SEQUENCE STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS AND RESERVOIR CHARACTERIZATION OF SA'DI FORMATION IN EAST BAGHDAD AND HALFIYA OILFIELDS

¹Ezzat I. Al-Fandi, ¹Zaid A. Malak* and ¹Naktal A. Hadid

¹Department of Geology, College of Science, University of Mosul, Mosul, Iraq

*E-mail: zaidmalak@uomosul.edu.iq

Received: 12 July 2019; accepted: 10 February 2020

ABSTRACT

Turonian-Early Campanian sediments (AP 9) are restricted to area of Mesopotamian and the Jezira Subzone. It was deposited in relatively narrow seaway that occupies the area of the salman, Mesopotamian, Foothill and high folded zones. The lower part of this megasequence is revealed by the Khasib, Tanuma, Sa'di and Kometan formations. This study is based on samples from two wells; the first is in East Baghdad field, Sa'di Formation about 146.7 m thick, and the second is in Halfiya field, Formation about 100 m thick. The Sa'di Formation consists of two members, they are Upper member, which is composed of bitty bioclastic, planktonic foraminiferal chalky limestone, with some calcsiphers, and lower member of the formation, which consists of homogenous, rich planktonic foraminiferal chalky limestone, in addition to small amounts of benthonic foraminifera and bioclastic grains. The Sa'di Formation is overlain the Tanuma Formation, and underlain the Hartha Formation. The Sa'di Formations is composed of four main facies subscribe as S1, S2, S3 and S4. The facies S2 appeared in the upper member, whereas the others are spread in the lower member, which were deposited in deep shelf margin environment. The Gamma Ray log is used to calculate the volume of shale of Sa'di Formation after removing the shale effect due to the porosity equation correction. Depending on the result of porosity values for both wells, the Sa'di Formation successions have been divided into members, they are; the lower and upper members. The lower member separated into two zones, the first have poor to fair porosity, and the second have fair to very good porosity. Whereas the upper member divided into two zones and the porosity wobble between good to very good.

Keywords: Sequence stratigraphy; Sa'di Formation; Baghdad Oilfield; Halfiya Oilfield

INTRODUCTION

The Late Turonian-Danian Megasequence is the most common megasequence in Iraq. It was deposited after ophiolite obduction occur in the south Neo-Tethys part. Because of the inversion broad N-S trending structures have formed in SE Iraq. NW-SE trending (extensional) and E-W trending (transextensional) basin formed in the Stable Shelf. Turonian-early Campanian sediments are limited to the Mesopotamian Zone and the Jezira Subzone but may have been distributed more extensively before Intra Senonian erosion (Fig.1). The lower part of the Megasequence is represented by Khasib, Tanuma, Sa'di and Kometan formations (Jassim and Buday, 2006).

Fig. 1. Turonian-Early Campanian geodynamic advance of the Arabian Plate (after Jassim and Goff, 2006)

Upper Turonian-Lower Campanian sediments are absent due to non-deposition in the Rutba Subzone (Fig. 2a), and erosion in the eastern subzone (Jassim and Buday, 2006). Ditmar and the Iraqi –Soviet Team (1971) suggested that the portion of the slopes of the Rutba and Khlesia highs were covered by a fringing, partly terrigenous, clastic belt. In late Campanian, ophiolites were further removed to the Arabian Plate NE margin. The compression blend with this obduction first make uplift of the Balambo-Tanjero zone and the immediately adjacent instable shelf pieces (Jassim and Goff, 2006). During this uplift considerable thickness of Upper Turonian- Lower Campanian sediments were abrading (Dunnington, 1958). restrictedly these sediments were entirely removed on the Mosul high and over large area of the Rutba-Jezira Zone (Jassim and Buday, 2006). These sequences are depicted by the Khasib, Tanuma, Sa'di and Kometan formations (Jassim and Buday, 2006) (Fig. 2a). The isopach of late Turonian-Early Campanian sequence shows three depocenter, in southern Iraq, near Baghdad and in Sinjar area in NW Iraq (Fig. 2b).

Fig. 2. (a) Late Turonian-Early Campanian palaeogeography. (b) Thickness of the Late Turonian-Early Campanian sequence (after Jassim and Goff,2006)

The sequence is comprising two main facies the first (deep inner shelf and lagoonal facies) of Khasib, Tanuma, Sa'di formations, and the second facies (outer shelf and basinal facies) of the Kometan Formation. The Sa'di Formation is a thick and widely spread formation of the late Turonian –Early Campanian Sequence. The type section was defined by Owen and Nasr (1958) from well Zubair-3. The formation comprises of 300m. of white, chalky, argillaceous and globigerinal limestones with well – developed 60 m. thick marl bed at the top (Bellen *et al.*, 1959). The upper contact of the formation is unconformable with Hartha Formation, whereas the lower contact with the underlain Tanuma is conformable and gradational.

STUDY AREA

The current study is building on samples taken from two wells in two locations; the first location is in East Baghdad oilfield (Well EB-11) and the second location is in the Halfiya field (Well HF-3) (Fig. 3). East Baghdad field is located within Mesopotamian Zone of the unstable shelf. The midpoint of the first location set at (44°21'57.23" E) and (33°27'55.34" N). The Sa'di Formation about (146.7m. thick) ranging between (1918m. – 2064.7m. depth). Halfiya field existed in the sedimentary depression of the Mesopotamian zone as reported by (Buday and Jassim, 1987). The midpoint of the second location set at (47°16'48" E) and (31°41'35" N). The thickness of the Sa'di Formation is of about 100 m, it's depth ranges between 2718 – 2818m.

Fig. 3. Location map of the studies locations (After Aqrawi *et al.*, 2010)

GEOLOGICAL SETTINGS

Sa'di Formation is one of the most famous formations of the secondary sedimentary cycle (Lower Turonian-Upper Campanian) which is regarded as reservoir rocks. Sa'di Formation, in east Baghdad and Halfiya oil fields was overlain Tanuma Formation, and underlain Hartha Formation, the lower and upper contact appeared gradational and conformable. The Sa'di Formation consists of two members: upper member which is composed of bitty bioclastic, planktonic foraminifera chalky limestone, with some calcsphere (Al-Hamadani, 1986). The thickness of this member in East Baghdad oilfield (location 1) is about 81.3 m. (from 1918m. to 1999.3m depth), while in Halfiya oil field (location 2) the thickness is of about 47m. (from 2718 to 2765m depth). The lower members of the formation consist of homogenous, planktonic foraminifera rich chalky limestone, with benthonic foraminifera and very rare bioclasts (Al-Hamadani, 1986). In East Baghdad oil field (location 1) the thickness about (65.4m. thick) ranging in depth from 1999.3m. to 2064.7m. depth and about (53m. thick) in Halfiya oil field (location 2) ranging in depth from 2765m. to 2818m. depth (Fig. 4).

MATERIALS AND METHODS

The present study is based on samples taken from two wells in two locations; the first location is in East Baghdad oilfield and the second location is in the Halfiya field. From the first location thirty-nine samples of well cutting were taken and twenty-six samples were collected from the second section of well cutting. Followed by description and drawing columnar sections. The thin sections of the samples were checked, using polarizing microscope, so, identify and describe the carbonate microfacies and microfossils. The qualitative microfacies analysis was based on the methodology elaborated by Dunham (1962). All thin sections were discolored with Alizarin Red Solution following Dickson's (1965) technique for detecting

calcite and dolomite. The sedimentological and biological evidences is used to decide and find the depositional environment according to Flügel, 1982 and 2004.

Fig. 4. Lithological description of Sa'di Formation in east Baghdad(right) and in Halfiya (left)

RESULTS AND DISCUSSION

Microfacies Analysis

The Sa'di Formations be composed of four main microfacies (S1, S2, S3 and S4), which reflect the paleoecology and the environments of the formation (Fig. 4).

1 - Planktonic Foraminiferal Lime Mudstone Microfacies (S1)

The facies in general is mud promoted with exceptional allochems. The allochems of these facies less than 10% of the material of the facies and is govern by globular planktonic foraminifera characterize by (*Globigerinid*), some calcispher and bioclastic angular to sub angular in shape are present (plate 1 a). The matrix involves of micrite. The facies influence

by dolomitization process in some interval of the facies. The presence of globular planktonic foraminifera and some calcispher refers to deposition this microfacies at middle to outer shelf environments (Al-Juboury and Al-Tharb, 2013; Mohammed et al., 2018). This microfacies can be correlated with the planktonic lime-Mudstones microfacies which is documented at the upper of the Mishrif Formation at Rumaila oilfield, southern Iraq (Al-Ali et al., 2019), and can matches with standard microfacies (SMF 3) in facies zone (FZ1) (Flügel, 1982; 2004).

Plate 1. a- Planktonic foraminiferal lime mudstone microfacies; b- Bioclastic lime mudstone microfacies; c- Planktonic foraminiferal (Globigerinid) lime wackestone microfacies; d- Globigerinid - bioclastic lime wackestone microfacies

2 - Bioclastic Lime Mudstone Microfacies (S2)

The allochems form less than 10 percent of the lime mudstone microfacies (plate 1 b). They consist of bioclasts of foraminifera, calcareous algae, echinoderm and calcispheres. In addition to small amount of planktonic foraminifera (*Globigerinid*). Rhomb of dolomite and spot of pyrite are present. The presence of muddy matrix, bioclasts of foraminifera, calcareous algae, some calcispheres and small amount of Planktonic foraminifera refers to deep shelf environments (Senlet et al., 2015). This microfacies can match with standard microfacies (SMF 2) in the facies zone (FZ3) (Flügel, 1982; 2004).

3 - Planktonic Foraminiferal (Globigerinid) Lime Wackestone Microfacies (S 3)

The allochems in this microfacies ranging between (15%-45%) consisting of planktonic foraminifer are presented by (*Globigerinid*), as well as small amount of calcispherical tests, small size bioclastic grains (plate 1 c). Micrite mode the most matrix of the wackestone microfacies. Some pyrite fills the chambers of some forams and biomoldic porosity can be recognized. The presence of fine micritic matrix containing common planktonic foraminifera and calcispheres, and mud-supported textures indicate a deeper shelf environment with low energy conditions for deposition of this microfacies (Senlet et al., 2015; Karimv and et al.,

2019). The paleontological evidence of this microfacies indicate environments in the deep-sea basin, setting under the base of the wave and under the euphotic zone with water depth of about various meters. This microfacies can be match with the standard microfacies (SMF 3) in the facies zone (FZ1) (Flügel, 1982; 2004).

4 - *Globigerinid* - Bioclastic Lime Wackestone Microfacies (S4)

This microfacies consist of planktonic foraminifera, molluska and echinoderm bioclasts, in addition to significant amount of *Globigerinid* (plate 1 d). These allochems reaches to (50%) of the total content. The matrix composed of micrite and pseudospar created by recrystallization. Sparry calcite, pyrite cement is present. The microfacies affected by dolomitization and compaction processes. The loss of sedimentary structures, the fine grained of matrix and the occupancy of planktonic foraminifera, suggest that these facies was deposited in deep water (Rahmani et al., 2009). *Globigerinid* and other bioclastics that contribute to the development of slope environment by cause of fluctuations in the sea level (Seyrafian, 2000). The paleontological evidence of this microfacies indicate to basinal and deep shelf settings. This zone characterized by high carbonate production and accumulation of fine bioclastic. This microfacies can match with the standard microfacies (SMF 3) in the facies zone (FZ1) and deep shelf margin (FZ 3) (Flügel, 1982; 2004).

Sequence Stratigraphy and Depositional Environments

After the wide regression took place at early Turounian for the basins in southern Iraq, (Mishrif) and Kifl formations were deposited. Followed by a wide marine transgressive covering all Iraq resulting firstly in deposition of the Khasib Formation, its lower facies reflect the deposition in shallow marine environments changed vertically to deep marine environments which reflects an increase in water depth upward in central and southern Iraq. Follow, partial regression in sea caused shallowing in the basin and sea level fall. During this time the lower part of Tanuma formation was deposited (shallow coastal facies). After Coniacian time, another local transgressive, caused by basin subsidence which is recorded at the upper succession of Tanuma Formation. With the beginning of Santonian time, another wide transgressive started caused by the continuous basin subsidence, associated with sea level rise of the two basins (Baghdad basin and the SE Iraq basin (Al-Hamadani, 1986), the rising of sea level (Transgressive system tract TST) registered at the base of the Sa'di Formation. The lower part of the formation showing an expanding in water depth upwards associated with increasing in planktonic foraminifera percentage, this event appears as planktonic foraminiferal (*Globigerinid*) lime wackestone microfacies (S 3) which is reflect the maximum flooding surface (MFS) of the formation (Fig. 3), and may be matched with the regional K 160 marine flooding surface.

According to (Cater and Gilchrest, 1994) the K160 marine flooding was widespread in central, western Iraq and eastern Syria, and covering both flanks and grabens of the Euphrates, Sinjar, and Anah rift graben systems, and was probably rift-subsidence related. Towards the plate margin in Turkey and Iraq, flooding was also pronounced. As we say the K160 MFS is the best expressed in SE Turkey, Jordan, NE Syria, Kuwait, Saudi Arabia (Late Cretaceous (Santonian), Date: 85 Ma) (Clarke, 1988). This MFS is recoded in Iraq too, in the basal Sadi Formation and upper Kometan Formation to the northeast (Buday, 1980), Kometan Formation above Tel Hajar Formation in Sinjar (Khaddouri, 1982) (Sharland et al. 2001). In this study the K160 MFS is position at depth 2060-2062 m, it seems to correlate it with the regional MFS K 160 (Fig. 4).

The planktonic foraminiferal (*Globigerinid*) lime wackestone microfacies (S3) overlain by the planktonic foraminiferal lime mudstone microfacies (S1), and *Globigerinid* - bioclastic lime wackestone microfacies (S4) indicates high stand system tract (HST) of the sequence. These microfacies appeared and concealment in random repetition and showing fluctuation in sea level as reflected by the more than one steps of transgression and regression that's clear at the middle part of Sa'di Formation. All previous microfacies are overlain by the bioclastic lime mudstone microfacies (S2) which is represent the top member of the Sa'di Formation, as same as display a decreasing water depth upward and record a progradational stacking system refers to a major regression marine environment which indicates high stand system tract (HST) of the sequence.

Sa'di formation, depositionally come after the tanuma formation after re-deepening of the basin its usually composed of planktonic mudstone and wackestone microfacies of open marine (outer shelf) environment (Aqrawi, 1996; Younis et al., 2015) The deep marine environment is recognized within the Khasib and Sa'di formations (Gayara and Al Khaykanee, 2015). In the present study Sa'di Formations was characterized by, miss of benthonic foraminifera in comparison with the elevated percentage contented of planktonic foraminifera, especially *Globigerinid*, which imitated the deep marine environment. Presence of abundant quantity of micrite as a matrix in the microfacies that's reflect a quiet, deep marine environment (Flügel 2004), and the existence of pyrite in some facies signify an anoxic deep-sea environment characterized by reduction conditions. All these evidences refer to deposition of in deep shelf margin environments (Fig.5).

Fig. 5. Schematic diagram showing the depositional environments assumed for Sa'di Formation (modified after Aqrabi, 1996)

RESERVOIR CHARACTERIZATIONS

Calculation of Shale volume by Using Gamma Ray

The gamma ray log used to measure the volume of shale (V-Shale) of the Sa'di Formation, the first step is of extraction gamma ray index (IGR) by using equation, (Schlumberger, 1972):

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

I_{GR}Gamma ray index

GR_{Log} Gamma ray reading of formation

GR_{min}Minimum gamma ray (clean sand or carbonate)

GR_{max} Maximum gamma ray (shale)

The second step is application of (Larionov, 1969)equation, which is special for Cretaceous age successions

$$V-Shale = 0.33 * (2^{(2 * I_{GR})} - 1)$$

The shale volume accounts of Sa'di Formation samples can be presented with depth then illustration the vertical distribution within the formation stratigraphy (Fig. 6).

Porosity Analogy by Porosity Log

Compensation Neutron log (CNL) and beds density log (FDC) technique were used to calculate the Sa'di Formation porosity in two wells as explain below:

- 1 - (CNL): used to calculate the direct porosity of the formations rock.
- 2 - (FDC): used to calculate the in directed porosity of the rocks, through record the density of

$$\phi_{\rho} = \frac{(\rho_{ma} - \rho_b)}{(\rho_{ma} - \rho_f)}$$
 ρ_f : Fluid density

ρ_f : Fluid density

For second section the equations which is used to calculate the true porosity and remove the effect of shale is (Schlumberger, 1979):

$$\phi_{tcor} = \phi_a + [V_{sh} (\rho_{sh} - \rho_{ma}) / (\rho_{ma} - \rho_f)], \phi_{tcor} = \phi_a + [V_{sh} (2.35 - 2.71) / (2.71 - 1.1)]$$

$$\phi_{tcor} = \phi_a + [V_{sh} (2.35 - 2.71) / 1.61], \phi_{tcor} = \phi_a - 0.2236 V_{sh}$$

Here the ρ_{sh} : shale density calculated from $GR_{clean} = 52API$

The effective porosity (ϕ_e) of both wells rocks calculated after removing the shales effect), by using correction equation subjected by Schlumberger (1979):

$$\phi_e = \phi_{tcor} \times (1 - V_{sh})$$

Depending upon effected porosity (ϕ_e) and whole porosity (ϕ_{tcor}), the dead porosity (ϕ_d) can be calculated by subtraction the first from the second ($\phi_d = \phi_{tcor} - \phi_e$), (Fig. 7).

Determine the Lithology by Using ($\rho_b - \phi_N$) Diagram

The bulk porosity and density values were dropped on Schlumberger diagrams to find the porosity values (Figs. 8 and 9). The two diagrams show random distribution which may refer to the lithology contrast. The two diagrams explain that the Sa'di formation consist of limestone (calcite), and the porosity between (7%–25%), means weak to very good. Although the most are classified on very good trend. These results correspond with the porosity values.

Fig. 7. The vertical distribution of porosity (ϕ_t , ϕ_e , ϕ_d) in the studied two wells

Fig. 8. Schlumberger diagram (ρ_b - ϕ_N) show porosity and lithology of Sa'di Formation in East Baghdad oilfield

Fig. 9. Schlumberger diagram (ρ_b - ϕ_N) show porosity and lithology of Sa'di Formation Halfiya oilfield

Depending on the results of porosity values for both wells, the Sa'di Formation successions are detached into; lower and upper members. The lower member separated into two porosities zones; poor to fair porosity zone and fair to very good porosity zone. While the

upper member separated into good to very good porosity zone and very good porosity zone according to North porosity classification (North, 1985). Based on the porosity values of the two members, each of them divided to subzones (Fig. 10):

Zone A: this zone represents the lower part of the lower members of the Sa'di Formation. The zone A about (22.7 m.) thick in the first location refer to planktonic foraminiferal (*Globigerinid*) lime wackestone microfacies (S 3) and *Globigerinid*- bioclastic lime wackestone microfacies (S4) and (53 m.) thick in the second location refer to planktonic foraminiferal lime mudstone microfacies (S1) in addition to S3 and S4 microfacies. These microfacies have biomoldic porosity. The porosity in this subzone is poor to fair (7%–14.9%). Therefore, this zone is poor to fair reservoir rocks.

Fig. 10. Divisions of reservoir rocks of the Sa'di Formation in the two wells

Zone B: this zone representing by the upper part of the lower members of the Sa'di Formation in the first location with about (42.67 m) thick consist of planktonic foraminiferal lime mudstone microfacies (S1) and planktonic foraminiferal (*Globigerinid*) lime wackestone microfacies (S 3) and the lower part of the upper members of the Sa'di Formation in the second location with about (26 m.) thick consist of bioclastic lime mudstone microfacies (S2). The rocks porosity in this subzone is fair to very good (10%-25%). So, the rocks classified as fair to very good reservoir.

Zone C: this zone represents the lower part of the upper member of the Sa'di Formation in the first location forms about (49.33 m) thick and the upper part of the upper members of the Sa'di Formation in second location of about (20 m) thick composed of bioclastic lime mudstone microfacies (S2). The rocks porosity in this subzone is very good (15%-28%). Which means that these rocks are classified as good to very good reservoir rocks.

Zone D: this zone existed in the upper part of the upper member of the Sa'di Formation in the first location with about (32 m) thick refer to bioclastic lime mudstone microfacies (S2). But don't record in the second location. The rocks porosity in this subzone is very good (21%-5%). Which means that these rocks are classified as very good reservoir rocks.

CONCLUSIONS

The current study is depending on samples of Sa'di Formation takes from two wells; the first is in East Baghdad field and the second is in Halfiya field. The formation consists of two members, composed of bioclastic, planktonic foraminiferal chalky limestone, and homogenous, rich planktonic foraminiferal chalky limestone, in addition to benthonic foraminifera and bioclastic grains. Four main facies which were reflects the depositional environments of the formation in deep shelf margin environment. According to the porosity values, the formation divided to two members, each of them divided to subzones they are (A, B, C and D), characterized by poor to fair, fair to very good, good to very good and very good reservoir rocks respectively.

ACKNOWLEDGMENTS

The authors are very grateful to the University of Mosul/ College of Sciences for their provided facilities, which help to improve the quality of this work.

REFERENCES

- Al-Ali, M.M., Mahdi, M.M., and Alali, R.A., 2019. Microfacies and depositional environment of Mishrif Formation, North Rumaila oilfield, Southern Iraq. *Iraqi Geological Journal*, 52(2): 91-104.
- Al-Juboury, F.N.H., and Al-Tharb, M.Y.M., 2013. Study of Planktonic Foraminiferal biostratigraphy and depositional environment of Khasib, Tanuma and Saadi Formations in well Agel -12-Northeastern Tikrite. *Iraqi Journal of Science*, 54(3):617-627.
- Aqrawi, A.A. M., 1996. Carbonate – Siliciclastic sediments of the upper Cretaceous (Kasib, Tanuma, Sa'di Formations) of the mesopotamian basin. *Marine and Petroleum Geology*, 13(7):781-790.
- Aqrawi, A.A.M., Goff, J.C., Horbury, A.D., and Sadooni, F.N., 2010. *The Petroleum Geology of Iraq*. Scientific Press Ltd., UK, 424 pp.
- Al-Hamadani, A.M., 1986. Stratigraphy and geochemistry of Khasib, Tanuma and Sa'dy formations. PhD Thesis, College of Science, University of Baghdad, Un. Publ, 328 pp.
- Bellen, R.C., Dunnington, H.V., Wetzel, R. and Morton, D.M., 1959. *Lexique stratigraphique international Asia*, Fascicule, 10a, Iraq. Central National deal Recherches Scientifique, Paris, 333pp.
- Buday, T., 1980: *The Regional Geology of Iraq, stratigraphy and paleogeography*, Dar Al Kutub Published house, Mosul Iraq, 445 pp.
- Buday, T., and Jassim, S.Z. 1987. *The Regional Geology of Iraq. Vol.2: Tectonism, Magmatism and Metamorphism*. State Establishment of Geological Survey and Mineral Investigation, Baghdad, Iraq, 352 pp.
- Cater, J.M.L. and Gilchrist J.R., 1994. Karstic reservoirs of the mid-Cretaceous Mardin Group, SE Turkey: tectonic and eustatic controls on their genesis, distribution and preservation. *Journal of Petroleum Geology*, 17: 253-278.
- Clarke, H.M.W., 1988. Stratigraphy and rock unit nomenclature in the oil-producing area of interior Oman. *Journal of Petroleum Geology*, 11: 5-60.
- Dickson, J.A.D., 1965. A modified staining technique for carbonate in thin section. *Nature*, 205: 587pp.
- Ditmar, V. and Iraqi – Soviet Team, 1971. Geological conditions and hydrocarbon prospects of the Republic of Iraq, Volume-I, Northern and Central Parts. Unpublished. Report, INOC, Baghdad.
- Dunham, R.J., 1962. Classification of carbonates rocks according to the depositional texture. In: Ham, W.E. (Eds.) *Classification of carbonate rock*. American Association of Petroleum Geologists, Memoir, 1:108–121.

- Dunnington, H.V., 1958. Generation, migration, accumulation and dissipation of oil in Northern Iraq. Reprint in *GeoArabia* (2005), 10 (2): 39 – 84.
- Flügel, E., 1982: Microfacies analysis of limestone. Christenson, K., (Translator) Springer – Verlag, Berlin, 633 pp.
- Flügel, E., 2004: Microfacies of carbonate rocks, analysis, interpretation and application, Springer, Berlin, 976 pp.
- Gayara, A.D., and Al khaykane, M.H., 2015. Paleoenvironments and Sequence Stratigraphy of the Turonian-Lower Campanian Succession at Majnoon Oil Field, Southern Iraq. *Iraqi Journal of Science*, 56(4A): 2880-2886.
- Jassim, S. Z. and Buday, T., 2006. Late Turonian –Danian Megasequence AP9, In: Jassim, S.Z. and Golf, J., C., (2006) *Geology of Iraq*. Published by Dolen, Prague and Moravian Museum, Brno., 155 - 168.
- Jassim, S.Z. and Goff, J. C., 2006: *Geology of Iraq*, Dolin, Prague and Moravian Museum, Berno. 341pp.
- Kaddouri, N.A.K., 1982. Late Turonian/Early Campanian sediments in Iraq. *Jour. Geol. Soc. Iraq*, 15(1), 9-18.
- Karimvand, F.N., Harami, R.M., Ghabeshavi, A.M.A., and Shabafrooz, R., 2019. Depositional environment and sequence stratigraphy of the Oligocene-Miocene deposits North and East of Dehdasht, Izeh zone, Zagros Basin, Iran. *Journal of sciences, islamic republic of Iran.*, 30(2): 143 – 166.
- Larionov, V.V., 1969. Borehole Radiometry, Moscow, U.S.S. R., Nedra, 127 pp.
- Mohammed, M.A.J., Mohammed, M.Y., and Saleh, A.S.M., 2018. Lithology and microfacies analysis of Shiranish Formation at selected section near Shaqlawa City- Northeastern Iraq. *Diyala journal for pure sciences.*, 15(2): 92-104.
- North, F.K., 1985. *Petroleum Geology*, George Allen and Unwin, Australia, 607 pp.
- Owen, R.M. S., and Nasr, S.N., 1958. Stratigraphy of the Kuwait – Basrah area, in: Lewis, L.G. (ed.): *Habitat of Oil*, Am. Assoc. petrol. Geol., A Symposium, 1252-1278.
- Rahmani, A., Moghaddam, H.V., Taheri, A., and Ali, G.A., 2010. A model for the paleoenvironmental distribution of larger foraminifera of Oligocene–Miocene carbonate rocks at Khaviz Anticline, Zagros Basin, SW Iran. *Historical biology: An international journal of paleobiology*, 21(3-4): 215-227.
- Senlet, S.E., Altiner, S.O., Altiner, D., and Miller, K., 2015. Planktonic foraminiferal biostratigraphy, microfacies analysis, sequence stratigraphy, and sea- level changes across the Cretaceous-Paleogene boundary in the Hayman basin, central Anatolia, Turkey. *Journal of sedimentary research*, 85: 489–508.
- Schlumberger, 1972. *Log Interpretation, Volume I – Principles*, Schlumberger Limited, U.S.A., 113 pp.
- Seyrafian, A., 2000. Microfacies and depositional environments of the Asmari Formation at Dehdez area (a correlation across central Zagros basin). *Carbonates and Evaporites*, 15(2): 121-129.
- Sharland, P.R., Archer, R., and Casey, D.M., 2001. Arabian plate sequence Stratigraphy, *GeoArabia*, Special Publication 2, Gulf PetrolLink, Manama, Bahrain. 371 pp.
- Schlumberger, 1979. *Log Interpretation Charts*, Schlumberger Wireline and Testing, Houston, Texas, 193 pp.
- Younis, W.A., Kadhim, L.K., Omar, F.M., 2015. Sedimentological study of the Hartha and Saadi Formation from selected wells in Qayara oil field Northern Iraq. *Kirkuk University Journal /Scientific Studies (KUJSS)*, 10(4): 393-414.