF and AL Yammuneh Fault.

Therefore, it was very important to investigate further in more datails the SLF and the accompanying faults in AL Ghab depression to detect any traces of tectonic events happend in Pliocene and Quaternary time, which caused faulting, folding or tilting of the existing rock types, and to determine the relative age of such deformations.

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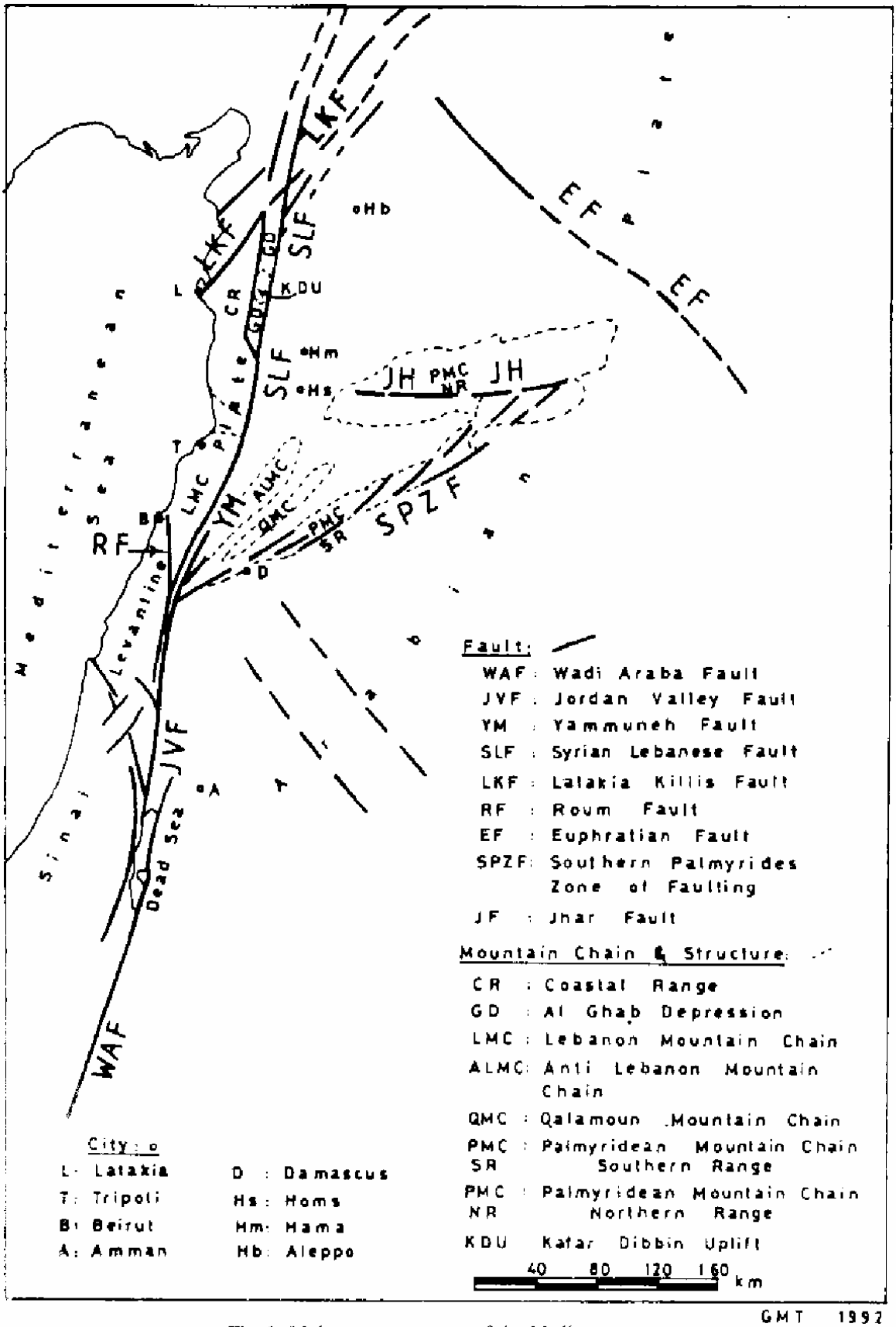

Fig. 1- Major structures east of the Mediterranean.

2- Evidences of Neotectonics Along the SLF in the Ghab Depression

The SLF stretches over 200 km in a prevailing N-S direction separating the Arabian plate east of the SLF from the Sinai Levantine plate west of it.

The ongoing northward left lateral movement of the Arabian plate relative to the Levantine one initiated before Neogene formed during the Miocene (20-6 M. years ago) Wadi Araba Fault, Jordan Valley Fault and Roum Fault. The continuation of the movement during Pliocene-Pleistocene and Holocene (the last 6 M.years) resulted in the formation of AL Yammuneh Fault, the SLF (Chaimov and Barazangi, 1990), and the development of distinctive pull apart basins such as AL Ghab Depression (Radwan et. al., 1991). AL Ghab Depression is divided by Kafar Dibbin uplift into two portions. The southern portion extends from Nahr EL Bared north of Missyaf graben up to Kafar Dibbin. It is separated from the coastal range by stepwise N-S trending faults which form benches of decreasing altitude towards AL Ghab depression. They are built of Middle and Upper Jurassic hard dolomitic limestone and far less of thinly bedded Albian limestone (Figs. 1 and 2).

The southern portion is separated from the coastal range in the south by NW-SE trending faults forming very steep and straight fault scarps built similarly of Middle and Upper Jurassic dolomitic limestone.

Towards east, the SLF is represented generaly by a single N-S trending fault generating prominent fault scarps built of Cenomanian and Turonian dolomitic limestone (Ponikarov, 1966).

The fault scarps in the Middle Eocene and Pliocene Chalky limestone and marl are heavily subdued or eradicated due to their high susceptibility to erosion.

For detecting the traces of tectonic activity many structural indices can be used. First of all the development of fault planes with a clear displacement and slickenside striations, in this regard the length and angle of plunge of the striations are strong criteria indicative for the direction and strength of the tectonic movement. For relative dating of the different successive tectonic movements, the intersection of the resulted faulting systems are of a great help. For the same purpose the degree of the alteration zone along fault planes, with predominently vertical component, can also serve. Fault planes of a cartain faulting system with a lower alteration degree in a certain rock is younger than other faults with higher alteration degree.

Faulting, folding or tilting of Quaternary deposits and the accumulation of rock and debris at the feet of fault scarps are decisive evidences for neotectonics. Far less common criteria are considered as very strong indications of neotectonics as well, among them is Stalactites and Stalagmites with their growth axes being off plumb, this proves, that the block contains the cavity, in which the Stalactites and Stalagmites have developed, is tilted (Vittori et al., 1990).

Beside the structural indices cited above there are a great deal of geomorphic indices in use for detecting any deformation caused by neotectonics. By applying such techniques along the major faults in Syria, Radwan et al. (1991), concluded, that the SLF among other faults, has been and is still active.

Through this study, structural indices exposed in rocks of different age outcropped at the margins of AL Ghab Depression along the SLF hav been acquired, discussed and evaluated in the following.

2-1 Structural Indices Observed In Jurassic Rocks

Many well preserved faults planes in the massive Jurassic dolomitic limestone outcropped at the western sidse of AL Ghab Depression. At AL Sermaniyeh village frequent west dipping faults planes show two clear striations sets, one plunges southwards while the other plunges northwestwards. Other fault planes dip northwards with striations plunging gently southwestwards.

From these observations it can only be deduced that Post Jurassic tectonics has generated N-S trending faults dissecting the massive rocks into mighty blocks displaced either southwards or northwestwards.

Nevertheless, the slight plunging angle of the striations suggests, that the horizontal component of the blocks movements is far higher than the vertical one. It can not be inferred from these observations alone the exact date of the postjurassic movements. However, the considerable straightness of the fault scarps and their high steepness, though effective weathering processes, may be considered as reasonable evidences of a recent formation of the scarps as neotectonic prouducts. This assumption is strengthened by frequent falls of rock

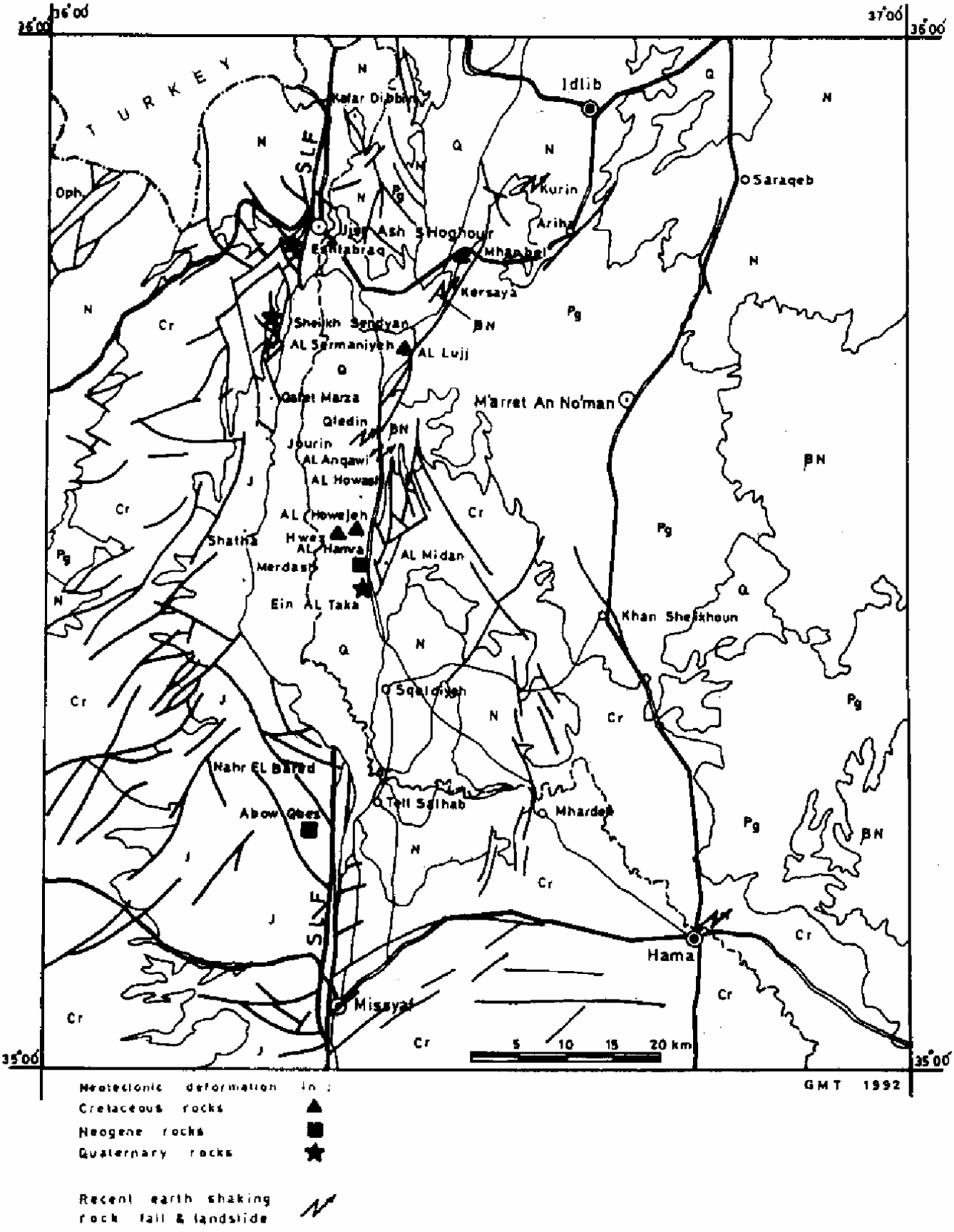

Fig. 2- Index Map of Neotectonic Indications Along the (SLF) in al Ghab depression.

blocks formed through the intersection of two or more faults and joints systems with bedding planes of the massive dolomitic limestone.

The separated rock blocks collapse and accumulate at the feet of fault scarps. In this connection more than one factor may play a role in the collapse of rock blocks. For instance, the percolation of surface water along faults and joints planes accelerate rocking of rock masses, hence it eases their collapse either by gravity or by a sudden earth shaking.

2-2 Structural Indices Observed In Cretaceous Rocks

Many fault scraps in the Cenomanian and Turonian thinly and thickly bedded dolomitic limestone are visible along the eastern margins of AL Ghab Depression. They have an average height of few meters to few tens of meters and a high steepness. A major fault trending (056°) extends from Mhanbel to AL Lujj, where it forms a distinguished fault scarp of a few kilometers length. Many minor faults planes of the direction (093°) display 15 mm striations plunging moderately (45°) to the west, were observed. Other minor faults planes normal to the AL Lujj main fault trending (145°) show also striations plunging at (48°) towards southsoutheast.

The intersection of the described faults sets resulted in the fragmentation of the Cenomanian-Turonian dolomitic limestone into huge blocks displaced differently under the effect of a continued stress. From the amount of the plunging angle of the striations it can be inferred, that the vertical compoment of the movement has equalized, if not surpassed the horizontal one. These faults are associated by metric-spaced joint sets, one of them is parallel to Al Lujj fault trending between (045°-060°) while another one is directed (005°) showing rare and minor displacement.

In Qledin a fault plane dipping steeply westwards and striking (025°), brings the Cenomanian-Turonian dolomitic limestone and the Pliocene basalt (2-5 M. years old) into contact.

A fault plane of a limited exposure of the same strike and dip amount displays striations plunging (68°) into SW (222°/68°). Here again the vertical component of the tectonic movement that caused faulting exceeded the horizontal one. The openness (up to 10 Cm) of the metric-spaced joints, and the gradual creep in the soil veiling the adjoining steep slopes indicate probable active tectonics to be involved in creating these phenomena.

In this regard the fault contact between the Cenomanian-Turonian dolomitic limestone and the Pliocene basalt, which should come to presence during Pliocene (2-5 M. years) is not clearly distinguished and geomorphologically is not well expressed. This may be attributed to intensnive levelling processes of the volcanic cones and of the deep faults scarps along which the Pliocene lava was extruded, in contrary to other steep and prominent fault scarps in the vicinity. Supposing that these prominent scarps were formed in the Pliocene time, then they should be equally subdued and levelled in similar way. Nevertheless, their morphology indicates that they have not undergone erosion and weathering for a long time. This means the prominent fault scarps were formed much later than the deep faults extruded the lava in the Pliocene time. The soil creep and the opening and widening of joints support the probabilty of the reactivation of these steep and prominent fault.

Other structuers in the Cenomanian-Turonian dolomitic limestone at AL Howejeh was mapped. The rock is heavily jointed by many joint sets stretching over few meters to few tens of meters in the N-S (005°), in the NNE-SSW (035°), in the ENE-WSW (070°), and in the SE-NW (130°) directions. The former joint set develops occasionally vey steep, (2-8) meters high, fault scarps of a few tens of meters in extension. They are unconformably overlain by either lacustrine Pliocene deposits high on the slopes, or by Upper Pleistocene alluvium down the slope in AL Ghab Depression.

This remark is in deed very important, since the absence of Upper Pleistocene alluvium on the slopes over the Pliocene sediments suggests a Pre-Pliocene tectonics faulted and displaced the Cenomanian-Turonian rocks along N-S trending faults to form an N-S elongated semisolated marginal basin. During the Pliocene the basin was submerged and filled by continental clastic sediments and lacustrine chalky marl and horizons of gastropods debris. The elevation of the Pliocene lake's level was 194 m at least, above the current sea level. Prior to U. Pleistocene, a subsidence along the N-S master fault, through tectonic reactivation, formed new fault scarps close to the depression. As a result of the subsidence, the then water level dropped to (172 m.) approximately above the current sea level, consequently the Cenomanian-Turnonian rocks and Pliocene rocks

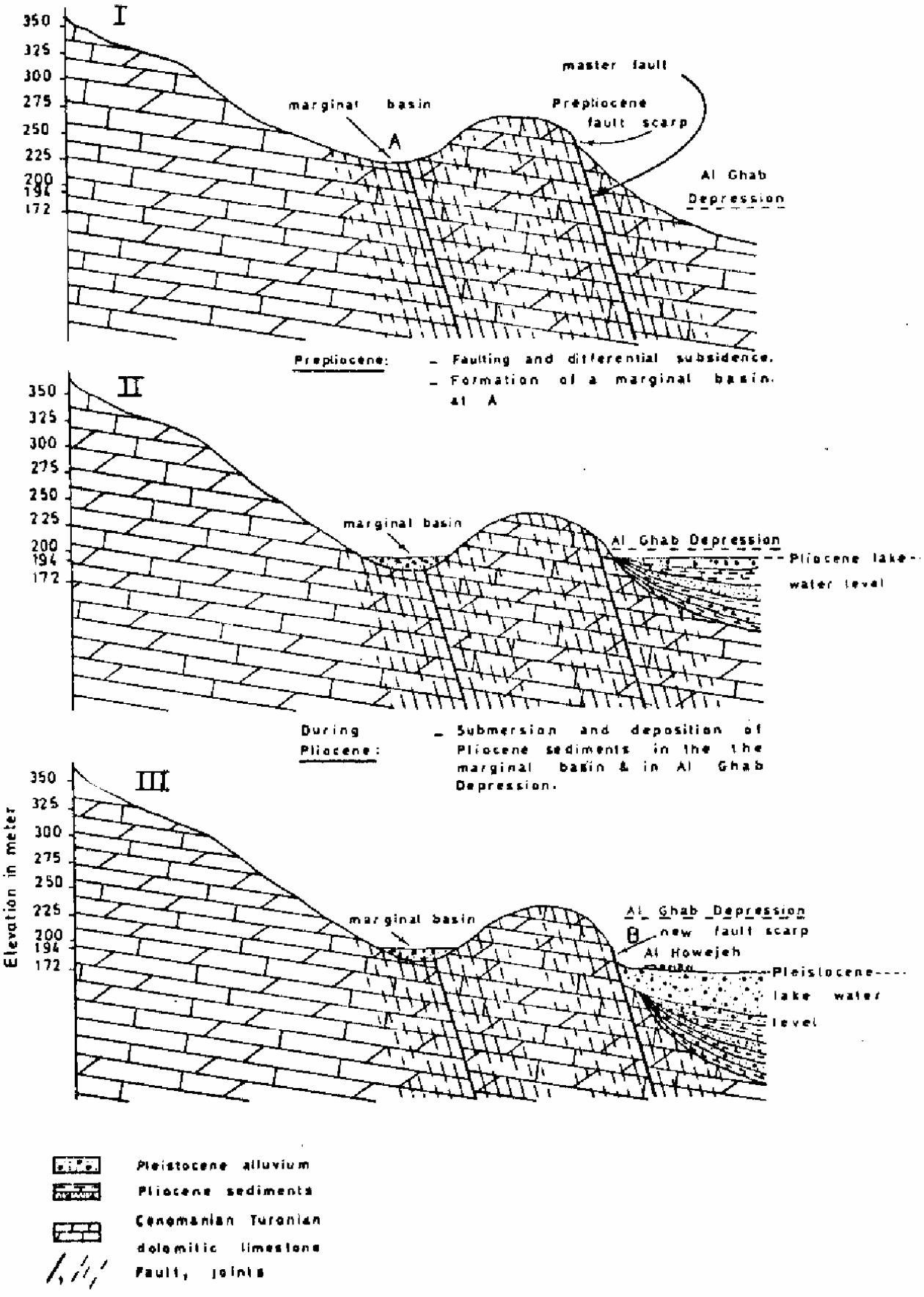

Fig. 3- A possible kinematic model to explain the tectonic & geological setting, Al Howejeh.

as well have emerged as shown in (Fig. 3). Hence the U. Pleistocene alluvium deposited on the newly formed fault scarp along the master fault in AL Ghab Depression only. No Upper Pleistocene alluvium was deposited on the Pliocen continental and lacustrine sediments in the elongated marginal basin mentioned in the foregoing, due to the drop of water level during the Upper Pleistocene which caused the emergence of the Cretaceous and Pliocene deposits.

The differnce between the elevation of the water level during Pliocene and Upper Pleistocene is about 22 m. This means, that the block under AL Ghab Depression should have displaced vertically (22m.) at least downward. Assuming that this displacement took place at the early Bleistocene, then the annual average of the vertical component can be estimated at (0.012 mm/y).

At this site the Cenomanian-Turonian dolomitic limestone is jointed by frequent metric-spaced joint sets trending (005°, 045°, 090°, 125°). They intersect the rock deeply, portioning it into blocks varied in size, sufferrd of frequent rock fall leaving back new (005°)-trending scarps. A similar scene is repeated at AL Hwez village, where vertical new fault planes trending (090°) in the Cenomanian-Turonian dolomitic limestone exposing fresh striations plunging westwards at (45) causing repeated rock falls.

2-3 Structural Indices Observed In Neogene Rocks

The Pliocene basaltic extrusions cover vast areas of the southern kafar Dibbin uplift which separates the northern portion of AL Ghab Depression from its southern one. The basaltic extrusions cover also other large areas of the eastern block of the SLF. These extrusions per se represent a very strong evidence of violont neotectonics along the SLF and the associated faults during Pliocene. The faults enabled the deep seated basaltic magma to ascend along them and reach the surface.

In turn the sedimentary Pliocene rocks outcropped near AL Hamra reveal neotectonic indications of other nature. For instance, a thirty five meters thick lacustrine pliocene sequence consist of polymictic conglomerate covered by white marl, limonitic sandstone and chalky limestone. The latter is 2 m. thick and forms a prominent cliff. This sequence overlies a (060°) trending fault scarp in the Cenomanian-Turonian dolomitic limestone but it is not effected by the fault. This indicates that the fault was formed in the post Turonion/Pre-Pliocene time.

The Pliocene sequence is gently convexed upward, so that the elevation of the convexity is higher than the elevation of the fault scarp. During the deposition of the pliocene sediments, they should have deposited horizontally or inclined toward AL Ghab Depression either lower than the fault scarp's elevation (lower than A, Fig. 4) or higher than it higher than (A). Arguing that the sequence has deposited higher than (A), then the fault scarp must be completly veiled by the overlying pliocene sequence. This contradicts the field observation of the sequence being convexed upward higher than (A) and higher than the fault scarp as well. This strengthens the belief that a probable post Pliocene differential subsiding of blocks (1, 2 and 3) triggerred by the reactivation of these faults, has deformed the already existed Pliocene sequence in the way described above.

A rare phenomenon indicative for very recent tectonics was observed also in the Pliocene lacustrine chalky limestone near AL Hamra also. Huge blocks of the mentioned rock typ are formed through the intersection of vertical to subvertical joint sets oriented (030°, 135°, and 165°). In a cavity of one these blocks, (30 cm) long stalactites and stalagmites, whose growth axes are (30°) inclined off plumb, were observed (photo 1). Since the growth axis must be vertical during the precipitation of a stalactic or a stalagmite, which usually are recent products of dissolution and precipitation of calcium carbonates, then the departure of growth axes of the stalactites and stalagmites observed from the vertical, points to a dislocation, downsliding and a (30°) tilting of block B that contains them. Although the possiblity of block (B) being slided down through gravity alone is not excluded. Nevertheless, faulting and rock falls observed in the Pleistocene alluvium outcropped in the vicinity, to be discussed in the forthcoming, suggest that recent tectonics are most likely behind the reactivation of the N-S trending fault exposed here causing rock falls, block sliding and tilting. (Fig. 5).

2-4 Structural Indices Observed In Quaternary Rocks

At Ain Al Taka at the eastern side of AL Ghab Depression Upper Pleistocene proluvium overlies a very distinguished steep (70°) fault plane in the Cenomanian-Turonian dolomitic limestone dipping steeply west southwestwards (250°/70°). The proluvium has frequently slided down, leaving on the fault plane three zones of

sliding, excellently marked by tone variation. The length of the upper zone is (55 mm) the middle one is (52.5 mm) while the lower one is (140 mm) long. The well preserved striations of (130 mm) length plunging steeply westwards (246°/75° and 250°/68°), exposed on the latter sliding zone, and the gravels forming the proluvium which display parallel fractures, give support to the belief that the sliding of the proluvium is most likely caused by neotectonics rather than by gravity. This belief is strengthened by the occurrence of an earthshaking of a calculated duration magnitude of (5), at (00:22) Damascus local time on (17.01.1990). The earthshaking was felt by the inhabitants of Ain AL Taka village. It caused a rock fall of three large blocks from the fault scarp described above, snatching off other blocks fixed in the proluvium to roll down together smashing the eastern wall and part of the ceiling of a house located at the road side crossing the village.

In this connection, earthshaking is frequent phenomenon along the SLF. For instance in (1976) a mild earthshaking was felt by the inhabitants of the village of kurin, a small village north of Ain Al Taka, and on the (3rd of June 1983). Another earthshaking in (1986) awaked the inhabitants of the village and brought the roofs of some old houses to collapse. It is worth mentioing that the old city of Apamea which is only (6 km) far from Ain AL Taka was damaged by the devastating earthquake of (1170 AD.). Castle of the knights which is located only (72 km) to the south of Ain AL Taka is in turn damaged by the same earthquake and by another one occurred in (1203 AD.), bearing in mind the catastrophic earthquake of (1759) whose damaging effect spread from Palestine, Turkey, through Lebanon and Syria.

Along the SLF, rock falls are very common and frequent. In one instance, a great deal of rock masses east of kersaya village fell from the Paleogene limestone fault scarps.Furthermore, frequent landslides are also familiar, e.g. in Qledin and EL Enqawi, gradual landslide has formed in the recent years, many stepwise slopes in the proluvium cover (photo 2). While in Kurin the foundations of houses built twenty years ago suffer from approximately (75 cm) drop. The location of the described phenomena close to or directly above the fault zone preponderate the probability, that they are more likely be formed by the reactivation of some segments of the SLF at least, though an interference of other factors such as gravity and steepness of slope angle is absolutly not excluded.

At the western side of the southern AL Ghab Depression Upper Pleistocene sediments bounded by the SLF reveal good signs of neotectonics. A fault-controlled valley oriented E-W to the south of Eshtabreq village exposes Cenomanian-Turonian dolomitic limestone, unconformably overlain by Pliocene chalky marl and Upper Pleistocene lacustrine sediments coming at the top. Well preserved fault plane striking E-W was observed in the Cenomanian-Turonian rocks in the valley, with fresh-looking striations plunging steeply (61°) westwards. This points to a displacement along E-W trending fault normal to the SLF during post Turonian. The Upper Pleistocene sediments outcropped here represent Lacustrine terraces dipping gently at (10°) towards AL Ghab Depression. They are composed mainly of poorly-cemented conglomerate whose major components are limy pebbles, cobbles and boulders. The conglomerate is faulted by a N-S trending fault parallel to the master fault dips steeply to the west causing a (140 cm) vertical displacement and a (50 cm) sinistral horizontal displacement of the fault western block.

In wadi sheikh sindian, only 5 km to the south of the former site, another N-S trending fault dips at (70°) eastwards brings the Cenomanian-Turonian dolomitic limestone and the Upper pleistocene lacustrine terraces deposits into contact.The Cenomanian-Turonian dolomitic limestone is folded and faulted forming a paleo fault scarp submerged first by the Upper pleistocene lake, wherein horizontal or slightly eastwards inclined lacustrine terraces were deposited.Subsequently, The terraces were faulted by a N-S trending fault parallel to the SLF dips at (70°) eastwards, whereby the western block of the fault is (125 cm) downthrown.

Towards south along the SLF at the western side of AL Ghab Depression between Jourin and Shatha the Upper Pleistocene lacustrine sediments and proluvium show no traces of folding or faulting. Nevertheless, the Pliocene conglomerate,consisting of pebble-cobble size limy components, outcropped in Wadi Abow Qbes is faulted by a number of stepwise faults dip at (60°) westwards causing vertical displacement in the order of (50-100 cm). Though it can be concluded that the faulting occurred in the postpliocene time i.e Pleistocene-Holocene, it can not be judged at what stage this faulting has happened, while the faulting observed in the Upper Pleistocene south of Ishtabraq and in Wadi Sheikh Sendyan occurred decisivelly during Holocene(100000 Years).

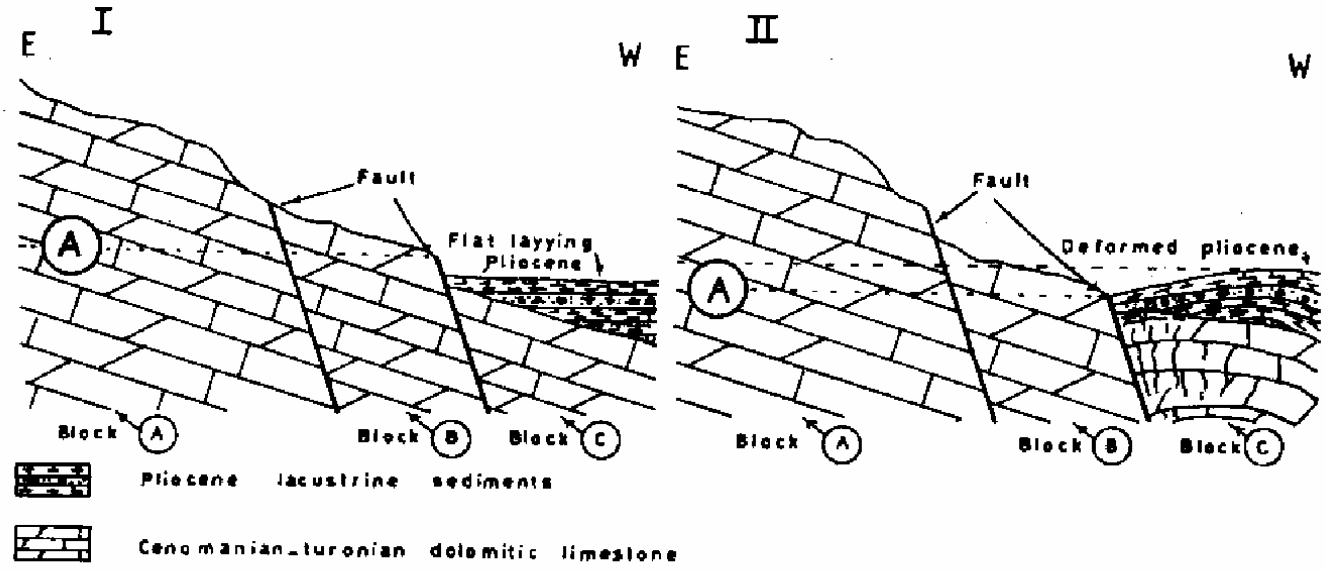

Fig. 4- Deformation of the pliocene sediments near Al Hamra.

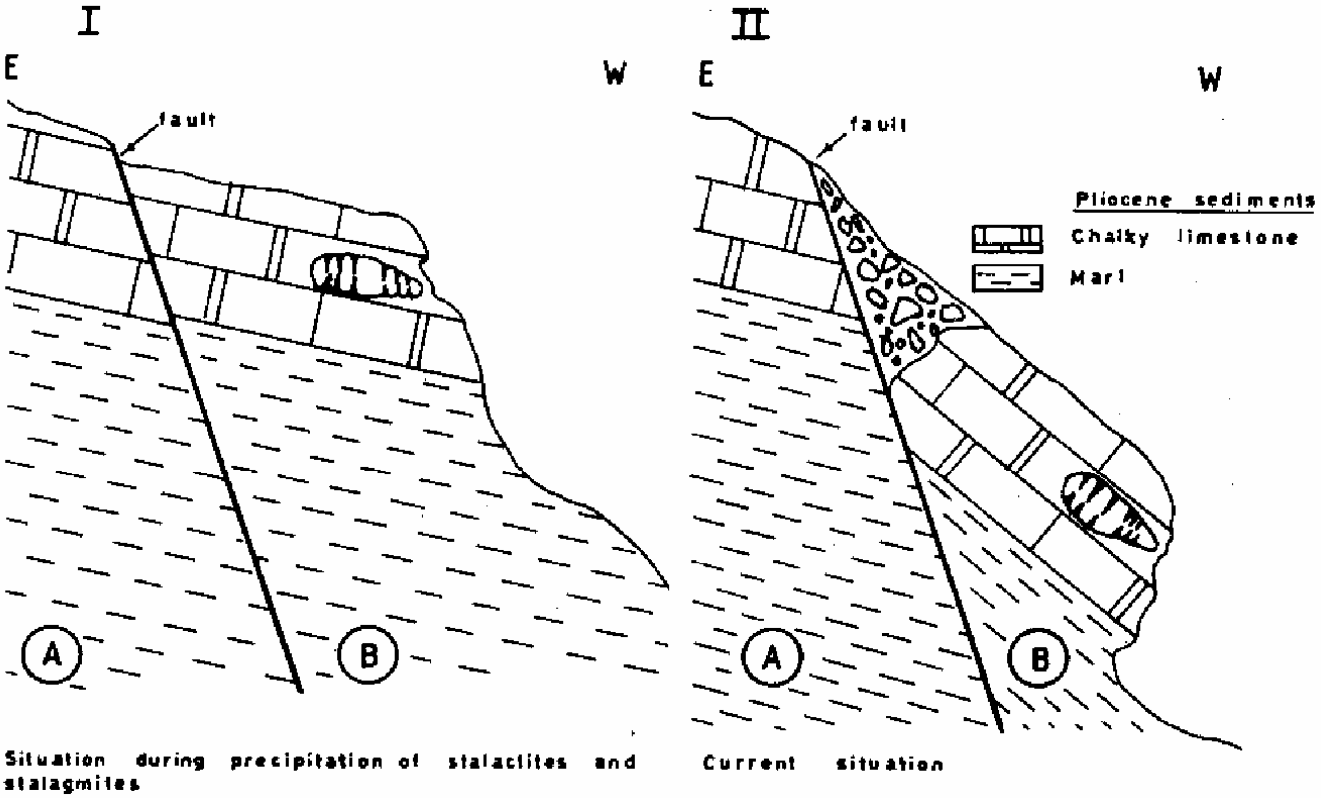

Fig. 5- Dislocation downsliding and tilting of a blok containging stalaactites & stalagmites, near Al Hamra.

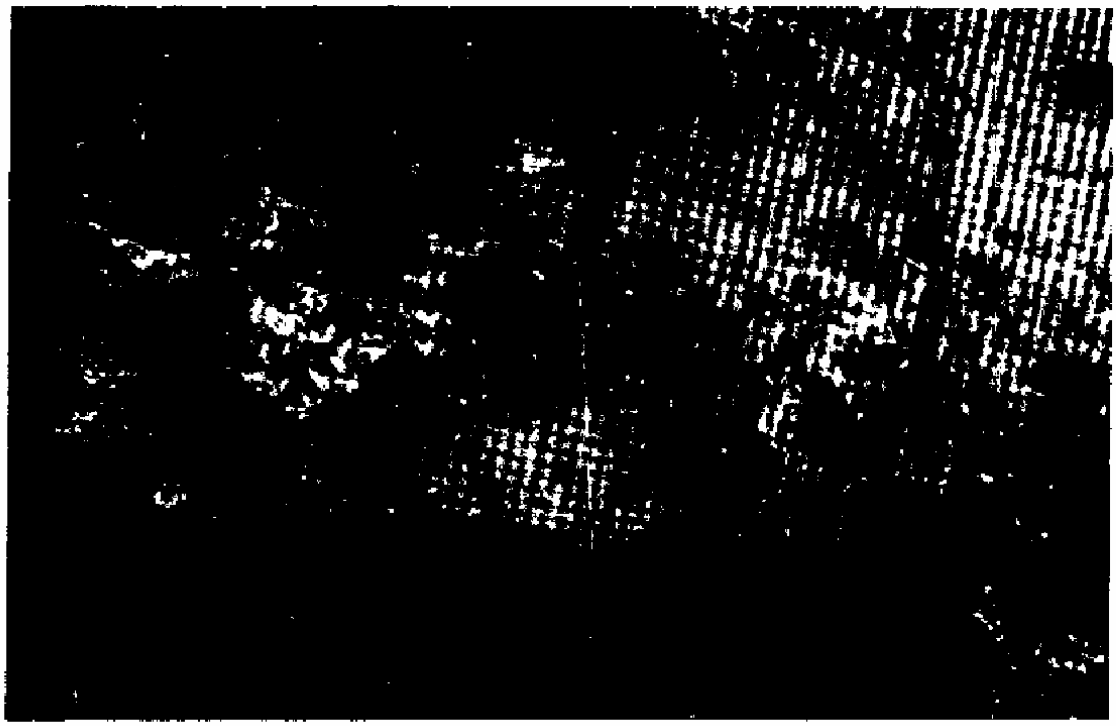

Photo 1- Non vertical stalactites and stalagmites, AL Hamra,AL Ghab Depression.

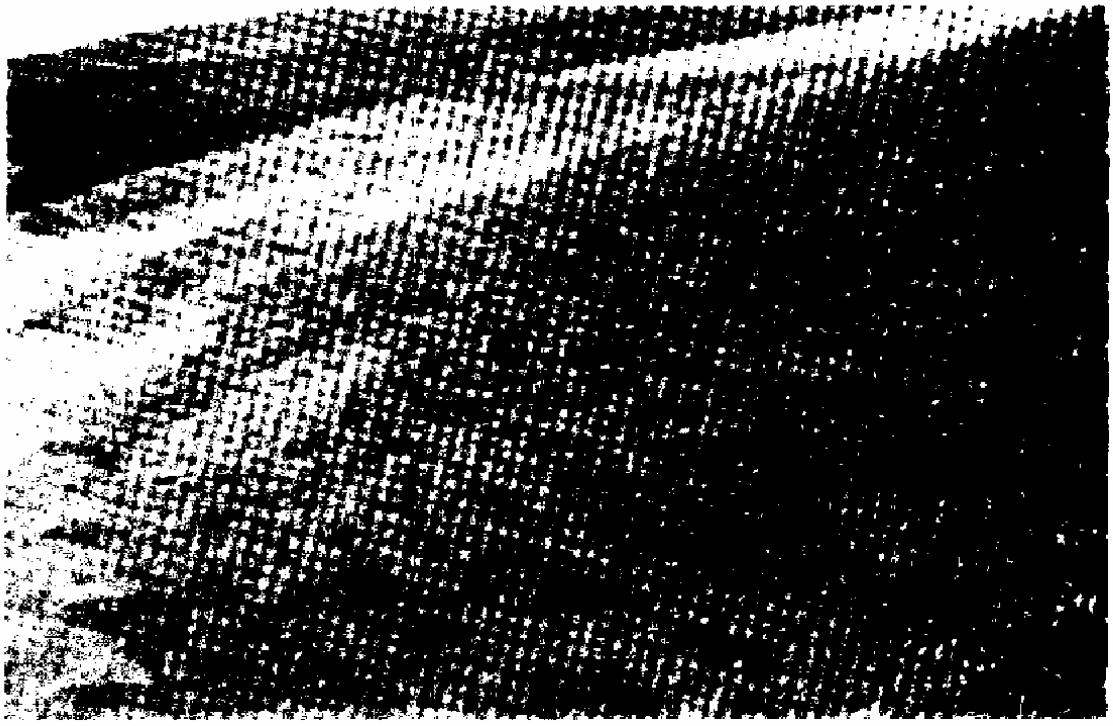

Photo 2- Gradual Landslide, El Enqawi, AL Ghab Depression

3- Conclusions

The reviewed structural indices were mapped in rocks of ages ranging from Jurassic, Cretaceous, Neogene to Quaternary. These indices together with the geomorphology of fault scarps, developed in them, and the well preserved striated fault planes proof convincingly that vigorous Post Pliocene tectonics (neotectonics) deformed the Jurassic, Cretaceous and pliocene rocks. The pleistocene Lacustrine sediments and proluvium give in turn evidences of faulting, folding, landslides and rock falls generated by neotectonics.

The historical seismic record of the area provides also evidences pointing out that the SLF, among other major faults in the country,was historically active. Other evidences reviewed in this study indicate that current tectonics, caused in the recent few years, frequent earth shaking accompanied by rock falls and landslides.

Precise radiometric dating of the deformations of Holocene sediments veiling the SLF along the entire AL Ghab Depression induced by paleoseismic shaking is of vital importance to determine more reliably the annual slip rates and the repeating time of paleoseismicity.

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