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Microbiostratigraphy of upper Cretaceous deposits (Bangestan Group) in the northwestern flank of Sepid Kuh anticline, W Iran

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Abstract
The benthic and planktonic foraminiferal contents of the Bangestan Group (Sarvak, Surgah and Ilam formations) in the Sepid Kuh anticline in the Lorestan Zone, W Iran, were studied. Bangestan Group consists of limestone, argillaceous limestone, dolomitic limestone and marl with thickness of 5400 m. In this section Bangestan Group overlies Garu Formation disconformably and its upper boundary is not exposed. By micropaleontological study on 176 thin sections, 8 genus and 34 species planktonic foraminifera were identified. 400 m of Sarvak Formation has very little fossil diversity that does not indicate a certain age. For this reason, this interval was called the indeterminate zone, which due to its stratigraphic position, is probably of Cenomanian age. Based on the biostratigraphical range of planktonic foraminifera distinguished, four biozones can be identified: Helvetoglobotruncana helvetica Total Rang Zone (Early- Middle Turonian), Marginotruncana schneegansi partial Range Zone (late Turonian), Diacarinella concavata Interval Zone (Coniacian), and Diacarinella asymetrica Total Zone (Santonian).
Keywords: *Bangestan Group, Lorestan Zone, Sepid Kuh, Senomanian, Santonian.*

1. Introduction
The accelerating opening of the Atlantic Ocean in the late Cenomanian compression within on the Afro-Arabian Plate and the Neo-Tethys realm (Sharland et al. 2001). The closure of the Neo-Tethys was accompanied by Continuation of compressive forces and subduction of Neotethys under the Iranian plate caused the emplacement of the Triassic to Mid-Cretaceous oceanic crust on the northeast edge Afro-Arabian plate (Heydary 2008). In front of this nappe complex (High Zagros Zone), two foreland zones (the Dezful Embayment and the Lorestan basin) developed on the subsiding broad continental margin (Sepehr and Cosgrove 2004). The Middle to upper Cretaceous deposits in the Lorestan basin consists of the Bangestan Group, which is economically important, especially hydrocarbons in W Iran (Motiei 1995).
The Bangestan Group was introduced by Slinger and Crichton (1959), and contains the Kazhdumi, Sarvak, Surgah and Ilam formations (Fig.1).The Kazhdumi Formation is expansioned in the Fars zone and Dezful Embayment. From northwest Dezful Embayment toward the Lorestan zone it interfingers with the argillaceous limestone of the Garu Formation. The type section of Sarvak Formation was measured at Tang-e Sarvak in the southwest side of Kuh Bangestan in the northeast of the Paris and Karanj oilfields in Dezful Embayment (Setudehnia 1972).The type section of Surgah and Ilam formations is in the south-western part of the mountain of Surgah in the Lorestan Zone. The Surgah Formation is well expansioned in Lorestan Zone only. In the western part of Lorestan Zone, it is changed to the Garu Formation (Parsi 1970; Desbordes 1972; Setudenia 1972). The Ilam Formation and its equivalent in the adjusting area (e.g. Hahul Formation) are present throughout Zagros zone and Persian Gulf (Ghazban 2007).
The major goal of this paper is to recognized a biostratigraphic zonation of Bangestan Group in the one surface section in northwest of khorram Abad in Lorestan zone (Sepid Kuh anticline).This provides useful tools for the chronostratigrapgy and reconstruction of the Bangestan Group on both of the outcrop sections and subsurface sedimentary successions.

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2. Material and methods
One stratigraphic section was studied in details alongside the northern side of the Sepid kuh anticline at 33°29′ N and 48°20′ E (Fig. 2). In this study, a total of 176 hard samples have been analyzed for the identification microfossils. The systematic of planktonic foraminifera performed here follows Premoli Silva and Verga (2004). The extension of recognized microfossils guided us to introduced biozones. Finally, identified biozones were compared to adjustment sections.

3. Geological setting
The Lorestan zone is an intrashelf depressions that is limited by the High Zagros Fault to the north and northeast (HZF) and Bala Rud (BRF) fault to the south

and southwest (Fig. 3). The western side of the Lorestan Zone is the Kirkuk Embayment (KE). The Northern part of the Lorestan Zone is the Thrust Zone which is identified by strong structural tiliting and faulting. Seventeen major structures have been recognized in the Lorestan zone (Parsi 1970). These are mostly long stretched, complex anticlinal system.

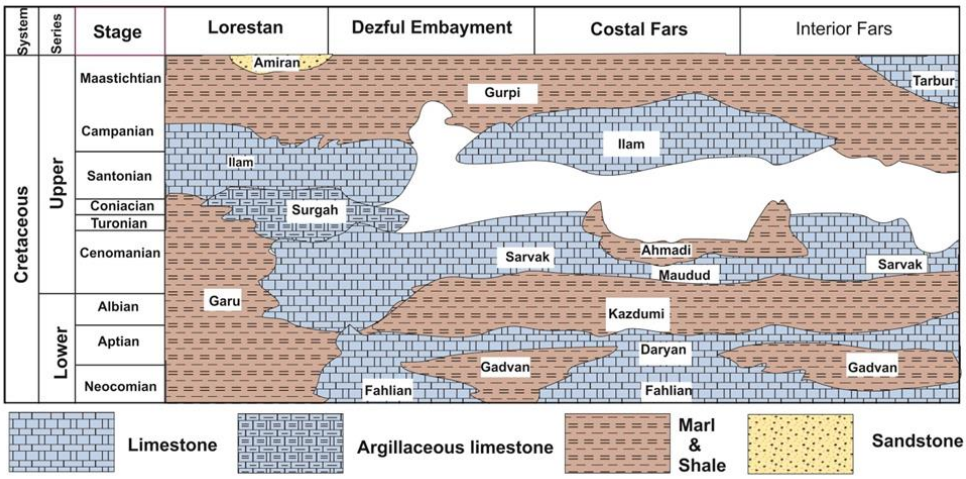

Fig.1. Upper Cretaceous lithostratigraphic units, SW Iran (adapted from James and Wynd 1965).

The Sepid Kuh anticline with its overturned southern limb and NW-SE trend is in the northern end of the Lorestan zone and the beginning of the Thrust zone, It is 70 Km long by 10 Km wide. The Garu Formation is exposed in the central axial portion of the Structure and comprises dark gray argillaceous limestone. It is placed under the Bangestan Group which contains Sarvak, Surgah, and Ilam formations (Fig 4).

The Sarvak Formation in the Sepid Kuh anticline contains of 400 m light gray limestone and dolomitic limestone. Its boundary with the Surghah Formation is conformable. The thickness of the Surghah Formation in this section is up 90 m and consists of light grey thin- to medium-bedded argillaceous limestone. Its upper contact with the Ilam Formation is conformable. The thickness of the Ilam Formation in Sepid Kuh is 50 m and including of white and light grey medium to thick - bedded limestone. Its upper boundary with Gurpi Formation is covered.

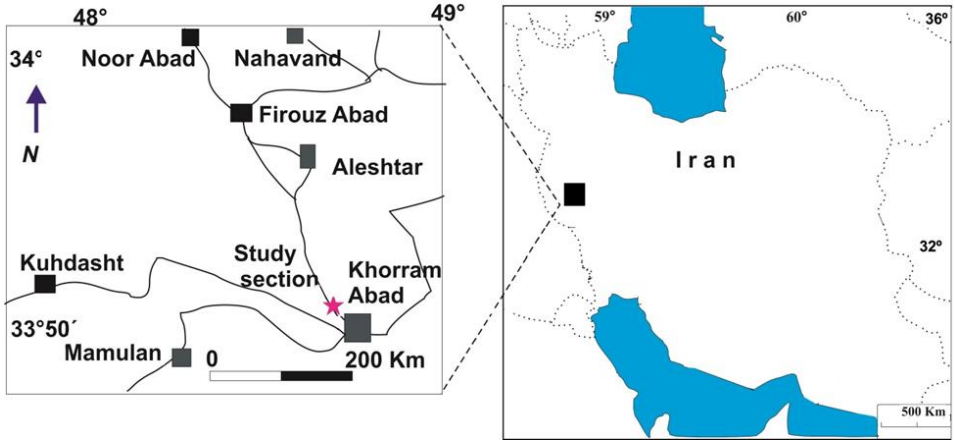

Fig.2. Roadmap to the studied section

4. Biostratigraphy

The pioneering work on the biostratigraphy in the Zagros basin began with Wynd (1965). Due to significant oil reservoirs existing in the Bangestan Group, the study of its stratigraphic characteristics was continued by enormous Paleontologist. A more recent publication on the biostratigraphy of the Bangestan Group is that of Kohsrow Tehrani and Fonooni (1994), Ghabeishavi et al. 2010; Afgha et al. 2014; GhasemShirazi et al. 2014-b; Afgahah and Fadei 2015; Reza 2020; Dehghanian and Afghah 2021; Dousti Mohajer et al. 2021a; Dousti Mohajer et al. 2021b;

Shapourikia et al. 2021), which follow the schame of James and Wynd (1965) in the Fars zone where the bangestan group has relative shallow facies (Setudehnia 1972). The Bangestan deposits in study section contain foraminifera and non-foraminifer assemblage. According to micropalaeontological and biostratigraphical studies the Sepid Kuh section, 8 genera and 34 species of plankton foraminifers and 5 genera and 1 species of benthic foraminifera were recognized and eventually 5 biozones were introduced (Figs. 5 and 6).

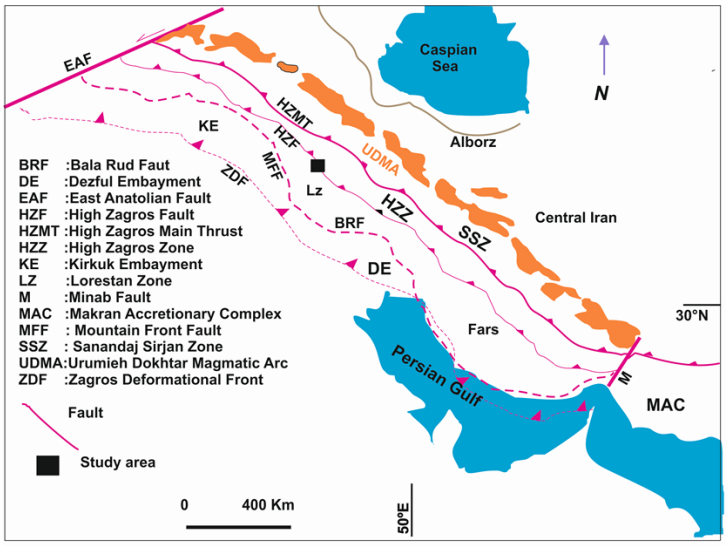

Fig.3. Different part of the Zagros basin (modified after Alavi 2007)

Indeterminate zone: This zone spans 423 metres of the Sarvak Formation. After this zone and the beginning of the next zone, an ecological change occurred in which planktonic foraminifera appeared. The most significant microfossils this zone are: *Calcisphaerula innominata* (Bonet 1956), *Lenticlina* sp., *Nezzezatinella* sp., *Orbitolina* sp., Miliolids, *Peneroplis turonicus* (Said & Kenawy (1957), *Planoheterohelix globulosa* (Ehrenberg 1840), Textularia sp., *Calcisphaerula innominate* (Bonet 1956), *Pithonella* sp., and rudist debris. Given that we could not find a significant microfossil in the lower part of the Sarvak Formation in the Sepid Kuh, interpretation on the age of this part is difficult, which explains why this is here presented to as an indeterminate zone. As to its stratigraphical position, We consider its age as Cenomanian.

Fig.4. O Bangestan Group in the southern side of the Sepid Kuh anticline (View to the SE)

***Helvetoglobotruncana hevitica* Total Range Biozone (Sigal 1955):** It is characterized by the total range of *Helvetoglobotruncana helvetica* (Bolli 1945). In the Sepid Kuh, this biozone cover 17m of light grey limestone of the Sarvak Formation and 24 m of the Surgah Formation. It was reported from Western and

Central Tethys (Caron 1966, 1981 and Sigal 1955), and the Atlantic Ocean (Pessagno and Longoria 1973). Caron (1985), Robaszynski and Caron (1995) and Premoli Silva and Verga (2004) attributed a latest Early to Middle Turonian age for this biozone.

The important taxa belong to *Helvetoglobotruncana helvetica* (Bolli 1945), *Marginotruncana undulata* (Lehmann 1963), *Marginotruncana sigali* (Reichel 1950), *Marginotruncana undulata* (Lehmann 1963), *Planoheterohelix globulosa* (Ehrenberg 1840; GhasemShirazi et al. 2014-a), *Planoheterohelix moremani* (Cushman 1938), and *Planoheterohelix punctulata* (Cushman1938).

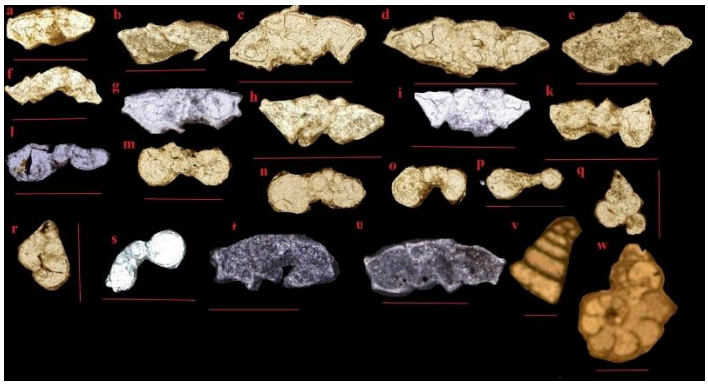

Fig. 5. Foraminifera recognized in the studied section. a) *Marginotruncana marginata* (Reuss1845), sample number 144; b) *Marginotruncana paraconcavata* (Porthault1970), sample number 179; c) *Marginotruncana renzi* (Gandolfi 1942), sample number 165; d) *Marginotruncana undulata* (Lehmann 1963), sample number 132; e) *Marginotruncana schneegansi* (Sigal 1952), sample number 132; f) *Marginotruncana sigali* (Reichel 1950), sample number 199; g) *Marginotruncana pseudolinneiana* (pessagno1967), sample number 144; h) *Dicarinella primitiva* (Dalbiez 1955), Sample number 135, i) *Dicarinalla concavata* (Brotzen 1934),sample number 131; k) *Dicarinella asymetrica* (Sigal 1952), sample number 196; l) *Globotruncana bulloides* (Vogler 1941),sample number 115; m) *Helvetoglobotruncana helvetica* (Bolli 1945),sample number 108; n) *Whiteinella baltica* (Douglas and Rankin1969), sample number 117; o) *Whiteinella aprica* (Loeblich and Tappan, 1961), sample number 120; p) *Macroglobigerinelloides bollii* (Pessagno1967), sample number 109; q) *Planoheterohelix globulosa* (Ehrenberg 1840), sample number 108 8; r) *Planoheterohelix punctulata* (Cushman1938), sample number 108; s) *Rugoglobigerina milamensis* (Smith and Pessagno 1973), sample number 250, t) *Globotruncana lapparenti* (Brotzen 1936), sample number 171, u) *Globotruncana linneiana* (d` Orbigny, 1839), sample No. 169, v) *Peneroplis turonicus* (Said and Kenawy (1957) sample number 19; w) *Nezzezatinella* sp. sample number 32, b) . Scale bars represent 500µm

***Marginotruncana sigali* Partial Range Biozone (Barr 1372):** It is characterized by the last outbreak of *Helvetoglobotruncana* to the first outbreak of *Diacarinella concavata* (Brotzen 1934). In the Sepid Kuh, this zone spans 54 of light to dark gray, medium to thick limestone of the Surgah Formation. This biozone is also named as the *Marginotruncana schneegansi Zone* (Robaszynski and Caron 1995), *Diacarinella primitiva— Marginotruncana sigali* Zone (Premoli Silva and Sliter 1981) or *Marginotruncana sigali— Diacarinella primitiva* zone (Premoli Silva and Sliter 1981). This biozone was attributed to the late Turonian (Caron 1985; Premoli Silva and Verga 2004). The dominant taxa belong to *Dicarinella primitiva* (Delbiez, 1955), *Marginotruncana marginata* (Reuss 1985), *Marginotruncana paraconcavata* (Porthault 1970), *Marginotruncana pseudolinneiana* (pessagno 1967), *Marginotruncana renzi* (Gandolfi, 1942), *Marginotruncana scheengansi* (Sigal, 1952), *Marginotruncana sigali* (Reichel, 1950), *Marginotruncana sinuosa* (Porthault, 1970), *Marginotruncana undulata* (Lehmann 1963).

***Dicarinella Concavata* Interval Biozone (Sigal 1955):** It is is defined by the primary occurrences of *Diacarinella concavata* (Brotzen 1934) to the first occurrences of *Diacarinella asymetrica* (Sigal 1952). In the Sepid Kuh, it contains 12 m of light to dark gray, medium to thick limestone of the Surgah Formation and 28 m of the Ilam Formation. Microscope investigations present the alternation of bioclastic wackestone and lithoclast wackestone– packstone. It was reported from South Lorestan (Vahidinia et al. 2016), Western Tethys (Caron 1966) and Central Tethys (Sigal 1977), Caribbean (Gradstein 1978), Western Pacific ocean (Premoli Silva and Silter 1999), and Tanzania (Petrizzo et al. 2013).This biozone was attributed to the late Turonian to early Santonian (Premoli Silva and Verga 2004).

The dominant taxa belong to *Dicarinella primitiva* (Delbiez, 1955), *Globigerinelloides bentonensis* (Morrow, 1934), *G. bollii* (Pessagno 1967), *G. prairiehillensis* (Pessagno, 1967), *Globigerinelloides ultramicrus* (Subbotina 1949), *Globotruncana linneiana* (d'Orbigny 1839), *G. lapparenti* (Brotzen 1936), *Marginotruncana coronata* (Bolli, 1945), *M. pseudolinneiana* (Pessagno 1967), *M. renzi* (Gandolfi 1942), *M. scheengansi* (Sigal 1952), *M. sigali* (Reichel 1950), *M. sinuosa* (Porthault in Donze et al. 1970), *M.*

tarfayaensis (Lehmann 1963), *Muricohedbergella holmdelensis* (Olsson 1964).

***Dicarinella asymetrica* Total Range Biozone (Postuma 1971):** It is characterized by the prime occurrence of *Diacarinella asymetrica* (Sigal 1952).

In studied sections, this biozone is extended in 22 m of light grey, medium limestone of the Ilam Formation. This biozone was introduced from West Lorestan (Sadeghi and Raziani, 2014), Western and Central Tethys (Caron 1966 and Sigal 1977), Caribbean (Gradstein 1978), Western Pacific ocean (Premoli Silva and Silter, 1999), and Tanzania (Petrizzo et al. 2013).This biozone was attributed to the Santonian (Premoli Silva and Verga 2004). The dominant taxa belong to *Dicarinella asymetrica* (Sigal 1952), *Globotruncana arca* (Cushman, 1926), *Globigerinelloides prairiehillensis* (Pessagno 1967), *Globotruncana lapparenti* (Brotzen 1936), *Globotruncana linneiana* (d`Orbigny, 1839), *Globotruncana ventricosa* (White 1928), *Gumberlina* sp. *Planoheterohelix globulosa* (Ehrenberg 1840), *Planoheterohelix moremani* (Cushman 1938), *Rugoglobigerina milamensis* (Smith and Pessagno 1973), and *Ventilabrella eggeri* (Cushman, 1928).

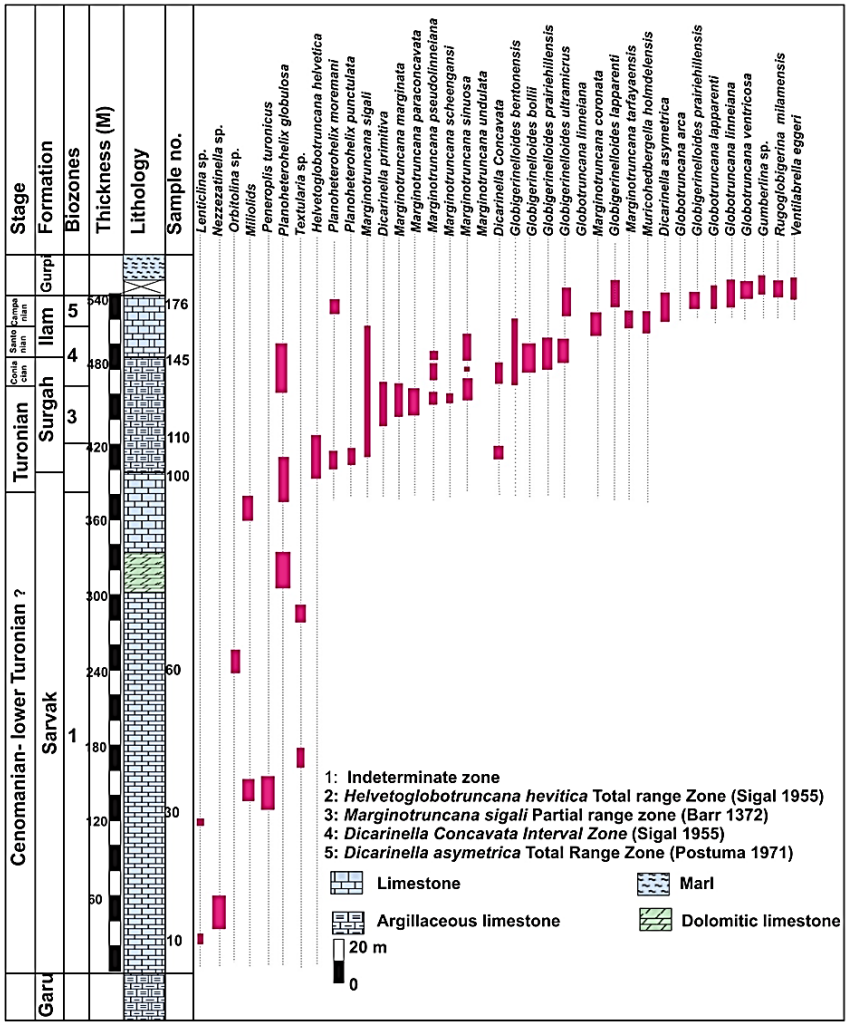

Fig 6. Distribution of foraminifera and biostratigraphic biozonation of the Sepid Kuh anticline

5. Discussion

The planktic foraminiferal zonation proposed in the present article corresponds to the Lower Turonian – Santoniann interval and it is similar to the zonal schemes of the Mediterranean Basin (e.g. Premoli Silva and Verga 2004). Generally the majority of our zones are taxonomically the same like the zones from the above mentioned area, but in some cases with different stratigraphical range that is results of differences in environmental conditions. The Sarvak Formation is spread in two types of facies throughout Zagros basin:

one deposited in a neritic environment, and the other formed under deeper- water conditions with a pelagic fauna (Setudenia 1972). The Former facies is present throughout the Fars zone and Dezful Embaymen as fine-grain argillaceous, nodular- bedded limestone containing grainstone, rudist- bearing packstone, and

thin-bedded oligostegina limestone. In the Mediterranean basin, Cretaceous bizones have been introduced on the base of planktonic and benthic foraminifera.

Table 1 Correlation scheme of the recorded foraminiferal biozones for the peri-Mediterranean Upper Cretaceous limestone with the established Upper Cretaceous foraminifera biozonation for the Sepid Kuh anticline.

Age	Mediterranean basin	SE Europe	Fars Zone	Izeh Zone	South Lorestan	North Lorestan
	Premoli Silva and Verga (2004)	VELIĆ (2007)	Vaziri Moghaddam (2002) Afgah et al. (2014)	Doosti et al. 2021b	Amiri 2009	This study
Santonian	*Dicarinella asymetrica* total Range Zone	*Murgella lata* partial-range zone or *Murgella lata–Calveziconus lecalvezae* interval zone	*Dicarinella asymetrica* total Range Zone		*Globotruncana concavata/ Ventricosa carinata* assemblage zone	*Dicarinella asymetrica* total Range Zone
Coniacian	*Dicarinella Concavata* interval zone	*Dicyclina schlumbergeri– Murgella lata* interval zone or *Dicyclina schlumbergeri* partial-range zone	*Dicarinella Concavata* interval Zone	*Hiatus*	*Marginotruncana sheeganzi Marginotruncana sigali* assembalage zone	*Dicarinella Concavata* interval zone
		Scandonea samnitica– Dicyclina schlumbergeri interval zone or *Scandonea samnitica* partial-range zone				
Turonian	*M.Sigali* Partial range zone	*Pseudocyclammina sphaeroidea– Scandonea samnitica* interval zone or *Pseudocyclammina sphaeroidea* partial-range zone	Hiatus		*Helvetoglobotruncana hevitica – Calvihedbergella-Hedbergella* assemblage zone	*M.sigali* Partial range zone
	Helvetoglobotruncana hevitica total range zone			*Nezzazatinella picardi-Mangashtia - Dicyclina* assemblage zone		*Helvetoglobotruncana hevitica* total range zone
Late Cenomanian	*Whiteinella archaeocretacea* Partial range zone	*Chrysalidina gradata– Pseudocyclammina sphaeroidea* interval zone	*Calcisphaerula innominata and Whiteinella paradubia* assemblage Zone)	*Cisalveolina fraasi (fallax) and C. lehneri - Praetaberina bingistani* assemlage zone	Olgostegina zone	Indeterminate zone

The Upper Cenomanian- Lower Turonian pelagic deposits corresponds to *Diacarinella algeriana* Subzone and *Whiteinella Arcaeocretacea* Zone of Caron (1985) and *Whiteinella archaeocretacea* Subzone of Premoli Silva and Verga (2004) (table 1).

The shallow bizones in the Mediterranean basin were established by the Velić (2007) who introduced *Chrysalidina gradata–Pseudocyclammina sphaeroidea* interval zone within the Upper Cenomanian- Lower Turonian shallow deposits of Žumberak (NW Croatia).

Amiri (2009) reported that the upper part of the Sarvak Formation of Darreh Baneh East well#1 , located in Southern part of Lorestan zone, consists of biozoes 26 (Oligostegina zone)and 27(*Helvetoglobotruncana hevitica – Calvihedbergella-Hedbergella* assemblage zone) of Wynd (1965). In Sarkan well, located in the southeast of Lorestan zone, the Sarvak Formation has the same biozones. But to the south and north of Dezful Embayment (Ferdows Well # 1), the upper section of Sarvak Formation to the Late Ceonomanin-Torunian age has a shallow facies and includes biozones 25 (*Nezzezata* – Alveolinids assemblage biozone) and 29 (*Valvulammina- Dicyclina* assemblage bizone) of Wynd (1965). To the north of the Sepid Kuh anticline, Aleshtar, the Sarvak Formation shows a lagoon and tidal flat fasies (Asadolahi et al. 2018). The Upper Cenomanian at northwestern flank of Sepid Kuh anticline was not biostratigraphically divided because it has rare planktonic foraminifera. Therefore, it seems that in the Late Cenomanian-Turonian age, the northern parts of the Lorestan and Thrust Zone had shallow facies, which deepened towards the southern Lorestan zone.

Afgah et al. (2014) reported *Nummoloculina heimi* zone and *Calcisphaerula innominata* and *Whiteinella paradubia* Assemblage Zone from the late Cenomanian sequence of Nour Abad (Fars zone). These biozones are correlated with *Nezzazata*- alveolinids assemblage zone and olgostegina zone of Wynd (1965), respectively. Dousti Mohajer et al. (2021b) distinguished *Cisalveolina fraasi* (fallax) and *C. lehneri* - *Praetaberina bingistani* assemlage zone and *Nezzazatinella picardi-Mangashtia -Dicyclina* assemblage zone from Pyun anticline in Izeh Zone.

Dousti Mohajer et al. (2021b), by comparing the percentage planktonic and benthic goraminifera of the Izeh and Fars basin, concluded that the Izeh basin was shallower than Fars zone in the Late Cenomanian.

During the Cenomanian/ Turonian, uplift of the Thrust zone caused a widespread Turonian unconformity in the Fars, Izeh and Dezful Embayment and influx of clastic sediments over large part of the lorestan zone (Ghazban 2007). At the same time, Lorestan zone begun to subsidence, which caused the emergence and spread of fauna of *Helvetoglobotruncana helvitica* zone and changed the sedimentation from the limestone of Sarvak Formation to the argillaceous limestone of the Surgah Formation. Comparison of biozones known of Surgah Formation with those of in the Tang-e Garab (Monjezi 2006), Kuh Surgah (Sadeghi and Adabi 2012) and Shah Nakhjir in west Lorestan (Sadeghi and Raziani, 2014), Maleh kuh in south of study section (Haddadi and Vahidinia 2013) suggests that these area are alike in biostratigraphic units and age. The Surgah Formation underlies the basinal facies of the Ilam Formation that is present throughout Lorestan zone. In Sepid Kuh anticline, only the lower part of Ilam Formation has an outcrop, which is similar to Maleh anticline (Haddadi and Vahidinia 2013), Sarkan (Amiri 2009) and Poshteh Jangal anticline in west of study section (Vatandoost et al. 2016) with Cenomanian

6. Conclusions

In this study, the foraminifera associations have been investigated of the Bangestan Group from the Sepid Kuh anticline. The thickness of the Bangestan Group is about 540 meters and composed of limestone, argillaceous limestone and dolomitic limestone. In total, 8 genera and 34 species of plankton foraminifers and 5 genera and 1 species of benthic foraminifera were recognized and eventually 5 biozones were determinate and ultimately have compared with Foraminiferal standard zones. The major part of the Sarvak Formation (400 m) in Sepid |kuh anticline lacks any important microfossils and the age can only be suggested on its stratigraphical position; it is here proposed to be Cenomanian. Based on the foraminifera declared, four bio-assemblages can be recognized Early- Middle Turonian age

Marginotruncana sigali Partial Range Biozone: appointed to be of late Turonian age

Dicarinella Concavata Interval Biozone: appointed to be of late Turonian- Early Santonian age

Dicarinella asymetrica Total Range Biozone: considered to be of early Santonian age.

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