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NANNOFOSSIL EVENTS AND STRATIGRAPHY OF THE ILAM FORMATION IN ZAGROS (SW IRAN)

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Abstract. Exploration studies of Cretaceous system in the Zagros region are very important due to the presence large hydrocarbon fields like the Ab-Teymur oilfield. The first data on the distribution of calcareous nannofossils in the Ilam Formation, belonging to the Bangestan Group in the Zagros Basin, are presented here. According to the distribution of calcareous nannofossils, the Upper Cretaceous deposits of the section are subdivided into three complete biostratigraphic units, namely: the *Micula decussata* (CC14-Late Coniacian), *Reinhardtites anthophorus* (CC15-late Early Santonian), *Lucianorhabdus cayeuxii* (CC16-Late Santonian) and base of CC17 zones. This record confirms the existence of biozone CC14 to basal CC17 of the zonation of Sissingh (1977), which suggests an age from Late Coniacian to Late Santonian for the studied sediments. Besides biostratigraphy, the presence of abundant calcareous nannofossils typical of warm climate and low latitude conditions in Ab-Teymur oilfield allows paleoenvironmental interpretations.

Introduction

The geological structure of Zagros basin is one of the biggest oilfields in southwestern Iran. The Zagros basin is divided into three zones: the suture thrust zone, the imbricated zone and the simply folded belt (Alavi 2004). Our study area is part of the Zagros simply folded belt (Fig. 1). The sedimentary succession of the Zagros fold-thrust belt comprises a 12 km thick section of Paleozoic through Cenozoic strata (Colman-Sadd 1978). During the Paleozoic, Iran together with Afghanistan and Turkey made up the long, wide and stable margin of Gondwanaland bordering the southern shores of the Paleotethys Ocean (Berberian 1995). During the Mesozoic, the Zagros basin steadily subsided and a thick sedimentary sequence (more than 10000 m) composed mainly of marine carbonates was deposited on the margin. The Coniacian–Santonian (Upper Cretaceous) sediments were deposited on the Arabian plate, forming the NE passive margin of Gondwanaland (Motiei 1993; Alavi 2004). The Ilam Formation is part of the Cretaceous deposits of the simply folded belt zone, Zagros. In order to study the nannofossil biostratigraphy of the Ilam Formation, one subsurface stratigraphic section of Ab-Teymur oilfield (E 31° 15'; N 48° 29') in North of Dezful embayment was selected. In this locality, the Ilam Formation consists of a 194-m-thick succession of marly limestones and brown, thick bedded limestones, overlying the limestone of the Sarvak Formation. At the type section, in the north-western part of the Kabir Kuh Anticline at Tang-e Garab in Lurestan, the Ilam Formation consists instead of grey regularly bedded, argillaceous limestone with thin, black, fissile shale, and is of Santonian to Campanian age (James & Wynd 1965). The Ilam Formation is overlain with a transitional boundary by the Gurpi Formation. Many authors have studied the structural positions, reservoir conditions and sequence stratigraphy of the Ilam Formation in the Bangestan Group (Hart 1970; Alavi 2004; McQuarrie 2004; Ghabeishavi et al. 2009; Soleymani et al. 2010). Most of the palaeontological studies on the Cretaceous of the Zagros and, particulary, of the Ilam For-

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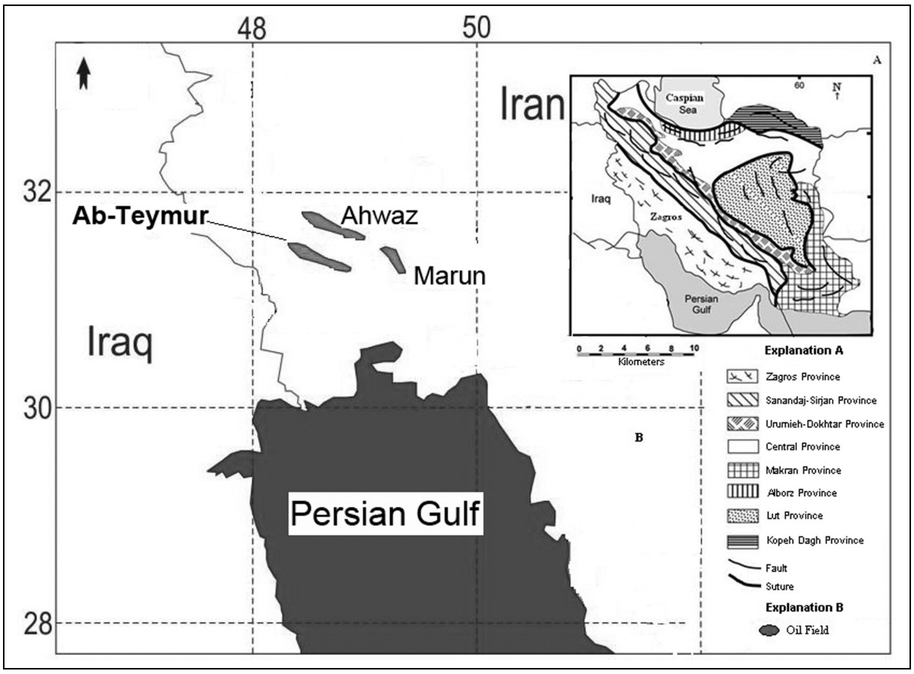

Fig. 1 - A) General map of Iran showing eight geologic structural zones, adapted from Heydari et al. (2003). B) Location map of the studied area (Ab-Teymur oilfield), after Motiei (1993).

mation have been performed using foraminifers (Desbordes 1972; Khalili 1976; Vaziri-Mogaddam 2002; Rezaeian & Taheri 2012 amongst others). These studies suggest a Coniacian to Campanian age for the Ilam Formation based on various localities in the Zagros. The present contribution is the first study concerning calcareous nannofossils from the succession of Ab-Teymur oilfield. The main purpose of our research is to establish a biostratigraphic zonation and a correlation with standard biozones.

Material and Methods

One hundred-twenty five samples representing the oldest and youngest strata of the 194-m thick succession were collected up to the contact with the Gurpi Formation. Of these samples, 21 were used to collect detailed assemblage data, with the remaining samples used to increase precision of nannostratigraphic markers. These samples were collected systematically all along the continuous core. The most detailed sampling was performed in the intervals at 1 m below and above the boundaries of the Ilam Formation. Slides of these samples were prepared using standard methods (smear slides) for calcareous nannofossil biostratigraphic analysis (Bown 1998). Smear slides were made directly from unprocessed samples, freshly cut rock fragments without centrifuging in order to avoid changes in the composition of the original assemblages. The sample preparation was performed under constant laboratory conditions (e.g., temperature of 20-25° °C). Slides were systematically examined with Olympus polarized light microscope at a magnification of ×1000. The used calcareous nannofossil biozonation is based on standard timescales of the International Commission of Stratigraphy (Sissingh 1977; Gradstein et al. 2004). Bibliographic references for these taxa can be found in Perch-Nielsen (1985) and Bown (1998). Species abundance considered in this paper is listed in Tab. 1 as: R = rare (1 specimen per field of view [FOV] 11-100), F = few (1 specimen per 2-10 FOV), C = common (1-10 specimen per FOV), A = abundant (>10 specimen per FOV).

Calcareous Nannofossils

Calcareous nannofossils represent a fundamental tool for biostratigraphic correlations of Mesozoic marine sediments (Thierstein 1976; Sissingh 1977; Perch-Nielsen 1985 amongst others). Nannofossils are usually recorded in great abundance and show a broad planktonic distribution and a rapid evolution in the Mesozoic. The continued evolution of many forms of calcareous nannofossils during the 34 million years of the Late Cretaceous Epoch has enabled the recognition of 18 biostratigraphic zonal units on the basis of the relative ranges of various species (Perch-Nielsen 1985; Witrock et al. 2003; Gradstein et al. 2004). The CC (Coccolith Cretaceous) nannofossil zonation of Sissingh (1977) is used in the present study.

Nannostratigraphy

Highly diversified and moderate abundances calcareous nannofossils assemblages were found in the Ilam Formation and allowed recognition of the CC14, CC15, CC16, and basal CC17 nannofossil zones. The nannofossil assemblage of the Ilam Formation comprises 26 species: *Lithraphidites carniolensis, Chiastozygus platyrhethus, Rhagodiscus angustus, Tranolithus orionatus, Eiffellithus turriseiffelii, Microrhabdulus decoratus, Quadrum gartneri, Eiffellithus eximius, Lucianorhabdus maleformis, Marthasterites furcatus, Micula decussata, Micula staurophora, Reinhardtites anthophorus, Lithastrinus grillii, Micula concava, Lucianorhabdus cayeuxii, Calculites obscurus, Calculites ovalis, Aspidolithus parcus expansus, Eiffellithus gorkae, Microrhabdulus belgicus, Tetrapedorhabdus*

Nannofossil events and zones

Formation	Period	Epoch	Age	Comparative biozone	Sissingh (1977)	This study
Gurpi	Creta.	Late Creta.	Campa.			
Ilam	Cretaceous	Late Cretaceous	Late Santonian	CC17	*Calculites obscurus*	Basal of CC17
				CC16	*Lucianorhabdus cayeuxii*	*Lucianorhabdus cayeuxii*
			late Early San.	CC15	*Reinhardtites anthophorus*	*Reinhardtites anthophorus*
			L. Coniacian	CC14	*Micula decussata*	*Micula decussata*
Sarvak	Creta.	Late Creta.	Cenomanian to Turonian			

Sample no.	Thickness (m)	*Aspidolithus p. expansus*	*Braarudosphaera bigelowii*	*Calculites obscurus*	*Calculites ovalis*	*Chiastozygus platyrhethus*	*Eiffellithus eximius*	*Eiffellithus gorkae*	*Eiffellithus turriseiffellii*	*Glaukolithus diplogrammus*	*Lithastrinus grillii*	*Lithraphidites carniolensis*	*Lucianorhabdus cayeuxii*	*Lucianorhabdus maleformis*	*Marthasterites furcatus*	*Microrhabdulus belgicus*	*Microrhabdulus decoratus*	*Micula concava*	*Micula decussata*	*Micula staurophora*	*Quadrum gartneri*	*Reinhardtites anthophorus*	*Rhagodiscus angustus*	*Tetrapedorhabdus decorus*	*Tranolithus orionatus*	*Watznaueria barnesiae*	*Watznaueria biporta*
125	194																										
	193		F	F	R		R		R			R	C	R			R		F						R	C	
		R					F	R	R		R	F	C	R			F	F	R	R		R				A	C
			F		R	R				R	F		F		R	R	F		R		R	F	R	R	R	A	C
		R	C				F	R	C				F	C			R	C	F		R					C	C
		C			F					F	F	F				F	F			R		F	F		R	C	C
		F					F		F	F			F						C				C			F	F
89	138		R			F	C					R	R		F		R			F	C	C				C	
		R					C		C	F	F	R		R		F		F	A					R	R	F	C
		F	R		R		F		F						R		F		C		R	F	F				F
		C				C			C		R	F						R		F	C		F		F	C	C
					F		C	F			R	R		F		F	C	F	A		F	F				F	F
		C	R				C		R	F		F				F	R		A		C	F			F	C	
							C		C			F		F				R		F			C				F
		F	R			F	F	F	C	F		R			F	F	C		C		R	R		F	R	F	C
42					F									R		F			A		C	R				C	
	54	F					C		R			F			R		R	R	C				F				F
			F		F	C	F	R	F	F		R								F	F				R	F	F
		R							R			R		R		R	F		F				F	R	F	F	
			F		R	F	F			R							F		F		F				R	C	C
6			F			R			R			R		R	F				F	R	R		R				C
	0						R								R		R		R	R					R	C	
1																											

Limestone; Marly Limestone

Tab. 1 - Nanno-stratigraphic chart of Ilam Formation based on Calcareous Nannofossils, South West of Iran, Zagros. Species abundance: R = rare (1 specimen per field of view [FOV] 11-100), F = few (1 specimen per 2-10 FOV), C = common (1-10 specimen per FOV), A = abundant (>10 specimen per FOV).

decorus, Watznaueria barnesiae, Watznaueria biporta, Braarudosphaera bigelowii, Glaukolithus diplogrammus.

Biostratigraphy/Bioevents

The first nannofossil biozone recorded from Ilam Formation is characterized by the interval (54 m-thick) comprised by the first occurrence (FO) of *Micula decussata* or *M. staurophora* (boundary of Sarvak-Ilam) to the FO of *Reinhardtites anthophorus*. This interval corresponds to the CC14 zone distinguished in the late Coniacian (Sissingh 1977; Perch–Nielsen 1985; Burnett 1998). In this zone, nannofossils are moderately diversified with a good preservation. The dominant taxa in this zone are *B. bigelowii, C. ovalis*, *Ch. platyrhethus, E. eximius, E. turriseiffelii, L. carniolensis, L. maleformis*, *M. furcatus, M. belgicus, M. decoratus, M. decussata, M. staurophora, Q. gartneri, R. angustus, T. orionatus, W. barnesiae* and *W. biporta.*

Zone CC15 is defined as the interval (84 m-thick) from the FO of *Reinhardtites anthophorus* to the FO of *Lucianorhabdus cayeuxii* (Sissingh 1977; Perch–Nielsen 1985). The dominant taxa recorded in the assemblage are: *A. parcus expansus, B. bigelowii, C. ovalis, Ch. platyrhethus, E. eximius*, *E. gorkae, E. turriseiffelii, G. diplogrammus, L. carniolensis, L. maleformis, M. furcatus, M. belgicus, M. decoratus, M. concava, M. decussata, M. staurophora, Q. gartneri, R. anthophorus, R. angustus, T. decorus, T. orionatus, W. barnesiae* and *W. biporta.* The age of zone is late early Santonian. In this zone, nannofossils are highly diversified with a good preservation.

The next nannofossil biozone, (55 m thick) recorded in the limestone of the Ilam Formation ranges from the FO of *Lucianorhabdus cayeuxii* to the FO of *Calculites obscurus* (55 m), which corresponds to the zone CC16, dated to the latest Santonian (Sissingh 1977; Perch–Nielsen 1985).

The Lucianorhabdus cayeuxii zone is characterized by the following species: *A. parcus expansus, B. bigelowii, C. ovalis, Ch. platyrhethus, E. eximius, E. gorkae, E. turriseiffelii, G. diplogrammus, L. grillii, L. carniolensis, L. maleformis*, *L. cayeuxii, M. furcatus, M. belgicus, M. decoratus, M. concava, M. decussata, M. staurophora, Q. gartneri, R. anthophorus, R. angustus, T. decorus, T. orionatus, W. barnesiae* and *W. biporta.* Because of the first occurrence of *C. obscurus* was found at 193 m from the base, only the basal part of Zone CC17 was identified. This zonal scheme is shown in Tab. 1 and is compared to the other commonly used zonations (e.g. Sissingh 1977). Most significant taxa discussed in this section are illustrated in Fig. 2.

Discussion

Preservation

Dissolution and diagenesis can alter the preservation of calcareous nannofossils and thus, their utility as indicators for temperature and productivity changes (Bown & Young 1998; Bown et al. 2004). Presumably, dissolution should lead to a reduction of total abundances of calcareous nannofossils and, at the same time,

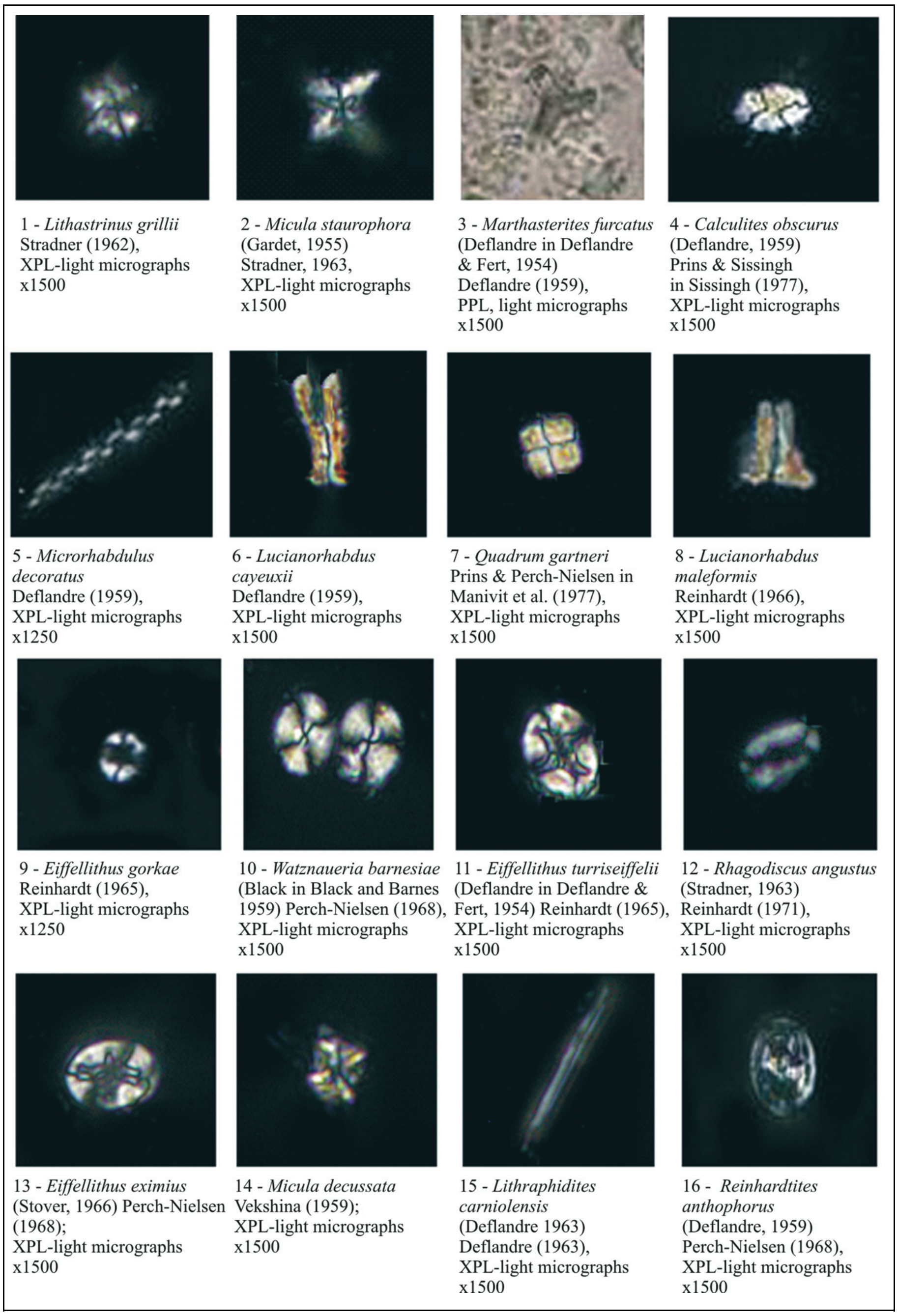

Fig. 2 - The most significant nannofossil species identified in the Ilam Formation.

increase the percentages of the dissolution-resistant taxa (Friedrich et al. 2005). In the studied samples, 26 taxa were identified, with a good preservation of the calcareous nannofossils assemblages. Most samples contain rich and diverse species with *Micula decussata, Watznaueria barnesiae, Eiffellithus eximius, Microrhabdulus decoratus* and *Lithraphidites carniolensis* as the most prominent taxa. Based on the variation and abundance of species (e.g. *M. decussata*, *W. barnesiae, L. cayeuxii* and *C. obscures*), the Ilam Formation was deposited in a relatively deep marine environment, whilst the basin depth is reduced towards top of the stratigraphic column.

Paleoenvironmental considerations

Calcareous nannofossils are good palaeoecologic indicators as their distribution was influenced by ecological conditions in marine waters in which they lived. The palaeoecology preferences of Upper Cretaceous nannofossils have been investigated by many authors (Paasche 1986; Brand 1994; Watkins 1996; Andruleit 1997; Hagino et al. 2005; De Bernardi et al. 2008; Shamrock & Watkins 2009). The relationship between calcareous nannofossils and productivity was discussed in various studies (Young 1994; Eshet & Almogi Labin 1996). The presence of calcareous nannofossils in our samples suggests favorable conditions in the surface waters for their productivity. Most of the observed nannofossils in the present study have low latitude affinities because of the presence of taxa that could have lived in warm waters. *Micula decussata*, for example, can be considered as an indicator either of preservation because it is a dissolution-resistant taxa, or as a temperature index taxa. Also, *Watznaueria barnesiae* is prominent in the samples from the upper part of section. It is accepted that the *W. barnesiae* is the most common shallow marine environment species (Watkins 1996; Henriksson & Malmgren 1997).

This species shows an opposite trend with respect to *M. decussata*, which shows lower abundances at the top of the section. *Micula decussata* shows moderate to high abundance during most of the Late Coniacian-late early Santonian deposits.

Conclusion

In conclusion, 12 families, 18 genera and 26 marker species of calcareous nannofossils from the standard zonation (Sissingh 1977) have been identified for the first time in the Ab-Teymur oilfield. Calcareous nannofossil abundances are moderate within the study area.

Twenty-six calcareous nannofossils species have been identified, all indicative of the low-latitude Tethyan Bio-province.

The calcareous nannofossils here described allow us to date the succession to the late Coniacian-late Santonian, based on the identification of CC14, CC15, CC16 biozones and basal CC17 zone.

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