SUBSURFACE SEDIMENTOLOGICAL STUDY OF INJANA FORMATION (LATE MIOCENE) IN THE AREA EXTENDED FROM BAIJI TO SAMARRA CITIES, CENTRAL IRAQ

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ABSTRACT

Detailed subsurface sedimentological study had shown that the sediments of Injana Formation (Late Miocene) in the area extended from Baiji to Samarra cities, central part of Iraq were deposited in fluviatile meandering channels system. These sediments represented by several large scale fining-upward cycles. In each cycle, two main facies were recognized; coarse grained sediments (facies 1) and fine grained sediments (facies 2). The coarse grained sediments facies represent channel deposits and are divided into two subfacies; intraformational conglomerates and sandstones. The fine grained sediments facies represent overbank environment and are divided into four subfacies; alternated claystone and/ or mudstone and siltstone sediments, mudstone and claystone sediments, coarsening-upward and small scale fining-upward sequences and carbonates.

It is believed that vertical crustal movements during Miocene were an important factor in the repetition of large scale fining-upward cycles. However, the coarsening-upward and the small scale fining-upward subfacies, which are random in nature and interrupted the flood plain sediments might be related to the overbank sedimentation produced by crevasse splays.

دراسة رسوبية تحت سطحية لتكوين انجانة (المايوسين الأعلى) في المنطقة الممتدة بين مدينتي بيجي وسامراء، وسط العراق

مزاحم عزيز باصي

المستخلص

أجريت دراسة رسوبية تحت سطحية على ترسبات تكوين انجانة (المايوسين الأعلى) في المنطقة الممتدة بين بيجي وسامراء على الجانب الغربي لنهر دجلة، وسط العراق. الدراسة بينت بان التكوين ترسب في بيئة انهار متعرجة وانه يتكون من عدة دورات كبيرة تتناقص في حجم حبيباتها نحو الأعلى. في كل دورة رسوبية تم تميز سحنتان رئيسيتان وهما سحنة الترسبات خشنة الحبيبات (سحنة 1) وسحنة الترسبات ناعمة الحبيبات (سحنة 2). إن سحنة الترسبات خشنة الحبيبات تمثل ترسبات القنوات النهرية المتعرجة وقسمت إلى سحنتان ثانويتان هما، سحنة المدملكات الداخلية وسحنة الصخور الرملية. سحنة الترسبات ناعمة الحبيبات تمثل ترسبات عبر الضفة وقسمت إلى أربعة سحنات ثانوية هي: سحنة الترسبات المتداخلة الطينية والوحلية والغرينية وسحنة الترسبات الطينية والوحلية وسحنة الترسبات التي تزداد حجم حبيباتها نحو الأعلى والمتناعمة في حجم الحبيبات الصغيرة وسحنة الكاربونات.

بينت الدراسة بان الحركات التكتونية خلال فترة المايوسين كانت أهم العوامل في تكرارالدورات المتناعمة نحو الأعلى الكبيرة. أما السحنات التي تزداد حجم حبيباتها نحو الأعلى والمتناعمة في حجم الحبيبات الصغيرة والتي لها توزيع عشوائي وغير متكرر ضمن ترسبات حوض الفيضان الطينية والوحلية ربما تمثل رواسب عبر الضفة ومتكونة بواسطة فلق شرف القنوات النهرية.

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INTRODUCTION

A subsurface sedimentological study of the Injana Formation (Late Miocene) was carried out in Baiji and Al-Mihzam localities in the area extended from Baiji to Samarra cities, on the western side of Tigris River, central part of Iraq (Fig.1). The formation is covered in the studied area by Quaternary sediments.

Injana Formation was studied stratigraphically and sedimentologically by many authors (e.g. Dunnington, 1958; Bellen *et al*., 1959; Kukal and Saadala, 1970; Basi, 1973; Al-Mubarak and Youkhanna, 1976; Al-Samarrai, 1978; Al-Banna, 1982; Jassim *et al*., 1984 and Al-Rawi *et al*., 1993). The formation is previously named as Upper Fars but later changed in Iraq to Injana Formation (Jassim *et al*., 1984 and Al-Rawi *et al*., 1993). All aforementioned previous works were carried out outside of the studied area and suggested that the formation is of continental to sub continental and deltaic to fluviatile environment. However, Al-Banna (1982) added that the formation in the northern part of Iraq was deposited by meandering and braided fluvial channels.

The aim of this work is to study the sedimentology of Injana Formation. The collected data was based on the sediments from boreholes, drilled in Baiji and Al-Mihzam localities (Potential Sites) as no sediments of the formation are exposed in the studied area. The work is part of a project carried out by the State Company of Geological Survey and Mining for engineering purposes (Site Selection).

THE CHARACTERISTIC FEATURES OF THE STUDIED FORMATION

The Injana Formation is studied in nine boreholes in Baiji and Al-Mihzam localities. The investigated sediments represent the upper part of the formation and the penetrated thickness of the formation ranges from (56 – 89) m. The sediments are composed of claystones, mudstones, siltstones and sandstones. The claystones, mudstones and siltstones being thick in comparison to the sandstone layers. Generally, the sediments form repeated fining-upward cycles. The cycle starts by sandstones passes gradually upwards into siltstones, mudstones and/ or claystones. However, some of the cycles are non-gradational. They start by sandstones pass sharply into claystones and/ or mudstones. The fining-upward cycles are considered in this study as large scale, when their lower sandstone beds range in thickness from about (3.5 – 16) m (Fig.2). The sandstones are medium to very fine grained, brownish in color and friable to medium tough. Internally, they are mostly very thinly to thinly bedded, cross-laminated and cross-bedded. The claystones and mudstones are tough, massive and sometimes laminated due to color variation. Pure gypsum veins and laminae were recognized in most of the sediments. The veins are irregular in trends. The laminae varies from less than one centimeter to five centimeters. The pure gypsum was considered as secondary precipitated from the groundwater. For more detail characteristic features of the Injana Formation in the studied area see Basi and Karim (1990) and Yacoub *et al*. (1990).

SEDIMENTARY FACIES OF INJANA FORMATION AND THEIR INTERPRETED ENVIROMENTS

It is useful to give the main environment of deposition of the studied formation, based on the characteristic features of the sediments, before discussion of its facies. Injana Formation consists of a sequence of repeated large scale fining upward cycles. The cycles are mostly characterized by distinct lower part of coarse grained sediments, which pass gradually (upward) into more thick fine grained sediments. Some of the cycles, however are non-gradational in nature. The lower coarse part of the gradational fining-upward cycle has mostly erosional base and is represented by medium to very fine cross-bedded sandstones. The sedimentary structures change in their type upward, too. They change from horizontal-bedding (if present) or cross-bedding at the base of the sandstones to cross-lamination, at the uppermost part of the sandstones. The upper fine grained part is thicker than the lower coarse part and consists of claystones, mudstones and siltstones. These features of the sediments suggested that the fining-upward cycles represent sediments of meandering fluvial channels, similar to those described by Allen (1964), Selley (1977), Al-Banna (1982) and Al-Haddad *et al*. (1996). The non-gradational nature of some cycles might indicate either that the detritus did not contain a broad spectrum of grain size or might represent straight channels.

Two main facies are recognized in Injana Formation; coarse grained sediments and fine grained sediments. These facies are divided into subfacies as shown in Fig. (2).

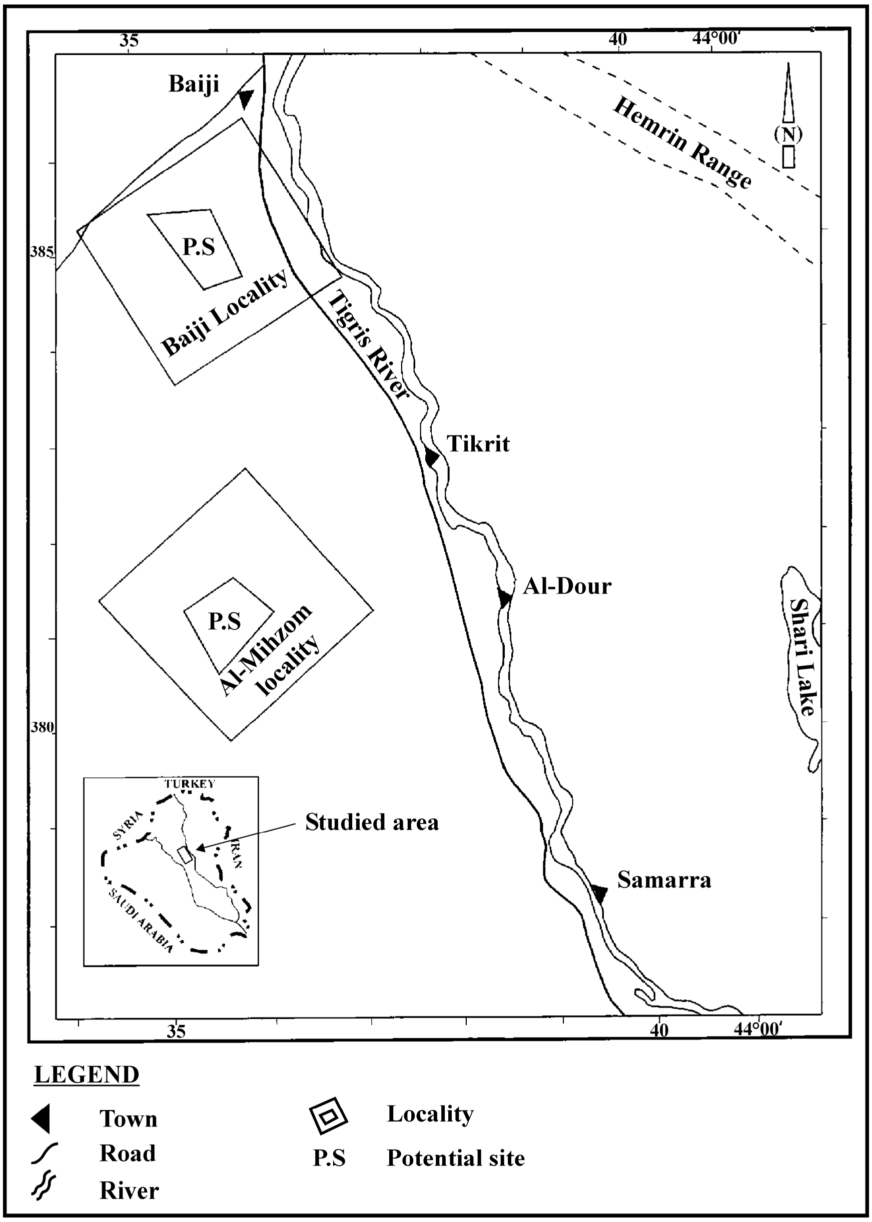


Fig. 1: Location map of the studied area (scale 1:500 000)

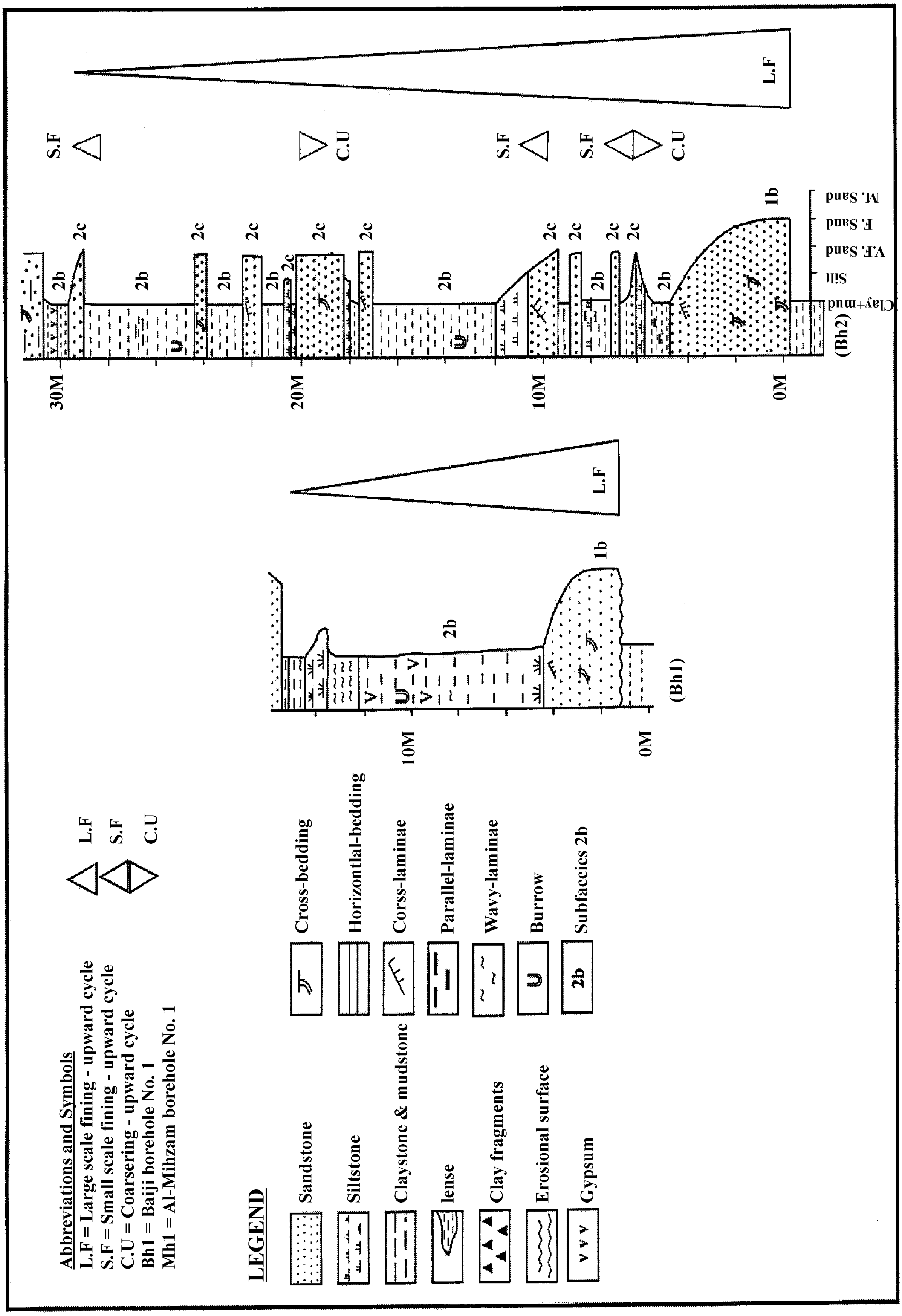
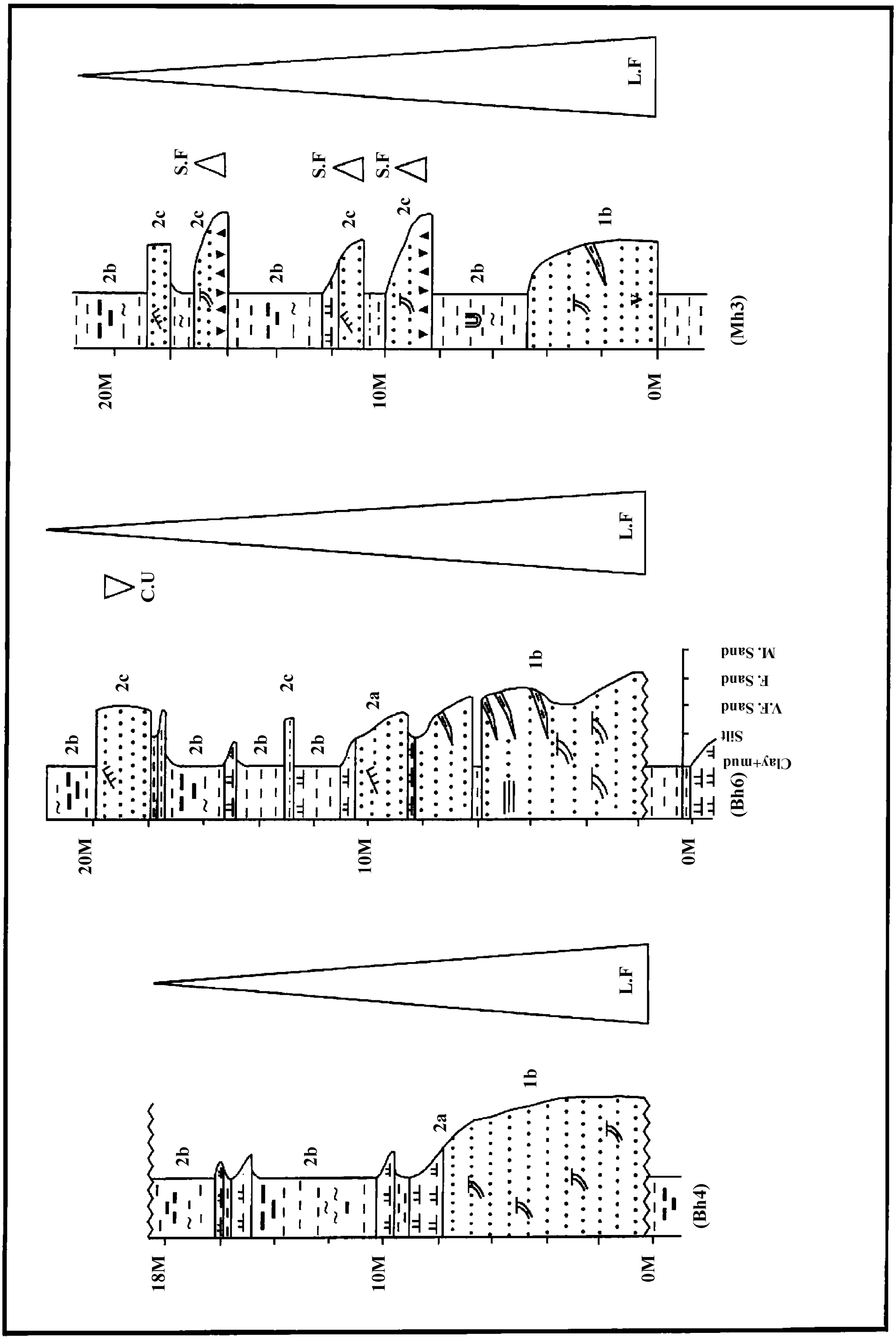


Fig. 2: Graphical logs showing representative cycles and subfacies in the subsurface sediments of Injana Formation


L.F
S.F
S.F
S.F
2b
2c
2c
2b
2c
2c
2b
1b
20M
10M
0M
(Mh3)
L.F
C.U
2b
2c
2b
2b
2c
2b
2a
1b
20M
10M
0M
(Bh6)
Clay+mud
Silt
V.F. Sand
F. Sand
M. Sand
L.F
2b
2b
2a
1b
18M
10M
0M
(Bh4)

Cont. Fig. 2

- **Facies 1: Coarse grained sediments (fluvial channels)**

This facies consists mainly of sandstone with subordinate intraformational conglomerates. It is divided into two subfacies:

Subfacies 1a: Intraformational conglomerates

This subfacies ranges in thickness from (10 – 80) cm and sometimes observed at the base of the sandstones. However, it is recognized at the middle of the sandstones, also. It is characterized by uneven basal surface and their highest amplitude reaches more than 5 cm, it consists of sandstones with claystone fragments, in which these fragments are believed to be not transported to far from their sources. These fragments are mostly angular to sub angular and range in size from (2 – 8) cm, it is believed that this subfacies is a channel floor sediments and formed due to erosion of the oldest beds (mostly claystones) by stream current in the upper flow regime. Many authors discussed the genesis of similar subfacies and considered them to represent channel floor sediments (e.g. Allen, 1964 and Selley, 1977).

Subfacies 1b: Sandstones

These sandstones subfacies range in thickness from (3.5 – 16) m. The sandstones have mostly erosional scour surface, at their bases and normally cutting sharply the underlying fine grained mudstone or claystone sediments (Fig.2). However, sometimes the intraformational conglomerates (Subfacies 1a) are underlying these subfacies. The sandstones are mostly medium tough, friable, in some parts (loose sand), medium to fine grained, moderately sorted and medium grey to brown in color. Sedimentary structures include large scale and medium scale cross bedding, in the lower part and micro-cross lamination in the upper part. Horizontal bedding, sometimes, is recognized in the lower and middle parts of the sandstones also. In some sequences the micro-cross laminations were not observed. These subfacies form the basal part of the large scale fining-upward cycles. They are overlain by the overbank facies (Facies 2). It is believed that these subfacies represent the point-bar sediments of meandering fluvial channels, similar to those described by Allen (1964), Selley (1977) and Al-Haddad (1996). The cross-bedding and micro-cross laminated units represent deposits of sub aqueous dunes and ripples, in the lower flow regime. The horizontal-bedding indicates a deposition in the upper flow regime.

- **Facies 2: Fine grained sediments (overbank flooding)**

This facies is comprised of sediments that are either overlying or laterally equivalent to facies 1. It is composed of considerably high proportions of claystone and mudstone sediments. Sandstone, siltstone and carbonate, however were also observed. It is believed that the sediments of this facies represent mostly fine suspended deposits formed by overbank flooding. The facies is divided into the following four subfacies:

Subfacies 2a: Alternated claystone and/ or mudstone and siltstone sediments

This subfacies consists of alternation of claystone and/ or mudstone and siltstone. Subordinate very fine sandstones were sometimes observed in some sequences. It is normally not exceeding 1 meter in thickness and if present is overlying the sandstones of subfacies 1b. Parallel, micro-cross and sometimes wavy laminations are the main sedimentary structures observed within the siltstones and sandstones. Burrows and rootlets (?) were sometimes recognized in some units. The mudstones and claystones are brownish in color and mostly massive. However, parallel-laminations due to color variation were observed also. This subfacies most probably represents levee sediments. It is similar to those described in Niger delta sediments by Allen (1965) and to inter-distributary bay sediments of the Mississippi delta (Coleman *et al*., 1964). The fine sediments of this subfacies mainly settle out from suspension as indicated by presence of claystones and mudstones and parallel lamination of the siltstones. However, the micro-cross lamination of some siltstones and sandstones units might indicate current action with formation of ripples.

Subfacies 2b: Mudstone and claystone sediments

This subfacies is composed mainly of claystone and mudstone sediments, however, siltstone units are observed. The sediments are massive and light brown to medium brown in color. Although most of these claystones and mudstones are looking massive but parallel-laminations due to variations in color or sometimes in grain size and wavy-laminations were observed. The predominance of clay and mud content in this subfacies and the presence of parallel-laminae suggested normal and quite flood water as the environment of deposition of these sediments.

Subfacies 2c: Coarsening-upward and small scale fining-upward sequences

These sequences, when present are forming part of the flood plain sediments of the large scale fining-upward cycles. The coarsening-upward sequence starts with claystones and/ or mudstones pass gradually into siltstones and sandstones. The small scale fining-upward sequence starts with sandstones normally range from (0.5 – 1.2) m in thickness, changes to siltstones and claystones and/ or mudstones. These sequences are randomly distributed and interrupted the usual fine grained sediments of the large scale fining upward cycles. Coarsening-upward sequence passes gradually into small scale fining upward sequence and vice versa cases were sometimes observed. Sandstone units with sharp bases of non vertical variation in the grain size and range in thickness from (0.3 – 1.4) m were also sometimes observed in the studied sediments. Based on the random distribution of these sequences, their interruption to the usual overbank sediments and the sharp bases of the sandstone units suggested that this subfacies was most probably laid down by crevasse splays. These crevasse splays are formed when the flood water passes through a distinct breach in the levee into adjacent basin. The claystones, mudstones and siltstones of this subfacies are thought to have been partly deposited by overbank flooding and partly from crevasse splays.

The coarsening-upward sequences most probably represent minor mouth bars, formed by the progradation of permanent crevasse splay(s) into flood basin (shallow lake) in a process similar to the processes of delta formation. This is indicated by the relatively small thickness of the sandstones, normally range from (0.4 – 4.0) m and their random distribution in the overbank sediments. The small scale fining upward sequences are similar to the large scale fining-upward cycles and represent small meandering channel deposits. The coarsening-upward sequences pass gradually to fining-upward sequences and vice versa, most probably suggested that the coarsening-upward sequences represent minor mouth bar sediments followed by the deposition of the fining-upward sequences, produced by small scale meandering crevasse channels, after the progradation of the mouth bar sediments. The switching of this crevasse splays, however might produce such sequences also, without progradation of the mouth bar. The gradual changes from fining-upward to coarsening-upward might indicate that the small meandering crevasse channel was switched and then the same area covered by shallow lake. In this lake minor mouth bars are formed by returning back of the previous small channel or by another crevasse channel and consequently coarsening upward sequence was deposited above the previous deposits of fining-upward sequence.

Subfacies 2d: Carbonate sediments

Very thin layers of carbonate units are sometimes randomly present in the fine grained sediments of Injana Formation in Baiji locality only. The sediments are light grey to grey in color. They consist of microcrystalline calcite, sometimes recrystallized into spary grains and contain fresh water fauna such as ostracods, gastropods and charaphytes. These sediments might represent an alluvial shallow lake deposits in an arid climate.

DISCUSSION

It can be seen from the mentioned explanations that the Injana Formation was deposited by meandering fluvial system. The investigation of the borehole sediments reflects cyclic arrangement both of coarse and fine sediments. These cycles are composed of repeated large scale fining-upward in grain size sequences. Randomly distributed and non repeated coarsening-upward and small scale fining-upward sequences were observed in the fine grained sediment facies of the large scale fining upward cycles of the studied formation.

Tuker and Shawkat (1980) indicated that the underlying Fatha Formation (Middle Miocene) of the Mesopotamian Basin of Iraq is cyclic in nature with common rhythm being marl, claystone, limestone and gypsum, formed mainly by tectonic activity with eustatic sea level changes and plate tectonics as contributory factors. Kukal and Al-Jassim (1971) pointed out that the tectonic is the most important factor for the cyclicity, reflected by the arrangement of sandstones and claystones of the overlying fluviatile Mukdadiya Formation (Pliocene) in the Mesopotamian Basin of Iraq, also.

Vertical movements were important during the Miocene in Iraq (Buday and Tyracek, 1980). It is believed that vertical crustal movements might be an important factor in the repetition of large scale fining-upward cycles, similar to those interpreted to the underlying Fat`ha and overlying Mukdadiya Formations. The randomly distributed and non repeated coarsening-upward and small scale fining-upward sequences (Subfacies 2c) in the fine grained sediment (overbank) facies of the large scale cycle of the studied formation might be related to the overbank sedimentation produced by crevasse splays. These crevasse splays might be formed in shallow lake coarsening-upward sequences formed by small lobes of sands and silts, similar to the lobes of delta, but smaller in scale. These crevasses could form small scale fining upward sequence in similar processes of the main fluviatile channels.

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REFERENCES

Al-Banna, N.Y.M., 1982. Sedimentological study of the Upper Fars Formation in selected areas – northern Iraq. Unpublished M.Sc. Thesis. Mosul University, 177pp.

Al-Haddad, A.A., El-Chair, M.M. and Ali, O.E.I., 1996. Depositional environments and facies of Late Jurassic – Early Cretaceous Messak Formation, Awbari – Sebha area, Murzuk Basin, SW Libya. J. Sabha University, 3, p. 1 – 25.

Allen, J.R.L., 1964. Studies in fluviatile sedimentation of six cyclothems from the Lower Old Red Sandstone, Anglo-Welsh Basin. Sedimentology, 3, p. 163 – 138.

Allen, J.R.L., 1965. Late Quaternary Niger delta and adjacent areas; sedimentary environments and lithofacies. Bull. Am. Ass. Petro. Geol., 49, p. 547 – 600.

Al-Mubarak, M. and Youkhana, R., 1976. Report on the regional geological mapping of Al-Fatha – Mosul area., GEOSURV, int. rep. no.753

Al-Rawi, Y.T.; Sayyab, A.S.; Jassim, J.M.; Tamar-Agha, M.; Al-Sammarai A.L.; Karim, S.A; Basi, M.A.; Dhiab S.H.; Faris, F.M. and Anwar, J.F., 1993. New names for some of the Middle Miocene – Pliocene Formations of Iraq (Fat`ha, Injana, Mukdadiya and Bai Hassan Formations). Iraq. Geol. J., 25, p. 1 – 17.

Al-Sammarai, K.I., 1978. Petrology of the Upper Fars sandstones and the origin of their cement. Unpublished M.Sc. thesis, University of Baghdad, 141pp.

Basi, M.A., 1973. Geology of Injana area, Hemrin south, Unpublished M.Sc. thesis, University of Baghdad, 127pp.

Basi, M.A., and Karim S.A., 1990. The stage report of the Local Geological Survey, Vol. II. Laboratory Studies, GEOSURV, int. rep. no. 264.

Bellen, R.C.V.; Dunnington, H.V.; Wetzel, R. and Morton, D.M.I., 1959. Lexique Stratigraphique International V.3, Asia, fasc. 10a, Iraq., Paris, 333pp.

Buday, T. and Tyracek, J., 1980. The regional geology of Iraq, Volume 1, Stratigraphy and Paleogeography. GEOSURV, Baghdad, 445pp.

Coleman, J.M., Gagliano, S.M and Webb, H., 1964. Minor sedimentary structures in a prograding distributary. Mar. Geol. 1, p. 240 – 258.

Dunnington, H.V., 1958. Generation, migration, accumulation and dissipation of oil in Northern Iraq, in weeks L.G. (ed), Habitate of oil, a symposium. Assoc. Petrol. Geol. Spec. Pub., p. 1194 – 1251.

Jassim , S.Z.; Karim , S.A.; Basi , A.; Al-Mubarak, M. and Munir, J., 1984. Final report on the regional geological survey of Iraq . Vol.3, Stratigraphy. GEOSURV, int. rep. 498 pp.

Kukal, Z., and Saaddallah, A.A., 1970. Paleocurrents in Mesopotamian Geosyncline, Sander Drukkans der Geologischen Runschan Band. 59, p. 666 – 685.

Kukal, Z. and Al-Jassim J., 1971. Sedimentology of Pliocene molasse sediments of the Mesopotamian Geosyncline. Sedim. Geol. 5, p. 57 – 81.

Selley, R.C., 1977. An introduction to sedimentology. Academic press London, New York, San Francisco, 408pp.

Tucker, M.E. and Shawkat, M.G., 1980. The Miocene Gachsaran Formation (formerly Lower Fars) of the Mesopotamian Basin, Iraq: Sabkha cycles and depositional control. Jour. Geol. Soc. Iraq (special issue). 13, p. 261 – 267.

Yacoub, S.Y., Deikran, D.B. and Ubaid, A.B., 1990. Earth science activities for site selection of nuclear power plant in Iraq, Local geological stage report. GEOSURV, int. rep. no. 2016.