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SEA LEVEL CHANGE, BIOGEOGRAPHY AND PALEOSALINITY OF THE ABDERAZ FORMATION (TURONIAN – SANTONIAN) AT DERAZ-AB SECTION, NE IRAN

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ABSTRACT

The Abderaz Formation (Late Turonian – Late Santonian) is investigated in this work at Deraz-Ab section, where a thickness of 400 m, comprised of light grey shale and marls, is exposed. The aim of the present study is to determine the Paleobathymetry and paleosalinity of the depositional environment based on planktonic foraminifera assemblages. Three swarming morphotypes, suggested by Leckie in 1987 are followed, in addition to the ratio of planktonic to benthic foraminifera to determine the sedimentation depth. Statistical study of the morphotype groups of planktonic foraminifera shows that they are of shallow water forms (SWF) and deep water forms (DWF). The planktonic to benthic ratio is high indicating specific conditions of oligotrophy and sedimentation in a relatively deeper marine condition. Salinity is considered minimum in the Coniacian and maximum in the Coniacian – Santonian boundary. Comparing planktonic assemblages recovered from the formation with those of Cretaceous biogeographical provinces indicate a close similarity with those of the Tethyan province.

التغير في مستوى سطح البحر والجغرافية الأحيائية القديمة والملوحة في تكوين ابديراز (تورونيان – سانتونيان) في مقطع ديراز-اب، شمال شرق إيران

محسن علامه

المستخلص

تشمل هذه الدراسة تكوين ابديراز (التورنين المتاخر – سانتونين المتاخر) في مقطع ديراز-اب والذي يبلغ سمكه حوالي 400 متر من صخور رصاصية فاتحة للطفل والوحل وذلك من أجل تحديد عمق وملوحة المياه القديمة عند ترسيب تكوين ابديراز. من اجل هذا الهدف استخدمت ثلاثة أشكال احتشاد تم اقتراحها من قبل Leckie في 1987 وتم استخدام نسبة المنخربات الطافية الى المنخربات القاعية من أجل تحديد عمق المياه. تظهر الدراسات الإحصائية للأشكال النمطية للمنخربات الطافية ان غالبينها من النوع الضحل والعميق بينما تشير نسبة الطافية الى القاعية منها الى ظروف تغذية قليلة وترسيب في بيئة بحرية عميقة نسبيا. كذلك اعتبرت أوطأ مستويات الملوحة في عمر الكونياسيان في حين بلغت ذروتها في نطاق الكونياسيان – سانتونيان. مظاهاة المجاميع الطافية من التكوين مع مثيلاتها في البيئة الجغرافية القديمة لأنطقة العصر الطباشيري تشير الى تطابق مع نطاق التيثس.

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INTRODUCTION

Although of their limited value for palaeoecology, planktonic foraminifera are useful for the paleoceanographic analysis of Middle and Upper Cretaceous sequences, including the study of sea level changes (Hart and Carter, 1975). When analysed in isolation, the Calsisphera group does not provide a valuable level of biostratigraphic detail for Upper Cretaceous sequences, but when used in conjunction with other planktonic groups (such as planktonic foraminifera), they can be useful for the investigation of carbonate sequences. Studies of the abundance and diversity of planktonic foraminifera and pithonellids are very important for paleoecology. For instance *Pithonella*, an opportunist genus found in the Tethyan realm, is extremely useful when investigating the paleoceanography of Cretaceous pelagic limestones. *Pithonella spherical,* a resistant species of pithonellid found in shallow inner neritic waters, has been found to be rather more of an opportunist than other *Pithonella* species (Dias Brito, 2000).

Paleodepth determination is an important component of paleoceanographic and paleoclimatic reconstructions as well as in basin analysis and reconstruction of the uplift and subsidence history of sedimentary basins, in addition to the construction of sea-level curves. The distribution of foraminifers throughout the oceans today is the basis for the interpretation of fossil morphotypes. Many species are temperature-dependent, in particular those which are restricted to temperate and warm waters. Warmer water species are usually large, thick-walled complex morphotypes, and populations are characterized by high diversity. Colder water species have globular chambers and populations are rather uniform (Caron and Homewood, 1983). The life-cycle is thought to be accomplished with a concomitant depth migration. The depth-range being different for individual groups and it has been suggested that the control is maintained by density.

The distribution of planktonic foraminifera depends on surface water temperature and density. Various geometric tests have been used to differentiate specimens found at particular depths down the water column. For instance, deep water planktonic foraminifera are more porous than those living in shallow water (Keller *et al*., 2002; Martinez, 1989; Luciani, 2002; Leckie, 1987).

Various methods have been used to estimate paleobathymetry. Shafiee Ardestani *et al*. (2009) used the Hart method (Hart, 1980) to determine the paleobathymetry of the Abderaz Formation in its type section. Many reputable micropaleontologists have used the planktonic to benthic ratio for the determination of sedimentation depth (e.g., Jorissen *et al*., 2007). Initial research in this field began between 1951 and 1955 (Phleger, 1951; Grimsdal and Van Morkhoven, 1955), with the discovery of the relationship between water depth and planktonic to benthic foraminifera ratios. One of the main aims of this research is to analyse the geometric architecture of the planktonic foraminifera tests of the Abderaz Formation in Kopeh-Dagh basin, located NE Iran (Fig.1), as well as the planktonic to benthic ratio, in order to determine past sea level changes.

STUDY AREA

Although named after the village of Abderaz, the type locality of Abderaz Formation is in fact located at Muzduran neck (Afshar harb, 1994). The Abderaz Formation (Late Turonian – Late Santonian) at Deraz-Ab section is situated northeast of Mashhad on the main Mashhad – Sarakhs road, approximately one kilometre from Muzduran at 61º 33' 20" E, 35º 10'30" N (Fig.1). The Thickness of Abderaz Formation at Deraz-Ab section is about 400 m, which consists of 11 lithological units which are: **1)** thin bedded, light grey marl, **2)** thin bedded, grey shale, **3)** thin bedded, grey to yellowish marl, **4)** thin bedded, light green marl, **5)** thin bedded, light grey shale, **6)** thick bedded, bluish limestone, **7)** thin bedded, light grey marl, **8)** yellowish chalk limestone, **9)** light grey marl, **10)** light grey shale, **11)** thick bedded chalk lime. A dark olive shale represents the lower boundary with the Aitamir Formation and chalk limestone represents the upper boundary with the Abtalkh Formation, which are disconformable and conformable contacts respectively.

The Abderaz Formation has a badland pattern consist of low permeable marl and shale. The studied section of the Abderaz Formation faces northeast at an angle of 65º, while the layers themselves extend northwest to southeast.

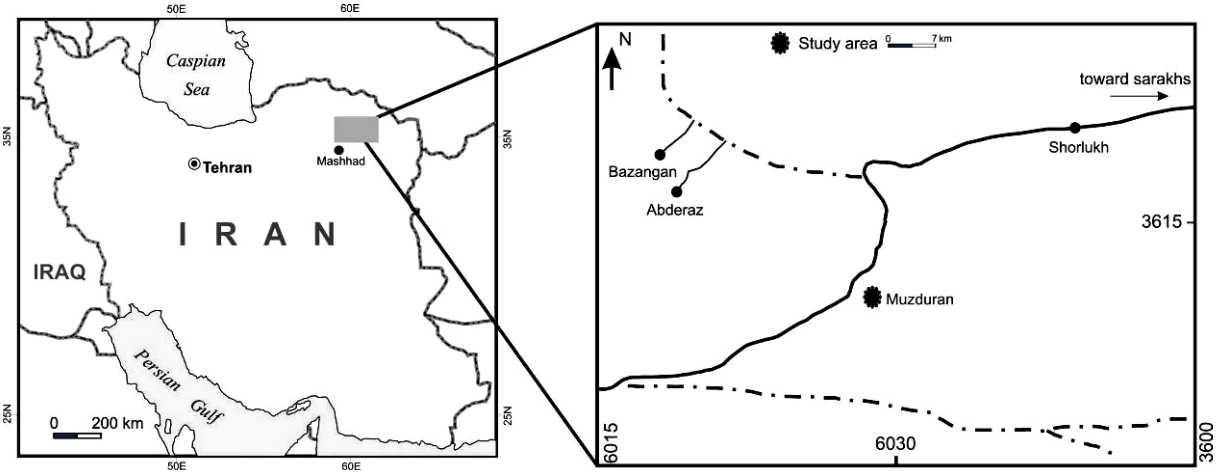

Fig.1: Geographic map and main access road for the Deraz-Ab section

MATERIAL AND METHODS

One hundred and thirty samples are collected systematically from the 400 m thick Abderaz Formation Deraz-Ab section. However, only 100 were studied. Initially all the studied samples were compacted and placed in 5 % H_2O_2, before being washed through 63 and 125 micron sieves in order to separate sediment and fossils. Accordingly, the total of 300 specimens of planktonic and benthic foraminifera specimens are taken from each sample which included the material processed through both mesh sizes. The samples were then placed in an ultrasonic bath for approximately 15 – 20 minutes, and then the specimens were washed to be ready for analysis under the microscope. In the present paper, sea level changes are estimated according to the method of Leckie, who, in 1987, used three swarming morphotypes (ESF, SWF, DWF), in addition to planktonic to benthic foraminifera ratio, for the estimation of sea level changes. The present work also includes determination of paleosalinity using planktonic foraminifera groups.

Various morphotype groups are used in this study, especially deep water forms, to distinguish trends in sea level change in the studied section. Analysis of planktonic foraminifera groups (*Hedbergella* and *Whiteinella*) is utilized for the determination of fluctuations in paleosalinity within the Abderaz Formation type section, based on the method outlined by Wolf *et al*. (1999) and Pierre (1999). The frequency and dispersal of all cold and warm water fauna in the studied section are compared with those of the Tethyan province. In this manuscript, text books published by several renowned authors have been used in the identification all specimens of planktonic foraminifera found in the studied section, including: Bolli, 1957; Postuma, 1971; Robaszynski and Caron, 1979, 1995; Premoli-Silva and Sliter, 1994; Loeblich and Tappan, 1988; Ellis and Messina, 1999; Premoli-Silva and Verga, 2004. All curve analyses used in this article are based on the methods outlined in Leckie (1987) and more recently by Shafiee Ardestani *et al*. (2009) after Hart (1980).

RESULTS AND DISCUSSION

Paleobathymetry

Varying with water column depth, three groups of planktonic foraminifera have been identified: Epicontinental Sea Forms (ESF), Shallow Water Forms (SWF) and Deep Water Forms (DWF) (Martinez, 1989; Shahin, 1992; Keller *et al*., 2002; Schmidt *et al*., 2004). These forms correspond to various depths of the water column in the sedimentary basin and are compatible with the planktonic/benthonic ratio (P) (Fig.2).

– **Epicontinental Sea Forms (ESF):** Specimens associated with this depth have straight (bi-/triserial) tests, for instance *Heterohelix* and *Guembelitria* (Leckie, 1987; Premoli-Silva and Sliter, 1999).

– **Shallow Water Forms (SWF):** Individuals associated with this particular depth have trochospiral and asymmetrical tests with spherical chambers and without any keel. They are also either light with a low trim, such as *Hedbergella delrioensis* (Leckie, 1987; Premoli-Silva and Sliter, 1999) or have a heavy hispid test, as seen for instance in *Whiteinella*. *Whiteinella baltica* is restricted to shallow waters, a fact confirmed by isotopic analysis (Hart, 1999). However, a large number of small planspiral specimens of *Globigerinelloides* spp. belong to the epicontinental sea form group (Eicher, 1969a; Eicher and Worstell, 1970; Sliter, 1972), as do others associated with the two previously-mentioned morphotype groups (e.g. Tappan, 1940, 1943; Loeblich and Tappan, 1950; Eicher, 1969a and b).

– **Deep Water Forms (DWF):** Specimens associated with this depth have asymmetrical trochospiral tests, with either depressed chambers or a primitive keel, such as *Praeglobotruncana*, or trochospiral with a depressed test and keel, such as *Marginotruncana* (Caron and Homewood, 1983; Leckie, 1987; Leary and Hart, 1989; Premoli-Silva and Sliter, 1999). All research investigating the Cenomanian – Coniacian transition have discovered that a number of species, including *Marginotruncana sinuosa*, *Heterohelix globulosa*, *Hedbergella delrioensis* and *Whiteinella beltica*, exhibit dinoflagellate symbiosis and therefore lived in the photic zone (Emiliani, 1955). The diversity and frequency of keeled specimens increases from shallow to deeper water (Douglas and Sliter, 1966).

All individuals belonging to keeled species are assigned to the deep water form group. The frequency of specimens belonging to the epicontinental sea form group, such as *Hedbergella delrioensis*, *Heterohelix globulosa*, *Heterohelix papula* and *Globigerinelloides ultramicra*, increased towards the base of the Abderaz Formation (i.e. the middle Turonian), indicating the presence of a shallow deposition basin at this time.

However by the Late Turonian, Deep Water Form individuals are observed, representing a shift in the planktonic to benthic foraminiferal ratio in this period relative to the Middle Turonian. An increase in the diversity of planktonic foraminifera suggests a high quality habitat, whereas in contrast, a reduction in the diversity of planktonic foraminifera indicates a low quality life for this group. Consequently it can be stated that the fall or rise in sea level results in a respectively lower or higher population diversity of planktonic foraminifera (Ottes and Nederbragt, 1992).

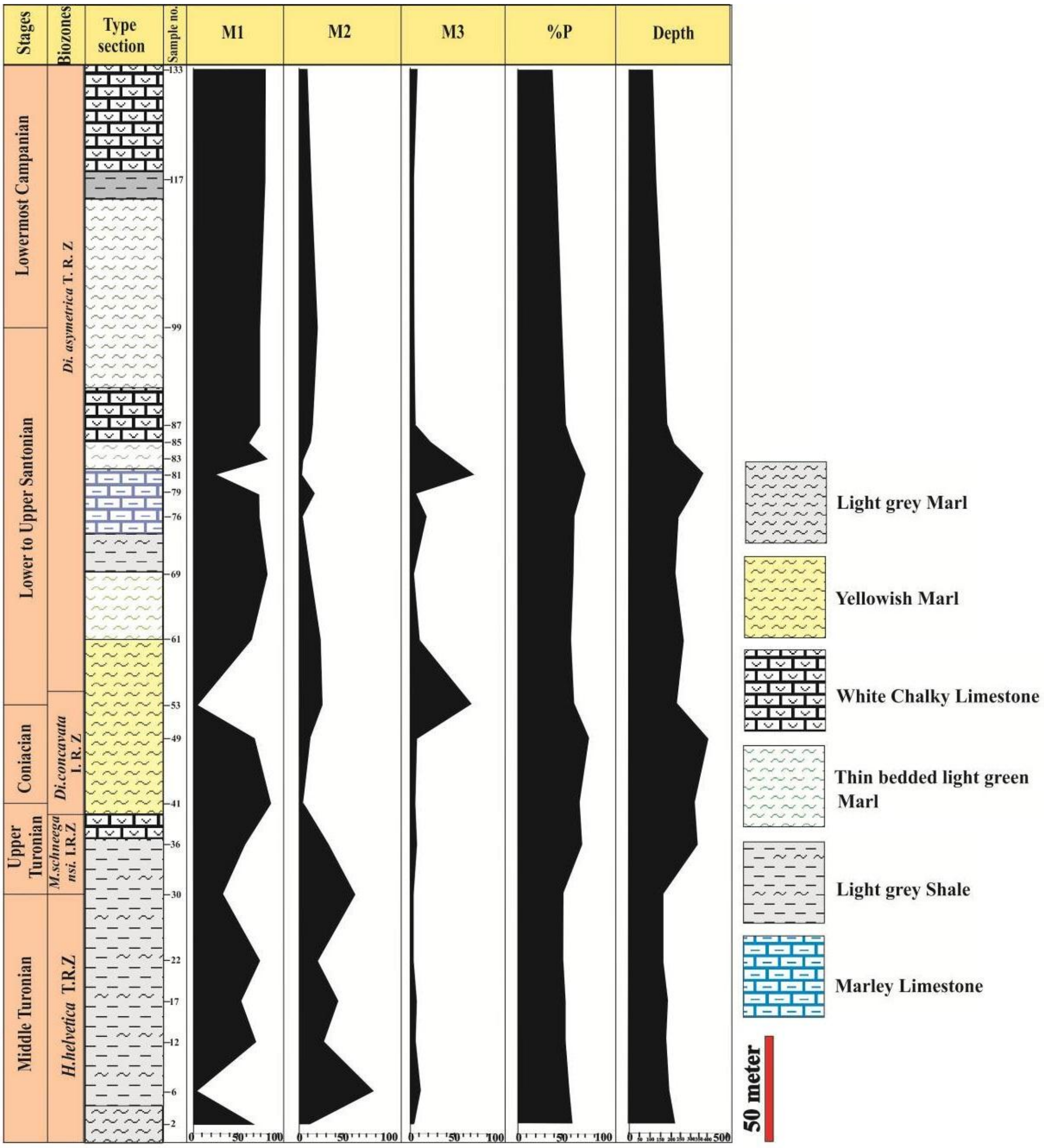

Fig.2: Change in the percentage of selected planktonic foraminifera genera within the Abderaz Formation at Deraz-Ab section {M1 = Morphotype 1(ESF), M2 = Morphotrpe 2(SWF), M3 = Morphotype 3(DWF) and % P = P/B %}

Examples of planktonic foraminifera species present in the studied section include *Marginotruncana sigali*, *Marginotruncana sinuosa*, *Marginotruncana schneegansi*, *Whiteinella brittonensis*, *Whiteinella aumalensis* and *Dicarinella canaliculata* (Figure 3). This complex mix of species represents the result of an increase in water depth during the Late Turonian. In the lowermost Coniacian, a decrease in water depth led to an increase in the number of certain biserial planktonic foraminifera belonging to the ESF group, while from the uppermost Coniacian to the lowermost Santonian (i.e. the Coniacian-Santonian transition) an increase in basin depth is associated with the appearance of other planktonic forms, such as *Globotruncana* and *Globotruncanita*. These two genera have been linked to the presence of mid- to deep water, as well as a geographical location associated with the tropical – subtropical Tethyan realm of the Cretaceous (Abramovich *et al*., 2002). Towards the end of the studied section (Late Santonian- lowermost Campanian), a decrease in water depth and an increase in heterohelicids and oligosteginids is observed, a trend representing a regressive cycle.

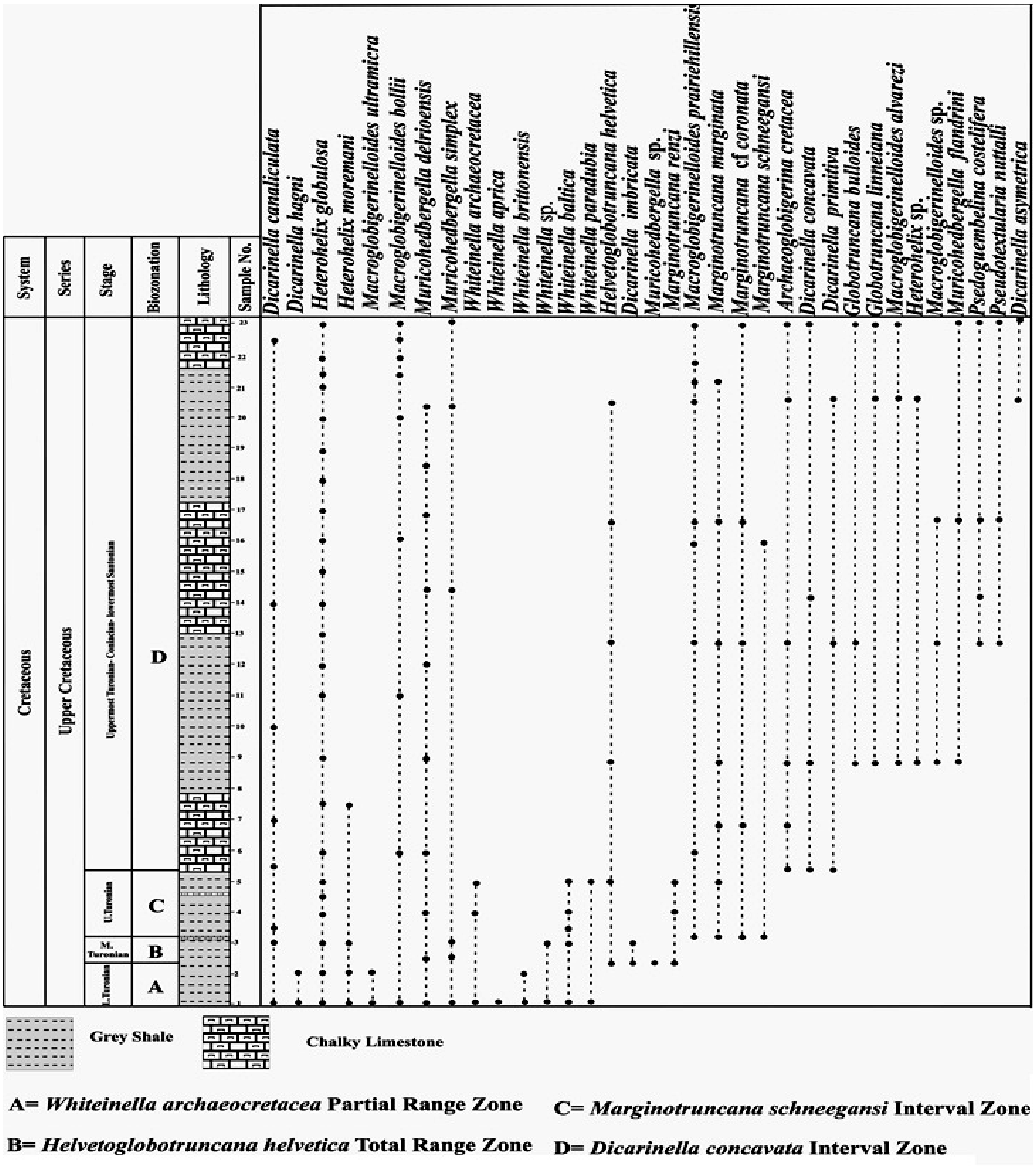

Fig3. Biostratigraphy of the Abderaz Formation, East of the Kopeh-Dagh sedimentary basin, NE Iran

- **Paleosalinity**

Planktonic foraminifera, such as *Hedbergella* and *Whiteinella* spp, are being increasingly employed by many researchers as proxies in the investigation of palaeosalinity (Pierre, 1999; Wolff *et al*., 1999). For instance, an increase in the relative abundance of *Hedbergella planispira* is indicative of a decrease in salinity, the arrival of terrestrial sediment and an increase in precipitation in a sedimentary basin. Often the use of $\delta^{13}C$ and $\delta^{18}O$ stable isotope analysis accompanies such studies (e.g. Wolff *et al*., 1999). Stable isotope analysis has indicated that *Hedbergella planispira* lived in surface waters (Price and Hart, 2002); a fact confirmed by its geographical distribution and abundance in shallow inland sea (epeiric sea) environments. In the Western Interior Seaway, *H. planispira* alternately dominated with low oxygen-tolerant biserial benthic foraminiferal species (Eicher, 1969b; Eicher and Worstell, 1970; Leckie, 1987; Keller and Pardo, 2004) (Figure 2). Two of the main Cretaceous planktonic foraminifera species, *Hedbergella delrioensis* and *Hedbergella simplex,* are used to determine paleosalinity as well as act as indices of surface and subsurface saline environments respectively. In addition, *Heterohelix,* another genus of Cretaceous biserial planktonic foraminifera, is also employed in the determination of paleosalinity.

Heterohelix has been identified as being tolerant of restricted oxygen (anoxic) conditions. As its relationship with the oxygen curve has an inverse relation with respect to that of *Hedbergella* and *Whiteinella.* The combined analysis of individuals of these genera thus provides a more accurate picture of changes in paleosalinity (Keller and Pardo, 2004). In this investigation of the Abderaz Formation Deraz-Ab section, a maximum frequency of *Whiteinella* and *Hedbergella* and minimum frequency of *Heterohelix* occur within sediments of Coniacian age, suggesting a dwindling paleosalinity at this time. In contrast, a minimum frequency of *Whiteinella* and *Hedbergella* and a maximum of *Heterohelix* are identified in sediments of the Coniacian-Santonian transition, indicating an increase in salinity.

- **Paleobiogeography**

Throughout the Cretaceous period there was less of a geographical gradient from pole to equator than what exists today. For instance the northern Atlantic Ocean separated two areas, boreal and Tethyan by means of a median belt and warm water current (Douglas and Sliter, 1966; Bailey and Hart, 1979). Some areas characterized by cold conditions, such as austral and boreal, have been shown to have been home to planktonic foraminifera with thin walls and globular chambers. Some of the genera shown to have lived in these areas include *Hedbergella*, *Globigerinelloides*, *Heterohelix*, *Whiteinella*, *Archaeoglobigerina*, *Rugoglobigerina* and *Globotruncanella*. Conversely within Tethyan areas associated with warm water conditions, planktonic foraminifera have been identified with thick walls and keeled chambers. Examples of such genera include *Globotruncana*, *Globotruncanita*, *Marginotruncana*, *Planomalina*, *Helvetoglobotruncana*, *Rotalipora*, *Dicarinella* and *Contusotruncana*.

All comparisons of cold and warm water realms have demonstrated a decrease in the number and complexity of species towards the poles (Caron, 1985). Most planktonic foraminifera restricted to warmer waters have larger tests, with thicker walls and a generally more complex morphotypes than those found in colder waters. It has also been proposed that populations of warm water planktonic foraminifera have diversified to a greater extent than their cold water counterparts (Caron and Homewood, 1983). All cold water index species have left-handed whorls with globular chambers and as a group are without any significant diversification. The initial and final occurrence of *Helvetoglobotruncana helvetica* and the last occurrence of *Falsotruncana maslakovae* are synchronous, occurring during the Middle

Turonian at a paleogeographic latitude between 20 N and 58 S. Both of these species lived in warm water habitats in the Tethyan realm, at maximum temperatures of 30º C. In contrast *Dicarinella asymetrica,* which lived from the Santonian to the lowermost Campanian at palaeogeographical latitude of between 20 N and 47 S, was restricted to deep and oligotrophic to mezotrophic marine environments (Premolisilva and Sliter, 1999; Petrizzo, 2002). These results suggest that the planktonic foraminifera present within the Abderaz Formation in Deraz-Ab section represent a warm water environment belonging to the Tethyan realm of the Upper Cretaceous (Table 1).

Table1: Paleobiogeography of the Abderaz Formation at Deraz-Ab section related to paleogeographical latitude

Cold water fauna	Warm water fauna	Some planktonic genera in the studied area
Archaeoglobigerina *Globigerinelloides* *Heterohelix* *Hedbergella* *Whiteinella*	*Dicarinella* *Globotruncana* *Globotruncanita* *Marginotruncana* *Helvetoglobotruncana* *Planomalina* *Rotalipora*	*Dicarinella* *Globotruncana* *Globotruncanita* *Hedbergella* *Helvetoglobotruncana* *Marginotruncana* *Whiteinella*

Analysis of the frequency of some planktonic foraminifera species within the Abderaz Formation type section, such as *Heterohelix globulosa*, *Hedbergella delrioensis*, *Marginotruncana peudolinneiana*, *M. marginata*, *Dicarinella canaliculata*, *Archaeoglobigerina cretacea*, *Hedbergella planispira*, *Globotruncana bulloides*, *Marginotruncana renzi*, *Dicarinella concavata*, *Dicarinella asymetrica* and *Globotruncnan Linneiana*, suggests that these species were more resistant to environmental change than other planktonic species, including *Praeglobotruncnana delrioensis*, *Contusotruncana pateliformis*, *Globotruncanita elevata*, *Heterohelix carinata*, *Shackoina multispinata* and *Guembelitria cretacea*.

CONCLUSIONS

- Three swarming morphotypes are identified in the present study in the Abderaz Formation at the Deraz-Ab section which are: Epicontinental Sea Forms (ESF), Shallow Water Worms (SWF) and Deep Water Forms (DWF).
- Shallow water conditions prevailed during the Middle Turonian, followed by deep water conditions in the uppermost Turonian. The Coniacian was characterised by permanently shallow water of less than 100 m, but towards the Coniacian – Santonian transition deep water conditions prevailed once more. Towards the top of the formation (Late Santonian – lowermost Campanian) the sequence experienced permanent shallow water conditions.
- The distribution of salinity-sensitive foraminifera revealed a minimum salinity during the Coniacian and a maximum salinity at the Coniacian – Santonian boundary.
- The planktonic foraminifera present within the studied section represent a warm water environment belonging to the Tethyan realm of the Upper Cretaceous.

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