Bulletin of the Geological Society of Malaysia, Volume 73, May 2022, pp. 163 - 169
DOI: https://doi.org/10.7186/bgsm73202213

A stratigraphic analysis of the Khasib, Tanuma and Sa'di formations in the Majnoon oil field, southern Iraq

Hamid A.A. Alsultan[1], Falah H.H. Maziqa[2], Mohanad R.A. Al-Owaidi[1,*]

[1] Department of Applied Geology, College of Science, University of Babylon, 51002 Hilla, Babylon, Iraq
[2] Directorate General of Education in Holy Karbala Province, 56001 Karbala –Iraq
* Corresponding author email address: sci.mohanad.rasim@uobabylon.edu.iq

Abstract: The carbonate platform is the environment of Khasib, Tanuma and Sa'di formations which were deposited within open shelf settings at the Majnoon oil field in eight microfacies. The deposition, based on the analysis of microfacies, took place within shallow open marine, shoal environment, deep marine and basin environments. Five third order cycles of succession consist in MJ-12 oil well and three third order cycles in the MJ-15 oil well. They represent successive episodes of sea level rise and standstills. The succession in the study area was formed in a high subsidence environment, reflecting the high subsidence as the main controlling factor in the sequence creation. Because of a significant transgression, the Khasib, Tanuma, and Sa'di formations were deposited on an extremely subsidential carbonate base, where sea level succession involved episodes of rise and standstills.

Keywords: Khasib Formation, Tanuma Formation, Sa'di Formation, stratigraphic analysis, Majnoon oil field

INTRODUCTION

This research focuses on the stratigraphy and paleoenvironment aspects of the Khasib, Tanuma, and Sa'di formations in the Majnoon oil field, south Iraq. Two boreholes are included in the present study *viz.* MJ-12 and MJ-15 oil wells.

The Majnoon oil field is a north-south anticline in southern Iraq located about 60 km north-west of Basrah. Overall, the extension is about 36.4 km in length and 11 km in width, covering an area of about 400 km^2. The Majnoon oil field area is situated within the Zubair sub-zone of Mesopotamia (Buday, 1980 in Jassim & Goff, 2006) (Figure 1). Basrah territory sits on the stable shelf of the Mesopotamian basin. It is characterized by the occurrence of gently elongated anticlines and dome-like structures (Aqrawi *et al.*, 2010). The Majnoon system is located on the eastern edge of the district of Basrah, not far from the western border of the orogeny belt of Zagros (Aqrawi *et al.*, 2010).

In Iraq, the Late Turonian-Danian Megasequence (Megasequence AP9) is most common. It is present throughout the region with the exception of the Zagros belt interior and on parts of the ENE-WSW-guided Hauran Uplift in western Iraq. It was deposited after the ophiolite interception that emerged in the southern part of New Tethys (Jassim & Goff, 2006). Because of such a reversal, broad north-south directional systems have been developed in southeastern Iraq. On the stable shelf, new basins have arised and developed, extending from northwest to southeast and others from east to west directions. The earliest Turonian deposits are limited to the Mesopotamian region and the sub-island region, although before the intra-Senonian erosion, they may have been broadly dispersed. The lower part of this megasequence is identified by the Khasib, Tanuma, Sa'di, and Komitan formations. The Hartha, Digma, Tayarat, Aqra, Bekhme, Shiranish, and Tanjero formations reflect the peak of the mega-hierarchy (Jassim & Goff, 2006).

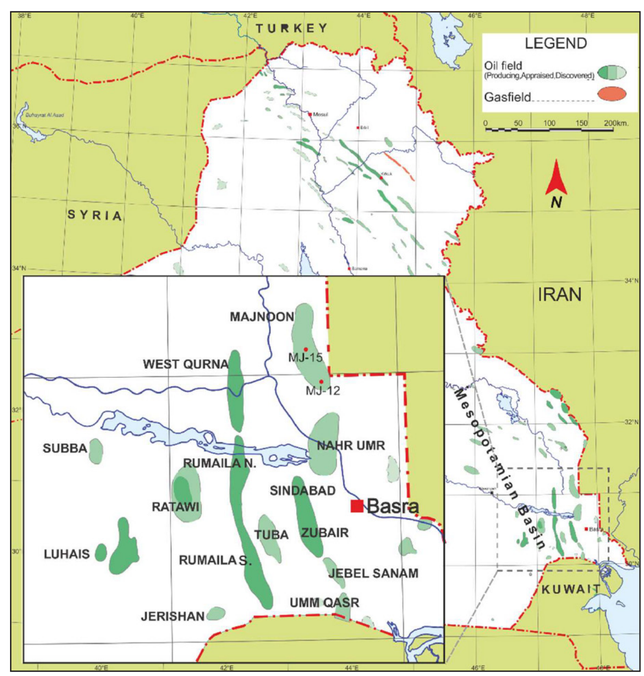

Figure 1: Location Map of the studied area (Majnoon oil field), modified from Al-Khafaji *et al.* (2021).

0126-6187; 2637-109X / Published by the Geological Society of Malaysia.

The Mesopotamian Zone is tectonically divided into three subzones, *viz*. Tigris Subzones, Euphrates Subzones, and Zubair Subzones. The Zubair Subzone includes the study area around the Basrah city (Jassim & Goff, 2006). The Megasequence (AP9) is divided into Late Turonian-Early sequence (which includes Khasib, Tanuma, and Sa'di formations) and Late Campanian-Maastrichtian sequence (which includes Hartha, Tayarat, and Shiranish formations).

A full sedimentary phase of the Khasib, Tanuma, and Sa'di formations represents the succession of the Turonian-Lower Campanian in the Mesopotamian Basin. In some oil fields, the carbonate series include several variations of shale and marl, alternating with some units of porous and broken carbonate (Aqrawi *et al*., 2010) (Figure 2). The Khasib Formation is the most proximal member of the Late Turonian-Early Campanian Series (Chatton & Hart, 1961). The Khasib Formation has been identified by Owen & Nasr (1958) from the Zubair Well 3 in the Mesopotamian Basin region. The thickness of it reaches to 100 m in SE Iraq (Aqrawi *et al*., 2010).

The upper part (with thickness reaching to 30 m) consists of fine gray, argillaceous calcareous grains (van Bellen *et al.*, 1959). The typically thickest of Khasib Formation is located in the Mesopotamian Zone within Tigris Subzone. The Khasib type section contains relatively rare fossils. While, many other wells contain relatively more rich assemblages (Darmoian, 1975), for example, the *Oligostegina* sp. assemblages that is plentiful. van Bellen *et al.* (1959) propose that the Late Campanian could be the established age for the formation. Chatton & Hart (1961) rule that the formation is Turonian-Early Campanian. A Turonian age corresponds to the appearance of the genus *Globotruncana lapparenti* in the planktonic foraminifera. The formation, according to Darmoian (1975), is from the Late Turonian to Coniacian period. The *Oligostegina* fauna and the dwarfed appearance of the fossils indicate that the deposition of the Khasib Formation lies in a restricted basin. It also offers free *Globotruncana* marine assemblages (Jassim & Goff, 2006).

In southern Iraq, Owen & Nasr (1958) describe the Tanuma Formation at Zubair-3 well. It consists of (30 m) fissile black (locally pyritic) shale with green, microcrystalline, argillaceous, and detrital (sometimes glauconitic) calcareous layers, with an oolitic calcareous layer at the top (Macleod, 1961; Safar, 1961; Kasim, 1962; Ditmar & the Soviet-Iraq Team, 1972). The thickness of the Tanuma Formation of southeastern Iraq exceeds 60 m but wedges out in all directions.

Darmoian (1975) determines the age of Tanuma and Khasib formations as a Coniacian, where the Tanuma Formation typically conformably overlies the Khasib Formation. The Sa'di Formation is the most prevalent, thickest, and youngest formation. Owen & Nasr (1958) have carried out the description of the typical section of the Zubair-3 well. Chatton & Hart (1961) and Ditmar & the Iraqi-Soviet (1972) have changed the formation concept and age. It contains parts of the Hartha (Pilsner) Formation in the Sa'di Formation. The Sa'di Formation consists of 300 m of gray, chalky, argillaceous and globigerinal calcareous with a 60 m thick marl bed at the edges. The upper part of the formation also includes calcareous organodetritals outside the type area (van Bellen *et al.*, 1959). The thickest Sa'di Formation along the Mesopotamian and Salman zones borders reaches to more than 450 m (same as the Hartha Formation). Owen & Nasr (1958) attribute the formation to a Late Senonian age. van Bellen *et a1*. (1959) propose that it could be of Late Campanian age.

The aim of the present study is to investigate the Khasib, Tanuma, and Sa'di formations in the oil field of Majnoon so as to perform facies analysis and, to interpret the depositional environment and the stratigraphic sequence responsible for the formation of basins.

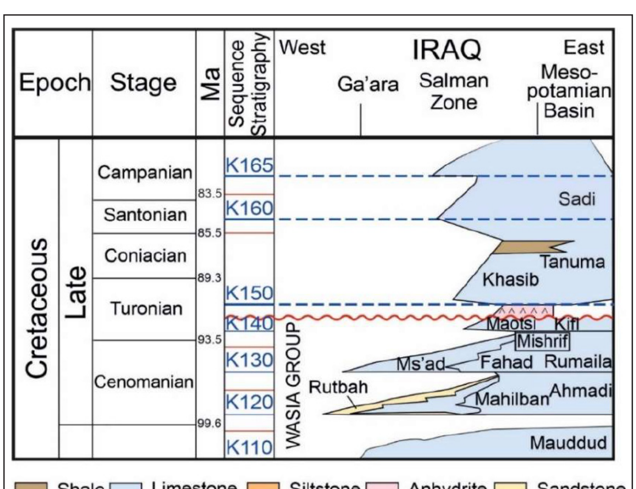

Figure 2: Stratigraphic correlation of southern Iraq modified from Sharland *et al.* (2001).

METHODOLOGY

The studied area is the Majnoon oil field, which is situated in the southern Iraq approximately 60 km northwest of Basra city near the Iraqi-Iranian frontier, where it extends north to the governorate of Missan. Two boreholes have been studied viz. MJ-12 (E 47°35′51″, N 31°2′3″) and MJ-15 (E 47°38′43″, N31°0′3″) (Figure 1).

The petrographic research and analysis of the microfacies focused on the examination of 120 thin sections prepared from rock cuttings from the selected wells (MJ-12, and MJ-15). The thin section study by using a microscope focused on determining the species of fossils that are present in each formation. The thin sections have been configured in the mineralogy laboratory of the Department of Applied Geology, University of Babylon. The rock samples of Khasib, Tanuma and Sa'di formations as well as the sequence stratigraphic subdivision and correlation studies were borrowed from the Basra Oil Company (BOC).

RESULTS AND DISCUSSION

Microfacies

Within a comprehensive petrographic analysis, the texture of depositional carbonate grains and their forms are treated. Expanded classification of Dunham (1962) has been used to define the classification of the carbonate rocks.

A comprehensive petrographic analysis of the sediment texture and particles forms of carbonate takes into consideration sediment microfacies types (Flugel, 2004; Wilson, 1979). Organic or inorganic limestone particles greater than the groundmass include grains, objects, materials, and assignments indicating grains that were physically deposited and, in most instances, have been transported. It is necessary to divide carbonate granules into skeletal granules and non-skeletal granules.

Segmented or full skeletons of animals, sized from 0.05 mm to several centimeters, are skeletal granules. The structural granules of organisms may consist of calcite, calcite magnesia, aragonite, or silica (Flugel, 2004). Non-structural granules are those not specifically derived from microorganisms structural materials. Only hi-energy granules are prevalent and are represented by ooids and peloids. Within the sections studied, four carbonate microfacies have been identified:

Planktonic mudstone (PM)

The main skeletal components, planktonic foraminifera such as *Heterohelix* sp., *Globigerina* sp., *Hedbergella* sp., at MJ-12 and MJ-15 oil well are normal in the middle part of Khasib (Figure 3A). Neomorphism, cementation and dolomitization including fractures filled with cement and geopetal structures are the typical diagenetic characteristics in this microfacies. It also has low intraparticles porosity. This relates to the standard microfacies (SMF3) in (FZ1)

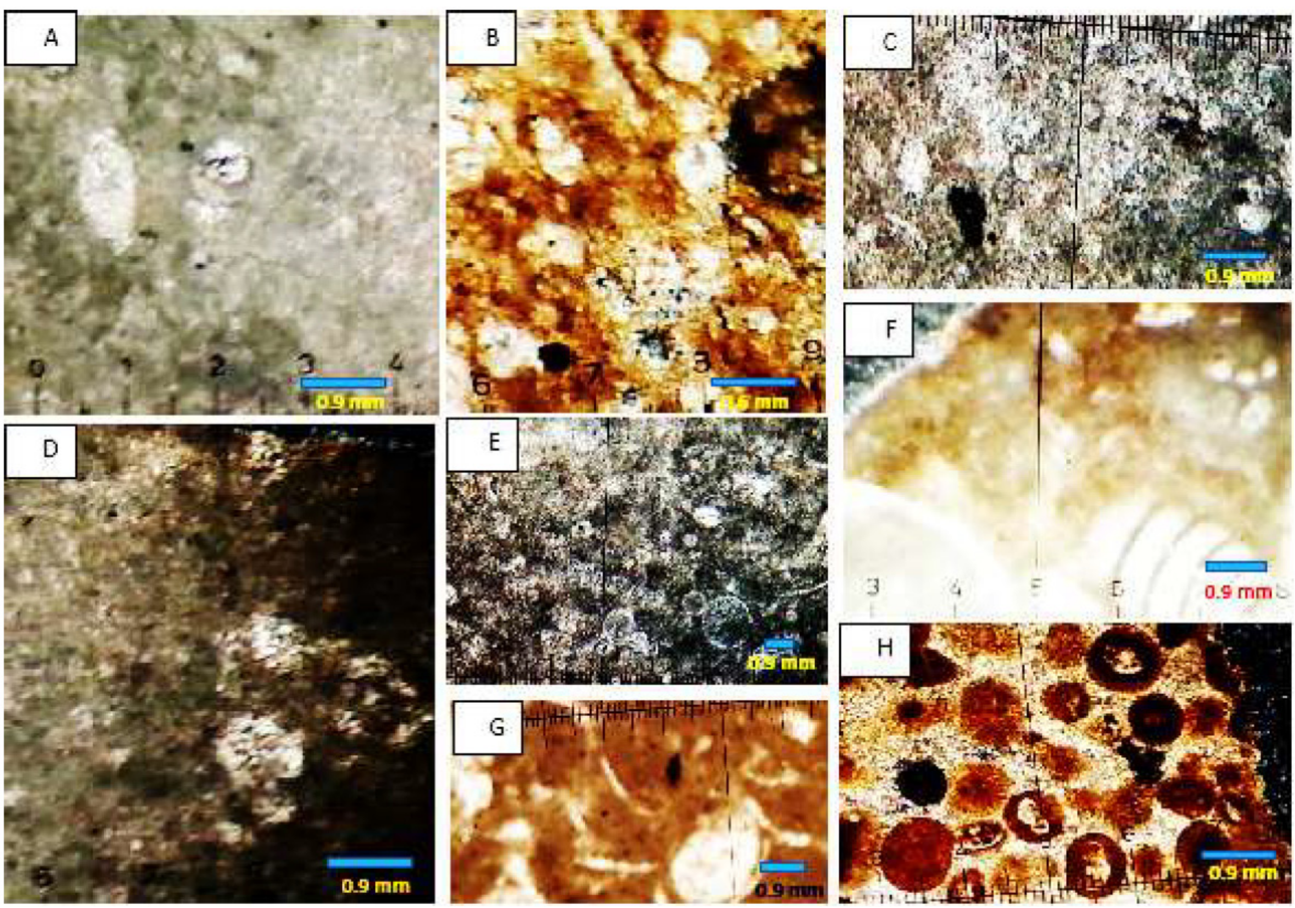

Figure 3: Microfacies of the studied formations :
A- Planktonic of mudstone (Khasib Formation MJ-12) at depth 2509 m.
B- Planktonic of wackestone (Khasib Formation MJ-15) at depth 2513 m.
C- Planktonic bioclastic wackestone (Sa'di Formation MJ-15) at depth 2411 m.
D- Planktonic bioclastic mudstone (Sa'di Formation MJ-12) at depth 2350 m.
E- Planktonic bioclastic packstone (Sa'di Formation MJ-12) at depth 2400 m.
F- Foraminifera bioclastic wackestone (Tanuma Formation MJ-12) at depth 2457 m.
G- Foraminiferal bioclastic packstone (Sa'di Formation MJ-15) at depth 2390 m.
H- Peloids grainstone (Tanuma Formation MJ-12) at depth 2470 m.
(All photos are crossed nicols).

of Wilson (1975), and according to him, it reflects a basinal setting as compared to the standard types of microfacies.

Planktonic fossiliferous wackestone (PW)

The primary constituents of this microfacies are *Heterohelix* sp., *Globigerina* sp. and *Hedbergella* sp. (Figure 3B). There are also a few benthos and rare radiolarians. Cementation, compaction, dissolution, and dolomitization are the main diagenetic processes affecting such microfacies. The microfacies of planktonic wackestone are identified as typical microfacies (SMF2) of (FZ-1) according to Wilson (1975), who described the basinal environment.

Planktonic bioclastic wackestone (BPW)

The components of the microfacies are small and some intervals have low diversity through the parts. Characterized by planktonic foraminifera, such as *Heterohelix* sp., *Globigerina* sp. and bioclasts, this microfacies is typical (Figure 3C). This may reflect a condition of low energy underneath the wave base (Flugel, 2004). The successful diagenetic characteristics include compaction (plane shell deformation), cementation (filling, fractures), and micritization. Authentic minerals (pyrite and glauconite) were found including the microfacies, which represent deposition of deep shelf (FZ.2 SMF-8 (Wilson, 1975)).

Four primary habitats have been identified as being shallow open marine environment, shoal environment, deep sea environment and basin environment (Figures 4 and 5).

Planktonic bioclastic mudstone (BPM)

Planktonic foraminifera such as *Heterohelix* sp., *Globigerina* sp. and *Hedbergella* sp. distinguish such microfacies (Figure 3D). Compaction and cementation are the diagenetic features in this microfacies, including glauconite and pyrite covered skeletal grains. This microfacies is identical with the regular microfacies (SMF-2) and (FZ-2) that characterize the deep shelf environment (Wilson, 1975).

Planktonic bioclastic packstone (BPP)

Planktonic foraminifera such as *Heterohelix* sp., *Globigerina* sp., and the bioclasts characterize this microfacies. The process of diagenetic affecting this microfacies is mainly neomorphism, dolomitization which occurs as floating subhedral to euhedral medium to coarse size scattered rhombs, cementation, and compaction where dissolution is also common (Figure 3E).

Foraminiferal bioclastic wackestone (FbW)

Foraminiferal bioclastic wackestone is characterized by benthonic foraminifera, shell fragments and echinoderm fragments assemblages. Neomorphism, dolomitization, dissolution and cementation are the diagenetic processes that affect this microfacies (Figure 3F).

Foraminiferal bioclastic packstone (FbP)

This microfacies is less common and has been recognized in small intervals. Benthonic foraminifera, small bioclasts and fragments of echinoderm characterize it (Figure 3A and G). Neomorphism, dolomitization, dissolution and cementation are the diagenetic processes that affect this microfacies.

Peloidal grainstone (OG)

This microfacies is made up of medium to coarse grain peloids and ooids and culminates in most cases with the upward coarsening series (Figure 3H).

DEPOSITIONAL ENVIRONMENT

The paleoenvironment of the Khasib, Tanuma, and Sa’di formations is primarily based on the microfacies type. Grain forms (skeletal and non-skeletal) and depositional texture determine the recognized microfacies. Facies associations have been contrasted with Flugel’s (2010) proposed model of standard.

Shallow open marine environment

The shallow open marine environment has been defined only in the Sa'di Formation (Figures 4, 5). This consists mainly of foraminiferous bioclastic, wackestone and packstone. Foraminiferal bioclastic wackestone microfacies, which are at various intervals is the most prominent in the Sa’di Formation.

They are distinguished by an abundance of benthonic foraminiferous fragments, shell fragments and Echinoderm fragments. Foraminiferous bioclastic packstone microfacies is less common and is recognized in small intervals. Benthonic foraminifera, minor bioclasts and echinoderm fragments characterize it.

The shoal facies grow under intertidal conditions in a high energy environment and in most cases it is the culmination of the upward coarsening sequence (Burchette, 1993).

The shoal facies within the Tanuma Formation is the most important environment. This facies is composed of medium to large grained peloids and ooids. It is mostly represented by ooidal grainstone microfacies, consisting of ooids and peloids. Neomorphism and dissolution are the diagenetic processes influencing this microfacies.

Deep marine environment

The deep marine environment is generally recognized within the Khasib and Sa’di formations. This condition is defined by bioclastic planktonic wackestone microfacies which is typical and characterize most parts of the Sa’di Formation, and very small intervals are common in Khasib and Tanuma formations with planktonic foraminifera such as *Heterohelix* sp., *Globigerina* sp. and characterized bioclasts.

Bioclastic planktonic mudstone microfacies is common and characterize the Khasib Formation, with small intervals

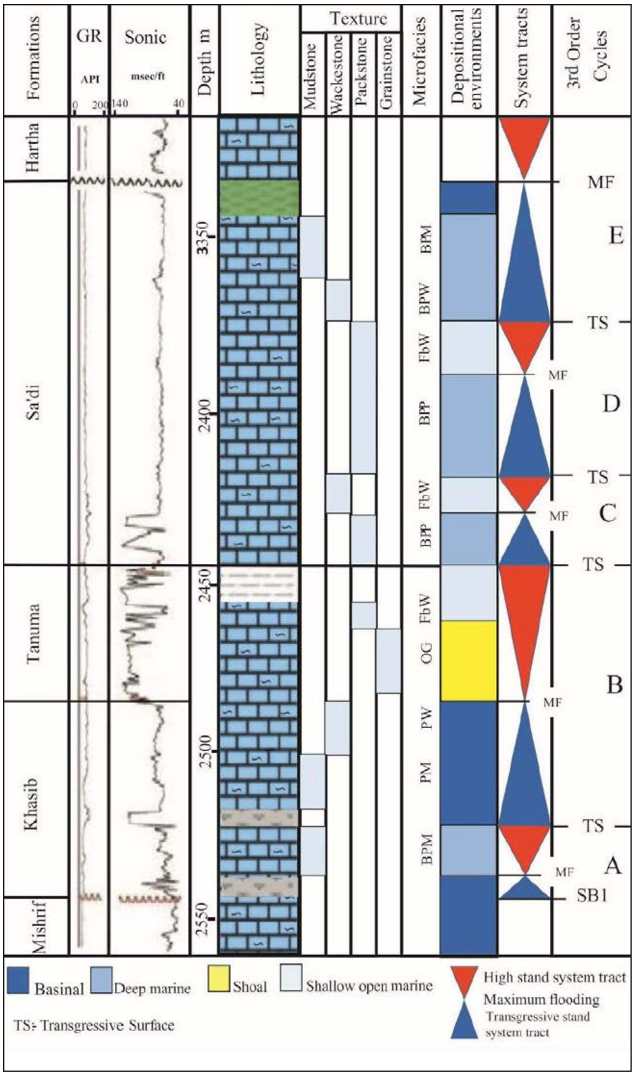

Figure 4: Sequence stratigraphy subdivision at MJ-12 oil well.

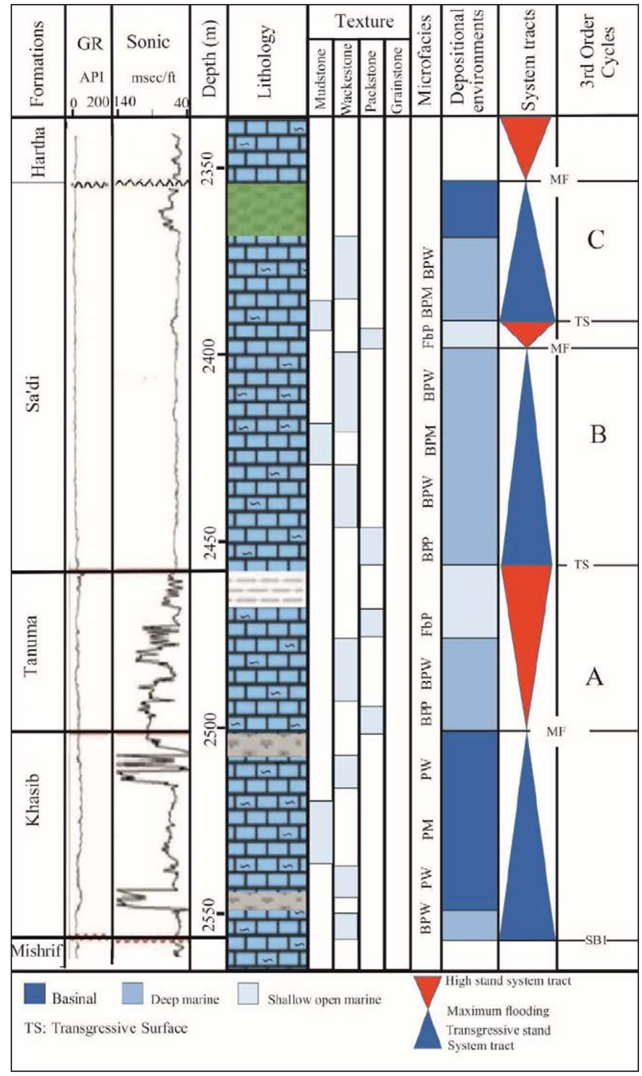

Figure 5: Sequence stratigraphy subdivision at MJ-15 oil well.

in Sa'di Formation. The planktonic foraminifera, such as *Heterohelix* sp., *Globigerina* sp. in addition to *Hedbergella* sp., characterize such microfacies where bioclasts also exist.

The process of diagenetic affecting this microfacies is mainly neomorphism, dolomitization which occurs as floating subhedral to euhedral medium to coarse size scattered rhombs, cementation, compaction, and dissolution.

Basinal environment

The basin environment is known to be literally the end of the aquatic environmental continuum, which starts from the coast area and ends in the deepest part of this sedimentary basin. Basinal surroundings are generally preserved against the action of waves, surface waves in addition to ordinary tidal effects, even at a few hundred meters deep. Basinal facies are most common in the Sa'di and Khasib formations; and represented by planktonic foraminifera mudstone, planktonic foraminifera and planktonic wackestone microfacies.

This microfacies is characterized by planktonic mudstone microfacies, such as *Heterohelix* sp., *Globigerina* sp. and *Hedbergella* sp., and is typical in Khasib Formation. It is also characterized by planktonic foraminifera species such as, *Hetrohelix*, *Globigerina*, and *Hedbergella*, planktonic wackestone microfacies, which is common within Khasib Formation. Neomorphism is the diagenetic processes affecting this microfacies.

SEQUENCE DEVELOPMENT

Sequence stratigraphy, depending on Van Wagoner *et al*. (1988) identification, is the analysis of facies associations genetically linked with periodic strata within a time span. By using and integrating numerous types of data, including seismic data, well data, and outcrop data, and by taking into account various geological disciplines, it has become a real instrument or technique in petroleum discovery and reservoir characterization. In siliciclastic structures (eg, Van Wagoner *et al.*, 1988; Wilgus *et al.*,

1988) as well as shallow water carbonate, this technique has been commonly applied (e.g., Loucks & Sarg, 1993; Kerans & Tinker, 1997).

In the work of Wheeler (1959) and Sloss (1962), principles of modern stratification can be traced back to 1962 and 1963. The significance and usefulness of connecting coordinated surfaces through geological divisions have been recognized by them. Their use of chronostratigraphy for stratification has provided the route to seismic strata development.

The succession studied represents five cycles of third order in well MJ-12, and three cycles of the third order (A, B, and C) in well MJ-15, and are represented in Figure 4 and Figure 5, respectively.

These are the intervals asymmetric. Every cycle starts with a transgressive system tract (TST), represented by microfacies of bioclastic planktonic packstone and bioclastic planktonic wackestone, or microfacies of planktonic mudstone and planktonic wackestone deposited in deep marine and basinal environments as retrograde parasequences.

The upper border is distinguished by maximum flooding (MF) followed by the high-stand system tract (HST), deposited as programmatic parasequences deposited within the shallow open marine environments (Figures 4 and 5). The cyclicity asymmetry is a result of the varying magnitude and symmetry of the relative fluctuation of sea level. The varying magnitudes reflect the successive intervals of the rise in sea level and its stands. The high-rate subsidence in this region has formed the succession in the study area, which indicates that it is the key factor that controlled the development of sequences.

CONCLUSIONS

The extensive petrographic study and microfacies analysis that has been accomplished from the Khasib, Tanuma and Sa'di formations in addition to information from MJ-12 and MJ-15 wells, representing the Majnoon oil field that is located about 60 km at northwest Basrah in southern Iraq, has provided detailed information on the various aspects of petrography, depositional environment and sequence growth.

The facies analysis shows the deposition environment of Khasib, Tanuma, and Sa'di formations has been shallow open marine, shoal environment, deep marine environment, and basin environment. Eight microfacies are identified: planktonic mudstone, planktonic wackestone, bioclastic planktonic wackestone, bioclastic planktonic mudstone, bioclastic planktonic packstone, foraminiferal bioclastic packstone and ooidal grainstone.

Five third order cycles (A, B, C, D and E) in MJ-12 well, and three as third order (A, B, and C) in MJ-15 well, which are asymmetrical; the cyclicity asymmetry is due to the varying frequency and symmetry of the relative fluctuation of sea level. They represent successive episodes of sea level rise and still-stand. The succession in the study area was formed in a high subsidence environment, reflecting the high subsidence as the main controlling factor in the sequence creation. Because of a significant transgression, the Khasib, Tanuma, and Sa'di formations were deposited on an extremely subsidential carbonate base, where sea level succession involved episodes of rise and standstills.

ACKNOWLEDGEMENTS

The authors are grateful to the Basra Oil Company of Iraq (BOC) for providing the cut rock samples, data, and reports. Many thanks and gratitude are due to the authority and mineralogical laboratory staff of the Applied Geology Department, the University of Babylon for their assistance in preparing the thin sections. Many thanks to the reviewers, who added their valuable comments that improved the manuscript.

AUTHOR CONTRIBUTIONS

HAAA and FHHM conducted fieldwork, took samples, carried out the facies analysis, and participated in the interpretation of the results. MRAA made the slides from collected samples, drew diagrams and maps, reviewed the manuscript, and did the corresponding with the journal.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare that are relevant to the content of this article.

REFERENCES

Al-Khafaji, A.J., Hakimi, M.H., Mohialdeen, I.M., Idan, R.M., Afify, W.E. & Lashin, A., 2021. Geochemical characteristics of crude oils and basin modeling of the probable source rocks in the Southern Mesopotamian Basin, South Iraq. Journal of Petroleum Science and Engineering, 196, 107641, 1-23. https://doi.org/10.1016/j.petrol.2020.107641.

Aqrawi, A.A.M., Goff, J.C., Horbury, A.D. & Sadooni, F.N., 2010. The petroleum geology of Iraq. Scientific Press Ltd., Beaconsfield, Bucks, UK. 242 p.

Buday, T., 1980. The regional geology of Iraq. Stratigraphy and paleogeography. Dar Al-Kutib Publ. House, Mosul, Iraq. 445 p.

Burchete, T.P., 1993. Shilaif basin in the Rub Al-Khali (Arabian) basin. Bp Exploration, Sunbury on Thames, Middlesex, U.K., 185-199.

Chatton, M. & Hart, E., 1961. Review of the Cenomanian to Masstrichtian stratigraphy in Iraq. Manuscript report No. 2/141, INOC Library, Baghdad, Iraq.

Darmoian, S.A., 1975. Planktonic foraminifera from the Upper Cretaceous of Southern Iraq. Biostratigraphy and systematic of the Heterohelicidae. Micropaleontology, 21(2), 185-214. https://doi.org/10.2307/1485023.

Dunham, R.J., 1962. Classification of carbonate rocks according to depositional texture. In: Ham, W.E. (Ed.), Classification of carbonate rocks a symposium. American Association of Petroleum Geologists, memoir 1, 108 -121.

Flugel, E., 2004. Microfacies of carbonate rocks: Analysis, interpretation and application. Springer-Verlag, Berlin, Heidelberg, New York. 976 p.

Flugel, E., 2010. Microfacies of carbonate rocks: Analysis, interpretation and application. 2nd Edition, Springer-Verlag, Berlin, New York, Springer. 984 p.

Jassim, S.Z. & Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Czech Republic. 341 p.

Kerans, C. & Tinker, C., 1997. Sequence stratigraphy and characterization of carbonate reservoirs. SEPM Short Course Notes, 40. 130 p.

Loucks, R.G. & Sarg, J.F., 1993. Carbonate sequence stratigraphy-recent developments and applications. AAPG Memoir 57. AAPG, US. 545 p.

Owen, R.M.S. & Nasr, S.N., 1958. The stratigraphy of the Kuwait-Basrah area. In: Weeks, G.L. (Ed.), Habitat of oil a symposium. Amer. Assoc. Pet. Geol. Tulsa. Petroleum Geologists Bulletin, 62, 201 – 222. https://doi.org/10.1306/SV18350C50.

Sharland, P. R., Archer, R. & D. Casey, 2001. Arabian Plate sequence stratigraphy. Geo Arabia Special Publication, Gulf Petro Link, Bahrain. 387 p.

Sloss, L.L., 1962. Stratigraphic models in exploration. Journal of Sedimentary Research, 32(3), 415–422. https://doi.org/10.1306/74D70CD6-2B21-11D7-8648000102C1865D.

Sloss, L.L., 1963. Sequences in the cratonic interior of North America. Geological Society of America Bulletin, 74, 93-114. https://doi.org/10.1130/0016-7606(1963)74[93:SITCIO]2.0.CO;2.

van Bellen, R.C., H.V. Dunnington, R.Wetzel & D.M. Morton, 1959. Lexique stratigraphique international Vol. 3, Asie Fasc. 10a Iraq. Centre National de Ia Recheche Scientifique, Paris. 333 p.

Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M.Jr., Vail, P.R., Sarg, J.F., Loutit, T.S. & Hardenbol, J., 1988. An overview of the fundamentals of sequence stratigraphy and key definitions. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A. & van Wagoner, J.C. (Eds.), Sae-level changes-an integrated approach. SEPM Spec, 42, 39-45.

Verma, M.K., Ahlbrandt, T.S. & Al-Gailani, M., 2004. Petroleum reserves and undiscovered resources in the Total Petroleum Systems of Iraq: Reserve growth and production implications. GeoArabia, 9(3), 51-74.

Wheeler, H.E., 1959. Unconformity bounded units in stratigraphy. AAPG Bulletin, 43, 1975-1977. https://doi.org/10.1306/0BDA5E85-16BD-11D7-8645000102C1865D.

Wilgus, C.K., Hastings, B.S., Kendall, C.G., Posamentier, H.W., Ross, C.A. & Van Wagoner, J.C., 1988. Sea-level changes-an integrated approach. SEPM Spec. Publ., 42, 407 p. https://doi.org/10.2110/pec.88.01.

Wilson, J.B., 1979. Biogenic carbonate sediments on the Scottish continental shelf and on Rockall Bank. Marine Geology, 33(3-4), 85-93.

Wilson, J. L., 1975. Carbonate facies in geologic history. Springer–Verlag, New York. 471 p.

Manuscript received 11 February 2021;
Received in revised form 28 April 2021;
Accepted 30 April 2021
Available online 19 May 2022