Environment and Ecology 37 (4A) : 1419—1432, October—December 2019
Website: environmentandecology.com ISSN 0970-0420

Biostratigraphy, Depositional Environment and Sequence Stratigraphy of the Gurpi Formation in Fars Zone, Zagros Basin (Southwest Iran)

Seyed Abdolkarim Gowhari, Vahid Ahmadi,
Hamzeh Saroea, Koros Yazjerdi

Received 23 July 2019; Accepted 7 September 2019; Published on 9 October 2019

ABSTRACT

In order to study the Gurpi Formation deposits in Fars area, 230 thin-sections belong to Well No. 43 have been studied. The Gurpi Formation is 155 m in thickness. Lithology of the Gurpi Formation is mainly composed of thin to medium limestone, argillaceous limestone and shale. Lower boundary of the Gurpi Formation with the Ilam Formation is continuous and its upper boundary with the Pabdeh Formation is disconformity. In biostratigraphy analysis, 14 species belonging to 31 genera of planktonic and benthic foraminifers were identified and 6 biozones were recognized based on planktonic Foraminifera as follow : *Globotruncanita elevata* Partial range zone; *Globotruncana ventricosa* Interval zone; *Radotruncana calcarata* Total range zone; *Globotruncanella havanensis* Partial range zone; *Globotruncana aegyptiaca* Interval range zone; *Gansserina gansseri* Interval range zone.

Based on the fossil contents and the identified biozones, the relative age of the Gurpi Formation is early Campanian-Maastrichtian. Petrographic studies of the Gurpi Formation led to recognize six facies including five carbonate facies and one shale facies. All facies of the Gurpi Formation belong to the open marine environment, which are deposited in a shelf model. Based on facies analysis and sea level curves, three depositional sequences along with four sequence boundaries due to discontinuities and relative levels of sea level falling were identified. The sequence boundaries at the lower boundary and in the middle part of the Gurpi Formation are type 2 sequence boundary (SB 2). Only the upper boundary of depositional sequence 3 (the boundary between the Gurpi and Pabdeh Formations) due to exposure and presents of erosion effects reveals as a type 1 sequence boundary (SBI).

Keywords Biostratigraphy, Depositional environment, Sequence stratigraphy, Gurpi, Fars area.

Seyed Abdolkarim Gowhari
PhD Candidate, Geology Department, Shiraz Branch,
Islamic Azad University, Shiraz, Iran

Vahid Ahmadi*, Hamzeh Saroea, Koros Yazjerdi
Assistant Professor, Geology Department, Shiraz Branch,
Islamic Azad University, Shiraz, Iran
e-mail : va.ahmadi26@gmail.com
*Corresponding author

INTRODUCTION

The Zagros sedimentary basin with length of about 2000 km is one part of the Alpine Himalayan orogeny belt, which begins with the Northwest-Southeast trend of Turkey and extends to the Makransubduction zone in the South-East of Iran. The Zagros sedimentary basin consists of a thick sedimentary sequence that covers the Precambrian basement formed during the Pan-African orogeny. The total thickness of the sedimentary column deposited above the Neoproterozoic Hormuz salt before the Neogene Zagros folding reach over 8 to 10 km (Alavi 2004). This occurred during the Turonian to Maastrichtian collision of the Western Iranian and Afro Arabian plates. In general, the sedimentary record shows that the late Cretaceous represents a period of major change in the area around the Zagros foreland basin. The Gurpi Formation is a part of deep marine deposits during the Cretaceous period. In which, as an oil source rock plays an important role in the sedimentary sequence of Zagros basin. The Gurpi Formation is extended in the Zagros fold trust belt in Khuzestan, Lorestan and Fars zones (Fig.1). The first stratigraphic studies on the Gurpi Formation was done by James and Wynd (1965) in Khuzestan, Tange Pabdeh, Southwest of the Pabdeh Mountain Range, North of the Lali oilfield,with a thickness of 350 m. The Gurpi Formation overlies the llam Formation and is disconformably overlain by the Pabdeh Formation at the type section. The lithology of the Gurpi Formation in the type section mainly consists of blue to gray shale with intercalation of thin to medium clay layers. This formation due to its low resistance to the weathering has eroded view.

Various fossil studies have been conducted on the Gurpi Formation by researchers. These studies have shown that the age of the Gurpi Formation is various in different parts of the Zagros basin. So that, the base of the Gurpi Formation in Lorestan zone is

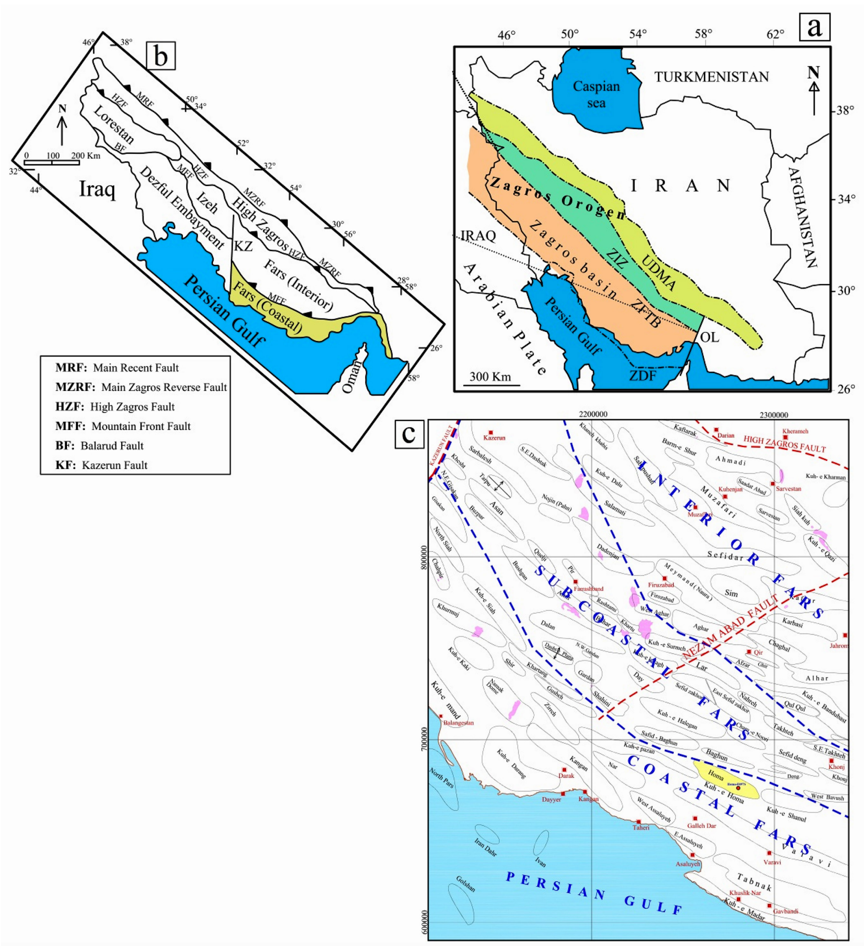


Fig. 1. a) The most important tectonic units of the Zagros basin. b) The structural zones of the including High Zagros, Lorestan, Izeh, Dezful Embayment, Interior Fars and Coastal Fars. c) The geographical position of Kangan gas field.

Campanian in age and the upper border of the Gurpi Formation has been continued to the Paleocene. In Fars and Khuzestan zones, age of the Gurpi Formation has assigned to the Santonian at the base and the Maastrichtian at the top. According to the fossil studies, such as Foraminifera and nanno fossil, it is obvious that the lower boundary of the Gurpi Formation is not synchronous in different parts of the Zagros basin. Various researches had focused on the Gurpi Formation in different parts of Southwest of Iran (Kameli 2004, Zarei 2005, Hemmati 2008, Mahdavian 2009, Darabi 2010, Bieranvand and Ghasemi 2013, Fereydoonpour et al. 2014, Bolli et al. 1987). The main purpose of this research is to identify the genus and species of planktonic and benthic foraminifers to providing the biozones of the Gurpi Formation based and determining the relative age. In the following petrographic analysis has been done to identifying the facies, sedimentary environments, depositional sequences and evaluations of relative changes in the sea level in the studied well.

Geological setting

From the early Cretaceous to nowadays Zagros orogeny affected the Zagros sedimentary basin that extends over the Northeastern Afro-Arabian continental margin (Alavi 2007). These events formed the Zagros fold-thrust belt (ZFTB), which economically is one of the most important tectonic units in Iran (Motiei 1993), (Fig. 1a). Motiei (1993) classified the Zagros fold-thrust belt based on its structural style and sedimentary history into six zones including High Zagros, Lorestan, Izeh, Dezful Embayment, Interior Fars and Coastal Fars (Fig. 1b). The studying well is located in southeastern of Kangan gas field. Kangan is one the largest gas fields in South of Iran. The Kangan gas field is a nearly symmetrical anticline, which is a part of the Coastal Fars in South-East of the Zagros basin that located in the Southern front of Zagros mountain and next to the Persian Gulf. From a geographical point of view, the Kangan gas field is located in South-East of Shiraz and 20 km from city of Varavi (Fig. 1c).

MATERIALS AND METHODS

In order to biostratigraphy, facies analysis and sequence stratigraphy of the Gurpi Formation in Fars zone at the Southwest of Iran, 230 thin-sections belong to these deposits were prepared and studied in Kangan oil field in Well No. 43. The studied thin-sections were stained with Alizarin red solvent for detailed petrography studies. After identifying and photographing the microfossils, the distribution of recognized microfossils was drawn in the stratigraphic column and the recognizable biozones have characterized. To classifying Foraminifera, several studies have been used such as Hoofker (1957), Caron (1985), Loeblich and Tappan (1988), Premoli and Verga (2004) . The lateral and vertical changes of sedimentary facies and changes in fossils content have been used to interpret and reconstruction of sedimentary environments. Sequence stratigraphy studies are based on the principles of sequence stratigraphy by Simmons et al. (2007), Catuneanu (2017).

RESULTS AND DISCUSSION

Lithostratigraphy

The thickness of the Gurpi Formation is 155 m in the studied well. The lower boundary of the Gurpi Formation with Ilam Formation is continuous and its upper boundary with Pabdeh Formation is discontinuous. The lithology of the upper part of the Ilam Formation consists of medium to thick layers of limestone. The base of the Gurpi Formation begins wih thin to medium layers of argillaceous limestone. The lower and middle parts of the Gurpi Formation consists of the alternation of thin to medium, rarely thick layers of limestone and argillaceous limestone that extends close to the upper part. There is a unit of 15 m of bright gray shale in the upper part of the Gurpi Formation. Top of the Gurpi Formation that is covered by the Pabdeh Formation consists of thin layer limestone and sometimes thin to medium layers of argillaceous limestone along with evidences of erosion discontinuity (red to gray erosion deposits with some glauconite grains) (Fig.2).

Biostratigraphy

In biostratigraphy analysis of the Gurpi Formation 22 genera and 12 species of planktonic Foraminifera, 9 genera and 2 species of benthic Foraminifera, as well

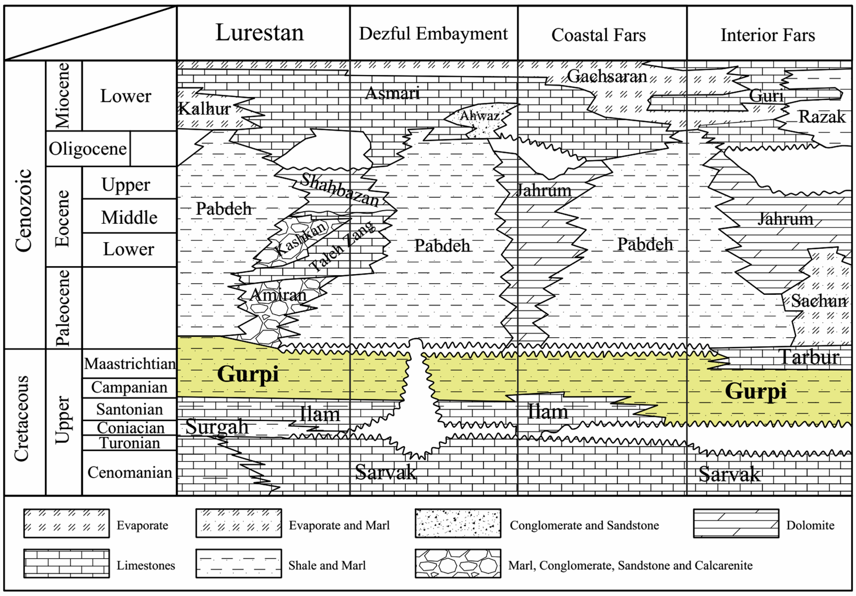


Fig. 2. Correlation chart of the upper Cretaceous, Paleogene and lower Neogene deposits of Zagros basin (adopted with change from Ala 1982).

as bivalves, echinoids, bryozoans, oligosteginids, Radiolaria and sponge spicules were recognized. Based on the planktonic Foraminifera and biozones of Premoli and Verga (2004), 6 biozones were identified. The images of the recognized Foraminifera have been shown in Figs. 3 and 4. Also, the distribution of planktonic and benthic Foraminifera was presented in Figure 5. The presented biozones in this study from base to top are as following : *Globotruncanita elevata* Partial range zone, *Globotruncana ventricosa* Interval zone, *Radotruncana calcarata* Total range zone, *Globotruncanella havanensis* Partial range zone, *Globotruncana aegyptiaca* Interval range zone, *Gansserina gansseri* Interval range zone.

***Globotruncanita elevata* Partial range zone**

Author : Dalbiez (1955)

Definition : Partial range zone from the first appearance of *Globotruncanita elevata* to the first appearance of *Globotruncana ventricosa.*

Characteristics : Whitin this zone numerous representatives of the genus *Globotruncanita elevata, Contusotruncana fornicata, Globotruncana hilli, Globotruncana bulloides, Globotruncana arca, Contusotruncana* sp., *Globotruncana* sp., *Dicarinella* sp., *Marginotruncana* sp., are present. *Rugoglobigerina* sp., *Ventilabrella* sp., *Heterohelix* sp., *Macroglobigerinelloides* sp., *Muricohedbergella* sp., *Lenticulina* sp., *Textularia* sp., *Gavelinella* sp., *Marsonella* sp. and *Bolivina* sp. are also present.

Remarks : In the study well, the lower boundary of this biozone was not determined due to lack of observation of *Dicarinella asymetrica* and probably the base part of this biozone is located in the upper parts of the Ilam Formation. The thickness of this biozone in the Gurpi Formation is 30 m.

Age : Early Campanian.

This zone was recorded from Caribbean W. Tethys, E. Tethys and Central Tethys from the early Campanian by researchers such as Caron (1985).

***Globotruncana ventricosa* Interval zone**

Author : Dalbiez (1955)

Definition : Interval zone from the first appearance

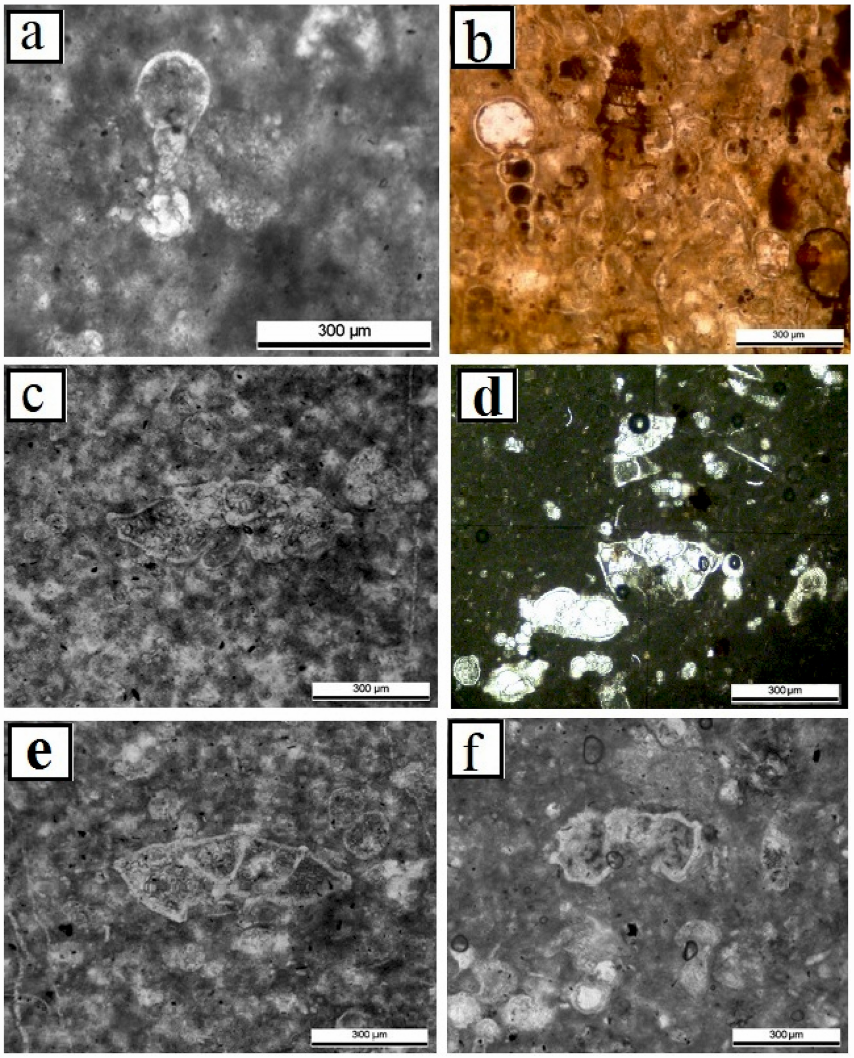


Fig. 3. (a) *Muricohedbergella* sp., (b) *Heterohelix* sp., (c) *Globotruncana arca*, (d) *Globotruncana ventricosa*, (e) *Globotruncanita stuarti,* (f) *Globotruncana* sp.

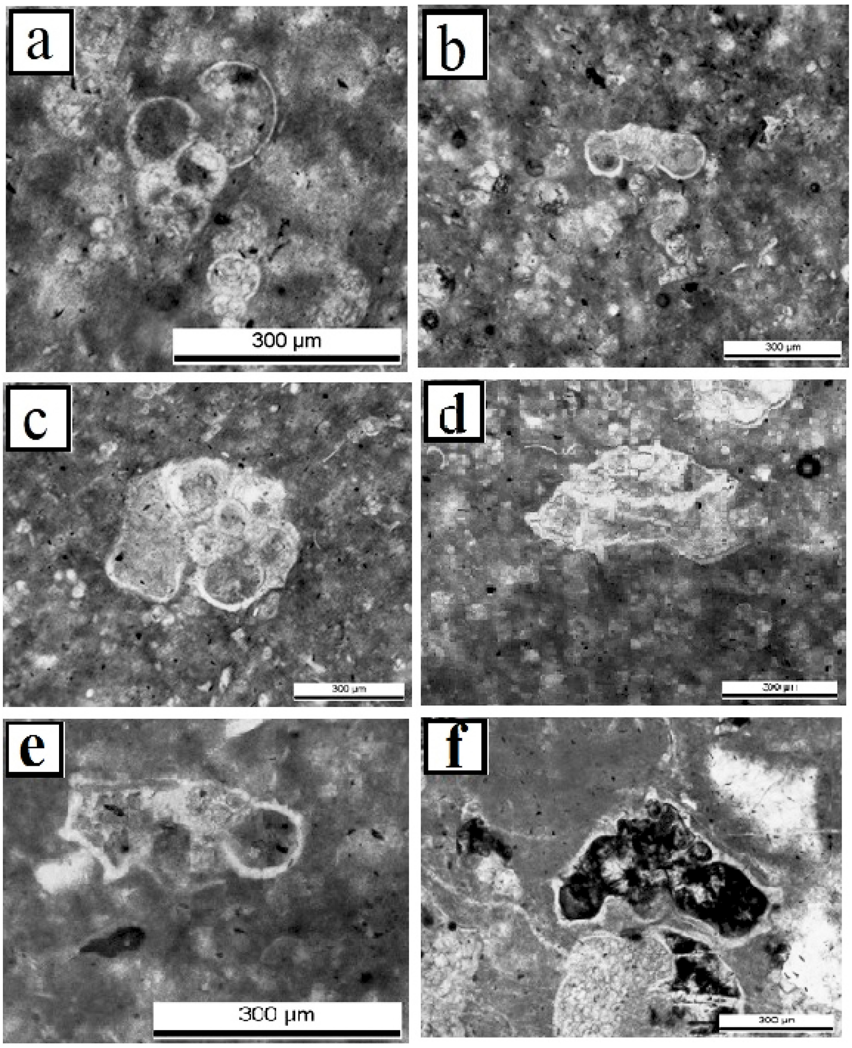
of *Globotruncana ventricosa* to the first appearance of *Radotruncana calcarata*.

Characteristics : *Globotruncana ventricosa, Globotruncanita elevata,Globotruncana hilli, Globotruncana bulloides. Globotruncana arca, Contusotruncana* sp., *Globotruncana* sp., *Macroglobigerinelloides* sp., *Muricohedbergella* sp.*, Rugoglobigerina* sp.*, Lenticulina* sp.*, Textularia* sp.*, Gavelinella* sp., *Marsonella* sp.*, Minouxia* sp., *Nodosria* sp., *Bolivina* sp. and valvulinids and oligosteginids are present in this biozone.

Remarks : The thickness of this biozone in the studied well is 44 m. The *Globotruncana ventricosa* biozone is identified in the lower parts of the Gurpi Formation.

Age : Middle to early late Campanian.

This biozone was introduced in different parts of the Tethys Basin By Caron (1985).



Fig, 4. (a) *Heterohelix* sp., (b) *Rugoglobigerina* sp., (c) *Globotruncana* sp., (d) *Globotruncanita conica* (e) *Globotrucana hilli*, (f) *Contusotruncana contusa.*

***Radotruncana calcarata* Total range zone**

Author : Herm

Definition : Total range zone of *Radotruncana calcarata.*

Characteristics : The dominant planktonic and benthic Foraminifera in this zone are *Radotruncana calcarata*, *Globotruncana bulloides*, *Globotruncana* sp., *Macroglobigerinelloides* sp., *Muricohedbergella* sp., *Rugoglobigerina* sp. *Textularia* sp. and oligosteginids.

Remarks : The thickness of this biozone is 4 m in the studied well. This biozone is recognized in the middle part of the Gurpi Formation. The last appearance of *Globotruncanita elevate* is recorded from the top of the zone.

Age : Late Campanian.
This zone was introduced from W. Pacific, Atlantic

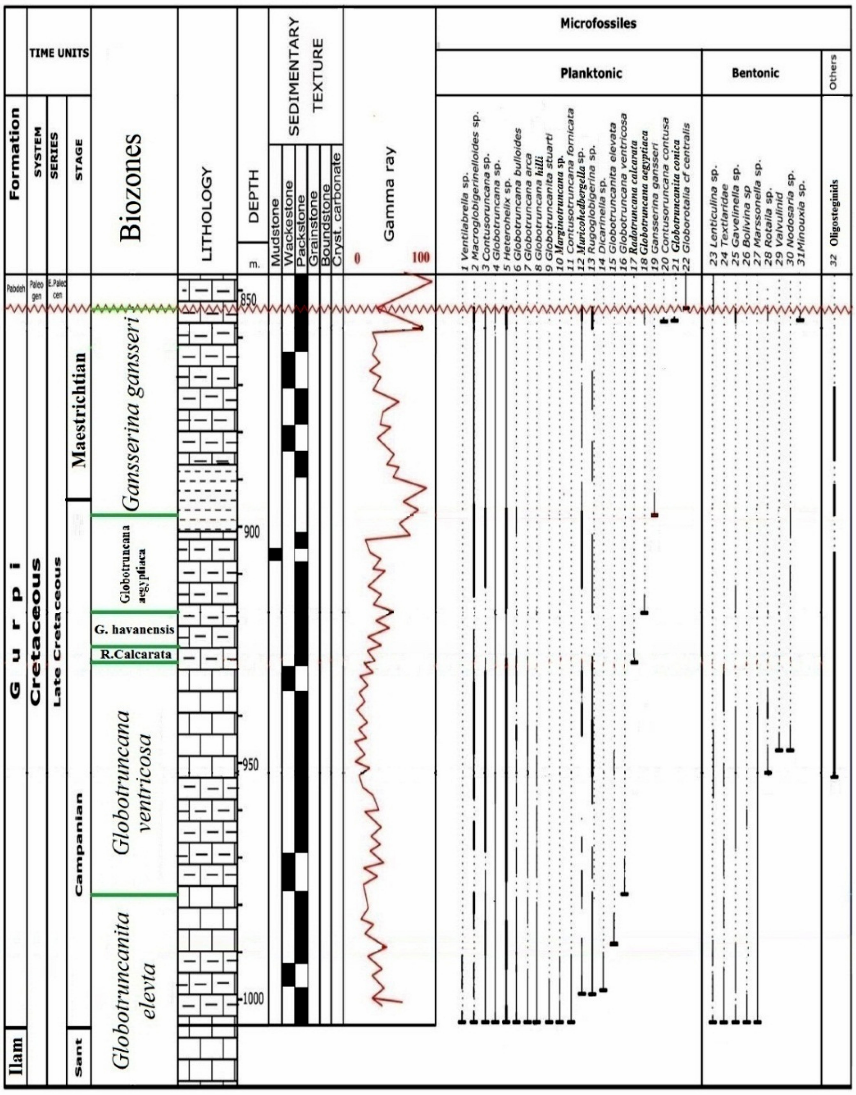


Fig. 5. The distribution of Foraminifers and recognized biozones in studied well.

realm (Premoli Bolli 1973), W. Tethys and Central Tethys (Caron 1985) all from the late Campanian.

***Globotruncanella havanensis* Partial range zone**

Definition : Partial range zone from the last appearance of *Radotruncana calcarata* and the first appearance of *Globotruncana aegyptiaca.*

Characteristics : The dominant planktonic and benthic Foraminifera are *Globotruncana bulloides, Globotruncana* sp.*, Macroglobigerinelloides* sp., *Muricohedbergella* sp., *Rugoglobigerina* sp., *Textularia* sp., and oligosteginids.

Age : Late Campanian.

Remarks : The thickness of this biozone is 10 m in the studied well. The *Globotruncanella havanensis* biozone was recognized in the middle to upper parts of the Gurpi Formation.

***Globotruncana aegyptiaca* Interval range zone**

Definition : Interval zone from the first appearance of *Globotruncana aegyptiaca* to the first appearance of *Gansserina gansseri.*

Characteristics : In this biozone, *Globotruncana aegyptiaca, Globotruncana bulloides, Globotruncana* sp., *Muricohedbergella* sp., *Rugoglobigerina* sp., *Macroglobigerinelloides* sp., *Contusotruncana* sp., *Heterohelix* sp., *Nodosaria* sp., *Gavelinella* sp. and oligosteginids are present.

Age : Late Campanian.

Remarks : The thickness of this biozone is 22 m in the studied well and were identified in the middle to upper parts of the Gurpi Formation.

This biozone is introduced in different parts of the Tethys Basin by Caron (1985).

***Gansserina gansseri* Interval range zone**

Definition : Interval zone from the first appearance of *Gansserina gansseri* to the first appearance of *Contusotruncana contusa.*

Characteristics : The dominant planktonic and benthic Foraminifera are *Gansserina gansseri, Globotruncanita conica, Globotruncana* sp., *Muricohedbergella* sp., *Macroglobigerinelloides* sp., *Contusotruncana* sp., *Rugoglobigerina* sp., *Heterohelix* sp., *Nodosaria* sp., *Gavelinella* sp., *Rotalia* sp.

Age : Late Campanian-Early Maastrichtian.

Remarks : This biozone is the last recognized biozone in the Gurpi Formation, with a thickness of 45 m. This biozone is introduced in different parts of the Tethys Basin by Caron (1985).

Comparison with type section

Based on the extensive distribution of plankton Foraminifers and the determination of existing biozones, it is possible to determine the beginning sedimentation of the Gurpi Formation in different parts of the Zagros basin. According to the presence of different species of planktonic Foraminifera and the determination of the biozones, the Early Campanian is to Early Maastrichtian suggested for Gurpi Formation, while the age of this formation is Early Campanian to Late Maastrichtian in type section (Kameli 2004). Due to the presence of the *Globotruncanita elevata* Partial range zone, the age of the base of the Gurpi Formation at the studied well is Early Campanian; the same biozone has been detected on the type section as well. Accordingly, the sedimentation of this formation was done from the Early Campanian similar to the type section.

The relative raising of the sea level in the Early Santonian and the continuation of the water flow in Santonian (Ilam Formation) and the former Campanian (the base of the water raising in Late Santonian) gradually affected the studied area and type section and thus the depth of the basin for sedimentation of the Gurpi Formation was appropriate. Sedimentation of the Gurpi Formation in the Zagros basin has continued until the Late Maastrichtian, so that the last biozone recognized in the Gurpi Formation at the studied area was *Gansserina gansseri* interval range zone, while the last biozone of the Gurpi Formation at type section is *Contusotruncana contusa* interval zone . In other hand, the sedimentation of the Gurpi Formation is completed in the studied well earlier than the type section.

In the Middle to Late Maastrichtian, the sedimentation of the Gurpi Formation is finished to a sudden descendant of the sea level. The Pabdeh Formation discontinuously took place on the Gurpi Formation with a time lag. In type section, sedimentation of the Gurpi Formation has been continued steadily until the Paleocene, and the Gurpi Formation is continuously covered by the Pabdeh Formation.

Facies analysis

Petrographic studies were done on the basis of main components and their size, sedimentary structures and texture. Our studies led to identifying five carbonate facies and one shalfacies in Gurpi Formation.

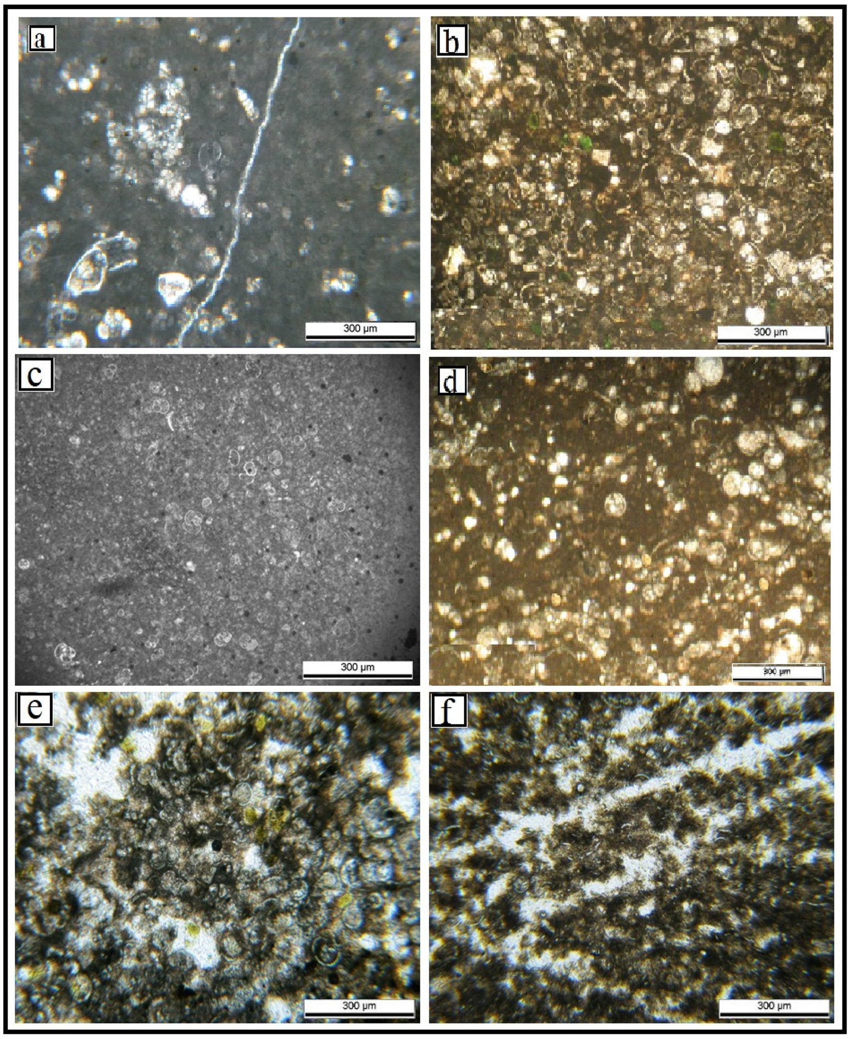


Fig. 6. Facies a) Bioclast peloid wackestone-packstone. b) Bioclast, intraclast planktonic Foraminifera wackestone-packstone. c) Echinoid planktonic Foraminifera packstone. d) Oligosteginid planktonic Foraminifera packstone. e) Spongy spicule oligosteginid packstone. f) Shale.

A1 : Bioclastpeloid wackestone-packstone

This facies is scattered within lower, middle and upper parts of Gurpi Formation. Main allochems are peliod and bioclast (Fig. 6a). The bioclast consists of echinoid, bryozoan, small benthic Foraminifera, pelecypod and planktonic Foraminifera. Intraclasts and reworked shell fragments from shallow marine environments are present in a minor amount. This facies in some samples have a few of allochems and show mudstone texture. Neomorphism in micritic texture and micritization are the main diagenetic processes in this facies.

Interpretation **:** The presence of fauna such as echinoid, bryozoan and planktonic Foraminifera reveals an open marine environment below the fair weather wave base (Flügel 2013). Small benthic Foraminifera indicate displacement and reworking of this biota from shallower parts of the environment ; this support by crunch and the effects of fragmentation in this biota. Furthermore, presence of intraclast in this facies can reveal displacement and rework from shallower parts to deep water environments (Flügel 2013).

A2 : Bioclast, intraclast planktonic Foraminifera wackestone-packstone

This facies is located mainly in middle part of the Gurpi Formation and partly in lower and upper parts. Main biota consists of bioclast, intraclast and planktonic Foraminifera (Fig. 6b). Intraclasts are intrabasinal fragments that dugout by currents from steeper part of shallow water environment and deposited in deeper part of the basin. Echinoid and spongy spicules formed the other shell fragments in a minor amount. Some of fossil chambers filled by pyrite. Neomorphism in micritic matrix is the most impoertant diagenesis process.

Interpretation **:** Component shredding and crushing indicate that this facies affected by reworking fragments from shallow water environments (Flügel 2013). Intaclast and normal water biota such as planktonic Foraminifera and echinoid reveals an open marine environment with low to moderate energy (Wilson 1975). High amounts of intraclast in this facies indicate their reworking and displacement from shallow water setting and deposition in deeper water environments (Flügel 2013).

A3 : Echinoid planktonic Foraminifera packstone

This facies located mainly in lower and upper parts of the Gurpi Formation. Main biota consists of planktonic Foraminifera and echinoid scattered throughout the micritic matrix (Fig. 6c). Spongy spicules, radiolarian, inoceramus, bryozoan and oligosteginid formed the other biota. Peloid, intraclast and small benthic Foraminifera are also present in a minor amount. Neomorphism is the most common diagenesis process in this facies.

Interpretation **:** Extensive presence of echinoid shell fragments reveals deposition in an open marine environment for this facies (Flügel 2013). Coexistence of bivalves, intraclast and echinoid with packstone texture indicates a low energy setting in open marine . High abundance of planktonic Foraminifera, echinoid and other open marine biota (e.g. spongy spicules, radiolarian and oligosteginid) confirms an open marine environment with low energy condition that has been deposited below the storm wave base (SWB).

A4 : Oligosteginid planktonic Foraminifera packstone

Oligosteginid planktonic Foraminifera packstone is the most abundant facies identified in different parts of the Gurpi Formation. Oligosteginid and planktonic Foraminifera such as Globotruncana, Muricohedbergella, Globotruncanella and heterohelix that scattered in a micritic matrix formed the main components (Fig. 6d). Radiolarian, echinoid and spongy spicules are also present in a minor amount. Some of planktonic Foraminifera chambers has been filled by pyrite. Glauconite is also visible partially. Common diagenesis processes are cementation and pyritization inside the fossil chambers, neomorphism and silicification.

Interpretation **:** High presence of planktonic Foraminifera and open marine fauna such as echinoid, oligosteginid, radiolarian and spongy spicules in a packstone texture reveals an open marine environment with low energy condition below the storm wave base (Flügel 2013). Shredding in biota components suggestes materials that shipped from shallow settings have influenced this facies. Presence of pyrite in planktonic Foraminifera chambers reveals a low energy and reducing condition during deposition of this facies that have provided in low-energy and quiet waters of open marine.

A5 : Spongy spicule oligosteginid packstone

This facies scattered throughout different parts of the Gurpi Formation, in abundance. Main biota consists of spongy spicule and oligosteginid that are dispersed in a micro-granular matrix. The most important Oligostiginids are including *Calcisphaerulla innominate, Cacisphaerula innomatalata, Pitonellaovalis* and *Pitonellatrejoei.* Planktonic Foraminifera, small fragments of echinoid and peloid formed the other biota. Glauconite and pyrite with different dispersions were observed in this facies. The most important diagenetic properties are including neomorphism and silicification.

Interpretation **:** High abundance of oligosteginid, spony spicule, echinoid, planktonic Foraminifera and stratigraphic association with oligosteginid planktonic Foraminifera packstone (A4) suggests deposition in a low energy condition in open marine environment below the storm wave base. Oligosteginids demonsrate environments with relatively warm and normal salinity waters saturated with calcium carbonate (Flügel 2013).

A6 : Shale

Shalyfacies were identified slightly in upper part of the Gurpi Formation. Planktonic Foraminifera such as Heterohelix, Muricohedbergella, Globotruncana and Globotruncanita formed the main biotic constituents. Pelagic bivalves, spongy spicules, oligosteginid, radiolarian and echinoid are also present in a minor amount. Pyritization in the fossil chambers and micritization are formed the diagenetic processes in this facies.

Interpretation **:** Shales with open marine fauna are deposits that formed after early lithification on the sea floor and below the storm wave base (Badenas and Aurell 2001). Presence of planktonic Foraminifera indicates that deposition took place in deep marine settings with low energy and quiet waters.

Sedimentary environment

Whole facies identified in the Gurpi Formation are belonging to open marine environments. Facies A1 is scattered in the middle part of the Gurpi Formation. Presence of planktonic Foraminifera in this facies indicates displacement of this biota from shallow water settings. Intraclasts can represent movement and relocation of these fragments from shallow water settings and deposition in deeper environments (Flügel 2013). Facies A2 has been identified mainly in middle part of the Gurpi Formation. High abundance of intraclasts suggests relocation of these particles from shallow water environments and sedimentation in deeper water settings (Flügel 2013). Facies A3 located mainly in middle and upper parts of the Gurpi Formation ; the main allochems with high amounts included planktonic Foraminifera and echinoids shell fragment that reveals deposition in normal waters of open marine environment with low energy condition and below the storm wave base (Flügel 2013). Facies A4 is the most abundant facies identified in the Gurpi Formation that scattered throughout the Gurpi transect. Abundance of planktonic Foraminifera and open marine fauna such as echinoids, spongy spicules, radiolarian and oligosteginid represents low energy waters below the storm wave base in open marine environments (Flügel 2013). Facies A5 was identifed in high amounts in middle and upper parts of the Gurpi Formation ; Its main constituents include oligosteginid, spongy spicules, planktonic Foraminifera and other open marine biota (e.g. radiolarian and echinoid) shows that this facies has been deposited in low energy waters of open marine below the storm wave base. The presence of oligosteginid in high amounts demonstrate an environment with relatively warm and normal salinity waters saturated with calcium carbonate (Flügel 2013). Shalyfacies (A6) identified only in upper part of the Gurpi Formation. Planktonic Foraminifera are predominant in this facies. Presence of planktonic Foraminifera in a clay matrix indicates that deposition took place in low energy and quiet waters of deep marine. Due to extensive abundance of pelagic facies, process of facies sudden changes in stratigraphic column and presence of slump deposits (facies A1 and A2) sedimentary environment of the Gurpi Formation has been suggested as a shelf setting. All facies are belonging to outer shelf and basin and facies related to middle and inner self were not identified (Fig. 7).

Sequence stratigraphy

In sequence stratigraphy sediments in a sedimentary basin will classify to depositional sequences. Sequence stratigraphic units are bodies of sedimentary rocks that are defined and characterized on the basis of their stratal stacking patterns and their stratigraphic relations. The bounding surfaces of sequence stratigraphic units are sequence stratigraphic surfaces, which are stratigraphic contacts that mark changes in stratal stacking pattern between the underlying and the overlying units. The sequence stratigraphic units and their bounding surfaces provide the basis for a genetic, process-based approach to stratigraphic mapping and correlation (Emery and Mayres 1996, Catuneanu and Zecchin 2013, Catuneanu 2017). In

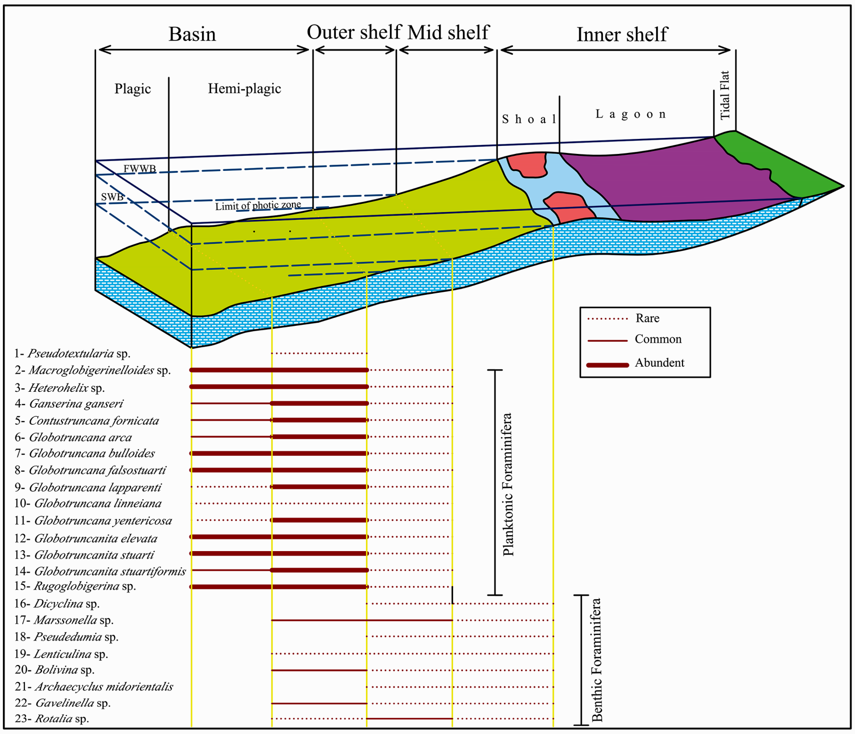


Fig. 7. Depositional model of a carbonate shelf system for deposits of the Gurpi Formation at Kangan oil Field in Fars region.

this study sequence stratigraphy has done by considering the facies vertical changes and identifying sedimentary environments associated with relative sea level changes. In order to determine the sequence boundaries more precisely gamma log has been used along with the sedimentary facies. Sequence stratigraphic studies of the Gurpi Formation in Fars region led to identification of three depositional sequences that bounded by type 1 and type 2 sequence boundaries (Fig. 8).

Depositional sequence 1

This sequence with early to Middle Campanian in age covered the lower part of the Gurpi Formation. The thickness of depositional sequence 1 is 74 m. Bioclastpeloid wackestone-packstone (facies A1) formed the onset of this sequence. Transgressive systems tract with retrogradational stacking pattern is formed mainly from facies Al and A2 . Spongy spicule oligosteginid packstone (facies A5) specified maximum flooding surface. Highstand system tract where the rates of creation of accommodation decrease begins with bioclast, intraclast planktonic Foraminifera wackestone-packstone (A2) and continues with facies A1 (Bioclastpeloid wackestone-packstone). The lower boundary of this sequence has not been identified and probably is located in upper part of the Ilam Formation but the upper boundary is a type 2 and specified by facies A1. This sequence is correlative with sequence K160 in Arabic plane (Simmons et al. 2007).

Depositional sequence 2

This sequence with Middle to late Campanian in age covered the middle part of the Gurpi Formation (with a thickness of 26 m). Transgressive systems tract is determined by echinoid planktonic Foraminifera packstone (facies A3). Maximum flooding surface at the end of transgression form during stages of positive accommodation and specified by facies A4 (oligosteginid planktonic Foraminifera packstone). Highstand systems tract consists of facies A1 and

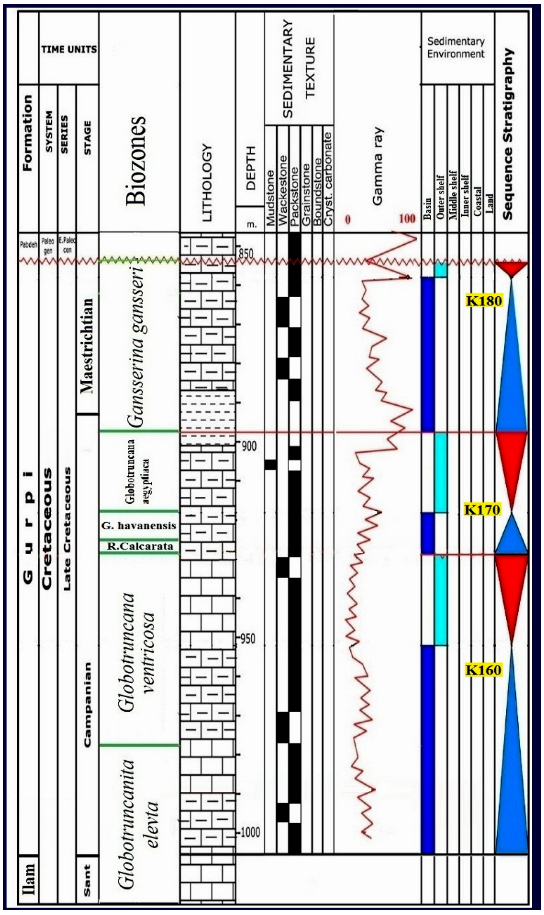


Fig. 8. Paleoenvironments and depositional sequences vertical distribution of the Gurpi Formation at Kangan Oil Field in Fars region.

facies A2 along its interval . Bioclastpeloid wackestone-packstone (facies A1) characterize the upper boundary which is a type 2 sequence boundary. This sequence is correlative with sequence K 170 in Arabic plane (Simmons et al. 2007).

Depositional sequence 3

This sequence with late Campanian to Maastrichtian in age covered the upper part of the Gurpi Formation. This sequence is 45 m thick. The onset of transgressive systems tract with a retrogradational stratal stacking pattern defined by shalyfacies (A6). This stratigraphic unit continues with facies A4 and facies A5. Maximum flooding surface which is a stratigraphic surface that marks a change in stacking pattern from transgression (below)to high stand normal regression (above) (Fanti and Catuneanu 2010) determined by Spongy spicule oligosteginid packstone (facies A5). Highstand syatems tract with a normal regressive stacking pattern which follows a transgression (Catuneanu 2017) mainly defined by facies A1. The upper boundary of this sequence, which is a type1 sequence boundary, is consistent with the Gurpi and Pabdeh Formations. Type 1 sequence boundary characterized by evidence of exposure, sediments subject to erosion and red to grey sediments. This sequence is correlative with sequence K 180 in Arabic plane (Simmons et al. 2007).

CONCLUSION

In Coastal Fars the Gurpi Formation with a thickness of 155 meters has a paraconformity stratigraphic contact with ilam Formation in its lower boundary and a disconformity with Pabdeh Formation in its upper boundary. The Gurpi Formation varies in lithology from limestone to clay limestone and shale. Detailed biostratigraphic analysis led to the recognition of 22 species belonging to 12 genera of planktonic Foraminifera and 2 species belonging to 9 genera of benthic Foraminifera. At the Kangan Oil Field, based on distribution of identified Foraminifera and comparing with biological zonation of Premoli and Verga (2004) six assemblage zones have been recorded, as follows : *Globotruncanita elevata* Partial range zone; *Globotruncana ventricosa* Interval zone, *Radotrucana calcarata* Total range zone; *Globotruncanella havanensis* Partial range zone; *Globotruncana aegyptiaca* Interval range zone; *Gansserina gansseri* Interval range zone.

Based on the biological zones the Gurpi Formation at the study area is Rupelian to Burdigalian in age. Petrographic studies led to recognition of five carbonate facies and one shalyfacies. All of the facies belonged to the outer shelf and basin and facies related to middle and inner self were not identified. A shelf depositional system is suggested for deposition of the Gurpi Formation at the Kangan Oil Field (Fig. 7); the identified facies, extension of pelagic sediments, slump deposits, reworking of benthic Foraminifera to deep waters and the effects of displacement and crushing in biota confirms this suggestion. In the other words, deposition of the Ilam Formation continued by the Gurpi Formation in the depths of open marine. This situation has been dominated until the end of the Gurpi Formation sedimentation and led to accumulation of a large volume of pelagic sediments. However, at the end of the Gurpi Formation sedimentary cycle, at the Cretaceous-Tertiary border, coincided with Laramide orangery sea level dropped suddenly and has resulted in an epeirogeny. Eroded sediments at the Cretaceous-Tertiary border with gray to reddish colors confirms this issue. Sequence stratigraphic studies in the Gurpi Formation led to recognition of three third order depositional sequence that are correlatable with K 160, K 170 and K 180 sequences in Arabic plane. Except for the upper boundary of depositional sequence 3 (Gurpi-Pabdeh Formations boundry) that because the evidence of exposure and erosion is a type 1 sequence boundary (SB1) all of the other sequence boundaries are type 2 (SB 2).

REFERENCES

Alavi M (2004) Regional stratigraphy of the Zagros fold-thrust belt of Iran and its proforeland evolution. Am J Sci 304 (1) : 1—20.

Alavi M (2007) Structures of the Zagros fold-thrust belt in Iran. Am J Sci 307 (9) : 1064—1095.

Badenas B, Aurell M (2001) Proximal-distal facies relationships and sedimentary processes in a storm dominated carbonate ramp, Iberian Ranges, Spain. Sedimentary Geol 139 : 319—340.

Bieranvand B, Ghasemi-Nejad E (2013) High resolution planktonic foraminiferal biostratigraphy of the Gurpi Formation, K/pg boundary of the Izeh Zone, SW Iran. Revista Brasileira e Paleontologia 16 (1) : 5—26.

Bolli MH, Saunders JB, Perch-Nielsen KP (1987) Plankton Stratigraphy : Cambridge University Press, New York, pp 970.

Caron M (1985) Cretaceous planktonic Foraminifera. In : Bolli HM, Saunders JB, Perch-Nielsen KP, (eds). Plankton stratigraphy : Cambridge University Press, pp 17—86.

Catuneanu O (2017) Sequence stratigraphy : Guidelines for a standard methodology. In stratigraphy and timescales. Acad Press 2 : 1—57.

Catuneanu O, Zecchin M (2013) High-resolution sequence stratigraphy of clastic shelves II : Controls on sequence development. Mar Pet Geol 39 : 26—38.

Darabi GH (2010) Biostratigraphy and lithostratigraphy of the Gurpi Formation in Marun Oil Field. MSc thesis in stratigraphy and paleontology. Shahid Beheshti University, pp 153.

Emery D, Mayres KJ (1996) Sequence Stratigraphy : Oxford, United Kingdom, Blackwell, pp 297.

Fanti F, Catuneanu O (2010) Fluvial sequence stratigraphy : The Wapiti Formation, West-Central Alberta, Canada. J Sediment Res 80 : 320—338.

Fereydoonpour M Vaziri-Moghaddam H, Taheri A (2014) Biostratigraphy and sequence stratigraphy of the Gurpi Formation at Deh Dasht area, Zagros basin, SW Iran. Acta Geologica Sinica-English edn 88 (6) : 1681—1695.

Flügel E (2013) Microfacies of carbonate rocks : Analysis, interpretation and application. Springer Science & Business Media.

Hemmati Nasab M (2008) Microbiaostratigraphy and sequence stratigraphy of the Gurpi Formation in the Kavar section. MSc thesis in stratigraphy and paleontology. University of Tehran, pp 146.

Hoofker J (1957) Foraminiferen der Oberkreide von Nordwest deutschland und Holland. Amtfür Bodenforschung, Hannover, pp 464.

Kameli A (2004) Biostratigraphy of the Gurpi Formation in Lali Area (Khuzestan). MSc thesis in stratigraphy and paleontology. Isfahan University, pp 126.

Loeblich AR, Tappan H (1988) Foraminiferal Genera and their Classification : Van Nostrand Rienhold, New York, pp 970.

Mahdavian Rad A (2009) Lithostratigraphy and biostratigraphy of the Gurpi Formation in the Kamestan Anticline (Northwest of Izeh) and comparison with its type section in the North of Lali Area, MSc thesis in stratigraphy and paleontology. Shahid Beheshti University, pp 157.

Motiei H (1993) Stratigraphy of Zagros. Treatise on the Geology of Iran 60 : 151.

Premoli Silva I, Verga D (2004) Practical manual of Cretaceous Planktonic Foraminifera, Course 3. In : Verga D, Rettri R (eds). International School of Planktonic Foraminifera : University of Perugia and Milano, Tripografiadi di Pontefecino, Perugia, Italy, pp 283.

Simmons MD, Sharland PR, Casey DM, Davies RB, Sutcliffe OE (2007) Arabian plate sequence stratigraphy : Potential implication for global chronostratigraphy. Geo Arabia 12 (4) : 101—130.

Wilson JL (1975) Carbonate Facies in Geologic History. Springer, Berlin, Heidelberg, New York, pp 471.

Zarei A (2005) Palynology, biostratigraphy and paleoecology of the Gurpi Formation in the type section. MSc thesis in stratigraphy and paleontology. University of Tehran, pp 151.