GEOLOGICAL RELATIONS BETWEEN CLASTIC, EVAPORITE AND LIMESTONE LAYERS OF FATHA FORMATION IN THE HIGH FOLDED ZONE, NE-IRAQ

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ABSTRACT

Fatha Formation (Middle Miocene) is a mixed clastic-carbonate-evaporite unit, which exposed in the Foothill (Low Folded) Zone in the northern and other area of Iraq. The relation between the three main lithologic constituents (clastic, carbonate and evaporate) was studied in the proximal (coastal) area of lagoonal basin (in Sulaimanyia Governorate). In this area, the clastic rocks (red claystone and sandstone) increase on the expense of evaporates as compared to basin center. In the proximal area, the lithologic signals of cyclicity are discussed by using the sea level changes and systems tract subdivision. The field study showed that the position (location) of each lithology on the sea level curve showed unexpected result, as concerned to the previous studies. All previous studies indicated the evaporates, carbonate (or marl) and clastic as low, transgressive and high stand system tract, respectively. On the contrary to this, the present study showed that the position of these lithologies (on the sea level curve) is high stand, transgressive and lowstand systems tract, respectively.

This means that the cycles begin with red claystone, as lowstand system tract and ends with evaporite, as high stand systems tract. This timing is based on the boundary conditions between the beds. The system tracts are argued in term of relation with Milankovitch band of astronomical climate changes, which consist of eccentricity by precision earth orbits around the sun and itself. During high eccentricity and precession orbits the sea level rises and the earth climate became warmer and both influx of seawater to the semi closed lagoon and evaporation increased, consequently evaporites are deposited in the basin periphery. But, during combination of the low orbits, a sea level fall occurred, which accompanied with decrease of seawater influx and evaporation. This was associated with dilution of the closed lagoon by fresh water from source areas, which deposited red claystone. The construction and destruction interference of these orbital cycles generate complete (ideal) and incomplete sedimentary cycles in the outcrop sections, of the basin periphery.

العلاقة الجيولوجية بين طبقات المتبخرات والطبقات الفتاتية والجيرية لتكوين الفتحة في نطاق الجبال العالية،شمال شرق العراق

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الملخص

تكوين الفتحة (المايوسين الاوسط)يحتوى على وحدات فتاتية و جيرية والمتبخرات و التى تظهر مكاشفها فى نطاق اقدام الجبال فى شمال شرق العراق. العلاقة بين الوحدات الثلاثة الرئيسة(الفتاتية و الكاربونية والمتبخرات) تمت دراستها فى المناطق الساحلية للحوض اللاغوني بحيث تزداد الصخور الفتاتية(الحجر الطينى الاحمر والحجر الرملي)من هذه المناطق مقارنة بالمتبخرات والتى تزداد نسبتها فى مركز الحوض خارج منطقة الدراسة.تم مناقشة التتابع الصخري

الدوري فى المناطق الساحلية وذلك باستخدام تغيرات مستوى سطح البحر و تقسيمات الانظمة المسارية.اظهرت الدراسة الحقلية بان الموا قع الصخرية تكون غير متوافقة مع منحنى لتغير مستوى سطح البحرو كما كانت واردة فى الدراسات السابقة والتى تشير الى ان صخور المتبخرات والكاربونا ت (او المارل)والفتاتيات تمثل الانظمة المسارية الواطئة و الانظمة المسارية العالية على التوالى .وقد بينت الدراسة الحالية بان المواقع الصخرية تمثل الانظمة المسارية العالية و الانظمة المساريةالواطئة على التوالى . وهدايعنى بان الدورات قد بدات بالحجر الطينى الاحمر وانتهت بالمتبخرات والتى تمثل الانظمة المسارية الواطئة . وقد اعتمد هذا التزامن على وضعية العلاقة بين حدود الطبقات .وهذه الانطمة المسارية تتطابق مع احزمة ميلانكوفيج الخاصة بالتغيرات المناخية الكونية والتى تتكون من (eccentricity and precession orbits) والمتعلقة بدوران حول الشمس ودوران الارض حول نفسها.وخلال وجود الارض فى حالة (eccentricity and precession orbits) العالية يودى الى ارتفاع مستوى سطح البحر وزيادة فى حرارة المناخ وزيادة فى تد فق المياه الى اللاكون الشبة المغلق مما يودى الى ترسيب المتبخرات .وبناء على ذلك تزداد المتبخرات فى حافات حوض الترسيب .وفى حالة وجود الارض فى حالة (eccentricity precession and orbits) الواطئة يودى ذلك الى حدوث انخفاض فى مستوى سطح البحر مما يودي الى تقليل تدفق المياة نحو اللاكون شبه المغلقة وبالتالي يودي الى انخفاض ترسيب المتبخرات.وهذا يترافق مع تخفيف مياه اللاكون بواسطة المياه العذبة من المناطق المصدرية مما يودي الى ترسيب الحجر الطينى الاحمر. ونتيجة لتداخل الدورات المحورية الرئيسية فان ذلك ادى الى تكون دورات كاملة نموذجية ودورات غير متكاملة والتى تظهر فى المكاشف الصخرية فى حافة الحوض.

INTRODUCTION

The studied area is located within Sulaimaniya Governorate in northeastern Iraq, at an area between High Folded and Foothill Zones. The Fatha Formation (previously known as the Lower Fars) has widespread distribution in the whole Foothill Zone and in some parts of High Folded Zone of Iraq (Fig.1A). The formation was originally described from Iran by Busk and Mayo (1918, in Bellen et al, 1959). Dunnington (1958) has drawn isopach Facies map for the distribution of the formation in Iraq(Fig.1B) In the basin periphery, the strata of the formation are onlapping unconformably on the either Late Eocene Pila Spi Formation or on the Oligocene units. The upper contact is gradational with Injana (previous Upper Fars) Formation and most probably (somewhat) diachronous (Bellen et al, 1959). Due to this onlapping the formation is missing in most parts of the High Folded Zone. Shawkat and Tucker (1978) have attributed the deposition of gypsum and anhydrite of the formation to sabkha environment.

The studied area represents the peripheral areas where the formation mainly consists of sandstone, red claystone and limestone while in the central part of the basin the share of evaporates and green marls increase in expense of others. Because of these lithologic changes and basin configuration the thickness of the formation is highly variable, which is high in the central part and shallow at the peripheral part. The present study is concerned with analysis of cyclicity in term of relation of the different lithologies in the basin, which depends on field observation, such as lateral and vertical lithologic changes and bedding boundary conditions in (nature of the boundary between different beds) addition to thin section studies.

The maximum thickness of the formation reaches up to 600m in the central depositional area, which is lying on the Foothill Zone(Buday,1980). The lower contact of the Fatha Formation is mostly unconformable with PilaSpi Formation in the northeastern margin area (Buday, 1980, p280). According to Bellen et al. (1959), the informal units from the bottom to the top are: The Transition Beds, which are composed mostly of anhydrite separated by thin limestones and mudstone. The Saliferous Beds are composed of rock salt and anhydrite with siltstones, mudstone and some limestone intercalation. The Seepage Beds consist of anhydrite with some siltstones and with some limestone beds. The Upper Red Beds composed of reddish mudstones and siltstones with relatively limestone and anhydrites. In the studied area, the formation is composed of cyclic repetition of red claystone, marl, gypsum and occasional interbed of limestone and sandstone.

GEOLOGICAL SETTING

The studied area is mainly located at the boundary between High Folded and Foothill Zones Buday (1980), Buday and Jassim (1987). It is bounded to the northeast by high amplitude anticlines, within the High Folded Zone, which is gradually change to low amplitude anticlines, inside the Foothill Zone. The Fatha Formation is well exposed at the southwestern limb of the anticlines such as Zimnako, Gulan, Sagrma , Darbandi Bazian, Qishlagh and Haibat Sultan. In these localities, the outcrops of the formation form flat irons and stratigraphic ribbons geomorphologic features. The basin is developed from the basin fill of the Neo-Tethys and collision of the Iranian and Arabian Plates. Karim (2004) included the basin of Fatha Formation in the late Zagros foreland basin. In the studied area the Fatha Formation is underlain directly by the Pila Spi Formation and is overlained by the Injana Formation.

SIGNAL OF CYCLICITY AND IDEAL CYCLES

The signals of the cyclicity are very strong and clear in the Fatha Formation. The studied area forms the proximal (or peripherial) part of the basin of the formation, during Middle Miocene. The signals of the cyclicity are regular repetition of the packages of lithologies for several times in each outcrop section. Each package consists of red claystone, marl and gypsum beds with or without limestone and sandstone (Fig.2). Each outcrop sections have the thickness of (10 – 40) m, which ends with sandstone and red claystone of Injana Formation.

According to Karim (1988), and Karim and Al-Rawi (1992) the cycles of the Fatha Formation consist of sandstone, green marl with laminated gypsum or anhydrite from the bottom to the top, these cycles also observed in the study area. The cycle mentioned by (op.cit) is ideal cycle, which belongs to upper part of Fatha Formation in the Mosul area. In the studied area the ideal cycle consists of red claystone (or sandstone), green marl and gypsum (or limestone). This ideal cycle can be seen in many places, but in most cases many incomplete cycles could be seen, which consists only of two lithologies such as red claystone - marl, marl- gypsum and red claystone-gypsum (Fig. 6, 7 and 8).

REASON OF CYCLICITY AND TIME RELATION BETWEEN LITHOLOGIES

The clear and accurate signal of cyclicity can be attributed to Milankovitch astronomical theory (or Milankovitch band) for interpreting of layering of sedimentary rocks. In this study the cyclicity of the formation is attributed to the earth orbital cyclicity (orbital signals) Haq,1991 and Doyle and Bennett. Orbital cyclicity, in tern, generates alternated warm and cold long and short durations (repeated climatic fluctuations), which reflected by arrangement of different rocks due to change of environment and climate of the sedimentary basins (Einsele, 2000). The climatic variations affect ice accumulation in the poles and see level change (rise and fall). Milankovitch band consist of three types of wave lengths which have the duration of 106, 41, 19 Ka. These wave lengths (earth orbits) are called eccentricity; obliquity and precession cycles, respectively, which are resulted from different orbital movement of the earth around it's self and the sun (for more detail see Haq, 1991, De Boer, 1991 and Gale, 1995, Holland, 1998).

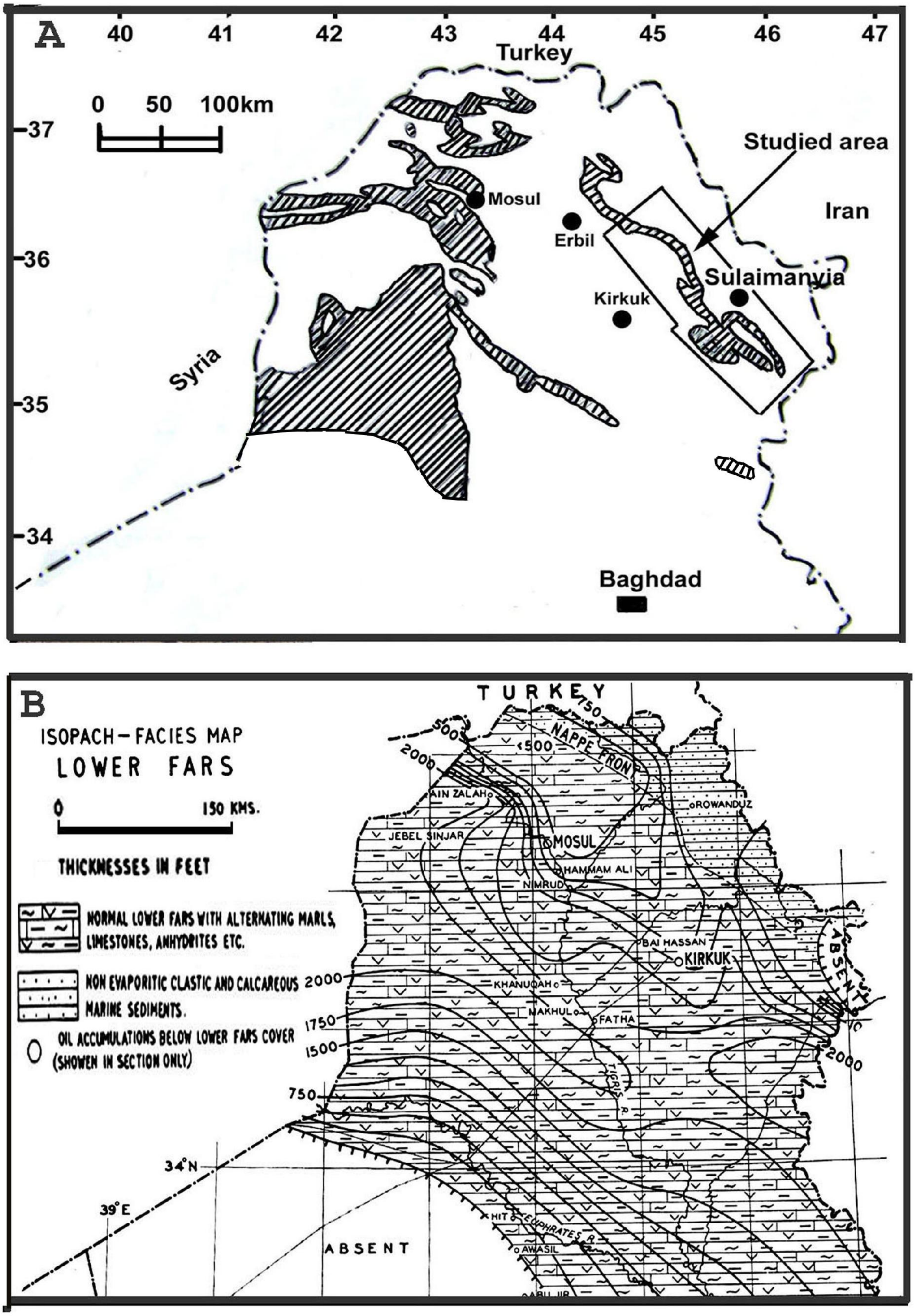

Fig.(1) A: Location map of the studied area and outcrops distribution of the Fatha (Lower Fars) Formation (modified from Sissakian, 2000). B: Isopach-Facies map of Lower Fars Formation (Dunnington, 1958).

The cyclicity of the Fatha Formation is most possibly located in the Milankovitch band, especially the wave length (sea level change duration) of 100 k.a (eccentricity), which is modulated by precession (20k.a.) and obliquity. This is because the total duration of the deposition of the formation is about 5m.y (Bellen, 1959; Buday, 1980; Jassim and Goff, 2006). The field study showed that the formation contains more than 50 complete and/or incomplete sedimentary cycles. When the total depositional duration of the formation, in the basin center, is divided by the number of the cycles 100k.a (kilo anus) is get. The deviation of many cycles from ideal one is most probably attributed to modulating of the eccentricity by obliquity and precession cycles together and singularity. The gypsum of the Fatha Formation is deposited during high eccentricity and precession, which means the nearness of the earth from the sun and tilting of the earth axis to it's orbit (Fig.5A).

During high eccentricity and precession, the claystone is deposited during cold duration when the earth was at long distant from the sun and the earth was at low tilt angle of it's orbit. But, gypsum is deposited in opposite situation to that of claystone. The marl and limestone are deposited at the intermediate distance. This timing relation, of the deposition of these lithologies are only valid for the periphery (proximal area) of the basin of the Fatha Formation. But, the central part of the basin is controlled by many other and more complex factors which are out of the aim of the present paper. The unusual influx of the fresh water into the basin periphery (studied area) from the source areas has also effect on the deviation of some cycles from the ideal one. For example, the influx of high quantity of freshwater with nutrient will change the deposition from gypsum to limestone in the proximal area, while the deposition of the gypsum will continue in the basin center (Fig. 5).

Fig.(2) A: centimetric lamination between marl and pure gypsum deposited by seasonal climatic variation. B: Nodular gypsum formed by diagenesis due to spontaneous deposition of gypsum and marl. C: Sharp contact (indicated by arrow) between papery marl and overlying red claystone. All photos are at 3km west of Takyia town, Bazian area.

LITHOLOGIC RELATIONS WITHIN THE SYSTEMS TRACTS

Within the systems tracts of the Middle and Late Miocene depositional sequence, the Fatha Formation can be assigned as transgressive system tracts. This sequence is consisted, in addition to Fatha Formation, of Injana (Late Miocene), Mukdadyia and Bai-Hassan Formations (Pliocene), the environment of these Formations are mainly fluvial and distal and proximal alluvial fan respectively. Within the main sequence, the mentioned formations are deposited during transgressive, highstand and lowstand systems tracts, respectively. The collecting of these formations in one depositional system is based on the gradational contact of these formations. The main sequence is tectonically controlled, which is related to subsidence of the basin at the beginning of deposition of the Fatha Formation and then started to uplift during deposition of other formation such as Mukdadyia and Bai-Hassan Formations.

The Fatha Formation as a main transgressive systems tract consists of many small depositional sequences. Each small sequence consists of one ideal cycle, which has duration of 100k.a. The main problem with the depositional sequence in the Fatha Formation is where to locate each lithology on the sea level curve. This problem includes what lithology to be assigned as transgressive, highstand and lowstand system tracts. Einsele (1998) discussed in detail the sequence stratigraphy of carbonate-evaporites successions (or systems). He assigned the evaporites as deposits of lowstand systems tract and carbonate as highstand systems tract (Fig.3). In his discussion, he referred to accumulation of gypsum on the slope during the sea level fall and referred to deposition of carbonate during sea level rise.

In Fatha Formation, we tried during field work, to find the principles mentioned by Einsele (1998) for deposition of gypsum and carbonate. But, the trials failed to prove deposition of gypsum during sea level fall and carbonate during sea level rise. Conversely, all evidences showed that for Fatha Formation, in proximal area (studied area), opposite is valid. These mean that the gypsum deposited as highstand systems tract and marl as transgressive systems tracts, while red claystone deposited as lowstand system tracts. The evidence for these new assignments of system tracts of carbonate-clastics-evaporites are as follows:

A- In the field, the cycles are associated with red claystone and some sandstone; these rocks represent the shallowest deposits in the basin, which represent the deposits of delta plain and distributaries channels. The green marl is located above the red claystone, which represent sediment of deeper water followed by gypsum or limestone (Figs.6,7 and 8). Therefore, it is more convenient to assign red claystone as sediment of LST, which is deposited during sea level fall (Fig. 5).

B- No erosion surface was found under the gypsum beds, as mentioned by Einsele (1998). Conversely, the contact of gypsum with green marl is gradational in most cases, which is represented by gypsiferous marl or marly gypsum rock at the contact (Fig. 4A,B).

C-The contact between gypsum beds and overlying red claystone is sharp, which refers to erosional surface (Fig.2C). This erosional surface may be attributed to shallowness of the water which induced the erosion by current activity. The erosion surface, most possibly, is equivalent to type3 or 2 of sequence boundary.

D- In the studied area, as observed by the present author and in the Mosul area as observed by Karim (1988), the most common rocks that associated with gypsum is marl. In many cases both rocks show laminated beds, which consist of regular alternation of millimeteric lamine of marl and gypsum (Fig.2A). When little marl is deposited continuously (spontaneously) with gypsum a nodular beds of gypsum is formed (Fig. 2B).

REASONS FOR DEPOSITION OF GYPSUM DURING HST (SEA LEVEL RISE)

Although the field evidences confirm the deposition of gypsum during high stand, but it remains not easily understandable. To make this assumption is acceptable; detail explanation for the factors and processes of deposition is needed. The climatic variations are resulted from combination of eccentricity and precession orbits that caused the thawing and accumulation of the ice at the poles. This cycle of melting and accumulation is associated with warm and cold intervals of time with intermediate ones. During warm climate seal level rise occurs due to melting of poles ice, while during cold times sea level fall due to ice accumulation. The important processes that enhanced deposition of gypsum during HST are four points. The first is that during warm intervals both evaporation and salinity are increased. During deposition of Fatha Formation, the evaporation is increased due to nearness of the earth from the sun with high precession while salinity is increased by flooding of marine water over the sill that separated the basin of formation from normal marine water (Fig. 5).

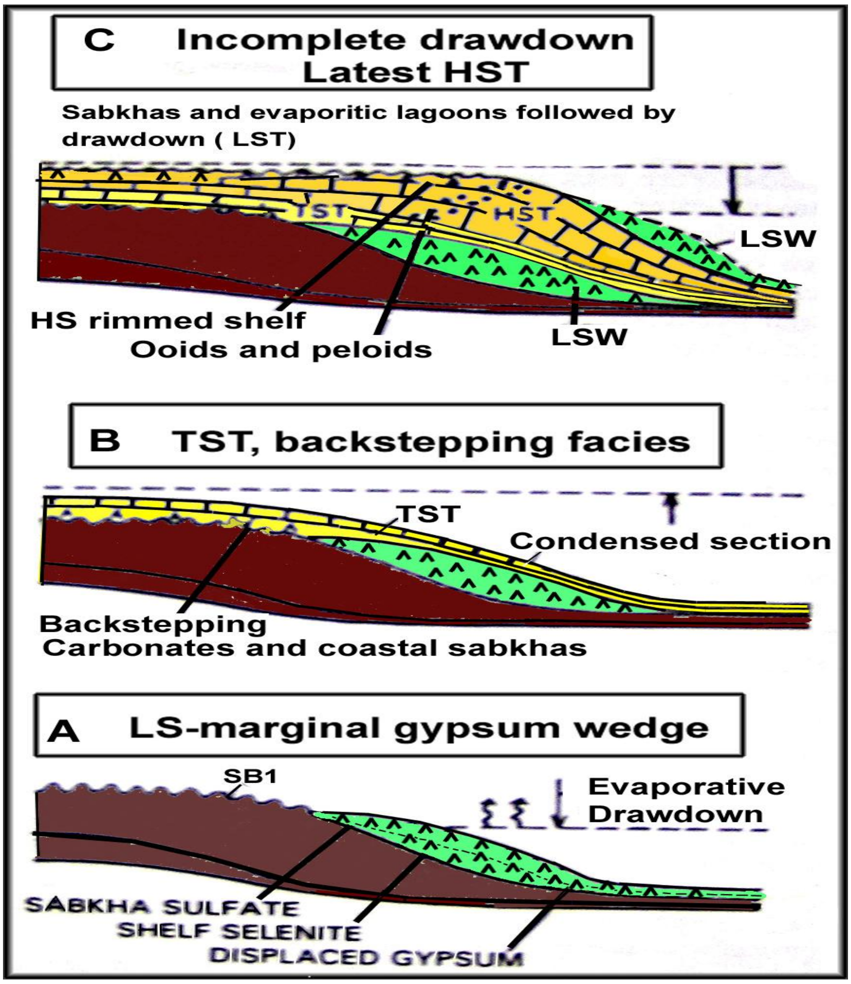

Fig. (3) Systems tract of carbonate -evaporites system of Einsele (1998) which shows evaporate as LST and carbonate as TST and HST.

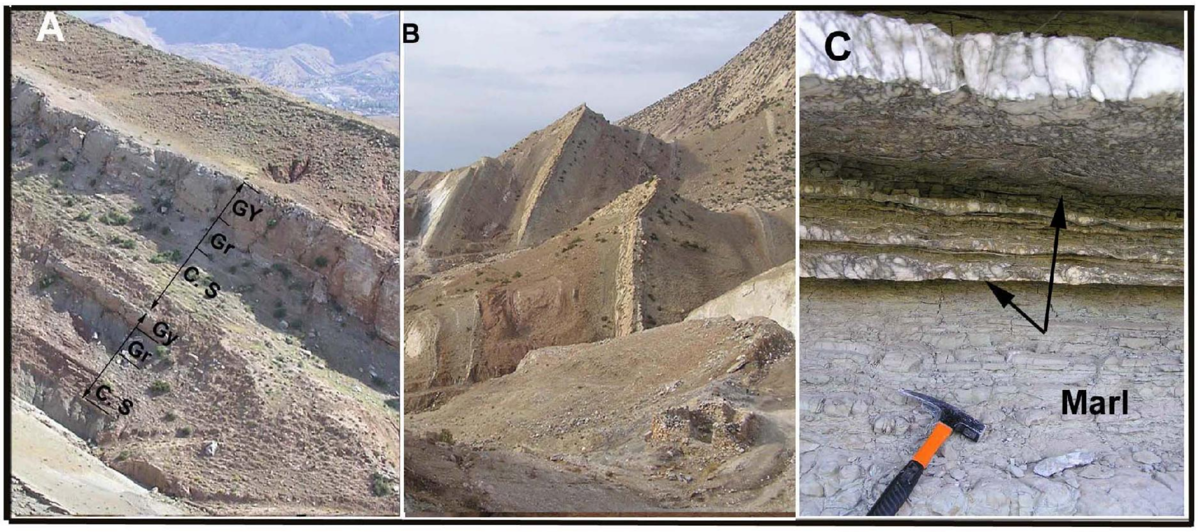

Fig. (4) A: Two ideal cycles of depositions red claystone (C.S), green marl (Gr) and gypsum (GY) at southeastern plunge of Sagrma anticline. C: Gradational contact between marl and gypsum, which is manifested by alternation of laminae of marl and gypsum (above the arrow). B: Common geomorphologic feature formed by limestone and gypsum beds (southeast limb of Qishlagh anticline.

The second point is that during HST the precipitation on the basin and source areas decreases , this prevent the dilution of the salinity of water of the basin, at least, in the proximal area. The climatic change of one cycle of the eccentricity (100, 000 years) during Middle Miocene was more or less analogous to the present climate change during one year at the studied area as concerned to alternation of warm(arid) and cold periods. The temperature will maximum when the high tilt angles of precession and obliquity were associated with eccentricity. The third point is that during remoteness of the earth from the sun with low tilt angle, the influx of marine water over the sill is terminated. In other side, the fresh water supply from the source area increased so that the water of the basin is diluted in the peripheral areas (at the studied area), this associated with decrease of evaporation. In these cases the sea level fall occurred and LST is deposited which is represented by red claystone and sandstone. The fourth point is that the deposition of HST has long duration as compared to TST and underwent shallowing as a result of sediment fill and evaporation (Vail et al., 1977, Van Wagoner, et al., 1988 and 1990, Haq, 1991, Emery and Myers, 1996).

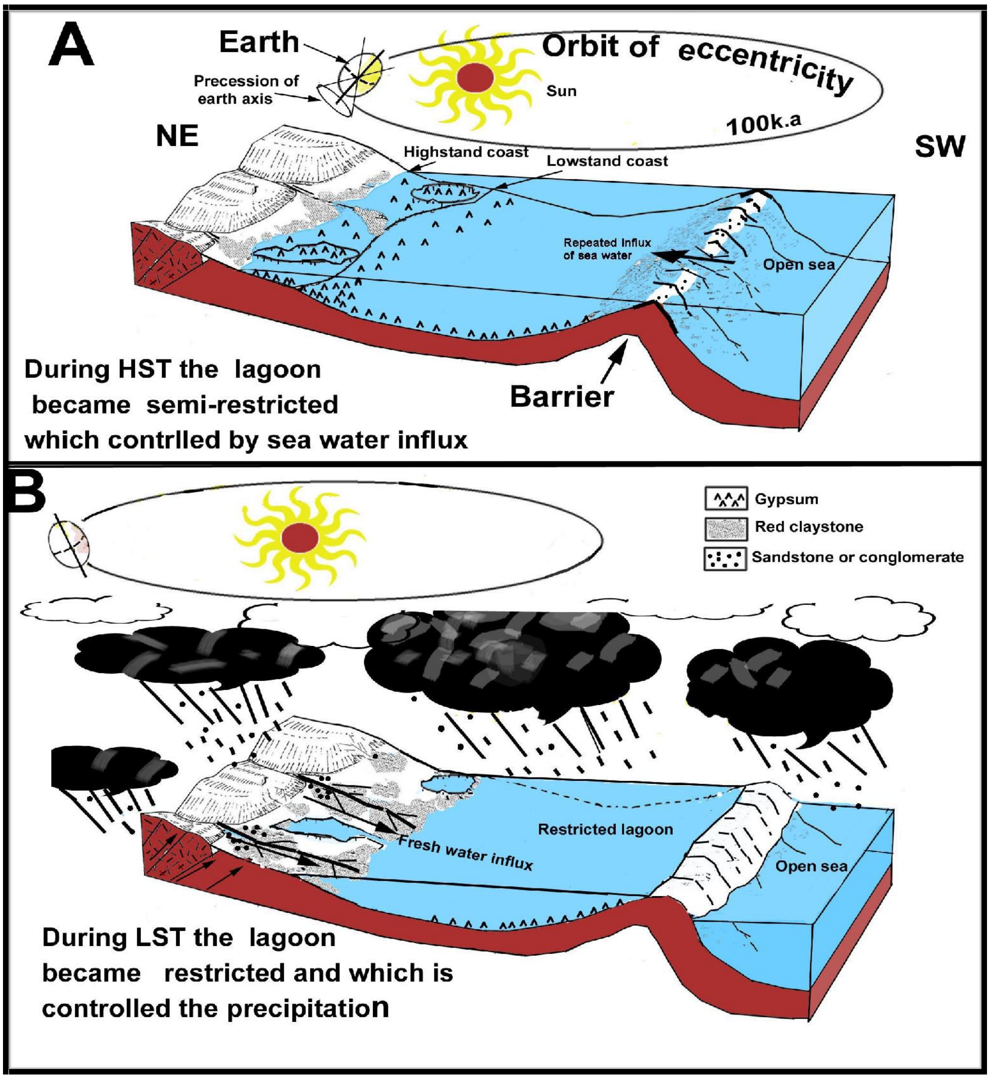

Fig.(5)A model of the present study which show the effect of eccentricity and precession of climatic change in the northern hemisphere during Middle Miocene. A: High eccentricity and precession generate HST and high evaporation in which gypsum deposited. B: Low eccentricity and precession generate LST and influx of fresh water to the closed lagoon.

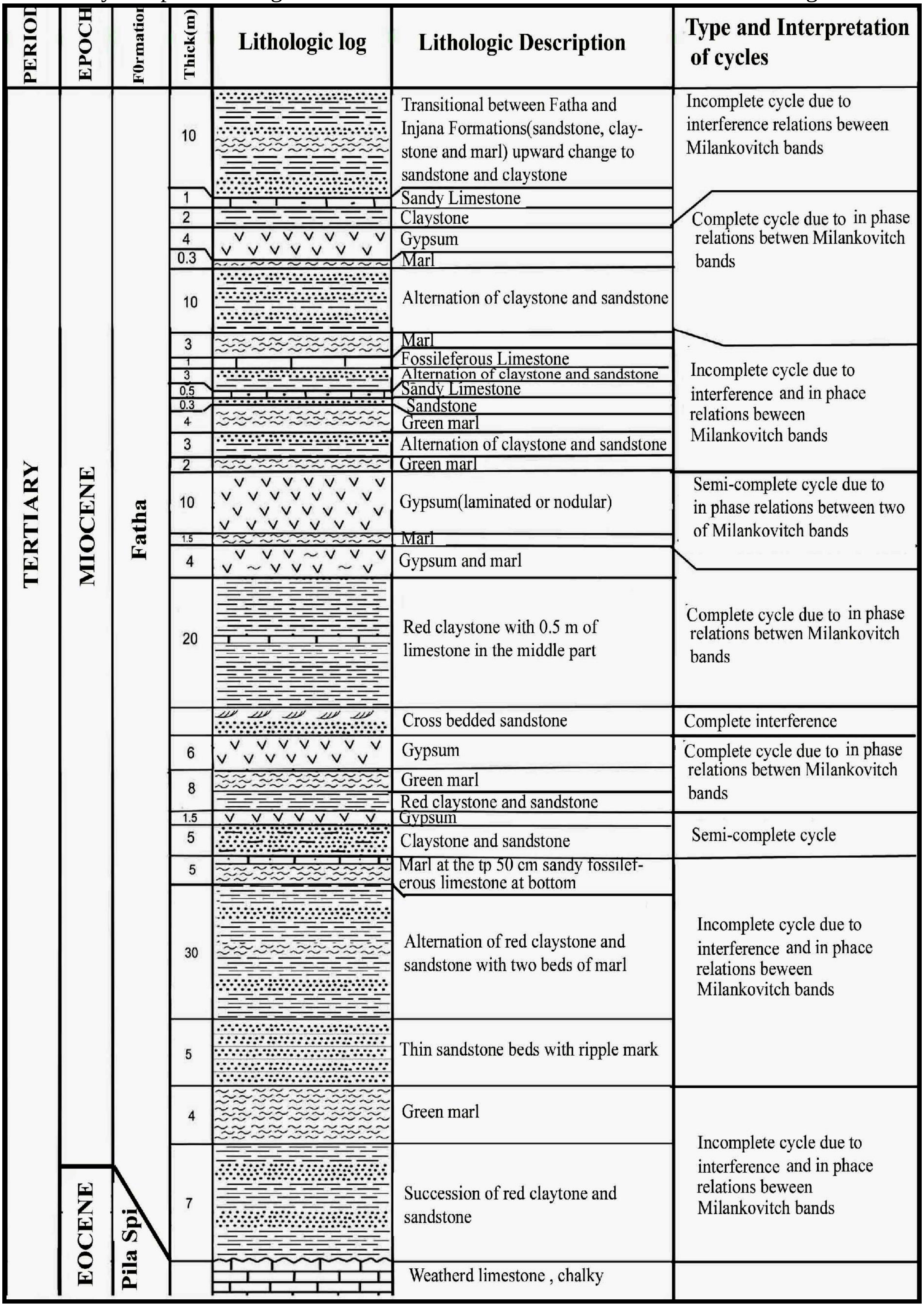

Fig.(6): Stratigraphic column of Gulan Anticline at 6km southwest of Darbandikhan town section which shows the type of cycles and their interpretation.

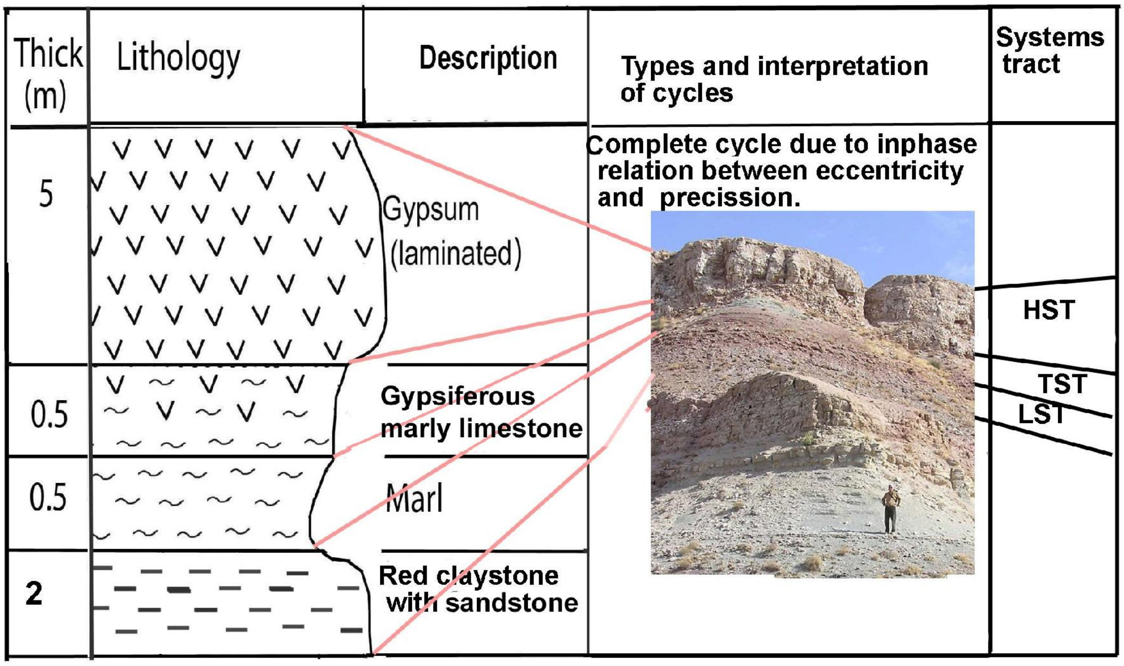

Fig. (7): An ideal cycle at the top of the Awa Spi section for which the lithologies and sequence stratigraphy are shown.

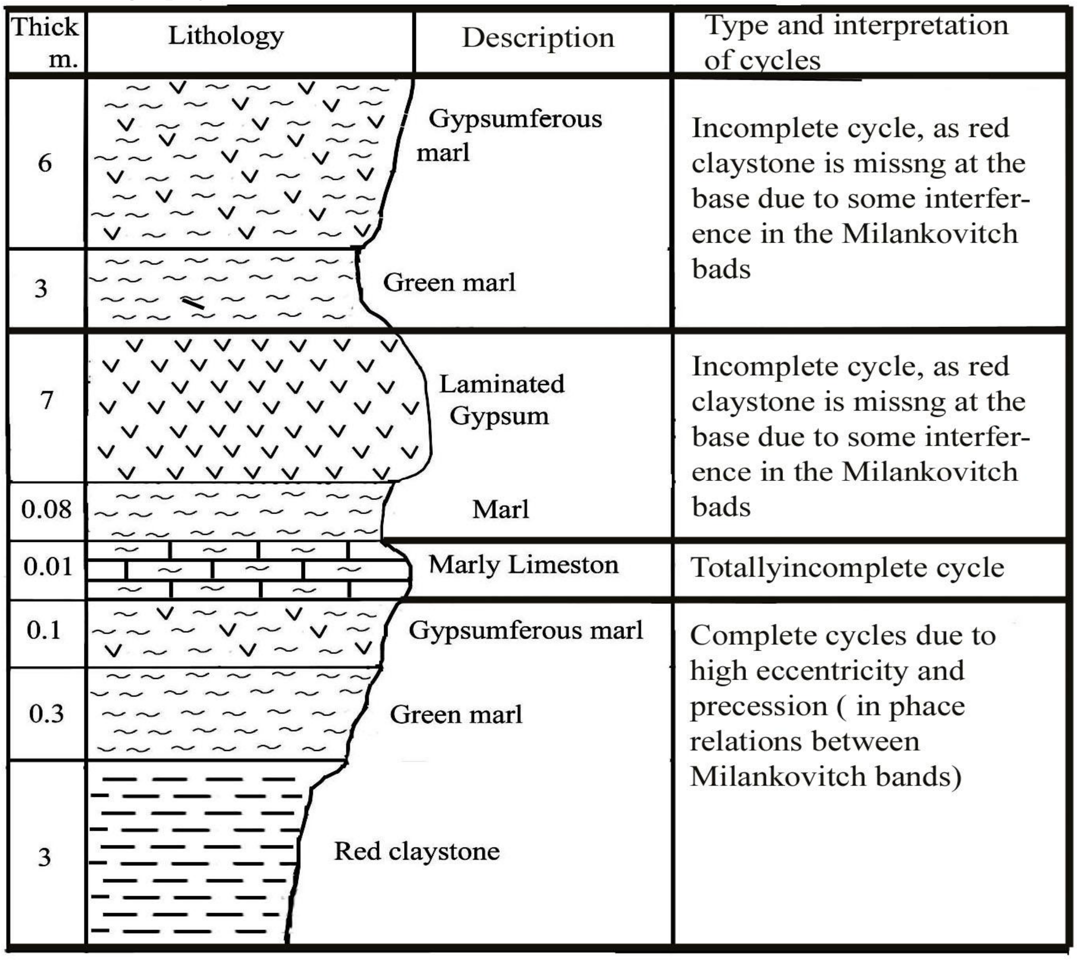

Fig.(8) : Stratigraphic column of Bazian section which shows the type of cycles and their interpretation.

CONCLUSIONS

This study has the following conclusions:

- The Fatha Formation, as a whole consists of transgressive systems tracts within Middle Miocene depositional cycle.
- This system tract contain tens of lithological packages, which are repeated regularly in outcrop sections in the basin periphery.
- Each package consists of red claystone, marl or gypsum (or limestone) as complete or (ideal) cycle which makes repeated cycles.
- The relation of these lithologies as concerned to systems tracts are opposite to the previous studies as red claystone, marl and gypsum are deposited during time of LST, TST and HST respectively.
- The timing relation of deposition of these lithologies area indicated by systems tracts that attributed to eustatic sea change.
- The deposition of each lithology during this system tract attributed to Milankovitch band which include eccentricity, precision and obliquity orbits of earth around sun and itself.
- The interference of these orbits generated cold and warm time intervals, which led to deposition of red claystone and gypsum, respectively.

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