Radiations and Extinctions of Maastrichtian Rudist bivalve and Benthic Foraminifera of Aqra Formation Kurdistan Region Northern Iraq

Salam I. Al-Dulaimi
Department of Geology, College of Science,University of Baghdad,Baghdad, Iraq
salamrudist@yahoo.com

Abstract

During the Maastrichtian, the rudists and benthic foraminifera of Aqra Formation underwent two major radiations, the first beginning in early Early Maastrichtian and peaking in the late Early Maastrichtian, and sconed extending from the early Late Maastrichtian to a late Late Maastrichtian peak.The radiations were punctuated and separated by prominent extinction episodes, fit with global Maastrichtian mass extinction.The high level of rudist, endemism [90%] allows definition of true regional origination and extinction pattern; these may represent global pattern for rudists. Radiation and extinction patterns in the northern Iraq [Kurdistan Region] can be variously related to relative sea level fluctuation and the rate of food and clastic sediments supply.The two Maastrichtian extinctions of Aqra Formation is true extinctions in that they occur during low or zero origination rates among rudists.

Keywords: Rudist, Extinction, Radiation,Maastrichtian, Aqra, Kurdistan,Iraq.

تطور وأنقراض الرودست والفورامنيفيرا القاعية خلال الماسترختيان لتكوين عقرة في أقليم كردستان، شمال العراق

سلام اسماعيل الدليمي
قسم علوم الارض, كلية العلوم, جامعة بغداد, بغداد, العراق

الخلاصة

خلال فترة الماسترختيان، فان الرودست والفورامنيفيرا القاعية قد عانت من تطورين شعاعين، اولهما بدأ في بداية الماسترختيان المبكر والذي وصل ذروته في نهاية الماسترختيان المبكر، وثانيهما أمتد من بداية الماسترختيان المتأخر الى ان وصل ذروته في نهاية الماسترختيان المتأخر. ان تلك الفترتين من التطور قد تم تميزهما بانقطاع فصل الفترتين بانقراضا جماعياً طابق الانقراض الجماعي الذي حدث على المستوى العالمي. ان تواجد الرودست وبنسبة عالية [90%] سمح لنا بالتعرف على نموذجاً حقيقيا لنشأة وانقراض تلك المتحجرات والذي من الممكن ان يمثل نموذجاً متميزاً على المستوى العالمي. ان تطور وانقراض الرودست في شمال العراق [أقليم كردستان] يمكن ان يعزى الى عدة عوامل منها عدم استقرار مستوى سطح البحر النسبي وكذلك معدل تجهيز المواد الغذائية والفتات الصخري. ان الانقراضين اللاتي تم تحديدهما في تكوين عقرة تمثل انقراضاً حقيقياً وذلك لان نسبة تواجد الرودست قد تناقصت الى ان وصلت الى فقدان كامل لتلك المتحجرات.

Introduction

Rudist bivalves,scleractinian. and larger benthic foraminifera were the major carbonate producer associated with Late Cretaceous Tethyan carbonate platform [1,2].While the corals largely survived the mass extinction at the Cretaceous- Tertiary boundary [3,4], the rudists and larger benthic foraminifera become extinct. The timing and pattern of biotic extinctions in the late Cretaceous leading up to the Cretaceous-tertiary boundary in tropical carbonate platforms and reefal ecosystem is poorly defined globally owing to imprecise biostratigraphic control [5, 6, 7]. The Late Cretaceous is one of the most significant periods in the geological history of the Arabian Peninsula, in view of the major structural and tectonic events that affected the region at this time [8, 9, 10, 11, 12].As result of this tectonic activity, the stratigraphic sequence records a greater complexity of facies changes than those pertaining to Early and Mid-Cretaceous times [13]. The Upper cretaceous rocks are widely exposed at the high folded zone north and north East of Iraq, beside its exposure at the western Desert. The Aqra Formation as being a unit building the Upper Cretaceous sequence and more specifically the Upper Campanian-Maastrichtian cycle. The cycle gains it is importance in the geological evolution of Iraq due to its widely spreading all over the country. The cycle began with a widespread transgression covered all parts of Iraq and was terminated by regression and uplift caused byphase of the Laramide Orogeny a round the Cretaceous-Tertiary boundary [12, 14, 15]. This study related to origination and extinction of rudists and benthic foraminifera [the terms origination and extinction traditionally convery the idea of a global data base, thereby confirming the stratigraphic of the true first and last occurrence of a taxon], from four stratigraphic sections Figure 1, Gulley Sheikh Abdul Aziz section, 500m NW of Aqra city; Gulley Zinta section, 8km SE of Aqra city; Mukaba section, 13km NW Chowarta town, and ZardaBee section, 17km NE Sulaymaniya city.

Geological Setting

During late Cretaceous the Arabian plate was subjected to both compressional and extensional stressed [16].In north margin of Arabian plate compressional stresses illustrated by the uplift of main Zagros reverse fault and high Zagros fault. This compression commend in Iran, Iraq and Oman in Middle Turonian with intiation of obduction of ophiolite complex. This resulted deep water foreland basin along northeast plate margin [10]. Foreland basin was in turn separated from what remained of Neotethys by a NW-SE high which later formed the Zagros imbricated Zone [17]. According to the eustatic curve of Haq [in 5]a eustatic transgressive occurred in Middle Campanian-Maastrichtian. During this time, an association of rudists rich thrived sediment was formed along the southeastern Neotethys [18]. This rock unit is Called Aqra Formation in Iraq and Tarbur Formation in Zagros Mountains, Iran.

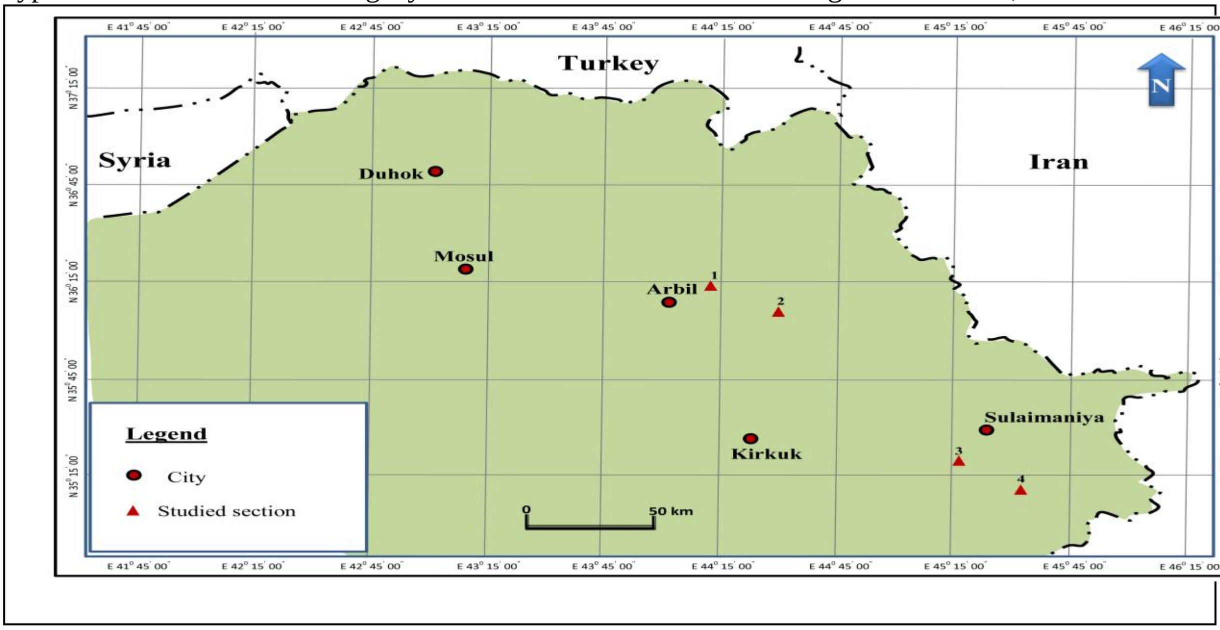

Figure 1- Location map of the studied sections [1 Gulley Sheikh Abdul Aziz,2 Gulley Zinta, 3 Mukaba, 4 Zarda Bee].

Palaeobiogeography

There is no distinct rudistid biogeographic provincialism in the considered region [7], except for the Campanian. Maastrichtian of the north-eastern Afro- Arabian margin, which was excluded from our clusters analysis [18]. Therefore the cluster most likely represent stratigraphically or ecolo-gically separated groups illustrated in [18] P. 96. TheCampanian-Maastrichtian palaeobiogeography of rudists in the Mediterranean Tethys has been repeatedly investigated [7, 19, 20, 21]. Provincialism within the central and eastern Mediterranean has been shown to be low by recent investigations, but a high degree of endemism is noted during the Campanian-Maastrichtian in the west Mediterranean Tethys. At the present state of knowledge, only a single endemic province is evident during the Cretaceous. It is formed byCampanian-Maastrichtian ssociations of the north eastern Afro-Arabian Margin, extending from south east Turkey, north and north east Iraq, Zagros range in Iran to the UAE and Oman. 40% of Campanian-Maastrichtian genera reported from Syria, Saudi Arabia, Iraq, the UAE and Oman are endemic to this region[18, 22].Typical genera are *Dictyoptychus* and *Torreites*, it the latter of which also occurs in the Caribbean [23], but has not been recorded to the west of the UAE. As several genera with widespread distribution in the Mediterranean are also found along the north-eastern margin of Afro-Arabian Figure2,south–eastward migration from Mediterranean Tethys was possible while north-westward migration from the north-eastern Afro-Arabian margin obviously did not occur. South–Westward migration was restricted by anoxic water on the shallow shelf of the Levantine and north African margin, but there was apparently no ecological or physical barrier that could have prevented dispersion to the west and north-west [18]. This suggests eastward surface currents in this region and can note be explained in the context of a westward flowing Tethyan circumglobol current[24,25], butwould be consistent with a clockwise gyre in the central Mediterr-anean Tethys [26].

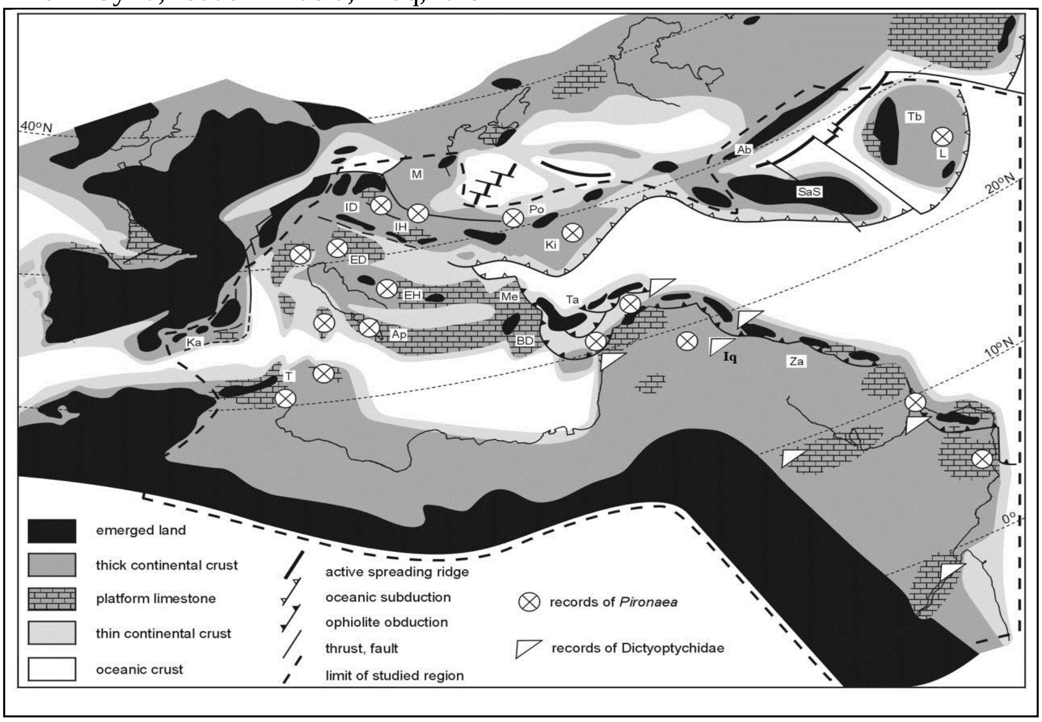

Figure 2- Maastrichtian palaeogeography of the Mediterranean and Middle East Tethys [modified from Dercourat et al., 1986] and Campanian-Maastrichtian distribution of *Pironaea* and *Dictyoptychius.* Ab, Alburz; Ap, Apulia; BD, Bey Daglari; ED, External Dinarids, ; EH, External Hellenids; ID,Internal Dinarids, Iq,Iraq; Ka, Kabylia; Ki, Kirsehir; L, Lut; M, Moesia; Me, menderes; P, Parnassus; Pa, Ponormides; Po, Pontids; Sa5, Sanadj-Sirian zone; T, Tunisia, Ta, Taurus; Tb, Tabas, Za, Zagros

Historical Background of Cretaceous Rudist Mass Extinction

The K-T mass extinction of the rudist bivalves, as well as numerous other characteristic Mesozoic group,This suggests eastward surface currents in this region and can note be explained in the context of a westward flowing Tethyan circumglobal current [24. 25], but was originally considered to be catastrophic at K-T boundary [e.g,27,28, 29,30]. However, as Late Cretaceous stratigraphic resolution increased and both biostratigraphic and isotopic dating methods were refined, the timing of the rudistid bivalve and overall Cretaceous reef extinction relative to there K-T boundary were reevaluated. As a result, rudists have recently been considered in context of both stepwise [31] and graded [32] Mass-extinction hypothesis. Argu- ment pertaining to each interpretation are as follows:

The Catastrophic Mass Extinction Hypothesis

Many authors have envisioned the end of the Cretaceous extinction of rudistids and associated reef ecosystems as essentially catastrophic, occurring abruptly at a peak in their evolutionary and ecological development very near to at the K-T boundary [e.g. 5, 27, 28, 30, 33, 34, 35, 36].

In recent year, high resolution stratigraphic studies of the Maastrichtion and K-T boundary interval worldwide have wholly contradicted the idea of terminal Cretaceous catastrophic extinct- tion of the rudist. Data from Caribbean and Mediterranean paleotropical sequences show that no rudistid reefs or frame-works are known from strata representing the last one million year or more of the Maastrichtian, and no rudist individual have been confirmed from highest Maastrichtian paleotropical strata [5].

The Stepwise Mass Extinction Hypothesis

Anumber of recent studies [e.g. 37, 38, 39, 40, 41, 42] have proposed that the rudistid reef ecosystem [including most Actaeonellid and Nerineid gadstropoda, many species of tropical bivalves, echinoids, coral and larger foraminifera and many specialized rudistid lineages] underwented a dramatic mass killing and short-term extinction somewhere between 1.5 and 2.5 M.Y. below the K-T boundary as a first event in the K-T extinction interval [5]. Within the same time from there were significant extinction among temperate molluscas [inoceramid, bivalves and ammonites [43,44] and terrestrial plants[Johnson, 1992in 5].

Additional events in molluscan extinction [31, 45, 46], and specialized calcareous plankton [29, 30, 47, 48], proceeded the K-T boundary event, and cool-temperate brachipoda and bryozoan extinction events postdated the K-T boundary to compose a 2-2.5 M.Y. long stepwise extinction interval [31].

For the rudistid data these calculations must await the difficult chronostratigraphic integration of observed data from isolated boundary sections in various parts of Caribbean, Mediterranean and Middle East provinces. There despite the obser-vations of [5, 31, 33, 34, 41, 42, 49] that rudistid reefs and frameworks disappeared well bellow the K-T boundary in continuously deposited carbonate platform facies, the relevance of this to stepwise extinction theory must remain a hypothesis until statistical tests confirm that this is not an artifact of preservation [5].

The Graded Mass Extinction Hypothesis

The graded hypothesis was developed to reflect an increase in the rate of background extinction due to relatively rapid Earth-bound enviro-nmental changes such as sea level, oceanic oxygen level, and large-scale volcanism [31]. 32 reported the [49] rudist data from Mediterranean province supported a gradualistic hypothesis for extinction of rudist reefs and lineages. 49 documented a dramatic decline in rudistids in the Middle Maastrichtian of the European- African- Arabian Tethyan region, a decline that was at slightly different times in different places. 49 attributed the Middle Maastrichtian rudistid extinction to a drop in sea level, which removed rudistid habitats.

The rudistid reef extinction has thus been cited as representative of three very different extinction scenarios. In this paper the anther present high-resolution Iraq data seem to fit closely the stepwise extinction hypothesis initiating with abrupt demise of reef ecosystems about 0.5-1 M.Y. below the K-T boundary [depending on the biochronlogy used], and including final extinction of the remaining subtropical to temperate adopted lineages just prior to the K-T boundary.

Biological Events of Aqra Formation Mass Extinction

It is concluded, through the set of the four sections chosen to study the depositional setting of Aqra Formation, that the manner of deposition of the formation at its north west part differ from its south east part. The controversy is related to the non continuity of the barrier on which the formation had deposited, beside to the instability of the sea level, during times of the deposition of the formation. A fact based on lithological changes, diversity and the abundance of the fossils. This research has detected some biological events related to environmental, sedimentation and sea level changes that indicated what had happened before the mass extinction of living creatures. These fact are discussed as follows

1. Planktonic Foraminifera

It is no doubt that the planktonic foraminifera had totally extinct during the K-T boundary. Very few studies have examined the faunal turnover in planktonic foraminifera populations during the Maastrichtian and most have concentrated on the last 50-100 cm [last 20-40 K.Y.] interval below the K-T boundary [e.g., 30, 52, 53, 54, 55]. Based on this short record most of the authors concluded that there were no significant pre- K-T biotic stresses could have caused species extinctions or prediposed species to extinctions by extreme environmental stress. The planktonic foraminifera had a limited recorded in Aqra Formation represented by the following species: *Heterohelix* sp.; *Globotruncana gagnebini*; *Hedbergella* sp.; *Rugoglobigerina rugosa* ;*Globigerinellides*, sp., Emphasizing that these species were found located at the middle part of the Mukaba and Zarda Bee sections and did not exit at their upper parts. While the rudist and benthic foraminifera continued to be present at upper part of the four sections.

2. Benthic Foraminifera.

Benthic foraminifera, in contrast, do not show significant extinction above background level at the end of the Cretaceous [56]. The assemblages show temporal faunal restricting, which has been related to collapse of the pelagic food web, which delvers food to the benthos [57].

Studing the benthic foraminifera located at the selected sections has revealed its diversity and its abundance was effected by many factors as sea level changes, rate of food supply and the supply of clastic material. The rate of changing these factors caused appearance and disappearance of some species at certain times within a particular sections, in addition to its variety among the studied sections. This happened before the demise of all organisms and before the K-T boundary Figures 3, 4, 5, 6.

At the lower and upper parts of this formation recorded the percentage of agglutinated foraminifera [30-60%, *Loftusia morgani*, *L. elongate*, *L.minor*, *L.coxi*, *Gyroconulina columellifera*, *Cuneolina* sp., *Chrysalidain decorate*, *Chrysalidina* sp.] indicates a considerable input of fine-graind clastic material flux was higher in the lower part of the four sections [Agglutinated foraminifera up to 50%] Figures 3, 4, 5, 6

The abundance and diversity of the calcareous foraminifers could be related to the increasing rate of food supply and decreasing of clastic material, coincide with increment of rudist especially at the ending portion of the lower part and at the starting portion of the upper part of the formation at sections Gulley Sheikh Abdul Aziz and Gulley Zinta. However the flourishing and the diversity of calcareous foraminifera was related with the appearance of rudist.

At the end time of depositing the formation and before the K-T boundary, all genus and species that dwell in Aqra Formation disappeared possibly due to the sea level fall and due to the decreasment of food supply beside to increasing of clastic material [58, 59, 60].

3. Rudist

Through stduing rudist at the location of the four sections the rudist reef of Upper Cretaceous could be explained as it reflected major changes in ocean/ climate system, showing two major mass extinctions during the Maastrichtian. These two extinctions coincide with disappearanc and appearance of benthic and planktonic foraminifera. As mentioned previously the rudist and benthic foraminifera are not the same at the studied four sections because of the discontinuity of the paleo-ridge and because of the frequent fluctuations in sea level.The sea level rise during the Campanian-Maasrtrichtian Cycle had led to a marine coverage of all the paleohigh, beside portions of Aqra- Bekhme ridge was formed during Early

Maastrichtian. This event was the beginning of stage during which Aqra Formation had been deposited. These sediments were characterized to be mobile, coarse and accompanied by recumbent rudist such as *Titanosarcolites* sp. and larg elevater rudist as *Durania cornupastoris* and rudist fragments, besides the presence of

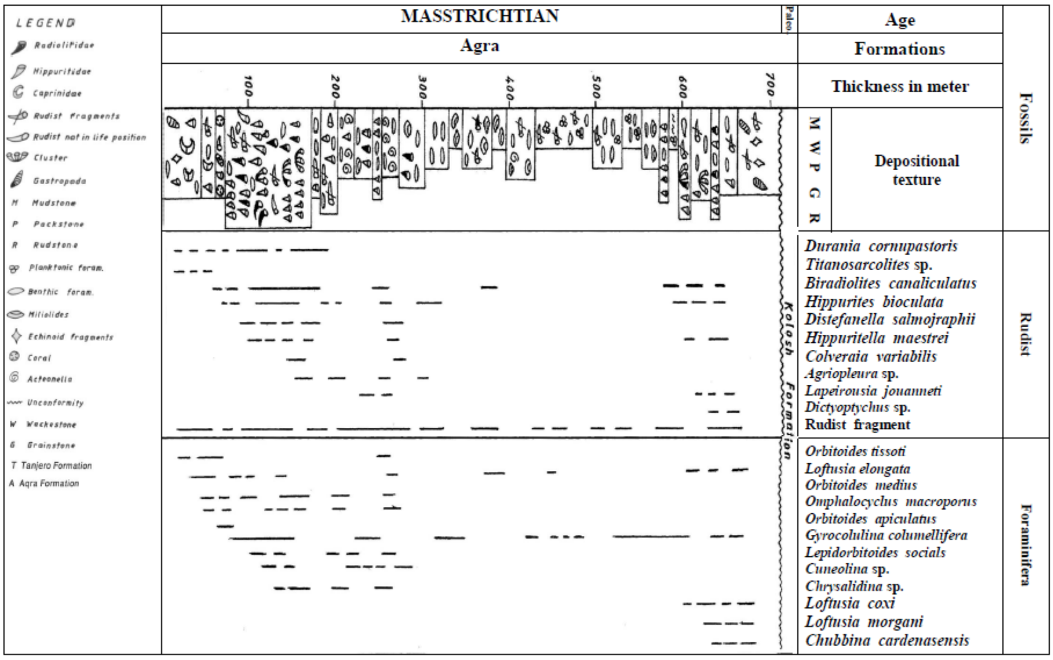

Figure 3- Distribution of rudist and foraminifera/ Aqra Formation/ Gulley Sheikh Abdul Aziz section

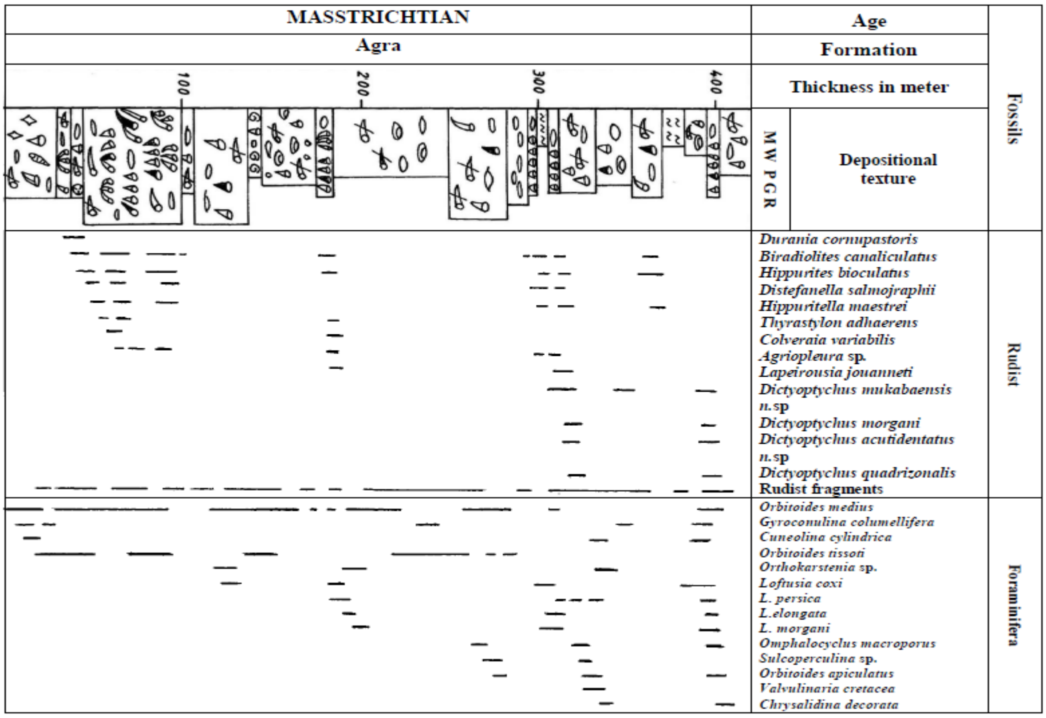

Figure 4- Distribution of rudist and foraminifera/ Aqra Formation/ Gulley Zinta section

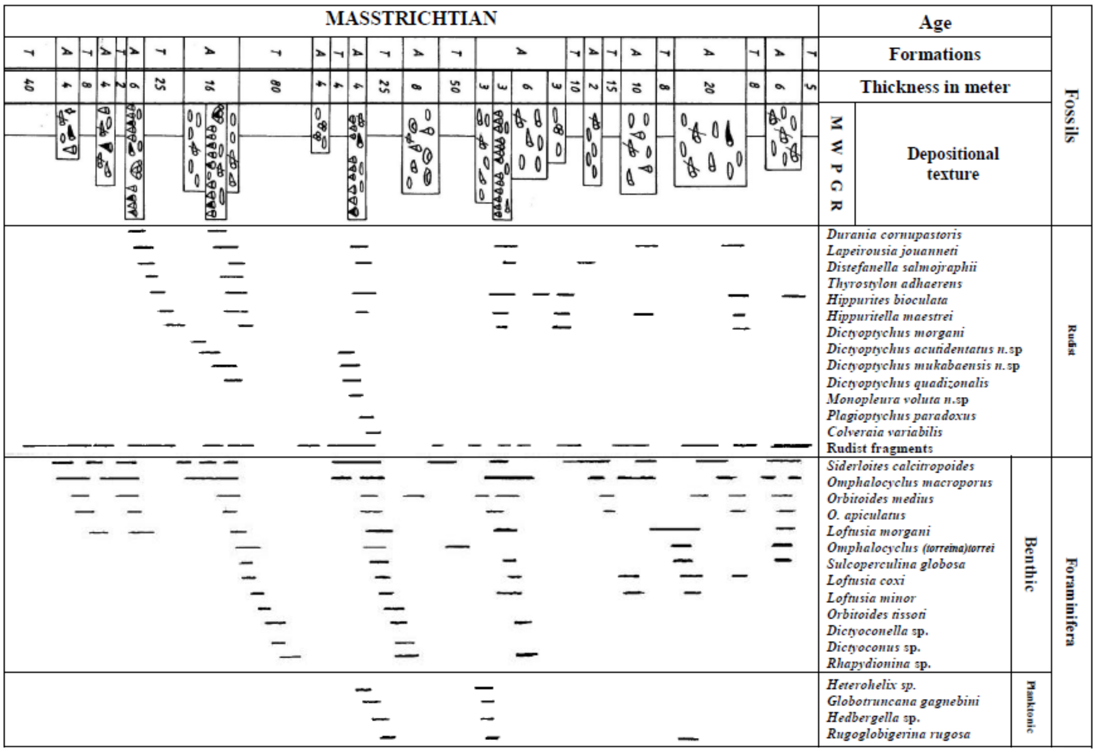

Figure 5- Distribution of rudist and foraminifera/ Aqra Formation/ Mukaba section

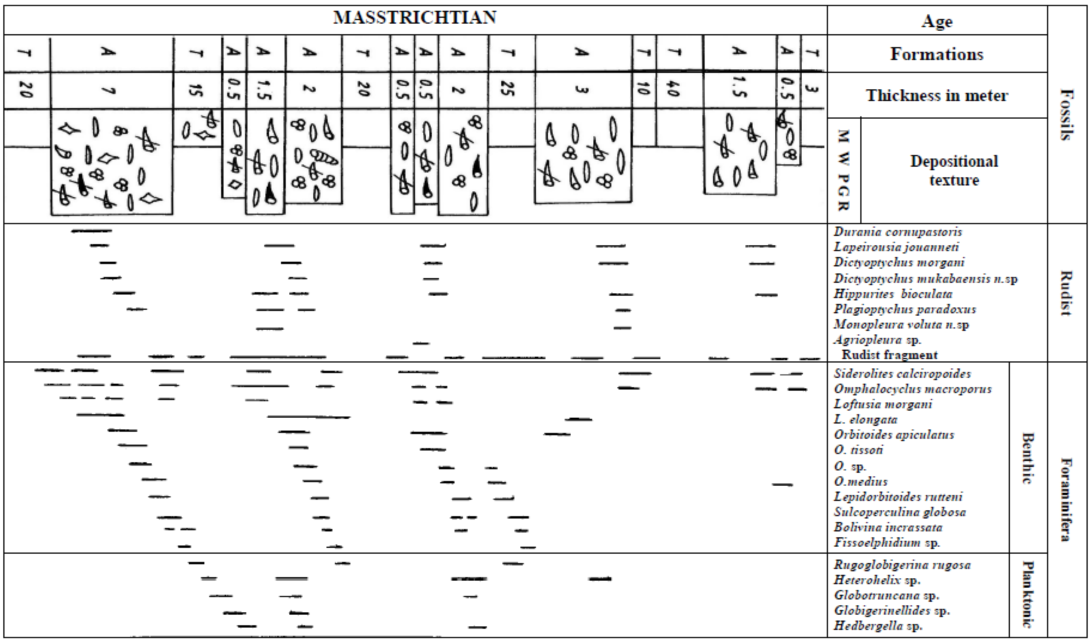

Figure 6- Distribution of rudist and foraminifera/ Aqra Formation/ Zarda Bee section

benthic foraminifera. Such sedimenta-tion indicates a shallow, high energy environment, low rate of sediments, favorable for flourishing of these two species of rudist [61, 62, 63].

By continuing sea level rise that overwhelm the remaining elevated barrier areas by shallow water. This period characterized by high rate of sedimentation with a low to medium energy. Such an environment is an ideal one for growth of elevator rudist such as:*Durania cornupastoris*;*Birdiolitescanaliculatus*;*Hippurites bioculatus*, *Distefanella salmojraphii*; *Hippurotella maestrei*, *Colveraia variabilis; Agriopleura* sp.; *Thyrastylon adhaerens*. All elevators managed to survive at times of high sedimentation rates, but intiate thickets they needed episodes of low or non-sedimentation. However the cluster rudist mostly dwell in areas of low/ medium energy and discontinuous sedimentation [63].

It is observed that during that the demise of *Titanosacolites* sp. and decreasing the number of *Durania corrupastoris.* As the sea level rise the occurrence of the rudist and most benthic foraminifera decreased. At the Middle Maastrichtian all the rudist of Aqra Formation vanished, and recorded mass extinction of rudist Figurs 3, 4.

The disappearance of rudist continued till early Late Maastrichtian, when it started to appear with time that the sea level had fall, causing the creation of an environment suitable for recovery of rudist. The elevators rudist and the benthonic foraminifera started to increase at the four sections Figures 3, 4, 5, 6, beside the appearance of species that belong to the family Dictyopty-chidae. At this time the sea level and rate of clastic material fluctuations were frequent. Their effect were not obvious to rudist at Gulley Sheikh Abdul Aziz and Galley Zinta sections. However it was clear upon rudist at Mukaba and Zarda Bee sections.

Where the clastic sediments of the Tanjero Formation alternated with Aqra Formation sediments which character-ized by large elevators rudist species with abundant benthonic foraminifer. However at late Late Maastrichtian before the K-T boundary the rudist had suffer a mass extinction, beside the benthonic foraminifera. This gets along with world researchers [e.g. 5, 29, 42, 64, 65, 66].This extinction began with a period of global cooling and sea level fall [5]. This climate cooling reached its Maximum a bout 0.5 Million year prior to the K-T boundary [30, 67].As a result the long term environmental changes have caused severe biotic stress before the very end of the Maastrichtian.

All Mass extinction studies concluded, most major mass extinction are not caused by impacts, but are more likely associated with major volcanic eruptions [30, 68, 69].

The hypothesis that dealt with cause of rudist extinction at time of K-T boundary didn't differ in idea with those basically proposed for mass extinction especially the research of [5, 42, 65,70].

However this research brings a new scenario causing mass extinction of rudist and related benthonic foraminifera that differ from mass extinction studies, because there are no evidence for the impact hypothesis, beside there are no evidence for the depletion of oxygen among Aqra Formation sediments. The main mass extinction cause of rudist and benthoic foraminifera of Aqra Formation is the relative sea level changes and rate of clastic sediment supply.

It has been clear the rising of the sea level due to removed the habitats of rudist, and caused the first demise of rudist at Middle Maastrichtian. However at the end of Maastrichtian the sea level fall caused the destruction of the rudist barrier accompanied by high rate of clastic material that exceed the rate of growth of rudist, which participated in destroying the dwellings environment of rudist and benthonic foraminifera. The classic material belong to Kolosh Formation restricted to north west of Aqra Formation locality beside the Tanjero Formation at the south east part of the Aqra Formation.

At both extinction periods the rise and fall of the sea level and rate of clastic sediments supply happened gradually, as its observed the disappearance of some organisms they didn't adaptable to the environmental changes, while other were able to bear the new environmental conditions in stepwise mass- extinction hypothesis order to a period that most of the organism perished at the two periods that recorded in Aqra Formation.

References

1. Philif, J. Pierre, J., **1995**; Stratigraphy and Rudest Biozonation of the Campanian and the Maastrichtian of Eastren Oman. Revista Mexicann de Ceincias Geologicas. Vol. 12, Numero **2**.pp. 257-266.
2. Schulter, M., Steuber, T., Parente, M., Mutterlose, J. **2008**; Evoluation of Masstrichtian-Paleocene tropical shallow carbonate platform [Qalhat, NE Oman] Facies. **54**, pp. 513-527.
3. Kiessling ,W., Baron-Szabo, R. **2004**; Extinction and recovery patterns of scleratinian corals at the Cretaceous-Tertiary boundary. Palaeogeogr., Palaeoclimatol., Palaeoecol., Vol **214**. pp. 195-223.
4. Aguirre, J., Baceta, J.I., Braga, J.C., **2007**; Recovery of marine primery producers the Cretaceous-Tertiary mass extinction: Paleocene calcar-eous red algae from the Iberian peninsula. Palaeogeogr., Palaeo-climatol., Palaeoecol., Vol. **249**. pp. 393-411.
5. Johnson, C.C., Kouffman, E.G., **1996**; Maastrichtian extinction patterns of Caribbean province rudistids. In Macleod, N., Keller, G [Eds.], Cretaceous-Tertiary Boundary Mass Extinction, Biotic and Environmental changes.W.W. Norton&Co., NY, pp. 231-274.
6. Macleod, N., Rawson, P.F., Forey, P.L. Banner, F.T., Boudagher-Fadel, M.K., Bown, R.R., Burnett, J.A., Chambers, P., Culver, S., Evans, S.E., Jeffrye, C., Kaminski, M.A., Lord, A.K. Milner, A.C., Milner, A.R., Morris, N., Owen, E., Rosen, B.R., Smith, A.B., Taylor, P.D., Urquhart, E., Young, J.R., **1997**; The Cretaceous-Tertiary biotic transition J.Geol. Soc. London, Vol. **154**, pp. 265-292.
7. Philip, J. **1998**; Biostratigraphie-et paleobiogeographie des rudistes: evolution des concepts et progress recents. Bull. Soc. Geol. France, Vol. **169**, pp. 689-708.
8. Glennie, K.W., Boeuf, M.G.A., Hughes-Clarke, M.W., Moody-Stuart, M., Pilaasr, W.F.H. and Reinhardt, B.M., **1974**; Geology of the Oman Mountain: Rayal Geol. and Mining Soc. [Netherlands] Trans., V. **31**, 423p.
9. Buday, T., and Jassim, S.Z. [ed], **1980**; The Regional geology of Iraq, Vol. 1: Direct general geology Surv. & Miner. Invest., Baghdad, 445p.
10. Lippard, S.J., Shelton, A.W., and Gass. I.G., **1986**; The ophiolite northern Oman. Geol. Soc. of London, Mem., 11, 178p.
11. Searle, M.P., Cox, J., **1999**; Tectonic setting Origin and obduction of the Oman Ophiolite. Geol. Soc. America Bull. V.**111**, pp. 104-122.
12. Jassim, S. Z., and Goff, J.C., **2006**; Geology of Iraq published by Dolin, praque and Moravian Museum, Srno. 341p.
13. Al Sharhan, A.S., and Nairn, A.E.M., **1990**; Areview of the Cretaceous formation in the Arabian Peninsula and Gulf, part 3, Upper Cretaceous [Aruma Group] stratigraphy and paleogeography. J. Peterol. Geol. Vol. **13**, pp. 247-266.
14. Bolton, C.M.G., **1956**a; The Geology of the Rowondus-Qala- Dizeh areas. Sit Inv. Co. Report, SOM Library, No. **268**, Baghdad.
15. Bellen, R.C. Van., Dunnington, H.V., Wetzel, R., and Morton, D.M., **1959**; Lexique stratigraphique Inter-national, Asia, Iraq. Int. Geol. Congr. Comm. Stratig. V. **3**, 10a, pp. 1-333.
16. Sharland. P.R., Ramond, A., Casey, M., Davis, R.B., Hal, S.H., Heward, A.P., Horbury, A.D., and Simmons, M.D., **2001**; Arabia plate Sequence Stratigr-aphy Geoarbia, Special publication, Manama, Bahrain, pp. 372.
17. Stoneley, R., **1974**; Evolution of the continental Margins Boun-ding a Former Southern Tethys. In: The Geology of continental Margins, Ih Burk Drake, C.L., [Eds]. Springer, Berlin, Heidel-berg, UK., pp.889-903.
18. Steuber, T., Loser. H., **2000**; Species richness and abundance patterns of Tethyan Cretaceous rudist bivalves [Mollusca: Hippuritacea] in the central- eastern Mediterranean and Middle East, analysed from a palaeontological database. Palae-ogeography, palaeoclimatology, Palaeoecology. Vol. 192, pp. 75-104.
19. Philip, J., **1982**; Paleobiogeographie des rudistes et geodynamiques des marges mesogeeneus au Cretace-superieur. Bulletin de la Societe-geologique de France. Vol. 24 [7], pp. 995-1006.
20. Philip, J., **1985**; Sur les relations des margeste thysiennes au Campanien et au Maestrichtien deduites de la distribution des

rudistes. Bulletin de la Societe geologique de France Vol. **1** [8], pp. 723-731.

21. Pons, J.M., Sirna, G. **1992**; Upper Cretaceous radists distribution in the Mediterranean Tethys: Comparison between platforms from Spain and south central Italy. Geologica Romana, Vol. **28**, pp. 341-349.
22. Al-Dulaimi, S.I., **2011**; Upper Cretaceous rudist reef and associated microfossils of Aqra Formation/ Northern Iraq. Unpublished PhD thesis. Baghdad University. 126p
23. Skelton, P.W., Wright, U.P. **1987**; A Caribbean rudist bivalve in Oman: island hopping across the Pacific in the Late Cretaceous Paleontology, Vol. **30**,pp505-529.
24. Lloyd, C.R., **1982**; The mid-Cretaceous earth Palaeogeography, ocean circulation and temperature, atomespheric circulation. J. Geol. Vol. **90**, pp. 393-413.
25. Bush, A.B.G., **1997**; Numerical simulation of the Cretaceous Tethys circumglobal current. Science, Vol. **275**, pp. 807-810.
26. Poulsen, C.J., Seidov, D., Barron, E.J., Peterson, W.H., **1998**; The impact of paleogeographic evolution on the surface oceanic circulation and the Marine environment within the Mid-Cretaceous Tethys. Paleoceano-graphy. Vol. **13**, pp. 546-559.
27. Schindewolf, O., **1962**; Neokat-astrophism? Zeitschrift der Drutschen Geologischen Gesellschaft, Vol. **114**, No.2, pp. 430-445.
28. Alveres, L.W., Alvares, W., Asaro, F., and Michel, H.V., **1980**; Extraterrestrial cause for the Cretaceous-Tertiary mass extinction: Science, Vol. **208**, pp. 1095-1108.
29. Halam&Wignall, **1997**; Mass Extinctions and Their Aftemath. Oxford University press, Inc., New York. 320p.
30. Keller, G., **2001**; The end Cretaceous mass extinction in the marine realm: year 200 assessment. Plantary and Space Sceience. Vol. **49**, pp.817-830.
31. Kauffman, E.Q., **1988**; The dynamics of marine stepwise mass extinction-Revista Espanola de paleontologia, Numero Extraor-dinario. Pp. 57-71.
32. Kerr ,R.A.,**1992**;Extinction with whimper .Science,Vol.**258**,p.161.
33. Dechaseaux, C., **1969**; Origin and extinction, in Moore, R.C., ed., Treatise on invertebrate Paleon-tology, Part N, Mollusca 6, Bivalvia, Vol. **2**: Boulder, Colorado, Geological Society of America [andUniversity of Kansas press], P.N 765p.
34. Kauffman, E.G., and Sohl, N.F., **1979**; Rudists, in Fairbridge, R.W., and Jablonski, D., eds., the encyclopedia of paleontology: Stroudsburg, Pennsylvania, Dowden, Hutchinson and Ross, pp. 723-736.
35. Jones, D.S., and Nicol, D., **1986**; Origination, survivorship, and extinction of rudist taxa, Journal of paleontology. Vol. **60**, pp. 107-115.
36. Keller, G., Li, L., Macleod, N., **1995**; The Cretaceous/ Tertiary boundary stratotype section at E/ Kef, Tunisia. How catastrophic was the mass extinction? Palaeogeog. Palaeoclimatol. Palaeoecol. Vol. **119**, pp. 221-254.
37. Alvarez, W., Kauffman, E.G., Surlyk, F., Alvarez, L., Asaro, F., and Michel, H.V., **1984**; the impact theory of mass extinctions and the ivertebrate fossil record across the Cretaceous-Tertiary boundary: Science, Vol. **223**, pp. 1135-1141.
38. Kauffman, E.G., **1979**; The ecology and biogeography of the Cretaceous-Tertiary extinction event, in Christensen, W.K., and Birkelund, T., eds., Cretaceous-Tertiary boundary events [Symposium proceedings], Vol. **2**: Copenhagen, University of Copenhagen, pp. 29-37.
39. Kauffman, E.G., **1984**a; The fabric of Cretaceous marine extinctions, in Berggren, W.A./ and Van Couvering, J., eds., Catastrophes in Earth history: The new Uniformitarianism: Princeton, New Jersey, Princeton University press pp. 151-246.
40. Kauffman, E.G., **1984**b; Paleobiogeography and evolu-tionary respose dynamic in the Cretaceous western Interior Seaway of north America, in Westermann, G.E.G., Jurassic-Cretaceous biochronology and Paleogeography of north America: Geological Association of Canda Special Paper **27**. Pp. 273-306.
41. Kauffman, E.G., **1995**; Global change leading to biodiversity crisis in a grecnhouse world: The Cenomanian-Turonian [Cretaceous] Mass extinction, in Stanley, S.M., Knoll,A. H., and Kennett, J., The effects of past global change on life: Washington, D.C., National Academy press: National research council, P. 47-71.

42. Johnson, C.C., and Kauffman, E.G., **1990**; Originations, radiations and extinctions of Cretaceous rudistid bivalve species in Caribbean province in Kauffman, E. G., and Walliser, O.H, ed., Extinction events in Earth history: Berlin, Heidelberg, New York, Springer-Verlag. Pp. 305-324.
43. Ward, P. D., **1988**; Maastrichtian ammonite and inoceramid ranges from Bay of Biscay Cretaceous-Tertiary boundary sections, in Lamolda, M.A., Kauffman, E.G., and Walliser, O.H., eds. Paleontology and evolution: Extinction events: Revista Espanola de Paleontologia, No. extraodinario, pp. 116-126.
44. Ward, p., Kennedy, W.J., MacLeod, K. G., and Mount, J., **1991**; End Cretaceous Molluscan extinction patterns in Bay of Biscay K/T boundary sections: Two different patterns: Geology, Vol. **19**, pp. 1181-1184.
45. Hansen, T. A., Farrand, R. B., Montgomery. H. A., Billman, H.G., and Blechschmidt, G., **1987**; Sedimentology and extinction patterns across the Cretaceous-Tertiary boundary interval in east Texas: Cretaceous Reserch, Vol. **8**, pp. 229-252.
46. Hansen, T. A., Upshaw, Banks, III, Kauffman, E. G., and Gose, W., **1993**; patterns of molluscan extinction and recovery across the Cretaceous-Tertiary boundary in east Texas; report on new outcrops: Cretaceous research, Vol. **14**, pp. 685-706.
47. Keller, G., **1989**a; Extended period of extinction across the Cretaceous/ Tertiary boundary in planktonic foraminifera of continental shelf sections Implication, for impact and volcanism theories Geological society of America Bulletin, Vol. **101**, pp. 1408-1419.
48. Keller, G., **1989**b; Extended Cretaceous/ Tertiary boundary extinctions and delayed population change in planktonic foraminiferal founas from Brazos River, texas: Paleocenography, Vol. **4**, pp.287-332.
49. Swinburne, N.H.M., **1991**; Tethyan extinctions, sea level changes and the Sr. isotope curve in the 10 Ma. Preccding the K/T boundary: Eos [Transactions, American Geophysical Union], Vol. **72**, p. 267.
50. Smit, J., **1990**; Meteorite impact, extinctions and Cretaceous/ Tertiary Boundary. Geol. Mijnb. Vol. **69**, pp. 187-204.
51. Canudo, J.I., Keller, G., Molina, E., **1991**; Cretaceous/ Tertiary boundary extinction pattern and faunal turnover at Agost and Caravaca, SE Spain. Marine Micropaleontol. Vol. **17**, pp. 319-341.
52. Keller, G., **1988**; Biotic turnover in benthic foraminifera across the Cretaceous/ Tertiary boundary at El Kef,, Tunisia. Palaeogeogrephy,Palaeoclimtology, alaeoecology. Vol. **66**, pp. 157-171.
53. Keller, G., Li, L., Macleod, N.**1885**; The Cretaceous/ Tertiary boundary stratotype section at El Kef,, Tunisia; how catastrophic eas the mass extinction? Palaeogeogrephy, Palaeoclima-tol., Palaeoecol. Vol. **119**, pp. 221-254.
54. Keller, G., Adatte, T., Stinnesbeck, W., Stueben, D., Kramar, U., Berner, Z., Li, L. Von Salis Perch-Nielsen, K., **1998.** The Cretaceous- Tertiary transition on the shallow Saharan platform of southern Tunisia. GEOBIOS **30** [7], pp. 951-975.
55. Molina, E., Arenillas, I., Arz, J.A., **1998**; Mass extinction in planktic foraminifera at the Cretaceous-Tertiary boundary in subtropical and temperate latitudes. Bull. Soc. Geol. France. Vol. **169**, pp. 351-372.
56. Culver, S.J., **2003**; Benthic foraminifera across the Cretaceous- Tertiary [K-T] boundary: a review. Marine Micropaleontology, Vol. **47**, pp. 177-226.
57. Alegret, L., Thomas, E. **2005**; Cretaceous/Paleogene boundary bathyal Paleo-environments in the central North pacific [DSDP Site 465], the Northwestern Atlantic [ODP Site 1049], the Gulf Maxico and the Tethys: The benthic foraminifera record.Palaeogeo-grephy, alaeoclimatology, Palaeo-ecology, Vol. **224**, pp. 53-82.
58. Alegret, L., Molina, E., Thomas, E., **2001**a; Benthic foraminifera at the Cretaceous/ Tertiary boundary around the Gulf of Maxico. Geology, Vol. **29**, pp. 891-894.
59. Alegret, L., Thomas, E., **2004**; Benthic foraminifera and environ-mental turnover across the Cretaceous/ Paleogene boundary at the Blake Nose, Western Atlantic [ODP Hole 1049C], Palaeo-geogrephy, Palaeoclimatology, Pala-eoecology,Vol. **208**, pp. 59-83.

60. 60-Alegret, L., Thomas, E., **2007**; Deep environments across the Cretaceous/ Paleogene boundary in the eastern South Atlantic Oceon [ODP Leg 208 Walvis Ridge]. Marine Micropaleo-ntology, Vol. **64**, pp. 1-17.
61. Kauffman, E.G., and Sohl, N.E., **1974;** Structure and evolution of Antillean Cretaceousrudistfre-meworks, erhandlungen Naturfors-chende Gesellshaft Basel, Vol. **84**, pp. 399-467.
62. Skelton, P.W., Nolan, S.C., and Scott, R.W., **1990**; Maastrichtian transgression onto the North-western flank of the Proto-Oman Mountains. Sequences of rudist bearing beach to open shelf facies. In: the geology and tectonic of the Oman region [Eds A.H.F. Robertson, M.P., Searle and A.C.Ries]. geol. Lond. Spec, publ. Vol. **49**, pp. 521-547.
63. Skelton, P.W., Gili, E., **1991**; Palaeoecological classification of rudist Morphotypes. In first International conference on rudists. Oct. 1988. Proceeding [Ed]. M. Sladic-Trifunovic. Pp. 71-86. Serbian Geological Society: Belgrade.
64. Mass, J. P., Philip, J., **1986**; L evolution des rudist au regard des pricipaux evenents geologique de Cretace. Bull Centres. Rech. Explorprod. Elf. Aquitaine, **10** [2], pp. 437-456.
65. Ross, D.J., Skelton, P.W., **1993**; Rudist formation of the Cretaceous: a Palaeoecological, Sedimentological and stratigraphic review. 73-91, In V.P. Wright [ed] Sedimentology Review, Blackwell, London. 142p.
66. Johnson, C.C., Kauffman, E.G., **1999**; Paleobiology revolution in Cretaceous tropics, Caribbean Region. Indiana University press, pp. 1-47.
67. Li, L., Keller, G., **1998**a; Maastrichtian climate, productivity and faunal turnover in planktic foraminifera in south Atlantic DSDP sites 525 and 21. Mar. Micropaleontol. Vol. **33**, pp. 55-86.
68. Courtillot, V., Jaeger, J.J., Yang, Z., Feraud, G., Hofmann, C., **1996**; The influence of continental basalts on mass extinctions; where do we stands In: Ryder, G., Fastovosky, D., Gartner, S. [Eds.], The Cretaceous- Tertiary event and other Catastrophes in Earth history. Geol. Soc. Am. Spec. Pap, Vol. **307**, pp. 513-525.
69. Macleod, N., **1998**; Impact and Marine invertebrate extinctions. In: Grady, M.M., Hutchison, R., McCall, G.J.H., Rothery, D.A., [Eds], Meteorites: Flux with Time and Impact Effects. Geol. Soc. London Spec. Publ. Vol. **140**, pp. 217-246.
70. Almeri,T.K.andLawa,F.A.,**1986**; oecological model and funal intraction within Aqra limestone Formation.North Iraq.Jour.Geol. Soc. Iraq.Vol.**19**,No.3,pp.7-27.